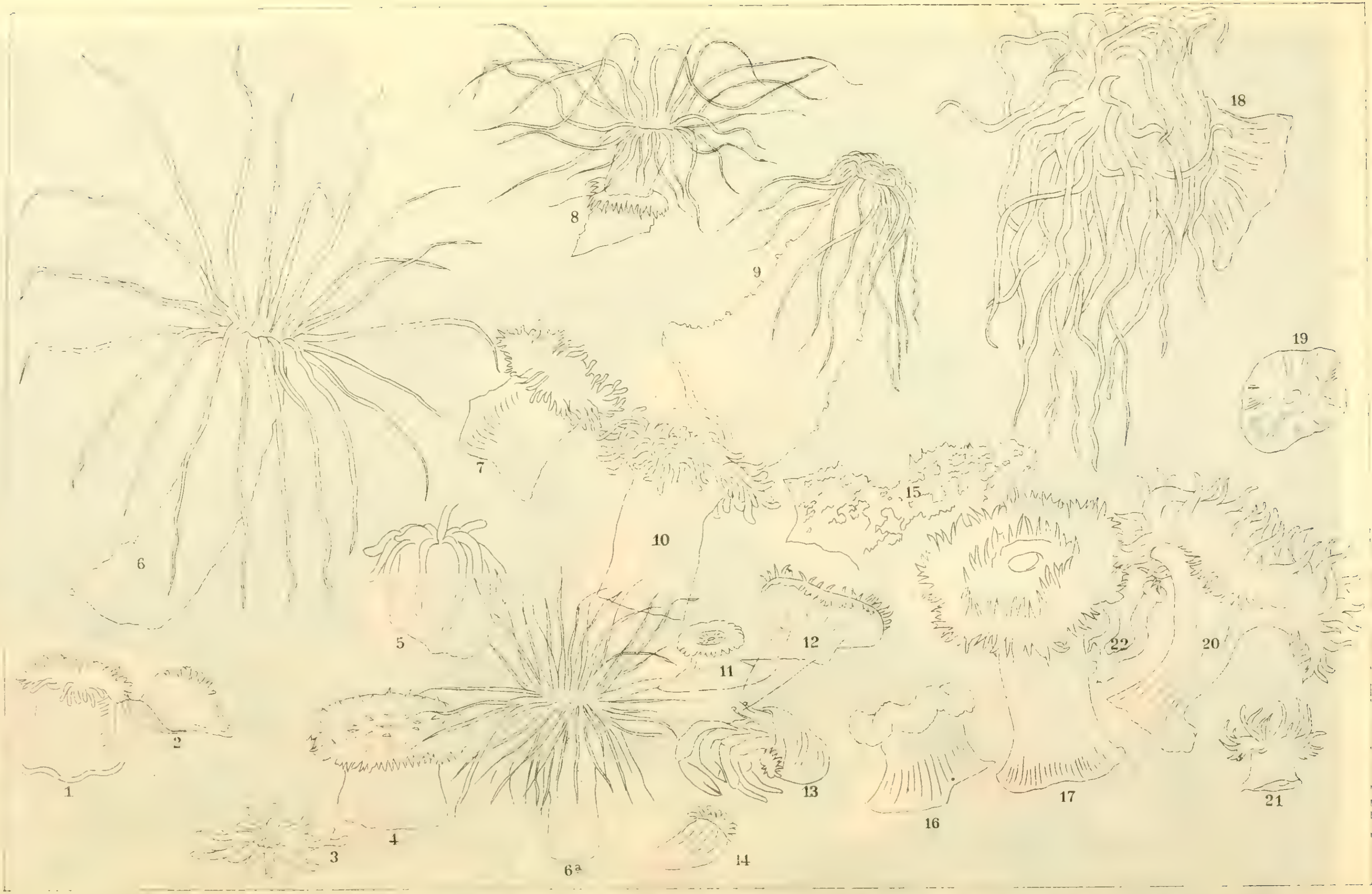
The Royal Natural History

by

Richard Lydekker

THE ROYAL
NATURAL HISTORY

SEA ANEMONES.



1, 2. *Actinia equina.* 3, 5, 14. *Eloactis mazelii.* 4. *Ragactis pulchra.* 6, 6*a*, 8. *Cerianthus membranaceus.* 7, 19. *Actinia cari.* 9. *Cladactis cortac.* 10. *Cercactis aurantiaca.* 11, 12, 16, 17. *Heliactis bellis.* 13. *Adamsia palliata.* 15. *Astroides calycularis* (*a coral*). 18. *Anemonia sulcata.* 20. *Aiptasia mutabilis.* 21. *Bunodes.* 22. A Tubicolous Worm.

THE ROYAL NATURAL HISTORY

EDITED BY

RICHARD LYDEKKER, B.A., F.R.S., ETC.

WITH PREFACE BY

P. L. SCLATER, M.A., PH.D., F.R.S., ETC.

SECRETARY OF THE ZOOLOGICAL SOCIETY OF LONDON

ILLUSTRATED WITH

Seventy-two Coloured Plates and Sixteen Hundred Engravings

BY

W. KUHNERT, F. SPECHT, P. J. SMIT, G. MÜTZEL, A. T. ELWES, J. WOLF,
GAMBIER BOLTON, F.Z.S.; AND MANY OTHERS

VOL. VI.

SECTION XII.

LONDON
FREDERICK WARNE & CO.
AND NEW YORK
1896

PRINTED BY MORRISON AND GIBB LIMITED, EDINBURGH.

.12

CONTENTS

INVERTEBRATE ANIMALS

CHAPTER VIII.—Stone-Lilies, Star-Fishes, Sea-Urchins, and Sea-Cucumbers,—Subkingdom *Echinodermata.*

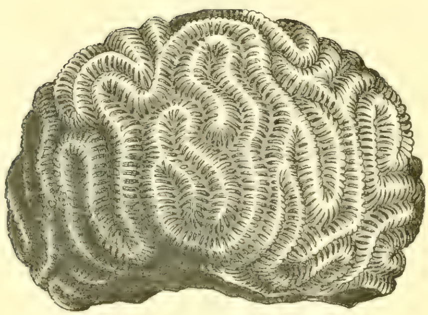
CHAPTER IX.—The Molluscs, or Shell-Fish,—Subkingdom *Mollusca.*

CHAPTER X.—The Molluscs,—*continued.* Class *Gastropoda.*

LIST OF ILLUSTRATIONS

COLOURED PLATES

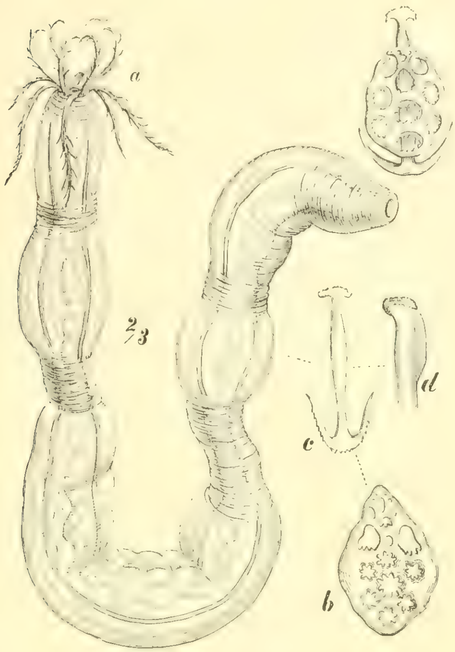
TEXT ENGRAVINGS



CHAPTER VIII.

Stone-Lilies, Star-Fishes, Sea-Urchins, and Sea-Cucumbers, Subkingdom **ECHINODERMATA.**

Characteristics of the Group. THE star-fish, the sea-urchin, the brittle-star, the feather-star, and the sea-cucumber—especially the three former—are well known to all frequenters of the seashore; while the fossil sea-urchins of the Chalk, whose flint-casts are so common on the downs of England, the so-called screw-stones found in the Mountain Limestone, the pentremites and crinoids, whose remains are so abundant in some parts of North America, are no less familiar to dwellers inland. Though these animals differ much from one another in shape, a slight scrutiny will discover many points in which they resemble one another and differ from other creatures. They and their relatives are, therefore, placed in one great group of the animal kingdom, the Echinodermata,—a group corresponding in importance to the Molluscs, or the Vertebrates. This group is, in fact, more clearly defined, and more widely removed from other groups than either of the two mentioned. If a star-fish, or any of the animals named above, even a sea-cucumber or holothurian, be touched with the finger, its skin will be found to have a rough surface; this is due to the circumstance that it contains a crystalline deposit of carbonate of lime. In a sea-urchin, a brittle-star, or a feather-star, this deposit is in the form of little plates, which build up a more or less rigid test; whereas in the star-fish it usually forms a kind of scaffolding, between which there stretches the more yielding, leathery skin. In the ordinary sea-cucumbers the deposit consists only of small spicules, which roughen the outer surface, and grate when the skin is cut with a knife. If a thin slice of the skin of one of these animals be cut and examined under a microscope, the spicules may easily be seen lying in its middle layer. It is this same deposit that forms the spines of a sea-urchin and the stalked column of a crinoid; and it is this which has enabled so many of the Echinodermata to be beautifully preserved as fossils. To this character is due the name of the group, derived from the Greek, *echinos*, a hedgehog, and *derma*, skin. Many animals have some deposit of lime, such as the shells of the Molluscs, and the bones and teeth of the Vertebrates, but the deposit of the Echinodermata differs in two characters: first, that its microscopic structure is that of a mesh-work, or rather of a beam-and-rafter work, since it is deposited in the spaces of a network of soft tissue; secondly, that each element, whether a spicule or a plate, is, despite its trellised structure, deposited around regular lines of crystallisation. Owing to these characters, the minutest portions of an echinoderm skeleton can be recognised, even when fossilised. This tendency of the Echinoderms to deposit lime is not confined to the skin, the walls of the internal organs being often strengthened by a deposit of similar structure. Although, as has been said, each element of the skeleton follows the laws of the typical crystallisation of carbonate of lime, yet the structure of the trellis-work varies greatly, and is often characteristic of the species in which it occurs. Thus, the species of sea-cucumber can be distinguished by the shape of their spicules; and the same is said to be the case with those sea-urchins that deposit spicules among their viscera.



ANCHOR SEA-CUCUMBER (*Synapta*).

a, Tentacles round the mouth; *c*, Anchor- and plate-shaped spicules; *b*, *c*, *d*, Similar spicules of an allied form.

The next feature noticeable is the radiate structure, in many cases giving to the animal a star-shape, to which the common names star-fish, brittle-star, and the like are due. The ordinary red star-fish, or cross-fish, of the English coasts has five distinct rays, or arms; and this number five, to a greater or less extent, controls the arrangement of the organs in the majority of the Echinoderms. It can be detected even in a sea-cucumber or holothurian, where, beside the feathery tentacles of the head, are rows of shorter sucker-like processes, which extend the length of the body; these rows being five in number. The internal organs, as will be seen later on, are variously affected in the various classes of the Echinoderms by this five-rayed symmetry. A radiate arrangement is not, however, confined to Echinoderms, as it also occurs in jelly-fish and sea-anemones. Hence those animals were once grouped with the Echinoderms, under the title of Radiata. But, if a sea-cucumber or a sea-urchin be opened, there is a marked distinction between it and a jelly-fish, in the presence of an intestine, shut off from the rest of the body-cavity, and often coiling round inside it. In this respect the Echinoderms resemble all the animals that have been dealt with in the preceding pages, whereas the jelly-fish and their allies differ from them in having no body-cavity separated off from the stomach and its processes. Moreover, Echinoderms resemble the higher animals in the possession of a system of branched tubes conveying blood through the body.

Examining a star-fish or a sea-urchin, one sees, on the under surface of the rays in the former, and passing in five bands from top to bottom of the latter, a number of small cylindrical processes, which are usually gently waving about like trees in a wind. They lie in each band, or in each ray, along two rows, with a clear space between, like trees on either side of an avenue; hence the whole band of them in each ray is called an ambulacrum (garden-walk). Most of these little processes end in sucker-like discs, which the animal can stretch out and attach to smooth surrounding objects; and it is thereby able either to hold itself firm against waves or currents, or to pull itself along. Hence these processes are usually called

SEA-CUCUMBERS AND A BRITTLE-STAR.

tube-feet; but sometimes they end in a point, and cannot assist in locomotion, though they may help respiration, when they are sometimes called tentacles. If a single foot be touched, it immediately shrinks up, and if the touch be vigorous, the adjacent tube-feet probably follow its example. Tube-feet torn from the animal sometimes continue their waving motion, showing that this is, partly at least, due to muscular action. Their movements are also caused by the squeezing of a fluid into them; for each foot is like an indiarubber tube closed at the end, and passing through the test (as the shell of the sea-urchin is termed) to join with one main tube, which runs along under the ambulacrum in a radial direction; and before it joins this radial canal, each tube-foot gives off a small swelling likewise filled with fluid, so that when this swelling is contracted all the fluid is squeezed up into the foot, and pushes it out like the finger of a glove when blown into. The radial canals pass along under the ambulacra till they join in a ring-canal surrounding the mouth. Eventually this circular canal is connected with the surrounding water by a canal passing right across the body-cavity to the other side of the animal, near the vent, where it opens to the exterior through a plate pierced with a number of pores. This plate is called the madreporite, and the canal leading to it—owing to the limy deposits formed in its walls—the stone-canal. This whole system of fluid-filled canals is termed the water-vascular system. The foregoing description refers to its arrangement in a star-fish, or regular sea-urchin; but the system occurs, with various modifications, in all Echinoderms, and is one of the features that separate the group from other animals.

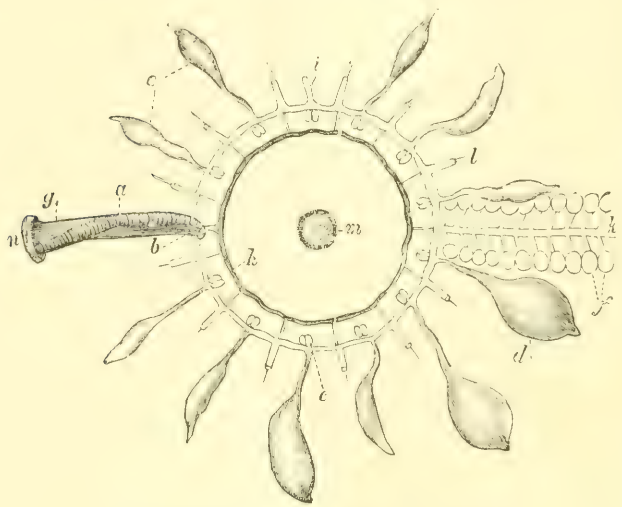


DIAGRAM OF AMBULACRAL SYSTEM OF A STARFISH.

f, Small swellings connected with the tube-feet; *k*, The radial canal with which they unite; *e*, Ring-canal into which the radial canals open; *c*, *d*, Membranous sacs that serve as reservoirs for water from radial canals; *a*, Stone-canal, leading from ring-canal to the madreporite, *n*; *m*, Mouth.

The Echinoderms are also peculiar in the possession of three, or perhaps four, different systems of nerves, of which three, or at least two, are present at the same time. One system supplies the skin, the tube-feet, and the intestine; its chief parts being a ring round the mouth, and radial nerves radiating therefrom. The second system has a similar arrangement, but lies deeper, and supplies the internal muscles of the body-wall. The third system, which is most fully developed in crinoids, starts from the other side of the body, opposite to the mouth, and supplies the muscles that work the arms and stem. If the arm of a star-fish be opened from the back, there will be seen a pair of pleated extensions from the stomach. If these be removed, there will be exposed a pair of orange-coloured tubes, somewhat branched and knotty, which communicate with the exterior at the angles between the rays. These are the generative glands. In all Echinoderms, except sea-cucumbers, these glands are affected by the radiate structure of the animals: in crinoids the generative products are even produced in the extremities of the arms.

Distinction of the Classes. Having glanced at those points of structure in which Echinoderms resemble one another and differ from the rest of the animal kingdom, we may shortly examine the main characters in which a sea-urchin, a star-fish, a crinoid, a brittle-star, and a sea-cucumber differ from one another. First may be noted obvious differences in form and in position in the living state. In an ordinary sea-cucumber (as shown in the illustration on p. 291) the body is cucumber-shaped, with the mouth at one end and the vent at the other; between these run the five ambulacra, one or two of which are often more developed than the others, so that the animal crawls along on that side of its body, with its mouth foremost. A sea-cucumber has no arms or projecting rays, but its mouth is surrounded by a circlet of tentacles, often branched, which can be retracted at will. A regular sea-urchin, such as the sea-egg (*Echinus*), shown in a later figure, resembles a sea-cucumber in being without projecting rays: but it is more spherical in shape, and moves with its mouth towards the sea-floor. On the other hand, in a heart-urchin (*Spatangus*), which moves through and swallows mud and sand, the body has become transversely elongate; that is to say, the long axis is at right angles to the position it occupies in a sea-cucumber; the mouth having moved a little forward, and the vent being transferred from the top of the body to its lower surface, so that both the mouth and vent lie on the under surface, at either end of the long axis. In a star-fish, as in a regular sea-urchin, the mouth is in the centre of the under surface, while the vent is almost in the centre of the upper surface, although absent in a few forms. The body is either markedly pentagonal in outline, or more or less star-shaped. In the latter case it is said to consist of a central disc extended into arms, as in the illustration on p. 304. The number of these arms varies from five (*Asterias*) to over forty (*Heliaster*); but in each species with more than six arms the number may vary slightly, although constant during the life of the individual; in *Labidiaster*, however, fresh arms grow out even in the adult. A brittle-star (illustrated on p. 291) resembles a star-fish in which there is a sharp distinction between arms and disc; the mouth being on the under surface, but the vent wanting. And whereas the arms of a star-fish are simply extensions of the body, containing the generative glands and processes from the stomach, those of a brittle-star are mere appendages to the body, with a stout internal skeleton of separate ossicles, working on one another by well-developed muscles, and containing only blood-vessels, water-vessels, and nerves. The arms of the brittle-stars are nearly always five in number, though sometimes there may be from six to eight. As in the star-fish, the arms are unbranched, except in the family *Astrophytidæ*, where they fork ten or twelve times, and where the numerous branches interlace so as to form a kind of basket-work all round the disc, whence these animals are called basket-fish, or medusa-head star-fish. A crinoid (illustrated on p. 297) differs markedly from a sea-urchin, star-fish or brittle-star, in that the mouth faces upwards; the vent being also on the upper surface. This position is due to the fact that, so far as we know, all crinoids are at some time of their lives attached by a stalk to the sea-floor, or some other object, so that the mouth and vent naturally move up to that side of the body furthest from the stalk. This fixed state of existence has also caused the development of arms, five in number, but often forked many times, which arms stretch out from the body on all sides of the mouth, and contain extensions of the nervous, blood-vascular, water-vascular, and generative systems. The representatives of the tube-feet are arranged along the sides of these arms, on their upper or oral surface, and between them is a groove, which is lined at the bottom with cilia, or extremely minute hair-like processes, that keep waving in the direction of the mouth, and so

GROUP OF STONE-LILIES (PENTACRINIDS).

maintain a constant stream of water towards the latter; such water containing the minute animalculæ and fragments of decaying organic matter on which the crinoid feeds. The extinct cystids and blastoids have their mouth in a similar position to that of the crinoids, and for a similar reason, but have not similarly branched arms. In the blastoids five grooves radiate down the body from the central mouth, and from the sides of these grooves there spring small, jointed, but unbranched processes, called pinnules. The stem of the blastoids is very short, so that when the pinnules have been lost, as is usually the case, the five-grooved body looks like a bud, whence the name of the class. It is difficult to describe a cystid as having any definite shape, for the various animals to which this name is applied differ greatly from one another in structure. Echinoderms are built upon one or other of the plans of structure just described. Moreover, the animals formed upon any one of these plans are found to agree with one another and to differ from the rest in yet other features. Hence zoologists have divided the Echinoderms into seven classes, each of which is again divided into orders.

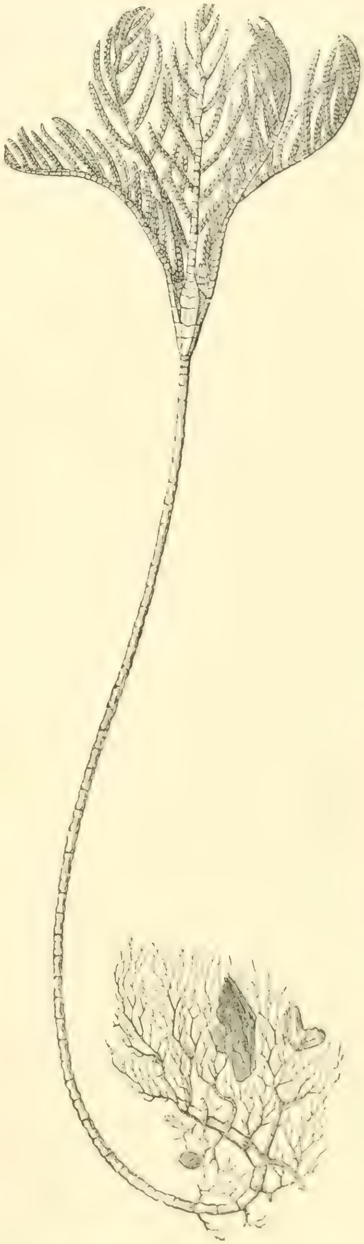
Mode of Life. All Echinoderms live in the sea, where they find in solution the lime-salts from which their skeletons are built. None have become modified for a truly fresh-water existence, and in this respect they are peculiar among animals; a few holothurians, however, are found in the mud of some estuaries and brackish-water lagoons, while a star-fish (*Asteracanthium*) and a brittle-star (*Ophioglypha*) occur in the brackish waters of the Eastern Baltic. Neither can Echinoderms live on land, and though they may exist for a short time out of the water when left by tides, still it is only in the water that they can breathe or feed. In the sea, however, they have a universal distribution; from ice-bound seas to the Equator; from shallow shore-pools to mid-ocean; from the surface to the abyss; on rocky shores, sandy beaches, muddy shoals, and bottom oozes, among the roots of the mangrove, or in the meadows of seaweed. This universal distribution renders their study one of importance for the geologist, especially as their calcareous skeletons are readily preserved as fossils. Their remains are known from rocks of every age in which animals are known to have existed, and even the spicules of sea-cucumbers have been found as far back as the Carboniferous period. Moreover, the rapidity of evolution in the group, and the short period of time during which any one species was in existence, combined with the wide area of distribution possessed by many species, render these fossils of great value for the correlation of strata in different countries.

The Cystids,—Class **Cystidea.**

The Cystidea have been extinct since the Carboniferous period. Not only are they among the oldest animals, but there is reason to suppose that they approach more nearly the primitive forms from which all the classes of the Echinoderms were derived. Many have not that regularity of symmetry which characterises later Echinoderms. Such forms as *Echinosphæra*, commonly called the crystal-apple, are mere round balls composed of a number of plates in which it is hard to see any arrangement. Some of them seem to have been unstalked, while in others the stalk is quite short. The arms are short, and vary in number, bearing but slight relation to the plates of the test. In some, however, such as *Glyptosphæra*, the ambulacral grooves, though rather irregular, are five in number and lie on the surface of the test, all meeting at the mouth, which is placed in the centre of the upper surface. Other cystids seem to be composed of an irregular number of plates; but they have become more definitely radiate in structure. Some, like *Agelecrinus*, are flat circular forms, which live attached by their under side to the flat surfaces of shells, and which have five distinct ambulacral grooves radiating from the central mouth on the upper side; while others, like *Mesites*,—which resembles *Agelecrinus* in the arrangement of its grooves,—were attached, if at all, by only a small part of the under side. Yet other cystids are definitely attached by well-developed stalks, and have their bodies enclosed by a limited number of plates arranged in regular order. Some of these present a six-rayed symmetry, such as *Caryocrinus*, while others are governed by a five-rayed symmetry, such as *Lepadocrinus* and *Porocrinus*. Both of these groups have as a rule better developed arms, which sometimes branch, and are usually five or six in number according to the symmetry of the cup. Hence these forms are much more like the crinoids than are the other cystids.

In other Echinoderms the rays with their numerous tube-feet help the respiration of the animal, but these were absent or very slightly developed in the cystids. There are, however, other structures that are supposed to have served the same purpose. In some (*Aristocystis*) the plates of the test are pierced by simple pores, while in others (*Glyptosphæra*) these pores are in pairs; but in either case the pores are scattered irregularly over the body, and possibly gave passage to minute tube-feet. The development of these and their concentration in certain areas of the test would produce an arrangement not unlike that of other Echinoderms. Other cystids have certain portions of the test pierced by slits (*Lepadocrinus*), and it seems probable that these permitted the surrounding water to pass in to the membrane, lining the interior of the test. These structures are called hydrospires (water-breathers), and somewhat resemble the cribriform organs found in some deep-sea star-fish of the present day (*Porcellanaster*), figured later on. Structures called hydrospires have also been described in such cystids as *Caryocrinus* and *Echinosphæra*; but it is doubtful whether these actually subserved respiration, although the true hydrospires may have been evolved from some such undeveloped structures.

Another point of interest in the cystids is the light they throw on the origin of the crinoid stem, which is formed of a series of flat rings. The simple round plates, with a circular hole through the middle, are often called St. Cuthbert's beads, while those marked with five petals, so common in the Lias at Lyme Regis, have been termed star-stones. Technically the two kinds are distinguished as Entrochi and Astroites. They are familiar in the polished slabs of Mountain Limestone, in which it may be seen how the long stem is formed of a number of these round ossicles jointed together, and pierced throughout by a narrow canal. The ossicles are joined by ligaments passing right through their solid substance, and endued with slight muscular power; the central or axial canal serving for the passage of blood-vessels, which are surrounded by a sheath of nervous tissue that controls the movements of the stem. By one end the stem is attached to the sea-floor, either by a flattish encrusting extension of its calcareous substance, or by a number of fine branches or rootlets, as in the root-crinoid (*Rhizocrinus*), herewith figured. By the other end the stem is attached to the plates forming the cup enclosing the body of the animal, and it is at this end that it grows, by the constant development of new ossicles between the cup and the upper segments of the stem. Now, if we suppose that the crinoids, like other Echinoderms, sprang from sac-like ancestors with a number of irregular and small plates, it is difficult to understand how such a stem was evolved; but the mystery is elucidated by some of the cystids and older crinoids. First, it may be noted, that in those cystids possessing a crinoid-like stem, as well as in many of the older crinoids, the axial canal of the stem is much larger than it is in later forms. Secondly, that in many older crinoids, the ossicles of the stem, instead of being simple rings, are generally composed of five equal parts. In other words, there are five radial sutures or joint-surfaces, running the whole length of the stem and dividing each ossicle into five parts. These sutures are more conspicuous towards the root end of the stem, which was of course the first to be formed in each individual. Thirdly, examination has shown that in some of these stems, especially towards the root end, the five portions of each ossicle do not lie regularly above the five portions of the underlying ossicle, but alternate with them to a certain extent, just in the same way as the circlets of plates that make up the cup of a crinoid alternate with one another. These facts alone would lead us to suppose that the stem was originally composed, like the cup still is, of a series of circlets of small plates, five in each circlet, and alternating with one another; that the stem was, in fact, nothing more than a continuation of the cup, with essentially similar structure. Turning to the cystids, we may see how this view is confirmed and extended. In certain forms, such as *Trochocystis*, that part of the stem next the body consists of a double series of alternating plates, which are thin and enclose a large hollow. In *Arachnocystis* the whole stem consists of four or five series of alternating plates. In *Dendrocystis*, the plates forming the upper part of the stem can only be distinguished by their smaller size from those forming the cup; below they merge into the normal series of single ossicles. *Cigara* is the name given to a stem entirely composed of small irregular plates. We may, therefore, conclude that the stem originated as a portion of the body of the animal, elongated, and gradually becoming more and more regular in its structure. The curiously elongate and irregularly plated form called *Pilocystis* may represent the earliest stage in its evolution, before one can even say that a stem is differentiated at all.

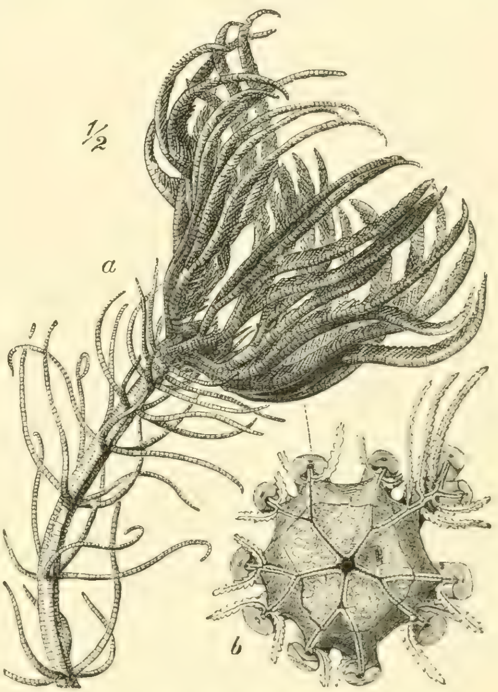


LOFODEN ROOT-CRINOIDS ($\frac{3}{2}$ nat. size).

The Stone-Lilies or Crinoids,—Class **Crinoidea**.

The crinoids differ from the more highly developed of the cystids in the greater regularity of their structure—the symmetry of which is nearly always governed by the number five,—in the greater development of the arms—which are often much branched,—and in the absence of special breathing-organs, which were no longer needed. It is easy to see how an organism that is fixed, and equally affected on all sides by the surrounding medium, whether air or water, develops a radiate symmetry; the same result being obvious in the case of most flowering plants. Slight consideration will also show why the number five has been favoured by these particular animals. The body of a crinoid is encased by a limited number of relatively large plates, united together by the skin in which they are developed, and it is clear that the sutures between these plates are lines of weakness. Supposing that there were four plates in each circle, then the four sutures would be in opposite pairs, and the lines of weakness would run right across the body of the animal, which would easily be broken; and the same result would follow if there were six plates and three pairs of opposed sutures. Though the test might be more flexible, still there would be three lines of weakness in each circle instead of two. But when there are five plates, each suture lies opposite to the middle of a plate, and so the line of weakness does not run right across the body. A few crinoids have essayed other forms of symmetry, but none have had a long existence. The alternation of the plates in a crinoid may be explained by similar mechanical considerations; for such an arrangement corresponds to the bonding of successive courses of bricks in a wall. There is reason to suppose that the ancestors of all crinoids, as well as most of the Palæozoic crinoids, were attached to the sea-floor or some other object throughout life by the stem. On hard rocky bottoms the attachment was by means of an incrustation, as in the pear-encrinite (*Apiocrinus*) of the Bradford Clay; but on oozy bottoms the end of the stem broke up into numerous branches called cirri, as in the *Rhizocrinus* of modern seas. In course of time these cirri were developed, not only at the root end, but also higher up the stem, and eventually they came in some genera to be arranged in regular whorls of five, as we see them in the living *Pentacrinus*. Since crinoids were at all times liable to be broken from their attachment, some of them gradually acquired slight faculties of locomotion, although they prefer to renew their attachment, even though this be transferred to some other object. Sometimes the whole end of the stem coiled itself around the stem of another crinoid, but usually it became anchored by such cirri as chanced to remain on the preserved portion. In those crinoids that have the cirri in whorls, the ligaments that unite the joints of the stem stop short just below each ossicle bearing a cirrus, so that the division between this ossicle and the one below yields readily to a bending or blow; and thus the crinoid can anchor itself easily by the whorl of cirri left at the end of its broken stem. In some cases there is developed at the end of the stem a little ball of calcareous tissue, serving as a weight to keep the animal right way up, as it moved slowly through the water by the waving of its arms; and in certain forms this ball developed spines, directed upwards like the flukes of an anchor, and serving the same purpose.

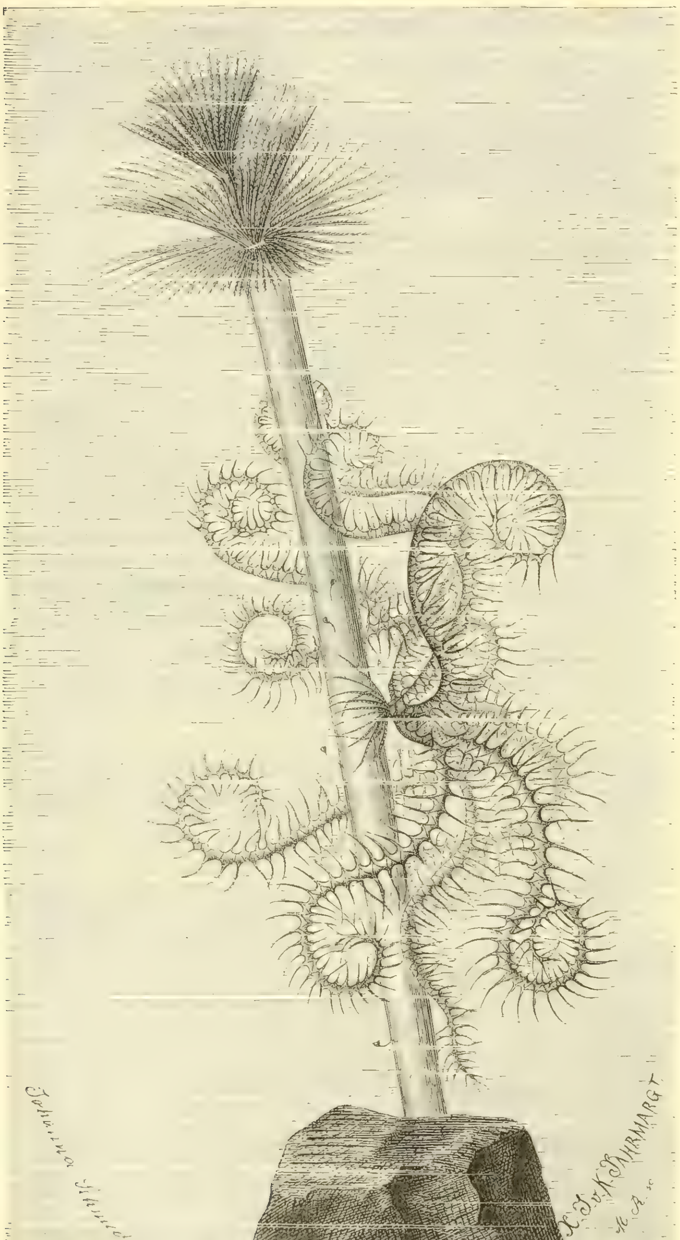
The stems of most crinoids have no great power of bending or coiling, since the ridges and ligaments are distributed equally all over the joint surfaces. Writing of pentacrinids, dredged in the Caribbean Sea, Professor Agassiz says: "They move the cirri more rapidly than the arms, and use them as hooks to catch hold of the neighbouring objects, and on account of their sharp extremities they are well adapted to retain their hold. The stem itself passes slowly from a rigid vertical attitude to a curved or even drooping position." Other crinoids, like *Herpetocrinus*, have, however, a single fulcral ridge running across the surface of the joints, allowing far more play between the latter. In *Platycrinus* the joints had an elliptical outline, and the fulcral ridge formed the long diameter of the ellipse. Such a structure would naturally give the stem great power of bending, but only in one plane. This restriction was got over by giving the joints a slight skew, so that the stem was twisted like a corkscrew and capable of movement in every direction. In *Rhizocrinus* the same end is attained by each joint being so twisted that the fulcral ridge at the top is at right angles to the one at the bottom. These types are, however, merely side branches from the main stem of crinoid evolution; the chief advance having proceeded along the lines of free locomotion. At various periods forms have existed, which, having once tasted liberty, have gradually dropped all traces of their former attachment. Thus, *Agassizocrinus* of the Coal-Measures is a crinoid that has nothing left of its stem but a solid knob at the base of the cup; *Millericrinus* of the Great Oolite has been found at all ages and stages of development, the young individuals with a normal stem which gradually withers as the animal gets older, till in full-grown specimens it is a mere tapering process. *Uintacrinus* and *Marsupites* from Cretaceous beds, are two genera as unlike in essential structure as crinoids well could be, but resembling one another in having thin-plated large cups, without the smallest relic of a stem. A little crinoid of Jurassic age called *Thiolliericrinus* appears, however, most nearly related to, if it be not the actual ancestor of, most of the free-moving unstalked living forms. It seems to have been related to *Bourguetierinus* and *Rhizocrinus*, but, like *Millericrinus*, gradually dropped its stem, while the upper joint of the stem coalesced and began to bear cirri. In the common feather-star (*Antedon*) of the British seas this process has gone yet further; the animal breaks away from its stem when quite young, but retains the uppermost swollen and coalesced segments of the stem, which form one solid mass bearing a number of cirri, while the two lower circlets of cup-plates almost entirely disappear, so that only the upper circlet of plates, from which the arms arise, remains. The *Antedonidæ*, which have all arisen since Jurassic times, include not only numerous species of *Antedon*, but at



MEDUSA-HEAD PENTACRINID.

a, Crown and part of stem (nat. size); *b*. Upper surface of the body, the arms broken away, showing the food-grooves passing to the central mouth.

least as many more of a closely allied genus, *Actinometra*, as well as three other less common genera, named *Atelecrinus*, *Eudiocrinus*, and *Promachocrinus*. They are far more numerous at the present day than the stalked crinoids, and occur in all parts of the world, but their head-quarters are in the Eastern Archipelago.



ROSY FEATHER-STAR, CLINGING TO A TUBE OF SABELLA WORM (nat. size).

There are a few crinoids that have diminished their stem, but have nevertheless remained attached, so that at last the cup has come to be fixed on the sea-floor without the intervention of a stem. Such a form is the stumpy and thick-set *Holopus*, which is among the greatest rarities in museums. It lives at depths of about a hundred fathoms in the Caribbean Sea. Similar forms occur in some of the shallow-water and reef deposits of Jurassic and Cretaceous age. Many of these have become a little unsymmetrical and bent over in one direction; which may, perhaps, be accounted for by their life on reefs, where food is brought to them by currents flowing only in one direction.

Next to the stem, the most characteristic structures of a crinoid are its arms. Each arm starts from one of the five plates that form the uppermost circlet in the cup. The arms are said to be radial in position, and those plates from which they start are specially distinguished as the "radials." In many forms, such as *Cyathocrinus*, the upper edge of each radial is notched by a horseshoe-shaped facet, provided with a transverse fulcral ridge and muscles, so that a regular articulation is formed for the working of the arm up and down. In such forms—known as Inadunata—the arms are quite separate from one another and are easily distinguished from the plates that compose the cup. But in the forms to which the names Flexibilia and Camerata are applied, smaller plates are developed in the spaces or interradii between the arms, and these additional plates bind the arms together and so incorporate them in the walls of the cup. A crinoid of this kind, such as *Actinocrinus* or *Uintacrinus*, has therefore a much larger body than a *Cyathocrinus* or *Pentacrinus*. Sometimes the arms form part of the cup without the intercalation of interbrachial plates; while yet other plates may be developed between the forks of the arms themselves. In the Flexibilia the plates that form the cup are rather loosely joined to one another, so that there is some play between them; the arms also have much power of motion. In the Camerata the plates are more firmly united, and additional fixity is given to the cup by the strengthening and solidification of the upper surface around the mouth. In the Inadunata and Flexibilia the grooves on the inner surface of the arms, which convey food to the mouth, pass over this upper surface of the cup, and are merely protected by the ordinary small plates that can be opened or shut down over them. But in the Camerata the plates of this upper surface of the cup have become so thick and welded together, that the grooves are no longer open, and even in some cases have been pressed down beneath the surface, underneath which they form regular tunnels. The mouth too is no longer visible on the upper surface. Crinoids of this type were most abundant in the Carboniferous period, and it is to a large extent their remains that make up the masses of Derbyshire marble.

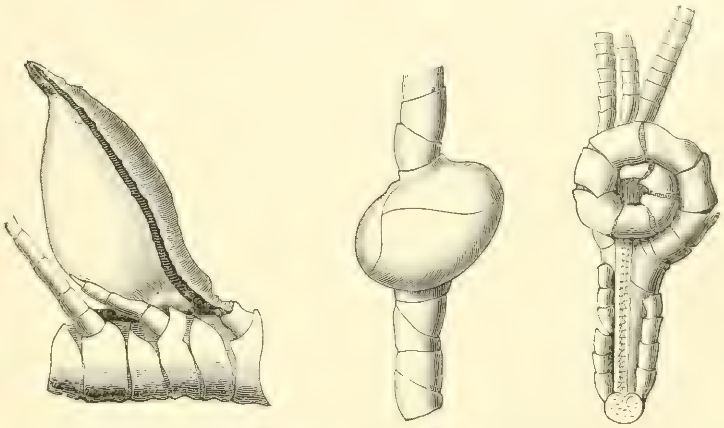
Among curious modifications of arm-structure may be mentioned the Silurian *Crotalocrinus*. Here the arms are forked many times, but all the separate branches are joined together at their sides, so that the arms when outspread form a single net. In *Petalocrinus* of the same age this process has been carried so far that the branches of each arm are solidly fixed together, and the crinoid appears to be provided with five paddles. In *Uintacrinus* the ten arm-branches reached the enormous length of 3 feet, and seem to have been capable of movement in various directions, so that the swimming powers of the crinoid must have been greatly enhanced. *Saccocoma*, which lived in the still lagoons where the Solenhofen lithographic stone was deposited, had a very light body and long, fine arms, provided with flat oar-like processes.

The locomotion of the free forms is effected by the raising and depressing of alternate arms, and the movements of these arms are correlated by the peculiar nervous system that has its headquarters at the bottom of the cup. This swimming has been observed in both *Antedon* and *Actinometra* kept in an aquarium. As a rule, however, these animals remain attached by their cirri to rocks, to the bottom ooze, to seaweeds, or to other marine animals. In this position the arms are outspread, and the small branches or pinnules that line their sides are kept slightly waving. If the water be ruffled, the first impulse of the crinoid is to flatten its arms out suddenly and to hold on to the rock or other object with its pinnules. The pinnules of an *Antedon* can be bent in any direction; those near the extremity of the arm being specially active. If its extremity be touched by any irritating substance, the arm is erected at right angles to the upper surface of the animal and so removed from the other arms, while the pinnules move something like the legs of a fly that is cleaning itself. If, however, this proves ineffectual, the arm bends over to the one on the opposite side, the pinnules of which then assist in the operation. The pinnules move in this manner to disembarrass the arm of fragments of foreign matter that are too large; but the hooks at the end of the pinnules can catch and retain minute fragments, which, as they decay, attract animalculæ, and so furnish food for the animal. If a stimulus be applied to any point on the under surface of the animal, the arms on the side from which it comes are simultaneously and forcibly pressed down, apparently to create a current that shall wash away the irritant. If an arm be cut off, it will continue to move for a short time. The crinoid, however, flattens its remaining arms, and rests immovable for half a minute; it then slowly crawls in a direction away from the wound. *Antedon* does not appear to like the light, and if placed on the surface of a stone in a glass vessel, always prefers to crawl to the under side, where it remains fixed by its cirri. If, however, a strong light be reflected on to the under side of the stone, while the top is kept dark, the animal will crawl back to the top. It is by crawling that the crinoid usually moves from place to place. The arms on the side towards which it intends to move, are stretched out; the pinnules are curved backwards towards the body, like so many grappling-hooks; and the arms are then curved up in S-fashion, thus dragging the animal along. Meanwhile, the arms of the opposite side move in the converse way, and their pinnules are directed away from the body, so that they push instead of pull.

At the present day crinoids live in all seas at depths between fifty and three thousand two hundred fathoms; but they prefer clear and undisturbed waters. The same has been the case in former geological periods, for while crinoids are abundant in limestones, of which their own remains form large masses, they are much rarer in sandstones and shales. As in the case of the well-known pear-encrinite, colonies of crinoids that lived in clear water have been suddenly overwhelmed by an influx of mud, which first killed and then preserved them. Unstalked as well as stalked crinoids live chiefly in colonies; but this is due less to sociability than to limited powers of motion even in the larval state. In the older rocks, individuals of many different genera and species may be found that lived in close association. In the later periods it is more usual to find numerous individuals of the same species in association; examples of such colonies among stalked crinoids are *Rhizocrinus* in the North Sea and off North America, *Bathycrinus* in the Southern Ocean, *Pentacrinus* off Portugal and in the Caribbean Sea, and *Extracrinus* in the Lias of Lyme-Regis.

The food of crinoids consists chiefly of foraminifera, diatoms, and the adults of small and the larvæ of larger crustaceans. Crinoids themselves form food for fish, though nowadays their place seems to be taken by the brittle-stars and an occasional sea-urchin. As protection against such attacks, some crinoids have been provided with spines, either as movable processes from the plates of the test, as in *Dorycrinus* from the Carboniferous of North America, or, very rarely, movably attached like the spines of a sea-urchin, as in *Hystricrinus* from the

Devonian of the same country. Parasites, however, find crinoids an easy and almost unresisting prey. A suctorial crustacean, eggs and all, has been found in the body - cavity, while a decapod crustacean occasionally inhabits the intestinal tube. The annexed figures represent the cysts formed by the crinoid in response to the irritation set up by the presence of a parasitic worm, in which cysts it takes up its abode. There are also worms that bore into the stem, as well as boring sponges, and corals that affix themselves to the stem. The crinoid generally makes some attempt to overwhelm these intruders by the rapid deposition of the calcareous skeletal substance; so that in the rocks greatly thickened stem-fragments are found enclosing the remains of corals, brachiopods, etc.



SWELLINGS IN THE PINNULES OF CRINOIDS PRODUCED BY A PARASITE (twice nat. size).

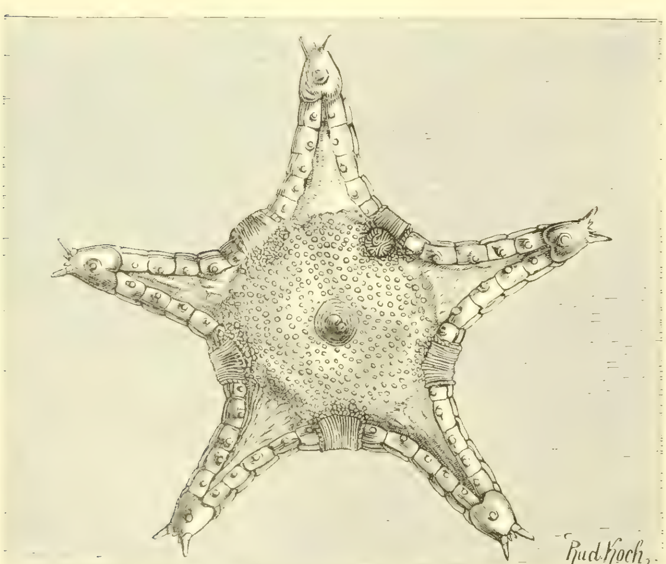
THE BLASTOIDS,—Class **Blastoidea.**

The Blastoidea constitute a compact group, pretty clearly marked off from both Cystidea and Crinoidea, which they resemble in the upward position of the mouth and the generally fixed habit. The chief character that separates blastoids from other echinoderms is the presence of an elongate plate, the lancet-plate, underlying the ambulacrum and pierced by a canal supposed to have contained the radial water-vessel. These five canals meet in a circular canal round the mouth, but there is no evidence that they were connected with tube-feet as in other echinoderms. Each side of each ambulacrum was lined by a row of delicate, unbranched arms; and the food-grooves of these arms passed to a single groove running down the middle of the surface of the ambulacrum, and these five grooves then passed up to the mouth.

The most interesting structures in the Blastoidea are the hydrospires. In such a form as *Pentremites* there are five openings (spiracles) round the mouth, placed in the interradial areas between the ambulacra. From each of these spiracles, a canal passes under the test in a direction away from the mouth. This canal soon branches, and a branch goes to the side of each ambulacrum. Each branch of the canal swells into a pouch with thin walls that are strengthened by a slight deposit of lime; and these walls are thrown into folds so that their surface is increased. There is thus a folded pouch running along the inside of the test under each side of an ambulacrum; and from this pouch short tubes are given off which open to the exterior through pores at the sides of the ambulacrum, which pores alternate with the arms and are not in any way connected with them. These hydrospires are clearly quite different structures to either of the two kinds of structures that go by the same name in the Cystidea. They have been compared with certain structures in the Ophiuroidea. In the latter animals are oval pouches, which lie at the sides of the arms where they spring from the body or disc, and which open to the exterior by slits. Their walls are strengthened by calcareous rods, and into them the ovaries open, so that developing young are often found in them, as in the marsupium of a kangaroo. They are known as genital bursæ, but their folded inner walls probably serve to bring the outer aërated water closer to the internal organs of the body, that is to say, their function is in part respiratory. We may, therefore, fairly suppose that the hydrospires of Blastoids served primarily for respiration, possibly in place of tube-feet, and secondly for the maturation and transmission to the exterior of the generative products. All blastoids have not hydrospires of precisely the same structure as those above described, since in some they are more like the slits previously mentioned in *Lepadocrinus* and *Porocrinus*; while they are always in the same interradial position, which is not the case with the cystids.

The Star-Fishes,—Class **Asteroidea.**

With the Asteroidea we come to echinoderms that differ from those hitherto described, and resemble those to be dealt with, in that none of them are fixed, but all are free-moving, and in the fact that the mouth is not directed upwards. There is, however, reason to believe that these free forms are, like the free crinoids, descended from ancestors that were fixed; and in the young *Asterina*, at all events, there is a prolongation of the forepart of the body, which not only corresponds in position to the prolongation that becomes the stem in crinoids, but actually serves for a short time as an organ of attachment. But whereas in the crinoid the mouth moves upwards to the surface opposed to this organ of attachment, and there becomes surrounded by arms, which similarly face upwards, in the asteroid the mouth and its surrounding arms are bent downwards so as to face the sea-floor, and the animal, instead of collecting its food from the water above, extracts it from the mud below. Correlated with this mode of life, the



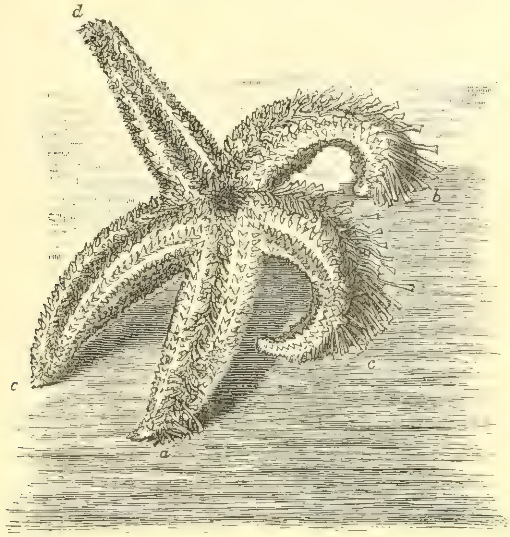
BLUE CHINA STAR-FISH (nat. size).

vent and madreporite are on the upper side of the body. So little is known of the Palæozoic star-fishes and their relations to later forms, that all classifications must be regarded as provisional. Subdivisions have been based on the character of the so-called pedicellariæ. These are small pincer-like organs that occur in star-fishes and sea-urchins, on the surface of the test, as shown in the illustration below. The movable spines covering the surface of these animals, and varying in size from minute, delicate, bristle-like structures to long rods, which may be thin and pointed, or thick, or even globular, are familiar to all. The pedicellariæ are probably derived from the smaller spines; two of these united at the base by a muscle, and slightly curved so as to approach one another at the ends, form the simplest kind of pedicellaria; and, by gradual modifications of this type, all the varieties may be derived. Many uses have been ascribed to the pedicellariæ, such as holding pieces of food, or removing dirt from the surface of the test. In some sea-urchins they are provided with poison-glands, which seems to show that they serve as weapons of offence in those cases. It has been considered that in sea-urchins their chief use is to catch hold of fronds of seaweed and keep them steady until the spines and tube-feet can be brought into action. The inner surfaces of the forceps in the pedicellariæ are remarkably sensitive, and the blades close on any minute object immediately their inner surfaces are touched by it. It seems, however, that in spite of the amount of attention devoted to these organs, we do not yet understand all their uses. Besides spines and pedicellariæ, star-fish also have on the surface of the skin small tubular processes, containing an extension of the body-cavity. These have very thin, contractile walls, and doubtless serve to assist respiration. All star-fishes have tube-feet, but in some these have no suckers at the end, and in all cases those which are at the ends of the rays are used only as feelers, and are stretched in the direction in which the animal is moving. At the extremity of each arm is a single tube-foot, which is the first to be formed, and is known as the unpaired tentacle; this being always stretched straight out. Immediately above this tentacle is a small eye, coloured by red pigment, and protected by small tentacles.

PEDICELLARIÆ.

a, Two-jawed, closed; *b*, Two-jawed, open; *c*, Three-jawed. (20 times nat. size.)

Star-fish are sluggish animals, rarely moving of themselves, and staying for days in the same position. Those kept in tanks or in glass vessels prefer to cling to the side, instead of lying on the bottom. When disturbed, however, a star-fish can travel at a considerable pace. Those star-fish that have suckers crawl by means of their tube-feet, while those that have no suckers still use their tube-feet slightly, but also progress by the muscular movements of the rays. The short-armed *Asterina* and *Astropecten* can right themselves in less than a minute, and accomplish the act by raising themselves on the tips of four rays, and then turning a somersault by throwing over the fifth ray. *Asterias* takes rather longer, and effects its purpose by first twisting over one or two of the rays and catching hold of the ground by the suckers. It then gradually turns over the rest of the body. *Cribrella* rights itself in the same way as *Asterias,* but, apparently because of the stiffness of its skeleton, takes much longer over the process. Star-fish, like other echinoderms, are a sociable class. Even the deep-sea forms sometimes live in swarms. Many shallow-water forms also are gregarious, and some species have been observed to pair at the breeding-season. The deep-sea star-fish, writes Alcock, "subsist largely on molluscs, the shells of which, along with the chitinous remains of prawns and amphipods, are often to be found in their stomachs; but some of the characteristic deep-sea forms appear to gorge themselves with globigerina-ooze." The shallow-water forms prefer hard ground, rocks, reefs, or beds of hard sand, where they find in abundance the molluscs and small crustaceans on which they feed.

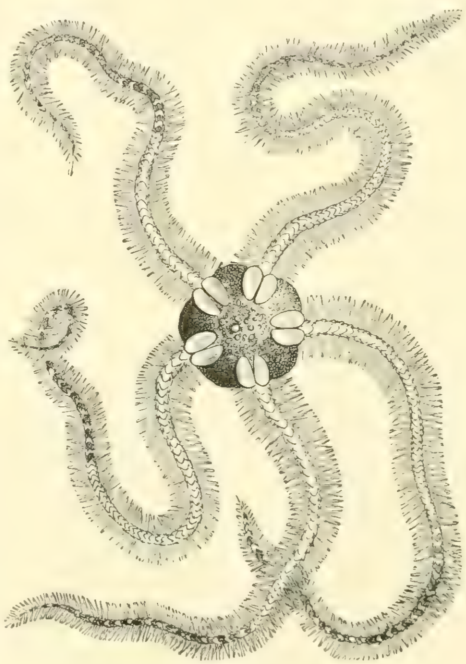


STAR-FISH TURNING OVER.

Between the Asteroidea and Ophiuroidea, the family *Brisingidæ* has been considered by some a link; but in all essential features of structure they agree with the Asteroids. Superficially they resemble the Ophiuroids in having long, thin, flexible arms, clearly distinguished from the small central disc or body.

The Brittle-Stars,—Class **Ophiuroidea.**

The name Ophiuroidea, given to the brittle-stars, refers to their long serpent-like arms, which are attached to a relatively small and usually rounded body or disc. The digestive and generative systems do not extend into the arms, but are confined to the body; so that the arms are appendages to the body, rather than portions of it. They are cylindrical, and have no groove on the under side, such as exists in star-fish, but have little openings through which the tube-feet pass. In this class it is the arms themselves, and not the tube-feet that are used for locomotion. The tube-feet accordingly have no terminal suckers, but are very sensitive to touch, and probably assist respiration. The greater part of each arm is formed by a central axis of successive calcareous segments, not unlike the vertebræ of a back-bone. Each arm-ossicle or vertebra is, however, composed of two parts, one on either side, and united in the middle line; the successive ossicles being connected by pairs of strong muscular bundles, and articulating with one another by tenon-and-mortice joints. According to the degree of development of these joints, the arms have varied powers of coiling. Thus, in the *Cladophiuræ,* the ossicles have more or less saddle-shaped faces, so that the arms can be twisted round foreign objects or rolled towards the mouth; in the *Streptophiuræ*, the faces of the ossicles have slight pits and processes, but none sufficient to prevent the ossicles being so twisted on their neighbours that the arms may be rolled up towards the mouth; in the *Zygophiuræ*, the faces of the arm-ossicles have articulating knobs and pits, which prevent the arms from being rolled up towards the mouth. These vertebral arm-ossicles are encased in the tough outer skin of the arm, in which are developed granules, plates, and spines, which are least definite and regular in the *Cladophiuræ*, most definite in the *Zygophiuræ*. The spines, which are clearly shown in the annexed figure of *Ophiothrix*, are borne on the side-plates of the arm, and aid the animal in locomotion. The integument of the disc also bears plates or scales of various sizes, often more or less covered with granules and minute spines. The precise arrangement of the plates on the top of the disc varies in different species; but five pairs of plates, known as the radial shields, are always present at the base of the arms, and are shown in the annexed figure. On either side of the arms where they join the disc, there is seen on the under surface a slit-like opening. These openings, known as the genital slits or clefts, are usually single but sometimes double; they lead into thin-walled pouches or bursæ at the sides of the rays. In a living ophiurid, the disc alternately expands and contracts, and thus water is pumped into and out of the pouches, through the slits. The entering water brings oxygen, which it exchanges, through the thin walls of the pouch, for the carbonic acid contained in the water of the body-cavity, and then goes out again by the return current. Hence the pouches are called respiratory bursæ. But they have another function, since the ovaries enter into them, and the ripe ova may either be carried out by the current through the slits, or they may remain and undergo direct development in the pouches themselves. Around the mouth are a number of short flat processes, or papillæ, serving as strainers, and keeping foreign bodies that are not wanted for food from entering the stomach. Round the mouth are also twenty tentacles, which are really the modified tube-feet of the two first arm-segments of each arm. They are in a state of continual movement, assisting the food to enter, and clearing away the undigested residue, which is ejected from the mouth.

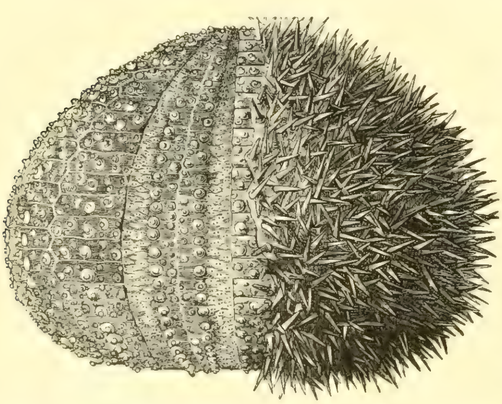


COMMON BRITTLE-STAR ($\frac{2}{3}$ nat. size).

The branched ophiurids, or *Cladophiuræ*, are sedentary, attaching themselves by coiling their branching arms around corals and suchlike animals; but can move when they please. The same mode of life is also affected by a few of the simpler forms; but, as a rule, ophiurids have considerable powers of locomotion, of which they readily avail themselves. Most walk rather than creep, raising themselves on their five arms as upon legs; stretching out one or two arms in front, and drawing the rest of their body in the same direction. Even in a state of repose, the arms alone touch the ground, the disc remaining raised above it In other forms, however, the rays of the body undulate laterally, and produce a creeping serpentine movement. Rondelet wrote that the common brittle-star creeps by the flexuous movement of its rays in the manner of serpents, and, placed on dry land, never ceases to move them, until it casts them off in pieces, which, although separate, move by bendings, like parts of worms and the cut-off tails of lizards. The little *Amphiura*, which lives under stones, among the roots of seaweed, can turn its arms very quickly around its disc, and so form itself into a little ball; thus, if it be disturbed, it can roll and sink quickly into deeper parts of the water. Sometimes ophiurids are seen to progress by a kind of rowing motion of the arms.

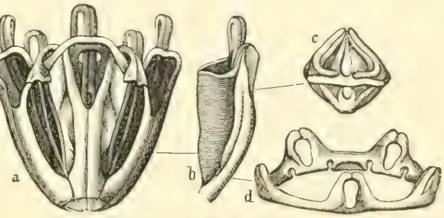
The Sea-Urchins,—Class **Echinoidea.**

The sea-urchins are the best known, as they are the most numerous of all echinoderms. The annexed illustration shows the test or shell of the egg-urchin, with the spines on the right side, but scraped away from the left. The plates of the test are seen to be covered with rounded tubercles of various sizes, and it is to these that the spines are attached by a ball-and-socket joint, surrounded by muscles that can move the spines in any direction. The tubercles do not, however, cover the whole test indiscriminately, but are disposed chiefly in five broad zones, extending from one pole to the other. Alternating with these are five narrower zones, bearing smaller and fewer tubercles, and pierced by small holes arranged in regular rows. Through these holes pass the tube-feet, which are all provided with suckers at the end. These latter zones are, therefore, the ambulacral zones; one of them being seen in the middle of the illustration. The other zones are called interambulacral, and one of them is shown on the left of the same illustration. All the zones converge towards the summit of the test, where the vent is situated in a circular space covered with membrane. This membrane contains a few irregular granules, and is surrounded by five large interradially placed plates, pierced by the ducts of the generative glands. One is also pierced by a large number of small water-pores, and is called the madreporite. Outside these five plates, and alternating with them, are five other plates, each situated at the top of an ambulacral zone, and pierced by the unpaired tentacles, which terminate the water-canals, and represent the unpaired tentacles near the eye at the ends of the arms of a star-fish. At the other pole of the body is another membrane, sur-

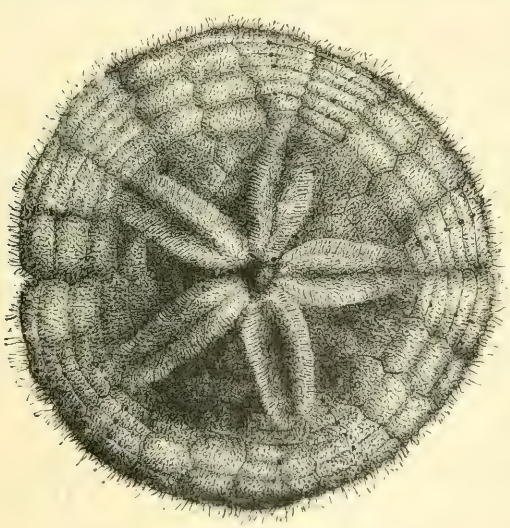


TEST OF EDIBLE SEA-URCHIN, WITH THE SPINES REMOVED FROM THE LEFT-HAND HALF (nat. size).

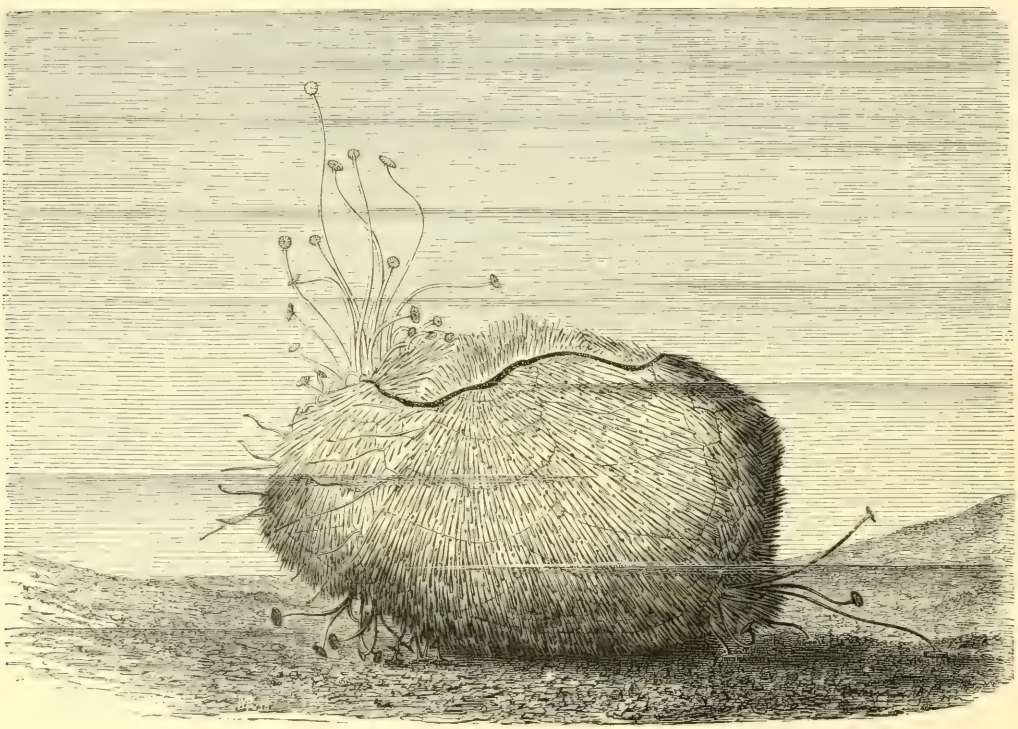
rounding the mouth-opening, through which may be seen five pointed teeth. These belong to a very elaborate masticating apparatus, shown in the illustration, and found in all the regular urchins, as also in the Clypeastrida among the irregular urchins. This consists of twenty principal pieces arranged into a five-sided conical mass, compared by Aristotle to a lantern (*a*). In the centre of the whole are five teeth (*b*, *c*), working in bony sockets, or pyramids, connected by muscles with one another, with the interior of the test, and with the arched processes, known as auricles (*d*), that surround the mouth-opening. There are yet other calcareous pieces connecting the pyramids together, and serving as attachments for yet other muscles. Such a sea-urchin as that described, preserves as much as any echinoderm the five-rayed symmetry of the group; but in many forms the five-rayed type is not so obvious, for the animal has become elongated along one of the axes, so as to have a superficial two-sided symmetry. This is naturally connected with constant movement in one direction, as though the animal had a head and tail; and such modification is found among those urchins that live on muddy bottoms, and especially in those from considerable depths. Not only is the test elongated, but the mouth moves forward to the front margin, and the vent downwards to the hinder margin, so as eventually to lie on the under instead of on the upper surface of the test. An earlier stage in this modification is shown in the illustration of the shield-urchin (*Echinarachnius*), and a fully developed one in the heart-urchin (*Brissopsis*), with its long tube-feet extended in the act of walking towards the left. These heart-urchins, as they move along through the sand and mud, scoop it up into their mouths, and pass it through the intestine, extracting on its passage such nutriment as the minute organisms it contains can afford. To enable them to scoop it up in this way, the hinder margin of the mouth is produced forwards in a kind of shovel shape, as is shown in the illustration of a *Pourtalesia* test from which the spines have been removed. These animals live at very great depths in the sea, and are the urchins most modified in this particular direction. Urchins of the heart-shaped type have short delicate spines, and move almost entirely by their long tube-feet, in the manner described; but the greater number of the regular urchins progress chiefly by the aid of their spines, which are much stouter, while the tube-feet often have the suckers very imperfectly



JAWS OF STONE-URCHIN (nat size).

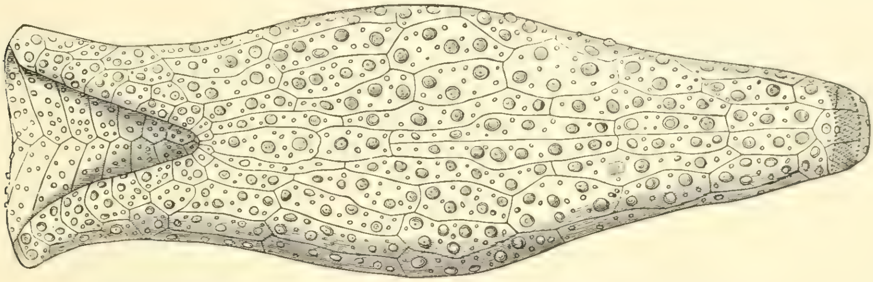

SHIELD-URCHIN, FROM ABOVE (nat. size).

developed. The spines of sea-urchins also serve as organs of protection; but their efficacy varies much in different forms. For instance, *Diadema setosum* has fine sharp spines, 8 or 10 inches long, which prick one almost before one can see them, and can pierce the stoutest boot; their danger being increased by the gregarious habit of the animals. Some sea-urchins have poison-glands attached to their spines. It is the smaller spines that are protective, and they are placed for this purpose near the main openings and organs of the body, such as the vent, genital pores, and eyes; they also protect the ambulacra, and bases of the larger spines. A *Porocidaris* feeling itself free from danger, in well aërated water, walks from one side to the other, doubtless in search of food; its ambulacral tentacles being



FIDDLE HEART-URCHIN, MOVING OVER THE SAND TOWARDS THE LEFT (nat. size).

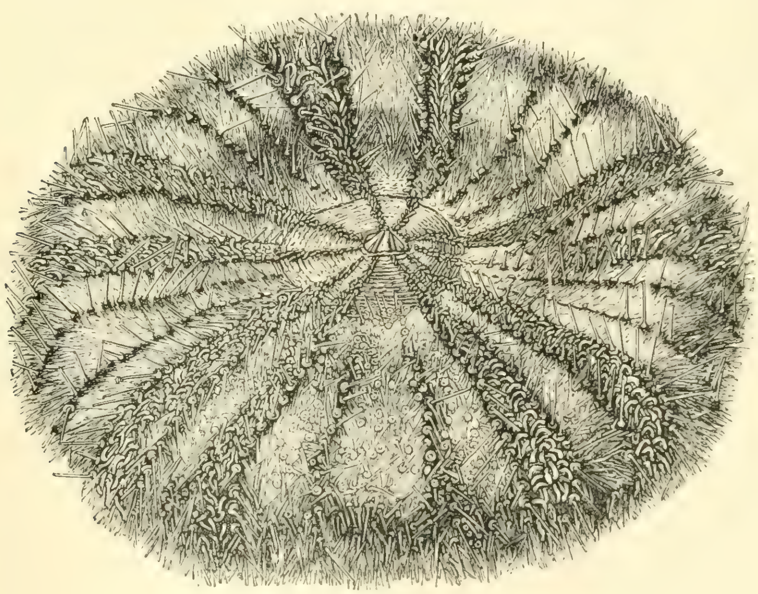
stretched out as feelers, and its long spines moving as described. The smaller spines are depressed to permit of the free movement of the larger ones, and those of the ambulacra raised to permit the extension of the tube-feet. If one slightly wounds the animal when thus expanded, the larger spines immediately stiffen on their tubercles, while all the smaller spines depress themselves, each over the organ that it is destined to protect. Though the tube-feet may not be used for locomotion, they are put to another useful purpose. If a *Strongylocentrotus* be placed in a tank with some dead shells or similar objects, it will raise them on to its back, and hold them there by means of the tube-feet, as a kind of concealment. Some sea-urchins cover themselves all over in this way with bits of seaweed, shell, and small pebbles, and so move about unobserved. Other sea-urchins do not move from place to place, but always stay in one spot, where they are generally found living in a hole. Sometimes the hole may have been there before the sea-urchins; sometimes may have been formed by the growth of calcareous algæ around the sea-urchin; but sometimes the urchin itself has bored the hole. This is accom-



PHIAL-SHAPED POURTALESIA; TEST WITH SPINES REMOVED (enlarged 4 times).

plished not by any acid secretion,—for on the west coast of Africa an *Echinometra* has been found boring into an augite lava,—but by the continuous movement of the teeth and spines. The common *Strongylocentrotus* is a well-known example of a boring sea-urchin. When the waves wash up against the urchin it sets its spines rigidly against the sides of its hole and so holds fast.

Although most of the sea-urchins have a rigid test, yet there are some in which the plates are only loosely joined together, so that the test is flexible.

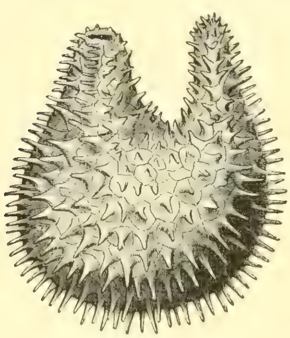


LEATHER-URCHIN ($\frac{2}{3}$ nat. size).

This is the case in an *Astropyga*; but is still more pronounced in the leather-urchin (*Asthenosoma*), and other members of the family *Echinothuridæ*. Respiration is effected in the regular sea-urchins by ten gills near the mouth. These are thin-walled ciliated extensions of the body-cavity protruding between the membrane round the mouth and the plates of the test. In the irregular urchins some tube-feet are modified for respiration, becoming broad, flat, and somewhat lobed; the hinder end of the intestine seems to be respiratory in function. Some sea-urchins possess eyes. In a *Diadema* there are five ovate pigment-masses of a brilliant ultramarine blue, placed at equal distances around the vent. There are certain other peculiar bodies supposed to be sense-organs of some kind, called sphæridia, which are of microscopic size, and in structure not unlike tiny spines. They lie near the mouth and on the lower ambulacral plates, are often set in small holes, and are provided with special nerves. Perhaps they test the water in which the sea-urchin lives, and thus may be said to serve the sense of smell. Sea-urchins are both animal and vegetable feeders, and are even cannibals when opportunity offers.

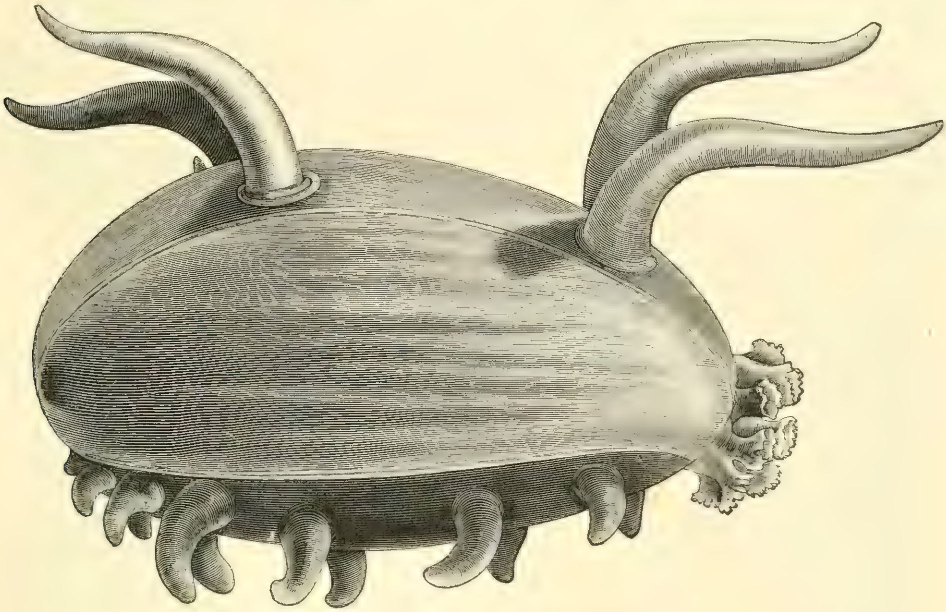
THE SEA-CUCUMBERS,—Class **Holothuroidea.**

Sea-cucumbers are, as we have seen, elongated and worm-like creatures, with a mouth at one end and a vent at the other. The skin is leathery, and contains a comparatively small amount of calcareous matter. Usually this occurs in small spicules, which assume very definite shapes, such as the anchors of *Synapta*, or the wheels of *Chiridota*; but in such forms as *Psolus* the spicules increase in size, so as to form a plated integument. There may also often be a ring of calcareous plates round the gullet, five of which plates have the same relation to the radial water-vessels as the auricles around the jaws of a sea-urchin, and they likewise serve for the attachment of muscles. In such a common form as *Cucumaria planci* there are five rows of tube-feet passing from mouth to vent. The five-rayed symmetry is not obscured, and is traceable in the arrangement of nerves and muscles, although it does not affect any portion of the digestive or generative systems. Around the mouth, in *Cucumaria*, is a fringe of branched tentacles, connected with the water-vascular ring. In most other echinoderms, it will be remembered, a canal passes from this ring and opens to the exterior by a madreporite; and in a few holothurians of primitive structure this is similarly the case. But in *Cucumaria*, as in most, the connection with the exterior is lost, and the canal, with its madreporite, hangs down into the body-cavity. In *Cucumaria* the tentacles are used like a net to intercept floating organisms in the surrounding water. Many holothurians swallow a great deal of sand, and the intestines of those that live near coral-reefs generally contain fragments of coral. They usually attach themselves by their tube-feet to rocks or seaweed, and wave the tentacles around. *Holothuria atra*, which lives on the great Australian barrier-reef, inserts its hinder extremity within a crevice of the rock, into which on being disturbed it speedily retreats.



U-SHAPED SEA-CUCUMBER ($\frac{2}{3}$ nat. size).

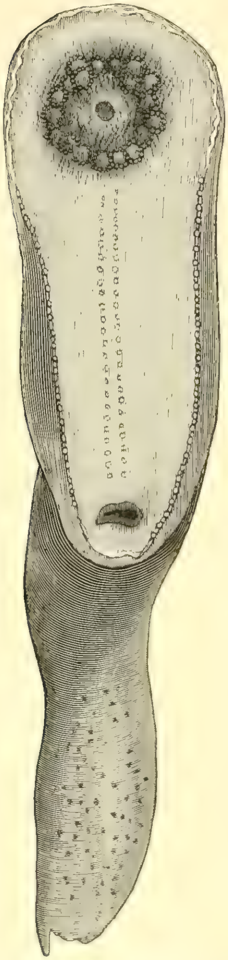
Some curious modifications of form have taken place among the holothurians. In the plated sea-cucumbers (*Psolus*), of which a specimen is illustrated on p. 314, the animal has become flattened, and the tube-feet restricted to three out of the five ambulacra, and by these three the animal creeps about, or holds itself fixed to the rock. A similar modification is carried to excess in the deep-sea holothurians known as Elasipoda. Here, as in the illustrated *Scotoplana*, there are a couple of rows of thick tube-feet, forming little stumps, with which the animal moves, as a centipede moves by its legs. In front there is a sort of funnel or scoop formed by the short tentacles, while a few of the tube-feet form long horns or feelers on the upper side. In the deep-sea *Psychropotes*, on the other hand, mouth, vent, and tube-feet are confined to a flat sole; while the posterior part of the body is



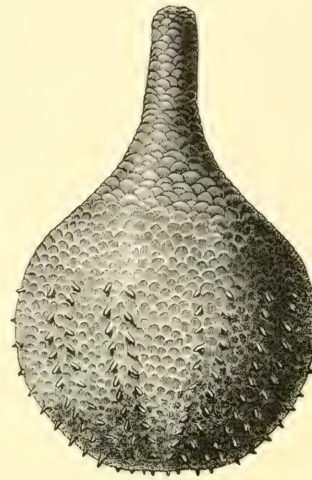
A DEEP-SEA HOLOTHURIAN, *Scotoplana* (nat. size).

extended in a long tail. Some holothurians live in mud; and by reason of constantly keeping both mouth and vent above the surface their bodies have become curved in U-fashion, as seen in the U-shaped *Ypsilothuria* (illustrated on p. 312). This is carried still further in the club-like *Rhopalodina* (illustrated on p. 314), a form shaped like a cherry, with a thick stalk; the openings of both mouth and vent being at the top of this stalk. A yet stranger modification is the holothurian described under the name *Pelagothuria*, which lives in the East Pacific, on the surface of the ocean. It has no calcareous spicules, the longitudinal muscles being mostly changed into a jelly tissue. Around the mouth the body is extended into a kind of disc, prolonged into thirteen to sixteen feelers. The animal swims by the movements of this disc.

Holothurians have no means of offence, but protect themselves for the most part by assuming the colour of their surroundings. The huge *Synapta besseli*, which reaches a length of 6 feet, has a habit, when taken in the hand, of squeezing the fluid contents of its body towards the portion that is grasped, till it becomes too big to hold. Some, when much irritated, seem to fade away and dissolve by breaking up their tissues; while others have an objectionable habit of shooting out a part of their intestines in long viscous strings; and it is owing to this that a common British form has gained the name cotton-spinner. It has been suggested that this habit has been acquired in connection with the presence in the intestine of small parasites, and these in their turn have their habits affected according as they live in holothurians that are or are not cotton-spinners. Among the parasites of holothurians should specially be mentioned a little fish of the genus *Fierasfer*, that inhabits the intestine of some species, and has its food provided for it by the holothurian; this fish is described on p. 438 of Vol. V.



A DEEP-SEA HOLOTHURIAN. *Psychropotes* ($\frac{2}{3}$ nat. size).

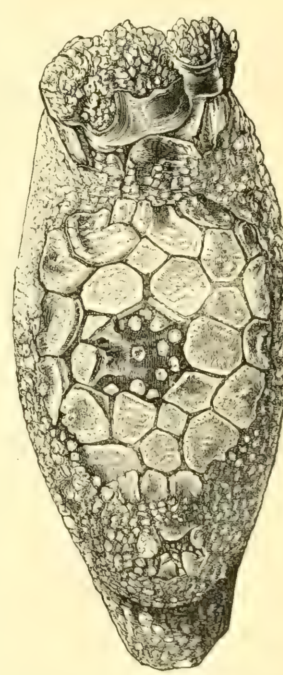


CLUB-LIKE SEA-CUCUMBER (*Rhopalodina*) (nat. size).

Holothurians are of interest, as furnishing a food known as trepang, which ranks with edible birds' nests among the delicacies of a Chinese table. The fishing for trepang, or *bêche-de-mer*, as the holothurians are called by the Portuguese, takes place very largely in Oriental countries, and is being extended to the Barrier Reef of Australia. All kinds are not equally esteemed, for some have too much calcareous deposit in their skin, and others get rid of their insides, and so become too lean.

Development of Echinoderms

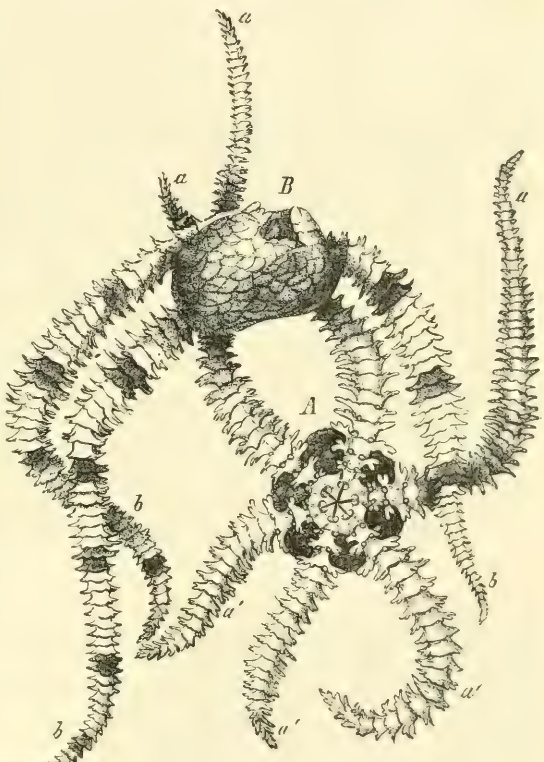
Few things about echinoderms are more remarkable than their modes of reproduction, which include both a sexual method, from the fertilised egg, and also one by budding or splitting of a single individual into two. Many echinoderms, as we have already seen, have the curious power of breaking off portions of themselves; as the brittle-star or crinoid can break off their arms. Also they are able to eject the whole or a part of their viscera, a faculty which has been specially developed in some of the holothurians. It is still more remarkable that the portions so broken off can be grown again, and that they



A PLATED HOLOTHURIAN (*Psolus*).

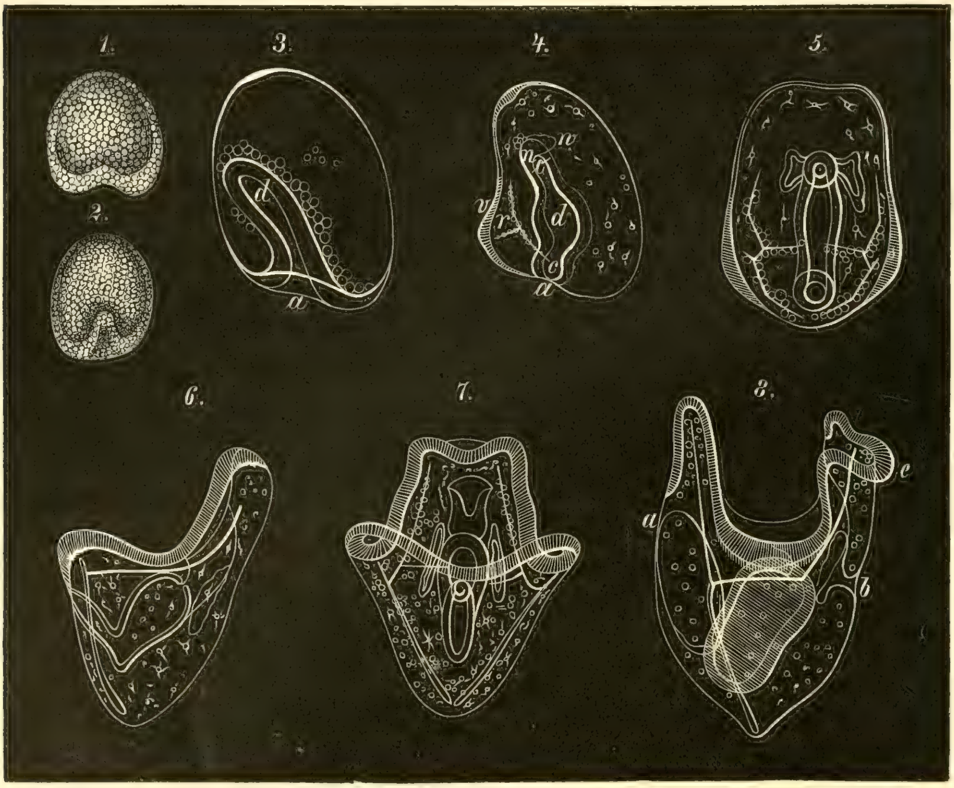
Some plates of the back, above the brood-pouch, are removed (enlarged 3 times).

themselves can, in many cases, grow fresh bodies, and become complete individuals. A star-fish of the genus *Linckia* commonly avails itself of this faculty; and it is by no means rare to find big arms with a small body at one end, and four little arms growing out of it; these are known as comet-forms. This power of reproduction is probably due to the extension of all the systems of the body into the arms: the arms of brittle-stars, which do not contain all the systems of the body, have not been known to reproduce individuals. In some cases echinoderms have been seen definitely to reproduce themselves by fission or splitting in half. Such division is well known to take place among the sea-cucumbers; and it is believed by some to take place even in brittle-stars; the specimens of the six-armed green snake-star (*Ophiactis*), shown in the annexed illustration, being thought to represent the result of such a process. The specimen *A* consists of two almost similar halves; but the three arms towards the bottom of the illustration, marked *a′*, are smaller than the others marked *a*, and indicate that this half is the later grown. The specimen *B*, which is seen from the back, has only just separated itself from its other half. The separation appears to take place by a forcible though spontaneous rent, and the edges of the wound subsequently grow together, and not merely heal up but reproduce the lost parts of the animal. As a rule, however, echinoderms reproduce by the ordinary sexual methods; although this, too, presents peculiarities. Just as a butterfly does not develop directly from the egg, but passes through the intermediate larval stage of the caterpillar, out of whose chrysalis the butterfly springs, so the sea-urchin or the star-fish egg gives rise to a larval form, in whose body, as it were, the mature form is developed. The particular shape of the larva varies in the different classes of echinoderms; but the differences are not essential, and it is clear that all the larval forms are modifications from one primitive type. The changes passed through in the development of the common sea-urchin (*Strongylocentrotus drœbachiensis*) are depicted in the illustration on p. 318, in which the drawings are very greatly magnified.



GREEN SNAKE-STAR (enlarged 5 times).

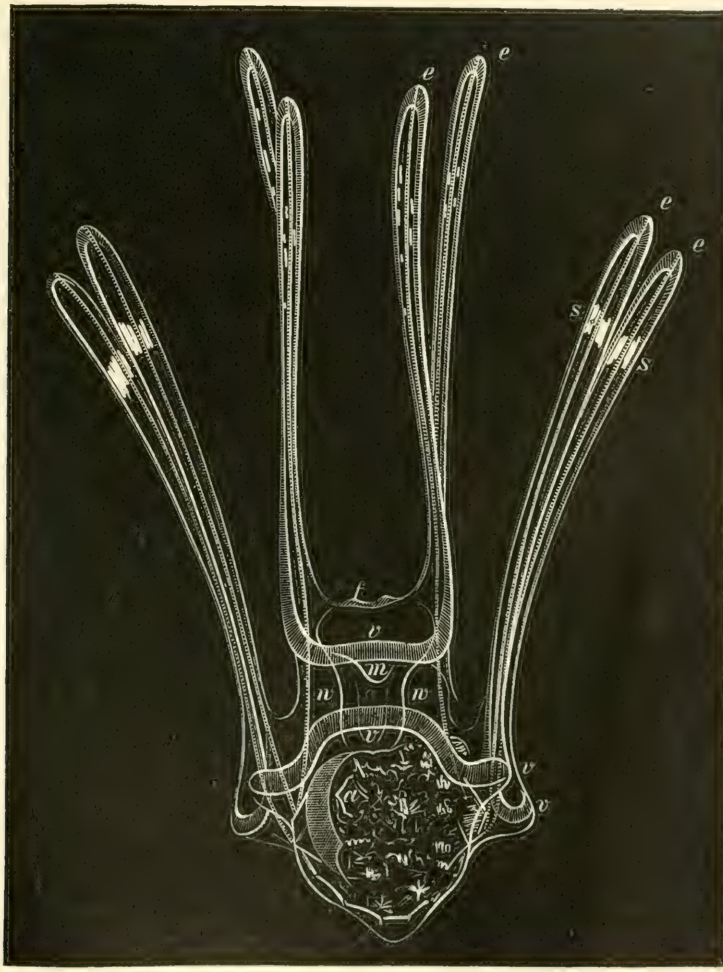
The fertilised egg divides and subdivides until a round ball of cells is formed. This is then pushed in at one end, as one might push in a soft indiarubber ball, so that there is formed a little sac with a double wall to it (stages 1, 2). Stage 3 shows this in outline as though transparent; and one sees the opening *a* turned downwards, and the canal *d*, which foreshadows the intestine. At the upper pole



DEVELOPMENT OF A SEA-URCHIN (stages 1–8).

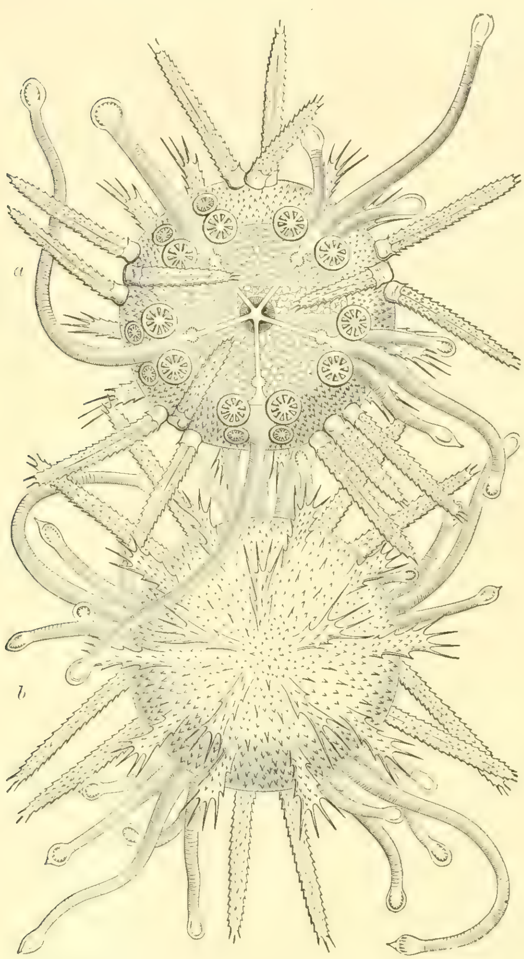
DEVELOPMENT OF A SEA-URCHIN (stage 9).

of the embryo, near the number 3, is a small tuft of cilia, by the motion of which the embryo swims about. In stage 4 this ciliated area is seen to have extended downwards to the letter *v*. The intestine now develops in such a way that the original opening (*a*) remains as the vent, the middle part (*d*) widens into a stomach, and a fresh mouth-opening (*m*) is pierced through at its upper end. This is seen from the side in stage 4, and from the front in stage 5. But before the mouth is formed, two ear-like processes (*w*) show themselves, which are important as being the beginnings of the ambulacral and water-vascular systems. There also appear a few delicate, symmetrically laced rods of carbonate of lime, which by and by grow into the skeleton of the larva, in shape something like an inverted easel. The two lower ciliated bands now grow towards one another, so that the vent comes to lie beneath them (stages 7 and 8). They also join themselves to the two upper bands, so that there is formed a single zone of cilia, which persists to the end of the larva's life. Already can be distinguished the beginnings of the apex and of the processes (*e*), which finally lengthen into the arms that give such a strange appearance to the larva, in the sea-urchins and also in the star-fish and brittle-



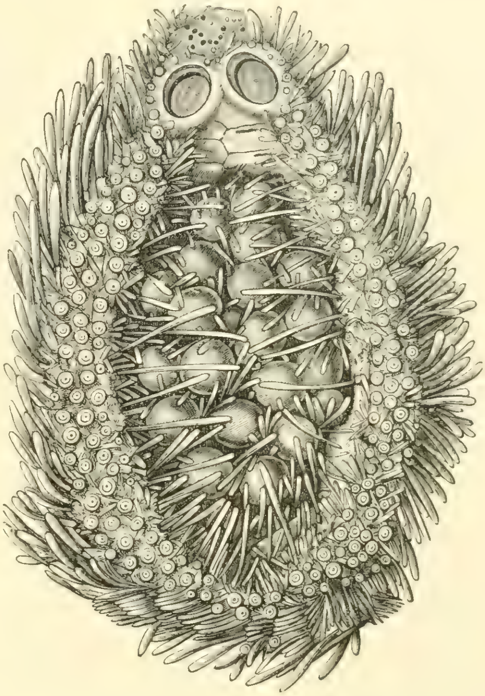
DEVELOPMENT OF A SEA-URCHIN (stage 10).

stars. In stage 8 can be seen, at *b*, the pore that admits water to the water-vascular system; and at this point will lie the madreporite of the future sea-urchins. The next illustration shows all these parts in a rather more advanced stage: *a* is the vent; *c*, the hinder intestine; *d*, the stomach, around which a deposit of spicules indicates the first beginnings of the body of the sea-urchin; *o*, the gullet; *m*, the mouth; *e*, the arms of the larva; *r*, the calcareous rods that support them; *v*, two more strongly-developed and slightly projecting portions of the ciliated band; and *w*, the water-vessels. The larva in its full development is shown in the illustration on p. 317, in which the letters have the same meaning. This larval form is called a *Pluteus*, on account of its frequent changes of shape, as it swims about with its arms constantly moving. It will be noticed that through the whole of its development it retains a two-sided symmetry, such that if cut down the middle it would be divided into two precisely similar halves. This is very different from the five-rayed symmetry of the sea-urchin, and the difficulties arise both in this class and in the others when we try to discover how the five-rayed form was produced from the two-sided one.



YOUNG SEA-URCHIN (*Strongylocentrotus*). *a*, From below; *b*, From above (enlarged 20 times).

From this larva only the stomach and the water-vascular system are continued into the sea-urchin, whose prickly body is now being formed around the stomach of the larva; and it is in just those two systems, especially in the madreporite and in the intestine, that we note in the adult the traces of the primitive bilateral symmetry. When the little body of the sea-urchin, which at first is like a flat box, has become provided with a mouth of its own, and with a circlet of comparatively large spines, then the parts not necessary to the new structure disappear. The calcareous skeleton of the larva is absorbed, and the lime salts thus set free help to build up the test of the sea-urchin. The arms sink in, and at last the outer larva remains as nothing more than a skin over the test of the urchin. The mode of life of the little sea-urchin, about one millimetre in diameter, is now completely altered. It is no longer carried about through the water, but crawls by means of its tube-feet and its spines, as shown in the above illustration. We cannot here follow the further changes that it undergoes; but a study of those later stages is of great importance. For by means of such study Agassiz has shown that many supposed genera are nothing more than undeveloped forms of well-known species, and he has thus been able to work out the relations of species and genera to one another. It is not, however, all echinoderms that pass through these curious larval stages, for in many species the young are developed in the shelter of the mother. We have already seen this to be the case with many brittle-stars, which are protected in the so-called genital bursæ. In a sea-urchin (*Hemiaster philippi*) there are depressions between the ambulacra, which are called brood-pouches; for in these the young develop from the egg, covered over by the spines of the parent, as in the annexed illustration. In some holothurians the young are attached to the body of the parent, as in *Cladodactyla crocea*; but in others, as in *Psolus ephippifer* (shown on p. 314), they live on the back of the mother under some large mushroom-like plates. Some star-fish, too, such as *Pararchaster*, have a kind of tent of plates in the middle of the disc, where the young grow up as in a nursery.



BROOD-POUCH OF A SEA-URCHIN (enlarged 5 times).

The direct development from the egg to the adult in these protected forms, seems to show that the elaborate shapes of the various larvæ have been developed secondarily for the special purpose of transporting the young and aiding in the dispersal of the species, and, therefore, that they are not relics of any ancestral forms. There can, however, be little doubt that the echinoderms were originally derived from some form or forms with a two-sided symmetry; and it is certainly curious what a close resemblance their assumed primitive larval form presents to the larva of *Balanoglossus*, the worm-like animal described on p. 573 of the last volume, and considered by many authorities to be in the ancestral line of the Vertebrata.

F. A. BATHER.

CHAPTER IX.

The Molluscs or Shell-Fish,—Subkingdom **MOLLUSCA.**

Science is never stationary, and consequently the scope of many groups of the animal kingdom has considerably altered since they were defined by their original founders. Such has been the case with the Mollusca of Cuvier. Besides the animals which constitute this subkingdom, as now understood, he included in it the Tunicata, Brachiopoda, and Cirripedia — branches of the zoological system, which more recent anatomists have long since removed elsewhere. At the present time the Mollusca comprise only such forms as the octopus, cuttle-fish, etc., all the marine shell-bearing animals of the whelk tribe, and other kinds, land and fresh-water snails, slugs, the tooth-shells, and bivalves of every description. The number of known species is very large, and fresh forms are constantly being discovered. Probably some fifty thousand recent species have already been described, the number of aquatic being more than double that of the terrestrial species. The aquatic kinds, however, will eventually be found to preponderate still more, for the sea appears to be inexhaustible in the production of new forms. It matters not in what ocean the dredge is let down, be it to a great depth, or in shallower water, something new is certain, sooner or later, to be gathered in. Drop the dredge to three thousand fathoms (more than three miles), and still molluscs are met with, and the extreme depth to which molluscan life extends has yet to be ascertained. The great coast lines of South America, Africa, Asia, and parts of Australia have been but imperfectly explored for the smaller kinds of Mollusca; for whenever a limited stretch of coast is carefully searched by the conchologist, considerable numbers of new species are forthwith discovered. On the contrary, with the terrestrial forms the case is different. They are more easily acquired, as they come under actual vision, and all the inhabitants of a given district can in course of time be known.

Definition. Molluscs are soft, cold-blooded animals, without any internal skeleton; but this is compensated for in the majority of cases by an external hardened shell, which serves at once the purpose of bones and as a means of defence. Their bodies are not divided into segments like those of insects and worms, but are enveloped in a muscular covering or skin, termed the mantle, the special function of which, in the majority of species, is the formation or secretion of the shell. Molluscs are more or less bilaterally symmetrical; but this bilateral symmetry in some cases, particularly among the Gastropods, is to some extent obscured by the contortion of the body. The foot, which serves the purpose of locomotion, or is used in burrowing in sand, wood, and rock, etc., is an organ highly characteristic of most Molluscs. The shells, in the vast majority, consist either of a single piece, as in the snail, whelk, etc., or of two portions (valves) as in the oyster, cockle, and most other bivalves. In one group, however (*Chitonidæ*), the shell takes the form of a series of eight adjacent plates, and in one group of bivalves (*Pholadidæ*) there are one or more accessory pieces in addition to the two principal valves. In the bivalves, with one or two exceptions, the shell is always external. Not so with the univalves, in some of which it is quite concealed beneath the skin, in others it is partially so. Shells are mainly composed of carbonate of lime, with a small admixture of animal matter. Their microscopic examination has revealed a great diversity of structure. Some are termed porcellaneous, others horny, glassy, nacreous, and fibrous. The shell is essential to the life of the inhabitant, it forms part of its organisation, and if it be removed, death ensues sooner or later. Although Molluscs have the power of repairing injuries to their shells, no case is known of a species removed from its shell having secreted a fresh one. Many shells exhibit an outer coat of animal matter termed the *periostracum*. It is generally of an olivaceous tint, but varies considerably in thickness and appearance. It is quite smooth, or of a velvety or silky aspect, or it may be produced into hair-like extensions. Its special function is the preservation of the shell from atmospheric and chemical action. Were it not for the periostracum, the shells of fresh-water molluscs would in time be dissolved by the carbonic acid gas with which water is more or less saturated. Owing to the thinness of the periostracum, or to its having been worn away, the apical portion of many fresh-water spiral shells and the tips or beaks (umbones) of the bivalves are frequently more or less eroded through this chemical action.

Growth. The shells of gastropods are enlarged with the growth of the inhabitant by the addition of fresh layers to the margin of the aperture, so that a shell which at its birth had only two volutions or whorls, may eventually consist of about a dozen. The growth of bivalves is more readily understood, being effected by additional concentric deposits along the outer margin of the valves. The adult condition of many shells cannot be detected by a superficial inspection. This is particularly the case with the bivalves. On the contrary, a little experience soon teaches us to recognise in the majority of cases if a gastropod shell is immature; but even among this class there are many exceptions where the most practised eye would fail to determine the period of growth.

Many shells exhibit conspicuous prominences on the surface in the form of spines and ridges, and it is a great puzzle to the uninitiated how this ornamentation is produced. It is, however, a very simple matter. Wherever a spine occurs on a shell we may be certain that it resulted from a corresponding filament or process upon the edge of the mantle, and these processes may be brought into use only periodically. A striking example of this periodic formation of spines occurs among the typical *Muricidæ*. On the contrary, spines or extensions may occur only upon the lip or edge of the aperture when the shell has arrived at maturity, and consequently we may assume that the necessary prolongations upon the edge of the mantle for the secretion of such spines are only developed at this period of the mollusc's life.

The diversity in shells with respect to form, size, and solidity is simply enormous. What resemblance, for example, is there between a *Chiton* and a

Dentalium, or a *Carinaria* and a *Turritella*, and among the bivalves between a *Pholas* and the hammer-oyster (*Malleus*). The difference in size is still more remarkable, some microscopic forms weighing not more than the fiftieth part of a grain, whereas the gigantic *Tridacna* occasionally turns the scale at over 500 lbs.

As every mollusc has a history of its own,—a certain course to pursue in the living world,—its means of existence and propagation will be found sufficient, although to the human eye the chances against it may superficially seem overwhelming. The glassy *Carinaria*, regarded as a dweller on the surface of the ocean, would seem ill-adapted to withstand the buffeting of storms at sea; and so it is, but there is very little doubt instinct has taught the mollusc the proper moment, and the sufficient depth to descend from the surface, to be safe from the tempest's violence. The dweller on the seashore, open to the onslaught of the same unpitying foe, defends himself with a stronger abode. What dash of the waves upon the undefended rock could in the slightest affect the conical shell of the limpet? In very deep water the tendency to tenuity in the molluscan shell is plainly apparent, yet there are species dwelling at depths beyond the influence of surface storms, the shells of which present considerable strength and solidity. We may ask how and why is this? Although we may not in all cases be able to answer these queries from actual knowledge, certain is it, that reasons, probably very near the truth, are easy of suggestion. For example, the large *Cyprina islandica* and the heart-cockle (*Isocardia cor*) of the British seas possess shells of considerable strength and solidity. These, being molluscs of large size, would prove dainty morsels to the hungry haddock or other fish, if they were unprotected by a powerful shell and their extermination thus prevented.

Coloration. The varied colours of shells are due to glands situated on the margin of the mantle. In most cases the colour markings are placed on the outer surface of the shell, beneath the periostracum, but occasionally the inner layer of porcellaneous shells is of a different colour to the outer. This is well instanced in the helmet-shells (*Cassis*), which are employed by the carvers of shell-cameos to produce white or rose-tinted sculptures upon a dark ground. The colour in some shells is liable to extreme variation. Take, for example, the common hedge-row snails, *Helix nemoralis* and *H. hortensis*. Here we find the ground-colour yellow, brown, pink, white, lilac, and various intermediate shades, and the bands which are usually brown, and normally five in number, may be altogether absent or vary from one to six, their position also being equally variable. This diversity in colour-markings results from the different position of the pigment-glands upon the mantle margin, but the cause of this variation in the position has not been ascertained, although it may be presumed; nor is the reason known of the difference of the ground-colour, which may occur among specimens of the same colony. White, black, red, green, yellow, olive, purple, slate-blue, and brown form the common ground-tints of shells, but pure blue is a colour hardly ever met with in the shells of molluscs. One or two species of land-shells (*Corasia*) from the Philippine Islands more nearly approach this tint than any other molluscs, but even in these there is a slight admixture of green. On the contrary, blue is a colour more commonly seen in the soft parts. The colour of the shell does not necessarily correspond with that of the mollusc. The latter may be of an intense black, the shell being quite white; the "animal" may be a most brilliant creature with a variety of many colours, and its test merely of some uniform sombre hue. Very gorgeously painted shells are, however, generally indicative of highly coloured inhabitants.

That light and warmth are great factors in the production of brilliant colouring is beyond question. This is conclusively proved by the results of deep-sea dredging. Whenever great depths are reached, where darkness reigns, and the water is intensely cold, the molluscan inhabitants are without colour, or of very sober tints, although the periostracum, generally greenish or olivaceous, is scarcely modified under these circumstances.

Age. Our information with regard to the duration of life in molluscs is very limited. Although certain species of land-shells have been kept alive in confinement for four or five years, or even longer, we cannot assert that they exist for so long a period under natural conditions. The length of life of individuals, as well as of different species, is probably very variable, some doubtless attaining to a good old age. Such a species as the giant clam (*Tridacna*), for example, it is rational to conclude must have a very lengthy term of existence, for, although the growth may be rapid, the formation of a shell weighing 300 or 400 lbs. must surely be the work of years; and, moreover, when the process of growth is ended, we know not for what period the shell may continue to live. It is likely that most land-molluscs are full grown in a year or two, but the term of their existence, after this, is probably very variable, according to the species. A specimen of the common periwinkle has been kept in an aquarium for nine years, but this scarcely indicates the limit of life of this species under natural conditions. Its average duration may be longer, but probably shorter. In connection with the length of life of molluscs, mention should be made of the long periods some of the species are capable of existing without food in a state of torpidity.

In cold climates land-snails bury themselves in winter-time in the ground or beneath dead vegetation, and in hot climates they assume a torpid condition in the hottest and driest season of the year, closing up the aperture of the shells with a temporary lid or door (called an *epiphragm*). Some of these summer-sleepers display great tenacity of life, many cases being on record of species which have lived for two, three, or even five years in a torpid state, without food of any description. Perhaps one of the most interesting instances, is that which has so often been quoted, of the specimen of the Egyptian desert-snail (*Helix desertorum*), which was fixed to a tablet in the British Museum for four years, and was discovered to be still living. Some fresh-water forms also are capable of living out of their native element for a considerable time. A species of Australian *Unionidæ* has been known to exist out of water for over a year, and some kinds of *Ampullaria* have lived for months after being taken out of their native rivers.

Reproductive System. The sexes are distinct in some molluscs, and united in the same individual in others, but reproduction is in all cases effected by means of eggs. These are usually secreted or attached in some suitable position, but in some instances the ova are hatched within the oviduct of the parent, as in the fresh-water pond-snail (*Vivipara*); and probably in most bivalves the eggs are retained within the parent shell until hatched. The ova of some of the gastropods, enclosed in capsules, are deposited in masses, and some of these form very remarkable and complicated structures. The number of eggs contained in some of these clusters is enormous. As many as forty thousand have been estimated in a mass, deposited by a single squid. The common whelk occasionally also piles up an enormous heap of capsules, as many as five or six hundred being massed together, each capsule containing several hundred eggs. Land-snails, in comparison with marine forms, produce comparatively few eggs. Some of those deposited by the large South American species are in a few cases half an inch to an inch in length, and have a strong calcareous shell. On the contrary, the productive power of some bivalves is enormous, the ova being counted not by hundreds but by hundreds of thousands, and even millions. The ova of molluscs may be gradually developed into the form of the adult, or there may be a free-swimming ciliated larval stage, or a special larval form as in the fresh-water mussel.

Food. Molluscs are both vegetable and animal feeders, but probably by far the greater number of gastropods are carnivorous. Bivalves imbibe a mixed diet of infusoria and microscopic vegetables. The carnivorous species of gastropods principally attack other kinds of shell-fish, bivalves being especially appreciated. Some however, like the common whelk, will feed on dead fish and carrion of any description. Many of them are mere cannibals, and attack their own kith and kin. Out on the high seas the glassy *Carinaria* enjoys the succulent jelly-fish, and the squids and cuttles are a terror to many pelagic fishes. The octopus, like the gastropods, is partial to a bivalve meal, and a repast on shrimps and other crustaceans is a daily occurrence. Most land-shells are herbivorous, but a few are carnivorous, preying chiefly upon their plant-eating relations, and one curious slug lives exclusively on living earth-worms.

Organs of Sense. Most molluscs which are provided with a more or less distinct head, namely, the cephalopods and gastropods, are furnished with visual organs, but the majority of bivalves (Pelecypoda) are sightless. Although an auditory apparatus exists, they appear almost insensible to sound. It is certain that most forms are endowed with the sense of smell, although the anatomist has frequently a difficulty in discovering the position of the olfactory organ. Land-molluscs appear to recognise their proper vegetable food by the smell as well as the taste, and the carrion-feeding whelks are probably attracted by odour. The senses of smell and taste are probably but imperfectly developed in the bivalves, which scarcely possess the power of selection as regards their food.

Locomotion. Molluscs exhibit various ways of progression. Some are free-swimmers, like the cuttle-fishes and squids, pteropods, heteropods, and a few bivalves; others are mere crawlers, like snails and whelks; and some creep along, but beneath the surface of the water. The *Melampus* moves onwards after the fashion of a looper-caterpillar, and the bivalves either crawl upon their foot, or progress by a jerking or leaping movement. Many species, like the limpet, *Saxicava*, and *Pholas*, are very sedentary in their habits, and others, which in their early career are active, in after life are stationary in their permanent abodes.

Uses in Nature and to Man. Molluscs form a large item in the food of many mammals, birds, reptiles, and fishes. Terrestrial forms are devoured by rats, ducks, thrushes, and other birds; by lizards, toads, snakes, and even by certain kinds of carnivorous insects. The fresh-water forms are consumed in vast quantities by water-birds of every description, by fishes, frogs, water-voles, and other mammals, and aquatic creatures of various kinds; and every seashore is constantly ransacked by flocks of sea-fowl for the repasts of shell-fish it affords. Out in the depths of the ocean many kinds of fishes, especially cod, haddock, gurnard, soles, and mullet, are great devourers of molluscs, which ever fall a prey, not only to one another, but also to crabs, holothurians, sea-anemones, and star-fishes; and, finally, among the pelagic pteropods the Greenland whale seeks his daily sustenance.

Molluscs of all kinds, but especially the marine species, are much eaten by the natives of most countries; and even in Europe, although the oyster is the most highly appreciated, several other species are used as food. Molluscs are not only of importance to man as an article of diet, but they are serviceable in other ways. Their shells are employed as personal ornaments, and are used in the manufacture of fishing-tackle by some uncivilised people. In England and other countries many of the pearly species are manufactured into ornaments and various useful articles, and the beautiful pearls themselves, secreted within the tissues of the pearl-oyster, are esteemed as jewels.

Noxious Molluscs. The utility of the molluscs to man probably far outweighs the injury which is occasioned by a few kinds. In the foremost rank of the noxious species stands the *Teredo*, the great destroyer of submerged timber. The damage done to piers, boat-bottoms, and in fact to wood of any description which is located in the sea, is enormous, and there seems to be no effectual means of meeting the attack of these molluscs, except by covering the timber with metal-sheeting. The stone-work of breakwaters occasionally becomes more or less damaged by the burrowing habits of the *Pholas* and *Saxicava*. On land, snails and slugs commit onslaughts upon our crops and gardens, but these pests are more easily overcome than their marine relatives.

Distribution. Although this is a subject very fascinating to some, it is one which pre-eminently opens the gates of speculation. That species have certain geographical and bathymetrical limits in their distribution, may be an admissible fact in very many cases, but when the reason for this limitation is sought we are reminded how little we know of natural causes. That certain tracts of coast have their own peculiar inhabitants, and that the molluscs of the eastern shores of America, for example, differ from those of the west we must admit; but how this has come about, is matter of conjecture. We say that differences of environment, of food and temperature, are sufficient reasons to account for such things. On the contrary, we are met with the fact that certain species in a given genus have a much wider range than others, and we are fain to ask how this is brought about. The range of terrestrial molluscs is much more restricted than that of most marine forms. This is readily understood, as the means of dispersal are very different. The early stages of marine molluscs, if not free-swimming creatures, are liable to be carried great distances by ocean currents, or the action of the tides and wind. On the contrary, land-molluscs are creatures of slow progression, and are liable to have their distribution hindered, either by rivers, mountains, or seas. Consequently we find that island faunas, as regards the terrestrial species, are mostly peculiar. It should be noticed that there are great differences in the molluscan land-fauna of different areas; that of North America being, for instance quite distinct from that of Central and South America.

It is a well-known fact that certain marine gastropods and bivalves inhabit particular parts of the sea-bottom. Some groups which occur between tide-marks, such as periwinkles and limpets, are termed littoral forms; others occurring below low-water mark, to about ten or twelve fathoms, are said to inhabit the laminarian zone, or the region where seaweed abounds. Below this, to about fifty fathoms, extends the coralline zone, so called from the abundance of corallines at this depth, which also furnishes a lurking-place for certain special forms. Beyond this is the deep-sea or abyssal region, of which certain species and genera are more or less characteristic.

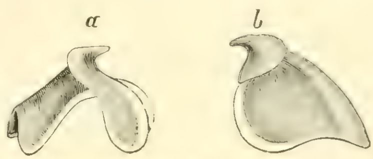
Other races, such as the squids among the cephalopods, the various forms of pteropods and heteropods, and a few other gastropods, pass their lives far out at sea upon the surface of the ocean, and are termed pelagic species.

Classification. The Mollusca constitute one of the principal divisions (a sub-kingdom) of the animal kingdom, and it is subdivided into five principal sections or classes, namely, Cephalopoda, Gastropoda, Amphineura, Scaphopoda, and Pelecypoda. These divisions are founded on peculiarities in the general conformation of the animals, but it is also worthy of notice that the shells of the different classes differ widely in type. An important feature characteristic of the three first of these classes is a structure termed the *radula*. It is situated within the mouth, and is a kind of muscular tongue armed with teeth, and used in obtaining or comminuting food. The armature of this radula, odontophore, or lingual ribbon, is subject to great variation, and these differences have afforded characters for distinguishing various groups among the gastropods. There are a few genera of Gastropoda which are peculiar on account of the want of this masticatory organ, and it is also unknown among the headless bivalves.

The Squids, Cuttle-Fishes, and Nautili,—Class **Cephalopoda.**

The cephalopods are considered the most highly organised of all molluscs, and some of the species are remarkable for the enormous size they sometimes attain. They are exclusively marine animals, leading a predatory life out on the high seas, or among rocks in shallow water, or about low-water mark. The sexes are distinct. They may be recognised by the symmetry of their general conformation, the fleshy arms or tentacles situated around their mouths and in front of the head, and by their retrograde mode of progression, which is effected by the expulsion of water from a particular organ, termed the siphuncle or funnel. With one exception—the nautilus—none of the living cephalopods possess an external shell, and they are consequently termed naked molluscs. Nearly all decapods, that is, those species which are provided with ten so-called arms—have a straight calcareous or horny internal shell, which is a strengthening support to the back. *Spirula*, however, although a decapod, is an exception, and possesses a segmented shell, coiled up like a ram's horn, and concealed within the hinder part of the animal's body. The external shell wherein the female argonaut dwells is not the equivalent of the shell of the nautilus, or of the gastropods. It is not attached to the animal by any special muscle, but held to the body by two of the arms, especially developed for this purpose. It is, in fact, merely a receptacle for the ova, but at the same time affords protection to the argonaut herself. All the rest of the octopods are without shells of any description.

The body of a cephalopod consists of a muscular sac, in the cavity of which the viscera are placed. In front of the body projects the head, which, in one of the two main sections into which the class has been divided—namely, the Dibranchiata, or those provided with only one pair of gills—is crowned with eight or ten fleshy muscular arms, in the midst of which the mouth is situated. This is armed with two strong jaws, in shape very similar to the beak of a parrot. They are curved, pointed, and of a horny substance in the two-gilled cephalopods, and somewhat calcareous in the four-gilled group. Within the mouth is the rasping tongue, covered with the sharp siliceous hook-like cusps or teeth, arranged in regular transverse series, one behind the other. The eyes, two in number, are placed on each side of the head, and are of enormous size in some of the decapods. On the ventral side the muscular sac is disconnected with the head, leaving a more or less wide opening admitting the water to the gills. The water is then expelled through the so-called funnel with more or less force, according to the requirements of the animal. If it be at rest, the expulsion of water is carried on very quietly, but, on the contrary, with much greater force if the animal is in motion. Besides water, other secretions from the body are extruded through the funnel, and especially a dark fluid secreted in a special ink-pouch. When disturbed or irritated, this ink is discharged by all cephalopods, excepting the nautilus, and is supposed to be a means of defence. Mixing with and clouding the surrounding water, we can well suppose that the attack of a pursuing fish might be checked, and the squid or cuttle effect its escape in the darkened fluid. The arms, or feet, of the octopods and decapods are more or less elongate and capable of movement in any direction, and are furnished on one side with numerous suckers, by means of which the animal holds on to anything that it may seize with such tenacity that the suckers themselves are liable to be torn away rather than loose their hold. They are often furnished at the edge with a toothed horny or calcareous ring, and connected with the arms by slender stalks. Cephalopods employ their arms in walking and climbing, and, owing to their position, have to progress head downwards when creeping on the sea-bottom. They are connected at the base by a skin, in some species extending some distance up the arms, and forming a sort of umbrella, which is doubtless of use in the capture of their prey. In the nautilus the arms are different, being short, pointed tentacles, unprovided with suckers.



UPPER (*a*) AND LOWER (*b*) PORTIONS OF THE BEAK OF A CUTTLE-FISH (*Sepia*).

The nervous system is more developed than that of other molluscs; it is concentrated around the gullet, and protected by a cartilaginous plate, a sort of rudimentary skull. The skin of the naked cephalopods is more or less thickly studded with points or dots of various colours. These pigment-cells are subject to alter their tint at the will of the animal, which, chameleon-like, assumes very different aspects

Some species also, which, when in repose or undisturbed, have the outer skin smooth, if irritated, become suddenly covered with conical tubercles or more or less elongate cirri.

Cephalopods are very voracious, feeding on fishes, molluscs, and crustaceans. Some species pursue and capture their prey, while others lie in wait and pounce upon it suddenly. Like every other group of animals, they have their enemies, being devoured in enormous quantities by cetaceans, fishes, and sea-birds. In some countries various species are esteemed as an article of food. Although about four hundred and thirty species of living cephalopods have been described, some of these are so inadequately defined, that the total, in round numbers, does not probably exceed about three hundred and eighty. These have been arranged in some seventy-five genera and fourteen families. About half the genera contain but a single species each, while nearly half the known forms belong to the three genera *Octopus*, *Sepia*, and *Loligo*. The cephalopods of bygone ages far surpass in number those which survive, and it is probable that we only know but a moderate proportion of the forms that have passed away in the various geological epochs; for what idea have we of the shell-less tribes which may have inhabited ancient seas, whose soft bodies have decomposed at death, leaving not a vestige behind? It is only those with internal or external shells which have been preserved; and what proportion of all the forms that have existed in all times do the fossilised remains known to us represent? The seas of our own times contain a large number of cephalopods, the existence of which in past geological ages cannot be proved; but, on the other hand, we know of great numbers of fossil genera and species of which there are no living representatives. The entire order of the Ammonoidea, which contains the well-known discoid, convoluted, chambered Ammonites, is entirely extinct, and it is a matter of uncertainty whether they should be classed with the dibranchiate or tetrabranchiate group, or be regarded as a distinct order by themselves. On the contrary, although the probability is that many existed in bygone ages, only a few fossilised remains of octopods have been identified with certainty, and the *Spirula* of to-day, which occurs in countless thousands, also appears to be unknown in the past.

Two-Gilled Group,—Order Dibranchiata.

Octopus Tribe, Suborder Octopoda,—Family *Octopodidæ*.

Commencing with the order Dibranchiata, we find this divided into the two suborders, Octopoda and Decapoda, according to the number of arms. Of these the octopods comprise several families distinguished by differences in the general build, the presence or absence of lateral fins, the number of rows of suckers on the arms, variations in the radula, etc. Since the establishment of public aquaria, in comparatively recent years, most persons have had an opportunity of seeing the unsightly octopus in its native element. An unpleasant, forbidding creature it is, contracting and swelling, or looking like a shapeless but living mass. We observe the eight tapering arms, with the two rows of suckers along the inner side of each, numbering about two thousand altogether in some individuals. We note the two staring eyes which seem ever on the watch, the funnel often exposed to view, and the mottled skin. About ninety species of octopus are known, which occur in all seas. Variations in colour, the relative length of the arms, the size of the suckers, and the character of the hectocotylised or modified arm of the male, are among the distinguishing features of the species. Although we usually speak of the octopods as shell-less or naked molluscs, an indication of an internal shell is present, in the form of two short styles, embedded in the tissues of the mantle. These molluscs are solitary creatures when adult, but they are said to herd together

COMMON OCTOPUS.

in small companies when young. They live in the fissures of rocks, or hide away beneath great boulders. When they walk or creep, they elevate the sack-like body above the head, and progress slowly upon the extremities of the arms, which are a little curved near the tip. They can creep in any direction, but they prefer a side-way movement. On the contrary, if their progress in walking is comparatively slow, this is compensated by the rapidity of their movements when swimming. Body foremost, with the arms stretched beyond the head, they dart backward with great rapidity, being propelled by the successive expulsions of water through the funnel. The arms are also made use of in swimming, and those which are provided with an extensive connecting web are the most effective swimmers. None of the octopods ever attain such enormous dimensions as some of the decopods, still some would be very dangerous foes to cope with beneath the water. Mr. J. K. Lord saw the arm of an octopus, captured at Vancouver Island, which measured 5 feet in length, and was as thick as his wrist; and M. Verany has given an account of a specimen which measured 3 metres from tip to tip of the outstretched arms. In the account of the molluscs, obtained during the voyage of the *Samarang*, Mr. Adams observes: "Octopi of enormous size are occasionally met with among the islands of the Meïa-co-shima group. I measured one, which two men were bearing on their shoulders across a pole, and found each arm rather more than 2 feet long, giving the creature the power of exploring an area of about twelve feet without moving, taking the mouth for a central point, and the extremities of the arms to describe the circumference."

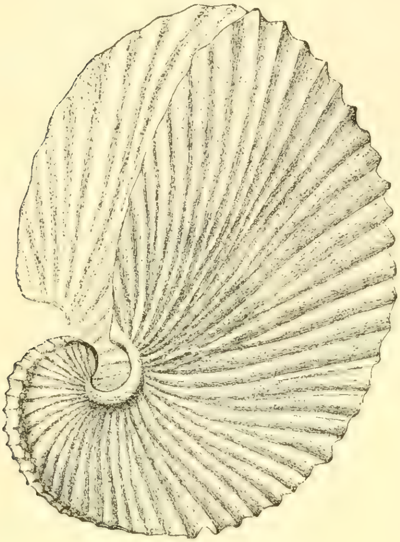
In 1872 a very large specimen was stranded on the beach in the Bahamas, the arms of which were 5 feet long, and the weight was estimated at 200 to 300 lbs. The eggs of the *Octopus vulgaris* when first laid are small, oval, translucent granules, resembling grains of rice, not quite the eighth of an inch long. They are fixed along and around a common stalk, to which every egg is separately attached. These clusters vary in length according to the condition or age of the parent; those produced by a young octopus seldom exceeding three inches in length, and from twelve to twenty in number; but a large, full-grown female will deposit from forty to fifty of such clusters, each about five inches in length. In each of these clusters Mr. Lee counted about a thousand ova, so that a single octopus may produce at one laying a progeny of from forty to fifty thousand. The mother octopus watches, tends, and guards the egg-clusters for about fifty days, when the young emerge from the capsules. The sexes differ scarcely at all externally, but at the breeding-season a curious modification in the third right arm of the male is noticeable. It becomes swollen, and from it a long worm-like process is developed, furnished with two rows of sockets (the *Hectocotylus*). From the end of this process extends a slender, elongated filament. When its owner offers his hand to a female octopus, she not only accepts it, but keeps it, for this remarkable outgrowth is then detached from the arm of her suitor, and becomes a moving creature, having separate life, and continuing to exist for some time after being transferred to her keeping. The lost portion of the hectocotylised arm of the male is gradually reproduced, and in due time assumes its former appearance.

A second group of octopods (*Eledone*), which occurs in the Mediterranean and also on the British coasts, differs from the common octopus in having but a single row of suckers down each arm. In *E. moschatus*, the body is very changeable in form, pouch-like, oval, rounded, or pointed behind, smooth or warty, just as the animal likes. The great size of the mantle-opening, which extends a little over the back, is also remarkable. It is of a grey, yellow, or yellow-brown colour, with blackish spots, and a bluish edge to the web, and is met with on sandy and gravelly bottoms at all times of the year, more rarely among rocks. The rapidity with which the creature changes its colour is amazing. At the slightest disturbance a dark shade passes with the rapidity of lightning over the whole body. When it seizes its prey its entire skin becomes yellowish, studded with blackish symmetrical spots, and covered all over with conical tubercles. These molluscs have a strong musky smell, but in spite of this they are not unfrequently seen in the Italian markets, and purchased by the poorer classes.

Other Families. Other octopods are *Cirroteuthis, Pinnoctopus, Tremoctopus, Amphitretus,* and a few other allied genera, and *Argonauta,* several of which represent families by themselves. In *Cirroteuthis* the arms are connected throughout their entire length with a thin membrane, forming a sort of umbrella, at the bottom of which is the mouth. They are furnished with only a single row of suckers down the middle, but have a series of short cirri on each side, and the body is provided with two lateral fins. Seven species of this genus are known at present. *C. maura* was captured at a depth of thirteen hundred and seventy-five fathoms, and *C. pacifica,* off New Guinea, in two thousand four hundred and forty fathoms. *C. muelleri,* the type of the genus, occurs on the coast of Greenland. *Pinnoctopus* is remarkable for a fin-like expansion, extending the whole length of the body and uniting behind. In *P. cordiformis*—the only known species, and an inhabitant of the shores of New Zealand—the arms are long, and united at the base by a somewhat large membrane. *Tremoctopus* has no lateral expansions or fins to the body. The female has the two dorsal pairs of arms united by membrane, the two other pairs free; the male is without the interbrachial web; the head is large, having two pores on the upper and under sides. Nine species altogether have been described from the Mediterranean, North Atlantic, and Pacific. The genus *Amphitretus* is one of the remarkable forms obtained during the *Challenger* expedition. It possesses the character, unique among cephalopods, of having the mantle fused with the siphon in the median line, so that there are two openings into the branchial cavity, one on either side, whence the name.

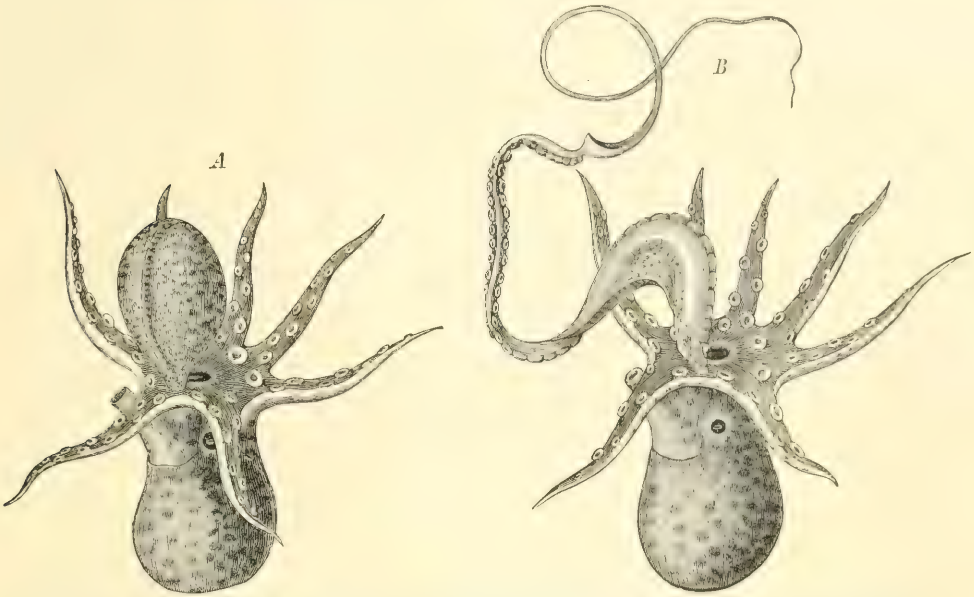
Family *ARGONAUTIDÆ.*

The argonaut, or paper-nautilus, is one of the most interesting of the octopods, for around it for many years there hung a mystery and uncertainty. Some concluded that the shell was formed by another mollusc, and was merely taken possession of by the cephalopod, as a convenient abode or boat to swim in, or rather to sail in, for it was stated to raise aloft its two expanded arms to catch the breeze, and thus to voyage onward. This, for many years, has been proved to be mere fiction. The shell, with which only the female is provided, is of her own manufacture, and she swims just the same as other cephalopods. It is large, not adhering to the body of the animal, but retained in position by the application on the outside of the dorsal pair of arms, which are dilated and especially adapted for the purpose. Whether the argonaut ever quits its shell voluntarily or only by accident is unknown; specimens have been captured at sea without any shell, and they have lived for some time in that condition. A specimen was placed in an aquarium at a time it was out of its shell. This it re-entered, and remained in it the whole period, about fifteen days, it was in captivity. It invariably swam at the surface of the water with the coiled part of the shell upwards, a small portion being above the surface, to which the aperture was at right angles or inclined at an angle of 45°. It appeared calm and not subject to agitation like the octopus. It remained perfectly immovable, for no menace or excitement appeared to affect this appearance of tranquillity. Like the octopus, it exhibited chameleon-like changes of the skin, but not so rapidly or with such intensity as that animal. During all the time the specimen lived, all the arms, which have two rows of suckers, were kept within the shell, except the expanded posterior median pair. These, however, were also sometimes drawn within. Four of the arms were bent upwards, four downwards, leaving the mouth with its parrot-like beak exposed in the middle of their bases. Between the lower or ventral pair of arms the funnel was protruded, by means of which it propelled itself backwards. This specimen was not seen either to walk or swim with its arms; but other observers state that the creature walks or crawls along the bottom like a gastropod, by means of the non-expanded arms, carrying the shell above its body. The eye is round, bordered with black, and the circular pupil is also black.



SHELL OF FEMALE ARGONAUT.

The shell is supposed to be secreted chiefly by the palmate arms, aided by the mantle investing the body. It is developed some time after the birth of the argonaut, and a female has never been seen with a shell before it had attained about an inch in length. The male argonaut is very different to the female, and much smaller, being only about an inch in length. It resembles an ordinary octopus in having neither palmate arms nor shell. The arms are tapering and alike, excepting the third on the left side, which is specialised. This at certain times, having passed through various stages of development, is cast off, and attaches itself to the female, living a free and independent life for a considerable period. The eggs are small, numerous, and connected together by a network of filaments. They are deposited far within the shell towards the convoluted portion, and are practically in contact with the posterior part of the body of the parent. The shell therefore serves, not only as a retreat for the argonaut herself, but also as a nest for the eggs, and possibly as a nursery for the young. Very little is known with regard to the food of the argonaut. As its habits are very similar to those of the octopus, it seems probable that it may feed upon molluscs and crustaceans, which it might capture when crawling at the bottom of the sea. A captive specimen was fed with small live fish, which it ate with avidity. About eight species are recognised, which have a world-wide distribution, occurring in all tropical and warm latitudes. The shells of the different species are all of a white colour, and exhibit two distinct types of surface ornamentation, the one consisting of simple, smooth, radiating wavy ribs, the other in which these ribs are more or less broken up into nodules or tubercles. *Argonauta hians* is the typical species of the former group, and *A. navicula* and *A. tuberculata* represent the latter.



A, MALE ARGONAUT (twice nat. size), WITH HECTOCOTYLUS ENCLOSED IN THE SACK ; *B*, MALE ARGONAUT, WITH HECTOCOTYLUS FURTHER DEVELOPED.

Suborder Decapoda.

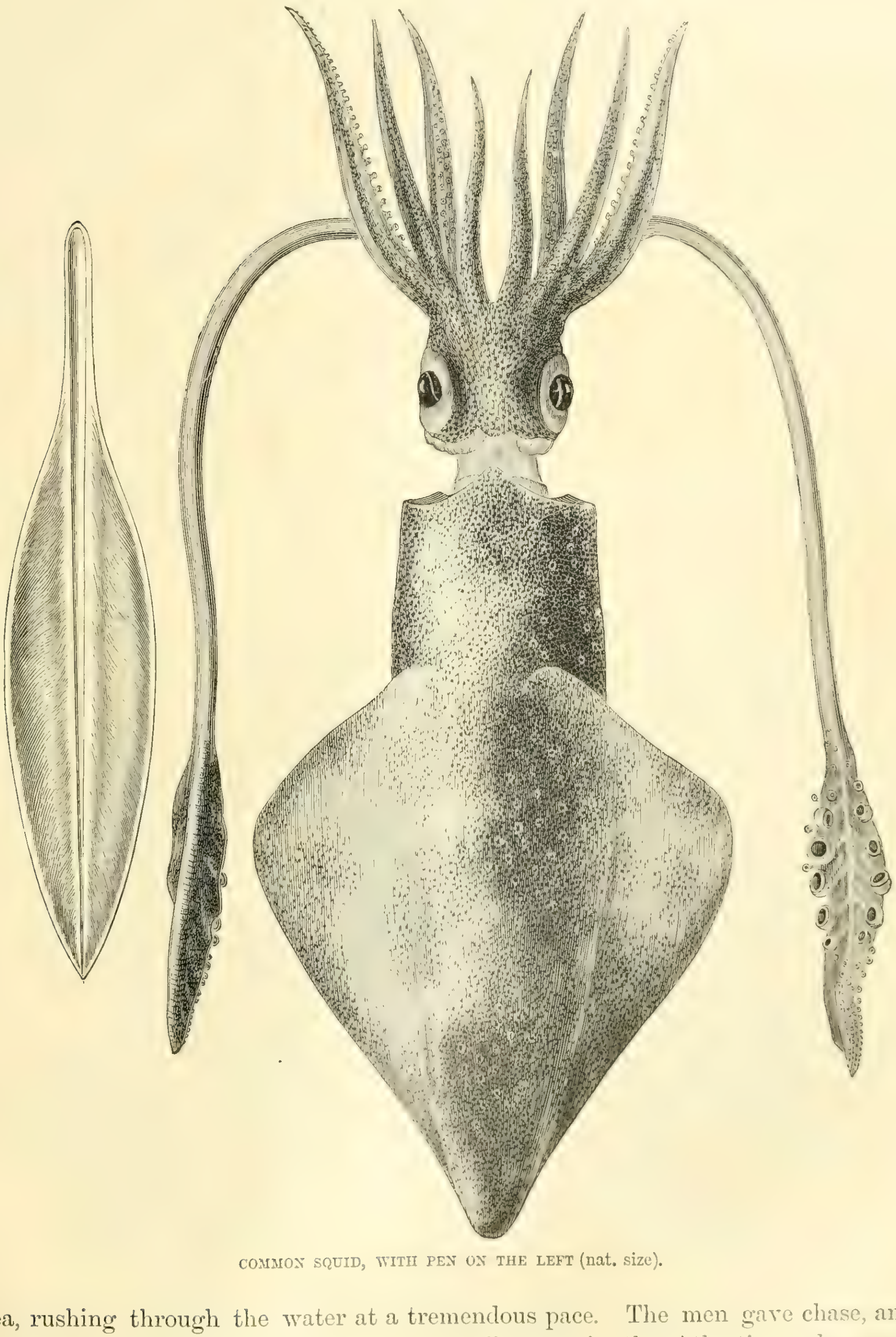
The Decapods form the second division of the two-gilled order, and differ from the Octopods, as the name implies, by the possession of ten, instead of eight, arms. The two additional arms differ from the rest in their greater length, and in having suckers only at the extremity. They are frequently completely retractile within pouches, and are used as prehensile organs in the capture of their prey. All decapods are provided with an internal shell. That of the living species is either horny—the so-called pen (*gladius*); or else calcareous—the bone (*sepion*) of the cuttle-fish. In *Spirula* the shell takes the form of a tube, beautifully coiled, and divided off into numerous air-chambers by a series of septa or partitions. The arms of the decapods are furnished with pedunculated suckers, armed with horny rings or hooks. The head is invariably distinct from the body. The eyes are free and movable, and either covered with a fixed, transparent lid or skin, or unprotected and in immediate contact with the water. All the species have either lateral or posterior fins, and the funnel is provided with an internal valve. They live for the most part out at sea, but some—*Sepia*, for example—are met with nearer the shore. The pelagic forms are often found in immense shoals, and are eaten in enormous quantities by many cetaceans and large fishes. When pursued by their enemies, squids have been known to dart out of the sea with such force as to fall upon the deck of a passing vessel. Decapods may be classified in three sections, according to the character of the shell, of which the different types have already been mentioned.

SQUIDS,—Family *LOLIGINIDÆ.*

Some of the commonest of the horny pen-bearing decapods are the true squids or calamaries (*Loligo*), which have a more or less elongate body, with very large lateral fins at the posterior end. The eight sessile arms are provided with two rows of suckers with toothed horny rings, and the two tentacular arms are long, slender, and terminate in an expanded club, bearing four rows of suckers. The pen is large, horny, as long as the body of the animal, and placed beneath the skin of the back. It is not in any way attached, so that if the skin be slit open, the shell can be drawn out entire. The common squid (*Loligo vulgaris*) is met with all round the British coasts, and occurs in shoals of greater or less extent in the Mediterranean and Atlantic. The spawn consists of numerous, long, semi-transparent, gelatinous sheaths, radiating from a common centre. Each sheath is about 4 inches in length, and contains numerous ova, and it has been computed that in a single mass of sheaths the deposit of one female contained as many as forty-two thousand perfect young squids. Mr. Lee observes that he has never seen these "sea-mops" attached to anything; and the pelagic habits of the calamaries render it probable that they are left floating on the surface of the sea. They are deposited in May or June. The calamaries are active animals, and always in motion. A second genus of squids (*Ommatostrephes*), frequently regarded as representing a distinct family, differs from *Loligo* in having the body very long, the posterior fins comparatively short, and the pen very narrow. They are gregarious, and frequent the open seas in all latitudes, and are extensively used as bait in the cod-fishery off Newfoundland, and also constitute the principal food of dolphins and the sperm-whale. They are also largely eaten by the albatross and other marine birds. By sailors they are called "sea-arrows" and "flying-squids," on account of the rapidity of their movements and their habit of leaping out of the water. It is said that they frequent the shore in pursuit of the fry of pilchards and other fishes.

The largest of all the Cephalopoda belong to the genus *Architeuthis*, which in general conformation considerably resembles *Ommatostrephes*. Many stories of gigantic cuttle-fishes appear in the works of old writers, and although, in the main, great exaggerations, they are to some extent founded on fact. We are, perhaps, too sceptical to believe in an octopus rising from the sea, and carrying off a three-masted ship. Yet some of the squids are of such enormous size, that we can imagine they constituted the source from which these old tales were derived. In November 1874 a specimen was brought ashore at St. John's, Newfoundland, by some fishermen, who captured it in their herring-nets. It was more or less mutilated in the capture, but the following measurements were taken from the parts preserved. Body 7 feet long, tail-fin 22 inches broad, tentacular arms 24 feet in length, short or sessile arms 6 feet long, some of them being as 10 inches round at the base. Particulars of several other specimens of gigantic squids, varying in total length from 30 to 52 feet, and also taken near Newfoundland, have been recorded; the estimated weight of one of these being 1000 lbs.

On the 24th of April 1875 a large calamary was met with off Boffin Island, on the Irish coast. The crew of a "currah" observed to seaward a large floating mass. They pulled out to it, believing it to be a wreck, but found it was an enormous cuttle-fish, lying perfectly still, as if basking on the surface of the water. Paddling up, they lopped off one of its arms. The animal immediately set out to



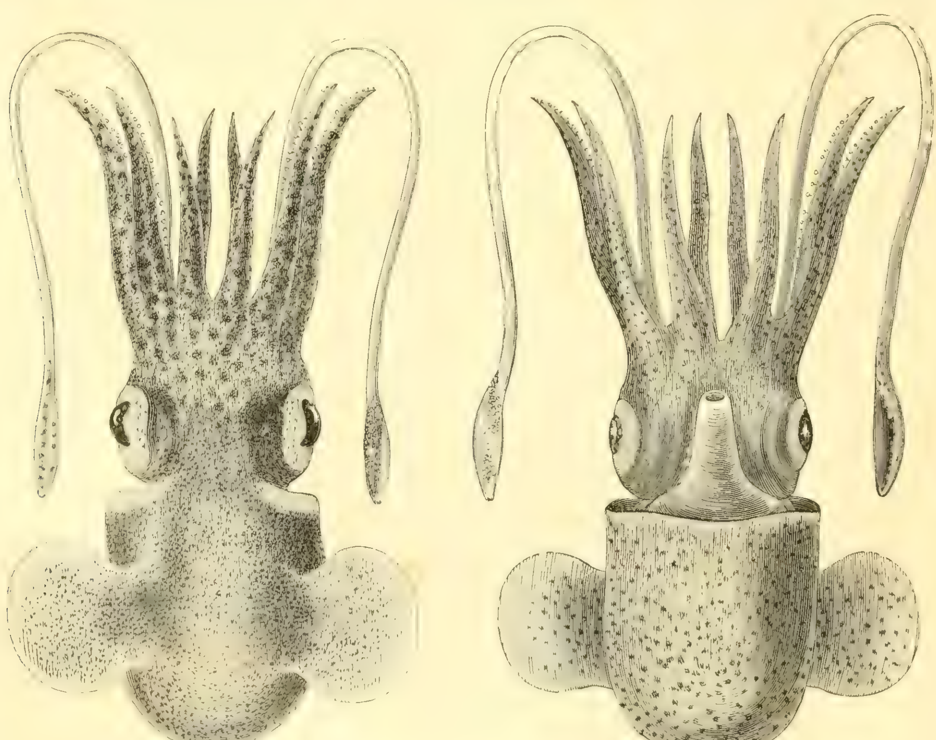
COMMON SQUID, WITH PEN ON THE LEFT (nat. size).

sea, rushing through the water at a tremendous pace. The men gave chase, and, after a hard pull, came up with it, five miles out in the Atlantic, and severed another of its arms and the head. The shorter arms measured each 8 feet in length, and 15 inches round the base; the tentacular arms are said to have been 30 feet long. A single arm of a large squid, supposed to have been found off the coast of South America, is 9 feet long and 11 inches round the base, and has two rows of suckers, with toothed, horny rings, each row consisting of one hundred and fifty suckers. The largest of these rings is half an inch in diameter, whereas the smallest, near the tapering end of the arm, is only about the size of a pin's head. Judging by other specimens, it is probable that this creature must have had a body 10 or 12 feet in length, with tentacles over 30 feet long.

Some portions of a remarkable gigantic cephalopod were obtained by the Prince of Monaco off the Azores, which were vomited by a harpooned sperm-whale in its death-struggle. The body of this huge squid was covered with scales arranged spirally like those of a pine-cone; and from this character—unique among the Cephalopods—it has been placed in a separate genus *Lepidoteuthis*.

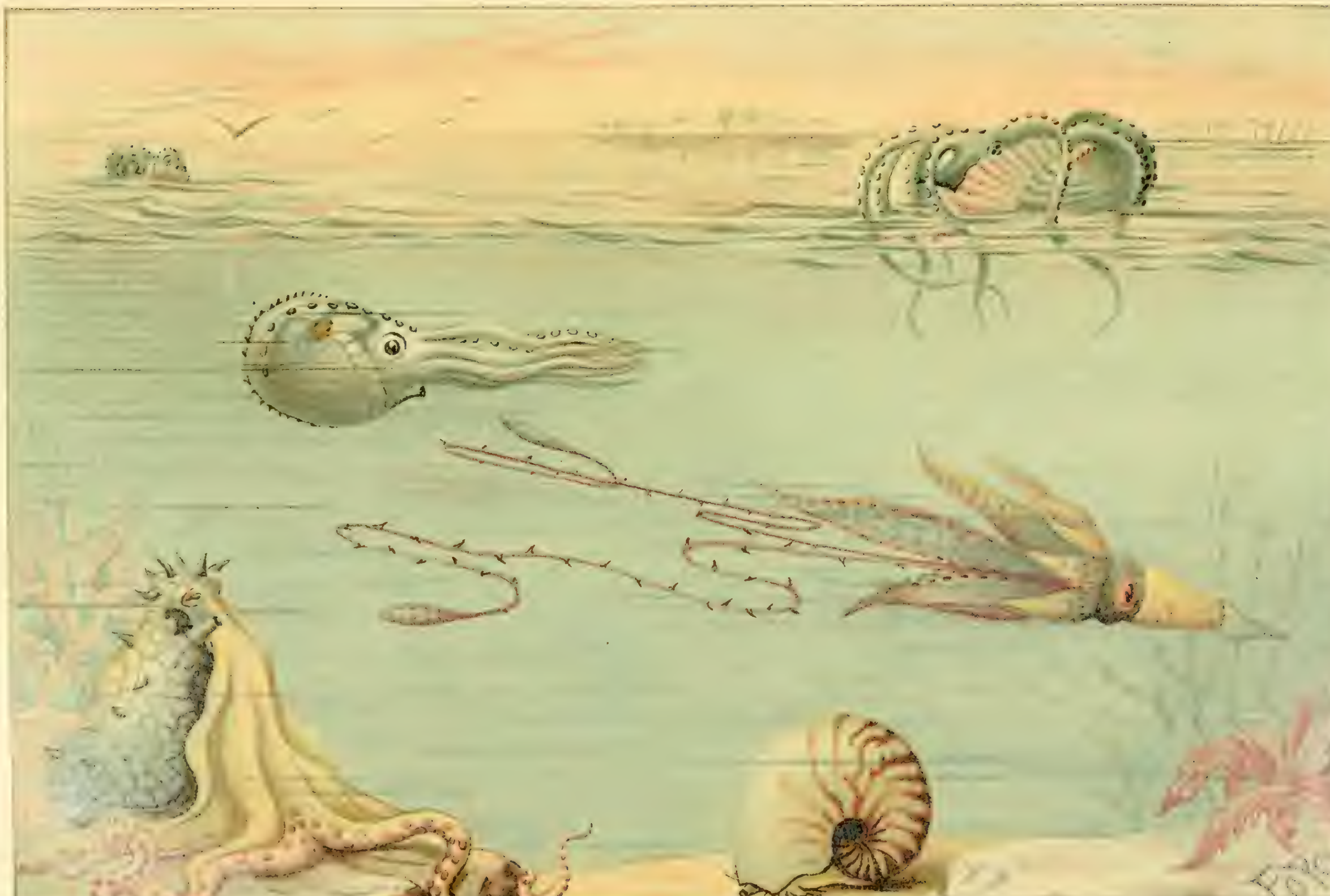
Family *SEPIOLIDÆ*.

Sepiola is represented by a small decapod not unfrequently found on the British coasts. Mr. Lee observes that "it has the faculty of rapidly changing colour, and,



UPPER AND LOWER VIEWS OF SEPIOLA.

if angered or alarmed, its hue is almost instantaneously altered, from a pale parchment dotted with pink to a deep reddish brown. In its habits this little animal



CEPHALOPODA

differs as much from the *Sepia* as the latter from the octopus. It naturally buries itself up to its eyes in the sand; but as sand is apt to harbour impurities, which in a bowl or tank become corrupt, and generate poisonous sulphuretted hydrogen, the bottom of these receptacles is usually covered with shingle. It is most interesting to notice how, in obeying its burrowing propensity, the *Sepiola* adapts itself to its circumstances and entirely deviates from its customary mode of procedure. To make a sand-pit for its hiding-place, it will direct upon it strong jets of water from its funnel, and thus blow out a cavity in which to seat itself, and allow the disturbed particles to settle over and around it; but, as the pebbles are too heavy to be thus displaced by its blasting apparatus, it removes them, one at a time, by means of its arms, which are large and strong in proportion to its little short body." This same species, *S. rondeletii*, is common throughout the Mediterranean, and is sold in the fish markets of Italy.

Families *ONYCHOTEUTHIDÆ* and *CHIROTEUTHIDÆ*.

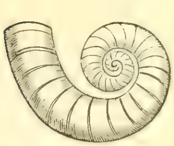
The squids belonging to the genus *Onychoteuthis* are very similar to *Loligo*, but are distinguished by having the club of the tentacular arms furnished with strong horny hooks. They are mostly of small size, only a few inches in length; but a very large species (*O. robusta*) was observed off the coast of North-West America, and measured 8 feet in length from the base of the arms to the posterior end of the body. It has since been placed in the allied genus *Ancistroteuthis*. One of the most remarkable of the decapods is the genus *Chiroteuthis*, easily recognisable by the enormous length of the tentacular arms, which are many times the length of the body, so that the animal is enabled to capture its prey at some distance. *C. veranyi* occurs in the Mediterranean, *C. bonplandi* in the Atlantic, and *C. lacertosa* off the east coast of the United States.

TRUE CUTTLE-FISHES,—Family *SEPIIDÆ*.

In the cuttle-fishes of the genus *Sepia* the body is oval with a fin on each side extending the whole length. The eight sessile arms are furnished with suckers having foot-stalks, and the long tentacular arms are entirely retractile within the head. The dorsal plate, shell, or cuttle-bone, is generally almost as wide as the body, and placed beneath the skin of the back, with the terminal spine posteriorly. This is supposed to protect the hinder parts of the animals, in the frequent collisions they are exposed to in swimming backwards. About sixty species of *Sepia* have already been described, none of very large size, the largest bone being only about a foot and a half in length. A fine specimen of *S. apama* in the British Museum is 17 inches long. They occur in all parts of the world, and three species are recorded from the coasts of Britain. They live near shore, and feed upon fish and crustaceans, which they seize with their rapidly unrolled tentacles. Speaking of the common cuttle-fish (*S. officinalis*), Mr. Lee observes that though flabby and clammy in death, it is a lovely object when alive. Unlike the octopus, but equally rapacious, it loves the daylight and freedom of the open sea. Like the calamaries, the sepia is extensively employed as an article of diet in many parts of the world. Dried cuttle-fishes are exposed for sale in the bazaars or markets throughout India, and may be seen among the articles of Chinese, Japanese, and Siamese food. The ink of the cuttle-fish was employed as a writing material in very ancient times, its use being mentioned in the works of some of the old Latin writers; the ink-bags of cuttles are still manufactured into sepia by artists' colourmen. Eggs of the common cuttle resemble black pointed grapes, each having a flexible stalk, looking and feeling like indiarubber. They are generally attached to the stems of seaweed. Each capsule contains a single young one.

Family *Spirulidæ.*

Spirula represents the last of the three divisions into which the living decapods have been divided. The shell of the spirula is abundant on the shores of some tropical countries, but the animal is scarcely ever met with. Only a few specimens have been captured, and most of these are in bad condition. The shell is entirely white, pearly within, placed vertically within the posterior part of the body, so that the spire corresponds to the ventral side of the animal. It is a loosely coiled structure, resembling a ram's horn, and is divided into a number of chambers by fine concave partitions, like the shell of nautilus, each one pierced by a slender tube or siphon near the inner curve of the shell. Three species are known, distinguished by differences in the soft-parts, the shells being similar.

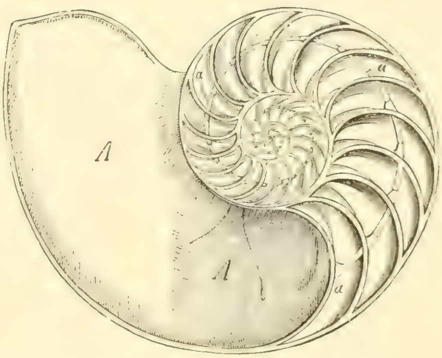

Spirula peroni.

Belemnites. To the same group as the *Spirula* belongs the extinct family of *Belemnitidæ*, ranging from the Lias to the Chalk, and whose skeletons are commonly known as thunderbolts. They possess a tapering chambered shell, inserted into the summit of a long spear-like guard. Most of the species belong to the typical genus *Belemnites.*

Four-Gilled Group,—Order Tetrabranchiata.
Family *Nautilidæ.*

The nautilus is the sole living representative of this order, and although not so rare as the spirula, the animal of the nautilus is by no means common in collections. It is probably an inhabitant of deepish water, and only likely to be obtained alive by dredging, although a few specimens have been occasionally captured at the surface. The animal is contained within the last compartment (*A*) of a chambered shell, within which it is completely retractile. It does not resemble any of the dibranchiate cephalopods, having numerous small retractile feelers or tentacles, without any suckers, in place of the eight or ten sucker-bearing arms of that order. The beaks are very solid and calcareous, not entirely horny as in the dibranchiates. The eyes are small, and raised on short stalks; the funnel is not a complete tube, being formed of two lobes which fold over one another, but are not joined together. To the posterior end of the body is attached a slender fleshy cord, termed the siphuncle (*a*), which passes through holes in the septa of the shell up the coiled spire. It is enclosed in a horny tube, which is again coated with a calcareous deposit.

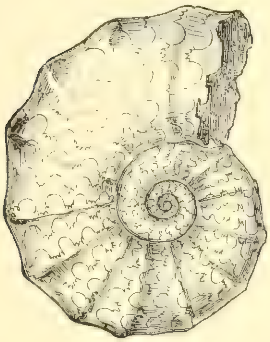
The function of the siphuncle probably is to preserve the vitality of the first formed portion of the shell, which without some such means of preservation would be liable to decay. The animal is somewhat feebly attached to the shell by two large adductor muscles one on each side of the body, which are, as it were, connected by a muscular girdle of the mantle passing round the body from muscle to muscle. The chambered shell is beautifully pearly within, but has an external porcellaneous coating. A full-grown shell has about thirty-six septa, which are relatively equidistant, showing that the growth of the animal is regular and gradual throughout life. The septa give immense strength to the shell, sufficient to resist the pressure of the water at great depths upon the air-chambers between them. These air-chambers undoubtedly serve to buoy up the shell when the animal is swimming or desires to rise to the surface; but the old stories of its filling the cells at pleasure with either air or water, and so rising to the surface or descending to the bottom, are mere fables, and comparable to the legends respecting the sailing of the argonaut. The shells of the male and female are said to present certain slight differences. Very little is known of the habits and economy of the pearly nautilus, but, as already remarked, it is most likely a deep-water animal, as a rule living at depths far beyond the action of storms. It would probably be obtained by dredging or by means of baited traps. A specimen dredged off the Fiji Islands, at a depth of about three hundred and twenty fathoms, was kept alive for some time in a tub of sea water. The mode of growth of the nautilus has been a subject of much discussion, and the way in which the successive air-chambers and septa are formed is not known with certainty. The living forms of *Nautilus* probably belong to three distinct species. *N. pompilius* has a wide distribution in eastern seas, specimens having been obtained in the Indian Ocean (Andaman Islands), at the Moluccas and Java, and in the Pacific at the New Hebrides and Fiji; *N. umbilicatus* is recorded from the Solomon Islands, and New Ireland; and *N. macromphalus* from New Caledonia and the Isle of Pines. The animal of *Nautilus* is used as an article of food among the natives of the New Hebrides, New Caledonia, and Fiji, it being captured by the Fijians in traps baited with boiled crayfish.

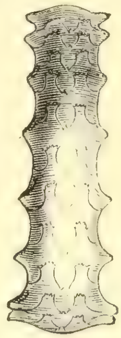


SECTION OF SHELL OF PEARLY NAUTILUS (much reduced).

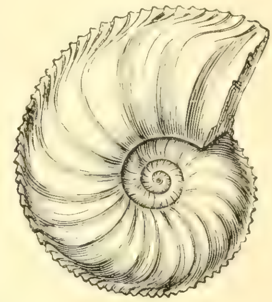
Allied Families. The genus *Nautilus* is of great antiquity, dating from an early epoch in the Palæozoic period, and forms the type of the family *Nautilidæ*, which includes several extinct genera. There are allied extinct families, collectively forming a group characterised by the simple structure of the septa of the shell, such septa having their concavities directed towards its aperture. Among these, the *Orthoceratidæ*, as typified by the Palæozoic genus *Orthoceras*, may be characterised as unrolled nautili, the shell—which sometimes reaches an immense length—forming a long cone.

Another well-marked group is that of the Ammonoidea, represented by the goniatites of the Palæozoic, and the various types of ammonites of the Secondary rocks, as well as by the turrilites of the Chalk. In all these the edges of the sutures, where they join the shell, are more or less complexly angulated or frilled, the complexity being very great in the ammonites, but a simpler type obtaining in the goniatites.





A CERATITE (*Ceratites nodosus*).



AN AMMONITE (*Cardioceras cordatum*).

Whereas in the two latter the shell is coiled in a flat spiral, in the turrilites it forms a cone, while in the hamites and baculites of the Chalk it is either straight or partially coiled. In the ceratites and ammonites (which include *Ceratites, Cardioceras*, and many other genera) the mouth of the body-chamber of the shell was closed by an operculum, which often consists of two pieces meeting in the middle line, and the whole being heart-shaped. In other forms the operculum was single. Mr. Cooke observes that "some authorities hold that the members of this suborder belong to the Dibranchiata, on the ground that the protoconch resembles that of *Spirula* rather than that of the Nautiloidea. Others again regard the Ammonoidea as a third and distinct order of Cephalopoda. Their distribution extends from the Silurian to (possibly) the early Tertiary. No trace has ever been found of an ink-sac, mandible, or hooks on the arms; and the shell was undoubtedly external."

EDGAR A. SMITH.

CHAPTER X.

MOLLUSCS,—*continued.*

THE GASTROPODS,—Class **Gastropoda**.

THE Gastropods constitute by far the largest division of the Mollusca, and include among their number forms which bear no external resemblance whatever to one another. Some are free-swimming animals, living far from land, out on the open seas; others occur in shallow water, or between tide-marks; while others are dwellers on the land, or frequent rivers and lakes. Some have internal, others external shells, whilst many have no testaceous structure of any description. Snails, whelks, and periwinkles are typical forms of Gastropods, and the more aberrant types are represented by the Nucleobranchs, Heteropods, and Pteropods. The typical Gastropods are all crawlers, moving like a slug or snail by a continual expansion and contraction of the muscular foot. Some breathe by means of gills, others by a lung, while certain forms are provided with both modes of respiration. They are generally furnished with a spiral shell when adult. They are mostly unsymmetrical animals, lying spirally coiled within the shell; this want of symmetry being particularly manifested in the breathing-organ. In many marine forms there is only a single gill, but in a few genera—*Fissurella* for example—the gills are paired. There is always a more or less distinct head, bearing one or two pairs of tentacles, and there are generally a pair of eyes situated at the base or end of the tentacles, or raised upon short stalks. The mouth is usually provided with one or more jaws, and the lingual ribbon, or radula, within the mouth, varies greatly in its armature, and plays an important part in the various schemes of classification which have been proposed. While enormously developed in some groups, such as the limpets, in a few it is entirely wanting. It consists of a thin chitinous membrane, the surface of which is beset with a multitude of so-called teeth, symmetrically arranged in transverse or oblique series. The teeth are siliceous, insoluble in acid, and capable of rasping away hard substances. With it the whelk and other carnivorous forms bore through the shells of bivalves, and the limpet eats away the calcareous nullipore. Not only is the form of the teeth extremely variable, but their number varies enormously in different groups. In an *Eolis*, one of the Nudibranchs, there are but sixteen teeth; in a *Doris*, belonging to the same group, there are as many as six thousand, whilst in a large species of *Helix* the number has been estimated at nearly forty thousand. The shells of Gastropods are usually spirally coiled as in the snail, but sometimes they are tubular or conical, like that of the limpet. The forms of spiral shells are innumerable and very unlike; some being globose, with simple rounded aperture, while others are narrow and long, with prolonged spires, and the mouth produced into a long anterior beak.

The colour and ornamentation of the surface are also as varied as the shape. Nearly all spiral shells are dextral, but a few genera (*Physa* and *Lanistes*) are normally sinistral; while in other groups (*Achatinella*, *Amphidromus*, etc.) some of the species are indifferently dextral or sinistral. A large proportion of the Gastropods entirely or partly close the aperture of their shells with what is termed an operculum. This is sometimes horny, like that of the common periwinkle, or it may be solid and calcareous as in the *Turbinidæ*. The different forms assumed by this structure have afforded characters for separating many groups generically. The operculum is generally attached to the hinder part of the foot, so that when the animal withdraws within the shell—it more or less closes the aperture, and thus protects itself. In many species the operculum is very small, and would not serve as a defensive weapon, whilst in others it is altogether wanting. Gastropods may be classified in three principal divisions or orders, namely, the Pulmonata, Opisthobranchia, and Prosobranchia.

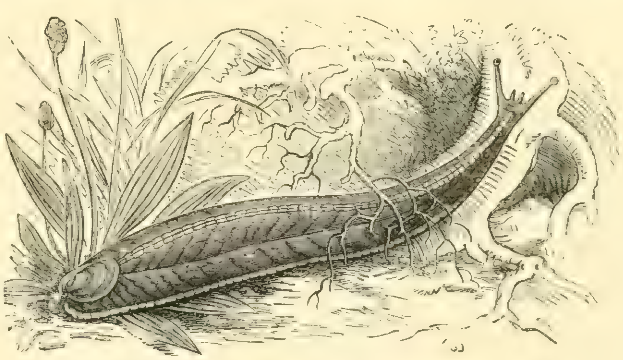
The Lung-Breathing Group,—Order Pulmonata.

The order Pulmonata comprises all the true land-snails,—excepting such as are provided with an operculum,—the inoperculated forms of fresh-water snails, and the family of the *Auriculidæ*. The latter forms a considerable group, the members of which are chiefly met with in salt or brackish marshes, although there are three or four genera which are strictly littoral in their habits. All the Pulmonata are provided with a breathing-cavity, which is not freely open as in the terrestrial and fresh-water Prosobranchs, but has only a small opening which is contractile so as to exclude the water in the aquatic species, and the hot air during the heat of summer in the terrestrial forms. This lung-opening is seen on the right side of most snails and slugs a little behind the head, and at once closes up if the animal be molested. With a few exceptions, the fresh-water Pulmonates rise to the surface to breathe, and are suffocated if prevented from obtaining the requisite supply of air. They can be drowned just as easily as a slug or snail beneath the water, but naturally the process would be longer in these animals, in which the breathing is habitually much slower. In the case of *Ancylus*, however, this could not be effected; and a fresh-water pulmonate, *Physa lamellata*, from Madagascar, possesses a well-formed gill.

The Pulmonata may be separated into two main divisions, according to the position of the eyes. In the Stylommatophora, represented by slugs and snails, these are situated at the tip of retractile tentacles, whereas in the Basommatophora they are placed at the base of the tentacles, which are only contractile and not retractile within themselves as in the former section. The Stylommatophora are mostly more or less slimy, and leave a mucous track behind when crawling. Although they are chiefly vegetarians, some are not only carnivorous, but even cannibals at times. They are found in all parts of the globe, from the Arctic regions to the Tropics, but are most abundant in those countries where there is plenty of lime and moisture. The sexes are not distinct but united in each individual. The eggs of terrestrial molluscs are far less numerous than those of the marine forms, and are deposited separately. They are mostly round or egg-shaped, and are generally laid in the earth under stones or leaves, and there left to hatch by themselves. On emerging from the egg, the animals are practically the same as the parent, but the form of the shell, when present, generally alters very much in the course of growth.

Shelled Slugs,—Family *Testacellidæ.*

The shelled slugs, or *Testacellidœ,* have no jaws, but are armed with a tongue bearing oblique series of long, narrow, pointed teeth, indicative of their carnivorous habits. While some members of the family are without any external shell, the majority are provided with shells capable of entirely covering the animals, but a few have only very small ear-shaped shells attached to the upper surface of the hinder end of the foot. To the latter group belongs *Testacella,* the typical form of the family. This genus includes elongated slug-like animals, with the breathing orifice at the posterior end of the body, which is capable of great extension and contraction. They prey upon earthworms, which are pursued in their burrows under ground. In a recent account of the habits of *T. scutulum,* Mr. Webb observes that it usually seized the anterior end of the worm, and gradually swallowed it; but occasionally the middle was seized, in which case the worm forced itself away. During cold northerly and easterly winds these creatures enclose their bodies in a kind of cocoon, like that of the silk-worms, which is secreted from the skin, and often mixed with earthy and extraneous particles. These slugs deposit a few calcareous eggs, which in form are as symmetrical as those of a bird, and large in proportion to the size of the animal. It is doubtful whether this genus is truly indigenous to Great Britain, or merely an introduction of comparatively modern times. The only other parts of the world besides Europe where *Testacella* occurs, are Algeria and the Azores, Madeira, and Canary Islands.

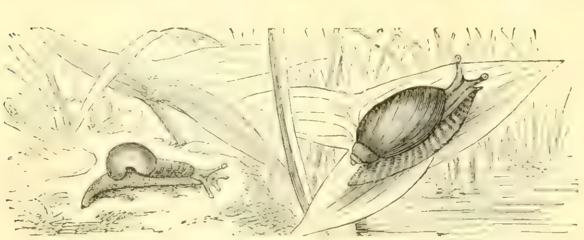


SHELL-BEARING SLUG, *Testacella haliotidea* (nat. size).

Glandina forms an extensive genus of *Testacellidœ,* chiefly restricted to the central parts of America; one species, however, being European. Like *Testacella,* these are very voracious, and even attack their own species. *Daudebardia* is another slug-like genus of this family, carrying a small shell upon the tail. They occur in Southern and Eastern Europe and Western Asia, and in New Zealand are closely represented by *Schizoglossa,* the external aspect of which is very similar. The allied *Streptaxis* is remarkable for the peculiar obliquity of the last or body-whorl in relation to the spire in most of the species. The first-formed part of the shell is regular in its growth, like an ordinary garden snail-shell, but suddenly the growth becomes irregular, giving the shells a very oblique and distorted appearance. The object of this deviation from the ordinary form of growth is not apparent, but it doubtless serves some special purpose. Nearly all the species of this genus are of a whitish colour, polished or obliquely striated. They chiefly occur in South America, Tropical Africa, Southern Asia, and certain islands in the Indian Ocean.

True Slugs,—Family *Limacidæ.*

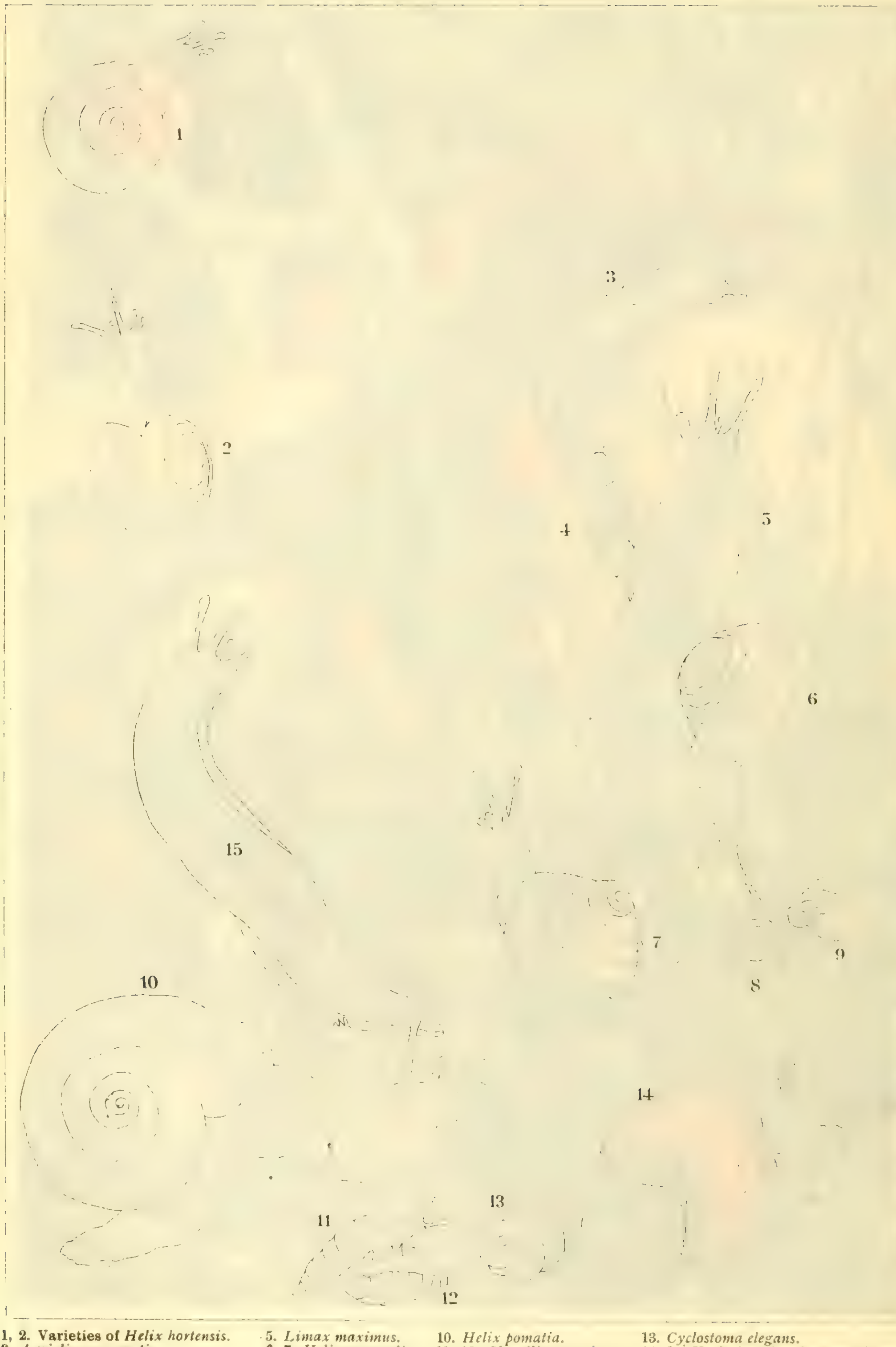
This family contains many genera of naked slugs, and several either partly or wholly protected by well-developed shells; the hinder end of the foot in some forms terminating in a conspicuous mucus or slime-pore. The typical slugs are mostly elongate animals, capable of great contraction, and always pointed or attenuated behind. The mantle forms a sort of shield, placed over the fore-part of the back, and beneath this is situated a small calcareous plate, representing the shell. These plates occur fossil in Eocene beds. The respiratory orifice is seen on the right side of the shield, but rather far back. The head is prominent in front, bearing two pairs of retractile tentacles, of which the upper are the longest, and furnished with eyes at the bulbous tips. The mouth is provided with a horny upper jaw, which is smooth, with the cutting edge produced into a sort of beak in the middle. The radula has numerous transverse series of horizontal or slightly oblique teeth, of which the central tooth is three-pronged, the laterals about the same height as the central one, while the marginal teeth are narrow and acute. The body is united to the foot, and is more or less wrinkled; the wrinkles being most conspicuous when the slug is contracted, and to some extent characteristic of the different species. The *Limacidæ* live in damp places, out of doors, or in cellars, and hide away during the daytime under stones, dead leaves, or in fact in any place where it is dark and moist. They feed chiefly on decaying vegetation, but some are more or less carnivorous. Certain species are great pests in gardens. *Limax agrestis*, the "milky slug,"—so called from the opaque white colour of its mucus,—is a very common species in England; it is very fond of strawberries, and is also said to feed upon earthworms. These slugs increase in numbers rapidly, and are said to produce several families in the course of a summer; a pair having been known to lay nearly eight hundred eggs. Some species of *Limax* are capable of lowering themselves to the ground from the branch of a tree by secreting a slimy thread. The largest species occuring in Britain is *L. maximus*, which has a very wide range on the Continent, and sometimes exceeds 6 inches in length. One may often notice numbers of a minute white parasitic mite (*Philodromus*) running about the body of this slug, and it is said also to live in the respiratory cavity, but does not appear to cause any annoyance or injury to its host.



GLASS-SNAIL (*Vitrina*) AND AMBER-SNAIL (*Succinea*). (Nat. size.)

In the genus *Vitrina* the animal is provided with a fragile, external, horny shell, not sufficiently large to receive it entirely, when contracted. The shells are all very much alike, and precisely similar to those of *Helicarion*, another genus of *Limacidæ*, which, however, is distinguished by having the foot truncated obliquely behind, and furnished with

LAND MOLLUSCS



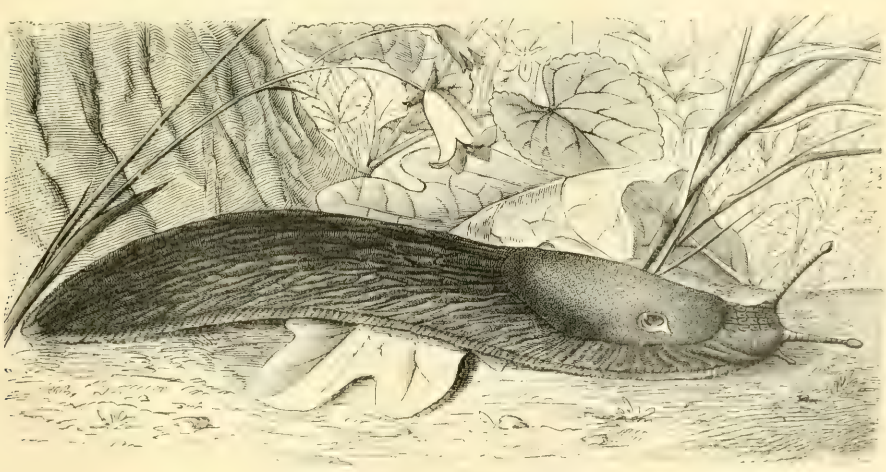
1, 2. Varieties of *Helix hortensis*.
3. *Agriolimax agrestis*.
4. *Buliminus moutanus*.
5. *Limax maximus*.
6, 7. *Helix nemoralis*.
8, 9. *Helix personata*.
10. *Helix pomatia*.
11, 12. *Clausilia ventricosa*.
13. *Cyclostoma elegans*.
14, 15. Varieties of *Arion empiricorum*.

a large terminal mucus-pore, and there are other anatomical differences. The single British species is here figured. Unlike *Vitrina*, the snails known as *Zonites* and *Vitrea*, together with some allied genera, are wholly retractile within their shells. There are several British species of *Vitrea*, and their identification from the shells alone is a matter of considerable difficulty. In their habits they closely resemble *Vitrina*, being carnivorous rather than vegetarian. They greedily devour any kind of animal food, even in a putrid condition, and are also said to prey upon some of the larger snails. They are generally found hidden away under stones, dead leaves, or moss, and some of them emit a strong smell, like garlic, which is perceivable at a distance of some feet.

The Snail Tribe,—Family *Helicidæ*.

Like the *Limacidæ*, this family includes forms with or without an external shell. In nearly all the genera the cutting-jaw of the animal is more or less ridged, and not smooth as in *Limax*. The principal distinguishing character occurs in the structure of the radula, which is composed of many rows of very numerous similar square-based teeth, arranged so regularly as to have a tesselated appearance. It is very broad, and the number of teeth in a row, although usually less, is sometimes as great or even greater than the number of rows. This family includes an enormous number of species from all parts of the globe. These occur everywhere and in all climates; in dense forests, on the top of grassy downs, in valleys, fields, lanes, in the arid desert, and at an elevation of some ten thousand feet both in the Old and New World.

To an ordinary observer, the members of the genus *Arion* (sometimes placed in a separate family, *Arionidæ*) are merely slugs. Externally the resemblance is



BLACK SLUG, *Arion empiricorum* (nat. size).

very close, but the different position of the respiratory orifice, and the presence of a mucus-pore at the end of the foot, readily separates this genus from *Limax*. Besides these differences, the radula is of a different type. In *Limax* the breathing-hole is situated near the hinder end of the shield, whereas in *Arion* it is much further forward. In the present genus there is no internal shield-like shell, as in *Limax*, but this is represented by a few unequal calcareous particles beneath the mantle. Nine species of this genus are said to occur in Britain, and of these the large *A. empiricorum* is the commonest and best known. It is sometimes intensely black, but it may be brown, red, yellow, greenish, or even white. This great variation in colour is unaccountable, for black and red specimens occur in the same districts where the natural surroundings are practically the same. The edge of the foot, when crawling, displays a yellowish or orange border crossed by closely-set black lines. This species usually feed on vegetable substances, but it has occasionally been known to devour earthworms. It ranges over a considerable part of Europe, and has been recorded from Siberia, Corsica, and as far as Madeira.

The genus *Helix* includes the true snails of the type represented by the garden-snail (*H. aspersa*), and the edible or vine-snail (*H. pomatia*), as it has been variously named. The animal is completely retractile within its shell, and the body distinct from the foot, and well protected by the spiral shell. The breathing-orifice is on the right side beneath the margin of the aperture of the shell. The genus *Helix*, as understood at the present time, is much more limited than it was some years ago, and the tendency of conchologists is to propose still further limitations. The necessity of dividing an enormous genus like *Helix* containing thousands of species, is universally recognised, but the danger arises of carrying this sectionising too far. Many of the divisions are partly founded upon geographical considerations. The form of the shell in *Helix* is extremely variable, as a glance at any collection will show. Some are sharply conical, others globular, or flat and acutely keeled at the circumference; and the variety of colour is endless, and changeable in specimens of the same species. The British *H. nemoralis* and *H. hortensis* are striking examples; and *H. picta*, a beautiful Cuban shell, is another remarkable instance. Not only does the ground-colour offer many variations, but the colour and disposition of the spiral lines or bands which adorn the surface are equally variable. The twenty-five species of *Helix* which occur in Britain are insignificant in comparison with their exotic relatives, although large enough to do a considerable amount of damage in the garden. The finest is the *H. pomatia*, popularly known as the apple-snail, but this name, as pointed out by various writers, although appropriate as regards its shape, was not derived from the Latin *pomum*, an apple, but from the Greek *poma*, signifying a lid or operculum. When winter is approaching, the animal secretes a diaphragm or covering to the aperture of the shell, a false operculum, to keep out the cold and wet when hibernating under ground. It is composed of slime and calcareous matter, but is not pierced with a minute breathing-hole, as is the case in some other species, although probably sufficiently porous to permit of whatever change of air may be necessary during the winter sleep. The eggs of *H. pomatia* are deposited in June in holes in the ground, formed by the snail itself. They are about the size of a small pea, and much resemble in colour and consistency the berries of the mistletoe. Only a day or two is occupied in the production of sixty to eighty eggs, and these are then covered up with earth and the ground so levelled that the place, or egg-nest, is difficult to discover. The length of time before hatching varies according to locality and the state of the temperature. It may be from about twenty to forty days before the young snail eats through the skin or shell of the egg, and this it is said to entirely consume. Although *H. pomatia* is commonly styled the edible snail, it should be remembered that other species are also considered a delicacy; *H. aspersa, H. naticoides*, and *H. vermiculata* being commonly eaten in parts of Italy and Sicily; while in Naples, *H. ligata* and *H. lucorum* are also to be seen for sale. *H. mazzullii*, which is collected near Palermo, possesses the power of boring into the rock; this being probably effected by means of the radula. The supposed object of these excavations is to secure a place of refuge during the period of excessive heat, and also to obtain a supply of lime for the formation of the shell. The Philippine Islands are the home of a beautiful genus of snails (*Helicostyla*), many of which are clothed with a peculiar periostracum, which, when wetted, becomes more or less transparent, disclosing the colour of the shell beneath. Two or three of the species are of a bluish tint, a colour not found among other land-shells.

The important genus *Bulimus* (now abolished in favour of *Strophocheilus*) formerly contained a large number of species from all parts of the world, but is now limited to a comparatively few forms occurring in South America; *S. oblongus* being one of the commonest and best known species. Another, *S. maximus*, is sometimes as much as 6 inches in length. The majority of the other species, originally classed in *Bulimus*, are now located in *Bulimulus* and its sections, or in *Buliminus*. These genera are distinguished by differences of the jaw and radula.

Other Families.

There are several other families of land-shells, which can only be briefly referred to. The *Cylindrellidæ* are very elongate, many-whorled shells, which occur principally in the West Indies and South America; many of them being remarkable for their slender forms and exquisite sculpture. A peculiarity of *Cylindrella* consists in the shell being almost invariably truncated, that is, the upper whorls are broken off when the animal reaches maturity. This may be done to lighten the shell, which otherwise would be too long for the mollusc to carry erect. The *Pupidæ* comprises a number of forms which are conchologically very dissimilar. The typical *Pupa* includes minute creatures, and appears to be found in all parts of the globe, but especially in temperate and mountainous regions. They are gregarious and live in moss, under stones, in the crevices of old walls, or among the roots of grass and other plants. Most of the species have what are called "teeth" within the aperture of the shell, and these in some species are so numerous as to almost close the opening, and thus make it, one would suppose, a matter of some difficulty for the animal to squeeze through them when emerging from its shell. *Vertigo* is a genus similar to *Pupa* as regards the shell, but separable on account of the animal having only one pair of tentacles, the lower pair being entirely wanting. The shells, according to the species, are dextral or sinistral. *Clausilia* is remarkable for the large number of species, the general similarity in the form of the slender shell, and the peculiar process within it, which serves as a door to shut in the animal when retracted. The shells are almost invariably reversed, and furnished with two or three folds or plicæ within the mouth, and other lamellæ still further within, which can only be detected by the transparency of the shell

Clausilia.

itself. About a thousand species have been described. They are most numerous in Europe and Eastern Asia, only a very few species being known from South America. *Achatina* is one of those genera the scope of which has been greatly altered since it was first founded by Lamarck. In those days any land-shell with a notch or truncation in the pillar-lip of the aperture was considered an *Achatina*. It is, however, now reserved for a group of large snails which are only met with in Africa, Madagascar, and a few other adjacent islands. They have fine handsome shells, vividly painted with more or less wavy stripes, and covered with a thin periostracum. *A. variegata,* in the tropical forests of West Africa, is sometimes $7\frac{1}{2}$ inches in length, and the largest of all the living land-shells.

The members of the extensive family *Achatinellidæ* are inhabitants of the Sandwich Islands, and occur in no other part of the globe; the species being all small, and many of them both dextral and sinistral. Some are found on trees

AGATE-SNAIL (*Achatina fulica*).

and shrubs, whilst others are always met with on the ground. Mr. Barnacle has given an interesting account of the production of musical sounds by these little land-snails. He described the sound as resembling that of hundreds of Æolian harps, and believed it was produced by the friction of the shells against the bark of the trees upon which the snails were crawling.

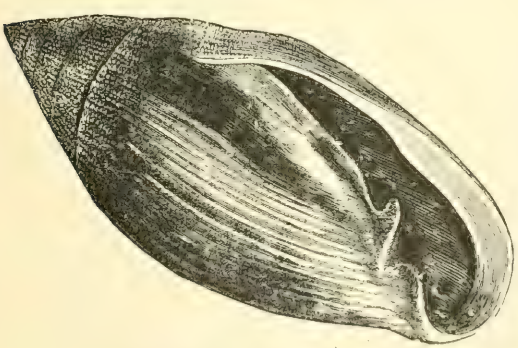
The amber-snails (*Succineidæ*) bear a strong family likeness to one another. The shells are all very fragile, oblong, yellowish, or reddish, with a more or less exserted spire and a very large body-whorl. They are found in damp situations, and have even been observed crawling beneath the water, upon which they can float in a reversed position. They are vegetarian in their diet, and deposit their eggs on the stems and leaves of aquatic plants, and also upon stones or other substances near the water's edge. Species of *Succinea* occur in most parts of the world, being met with in such remote localities as Greenland, Patagonia, India, Japan, Australia, and the South Sea Islands. The species figured on page 344 is found all over Europe, and ranges even as far as Afghanistan. The character of the radula is shown in the figure on the next page.

The family *Oncidiidæ* includes about fifty shell-less air-breathing molluscs, somewhat slug-like in general appearance, but provided with a thick mantle covering the whole dorsal region. This is frequently more or less tubercular, some of the tubercles being furnished with eyes which, simple as they are in structure, are identical in type with those of the Vertebrata. These snails live on the seashore or in brackish marshes, eating nothing but sand, but, of course, only digesting the nutritious organic particles contained in it. Professor Semper has given an account of their habits, and how they are pursued by certain fishes (*Periophthalmus*), which come ashore after them. One species, *O. celticum*, is found in Cornwall and South Devon, others occur in America and the Pacific.

Basommatophora. The numerous forms belonging to this group, comprising the rest of the Pulmonata, differ from those already indicated, in having the eyes situated at the base of the tentacles, as in the marine whelks and periwinkles, instead of at the tips. An external shell is always present, and capable of containing the entire animal. The members of the family *Auriculidæ* mostly

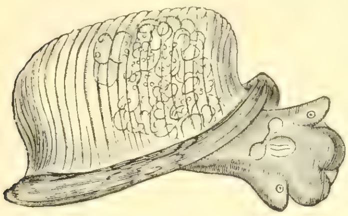
Pythia scarabæus (nat. size).

Earlet Shells. Auriculidæ. inhabit salt or brackish marshes, and were formerly regarded as marine molluscs. The shells generally are rather solid, of different forms, but usually with narrow apertures, more or less contracted by teeth. The internal septa between the whorls of the spire are often absorbed or dissolved, excepting that between the last and penultimate volutions. Some species of the typical *Auricula* have large heavy shells, and are met with in mudbanks and in swamps, in the Indian Archipelago. Those belonging to *Pythia* have oval, compressed shells, with toothed apertures, and occur in great numbers in most places in woods near the sea, are wholly terrestrial in their habits, and feed on decayed vegetation. One member of this family (*Carychium minimum*) is found in Great Britain, and on the Continent. It is an extremely small shell, less than the tenth of an inch in length, transparent, glossy, having three teeth-like projections within the aperture. It hides away at the roots of grass, among moss, dead leaves, or under stones or dead wood, in damp situations.



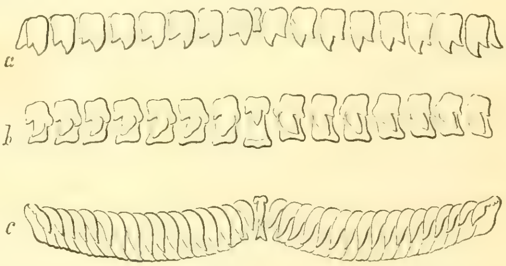
EARLET SHELL, *Auricula judæ* (nat. size).

Pond-Snails, etc. The three families *Limnæidæ*, *Physidæ*, and *Chilinidæ* form a second group of the Pulmonates with sessile eyes, all being inhabitants of fresh water, but rising occasionally to the surface to renew the supply of air. They are mostly herbivorous, but some kinds of *Limnæa* and *Physa* are said to become carnivorous occasionally. In the first family the members of the genus *Ancylus* are popularly known as fresh-water limpets, on account of the resemblance in form of their shells to the true limpets. They have all small thin shells, with the apex somewhat posterior, but generally inclining a little to the right or left. They are found on all four continents, as well as in Australia, New Zealand, the West Indies, and other islands; two species being British. *A. fluviatilis* occurs generally on stones, but occasionally on plants in shallow streams, and running brooks, whereas *A. lacustris* invariably adheres to the stems and leaves of plants in ponds, lakes, and canals. On account of this difference of habit, and also for various anatomical reasons, the latter species has been placed in a separate section (*Velletia*). The illustration represents the embryonic stage of this species just prior to its quitting the ovum.



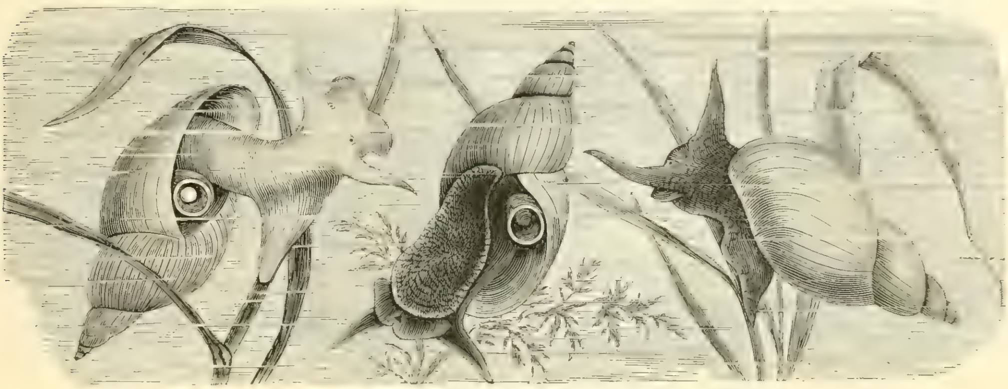
EMBRYO OF RIVER-LIMPET (*Ancylus*).

The fresh-water snails belonging to the genus *Limnæa* have thin horny shells, with more or less sharp spires, and are usually dextral, but certain forms occurring in the Sandwich Islands, Australia, and probably other neighbouring localities, are constantly sinistral, so that it is impossible to separate them from the genus *Physa* by the shells only. An examination of the animals, however, at once determines their proper position. In *Limnæa* the two tentacles are compressed and triangular, with the eyes at their inner base. In *Physa* they are cylindrical. The jaw and radula are also different in the two genera. The species of *Limnæa* frequent shallow and still waters, in most parts of the globe, often swimming at the surface of the water in an inverted position. They are prolific and gregarious, and the eggs are enclosed in transparent gelatinous capsules, and deposited in continuous series, and attached to submerged stones as well as to the stems and leaves of aquatic plants. *L. stagnalis*, which is common in ponds, marshes, and slow rivers, is the largest species, and six other species occur in Britain. The other figured forms illustrate the great variation which occurs in the relative length of the spire and aperture. In one of these (*L. truncatula*) the liver-fluke, so destructive to sheep, passes one stage of its existence.



ROW OF TEETH OF RADULA OF — *a*, *Limnæa stagnalis*; *b*, *Ancylus fluviatilis*; *c*, *Succinea putris*. (Greatly magnified.)

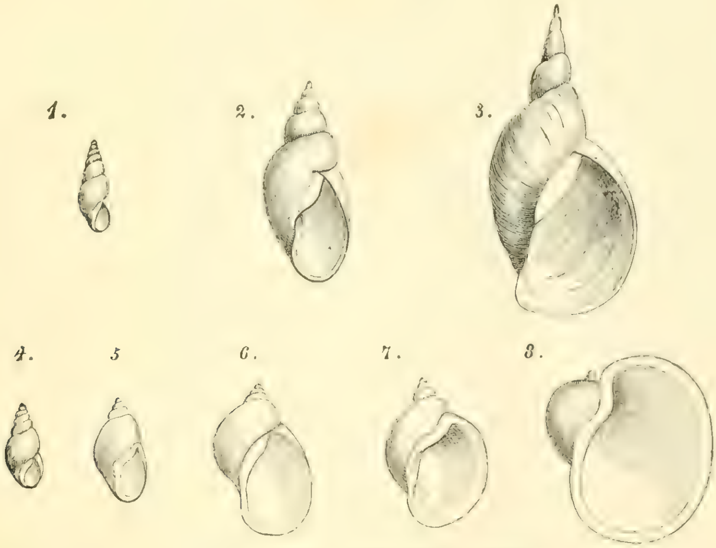
The animals of the genus *Planorbis* are small, and have the vital organs on the left side. The tentacles are slender as in *Physa*, but there are no lateral mantle-lobes. The shells are all very similar, being sinistrally and spirally coiled up like a rope, in the same plane. They frequent stagnant pools and ditches, or slowly running water, in all parts of the world. The well-known *P. corneus* is not only by far the largest of the eleven British species, but also larger than any



COMMON POND-SNAIL (*Limnæa*).

other known form, although some of the South American types approximate closely. When disturbed, it emits a purple-coloured fluid, probably as a means of defence.

In *Physa* the animal is always sinistral, having the respiratory and genital orifices on the left side. The tentacles are cylindrical, and the eyes are at their



VARIOUS FORMS OF THE GENUS LIMNÆA.

1, *Limnæa glabra*; 2, *L. palustris*; 3, *L. stagnalis*; 4, *L. truncatula*; 5, *L. peregra*; 6, *L. vulgaris*; 7, *L. ovata*; 8, *L. auricularia*.

inner base, as in *Limnæa*. The mantle is furnished on each side with more or less elongate lobes, which, when the mollusc is crawling, are folded back upon the exterior of the shell. In their habits these snails resemble the preceding genus, and they are almost cosmopolitan in their distribution. *Physopsis*, a Central and South

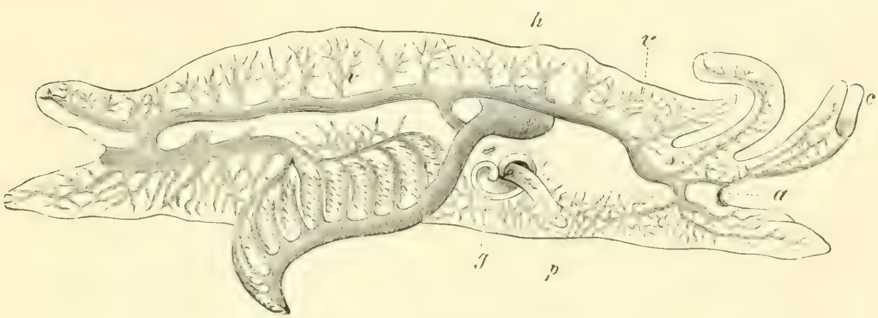
African form, has a reversed shell like *Physa*, but is distinguished by having a tooth or fold on the columellar margin of the aperture. In *Chilina* the shell is dextral, like that of *Limnæa*, but differs in being covered with a periostracum, and exhibiting reddish wavy colour markings. The columella is thickened and furnished with one or more folds or plaits. They are found only in clear running streams of South America.

RAMSHORN SNAIL (*Planorbis corneus*).

The curious pulmonate known as *Amphibola* somewhat resembles a periwinkle in form. It lives between tide-marks in brackish or salt water, on mud-flats at the mouths of rivers in New Zealand, and is used as food by the natives. It is abundant in some places, and is a sluggish creature, subsisting upon the vegetable matter contained in the mud, large quantities of which it passes through the alimentary canal. Professor Hutton says that it will live for a week or ten days in fresh water, and more than a fortnight in salt water, without being exposed to the air. The breathing-orifice is situated on the right side of the neck, and the radula shows some affinity to that of *Physa*. The shell is solid, globular, with a short spire and an oval aperture. The animal is furnished with a thin horny subspiral operculum.

THE HIND-GILLED GROUP,—Order OPISTHOBRANCHIATA.

The Opisthobranchs form the second of the three main divisions of the gastropods, and are all marine forms, having the sexes united in each individual, and breathing chiefly by gills or branchiæ. This character at once separates them from the Pulmonata, and the different positions of the branchiæ, and their hermaphrodite nature, serve to distinguish them from the Prosobranchia, the third and last main branch of the Gastropods. In the Opisthobranchs the branchial veins as well as the auricle are placed behind the ventricle of the heart, but in the Prosobranchs the branchial system is anterior to the heart. The majority of the molluscs included in this order are unprovided with a shell in the adult state; but there are some exceptions, such as the shell-bearing Pteropods, and many of the Tectibranchs. They are generally furnished with a pair of tentacles and labial palpi, or an expansion of the skin like the veil of the larval form. To comprehend the character of the internal organisation, the above illustration should be consulted. It represents a longitudinal section of the animal; *p* is the foot; *a*, the mouth, covered above with the veil-like expansion, over which are the tentacles *c*; *v* shows the branchial veins carrying the blood to the gills, from which it flows into the heart. This position is the opposite of that which characterises the Prosobranchs. Another anatomical peculiarity, which may here be referred to, is the direct communication of the system of blood-vessels with the surrounding medium—a character common to most other molluscs, and on which depends the



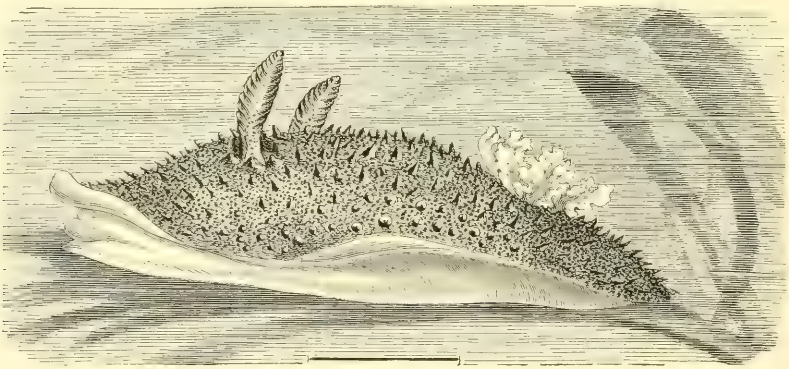
CIRCULATION IN *Pleurobranchus aurantiacus.*

changeable external appearance of the individual. In the illustration of *Pleurobranchus*, as above, *g* indicates the opening of a duct which conveys water direct to the blood, and through which the blood-vessels permeating the back and foot, like the holes in a sponge, can be filled or emptied at the will of the animal. Although this, in the main, is the principle of the circulation in most Opisthobranchs, one branch of the order possesses no special breathing-organ, respiration being effected through the naked skin of the body. The Opisthobranchia may be divided into three principal suborders, namely, Nudibranchiata, Tectibranchiata, and Pteropoda.

NAKED-GILLED SUBGROUP,—Suborder **Nudibranchiata.**

The naked-gilled Gastropods constitute a large assemblage of extremely beautiful molluscs, of remarkable shape, and often brilliant coloration. The distinguishing characteristic of the typical forms consists in the breathing-organs being exposed on the back of the animal, and not protected by the mantle. Other groups, however, are classed within this suborder, in which either the position or character of the respiratory organs is different. The gills may be situated on each side of the body between the back and the foot, or respiration be effected by the ciliated surface of the body. For these and other reasons the Nudibranchs have been arranged in four groups, Anthobranchiata, Inferobranchiata, Polybranchiata, and Pellibranchiata. A fifth group, Parasita, has also been proposed for a very curious mollusc (*Entoconcha*), which lives parasitic within an echinoderm (*Synapta*). Nudibranchs are found in all parts of the world, and are most abundant in depths where seaweeds and corallines flourish, although they are also found at low water or even between tide-marks. A few species have been dredged at great depths. Some even pass their life in the open sea, attached to floating seaweeds, or swim about freely like Pteropods or Heteropods.

Anthobranchiata. The animals belonging to this group are characterised by their symmetrical form, and the position of the vent. This is placed upon the posterior or central part of the back and surrounded by the branching gills, which are more or less contractile. The body is protected above by a large dorsal shield of a spongy texture, and made more or less rigid by calcareous spicules which are embedded in it. The tentacles are dorsal, and retractile through holes



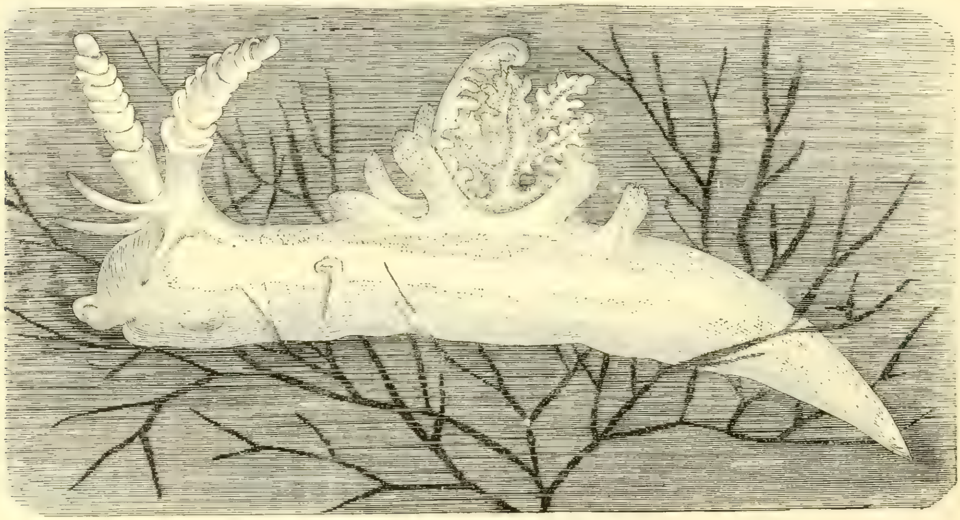
Acanthodoris pilosa (magnified).

in the mantle some distance from the anterior extremity of the body. They are smooth at the base, but lamellated towards the tip. The eyes are minute and situated in the skin behind the tentacles.

Doris Tribe. A large number of species from all parts of the world, at one time considered forms of the old genus *Doris*, are now placed in the distinct group *Doridopsidæ*, on account of differences in the oral organs. The general aspect of the animals of this family is the same as that of *Doris*, the gills being arranged in a circle around the vent on the posterior part of the back. The buccal mass or eating apparatus is small, without jaws or radula, and organised for suction. The extensive family *Dorididæ*, contains a considerable number of genera and subgenera, characterised by differences in the branchiæ, the relative proportion of the mantle in regard to the foot, and variations in the radula and jaws The general aspect of the genus *Doris* is represented by the figure here given of *Acanthodoris pilosa*. The species are very numerous, and some of them are amongst the largest of all Nudibranchs. They are world-wide in their distribution, over twenty species occurring in British Seas. When living, they are most beautiful objects, and must be studied in that state, for when dead and immersed in spirit, they so contract that their natural form can only be guessed, and all the beautiful and varied colours disappear. The spawn of *Doris* and other Nudibranchs is deposited in the shape of a gelatinous band, always arranged in a more or less spiral form, and fastened by one of its edges to corallines or the under sides of stones. The ova are minute and very numerous, amounting in some species to several thousands. Before the period of exclusion, the young may be seen revolving on their own axis, by means of vibratile cilia, and on escaping from the egg they swim about freely in the water by the same means. The larva is extremely minute, and has more the appearance of a wheel-animacule than a mollusc. It is enclosed in a transparent, calcareous, nautiloid shell, with an operculum. Its structure is very simple, showing no signs of the external organs that distinguish the future adult; the principal portion visible outside the shell being composed of two flat discs or lobes, fringed with long cilia, by the motion of which it swims freely through the water. These are often withdrawn into the shell, and the operculum is closed upon them when the animal is at rest. *Doris mabilla*, a fine handsome species, having a wide distribution in the Indian and Pacific Ocean, is fully 4 inches long and 2 to 3 in width. It has been obtained at the Seychelles, Andaman, and Samoa Islands. *Bathydoris abyssorum* was dredged in the mid-Pacific, at a depth of two thousand four hundred and twenty-five fathoms. It is a large animal, about 5 inches in length, of a nearly spherical form, subgelatinous, subpellucid, and greenish white, with a dark purple foot. The branchiæ are non-retractile, and disposed in six groups. It forms a remarkable connecting link between the *Tritoniidæ* and the *Dorididæ*. In the genus *Hexabranchus* the gills are arranged in a circle round the vent, and are composed of six separate plumes, each of which is retractile within a special cavity of its own, and not within a common cavity as in *Doris*. The species are not numerous, and have only been met with in warm seas, such as the Red Sea, and Indian and Pacific Oceans. *H. sandwichensis*, a handsome species of a pale crimson tint occurring at the Sandwich Islands, is nearly 6 inches in length when alive.

The family *Polyceridæ* is distinguished from the *Dorididæ* by having non-retractile gills; the principal genera being *Goniodoris, Acanthodoris, Idalia, Ancula, Polycera, Plocamophorus, Triopa,* and *Ægirus*. *Ancula cristata* is an elegant little creature, about half an inch in length, occurring upon most of the British coasts. It is white, with the processes tipped with yellow or orange. The tentacles are laminated and non-retractile, each having two styliform appendages at the base. The gills are placed in the middle of the back, on each side of which there are a few compressed appendages.

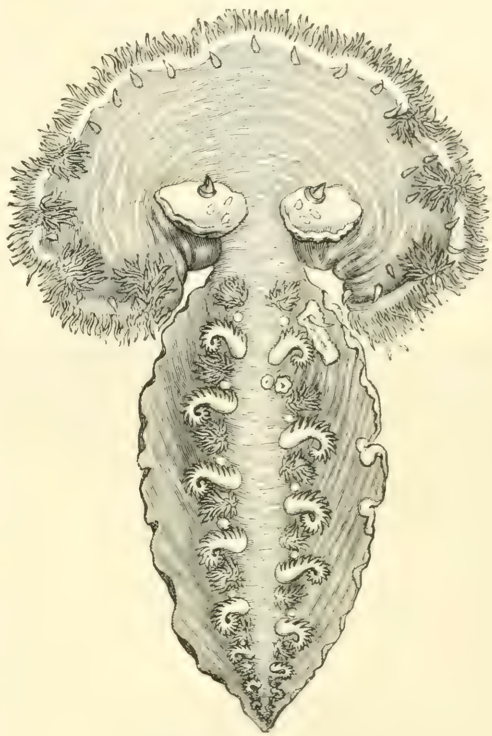
Inferobranchiata. This division of Nudibranchs was established for a group of naked marine molluscs having the gills placed symmetrically along each side of the body between the margin of the dorsal mantle and the edge of the creeping disc. *Phyllidia* and *Pleurophyllidia* are the typical genera originally described, and may be regarded as the principal representatives of this group of molluscs. One group of Inferobranchs, however, is abnormal in being destitute of external branchiæ. In the genus *Phyllidia*, containing several very handsome species, the animal is somewhat depressed, and covered with a leathery and sometimes tuberculated mantle; the head is small and concealed between the foot and back: and the two oral tentacles are short, the dorsal pair retractile into cavities towards the anterior end of the body as in *Doris.* The laminated gills extend the entire length on both sides. The vent is dorsal and at the posterior part of the mantle, and the reproductive organs are on the right side. In the disposition of the branchiæ these animals are very like the chitons and limpets. They are remarkable for possessing neither jaws nor radula, the mouth being modified into a sucker, as in the *Doridopsidæ.* These animals are so apathetic that they have never been observed to make any movement, but appear as if dead. They are inhabitants of tropical seas, the few species that are known occurring in the Red Sea and the Indian and Pacific Oceans. In the allied *Pleurophyllidia* the animals have at the anterior end a sort of shield above the head. The gills are situated as in *Phyllidia,* but the vent is on the right side. The mouth is provided with two strong jaws, and a well-developed radula. The dorsal tentacles are small, and situated between the mantle (*notæum*) and the head-shield, and not passing through



Ancula cristata (much enlarged).

the mantle, as in *Doris* or *Phyllidia. P. lineata,* from the Mediterranean, is a typical form of this genus. It is about 2 inches in length, of a golden colour, with longitudinal parallel whitish lines on the dorsal mantle.

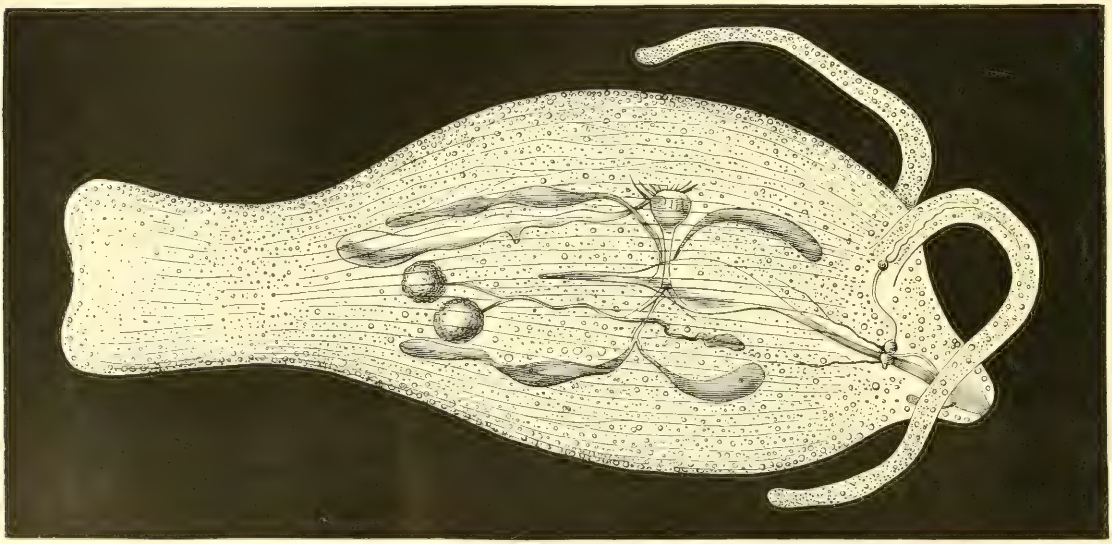
Polybranchiata. This division of the Nudibranchs contains some of the most beautiful species of the entire order; and includes those forms which have the dorsal branchial processes arranged along the sides of the body, and not grouped around the vent, as in the Anthobranchiata. They have no spicula embedded in the skin. The branchial processes are sometimes simply cylindrical or linear, papillose or fusiform, but in other cases conspicuously branched. *Æolidia* is an example of the group in which they are unbranched, and *Dendronotus* exemplifies those in which the gills are branched. *Tethys, Melibe, Tritonia, Scyllæa, Glaucus,* and *Doto,* are, besides those already mentioned, some of the best known genera of the Polybranchs. *Tethys leporina* is a curious-looking animal, met with in the Mediterranean. The body is swollen, almost colourless, and transparent like the gills, contrasting wonderfully with the red-tipped dorsal processes and the blackish irregularly white-edged dorsal eye-spots. It is vividly phosphorescent in the dark, and the phosphorescence at once appears if the creature is in any way disturbed. It is said to be lively in its movements, and capable of swimming freely in any direction; but has neither jaws nor radula. Specimens are sometimes captured 8 inches to a foot in length. In the genus *Tritonia* the branchiæ are numerous, and arranged in a row along the lateral margins of the back. There is a large frontal veil above the mouth as in *Tethys*, and the retractile tentacles are branched at the ends. The horny jaws are large, and the radula well developed. *T. hombergi* is the largest of the British nudibranchs, being sometimes 7 or 8 inches in length. It varies in colour from dark purple-brown to light brown, flesh-colour, and yellowish white. *Dendronotus arborescens* is one of the most beautiful of the naked Mollusca, the accompanying figure giving a good idea of the branched character of the gills. It will be noticed that they are arranged along each side of the tapering body, that the head-veil is also branched, and that the laminated tentacles are retractile within branched sheaths. The back is reddish or yellowish brown, marbled with darker brown, and spotted with white. The animal is about 2 inches in length, and has both jaws and radula. It is not uncommon on most parts of the British coasts, from low-water mark to deep water, and it also ranges northward to Greenland. It is also re-



Tethys leporina.

Dendronotus arborescens (enlarged)

corded from the Atlantic coasts of North America, north coast of France, and some parts of the Baltic. The animals belonging to the genus *Scyllæa* live upon floating seaweed out on the high seas; *S. pelagica* being usually found upon the gulfweed of the Atlantic, which it resembles in its coloration. The foot is narrow, the sides being thin, and capable of clasping the stems of the seaweed. The body is much compressed laterally, and produced into two large leaf-like appendages on each side of the back, on the inner surface of which the tufted branchial processes are situated; a median supra-caudal crest also bearing branchial filaments. The tentacles are slender, laminated, and retractile within long compressed trumpet-shaped sheaths. The genus contains only a few species, but it has been found in almost every sea. *Phyllirhöe* is a genus of Nudibranchiata remarkable for the absence of both foot and gills. The body is compressed laterally, and so translucent that all the internal



Phyllirhöe bucephala IN THE LIGHT, SHOWING INTERNAL ANATOMY (greatly magnified).

anatomy is visible. These animals are pelagic and eminently phosphorescent. Specimens kept in aquaria have been observed to be instantly luminous if touched.

In the *Æolidiidæ* the body is slug-like and tapering posteriorly. There are two labial and two dorsal tentacles, and the dorsal branchial papillæ are cylindrical or fusiform, and arranged in transverse rows on the sides of the back; the front of the creeping disc is often produced on each side in the form of tentacles; the horny jaws are large, and the radula consists generally of a single series of spinous plates. *Æolidia papillosa*, the largest of the British species, may be found under stones between tide-marks on many parts of the coasts. It is brown, grey, or orange, spotted with brown or purple and white; the dorsal tentacles are brown with white tips, and the papillæ are speckled with brown or lilac and white, with white tips. These molluscs are animal-feeders, partial to sea-anemones. Their fecundity is very great, as many as sixty thousand eggs being deposited by a single individual at one time. These are enclosed in a perfectly transparent mucus, and the fry generally emerges in about ten days or a fortnight. Like *Scyllæa*, the animals known as *Glaucus* live in the open sea upon floating seaweed, and feed upon jelly-fish of various kinds. The form of the body is peculiar, having three lobes or expansions on each side, supporting the linear branchiæ. Pelagic animals generally seem to be either colourless or specially coloured, with a view to protection from enemies both above and below the surface

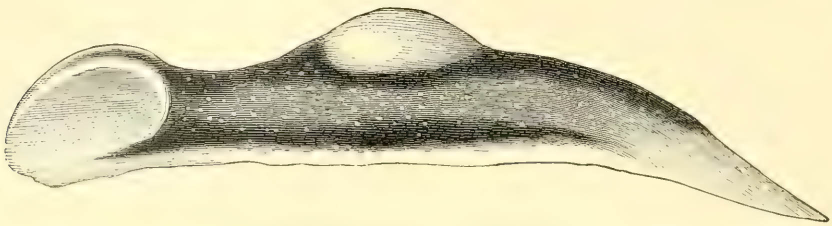
Æolidia papillosa.

of the water. Probably the blue colour of *Ianthina* is protective, as resembling that of the ocean water. The blue tint of *Glaucus* may also serve this purpose.

Pellibranchiata. This group of Nudibranchs comprises a number of forms which have no external branchiæ, but effect respiration through the general ciliated surface of the body. A typical example of this section is illustrated by the accompanying figure of *Elysia viridis* which is a little creature about an inch

Elysia viridis (magnified).

in length, of a dark green colour, varied with white, greenish blue, and reddish white dots. It lives upon seaweed, and, owing to its colour, is difficult of observation. The absence of external branchiæ is noticeable, and the ramified blood-vessels seen in the lateral expansions of the body are presumed to be connected with the respiratory function. This is the only species found upon the shores of Britain, and is most common on the south and south-west coasts. It is said to mimic the colour of the different seaweeds upon which it occurs. *Limapontia* is another example of the Pellibranchs. It is slug-like in form, but without any tentacles. The species figured (*L. capitata*) is a minute animal, about a sixth of an inch in length, chiefly of a black colour, but occasionally somewhat transparent and colourless. Alder writes that "this curious little animal is probably pretty generally diffused, but on account of its minute size it may readily be overlooked. It is gregarious; and, wherever met with, it has usually been found in abundance, appearing when contracted like little black dots scattered over the conferva on which it feeds."



Limapontia capitata (much magnified).

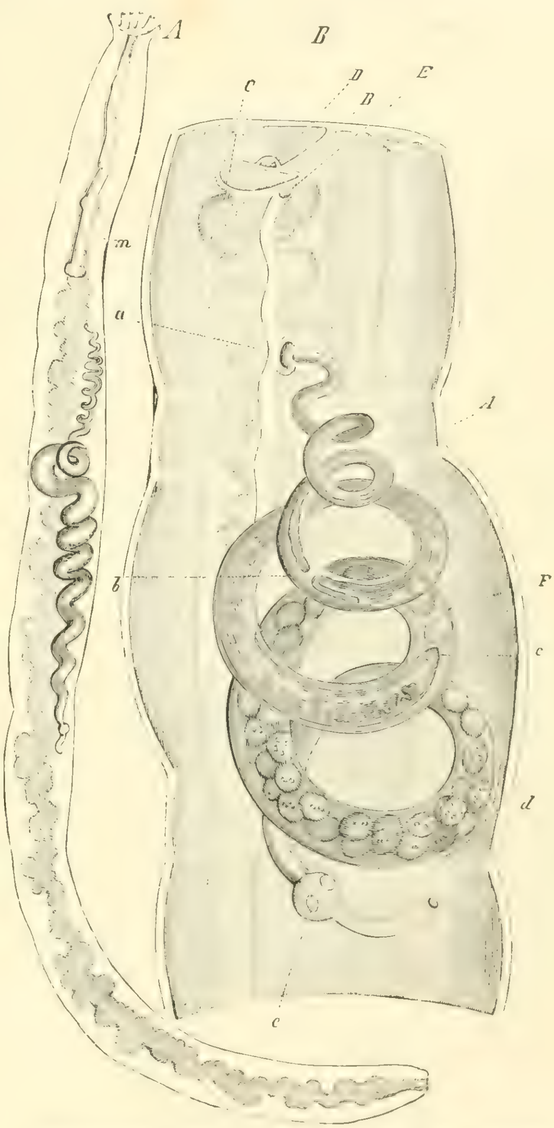
It lives between tide-marks, feeding upon small algæ, and deposits its ova in small pear-shaped capsules, each containing about one hundred eggs.

Parasita. The only form belonging to this group, the position of which is not settled, is the parasitic genus *Entoconcha*. The animal is worm-like and spirally coiled, and attaches itself by the oral end (*a*) to one of the blood-vessels (*E*), within the visceral cavity of a certain group of Echinoderms. One species is found in *Synapta*, and a second (*E. muelleri*) occurs in the trepang (*Holothuria*) of the China Sea. In the very early or larval state *Entoconcha* is contained in a minute operculated glassy shell. The subsequent changes between this and the perfect condition have not yet been observed. It is the lowest type of Nudibranchiata, if indeed it really belongs to that suborder, which is not absolutely certain, some authors even locating it near *Natica*. Were it not for the form of the larva, one would hardly have supposed that this worm-like creature belonged to the Mollusca at all. It has neither jaw nor radula, but the mouth is adapted for sucking. The sexes, as in the typical Nudibranchs, are united in the same individual. The female element (*b*) is somewhat anterior, the male organ (*c*) being at the opposite extremity. The central portion of the animal serves for a certain time as a nursing-pouch for the embryos, which subsequently are extruded at an opening at the posterior end. Only one out of every hundred or two hundred specimens of *Synapta* is infested with the *Entoconcha*. Pelseneer locates it next to *Eulima* among the Pectinibranchs.

Covered-Gill Subgroup,—Suborder **Tectibranchiata.**

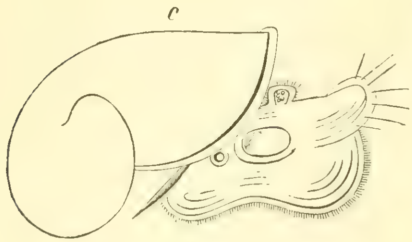
This constitutes the second suborder of Opisthobranchiata, and includes certain molluscs characterised by the possession of a lateral gill, protected by the mantle, or a shell. The members of the group are hermaphrodite animals, and differ from the Nudibranchs, not only in their respiratory organs, but also in the possession of a true mantle, which, in the Nudibranchs, is represented by the dorsal shield. On the other hand, they show affinity with certain

Nudibranchs in regard to the position of the rhinophores, the lateral expansions of the body, and the radula. Nearly all the Tectibranchs possess a shell which sometimes is wholly concealed beneath the mantle, sometimes partly covered, and, in many instances, wholly external. Some are carnivorous, others entirely phytophagous or vegetable-feeders; they mostly progress like an ordinary snail by means of the foot, but a few of them are free swimmers. The ova are generally deposited in long ribbons more or less coiled, and the embryos are provided with an operculated spiral shell. The Tectibranchs are classified in a number of families, separated from one another by differences in the general conformation of the animals, the shell, and the radula. The following are the more important genera:— *Actæon*, *Scaphander*, *Bulla*, *Acera*, *Aplustrum*, *Ringicula*, *Gastropteron*, *Philine*, *Doridium*, *Aplysia*, *Lobiger*, *Pleurobranchus*, *Umbrella*, and the aberrant *Siphonaria*. *Actæon*, of which about thirty species are known, is found in all seas. The animals are provided with a sort of head-shield, which is notched behind, and have the sessile eyes in front of the notch. They all are furnished with an ovate, often spirally punctate shell, which in some cases is prettily striped or spotted, and is capable of receiving the entire animal when contracted. In *Scaphander* the animal is too large to be wholly contained within the shell, and has an enormous head-disc; and the sides of the body are produced into lobes or epipodia, which can be partly reflexed over the shell. It has no visible eyes, as these would scarcely be of service to an animal which burrows into mud and sand in search of its food. Unlike many of the carnivorous Gastropods, which bore a hole in the victim's shell, and suck out the contents, *Scaphander* bolts



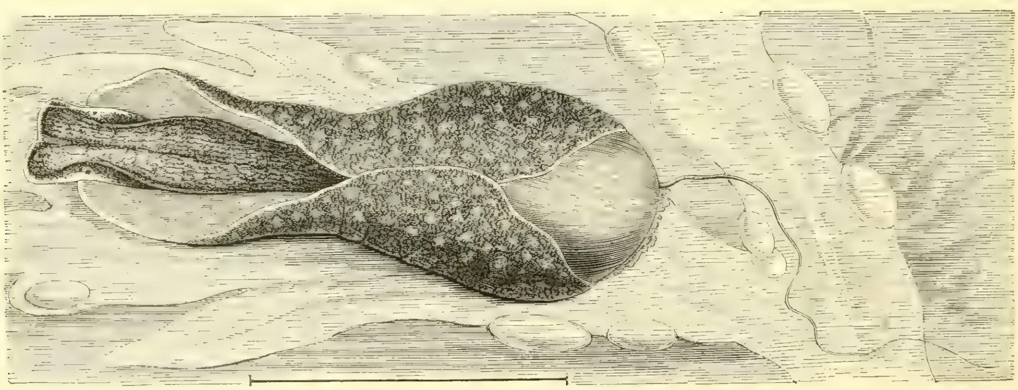
Synapta digitata, WITH PARASITIC *Entoconcha*, AND MIDDLE PORTION ENLARGED.

its prey whole, shell and all. The shell is then broken up by the aid of a very remarkable gizzard, and the soft parts digested. This gizzard consists of three strong calcareous plates of different size and form, which grind against one another by powerful muscles. The shells of *Scaphander* are mostly thin, spirally striated, oblong, convolute, without any visible spire, having the aperture narrow behind, and much wider in front. The known species are not numerous, and occur chiefly in seas of the Northern Hemisphere, but a few have been described from other parts of the world. *S. mundus* was obtained at the Aru Islands, at a depth of eight hundred fathoms, and *S. gracilis* off the Azores, in one thousand fathoms. By far the largest known form is the common British *S. lignarius*, which ranges from Finmark to the Mediterranean.



LARVA OF *Entoconcha* (much magnified).

The bubble-shells (*Bullidæ*), as this group is popularly called, are something like *Scaphander* in form, but rather rounder and stronger in their structure. Most of those belonging to the typical genus *Bulla* are prettily painted with blotches, clouds, and dots. The animal is not too large for its shell, has distinct eyes, and a different type of radula to that of *Scaphander*, which these molluscs resemble in their predatory habits. Another genus is represented in Britain by

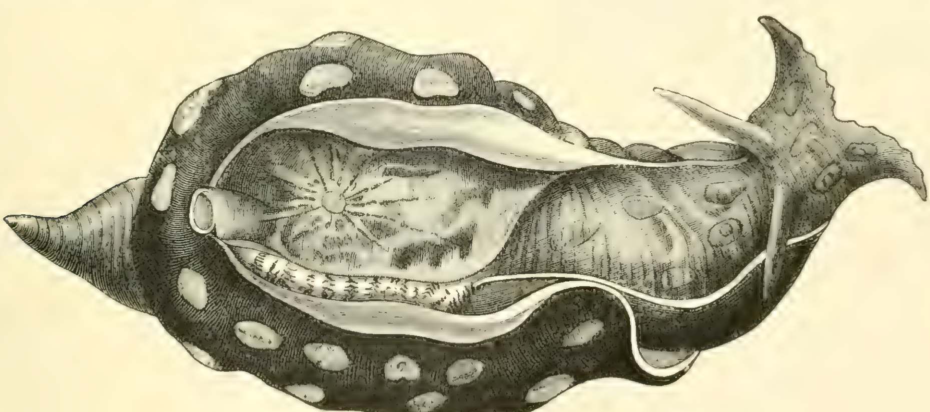


Acera bullata (twice nat. size).

Acera bullata, which occurs on oozy ground and mud-flats in many estuaries. It also ranges from Finmark to the Mediterranean; and is remarkable for its thin, horny, convolute shell, with a slit at the suture, through which the animal protrudes a long, thread-like mantle-appendage. The side-lobes are largely developed, and can be reflexed so as to completely envelop the shell. They are also employed in swimming. Another family is represented by *Ringicula*, all the members of which are very small, not a quarter of an inch in length. The shells are entirely white, more or less globular, with a pointed spire, and with the aperture—which is notched in front—to some extent contracted with folds. The channelled character of the aperture is rather exceptional, the shells of the Tectibranchs being almost exclusively holostomatous, that is, with uninterrupted apertures. *Gastropteron,* which typifies another family, is remarkable for the great lateral expansions, or epipodia, which are used by the animal in swimming. The gill lies exposed on the right side, the head-shield is truncate in front and pointed behind, and the mantle terminates behind in a slender, whip-like appendage. At one time this mollusc was supposed to be shell-less, but in reality an internal shell does exist; but, as it is only $\frac{1}{50}$ of an inch in diameter, it may be easily overlooked. *G. meckeli,* of the Mediterranean, is of a vivid red colour, with a few white spots, and a pale or bluish border to the lobes. In the *Philinidæ,* as typified by *Philine,* the shell is very thin, and wholly concealed beneath the mantle. In form it somewhat resembles *Bulla,* but has the aperture larger. *P. aperta,* a very common British species, lives in shallow water all round the coast, feeding upon foraminifera and even small sea-urchins. The animal is white, has a very large frontal-shield, but no tentacles or eyes. It is provided, as in the case of *Scaphander,* with a powerful gizzard. The ova, which are very numerous, are deposited in a single series, in a long and loosely-twisted cord, enclosed within an ovoid, gelatinous capsule.

Philine aperta (nat. size).

The sea-hares (*Aplysiidæ*), so called on account of a slight resemblance to a crouching hare, and not for their nimbleness of foot, are elongate creatures, with a long neck, distinct head, oral and dorsal tentacles, and furnished beneath the mantle with a shelly plate to protect the branchiæ. The mouth is provided with



SEA-HARE, *Aplysia* (nat. size).

horny jaws, and the gizzard is armed with horny spines, which prepare the food for digestion. The sides have large thin lobes, which are either folded over the back, or used in swimming. *Aplysia* includes both animal- and vegetable-feeders, inhabiting shallow water in all parts of the world. In olden time there were many stories in vogue respecting the poisonous nature of the sea-hare, but it has been shown to be harmless. It has the faculty of emitting a nauseous smell; and a beautiful purple fluid is discharged from glands in the edge and inner surface of the mantle. The species illustrated (*A. depilans*) occurs on the coasts of France and in the Mediterranean. It is reddish brown, with irregular and variable greyish blotches and spots. It occurs in numbers on the Portuguese coast, and in stormy weather is sometimes cast upon the shores in such quantities as to be the cause of epidemics, and almost to render it worth while to extract the purple for economic purposes.

Of another family (*Oxynoidæ*), we may take as an example *Lobiger*, which includes elongate molluscs provided with a thin transparent shell, and having on each side of the body two long parapodia, used as fins in swimming. The animal has the power of casting off these lobes, and probably the posterior end of the foot can also be spontaneously detached. Four species have been described from the Mediterranean, Ceylon, Guadeloupe, and the Society Islands. They are separable on account of certain differences in the soft-parts, but in a conchological point of view they appear to be indistinguishable. In the family *Pleurobranchidæ*, the typical genus *Pleurobranchus* contains a number of species from many parts of the world, two of which occur on the British coast. The one illustrated (*P. peroni*) is a native of tropical seas, and was originally obtained from the Mauritius. The body is convex, ovate, with the mantle extending over the back, and having a free margin at the sides. Beneath this, on the right side, is situated the large branchial plume. The head is furnished with both labial and upper tentacles, and at the inner base of the latter are situated the eyes. A thin, membranous, flat shell is concealed beneath the mantle, over the back. *P. (oscanias) membranaceus* and *P. plumula* have both been found on various parts of the British coast. Both range as far as the Mediterranean. The spawn of *P. plumula* is deposited in ribbon-like and spirally arranged masses, resembling those of *Doris*.

Pleurobranchus peroni (nat. size).

The animal of the genus *Umbrella*, which typifies another family, is very large, and carries upon its back a flat, circular, external shell, recalling the form of an umbrella of the Chinese pattern. The gill, as in *Pleurobranchus*, is on the right side, beneath the mantle, and protected by the shell. This unsightly creature is remarkable for the enormous development of the foot, which extends everywhere beyond the margin of the shell, and practically encloses the head in front. One species occurs in the Mediterranean, and three or four others are met with in the Indian and Pacific Oceans. The shell of *U. indica* is sometimes fully 5 inches in diameter.

The families *Siphonariidæ*, *Gadiniidæ*, and *Amphibolidæ*, already mentioned, constituted, until recently, a suborder of Pulmonata, to which Gray gave the name Thalassophila. According to Haller, however, *Siphonaria* and *Gadinia* should be regarded as modified Opisthobranchiates, and placed next to the *Umbrellidæ*; but their systematic position cannot be considered definitely settled. The *Siphonariidæ* look like ordinary limpets, and attach themselves to rocks in the same way at about high-water mark. The shells are distinguishable by a groove on the right side of the inner surface, interrupting the muscle by which the animal is attached. *Siphonaria* much resembles *Auricula* as regards the pulmonary cavity, which is adapted for breathing air or water, there being both a lung and a modified gill. It is, however, protected or closed by a valve-like lobe of the mantle. The horny jaw has a smooth and curved cutting edge. The radula consists of a single central or rachidian tooth and numerous laterals, very similar in type to that of certain groups of Pulmonata. About fifty species are known. The genus has an extensive range from Vancouver Island in the north to Cape Horn in the south. One species occurs on the coast of Portugal, but the majority inhabit eastern seas. In *Gadinia* the breathing-chamber is without any sign of branchiæ. It is a limpet-like animal with a circular foot by which it attaches itself to rocks or stones, in the same manner as limpets. It is probably a poor traveller. The pulmonary orifice is placed on the right side near the head, and is closed by a small valve. The head is large, without tentacles, with the sessile eyes placed at the sides. Mr. Dall, who watched a colony of *G. reticulata*, noticed that "as long as the rock on which they were remained damp, they continued with the margin of the shell firmly applied to it. As soon as the boulder became dry, under the hot sun, I perceived a simultaneous motion in the colony. Each shell was raised above the surface of the stone, the head and foot were protruded, and the orifice of the pulmonary cavity was expanded. They were evidently enjoying the warm air."

Suborder **Pteropoda.**

Until within the last few years, the molluscs included in this suborder were considered to constitute a separate class. Some systematists located the group near the Cephalopoda, others, believing them to be of a more degraded type than the Gastropoda, assigned them a position between that class and the bivalved Mollusca. Dr. Mörch and others, long ago pointed out the affinity of the Pteropods with the Opisthobranchs, and Dr. Pelseneer has come to the conclusion that these molluscs should be included in two of the Tectibranchiate groups of the Opisthobranchs. The Pteropods seldom come near land, except when driven by currents and tempests, and although they rise to the surface principally at night, they have been observed during the daytime. They are characterised by two delicate fins or lateral expansions of the foot (*parapodia*), placed at the anterior end of the animal, and used in swimming, being moved with considerable rapidity, like the wings of a butterfly. When they wish to sink, their fins are contracted, and the anterior part of the body, in some cases, is more or less withdrawn into the shell or the mantle, and they thus fall to the depth desired. At times they remain stationary, by keeping the fins merely extended. Some—*Clio, Pneumoderma,* for example—adhere to floating bodies by means of oral appendages provided with suckers, others by means of a sufficiently developed foot. The fins, termed *epipodia* by Huxley, are sometimes united, forming a single disc, sometimes partly connected, or, finally, entirely separated. The Pteropods are hermaphrodite, or have the sexes united in each individual. They deposit their ova in the form of long bands which float on the surface of the sea. They are carnivorous in their habits, and live upon minute animals which abound in the sea, including small Mollusca, and Entomostraca and other Crustacea. Some of them possess prehensile organs for seizing their prey, but many appear to be totally unprovided with any special appendages for this purpose. In the early stages of development a shell always exists, but when adult, only certain forms are furnished with such protective covering, the others being naked molluscs. They possess a heart, consisting of auricle and ventricle, enclosed within a pericardium. The branchiæ are either internal or external. The head, distinct in some groups, and furnished with one or two pairs of tentacles, is practically wanting in others, and reduced to a mere mouth at the base of the fins. Nearly all the various forms have a radula, and some horny jaws. There are no eyes, or these are only represented by minute pigment dots upon the visceral sac, or on the tentacles. The fry of the Pteropods closely resembles that of ordinary Gastropods; but subsequently the frontal veil of the Pteropod disappears, and is replaced by the parapodia or permanent fins.

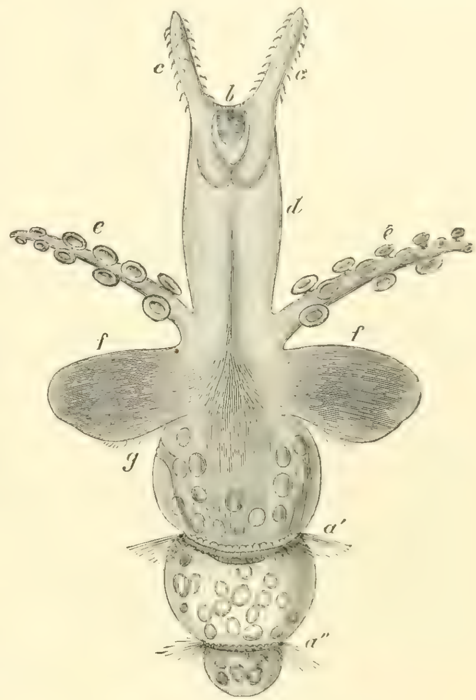
The number of species of this group is inconsiderable, and may be estimated at about fifty-four; but, as regards individuals, the numbers are inconceivable. The bottom of the sea in various parts of the Gulf of Mexico, the Bay of Biscay, and the Mediterranean, is paved with an accumulation of the dead shells of *Cavolinia*, *Cleodora*, and other forms. Their tiny forms occur in shoals in the tropics, and in more temperate seas, and, even in Arctic latitudes, they exist in such myriads as to discolour the water for considerable distances. They there form a large item in the diet of the Greenland whale. Some of the species have a wide distribution, occurring in the Atlantic, Pacific, and Indian Oceans, others are more localised.

Gymnosomata.

The Pteropoda are divided into two sections, namely, Gymnosomata and Thecosomata. The animals belonging to the former group have no mantle or shell in the adult state. The body is generally elongate, the head distinct, and furnished with two pairs of tentacles, the posterior bearing rudimentary eyes. The swimming-lobes are attached to the sides of the neck, which is somewhat narrowed and constricted. The breathing-organ is external, lateral, or at the posterior end of the body. The foot is rudimentary and ventral. The radula is composed of numerous rows of teeth as in some of the Nudibranchs. The young at first are contained in a minute straight shell, and swim by means of a ciliated frontal veil (*velum*). Subsequently these structures disappear, and the larva progresses by means of circles of cilia which surround the body at intervals. In the final metamorphosis, the cilia disappear, the parapodia are developed, and the animal assumes the adult condition. The gymnosomatous Pteropoda are only few in number of species, but, like the rest of the group, occur sometimes in enormous numbers, and are very widely distributed. All are small creatures, the largest not exceeding an inch and a half in length; they are carnivorous, and often, it is said, feed upon their shell-bearing relatives. The position assumed by the Gymnosomata when swimming is vertical, with the head uppermost, or else slightly sloping.

The Gymnosomata are arranged in five families, comprising only seven genera, namely, *Dexiobranchæa*, *Spongiobranchæa*, *Pneumoderma*, *Clionopsis*, *Notobranchæa*, *Clione*, and *Halopsyche*. Dr. Pelseneer locates them next to the *Aplysiidæ*.

Thecosomata. The forms belonging to this section of Pteropoda are characterised by the presence of a delicate external shell, by the foot being represented only by the two anterior symmetrical fins, by the existence of a mantle, by the absence of eyes, and (except in a few cases) of a gill. The head is indistinct and furnished with a single pair of tentacles. The mouth is unprovided with hook-sacs, as in the Gymnosomata. The radula has only a single lateral tooth on each side, with a small basal piece. The Thecosomata are divided into the three families, *Limacinidæ*, *Cymbuliidæ*, and *Cavoliniidæ*.



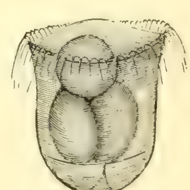
LARVA OF *Pneumoderma* (magnified).

The members of the family *Limacinidæ* possess a small sinistrally coiled shell, provided with a delicate glassy operculum, which is attached to the posterior lobe of the foot. The animal can withdraw completely within the shell, which, when the animal is swimming, has a lateral position, or possibly rests with the spire inclining somewhat downwards. Two genera are included in this family, namely, *Limacina* and *Peraclis*. In *Limacina*, of which ten species are known, the shell is rather globose, umbilicated, with a short spire, and the aperture somewhat prolonged at the base. The lip of the aperture is simple, but the columella is reflexed. The fins of *L. helicina* are broad and squarish at the ends and notched on the inner edge. The operculum is oblong, transparent, paucispiral, the nucleus being lateral. This mollusc lives in immense shoals in the Greenland seas, and it is one of those fed upon by various whalebone whales. Two species only are known of *Peraclis*. The shells are excessively fragile, sinistral, rather like a fresh-water *Physa* in shape, but having the aperture produced below into an acute rostrum. The animal has a minute glassy operculum, and differs from *Limacina* in having a distinct head, prolonged into a proboscis, and other anatomical characters. Both forms occur in the Atlantic, but *P. reticulata* is also known from the Pacific and the Mediterranean.


Clione (somewhat enlarged).

The molluscs of the family *Cavoliniidæ* have external, semi-transparent shells, which are non-operculate, bilaterally symmetrical, and not spirally coiled. They are variable in form in the different genera. The animals are completely retractile within the shell, and the form of the fins and of the hinder lobe of the foot varies considerably. The mouth, lips, and tentacles are the same as in *Limacina*. Three genera are comprised in this family, namely, *Clio*, *Cuvierina*, and *Cavolinia*. *Clio* is subdivided by Dr. Pelseneer into four groups, *Creseis*, *Hyalocylix*, *Styliola*, and *Clio*. In *Creseis* the shell is elongated conical, circular in section, smooth, and the embryonic portion marked off by a deep constriction. The shell of *Hyalocylix* is elongate, conical, oval in section, with a recurved apex, and marked with transverse grooves and ridges. *H. striata*, the only known species of this genus, is cosmopolitan. *Styliola* has a slender tapering shell, sometimes an inch in length, and not more than a sixteenth of an inch in diameter at the aperture. It appears quite smooth and glossy, and, like *Hyalocylix*, occurs in all tropical seas. *Clio* is one of the most beautiful of all Pteropods. The shell is often rather triangular in shape, keeled along the sides, the lateral angles being sometimes produced into long, straight, sharp spines. It is of a most delicate glassy substance, and highly glossy. The so-called genus *Balantium* is synonymous with this group. Eight species are recognisable. The genus commonly known as *Cuvieria* contains only a single species (*C. columnella*), which has been obtained in the Atlantic, Indian, and Pacific Oceans. It is glassy, excessively thin, somewhat cylindrical, but produced posteriorly to an acute point. This narrowed portion is generally wanting in adult shells. In the soft-parts it closely resembles *Clio*, and it is chiefly on conchological grounds that it is separated. The genus *Cavolinia* is perhaps the commonest of all. The shell is generally pale horny brown, often globose, composed of a ventral and dorsal plate, which are united inferiorly, but not along the sides or above. The dorsal piece is flattish, and the ventral generally very globose. The shell is produced into a spine behind, and the sides generally terminate posteriorly in sharp points or spines. The animal somewhat resembles *Clio* in its external characters, but is remarkable for the presence of lateral prolongations of the mantle, which project through the lateral slits in the shell. Eight species are recognised by Dr. Pelseneer. *C. tridentata*, *C. uncinata*, *C. globosa*, and *C. trispinosa* are the best known.

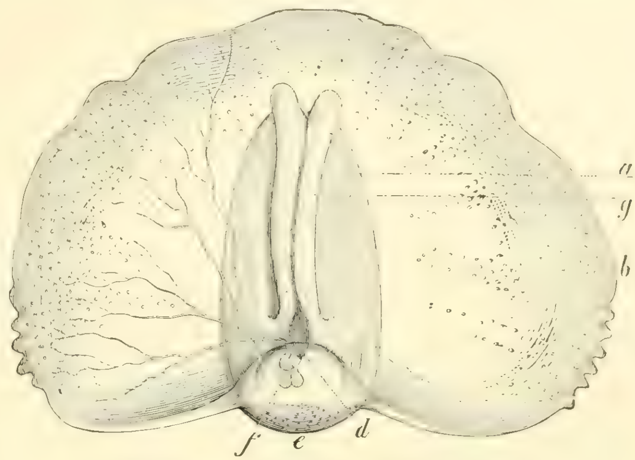
Cavolinia tridentata.



LARVA OF *Cavolinia gibbosa.*

In the family *Cymbuliidæ* the shell is very different from that of other Thecosomata. It is cartilaginous or gelatinous, bilaterally symmetrical, and somewhat resembles a slipper in general form. It is very easily detachable from the animal, and consequently a number of species, which in reality belong to this family, have been characterised as shell-less. Pointed at the ventral extremity and truncated at the dorsal end, it is covered with acute spine-like tubercles arranged in longitudinal series. The modified foot, or fins, are large and rounded. The animal is furnished with a radula. Of *Cymbulia*, two species are known. *C. peroni* is common in the

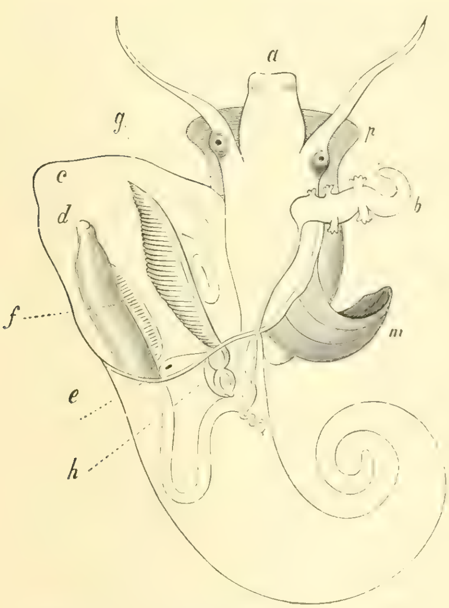
Mediterranean, and it probably also occurs in the Atlantic. The second species, of which only the shell is known, was found in New Zealand. *Cymbuliopsis* and *Gleba* are the two remaining genera of this family.



Gleba cordata. *a*, Body ; *b*, Fin ; *e*, Proboscis.

Front-Gilled Group,—Order Prosobranchiata.

The Prosobranchs, which include the majority of marine gastropods and a few groups of terrestrial forms, are always contained within or protected by a shell, and organised for crawling. The branchial or pulmonary cavity is in advance of the heart, and the auricle of the latter in front of the ventricle. This important anatomical character, which is expressed or referred to in the term Prosobranchiata, can best be understood by observing the accompanying figure representing the male of one of the periwinkles (*Littorina*). Here the respiratory organs are lodged in a chamber formed by the mantle behind the head; the gills are variable in the different suborders. In some forms, with nonspiral shells, they are double and symmetrical, but in others, and these are the majority, where the shell assumes a spiral form, the gill is usually single. Some of the Prosobranchs have horny jaws, but others are without; most are furnished with a radula, but this is sometimes absent. Characters derived from this organ have been largely employed in the classifications of the suborders. The sexes are separate; the head is distinct, and furnished with a pair of tentacles, sometimes having the eyes at the ends, but mostly at or near their base. An operculum, which is unknown among the Opisthobranchs and Pulmonates, except in the case of *Amphibola*, is developed in the majority of Prosobranchs, but the number of genera in which this appendage is absent is considerable. It assumes very different forms, and its size is very variable in proportion to the dimension of the aperture of the shell. In some



ANIMAL OF MALE PERIWINKLE, WITH THE SHELL REMOVED.

a, Mouth ; *b*, Sexual organ ; *c*, Reflexed mantle ; *d*, Vent ; *e*, Kidney ; *f*, Slime-gland ; *g*, Gill ; *h*, Heart ; *m*, Shell-muscle ; *p*, Foot.

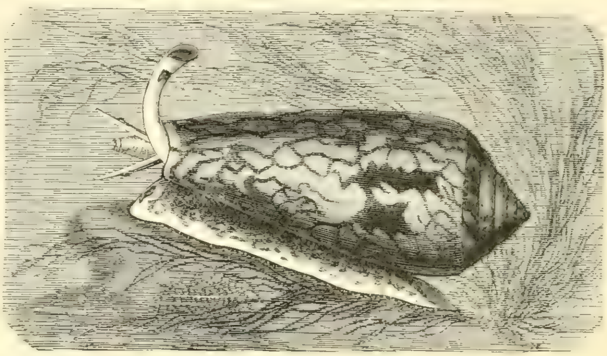
genera it is as large as the aperture of the shell (*Ampullaria, Natica, Bithynia*), while in others it only partly closes it; and in other cases it is so small as to be of no use for closing the shell. It is mostly horny, but in a few instances is more or less thickened and strengthened with a shelly or calcareous layer. The horny opercula are mostly flattened, but in a few cases are thickened, or conical (*Torinia, Cœlopoma*). The shells of Prosobranchs comprise some of the most beautiful, and most prized by collectors. The order may be separated into three main divisions, namely, Pectinibranchiata, Heteropoda or Nucleobranchiata, and Scutibranchiata, severally characterised by differences, as the names imply, in the breathing-organ, coupled with other characters in connection with the genital organs, radula, etc.

Suborder **Pectinibranchiata.**

The molluscs included in this suborder have the body twisted, and contained in a spirally-coiled shell. They are chiefly aquatic, and mostly marine, but a few families are strictly terrestrial. The gills are comb-like, that is, consist of plates arranged side by side and attached to a common stem, like the teeth of a comb to the thickened back. They are situated in a vaulted chamber, formed by the mantle over the neck, which is open in front for the admission of air or water. The Pectinibranchs have been subdivided into several sections, founded upon modifications of the radula or lingual ribbon. The following are the most important in the arrangement adopted by Paul Fischer, namely, Toxoglossa, Rhachiglossa, Tænioglossa, Ptenoglossa, and Gymnoglossa. A large proportion of the Pectinibranchs are furnished with a long proboscis, extensile and retractile at the will of the animal. In almost every instance, molluscs of this proboscis-bearing group are provided with shells which may be recognised by a notch or canal at the front of the aperture, through which the so-called siphon is protruded. This consists of a more or less elongate fold of the mantle, and conveys the water to the branchiæ. In another large section of the Pectinibranchs—Rostrifera—there is no extensile proboscis, but the head terminates in a more or less prolonged snout which is not retractile, and is termed the rostrum. These two groups, however, are now abandoned on the ground that better characters are furnished by the radula.

SECTION TOXOGLOSSA.

In this group, including the families *Conidæ, Terebridæ, Pleurotomidæ*, and *Cancellariidæ*, the radula is composed of two rows of long, barbed, marginal teeth. The cones (*Conidæ*) form an extensive family, containing about five hundred and fifty species. They have always been great favourites with collectors, on account of the great beauty and variety of the colour-markings, and are almost exclusively tropical, only a few species ranging northward to the Mediterranean and Japan. Some of them have a very wide distribution, being found in the Red Sea, Indian Ocean, and in various parts of the Pacific. Others, on the contrary, have an equally limited range. These animals are all predaceous, having a short strong foot, truncate or square in front, and pierced with a water-bearing pore at the anterior part. The head has two slender tentacles, with the eyes on the outside near the middle. The siphon is long, and protruded through the notch at the anterior or narrow end of the shell. They are not very active creatures, but crawl about slowly in holes in the rocks, or fissures of coral-reefs, in depths ranging from low-water mark to thirty or forty fathoms. The shells are generally strong and solid, and as the animal grows and requires more room, it absorbs the early whorls, leaving only a very thin partition between them; but, in order to preserve the proper weight of the shell, it thickens up the spire within. All the species are formed on one plan, but the extremes vary considerably in form. This variation, difference of sculpture, periostracum, and colour, constitute the characters upon which the species are founded.



TEXTILE CONE, *Conus textile* (nat. size).

Some of the handsome and rarer forms fetch very high prices. *Conus cedo-nulli*, which is found in the West Indies, is, besides being rare, remarkable for the variation of its colour-markings. *C. cervus*, *C. adamsoni*, *C. thomæ*, *C. nobilis*, and *C. delesserti*, are some of the most highly treasured, but the celebrated *C. gloria-maris*, from the Molucca and Philippine Islands, of which only about a dozen specimens are known, is still considered the finest shell of all, and a full-grown specimen in good condition would probably now realise about forty or fifty pounds. Some, such as *C. betulinus* and *C. suratensis*, are extremely solid, but a few, *C. geographus* and *C. tulipa*, are very thin. It has been asserted that certain species have no operculum, but this is now believed to be incorrect. This structure is small, horny, narrow, and, being much smaller than the aperture of the shell, in no way serves the purpose of defence. A large number of fossil species have been described from the Tertiary formations. Some instances are on record of persons having been bitten by cones when handling them, and it is said that the bite, to some extent, is poisonous, but whether this character is peculiar to a few, or common to all the species, we have no means of knowing.

The auger-shells, *Terebridæ*, have a very different appearance to the cones, and conchologically do not exhibit any particularly close relationship; although the characters of the dentition certainly indicate their approximation. The molluscs of this family have a small head with two small cylindrical tentacles, with minute eyes at the tips. The foot is small, rounded in front, and elongate behind, and supports a small, oval, horny operculum, with an apical nucleus. About two hundred and thirty species have been described. They abound in tropical regions, but a few occur in more temperate localities, such as Japan, California, and New Zealand. Some of the shells are so solid (*Terebra maculata*), and others so extremely elongated (*T. pretiosa*, etc.), that it would appear impossible for the animals to carry them erect. Probably, in these instances, the shells are dragged along resting upon the surface of the sand. They are all elongate in form, with a small aperture, notched in front for the passage of the siphon. The whorls are flat and generally divided below the suture by a spiral furrow. They are longitudinally fluted, smooth or noduled, and it is upon these differences in sculpture that the various subgenera are founded.

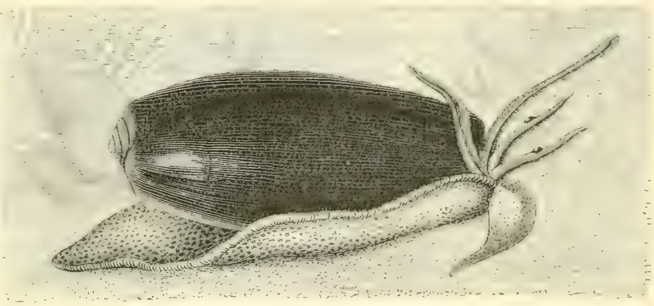
The third family—*Pleurotomidæ*—contains an enormous number of species, certainly more than a thousand having been described. They are mostly small, and show great variety in form. The species of the typical genus *Pleurotoma* are spindle-shaped, that is, have a long tapering spire at one end, and a prolonged beak or canal at the other, and the outer lip has a distinct slit somewhat below the suture. In *Surcula* and *Drillia* the slit or notch is at the suture, in *Bela* it is indistinct. Some forms, *Clavatula* and *Pusionella*, have a semi-ovate operculum, with the nucleus lateral; in *Pleurotoma*, *Drillia*, etc., it is ovate-pyriform, with a terminal nucleus; whilst in *Mangilia*, *Cythara*, etc., it is altogether absent. *Columbarium*, containing only a few species, is remarkable for the great length of the anterior canal, and the spine-like ornamentation of the whorls. *C. pagodoides*, dredged off Sydney in four hundred and ten fathoms, is one of the most beautiful of all the family. All degrees in the length of the canal are observable, until we find it reduced to a mere notch at the base of the aperture. *Pleurotomidæ* exist in every sea, but certain groups are more characteristic of cold and temperate climates. *Bela*, for instance, may be regarded as a representative northern genus; whereas, on the other hand, *Cythara* and *Pusionella* are tropical. They are generally rare in individuals, although numerous in species. They occur at all depths, from low-water mark to two thousand or more fathoms; indeed, a very delicate form, about an inch in length,—*Clathurella monoceros*,—was dredged in mid-Atlantic, to the south-west of Sierra Leone, in two thousand five hundred fathoms. The extinct forms of this family, occurring chiefly in the Tertiary deposits, are perhaps as numerous as those now living.

In the family *Cancellariidæ* the proboscis is small or rudimentary, the foot small, the siphon very short, while the eyes are placed at the outer base of the tentacles; the operculum being wanting. The Cancellarias have very beautiful shells, generally elegantly sculptured with longitudinal and spiral ridges, producing a cancellated surface. The forms are variable; some are oval, others turreted, and the most remarkable of all (*Cancellaria trigonostoma*) has the spire drawn out like a cork-screw. A constant feature in this family consists of three or four folds, plaits, or plicæ upon the columella. A few of the species are common, but many are extremely rare. About a hundred different forms are known. They are mostly tropical, but the genus *Admete* has a more northern range, extending as far as Greenland. They are usually obtained in shallow water, but a few specimens have been dredged at a depth of nearly seven hundred fathoms.

SECTION RHACHIGLOSSA.

This group of Pectinibranchs includes a large number of genera and species superficially very different. They are all marine gastropods, with a well-developed extensile proboscis, sometimes as long as, or even longer than the body. The radula is generally long, narrow, and armed with three teeth in a transverse row, one central or rhachidian, and one lateral on each side; the latter, however, are wanting in certain groups. The respiratory siphon is rather long, fitting into the anterior canal or notch of the aperture. The eggs of these molluscs are deposited in strong leathery capsules, each capsule often containing a large number of ova. The genus *Yetus*, however, which is viviparous, produces a comparatively small number of young. All have shells, which in nearly all cases are capable of sheltering the entire animal. The principal families in this group are the *Olividæ*, *Harpidæ*, *Marginellidæ*, *Volutidæ*, *Mitridæ*, *Fasciolariidæ*, *Turbinellidæ*, *Buccinidæ*, *Nassidæ*, *Columbellidæ*, *Muricidæ*, and *Coralliophilidæ*.

The Olives (*Olividæ*) are mostly cylindrical shells, often beautifully ornamented with markings of various patterns, and always having a highly glossy or enamelled appearance. The aperture is narrow or notched in front, and the columella is not strongly plaited as in some of the families which follow (*Marginellidæ*), but there are numerous, slight, oblique folds, some of which pass round the base or anterior part of the shell, which is thus marked off from the rest of the surface into a distinct area. The animal has a very large foot, capable of covering the shell to a great extent, pointed behind, and with its anterior portion (*propodium*) divided into two lobes. The head is small, with pointed, slender tentacles, and the eyes about midway along their outer sides. The mantle is produced in front into a slender appendage, which protrudes with the breathing-siphon through the notch of the aperture; posteriorly it terminates in a thread-like process, which passes up the channelled suture of the spire. There is no operculum. The olives are very active, and burrow in the sand in search of bivalves; and are sometimes seen in countless numbers, the sands at low tide for miles being covered with them. Although about one hundred and fifty to two hundred species, mostly tropical, have been described, a few extend to more temperate seas as far north as Japan, and southward to Patagonia. The olives are frequently used in the manufacture of shell-ornaments. The genus *Olivella* differs from the typical *Oliva* in having neither tentacles nor eyes, and the spire of the shell is longer and more pointed. *Ancilla*, another important genus, comprises a number of polished species, which are nearly always of a uniform white, yellow, fawn, brown, or reddish colour, and without the markings of the olives.



BLACK OLIVE, *Oliva maura* (nat. size).

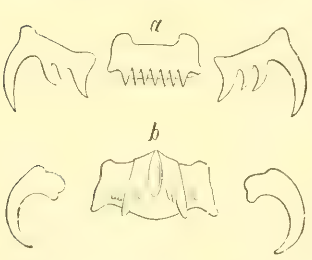
The family *Harpidæ* contains but a single genus, the well-known harp-shells (*Harpa*). These are strong, broad, ventricose structures, highly coloured, and adorned with numerous curved ribs, running parallel with the outer lip of the aperture. The columellar margin is smooth, and covered with a thin brilliant callus. The animal has an enormous foot, which is not wholly retractile within the shell; and when disturbed it not unfrequently casts off the hinder part. About ten species are recognisable. They occur in the Red Sea, many parts of the Indian Ocean, Philippine Islands, South Sea Islands, Panama, and on the west coast of Africa and at Ascension Island. The members of the family *Marginellidæ* are mostly small, some very minute, but many of them have very beautifully coloured and highly polished shells. Nearly all are tropical, and many of the finest and most valued are inhabitants of the West and South African coasts. They are mostly ovoid, or subconoidal in form, with rather contracted apertures, slightly notched in front; the outer lip is involute and thickened, and the columella has a few oblique plaits upon the lower or anterior portion. There is no operculum; and, as in the majority of the volutes, the radula has only a central row of teeth. In *Pseudomarginella*, from Gorée, on the west coast of Africa, the shell is identical in every respect with *Marginella glabella* of the same locality, but the mollusc and its operculum are said to belong to the *Buccinidæ*.

Nearly all the species of the family *Volutidæ* have large showy shells, and some of them, on account of their extreme beauty and rarity, realise very high prices. As in the *Marginellidæ*, the columella exhibits a number of oblique folds, but the aperture is rather more deeply notched in front for the passage of the siphon. The form of the shell is variable; in some the spire being very short, and scarcely rising above the last or body-whorl; while in others (*Zidona*) it is drawn out into a conical spire. The apex is sometimes (as in *Yetus*) enormous, and all intermediate sizes occur until we come to *Volutilithes*, in which it is quite small. This latter genus—a very common Eocene fossil of the London and Paris basins—has very feeble columellar plaits, and is now represented by a single species obtained in one hundred to one hundred and fifty fathoms off the Cape of Good Hope. The animals of the volutes are large, sometimes incapable of withdrawing entirely within the shell, and mostly without an operculum. The radula usually has only a single row of teeth, but, in a few instances, a lateral on each side is present. The *Yetus* shells are large, thin, with enormous apertures, having three or four strong, oblique plaits on the columella. They are found on the west coast of Africa, in the Indian and Pacific Oceans, and also off the Philippine Islands. *Y. proboscidalis* is viviparous, and produces four or five young at a time, about an inch long. The flesh of this enormous animal is said to be eaten, after being dried in the sun, by the natives of Senegal. As an example of the genus *Voluta*, we may mention the handsome West Indian *V. musica*, popularly known as the music-shell, from the colour-markings, which resemble the lines and notes of music. It is one of the few forms provided with a small horny operculum, and on this account has been placed in a distinct genus (*Volutolyria*) by some writers. Like the rest of the true volutes, it is oviparous. The allied genus *Volutomitra*, as the name implies, has affinities both with *Voluta* and *Mitra*; the shell and animal being for the most part mitroid, but the tongue resembling that of the volutes. It may therefore be regarded as a link between the two families. Three or four species are known, one from the shores of Greenland, and two or three from Tasmania and Kerguelen Island. The largest member of the *Volutidæ* (*Cymbium broderipi*), which is found at the Philippine Islands, sometimes attains a length of 14 inches and 30 in circumference. Rather more than a hundred species of this family are known.

The gorgeously-coloured mitre-shells (*Mitridæ*) always have been and still remain a favourite group with collectors. Like the Marginellas, they have no operculum, and are small in comparison with the volutes, but they equal if not surpass them in the beauty of their colour-markings and surface sculpture. The columellar lip is always plaited, the hinder plaits being the strongest. A remarkable feature of the genus, at all events in some instances, is the enormous length of the proboscis, which seems to be out of all proportion to the animal. The tongue of the mitras has three rows of teeth, all serrated in some species, but in others, with the two laterals simple, and of a somewhat different type. The common *Mitra episcopalis*, a striking, scarlet-spotted, heavy shell, is abundant at the Philippine Islands, and occurs in Ceylon and in Polynesia. The animal is sluggish in its movements, and buries itself in the sand when the tide recedes. The mitras with simple lateral teeth are mostly ornamented with longitudinal ribs or plicæ, and constitute the group *Turris*. Some frequent coral-reefs, and others are found, often in considerable numbers, crawling upon the sands in sheltered and shallow bays. Over five hundred species of *Mitridæ* are known. They abound in the islands of the Indian and Pacific Oceans, and seem to be scarcer on the shores of the great continents. They are not very numerous in the Atlantic, and even the tropical islands of the West Indies produce but an insignificant number, of unattractive form. *Mitra zonata*, found in deepish water off Italy and in a few other parts of the Mediterranean, is a fine species, and one of the rarest of the family. A few species of *Mitridæ* range as far north as Japan, and others occur at the Cape of Good Hope and New Zealand.

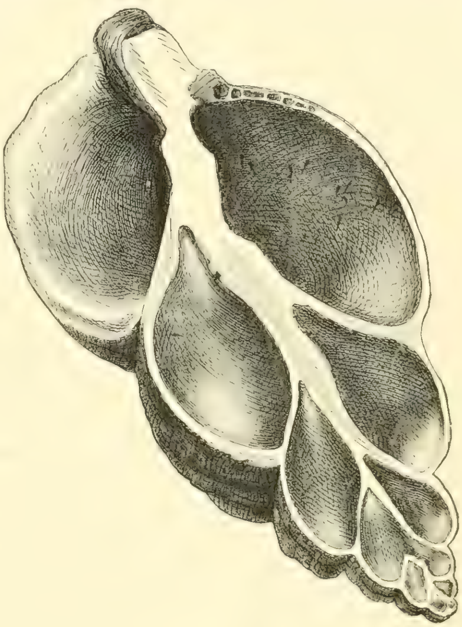
The tulip-shells, forming the family *Fasciolariidæ*, are mostly fusiform (spindle-shaped), some having very long spires and anterior canals. They never have a thickened lip to the aperture, which is often grooved and striated within. The typical genus *Fasciolaria* and also *Latirus* exhibit oblique folds on the columella, a feature absent in the slender *Fusus*. All are furnished with a horny operculum. The radula has three rows of serrated teeth, the central tooth being narrow, and the laterals broad. *Fasciolaria gigantea*, from the coast of South Carolina, is one of the largest gastropods, attaining a length of 2 feet. In *Leucozonia*, a group of the genus *Latirus*, the outer lip of the shell has a more or less prominent spine-like tooth in front. In *L. cingulata*, from Panama, it is sometimes five-eighths of an inch in length, and although it appears as if it would be a hindrance to the animal when crawling, it doubtless serves some purpose in its economy. The allied family of the chank-shells (*Turbinellidæ*) is not numerous in species, but contains several large and interesting forms. They are grouped together, on account of a similarity in dentition. The radula has three rows of teeth, the central tooth being nearly always three-pronged, and the laterals generally armed with a single or two unequal cusps. The typical species of *Turbinella* have very solid, heavy, pear-shaped shells, covered with a thick, fibrous periostracum, and exhibit a few strong oblique folds on the columella. The *T. scolymus*, a West Indian form, is sometimes 18 inches long. In India, *Turbinella* is largely used in the manufacture of carved bracelets, anklets, necklaces, and other ornaments. They are known under the name of chank-shells, and a fishery is carried on in the Gulf of Manaar. Occasionally sinistral examples are obtained, considered sacred by the Hindus, and also valued by the Buddhist priests of Ceylon and China. In *Cynodonta*, another group of *Turbinellidæ,* the shells are compact and very strong, tuberculous or spiny, with short spires, and the anterior canal considerably shorter than in *Turbinella.* The aperture is armed with a few folds on the middle of the columella, and is closed by a thick and somewhat twisted operculum. The eight known species are distributed over the Red Sea, Philippine Islands, Polynesia, Pacific coast of Central America, and the West Indies. *Fulgur* and *Melongena* both include large striking shells from the United States and West Indies; and *Sycotypus canaliculatus,* also from the States, is remarkable for the deeply channelled suture separating the whorls. The egg-capsules are very curious, consisting of a long string of round discs, about the size of a shilling, but somewhat thicker, attached to the cord by one edge. Each capsule contains a number of eggs, and the young eat their way out at a spot opposite the points of attachment. *Semifusus colosseus* is one of the largest living gastropods, attaining a length of about 14 inches. It is an inhabitant of the Indian Ocean, and also occurs at the Philippine Islands. Another giant is the well-known *Fusus proboscidiferus,* of which the broadly fusiform shell sometimes attains a length of 2 feet. It is found on the west and north-west coast of Australia, and on account of the peculiar nucleus of the spire has been placed in a separate genus, *Megalatractus.* The egg-capsules form a cylindrical mass marked with a dozen longitudinal equidistant ridges, and divided off into compartments, each compartment containing from twenty to thirty young. When they quit the egg-case, they are about an inch in length, and bear no resemblance to the full-grown shell.

The whelks form the characteristic group of the family *Buccinidæ,* which also includes a considerable number of other genera, and numerous species. The animals usually have a long siphon and a large foot, more or less square in front and somewhat pointed behind; the head is provided with a pair of tentacles which support the eyes on the outside. The lingual ribbon is well-developed, with three rows of pronged teeth, the central with three to six cusps, the laterals two- or three-pronged. The form of the shells is variable; some are fusiform, with a distinct anterior canal, others ovate, with the canal reduced to a mere notch. All are provided with a horny operculum, which assumes different forms in the various genera.



ROW OF TEETH FROM THE RADULA OF (*a*) *Buccinum undatum*, (*b*) *Murex erinaceus.*

Chrysodomus is essentially a northern or Arctic race, and one of the fusiform types with a distinct siphonal canal. *C. antiquus,* the largest of the British marine gastropods, was also common in the English Crags. Reversed or sinistral specimens were the commonest form in the Red Crag. *C. contrarius,* found living on the coast of Spain and Portugal, is a closely allied species. *Sipho, Volutopsis,* and *Jumala* are other northern fusiform groups, which have a few British representatives. The common whelk (*B. undatum*) is the typical representative of the genus *Buccinum,* and is such a familiar object that a description of the shell is needless. We may, however, direct attention to the variations existing in this species, these being due to difference of locality, depth, etc. Specimens from deep water have much thinner shells than shallow-water forms, and those found on some parts of the Northumberland coast are remarkable for their solidity. Thousands of bushels of this mollusc are annually consumed in London alone, and as much as £12,000 has been realised in a year by the whelk-fishery off Whitstable. Whelks are used as bait in the cod-fishery. The operculum of this species is roundly ovate, formed of concentric layers, the nucleus being a little excentric. It is comparatively small, and of no use as a defensive door to the shell. On the coast of Kent and Sussex a race exists, provided with two and sometimes three small opercula, instead of one as usual. It is a peculiarity which apparently has become permanent to some extent, but how it originated is a matter of conjecture. The whelk has a wide geographical range, occurring all over the North Sea to the Norwegian Coast, as far north as Iceland, and on the east coast of the United States from Cape Cod northwards. It is found fossil in the Coralline Crag. Owing to the variability in the shell, a considerable number of so-called species of *Buccinum* have been described; but the total of recognisable forms does not probably amount to more than about sixty or seventy. These are mostly Arctic or northern, but a few are known from Japan. *Volutharpa* is scarcely separable from *Buccinum*, but the shell is thinner, and the aperture very large. On the contrary, the operculum is minute, that of *V. perryi* from the Japanese seas—a shell about 2 inches long—being only about $\frac{1}{14}$ of an inch in diameter. *Neobuccinum* is the Antarctic representative of *Buccinum*; the single known species occurring at Kerguelen Island in the Southern Ocean. The operculum differs from that of *Buccinum* in being somewhat spiral, instead of concentric, and the lingual dentition is slightly different. *Cominella, Cyllene, Tritonidea, Pisania*, and *Euthria* are genera referred to the family *Buccinidæ*, on account of general similarity in the animals, and especially of the radula. They comprise a considerable number of species from tropical and temperate localities, but are not of sufficient interest to be further mentioned. We may, however, call attention to the genus *Euthria*, as a remarkable instance of wide geographical range. The typical species, *E. cornea*, which is very common in the Mediterranean, has also been found on the coast of the island of New Caledonia, eastward of Australia. The genus *Phos* contains a small number of very beautiful species with highly ornamental cancellated sculpture. On the other hand, the closely allied *Eburna* is remarkable for the smoothness of the shell, and the spotted character of the colour-markings.



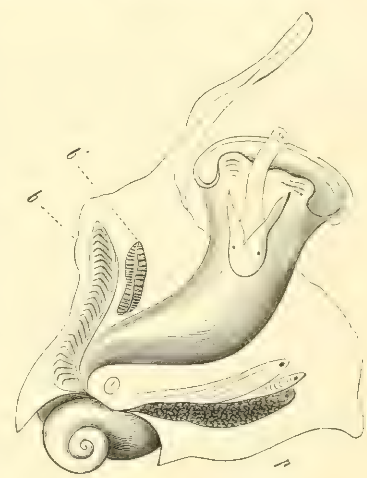
SECTION OF WHELK (nat. size).

All the members of the family of dog-whelks (*Nassidæ*) are comparatively small, none exceeding 2 inches in length. The animal frequently has the foot—

which is large—bifurcated behind. The radula differs from that of the *Buccinidæ* in having the central tooth curved and finely serrated. The typical genus *Nassa* comprises an extensive group of small molluscs, which exhibit a considerable amount of variation in form and sculpture; and upon these characters many subdivisions have been proposed. The shells are mostly solid, ovate or turreted, smooth, granulated, or longitudinally ribbed. The aperture has a distinct oblique siphonal notch, the columella is more or less coated with callus, and the outer lip is thickened and denticulate, or grooved within. About two hundred and forty species are recognisable, of which three are met with in Britain. The majority are found in tropical seas. They often occur in immense numbers, and burrow in sand and mud in search of bivalves. The operculum is often somewhat triangular, with fine serrations along the sides. *N. reticulata*, the largest of the British species, is common all round the coast. It is a great nuisance on oyster-beds, and although exhibiting a preference for young oysters, also attacks those of more mature growth. The egg-capsules are roundish, very compressed, and attached by a short stalk to seaweeds. They are arranged close together in compact series, and have a small hole at the top, through which the young escape. The subgenus *Demoulia* resembles *Nassa* as regards the shell, but the animal (of *D. retusa* at all events) has no prolongations at the posterior end of the foot. The operculum is present in some species, wanting in others. Four of the seven known species are from West and South Africa, and one or two are said to be Japanese. *Cyclonassa*, another subgenus, agrees with the typical *Nassa* as regards the soft-parts, but is characterised by a very aberrant form of shell. This is smooth, flattened, somewhat like a *Nerita*, and has an oblique distorted look about the aperture. *C. neritea* is a very common Mediterranean shell; two other species being known, one also Mediterranean, the other from the Black Sea. In the genus *Bullia* the animal is very similar to that of *Nassa*, but the foot is larger, and the eyes are wanting. The shells are mostly smooth, and the suture between the whorls is generally filled up with a deposit of callus. The south of Africa may be regarded as the metropolis of this genus, but a few species also occur on the west and east coast, and in Mauritius, Madagascar, and Patagonia.

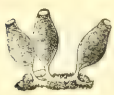
The dove-shells, or *Columbellidæ*, are likewise a very numerous family as regards species, upwards of three hundred having been described. The animal is similar to that of the *Buccinidæ*, but the central tooth of the radula is not armed with cusps, and the laterals are of a peculiar type. The shells are all small, some quite minute, and offer considerable variation in form and sculpture. Most of the species are prettily coloured, and many occur in enormous numbers, and are employed in the manufacture of shell-boxes and other ornaments. *Columbella* abounds in the tropics, but many are found in temperate latitudes all over the world, and two species belong to the British fauna. All are carnivorous and mostly littoral, but some affect depths of five or six hundred fathoms.

The extensive family of the *Muricidæ* contains some of the handsomest and most striking forms of all the Rhachiglossa. The animals have a moderate-sized foot, squarish in front and somewhat pointed behind; the tentacles are slender and pointed, supporting the eyes on the outer margin. The siphon is long, and the retractile proboscis, containing the radula, is well developed. The latter is long and narrow, with three rows of teeth; the central tooth having three principal cusps or spines, and other secondary denticles, and the laterals being simple. The horny operculum is variable, having either a lateral or terminal nucleus. The shells exhibit much diversity of form in the different groups. Murices are carnivorous, feeding upon other molluscs, both gastropods and bivalves. In the typical genus *Murex* the animal, as it increases in size, produces at intervals beautiful foliations or spine-bearing ridges, nearly always three or more on a whorl, which are sometimes continuous up the spire; the siphonal canal being sometimes remarkably long and slender, almost closed and nearly straight. In this group many of the species are armed with numerous long spines upon the ridges; *M. tenuispina* from the Indian Ocean, Philippine Islands, and neighbouring localities, being a striking example. In the section *Chicoreus* the shells are strong, with three beautifully branched ridges, and the canal shorter than in the preceding group; *M. ramosus*, a large and abundant species from the Red Sea, Indian Ocean, Polynesia, etc., and the beautiful *M. palma-rosæ*, from the Philippines, being examples. The species of *Muricantha* are like *Chicoreus* in form, but with numerous varices. The west coast of Tropical America and West Africa produce some of the largest and handsomest species. Of all the group, perhaps none surpass in beauty of construction some of the forms of *Pteronotus*; *M. lobbeckei*, from the China Sea, which is of a uniform delicate rose-pink tint, and ornamented with elegant fluted frill-like varices, being pre-eminently beautiful. There are several other groups, containing a number of species of considerable interest, which cannot be further referred to in this account. Some mention, however, must be made of the dye which can be extracted from the animals of this family. Species of *Murex* and probably of *Purpura*—a genus referred to subsequently—were both employed in ancient times in the manufacture of the Tyrian purple. The dye was obtained from a white vein at the upper part of the neck of the mollusc. When first extracted, it is of the colour and consistency of cream, but subsequently changes, on exposure to light, to the deep purple tint. The common British *Purpura lapillus* affords similar dye. Its scarcity and the use of cochineal, and other dyes, render it valueless as a commercial product. *Murex erinaceus*, the only British species, is common on oyster-beds, to which it is destructive. All the forms yet referred to have a somewhat roundish or ovate operculum, with the nucleus terminal or subterminal, whereas in those which follow (*Purpurinæ*) it is lateral. All the members of the genus *Purpura* are furnished with strong, heavy shells, suitable for protecting the inhabitants from the rough usage of the sea upon the rocky shores they mostly inhabit. They range from the Arctic to the Antarctic regions, the handsomest species coming from tropical seas. The fry of several species are pelagic, and swim at the surface of the water.

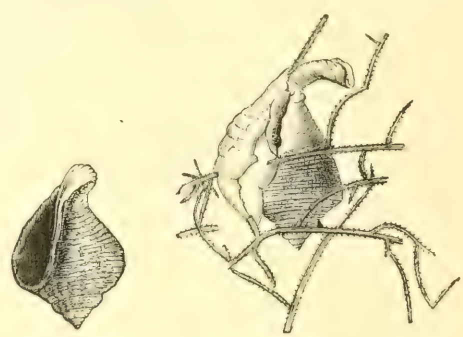


ANIMAL OF *Murex*. *b*, Gill; *b′*, Osphradium, or olfactory organ; *p*, Purple-gland.

Like the murices, these molluscs are devourers of Bivalves. The annexed illustration represents the egg-capsules of the common British *P. lapillus.* The animal and shell of *Acanthina* are similar to those of *Purpura*, but the outer lip of the aperture is furnished at the anterior end with a more or less prolonged conical tooth or prong. *Rapana, Concholepas,* and *Sistrum* are other nearly allied forms. The members of the family *Coralliophilidæ* resemble the purpuras, but are characterised by the want of a radula, and their singular mode of life, dwelling either in or upon corals. *Rhizochilus* in early life is like the young of *Purpura*, but subsequently it attaches itself to barked corals (*Antipathes*), living a prisoner's life, immured within its own shell. It prolongs the lips of the shell around the stems of the coral, completely closing the aperture, with the exception of the siphonal end, which it extends into a distinct tube, serving to carry both water to the gill and food to the mouth. What the nature of its nourishment may be—possibly derived from the *Antipathes* itself—and what may be the reason of this self-immurement, are problems to be solved. *Coralliophila madreporarum* attaches itself to corals; other species live a more active life, crawling over the surface of the coral. Several are tinted with lilac, and have purple apertures; others, however, are entirely white. *Leptoconchus* and *Magilus* are both dwellers in coral. The former lives in crypts excavated in brain-stone corals, and resembles, as regards the shell, the young state of the latter. *Magilus* affects coral-reefs, and is remarkable for the great alteration which takes place in the course of its career. At first it assumes the form of an ordinary spiral shell, and takes up its abode within the crevices of growing coral. The coral slowly advances around the shell, and would soon enclose it, if the mollusc were not provided with some means of defeating this. The creature prolongs the lips of its aperture into a long, but mostly crooked tube, so as to keep pace with the growth of the coral, and keep the tube open for the free ingress of the water. As the tube increases it becomes too long for the animal; consequently the mollusc fills up the spiral portion, and as much of the tube as is not required. These shells are found in the Red Sea, and the Indian and Pacific Oceans.



EGG-CAPSULES OF *Purpura lapillus.*



a *b*

Rhizochilus antipathum. *a*, Young; *b*, Adult.

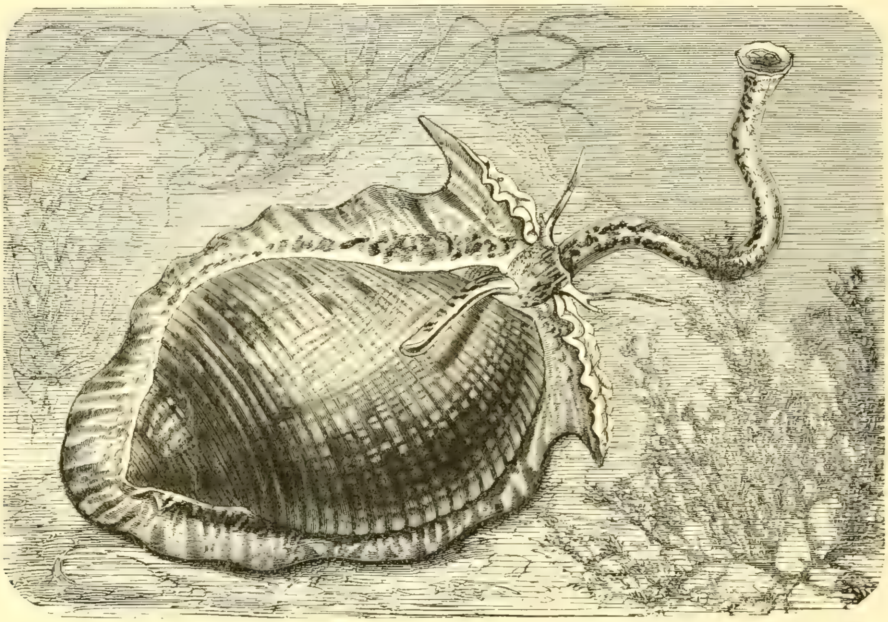
SECTION TÆNIOGLOSSA.

The majority of the molluscs included in this section of Pectinibranchs are marine forms; although a few families are found in fresh water, while others are terrestrial and air-breathers. Typically, the radula has seven rows of teeth, one central, and three laterals on each side; but there are a few families in which this armature is modified. Sometimes there is only a single lateral on each side; but, on the contrary, the number of laterals occasionally reaches five a side. They are curved and claw-like in some groups, but in others merely have serrated edges. Forty-two families are included in this section; but the limits of this work admit only of an account of some of the more important. The animals of one group are provided with shells, which either have a distinct, prolonged anterior canal, or else the aperture is more or less deeply notched at the base. In another group the mouth is entire, without notch or siphonal canal. Some have a retractile proboscis, like murices and whelks; others have a longer or shorter muzzle or rostrum, which is somewhat contractile.

The first family is that of the tritons (*Tritonidæ*), many of which possess large, handsome shells, exhibiting strengthening ridges (or former lips) at intervals upon the spire. The animal has a shortish foot, a large head projecting between the slender, pointed tentacles, supporting the eyes at the sides or at the base, and a horny operculum. *Triton* and *Ranella* are the two genera constituting this family. In the former, the large *T. tritonis*, the war-trumpet of the South-Sea islanders, is the typical kind. It attains more than a foot in length; and when the top of the spire is broken or ground off, a booming note can be produced. A similar species (*T. nodiferus*) lives in the Mediterranean, and was employed in the same way by the Romans. Most of the tritons are covered with a conspicuous periostracum, and in some cases this is beset with short hairs or bristles. The form of the shells is very variable in the different subgenera, but all exhibit the character of periodic ridges. The shells in the genus *Ranella* are very like *Triton*; but the typical forms possess a posterior canal or sinus at the upper part of the aperture, which is not met with in the latter. The varices are mostly in two continuous series, one up each side of the spire. The species of this and the preceding genus are not very numerous—hardly two hundred altogether—and are chiefly inhabitants of warm climates. A few range as far north as Alaska and Japan; others occur on the shores of Patagonia, the Cape of Good Hope, Amsterdam Island, and New Zealand. Two species—*T. nodiferus* and *T. cutaceus*—have been occasionally obtained from the Channel Islands. Like *Strombus*, this group of molluscs appear to be great scavengers. M. Vélain, when at Amsterdam Island, observed that the dead carcases of seals, left by fishermen on the rocks at low water, were literally covered with lobsters and *Ranella* at the following tide. In the helmet-shells, family *Cassididæ*, the shells develop varices at intervals, like

HELMET-SHELL (*Cassis glauca*).

the tritons, but they are broader, more globose, and have shorter spires. The aperture is more or less dentate on each side, and the siphonal canal short, and sharply recurved. Upon the columellar side the animal deposits a strong shelly callosity, which in some species is enormous, and unites with the outer lip above. The animal closely resembles that of *Triton*; its dentition is similar, but the opercula in this family are peculiar, having a lateral nucleus, and often being rayed like an expanded fan. The shells of some species consist of different-coloured layers, and are made use of for carving shell-cameos, in order that the subject may stand out in relief upon a differently-coloured ground. This family includes the genus *Cassis* and its subgenera, and the genera *Morio* and *Lambidium*. Nearly all the species are from hot regions, but a few occur in Japan and New



TUN-SHELL, *Dolium perdix* ($\frac{1}{3}$ nat. size).

Zealand; and the well-known Mediterranean *Morio tyrrhenus* has of late years been dredged living in deep water off the south-west of Ireland.

The tun-shells (*Doliidæ*) are mostly thinnish and of globose form, sometimes of very large size, and always spirally ribbed and grooved. They have no varices, and are without opercula. The foot of the animal is large, and the retractile proboscis long, and furnished with an expanded disc at the end, as in the figured *Dolium perdix*. The shells of the subgenus *Malea*, which have the outer and inner lips strongly dentate, form a connecting link with the *Cassididæ*. Nearly all the species, about fifteen in number, are tropical. Two, however, occur in the Mediterranean, and several in Japan; *Dolium galea*, which occurs off the south of France and other parts of the Mediterranean, has a shell 8 to 10 inches in length, and is the largest gastropod of that region. This mollusc, as well as various species of *Cassididæ* and *Tritonidæ*, are said to secrete sulphuric acid.

The fig-shells (*Pirula*) have an extensive foot, like *Dolium*, but the mantle is largely lobed on each side, and reflexed upon the shell. This is of an elongate pear-shape, with a short spire and a long canal, and has the surface transversely striated or ridged, or more or less cancellated. There are nine recent species belonging to this genus, which is also found fossil in the Chalk and Tertiary deposits. The genus is included in the *Doliidæ*.

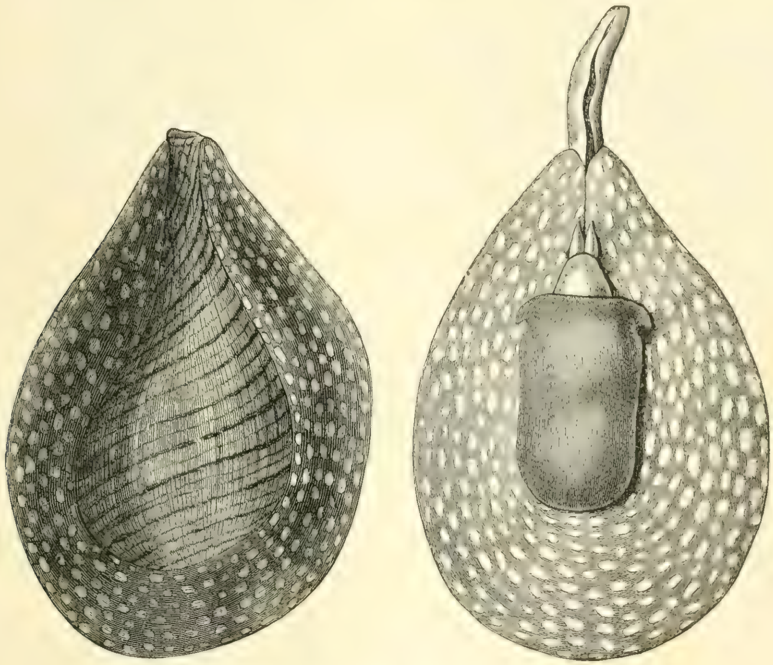
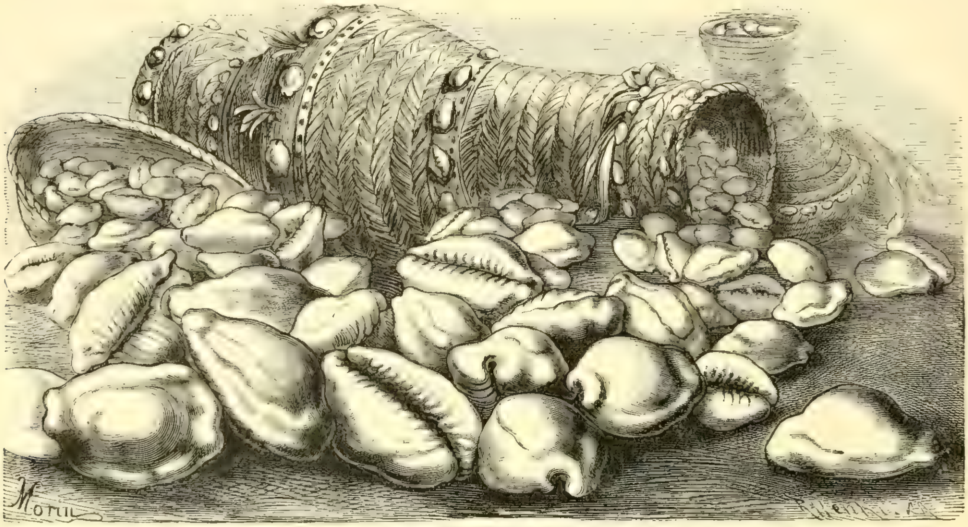


FIG-SHELL (*Pirula ventricosa*), FROM ABOVE AND BENEATH (nat. size).

The cowry, or, more properly, kauri shells (*Cypræidæ*), are so well known that a description is scarcely necessary. They are all formed much after the same pattern, and are almost always coated with a brilliant enamel, caused by the lateral lobes of the mantle being reflexed upon the shell. In the young the shells exhibit a short spire, which in the course of growth becomes entirely or almost concealed. Many of the shells are exceedingly beautiful, and some of the animals are even more brilliantly coloured. The cowries have no operculum, but a large foot, and can retract their bodies entirely within the shell, notwithstanding the narrowness of the aperture. The shells, as is well known, are sold as ornaments, and some of the rarer kinds are greatly prized by collectors. A small yellow species, the money-cowry (*Cypræa moneta*), abundant in some parts of the Indian and Pacific Oceans, is used as coin in India and among the negroes of certain parts of Africa. The orange cowry (*C. aurora*), one of the finest of the group, used to be worn by the chiefs in the Friendly Islands. The cowries, of which nearly two hundred species are known, are found most abundantly in tropical regions, but a few stragglers occur in temperate seas. Only one small and ridged species (*C. europæa*) is found on the British coasts, and about a hundred fossil forms, chiefly Tertiary, are known. The genus *Ovula* is allied to *Cypræa* as regards the general conformation of the animal, but has a somewhat different radula and shell. It contains several subgenera, the most important being *Radius*, *Ultimus*, and *Calpurnus*. *Radius volva* is perhaps the most remarkable of all the species. Many of them live parasitically upon sea-fans, the shells assuming the



MONEY-COWRIES.

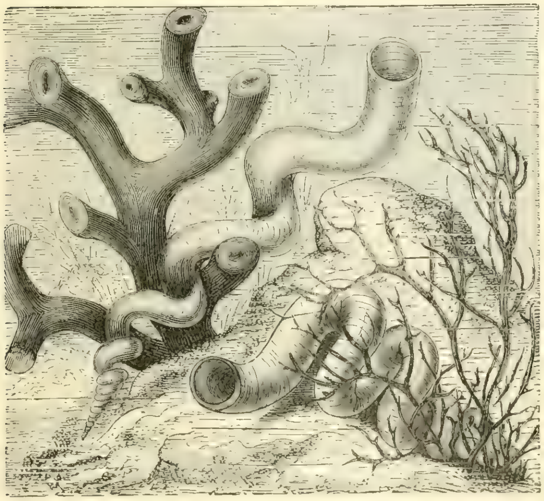
same colour as the bark of the coral. *Pedicularia* and *Erato* also belong to this family, although the shell of the former appears to possess no relationship with its other members.

The wing-shells, or strombs (*Strombidæ*), include some very large species, which when young somewhat resemble a long-spired cone. When mature, however, the outer lip thickens and spreads out, and upon the edge may be developed six, or more, claw-like appendages (*Pterocera*). The aperture is notched anteriorly for the short respiratory siphon, and the outer lip situated near this siphonal notch, and also often posteriorly at its junction with the whorl above. The general form of the shell is shortly or elongately fusiform, or conical. The animals have a well-developed, ringed, contractile proboscis, with the mouth at the end, at the base of which arise two enormous eye-stalks, supporting on their inner side the true, but very small tentacles.

WING-SHELL (*Strombus lentiginosus*).

The eyes are situated at the truncate ends of the long, cylindrical stalks, and, like those of the Cephalopods, are more highly organised than in many fishes, having a distinct crystalline lens, with a highly-coloured iris. The foot is unlike that of ordinary gastropods, and not adapted for crawling; being a powerful, muscular organ, so modified as to serve the purpose of a lever in their hopping or leaping mode of progression. The operculum is claw-shaped, and attached to the hinder branch of the foot. These molluscs are great scavengers, and feed upon decomposing animals of any description. About sixty species of *Strombus* have been described, almost exclusively confined to tropical seas. The beautiful pink *S. gigas*, of the West Indies, is brought to Europe in immense numbers, and, when ground to powder, employed in the manufacture of the finer kinds of porcelain. It is also used for cameo-carving, and produces pink pearls. The spider-shells (*Pterocerus*), with the claw-like projections from the outer lip, have already been referred to. The beak-shells (*Rostellaria*) are remarkable for the long, acuminate spire, and the prolonged, slender, anterior rostrum. On the contrary, in *Terebellum*, the last genus of this family, there is no canal whatever, but merely a slight sinus or emargination at the base of the outer lip. Allied to this family are the *Aporrhaiidæ* and *Struthiolariidæ*, the former including some remarkable fossil forms. *Aporrhais pespelecani* is a common British shell, occurring all round the coast, and usually known as the pelican's foot. In the *Cerithiidæ* the shell is typically elongate, and more or less pointed, with a notch or recurved canal at the front part of the aperture, which is rather short. It is generally solid, tubercular, or ribbed, and has no periostracum. The animals are very like the periwinkles, and are provided with a horny operculum. They are vegetable-feeders, very numerous in species, and inhabit both salt and brackish water. Whereas the species of *Cerithium* are all marine, such forms as *Potamides*, *Pyrazus*, and *Cerithidea* occur in brackish marshes, and at the mouths of rivers. The fossil species of this family far exceed the recent, both in point of numbers and

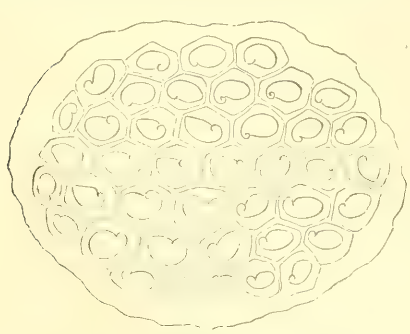
PELICAN'S FOOT (*Aporrhais pes-pelecani*).



WORM-SHELL (*Vermetus lumbricalis*).

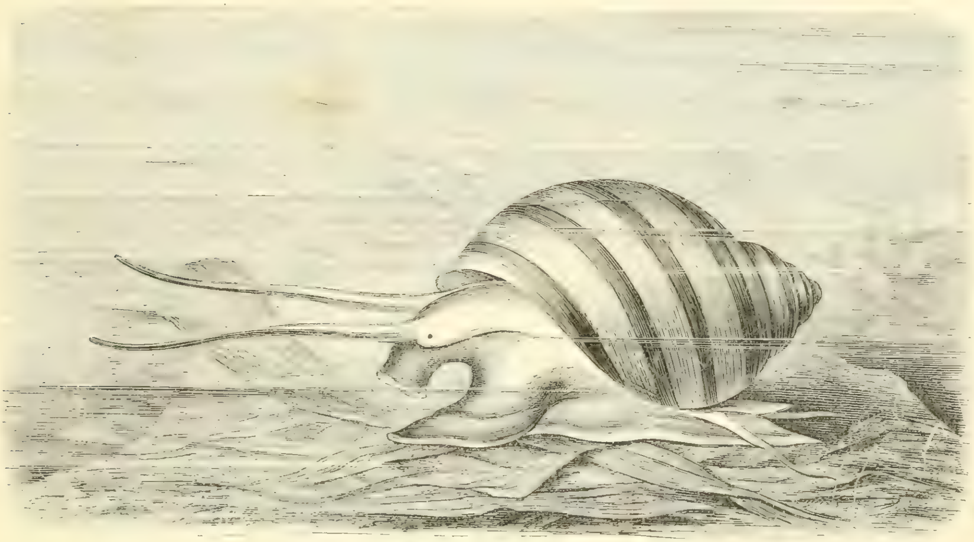
size; *Cerithium giganteum*, an Eocene form, attaining quite a foot and a half in length.

One of the most curious groups of gastropods is that of the worm-shells (*Vermetidæ*), in which the shells might be mistaken for the tubes of marine worms, as they are similarly twisted and attached to stones and other substances in the same way. They are free and spiral in early life, and crawl about like ordinary gastropods, but they afterwards settle down and become stationary for the rest of their existence. In these circumstances, a walking-foot, being of no further use, becomes modified into a mere support of the operculum. The animals are worm-like, with a short proboscis, horny jaws, and radula, and the head supporting two short tentacles, with the eyes at the base. The species are not numerous, and occur chiefly in warm and temperate seas. The members of the extensive family of the *Melaniidæ* are inhabitants of fresh water, and are abundant in all subtropical parts of the globe. The shells are not, as a rule, attractive, being clothed with a dark or olivaceous periostracum. Some are long, slender, and acute, others quite globular. Perhaps the most remarkable form is *Tiphobia horei*, an inhabitant of Lake Tanganyika, in Central Africa. In the typical *Melania* the aperture of the shell is entire, but in some of the other genera, such as *Melanopsis* and *Faunus*, it is distinctly notched in front. The animal is provided with a horny operculum, and many are viviparous. Hundreds of species have been described, but many, as is the case in all fresh-water groups, are distinguished by very slight differences. The *Strepomatidæ*, or *Pleuroceridæ*, are the North American representatives of the *Melaniidæ* of the Eastern Hemisphere, from which they are distinguished by the absence of the marginal mantle-fringes, and in being oviparous in their mode of reproduction. In certain places they abound in such countless numbers as almost to cover the bed of some of the streams in Tennessee and Alabama. About five hundred forms have been recognised. The genus *Io* contains the largest and most striking species of all. They are short, spindle-shaped shells, often with nodose or spinose whorls, and with the aperture prolonged into a distinct anterior canal. They are restricted to certain parts of Virginia and Tennessee. The little sea-snails known as periwinkles (*Littorinidæ*) are dwellers on the shore. They are all vegetarians, and occur in the Arctic and Antarctic regions, as well as in temperate and tropical shores, wherever they can find rocks and stones to crawl upon. Some occur at low water; others live at high-water mark, or where they are only occasionally reached by spring tides. Some ascend the mangrove trees, and have been found hundreds of yards from the sea. Four species of *Littorina* inhabit the English coast, the commonest being the well-known *L. littorea*, which is consumed in such enormous quantities. The periwinkles have horny jaws, and a very long radula, sometimes two or three times as long as the animal itself; and they are all furnished with a horny operculum to protect themselves with, when



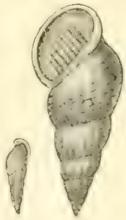
SPAWN OF PERIWINKLE (magnified).

retracted within their shells. The spawn of this species is illustrated in the figure. Nearly allied to the last is the genus *Lacuna*, in which the animal has long, slender tentacles, while on the upper part of the foot there are two long appendages, which extend much beyond its pointed extremity. The species illustrated occurs on the British coasts, and, like the periwinkles, feeds upon seaweeds. The so-called staircase-shells (*Solariidæ*) are all formed much upon



HORNED WINKLE, *Lacuna divaricata* (enlarged).

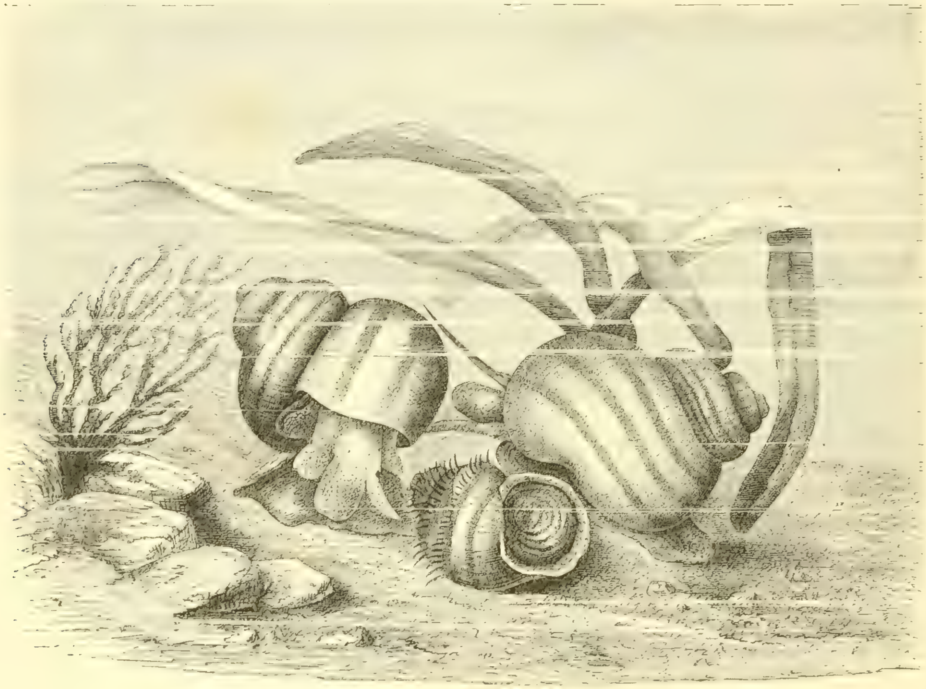
one and the same plan. They are more or less conical, flattened, and umbilicated beneath, and nearly always beautifully sculptured. In *Solarium* the umbilicus is often very wide, and is bordered by a crenulated edge, winding upwards to the apex of the shell, and terminating in a notch upon the aperture. The embryonic shell is sinistral, and in the course of growth becomes turned spire-downwards, and, with the exception of its base, concealed by the succeeding whorls. About twenty species are known, and are chiefly met with in tropical seas. In *Torinia* the shells are more narrowly umbilicated, and not carinate at the margin like *Solariium*, and the operculum is very remarkable, being conical, and consisting of many whorls.



Rissoa.

All the molluscs belonging to the *Rissoidæ* are very small. The shells are something like a minute *Littorina*, but they are often longitudinally ribbed, a style of sculpture not met with in the periwinkles. They are found everywhere, and live upon algæ. A large number of species have been described, and doubtless many forms from all parts of the world remain to be discovered. Even upon the English shores between twenty and thirty forms are met with. This family has been divided into a number of genera and subgenera, partly on differences in the soft-parts, and partly upon conchological grounds. The *Hydrobiidæ* are closely allied to the *Rissoidæ*, and may be regarded as their representatives in fresh and brackish water. Like the periwinkles, although furnished with gills, they are more or less amphibious, passing part of their time out of the water. Four are British.

The viviparous pond-snails (*Viviparidæ*) in general appearance are not unlike periwinkles, having a longish contractile rostrum and elongate pointed tentacles with the eyes situated upon short projections at the base. There are two neck-lappets, the right forming a rudimentary respiratory siphon. The foot is broad in front and narrowed behind. The species of *Vivipara*, as their name implies, are viviparous, and the young are brought forth provided with a shell having three rows of bristles, and at once start upon an independent career, like the adult. They are sluggish creatures, and generally live more or less in mud at the



VIVIPAROUS POND-SNAILS, *Vivipara*; male on left, female on right, young (magnified) in front.

bottom of rivers or canals, and feed upon decaying vegetable or animal matter. The North American species form the genera *Melantho* and *Tylotoma*, and most have more solid shells than in *Vivipara*. One of the finest species occurs in Lake Tanganyika, and is remarkable on account of the aperture being somewhat effuse at the base, and in having the outer lip slightly sinuated in the middle. On this account it was at one time placed in the separate genus *Neothauma*, but examination has shown that it does not essentially differ from *Vivipara*. The character of the lingual teeth in this family is shown in the accompanying figure representing a single transverse series. Two species occur in England, one of which (*V. contecta*) is here figured. The *Valvatidæ* comprise a few small molluscs closely allied to the last. They occur in Europe and North America, and are remarkable for protruding a plume-like gill beyond the mouth of the shell, which is somewhat discoid or turbinate in form. *Valvata cristata* and *V.*

piscinalis occur in places throughout the British Isles. The shells of the *Ampullariidæ* are not unlike those of the *Viviparidæ*, but are mostly larger, and rather more globose. They are covered with a shiny, greenish, or olive periostracum, and often ornamented with transverse colour-bands. All are provided with large ovate opercula of concentric growth, which in species from the Western Hemisphere are thin and horny, whereas in the Old World forms they are thickened internally with a shelly layer. Although these shells have entire mouths (holostomatous), without a canal or even a notch in the aperture, the animal is provided with a long respiratory siphon. The species of *Ampullaria* are amphibious, and inhabit marshes in tropical countries. They are provided with both lungs and gills, and breathe both air and water.

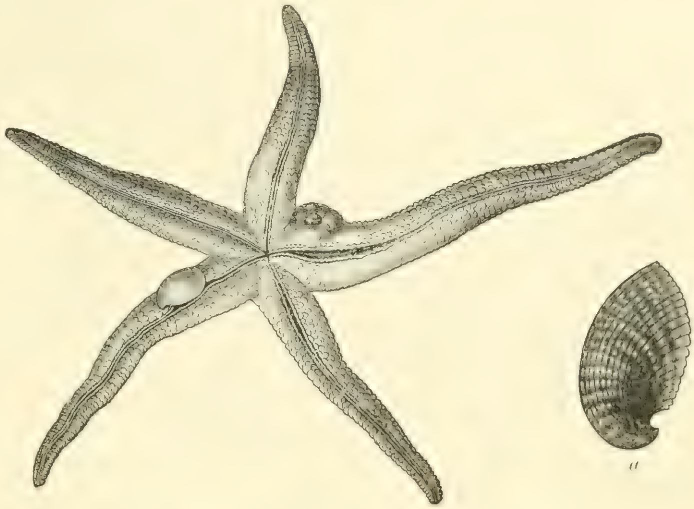
ROW OF TEETH FROM THE RADULA OF *Vivipara* (greatly magnified).

Professor Semper observes that these molluscs "breathe not only with both gills and lungs, but they do so in regular alternation; for a certain time they inhale air at the surface of the water, forming a hollow elongated tube by incurving the margin of the mantle, so that the hollow surface is closed against the water and open only at the top. When they have thus sucked in a sufficient quantity of air, they reverse the margin of the mantle, opening the tube, into which the water streams." They are capable of living out of the water for a long time, and it has been stated that some specimens kept in Calcutta for five years were alive at the end of that period. South America produces the largest forms, but there are also a few handsome species from Central Africa, Madagascar, India, and the Eastern Archipelago. In the genus *Lanistes*, which occurs only in Africa, the shells are all sinistral, and have horny opercula.

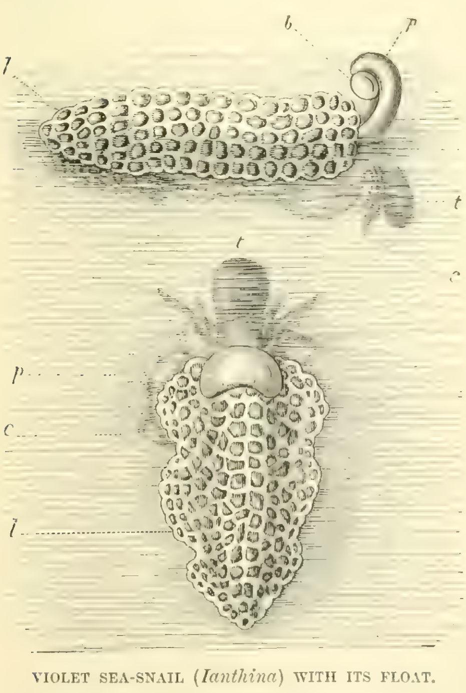
The families *Cyclophoridæ* and *Cyclostomatidæ* comprise a large number of air-breathing land-snails, formerly classed with the Pulmonata. The breathing-organ is not a true lung, like that of the snails and slugs, but a vascular branchial chamber, modified for air-breathing, and open in front, the mantle being free above the nape of the neck. The animals are unisexual, and formed much after the fashion of periwinkles. They have a long rostrum, two contractile tentacles, with the eyes at the base, and the radula has seven rows of teeth, arranged as in *Littorina* and allied genera. Another distinguishing feature is the presence of an operculum, which is possessed by all the species. In the *Cyclophoridæ* this is generally horny, circular, and multispiral, with a central nucleus, whereas in the *Cyclostomatidæ* it is mostly of a shelly texture, and paucispiral. In the latter family the animals have the sole of the foot divided down the middle by a groove, and, when walking, the halves are alternately advanced. The species of these families are numerous, and are principally found in hot climates. A few, however, occur in more temperate regions; two, belonging to distinct genera, being found in Britain. The shells are variable in form, and can only be appreciated by studying a series of specimens or figures. The species are classified in a large number of genera, which, although based on a combination of characters, are mostly distinguishable by differences in the opercula. *Cyclostoma*, *Otopoma*, *Chondropoma*, *Choanopoma, Cistula, Tudora, Omphalotropis,* are the principal forms of *Cyclostomatidæ.* Some of the handsomest and largest species are found in Madagascar and Mauritius, but some of the West Indian islands are noted for the immense number of species they produce. Among the *Cyclophoridæ,* the most important groups are *Cyclophorus, Leptopoma, Cyathopoma, Pterocyclus, Opisthoporus Pupina, Cataulus,* and *Megalomastoma.* The minute forms, known as *Opisthostoma* are, perhaps, among the most wonderful structures of the whole family.

The species comprised in the family *Truncatellidæ* are all small, and live either between tide-marks (*Truncatella*) or upon the land (*Geomelania*). The shells are elongate, and in the young state terminate in a pointed spire, which is subsequently cast off, the shells then assuming a truncate appearance at the top. They have a very peculiar mode of progression, resembling that of the looper caterpillars, the end of the muzzle and the foot being successively advanced. The characteristic feature of the typical genus (*Hipponyx*) of the allied family *Hipponychidæ* is the secretion by the foot of the animal of a shelly plate, which is attached by its outer surface to stones, shells, or other substances. It forms a permanent resting-place for the conical shell, and is attached to the adductor muscle of the animal. In some of the fossil species these lower plates are so greatly developed that they were at one time regarded as bivalved shells. *Amalthea* has a shell very like *Hipponyx*; it does not form a basal plate, but excavates a hole in the surface of other shells to fit the aperture of its own.

The members of the family *Calyptræidæ* are limpet-like in their mode of life, living attached to stones, shells, etc. The shells are more or less conical, but spiral towards the apex. The interior is either simple, as in *Capulus,* parted off by a transverse septum (*Crepidula*), or a cup-like process, varying in form, is developed in the upper part (*Crucibulum*). The animals have a short proboscis, two slender tentacles with the eyes near the base, and the mouth furnished with a radula bearing a prolonged tusk, like the *Naticidæ.* Being permanently located, it becomes a matter of conjecture what they feed upon. Possibly the minute forms of life which abound in the sea form their staple nourishment. The various genera are for the most part recognisable by differences in the shell, the form of the internal septum and "cup" furnishing good characters. The number of living forms is considerable, and they are found in all seas. Two occur on the British coast,—*Calyptræa chinensis* and *Capulus hungaricus,*—and a third, *Crepidula fornicata,* supposed to have been imported with American oysters, is becoming an established resident on the Essex coast. Closely allied to *Capulus* is *Thyca crystallina,* which lives parasitic upon star-fish at Mauritius and in other parts of the Indian Ocean. In the family *Xenophoridæ* are contained a remarkable group of molluscs known as carrier-shells, so-called from the instinctive habit some of them possess of carrying about with them shells, stones, and other substances, which they cement to the exterior of their own trochiform shells. Doubtless this concealment is to some extent protective. The animals bear some resemblance to *Strombus,* but their eyes are very inferior, and placed at the base of the tentacles. They are furnished with opercula, which, however, are more like those of *Purpura* than *Strombus.* They resemble the latter in their leaping and scrambling mode of progression, not gliding along on the sole of the foot like most other gastropods. In the family of the naticas (*Naticidæ*), which is numerous in both recent and fossil species, the shells are more or less globular or ear-shaped, and the animals remarkable for the enormous development of the foot, which is used as a plough to drive through the sand in search of other molluscs—mostly bivalves—upon which they feed. The foot is so large as almost to conceal the shell, and the front part of it (the *propodium*) hides the head, which has no visible eyes. The shells are quite closed in some of the groups by a paucispiral operculum, which is either horny or shelly. Naticas are found in all parts of the globe. The largest living species (*Lunatia heros*) occurs on the eastern coast of North America, but some of the more highly-coloured forms are found in tropical seas. About half a dozen species occur in Britain. The spawn-cases are curious objects, resembling a broad sandy strap coiled round like a horseshoe.



STARFISH WITH *Thyca*; *a*, Shell of latter enlarged.



VIOLET SEA-SNAIL (*Ianthina*) WITH ITS FLOAT.

b, A bubble, drawn, somewhat too large, about to be joined to the anterior end of the float; *c*, Shell; *l*, Float; *p*, Foot; *t*, Head.

SECTION PTENOGLOSSA.

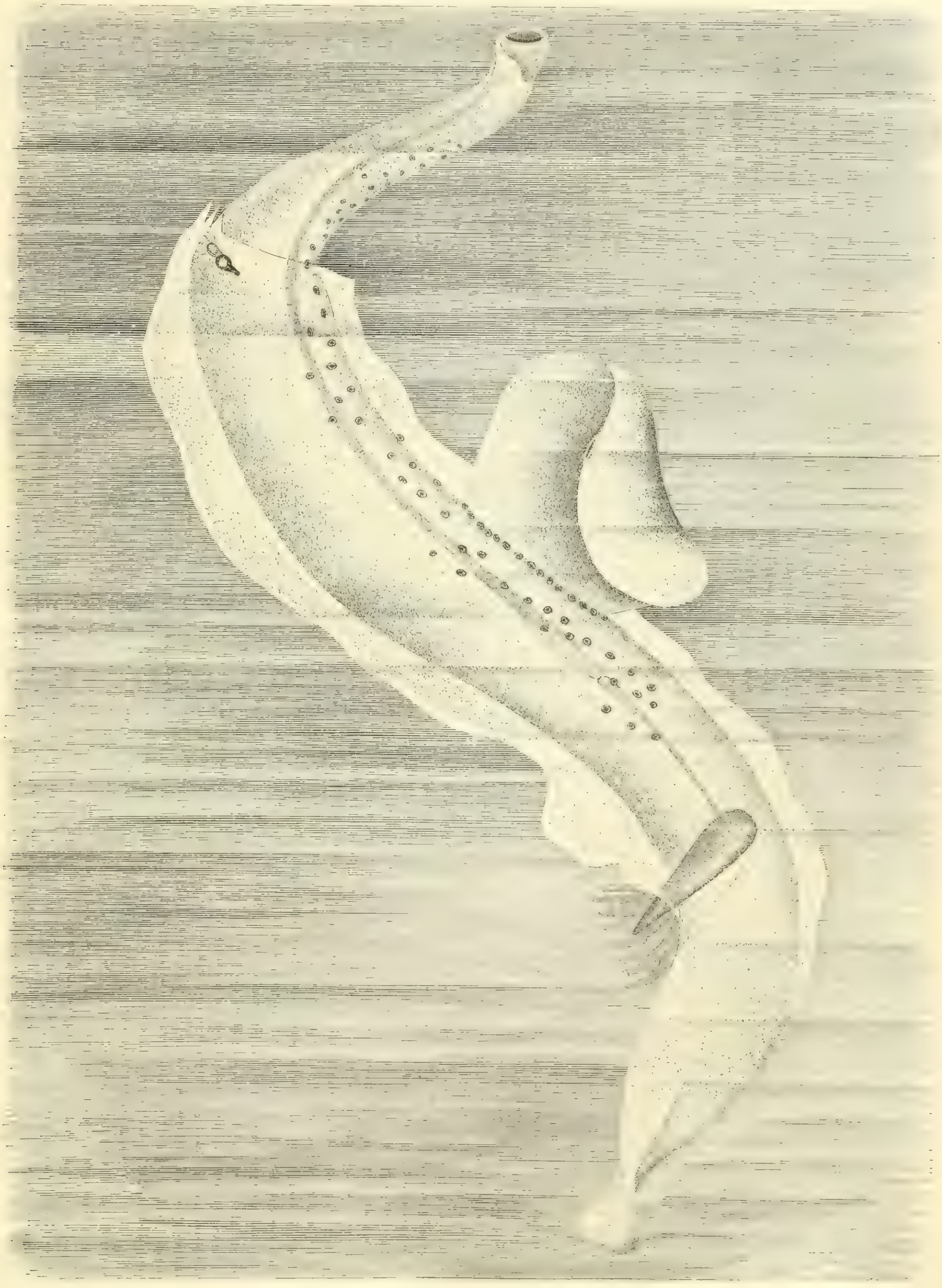
In this unimportant group of Pectinibranchs—which includes only the families *Ianthinidæ* and *Scalariidæ*—the radula consists of numerous rows of pointed teeth, arranged in cross series forming an angle in the middle. There is no central or rhachidian tooth. The violet sea-snails (*Ianthinidæ*) have thin trochiform shells, adapted for a pelagic life. These are mostly of a violet colour, the base or underside, which is turned upwards and exposed to the light when the animal is swimming at the surface of the sea, being more deeply tinted than the rest of the shell. The most interesting feature in connection with these oceanic snails is the curious float which they construct to support their egg-capsules. It is a sort of gelatinous raft, enclosing air-bubbles which cause it to float at the surface; and is attached to the foot, the egg-capsules being suspended from its under surface. The violet-snails feed on various kinds of jelly-fish, and occur in shoals on the high seas. Being unable to sink, so long as they are in connection with their floats, they thus escape from storms and are often cast ashore in immense numbers. The species are few, and, like other pelagic forms, are widely distributed. *Recluzia*, the only other genus in the family, has a pale brownish shell with a longer spire than *Ianthina*. It likewise forms a raft. The shells of the wentle-traps (*Scalariidæ*) are mostly white, and formed on the same plan. The spire is more or less elevated, the aperture entire, and the whorls are ornamented with a succession of ribs or varices which give the shells a pretty appearance. The animals are carnivorous. More than one hundred and fifty species are known, and they occur in all seas, as far north as Greenland. Four inhabit the British shores, one (*Scalaria communis*) being the most prettily coloured shell of the genus. *S. pretiosa*, a native of the China Seas, is the largest member. It was formerly of value, between twenty and thirty pounds having been given for a specimen.

SECTION GYMNOGLOSSA.

This, the last of the five sections into which the Pectinibranchs are divided, is characterised by the absence of the radula. Two families are included in it, namely, the *Eulimidæ* and *Pyramidellidæ*. The former have white, polished, pointed shells, with an ovate aperture, closed by a thin, horny operculum. Many of them are curved in the course of growth. Some are known to live commensally or parasitically upon or within various species of holothurians. *Stylifer*, which lives in or upon star-fish and sea-urchins, usually has a thinner and more glassy shell than *Eulima*, and has no operculum. A few species are found in Britain, but the family is more numerous in warmer latitudes. In the second family the majority of the species are very small; and while all are dextral in the adult state, the young shells are remarkable for having the nuclear whorls sinistral. Some are longitudinally plicate, others transversely ridged, cancellated, or smooth, and the columella often exhibits one or more plaits or denticles, which are conspicuous in some and almost obsolete in others. The diversity of form and surface ornamentation, in the very numerous species of this and many other families, can only be seen in a collection of specimens, or a good series of illustrations. About forty species are British, none of which belong to the typical *Pyramidella*.

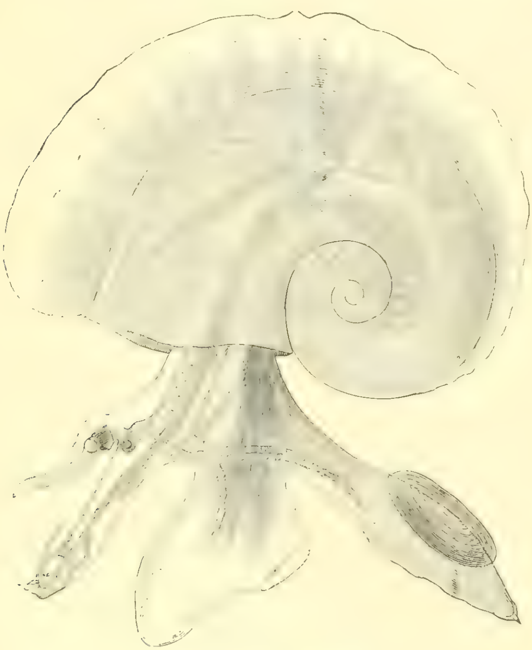
Suborder **Heteropoda.**

This group is regarded by some systematists as a distinct order, and by others merely as a division of the Pectinibranchia; and it sometimes appears under the name of Nucleobranchiata. It includes gastropods modified for a pelagic life. The foot, in place of being adapted for crawling, is laterally compressed, and serves the purpose of a fin, and is also used as a means of attachment to the prey or any floating substances. The Heteropods are found on the high seas in every warm part of the globe. They have distinct sexes, are predatory in their habits, feeding upon all sorts of pelagic life which surrounds them. They have no jaws, but are furnished with a radula with seven rows of teeth like the tænioglossate gastropods. Some have shells capable of containing the retracted animal; in others, the shell



A PELAGIC HETEROPOD, *Pterotrachea* (nat. size).

only serves the purpose of protecting the vital organs, and in some forms it is altogether wanting. The Heteropods may be divided into two families, *Pterotracheidæ* and *Atlantidæ.* The former includes the genera *Pterotrachea, Firoloida, Cardiapoda, Carinaria,* and *Pterosoma*; a species of the typical genus being shown on the preceding page. It is a transparent gelatinous creature. The gills are exposed near the tail, and the fin-like foot, with the minute sucker upon the edge, is seen on the opposite side. The sucker is smaller in the females than the males. About sixteen species are more or less determinable. *Firoloida* has no gill and the visceral nucleus is situated at the posterior end of the body, with scarcely any caudal prolongation beyond it. The males are provided with two slender tentacles in front of the eyes, the females being without these appendages, and the fin-sucker, as in *Pterotrachea,* is also larger in the males. Neither this genus nor the preceding has any shell. In the allied *Cardiapoda* the nucleus is pedunculated, and partly protected by a minute glassy spiral shell. The most interesting of this family is *Carinaria,* on account of its beautiful vitreous cap-shaped shell; the animal being rather like that of *Cardiopoda.* The commonest species is the well-known Mediterranean *C. lamarcki,* but the largest is *C. cristata* from the Indian and China seas. The embryonic shell of *Carinaria* is spirally coiled like a snail-shell, and bears no resemblance to the beautiful adult structure. The latter at one time was so rare that one hundred pounds is said to have been given for a specimen. Even now, large and perfect shells are rare. The *Atlantidæ* contains two genera, *Atlanta* and *Oxygyrus.* The shells are small, compressed, and spirally coiled, of a glassy texture, and capable of containing the animal. The gills are situated in a dorsal cavity of the mantle, and the foot is trilobed, one portion of it supporting a minute, subtrigonal operculum. About twenty species are recognisable, *Oxygyrus* being represented by only two. They abound in the warmer parts of the Atlantic, Indian, and Pacific Oceans.



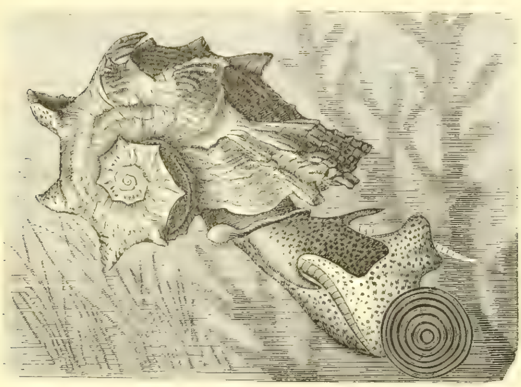
Atlanta peroni (magnified).

Suborder **Scutibranchiata.**

The great feature of these animals is the absence of certain functional organs in the different sexes; the radula being also of a peculiar type, and armed with several central and lateral teeth. The two sections of the suborder, Rhipidoglossa and Docoglossa, are based upon differences in the radula. In the former there are nearly always several central teeth, one lateral and many small marginals; and in the latter the typical radula, which is very long, has one or two pairs of central teeth, a large single lateral on each side, with a few small marginals. The first family (*Helicenidæ*) forms a numerous group of small operculated land-shells, which abound in the West Indies and the islands of the Pacific and Indian Oceans. A few occur in Australia, China, and Central and South America, but they are unknown in Europe or Africa. Many are attractively coloured, and a few remarkable for the serrate keel at the periphery. Next come the nerites (*Neritidæ*), all of which are aquatic, and feed upon vegetable substances. In *Nerita* the shells are globular, and strongly made to resist the action of the waves, for these molluscs are inhabitants of the seashore. They are furnished with a shelly operculum, which has a process jutting out from beneath and fitting under the toothed or wrinkled columellar lip when the mollusc retires within its shell. The species of *Neritina* have mostly thinner shells, especially those which inhabit fresh-water streams, and are also furnished with an operculum, like *Nerita*, but thinner. The pillar-lip is thin and smooth, or only finely dentate at the edge. In the section *Clithon* the shells are beset with a coronet of spines. The most remarkable form of that group is *N. longispina*, from mountain streams in the Mauritius. About two hundred species of *Neritina* are known, which abound in intertropical regions and the islands of the Pacific. One small species, *N. fluviatilis*, occurs in Britain, where it is found in slow rivers with a stony or gravelly bottom, and is often coated with a calcareous deposit. The animal has a stout proboscis, long, pointed tentacles, and eyes placed upon short stumps at the base of the tentacles. The species of *Septaria* are somewhat limpet-like, but with the apex of the shell bent towards one end. They also have an operculum of a peculiar type, partly embedded in the foot. The species are principally met with in tropical islands. Among the fossil forms, *Velates conoideus* is interesting on account of its exceptional mode of growth. The top-shells (*Turbinidæ*), like those of the next family, have one characteristic in common, namely, a brilliantly pearly layer beneath the outer calcareous surface. The animals of both groups are vegetable-feeders and much alike, and are peculiar on account of the tentacular processes on the sides of the foot. In the *Trochidæ* the operculum is horny, circular, multispiral, and with a central nucleus; in the *Turbinidæ*, it is thickened with an outer shelly layer, consists of fewer whorls, and often has the nucleus excentric. The latter family is typified by the genus *Turbo*, which has been divided into a number of groups or subgenera on account of differences in this structure. The species are fairly numerous in tropical seas, but rare in more temperate regions. Of the allied genus *Phasianella* only one species (*P. pullus*) reaches the British shores. The *Trochidæ* have a wider range, are far more numerous, and occur everywhere from the Arctic to the Antarctic circles. The beauty of sculpture and coloration of many of the species of the typical genus *Trochus* is beyond description, and can only be appreciated by an examination of the shells themselves. Most forms are littoral, or inhabitants of shallow water, but a few, and these among the most beautiful, have been dredged at enormous depths. Nearly twenty different species occur around the British coast, and some of them are extremely elegant in

FRESHWATER NERITE, *Neritina* (nat. size).

form and structure. The family *Delphinulidæ* in many respects resembles the *Trochidæ*, and is represented only by the single tropical genus *Delphinula*. The ormers (*Haliotidæ*), although few in number, form an important family, on account of the economic value of the beautiful pearly shells which are employed in inlaying. They are ear-shaped, depressed, with a very small spire, and the last whorl, which practically contains the entire animal, correspondingly large, and pierced with a series of holes commencing at the spire and extending to the front margin, in a line subparallel with the left side. The outer surface is calcareous, and often beautifully sculptured and coloured, but the interior is lined with the most brilliant pearl. The holes in the shell admit water to the gills through a slit in the mantle beneath, and on the edges of the slit there are three tentacular processes which the animal passes through certain perforations. *Haliotis*, like the limpets, has a large foot, adapted for adhering to rocks. Some of the larger forms hold on with such tenacity, that it is impossible to remove them without damaging the shells, except with the aid of hot water. The genus is most abundantly represented in Japan, California, and Australia; but is also met with in New Zealand, the Philippine Islands, Oceania, some parts of the Indian Ocean, and round the African coast, while one species (*H. tuberculata*) ranges as far north as the Channel Islands. They are locally known as ormers, and are consumed in considerable quantities. When properly prepared and cooked, they make a savoury dish. It is worthy of notice that *Haliotis* does not inhabit the South American coasts, nor is it found on the Atlantic side of North America. Until some fifty years ago, the typical genus of the family *Pleurotomariidæ* was supposed to be extinct. Four recent forms are now known, one from Japan, one Moluccan, and two West Indian. Two of these are larger than any of the extinct species. *Pleurotomaria* has a trochiform, discoid, or globose shell, pearly within, with a more or less deep slit in the outer lip of the aperture; the latter being the characteristic feature of the group. It has existed since the Palæozoic epoch. In *Trochotoma*, an allied genus, there is a hole behind the lip in place of the slit, and *Polytremaria* exhibits a whole series of perforations. The anatomy of *Pleurotomaria* shows that it has close relationship with *Haliotis*. Like *Trochus*, it is furnished with a horny spiral operculum. A magnificent specimen of *P. adamsoniana* is exhibited in the shell-gallery at the Natural History Museum. *Scissurella* is another genus of this family, containing a number of very minute shells with a slit in the lip like *Pleurotomaria*; *S. crispata* being a pretty little mollusc found in Britain. The members of the so-called key-hole limpets (*Fissurellidæ*) mostly have shells like those of the limpets in form, but either perforated at the apex, as in *Fissurella*, slit at the front margin (*Emarginula*), or

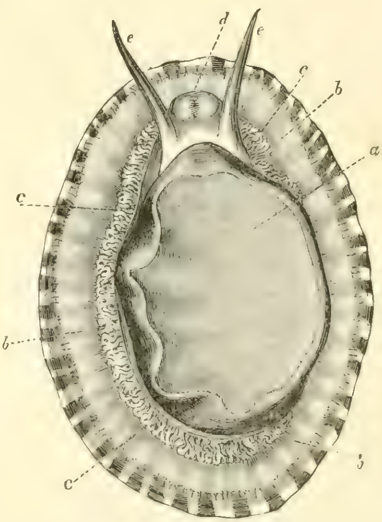


DOLPHIN-SHELL, *Delphinula laciniata* (nat. size).

with a hole between the front edge and the apex (*Rimula*, *Puncturella*). In *Scutum* the shell is less conical, and more elongate, and only very faintly sinuated at the front margin. It is white, and almost wholly concealed beneath the mantle. The holes and slits in these shells serve excretory purposes. The animals are remarkable for their two symmetrical gills, and certain points in their internal anatomy, which offer some resemblance to the bivalves. More than a hundred species of *Fissurella* are known from all seas, except the Arctic. The west coast of South America produces some of the handsomest kinds; but the giant of the genus, *F.* (*Lucapina*) *crenulata* inhabits the shores of California.

SECTION DOCOGLOSSA.

The second group of Scutibranchs comprises the families *Acmæidæ*, *Patellidæ*, and *Lepetidæ*, all being limpet-like molluscs, with a peculiar form of dentition, as already described. The shells of these families are alike in construction, but the animals differ essentially in their respiratory organs. In *Acmæa* there is a single branchial plume, or ctenidium, over the neck; in *Patella* the gills are arranged in almost a circle around the foot; and in *Lepeta* the gill is entirely wanting. In addition to these differences the radula affords further distinguishing characters. Limpets are generally attached to stones and rocks, but when the tide is up they quit their resting-place in quest of food, which consists of various kinds of Algæ. As the tide ebbs they creep home again to the spot which each appropriates as its own location. The common limpet is one of the molluscs eaten on certain parts of the British coasts. With regard to the tenacity with which the limpet holds on, experiments have been made showing that a force of sixty-two lbs., or one thousand nine hundred and eighty-four times its own weight, is required to detach it from the rock.



UNDER SURFACE OF LIMPET.

a, Foot; *b*, Mantle; *c*, Gills; *d*, Mouth; *e*, Tentacles.

EDGAR A. SMITH.

CHAPTER XI.

MOLLUSCS,—*concluded.*

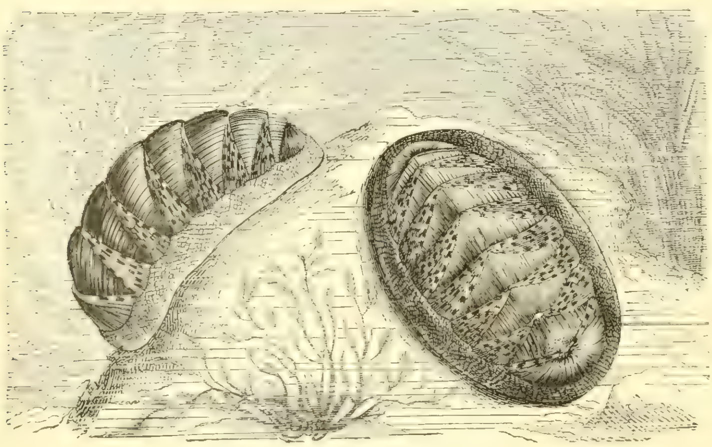
CHITONS TOOTH-SHELLS, AND BIVALVES,—Classes **Amphineura, Scaphopoda, and Pelecypoda.**

THE CHITON GROUP,—Class **Amphineura.**

THE Molluscs included in this class may be regarded as aberrant gastropods, differing from ordinary forms in their symmetrical conformation, having the mouth and excretal orifice at the two extremities of the body, and the tissues of the mantle more or less spiculose. The symmetry which characterises the external parts also extends to the internal organisation. The group is divided into the two orders Polyplacophora and Aplacophora; and is regarded by some authors, and perhaps correctly, merely as an order of Gastropoda, and not forming a distinct class.

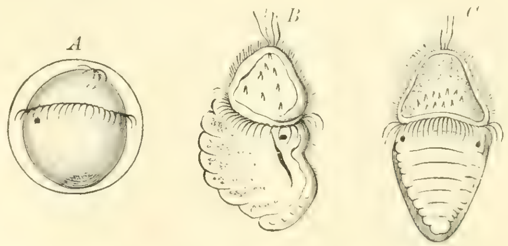
CHITONS,—Order POLYPLACOPHORA.

The well-known chitons (*Chitonidæ*) are the only forms included in this order, and are externally recognised by their shells consisting of eight separate pieces or valves, as they are termed, which are arranged over the back, and connected at the sides by the tough margin of the mantle in which they are embedded. In most cases the valves are close together, extend right across the back, and are exposed; but in some genera they are far apart (*Cryptoplax*), and in others entirely covered by the mantle (*Cryptochiton*). The foot occupies the entire ventral surface of the body, and the mantle covers the upper surface, extending laterally beyond the shell. This portion is known as the girdle, and is nearly always covered with spines, scales, or spicules, which, to some extent, are

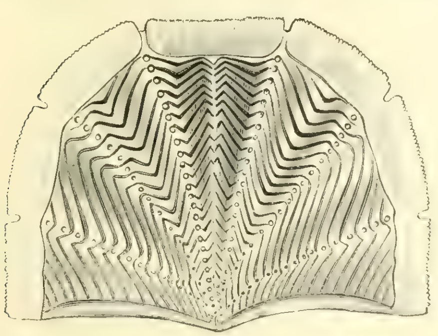


COMMON CHITON (*Chiton squamosus*).

characteristic of the different groups into which the *Chitonidæ* have been divided. The gills are placed on each side between the mantle and the foot, and vary in length. Adult chitons have neither eyes in their head nor tentacles, but the mouth is provided with a long radula, the teeth of which are arranged in a very peculiar complicated manner. The chitons are bisexual, but, like the limpets, destitute of certain functional organs. In the early stages the young chiton bears no resemblance whatever to its parent. This can be appreciated by observing the accompanying figures illustrating three stages in the development of *Chiton marginatus*, one of the dozen species found on the British coasts. The embryo (*A*) is a spherical body, $\frac{1}{31}$ of an inch in diameter, divided into two unequal parts, the dividing line being marked by a row of cilia, and a tuft of similar cilia being situated at the vertex of the smaller half. The eyes are visible upon the lower portion below the cilia. In a later stage (*B* and *C*) the division of the back into eight sections is remarkable and unique in the Mollusca. At this stage the foot begins to develop, the forepart of the animal being ciliated. In later stages of the development the eyes and cilia disappear, the forepart shrinks up into the ridge surrounding the mouth, and the back develops the eight shelly plates. It has already been stated that the adult *Chiton* has no eyes. This is only true as regards the head of the mollusc, for Moseley made the discovery that certain forms have the shell studded with eyes, of which as many as eleven to twelve thousand sometimes exist in a single individual. They are not unlike those already referred to as present on the back of *Onchidium*. Chitons live principally on rocks and under stones at low water, or at moderate depths, but a few have been obtained as low down as two thousand three hundred fathoms. They are all marine, very sluggish in their movements, and, if disturbed from their resting-place, roll themselves up into a ball like a wood-louse. The number of recent species is considerable, and they appear to range all over the globe. Fossil remains of certain forms have been found in most geological periods, since the Silurian.



DIFFERENT STAGES OF THE LARVA OF CHITON (magnified).

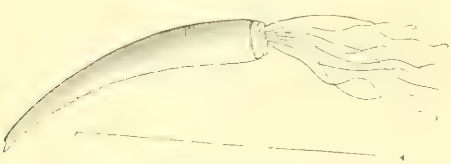

EYED CHITON (*Schizochiton incisus*). Anterior valve, with six rows of eyes (enlarged).

Order Aplacophora.

The molluscs of this order are somewhat worm-like, with a mantle enclosing the entire body, but not secreting a shell, and more or less studded with spicules. They are related to the chitons by certain points in their anatomy, especially with regard to the disposition of the nervous system. The respiratory organs, when present, are terminal and placed within the anal cloaca. In most of the forms the foot is reduced to a mere longitudinal groove, and does not appear adapted for a locomotive organ. The number of known species is limited. They occur at moderate to abyssal depths in the Arctic and Atlantic Oceans, from the Barents Sea to the coast of Spain. Two families constitute this order, namely, *Chætodermatidæ* and *Neomeniidæ.* The former contains but a single genus, *Chætoderma.* This degraded mollusc, at one time placed among the Gephyrean worms, has an elongate worm-like form, with an inflation at both ends. The mouth is terminal, and armed with only a single tooth—a poor representative of the molluscan radula. The pedal groove is wanting, and the sexes are separate. The only known species—about an inch in length—occurs under stones on the shores of Norway, but has also been dredged in deep water off the coast. The *Neomeniidæ* comprise the genera *Neomenia*, *Proneomenia*, *Lepidomenia*, *Ismenia*, *Paramenia*, and *Dondersia*. *Neomenia*, which has been found off the west of Scotland, ranges from Scandinavia to the Mediterranean, and is the best known. *N. carinata* is about an inch long, rather compressed laterally, curved longitudinally, with the back keeled and the ventral side with a narrow foot-groove, extending the greater part of its length. The mouth is unarmed with a radula, and the sexes are united in each individual.

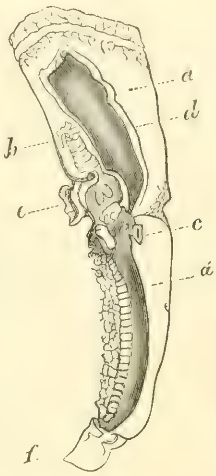
THE TOOTH-SHELLS,—Class **Scaphopoda.**

Everybody knows the tooth-shells, resembling in miniature the elephant's tusks, and often found on the sandy shores of England. They are scientifically known as *Dentaliidæ*, and in former times were associated with the marine worms, their shells bearing a strong resemblance to the tubes of certain annelids. They are more or less elongate, nearly always slightly curved, and are bisexual. The head is rudimentary, and in this respect the scaphopods resemble the bivalves. They have no tentacles, eyes, or heart, and the organs of respiration and circulation are rudimentary. At the anterior end of the animal is situated the foot, which is not a creeping disc, but adapted, like that of some bivalves, for burrowing in sand and mud, in which they live and obtain their food, consisting of diatoms and foraminifera. They are said to capture these minute organisms by means of a number of long contractile filaments with expanded extremities (*tentacula* or *captacula*) which are situated near the mouth, which is armed with a radula, and surrounded by labial palpi. The shell is cylindrical, usually somewhat tapering posteriorly, open at both ends, and generally white. A few species, however, are of a greenish tint, and others are pinkish. They are smooth, longitudinally striated and ridged, mostly circular in section, but a few are angular, compressed, and otherwise irregular as regards form. Some are simple at the narrow end; but others exhibit a more or less elongate notch or slit on the ventral or convex side. In some species of *Dentalium* the end has several notches,



COMMON TOOTH-SHELL, *Dentalium vulgare* (nat. size).

and in *Schizodentalium* a series of holes takes the place of a ventral slit. Fossil tooth-shells are numerous from the Devonian epoch upwards, but are most abundant in the Tertiaries. The living forms, of which about a hundred have been described, occur in all parts of the globe, and have been dredged at the greatest depths, although they are probably most abundant in a few fathoms.

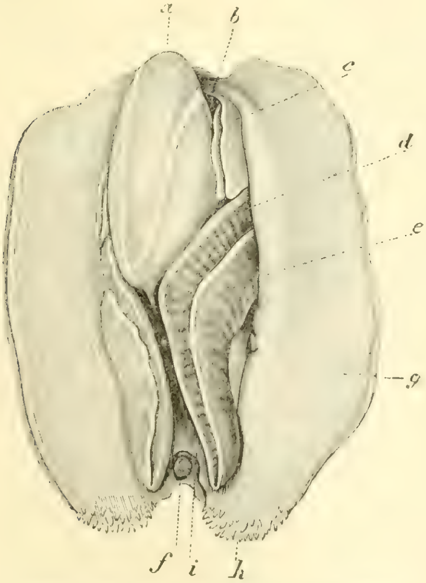


SECTION OF ANIMAL OF *Dentalium* (enlarged).

a, Front mantle-cavity; *á*, Hinder mantle-cavity; *b*, Mouth process; *c*, Anal opening; *d*, Foot-cavity; *e*, Tentacle supports; *f*, Posterior end.

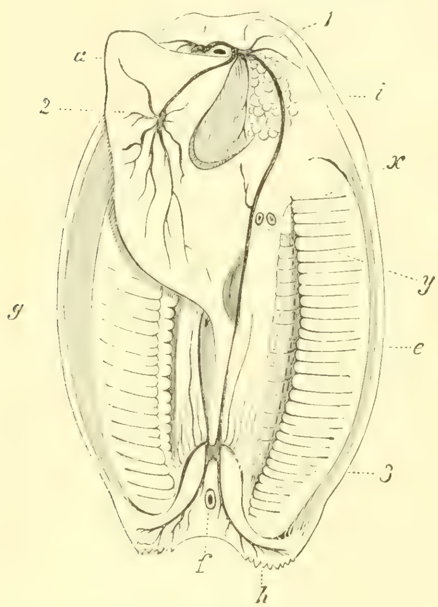
THE BIVALVES,—Class **Pelecypoda.**

This great division includes all forms which secrete a bivalved shell, like the oyster, cockle, and mussel. The Pelecypods offer a different type of organisation from that prevailing in the other classes. The absence of a head, and the bilateral symmetry of the animal, enclosed within a bivalved shell, are characteristic of the class. The mantle is divided into two similar lobes (*g*), right and left, forming a flap on either side of the body, to which it is connected at the upper part beneath the hinge-line of the shell. It is usually very thin, excepting at the edges, which are sometimes double or even threefold. In some genera the edges of the two lobes are free or unconnected at any point excepting at the dorsal attachment, in others they are joined in one or more places, leaving orifices for the protrusion of the foot (*a*) in front, and for the entrance of the water to the gills (*d*, *e*), and for the extrusion of waste and other matter at the posterior end (*f*). The mantle at this posterior opening is often considerably produced, forming one or two distinct tubes or siphons (*h*), which vary considerably in length in different groups, equalling in some instances several times the length of the shell. The extreme development of these siphons obtains in *Teredo*, where they constitute the principal mass of the animal. Some pelecypods appear to be all foot, this member being enormously developed in the razor-shells (*Solen*), for example. In others it assumes smaller dimensions, or it may be absent, as in the oyster. It is used either as a means of locomotion, or for burrowing in sand or mud, or perforating rocks, wood, and other substances; its form consequently being very variable. The mouth (*b*) is situated at the anterior end of the body, at the upper front part of the foot, forming a simple transverse aperture. The



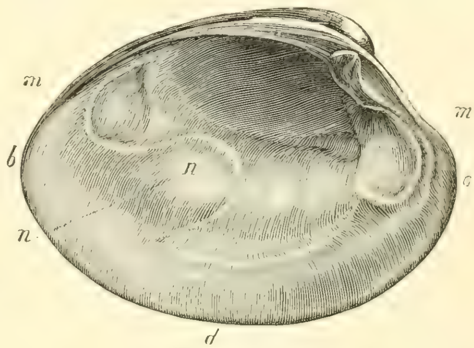
SOFT-PARTS OF RIVER-MUSSEL (*Anodonta*).

lips, upper and lower, are usually prolonged on each side into two lobes (*c*), or labial palpi. These vary in form, but are mostly triangular. In some groups they are very large (*Tellinidæ*), but in others they are practically wanting. The mouth is not armed with jaws or radula, for in creatures which never prey upon other animals, or go about seeking their food, such structures would be useless. Bivalves obtain their food—consisting of microscopic organisms—in the course of respiration. Whatever is carried in by the inflowing current is collected on the gills, and then conveyed by the palpi to the mouth. The leaf-like gills (*d*, *e*) are arranged on each side of the body, and enclosed by the mantle. Each gill is partly attached by its upper or dorsal margin. This gives rise to two rows of hollow filaments, which are in a few cases simple and disposed in opposite directions, but are generally parallel with one another and directed towards the ventral side, with the filaments long and refolded upon themselves, so that each row forms a double lamella. These filaments are united one to another by cilia. The gills and the inner surface of the mantle-cavity are covered with microscopic cilia, which through their vibratile motion produce the currents of water necessary for respiration. The water generally flows into the pallial cavity at the posterior ventral side, and there is filtered through the gills, passing out again posteriorly through the anal opening. The nervous system consists of three pairs of ganglia, a cerebral or supraœsophageal, a pedal, and a visceral pair. The cerebral ganglia (1) are mostly placed above the œsophagus, the pedal pair (2), as their name implies, within the foot, and the last pair (3) are situated in front of or just beneath the posterior adductor muscle.



ANATOMY OF RIVER-MUSSEL.

Most pelecypods are endowed with the senses of touch, smell, and hearing, and some are provided with eyes. These are found either upon the edges of the mantle or at the end of the siphons; and in some forms, such as *Spondylus* and *Pecten*, they are highly developed. The sexes are generally distinct, but occasionally united. The young are produced from eggs, which are either cast free in the water, or are hatched between the branchial lamellæ of the parent. The shell, as already stated, is composed of two pieces, right and left valves, which are protective of the soft parts, and correspond each to a lobe of the mantle. They are generally of equal size and shape, but in certain groups they differ considerably in these respects. They are nearly always joined dorsally by an elastic ligament, or *resilium*, and often interlocked at the same place by projections on the edges of the valves, termed hinge-teeth. In the majority of species the valves shut closely together all round the edges, but in many they gape at one or both ends, or at the ventral side. In certain species of *Pinna* the two valves are actually united along the dorsal margin, but they are never connected on the ventral side. Bivalves clothe their shells with a more or less distinct periostracum, which is sometimes thin, smooth, and shining, and often of a yellowish or olivaceous tint, or it may be thick, pilose, velvety, or rugged. It has been already noticed that the valves are nearly always connected dorsally by a ligament. This is not, however, the means by which they are held together, or closed with such force; this closure being effected by one or two muscles (adductors), firmly attached to the inner surface of the valves, and endowed with such power of contraction, that it is an impossibility to force them apart without injury. The places of attachment of these muscles (m, m') are generally visible, as well as other minor scars caused by the pedal retractor muscles. The point of attachment of the edge of the mantle, known as the pallial impression, is often quite distinct; it is parallel with the lower margin of the valves, and, in some groups, is more or less deeply sinuated (n) below the posterior adductor impression. All pelecypods are aquatic, the majority being marine. They are less numerous than gastropods in species, but in individuals are at present, as in past ages, relatively far more so. They are found at all depths, from low-water mark; many having been dredged in more than two thousand fathoms. Bivalves, however, are most abundant in shallow water. They live buried in the sand or mud, or attached to rocks and other substances, either by the shells themselves, or by means of a *byssus*, consisting of horny fibres secreted by a gland near the extremity of the foot. Others bore into rocks, wood, and other substances, and a few take up their abode in the tests of certain Tunicata, and in sponges, in the grooves of sea-urchins; and one species (*Entovalva*) lives parasitically inside a sea-cucumber. Dr. Pelseneer divides the class into five orders, based mainly upon the structure and morphology of the gills, but at the same time upon the general conformation of the animal. To explain in detail the differentiating anatomical characteristics of these orders would be beyond the scope of the present work, and consequently only salient features can be mentioned.



LEFT VALVE OF *Meretrix.*

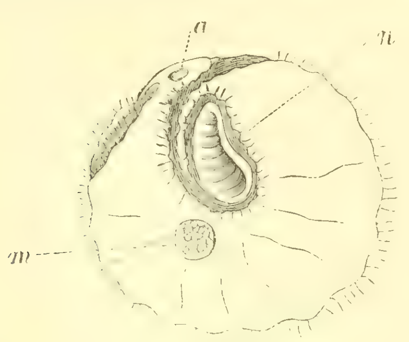
a, Anterior; *b*, Posterior end; *c*, Umbo; *d*, Ventral margin; *m'*, Anterior adductor scar; *m'*, Posterior; *n*, Pallial sinus.

Order PROTOBRANCHIATA.

In these bivalves the gills have simple unreflexed filaments, disposed in two rows in opposite directions; the foot being expanded, with crenulated margins, and with scarcely any byssal gland. The families *Nuculidæ* and *Solenomyidæ* constitute this order. The molluscs belonging to the former are all marine; and have the mantle free all round, or forming two small posterior siphons. The gills are small, but the labial palpi very large. In the typical *Nucula* the shell is small, more or less triangular, generally covered with a greenish olive periostracum without a pallial sinus, and pearly within. The hinge is composed of numerous pointed interlocking teeth on each side of the cartilage-pit beneath the umbones. Unlike *Nucula*, the genus *Nuculina* is provided with two small adjacent siphons. The shell is usually somewhat produced or beaked posteriorly, has a slight pallial sinus, and is not pearly within. The hinge-teeth and the resilium are as in *Nucula*. *Yoldia* is like *Nuculina* in shape, but has longer siphons, and the periostracum more glossy. The shells of *Malletia* are like those of *Yoldia*, but the ligament is external. *Nucula* and *Nuculina* have a world-wide distribution, and are numerously represented in species. *Yoldia* and *Malletia*, on the contrary, have comparatively a few representatives in Arctic, Northern, and Antarctic regions. The fossil forms belonging to this family are far more numerous than the recent, and include several generic groups which no longer exist. In the second family, *Solenomyidæ*, the animal is remarkable for its proboscis-like foot, expanded at the end into a flattened disc with a dentate edge. The mantle is united ventrally, but open in front for the passage of the foot, and posteriorly for the siphons. The shell is elongate, compressedly subcylindrical, without hinge-teeth, and clothed with a thick dark chestnut-coloured horny periostracum, which, when dry, is very brittle. Only about six species of one genus, *Solenomya*, are known, but these are widely distributed, being found in the Mediterranean, on the east coast of North America, in Patagonia, the Indian Ocean, Australia, and New Zealand.

Order FILIBRANCHIATA.

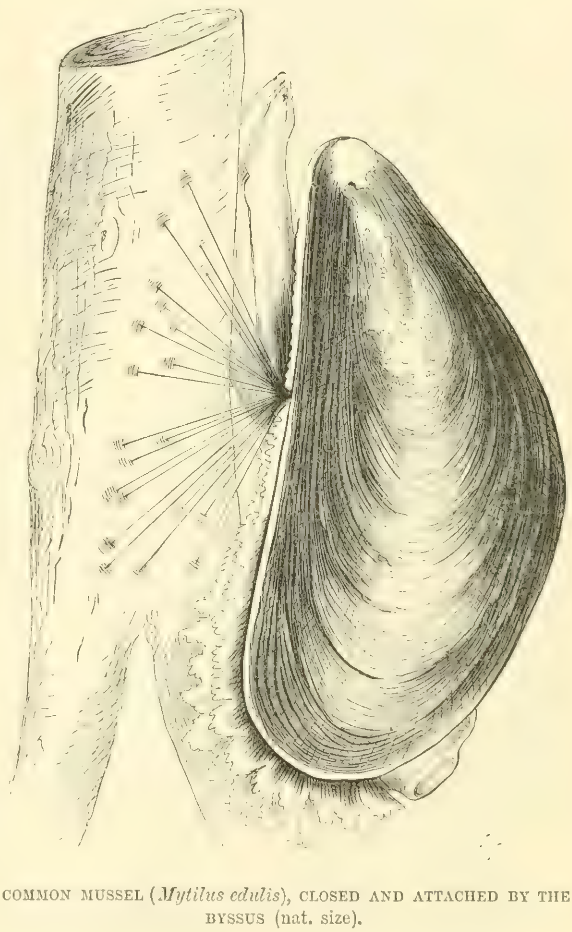
In this group the gills are smooth and their parallel filaments are directed ventrally, reflexed, and provided only with ciliated interfilamentary junctions; the foot being usually furnished with a byssal gland. In the family *Anomiidæ* the shells of the typical genus *Anomia* are generally very irregular in their growth, inequivalve, and somewhat pearly within; the more convex valve being remarkable for the large number of muscular impressions, and the flat valve for a perforation near the hinge. This aperture is for the passage of a calcified byssus (n), by means of which the mollusc attaches itself to rocks and stones. The animal has a small foot; the mantle is free all round, and there is but a single central adductor muscle (m). About forty species are known, two of which occur in Britain. *Placuna* is another genus of this family, in which the shells are very flat, without any byssal opening; the valves being thin, somewhat nacreous, with two long divergent hinge-teeth to which the ligament is attached. About half a dozen species from the Indo-Pacific Ocean are known. *P. sella* has a somewhat wavy or cockled appearance, and is known as the saddle-oyster, on account of its saddle-like form. The arks (*Arcidæ*) are nearly all strong heavy shells, generally equivalve, but in



RIGHT SIDE OF *Anomia*, WITH SHELL REMOVED.

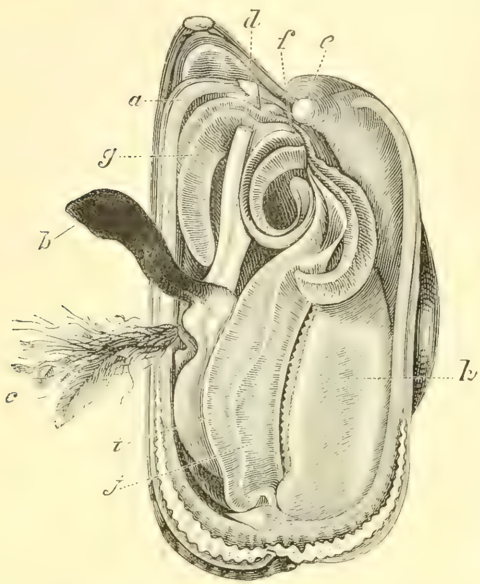
a, Opening for hinge; *m*, Adductor muscle; *n*, Calcified byssus.

some instances more or less inequivalve; and always remarkable for their straight hinge-line, furnished with very numerous teeth. The form is variable; but the valves are generally radiately ribbed, and more or less covered with a periostracum, which may be smooth and thin, or thick, and very rugged. They may either meet all round when closed, or may gape ventrally for the passage of a byssus. There are two adductors far apart, and the pallial line is simple. The species—both recent and fossil—are very numerous; and at the present time occur in all seas, some having a very wide distribution. For instance, the little *Arca lactea*, which is found on the British coast, also occurs in the Philippine Islands, the Red Sea, South Africa, Ascension Island, and the Mediterranean; and another species (*A. corpulenta*) has been dredged off North Australia, south of Amboyna, in Mid-Pacific, and off the coast of Chili, in depths ranging from two hundred to two thousand four hundred and twenty-five fathoms. In the allied *Pectunculus* the shell is rounded, strong, equivalve, with the hinge-teeth in a curved line; the outer surface being sometimes covered with a velvety or pilose periostracum. *Limopsis* somewhat resembles *Pectunculus* in form, but the shells are more compressed and clothed with a fibrous periostracum, and the animal spins a byssus. Several of the species have been dredged at enormous depths in the Atlantic. The genus *Trigonia*, represented by about half a dozen species occurring on the shores of Australia, is all that now remains of the large family *Trigoniidæ*, of which several other genera, with a very large number of species, occur fossil in the Secondary and Tertiary rocks. The valves of *Trigonia* are beautifully pearly within, equal, radiately ribbed, with an external ligament, and a few strong striated divergent hinge-teeth. The umbones are inclined posteriorly—a very unusual feature in bivalves. The foot of the animal is large and powerful, used in crawling and leaping, and without a byssus. In some of the Jurassic rocks of Weymouth trigonias form a bed several feet in thickness. Mussels (family *Mytilidæ*) are such well-known shells that a description is unnecessary. They are found all over

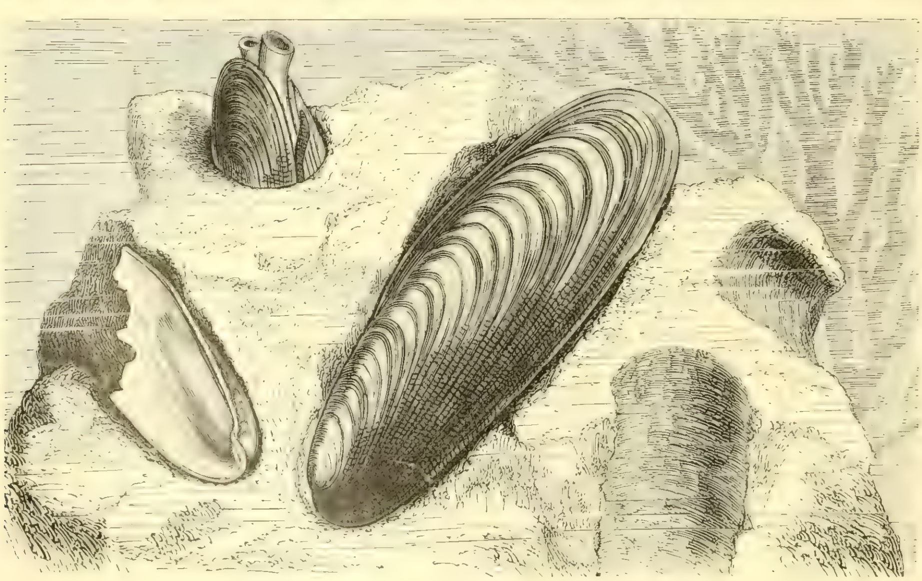


COMMON MUSSEL (*Mytilus edulis*), CLOSED AND ATTACHED BY THE BYSSUS (nat. size).

the world; one very large species from the shores of California sometimes reaching fully 9 inches in length. They anchor themselves by a byssus, but also have the power of moving from place to place, by casting off the byssus, extending the foot in the direction they determine to proceed, and attaching a byssal thread, which supports the animal while the foot is again extended and another thread spun. This process is repeated again and again, and thus progress is made. The structure of the animal may be understood by observing the accompanying illustration, where *a* represents the edge of the mantle; *b*, the foot; *c*, the byssus; *d.e*, the foot-muscles; *f*, the mouth; *g*, the labial palpi; *h*, mantle-lobe; and *i.j*, the inner and outer gill-plates. To the same family belong the date-shells (*Lithodomus*), which, as shown in the accompanying illustration, are stone-borers. The shells are date-like, thin, and covered with a yellowish or brown periostracum. The boring is chiefly effected by the foot. The columns of the temple of Serapis at Puteoli are perforated by a species of these molluscs, at a point far above the present sea-level, thus showing that these



COMMON MUSSEL, OPENED TO SHOW THE VARIOUS ORGANS (nat. size).

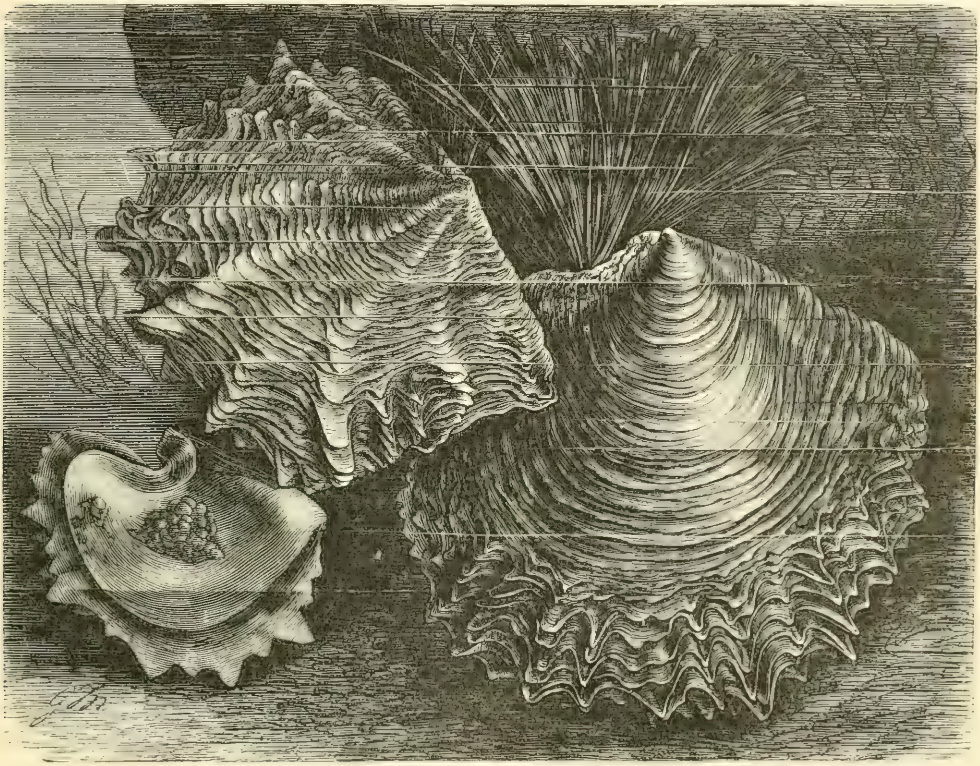


DATE-SHELLS IN THE ROCK (nat. size).

ruins must at some time have been submerged, and that the coast has changed its level within historic times at several epochs.

Order Pseudolamellibranchiata.

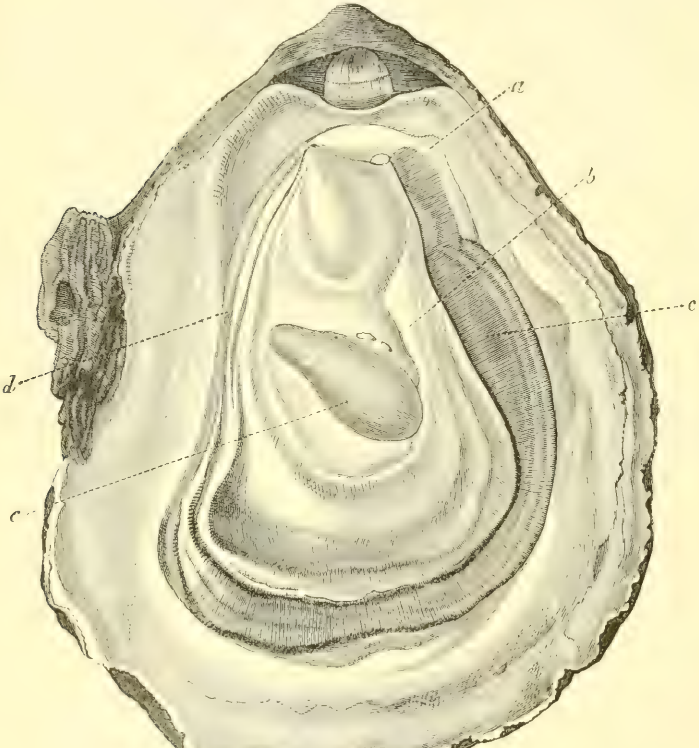
The gills in this order are folded, and their filaments furnished with conjunctive or vascular interfoliary junctions; the mantle being free all round, and the foot small or absent. *Aviculidæ, Prasinidæ, Ostreidæ, Pectinidæ. Limidæ, Spondylidæ,* and *Dimyidæ* are the families constituting this order. The first family (*Aviculidæ*) is of importance as including the pearl-oysters. The shells are mostly compressed, but vary much in outline. In the typical genus *Avicula* the shell is oblique with a straight hinge-line, more or less produced into wings, which



PEARL-OYSTERS ($\frac{1}{2}$ nat. size).

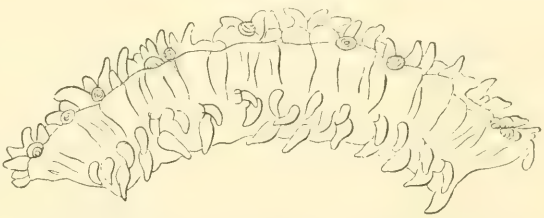
are sometimes long and slender. In the pearl-oysters, *Meleagrina*, there are, however, no wings, and in the case of *M. margaritifera* the shells become very thick and heavy. This species is one of the principal pearl-producers, and is largely collected by divers off the north coasts of Australia and other places, not only for the pearls which they may contain, but also for the shells themselves, which are valuable as mother-of-pearl. Until recently, the fishery was carried on by native divers, but now the diving-dress is largely employed. The Ceylon pearl-oyster, *M. fucata,* is much smaller than the Australian species. This fishery has been carried on for over two thousand years, and the accumulation of shells is so enormous as to extend for miles several feet deep. The shells are thin and of little use as mother-of-pearl, consequently they are thrown away, after being examined for pearls. Pearl-fishing is also carried on in the Persian Gulf, the South Sea Islands, Panama, West Indies, and a few other localities. The spherical pearls, like the shell itself, are produced by the mantle, and probably other parts of the animal also. They consist of layers of pearl, deposited round some foreign substance which has intruded itself within the shell. This may be a grain of sand, but is said to be usually an egg of the mollusc itself, which has not properly developed. The hammer-oyster (*Malleus*), *Vulsella, Crenatula*, and *Melina* are other interesting existing forms of *Aviculidæ*, and many extinct genera have been referred to this family.

The shells of the oysters (*Ostreidæ*) are so familiar that no description is necessary. The animal has no foot, and the mantle-lobes are free nearly all round, the borders being fringed with short papillæ. The shells, excepting in the very early stages, are closed by a single adductor. The sexes are separate in the American oyster (*Ostrea virginiana*), but united in the British *O. edulis*. In a gastronomic point of view the oyster stands far above all other molluscs, and its artificial cultivation was practised by the ancient Romans, and at the present time forms a most important industry in many parts of the globe. The oyster is very prolific, a single individual of the common species having been estimated to contain over a million embryos, whilst the American form is said to discharge ten times as many. *O. edulis* is not full-grown until about five to seven years old. Oysters are incapable of motion, and attach themselves to other shells, rocks, and other substances by the convex or deeper valve. During May, June, and July, the eggs are discharged into the gills, where they remain until hatched; and it is during this period that oysters are out of season. Oysters are cosmopolitan; wherever there is a rocky coast, excepting in Arctic climates, they are sure to

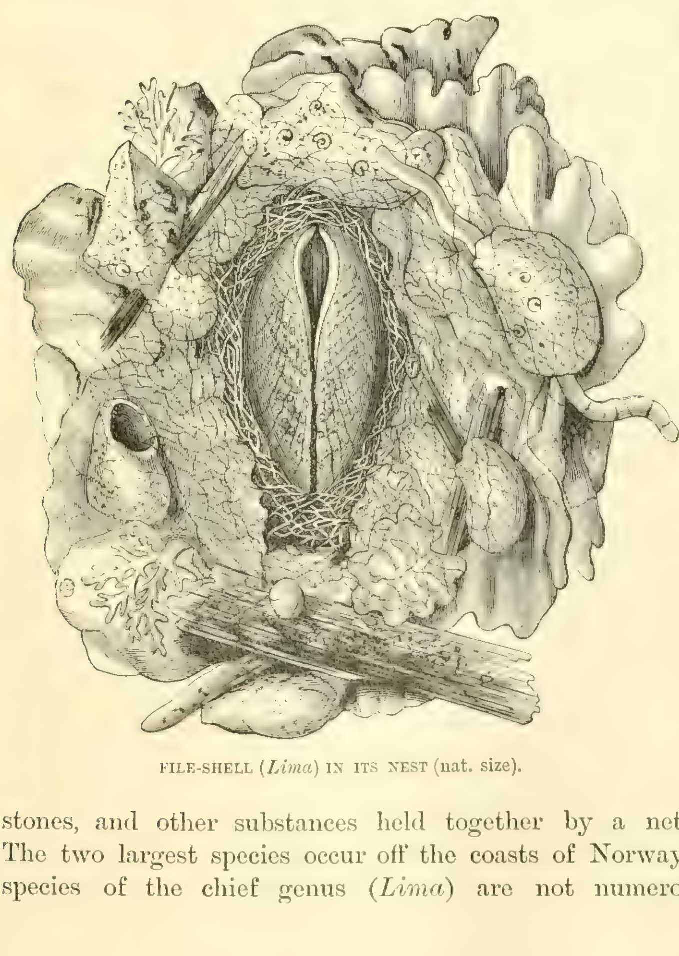


ONE VALVE AND SOFT-PARTS OF COMMON OYSTER.
a, Position of mouth; *b*, Mantle; *c*, Adductor; *d*, Junction of mantle-lobes; *e*, Gills. (Nat. size.)

be found. They are irregular in their growth, and consequently the determination of the species is a matter of difficulty. The pectens or scallop-shells (*Pectinidæ*) are remarkable for the variety and beauty of their coloration and sculpture. In most species the shells are nearly equivalve; but in a few, of which the common edible scollop is an example, the right valve is convex, and the left flat. One species (*Pecten jacobæus*) of the Mediterranean was worn as a badge by pilgrims who had been to the Holy Land. Most of the pectens are ornamented with radiating ribs, but a few are smooth. Some swim freely by flapping their valves, others live permanently attached by a byssus. The animal has the mantle free, and frequently bears a row of brightly coloured eyes on the margin. The foot is small, the gills are extremely delicate, and the single adductor muscle in the adult is excentric. They are generally hermaphrodite, but sometimes the sexes are separate. More than a hundred species from all parts of the world and all depths have been described. Ten occur on the British coasts, and fossil species are numerous in all formations, from the Carboniferous. The file-shells (*Limidæ*) somewhat resemble the scallops, but are nearly always white, and the edges of the mantle, which have no eyes, are furnished with long tentacular filaments. Some swim freely by flapping their valves, others attach themselves by a byssus, or, as in the accompanying figure, construct a nest of broken shells, stones, and other substances held together by a network of byssal threads. The two largest species occur off the coasts of Norway and Japan. The recent species of the chief genus (*Lima*) are not numerous, and some occur at



MARGIN OF MANTLE OF PECTEN, SHOWING TENTACLES AND EYES (somewhat magnified).



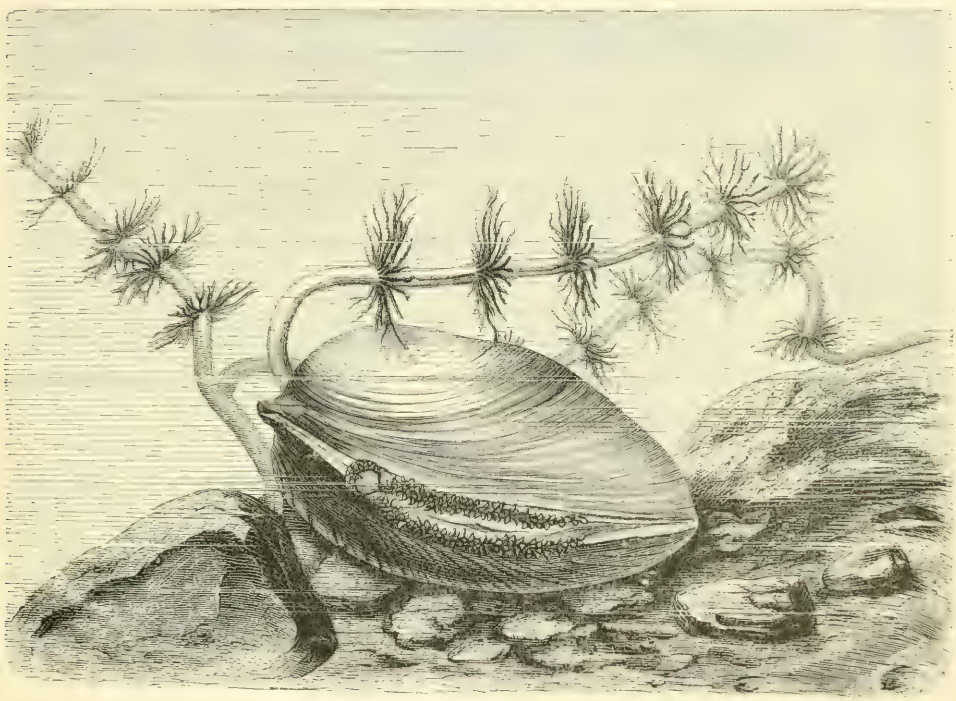
FILE-SHELL (*Lima*) IN ITS NEST (nat. size).

great depths. The fossil forms, on the contrary, are more abundant, from the Carboniferous age, and some of the species from the Lias (*Plagiostoma*) are of very large size. The members of the allied family *Spondylidæ* are known popularly as thorny-oysters, on account of the spiny character of their surface-ornamentation. In general shape they are rather like the pectens, and similarly brilliantly coloured; but they have much more solid shells, and the hinge consists of powerful interlocking teeth, while the animal has no byssus, a more rudimentary foot, and lives, with a few exceptions, attached by one of the valves to rocks and stones. The ligament of *Spondylus* is internal. The single adductor muscle is a little excentric, and the mantle-margin has a row of eyes.

Order EULAMELLIBRANCHIATA.

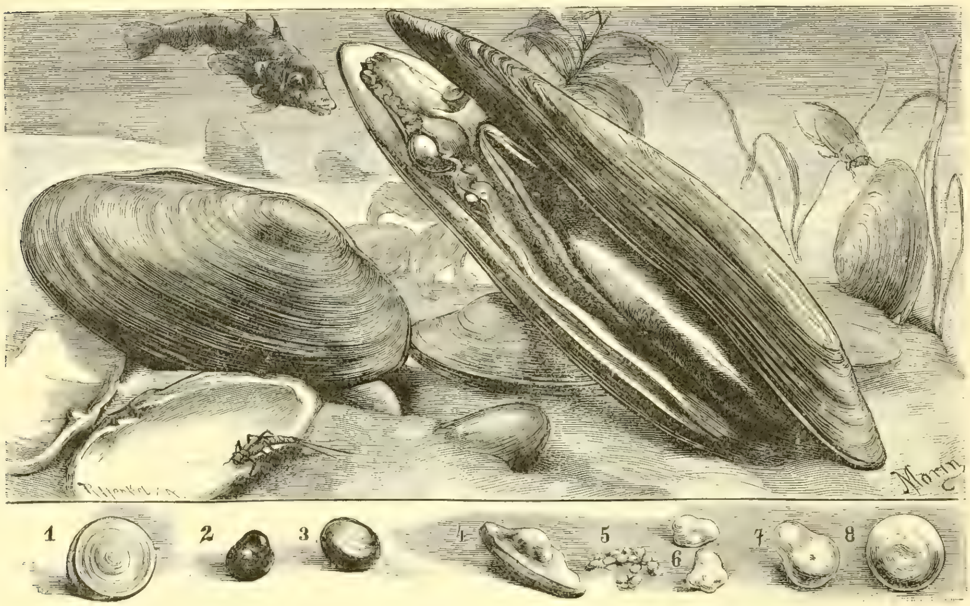
In this order the gills have vascular, interfilamentary, and interfoliary junctions; and the mantle is always united at one or more points, and there are generally two adductor muscles. The order is the largest of all, and comprises nearly sixty different families, of which only the most important or remarkable can be mentioned. In the first (Submytilacea) of several suborders into which the order is divided, mention may be made of a curious little species of the family *Carditidæ*, namely, *Thecalia concamerata*, which is a native of South Africa, and remarkable for a cup-like process formed by the female within the ventral margin of the valves, serving as a nursing-pouch for the young. *Milneria minima*, a Californian species, forms a similiar marsupium. In the family *Cyprinidæ*, *Isocardia cor* is one of the finest of the British bivalves; and is a large strong globose shell, with the umbones prominently curved anteriorly. The ligament is external, and the hinge-teeth are strong and of peculiar form. The animal has short siphons, large gills, and a small foot for burrowing in the sand. In the *Lucinidæ* the shells are mostly white, round, globose, or compressed, and peculiar on account of the great length of the anterior muscular scar, which falls within the uninterrupted pallial line. Sometimes the animals have only a single branchial lamella, and the foot is generally slender and without byssus. The families *Leptonidæ*, *Galeommidæ*, and *Chlamydoconchidæ* also belong to this order. *Lepton* often lives commensally with Crustacea, *Galeomma* has the mantle reflected over a considerable part of the valves, and in *Chlamydoconcha* the shell is wholly covered by the mantle, a unique feature among the bivalves. The family *Ætheriidæ* includes a few remarkable bivalves known as fresh-water oysters. They occur in the Nile and some other rivers of North Africa, and some parts of South America. When young, *Ætheria* is a freely creeping mollusc, but when adult becomes attached to stones and other substances like the oyster. The shells are irregular in their growth, and are of an olive-green colour. The somewhat pearly interior of the valves is marked with two adductor scars, and the pallial line is entire. They may be regarded as irregular forms of *Unionidæ* without a foot, modified for a sedentary life.

The numerous kinds of fresh-water mussels (*Unionidæ* and *Mutelidæ*) occur in the lakes and rivers of all continents, and the large islands of the Malay Archipelago and New Zealand; although in most of the smaller islands they are unknown. North America, and especially the drainage-area of the Mississippi and its tributaries, is the great home of the *Unionidæ.* The species may be counted by hundreds, some being the most remarkable and beautiful that exist in any part of the globe. The shells are usually equivalve, and joined by an external ligament, but exhibit great variation in shape. The hinge is sometimes destitute of teeth (*Anodonta, Mycetopus*); or powerfully formed with strong complex interlocking teeth, as in many of the North American forms; or it may consist of very numerous teeth on a straight hinge-line (*Pliodon*), recalling the form of hinge obtaining in the *Arcidæ.* The exterior is covered with a thick, often glossy periostracum, varying in colour, the prevailing tints being



LARGE RIVER-MUSSEL, *Anodonta cygnea* (nat. size).

greenish olive, brownish yellow, brown, and black. Many are beautifully rayed with green. The solidity of many of the species—especially the North American forms—is remarkable, although others are thin and fragile. Some are pearly within, and others white, pinkish purple, salmon-colour, yellow, or iridescent. The shells are marked with two adductor scars, and the pedal scars are also often clearly visible, while the pallial line is uninterrupted by a posterior sinus. The animal of *Unio* has the lobes of the mantle free, excepting posteriorly, where they are connected, forming two orifices, the lower or branchial for the passage of the water to the gills, and the upper for excretal purposes. The former is fringed with several rows of papillæ. The foot is large, thick, tongue-shaped, and used as a creeping and burrowing organ. The sexes are united in the European species, but distinct in the American. A remarkable feature in connection with the *Unionidæ* is the parasitic life of the early stages. The eggs, after being hatched between the gills of the parent, and having undergone the first stages of development, subsequently develop into minute bivalves, each valve having a hook-like process on the front edge, and are expelled from the brood pouches. They at once attach themselves to some extraneous object, by means of a byssal thread, and at this stage are known as *Glochidia.* They attach themselves, as soon as possible, to the gills and other parts of fishes, by means of the valve-hooks, and there complete their metamorphosis, finally quitting their host, sinking to the bottom, and assuming the parent form. Four species are found



PEARL-MUSSELS (*Unio margaritifer*), SHOWING PEARL WITHIN THE SHELL, AND DETACHED PEARLS (1–8).

in Britain, one of which (*Unio margaritifer*) is famous for the pearls it produces. Some of the rivers of Scotland, and the Conway in North Wales, have always had a great reputation for their pearl-fisheries. Although not equal in lustre to the Oriental jewel many of these river pearls are beautiful. Unlike *Unio*, the *Dreissensiidæ,* as represented by *Dreissensia*, have the mantle-margins united ventrally, with an anterior opening for the slender foot and byssus, and prolonged posteriorly into two siphons. The shell is shaped like the common marine mussel. The European *D. polymorpha* was first noticed in England about seventy years ago, and is supposed to have been introduced attached to Russian timber.

Suborder **Tellinacea.**

This group includes the families *Tellinidæ, Scrobiculariidæ, Donacidæ, Mactridæ, Mesodesmatidæ,* and *Cardiliidæ,* the first of which is the most extensive, and contains the most beautiful forms. Here the animal is remarkable for the great length of the slender separated siphons, the fringed mantle-margins, and large labial palpi and foot. The shells are nearly always compressed, subequivalve, joined by an external ligament, and furnished with hinge-teeth. The scars of the adductors are far apart, and the pallial impression is generally very deeply sinuated. None of the bivalves are more beautifully coloured than the tellens, the prevailing tints being purple-red, crimson, and various shades of yellow. The surface-sculpture of the valves is often beautiful and delicate. Tellens live in sand or mud at slight depths in every sea, and the species may be counted in hundreds. Nine species of *Tellina* are British. The *Scrobiculariidæ* form a smaller and less showy family than the preceding, the shells being united by an internal ligament, and sometimes by an external one also. The soft-parts are like those of the *Tellinidæ*. Some species of the genus *Abra* have been dredged at enormous depths, both in the Atlantic and Pacific, but the majority of the family have been obtained in comparatively shallow water. The British *Scrobicularia piperata* buries itself in the mud of estuaries, and can extend its siphons five or six times the length of its shell. Although in some respects the wedge-shells (*Donacidæ*) agree with the *Tellinidæ*, they differ as regards the gills. In *Donax* the shells are of a triangular or wedge-shape, and have the inner margin of the valves crenulated. They are united by an external ligament, and furnished with cardinal and sometimes lateral teeth. The wedge-shells live buried in the sand in shallow water in warm regions all over the world, and three species occur on the British coasts. The genus *Iphigenia*, which has no lateral teeth, inhabits estuaries on the coast of Africa, Brazil, the West Indies, and Central America. In the mactras (*Mactridæ*) the shells are often more or less triangular, and have an internal ligament, the siphons being united the entire length, and fringed at the ends. About one hundred and fifty species of *Mactra* are known. They occur on sandy shores in most parts of the world at shallow depths, six being British. This family comprises a large number of genera and subgenera, mainly distinguished by modifications of the hinges; *Mulinia*, *Spisula*, *Standella*, *Rangia*, *Ræta*, and *Eastonia* being the more important. The remaining familes, *Mesodesmatidæ* and *Cardiliidæ*, are not of special importance, and may be passed without further reference.

Suborder Veneracea.

In the *Veneridæ*, which form the first family of this group, the animal has rather short, more or less united siphons, with fringed openings. The mantle is open in front for the passage of a tongue-like foot, which is sometimes furnished with a byssus. The shells are solid, equivalve, and often beautifully coloured and sculptured, with the hinge-teeth large and divergent, and the ligament external. In the typical genus *Venus* the shells are more or less circular, globose, and often have the surface cancellated, and the inner edge of the valves crenulated. There are several British forms of *Veneridæ*, but none are eaten to any great extent. On the contrary, the large *Venus mercanaria*—the clam of the Atlantic States of North America—is sold in large quantities in the fish-markets of New York and Philadelphia. In *Dosinia* the shells are more compressed, circular, and marked within with a deep, narrow, pallial sinus. In *Circe*, on the contrary, the mantle-impression is unsinuated. The shells of *Tapes* are longer than the typical forms; the foot is long, grooved, and frequently furnished with a byssus, the siphons being separate at the ends and beautifully fringed. They are most abundant in the warm seas of the Eastern Hemisphere, but four species range as far north as England. The large species of the allied genus *Cyrena* are found in brackish water at the mouths of rivers, and in mangrove-swamps; while the smaller forms known as *Corbicula*, *Sphærium*, and *Pisidium* occur in fresh water in most parts of the world. The shells of the last two groups are very similar, but the animals are readily distinguished by the number of the siphons. In *Sphærium* there are two which are united at the base, but separated at the extremities, whereas in *Pisidium* only a single anal siphon is present. In this genus the water is conveyed to the gills through the pedal opening of the mantle. There are four British species of *Sphærium*, and five of *Pisidium*, all of which possess the faculty of floating in an inverted position at the surface of the water, or they suspend themselves from the surface by a fine byssal thread. One species (*P. pusillum*) does not require a constant, or even a frequent supply of water, often living at the roots of bog-moss and grass, and it has also been found between the bark and wood of fallen trees in moist places.

Suborder **Cardiacea**.

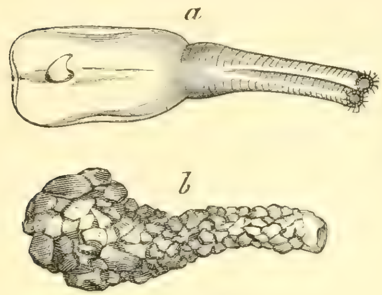
The *Cardiidæ*, *Tridacnidæ*, and *Chamidæ* are the principal families belonging to this suborder of which there are living representatives, but a few extinct families, such as the *Hippuritidæ*, are also considered to belong here. The cockles (*Cardiidæ*) abound in shallow water in most parts of the world, where there are sheltered sandy bays. Some of the exotic forms are beautifully sculptured, and their colours also are often very bright and varied. The animals have short fringed siphons, and the long foot is bent and used for leaping. Probably many are eatable, like the common cockle. In addition to this kind, nine species are found on the British coast. The typical species of *Cardium* have the convex valves ribbed, the ribs interlocking at the margins. In *Lævicardium* the shells are smooth, in the beautiful *Cardissa* they are flattened, heart-shaped, and keeled at the sides. The true clams (*Tridacnidæ*) differ from other bivalves with united mantle-margins in having only a single adductor muscle, like the oyster, the anterior being obsolete. The mantle has three distant openings, pedal (*d*), branchial (*a*), and anal (*b*). The foot is small, finger-like, and capable of producing a stout byssus (*e*). The shells are equivalve, ponderous, with a few stout ribs radiating from the umbones, and

VALVE AND SOFT-PARTS OF *Tridacna*.

terminating on the edge of the valves in pointed projections. The genus *Tridacna* contains the largest of all bivalves, *T. gigas* sometimes measuring more than a yard in length, and weighing as much as 500 lbs. The animals are gorgeously coloured, and a mass of them nearly a mile in extent has been compared to a bed of tulips. The six or seven species are found in hot latitudes, such as the Red Sea, and Indian and Pacific Oceans. The adductor muscle is said to be good eating. *Hippopus* differs from *Tridacna* in having no gape in the anterior end of the shell for the passage of a byssus. *H. maculatus* is one of the most common shells used as ornaments. The *Chamidæ* are remarkable for their strong irregular oyster-like shells, which are often brilliantly coloured, and covered with spines or ridges like the thorny-oysters. The shells exhibit two well-marked muscular scars, strong hinge-teeth, and an external ligament. These bivalves inhabit tropical or subtropical seas, and are usually attached by one of the valves to rocks. The animal has the margins of the mantle united, excepting at the siphonal openings and the pedal orifice. To a mollusc leading a stationary life, and not given to spinning a byssus, a foot would appear to be useless; nevertheless *Chama* possesses a reduced form of this member, but what purpose it serves it is difficult to conjecture. Some of the fossil members of this family, *Diceras* and *Requienia*, for example, have remarkable shells, quite unlike those of the existing forms.

Suborder Myacea.

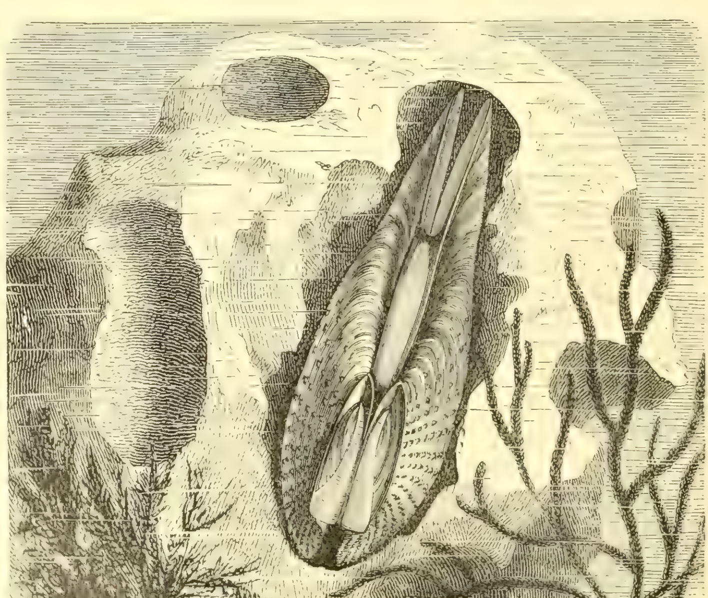
In the family *Psammobiidæ* the typical genus *Psammobia* has the siphons very long, slender, and separated as in *Tellina*, the foot large and tongue-like, and the edges of the mantle fringed. The shells are long and narrow, compressed, slightly gaping at both ends, generally somewhat obliquely truncate posteriorly, often brilliantly coloured, and beautifully sculptured. Four species occur on the British coasts. The gapers (*Myidæ*) take their title from their widely gaping shells, which are covered with a wrinkled periostracum extending also over the siphons; these being united their whole length, and fringed at the ends. *Mya arenaria*, a common British species, also abounds on the sandy shores and mud-flats of the Eastern States of North America, where it is eaten in quantities. The clams, as they are commonly called, live in deep burrows in the sand or mud, the shells often being a foot below the surface. A recent writer observes that when the flats are covered with water, the clams extend their long siphons up through the burrow to the surface of the sand, and through one of these tubes the water and its myriads of animalcules are drawn down into the shell, furnishing the gills with oxygen, and the mouth with food, and then the water, charged with carbonic acid and fæcal refuse, is forced out of the other siphon. Two species of *Mya* constitute the staple food of the walrus. The *Solenidæ*, or razor-shells, are also great sand-burrowers, and indeed bore with such rapidity, and to such a depth, that they often elude capture. They possess very elongate shells, and are remarkable for the great development of the foot. They not only burrow in sand, but also have the power of darting through the water like scallops. They are eaten by the poorer coast population. In the *Saxicavidæ* the species of the typical genus *Saxicava* are some of the few bivalves which have the power of boring into limestone and other soft rocks, although they more often hide in crevices or at the roots of seaweed, mooring themselves by a byssus. The shells are very irregular, their form varying according to the hole or crevice they inhabit. In the *Gastrochænidæ*, forming the last family of this group, *Gastrochæna* comprises bivalves which live buried in the sand. These form a long, slender, club-shaped fragile tube, covered with adhering particles of sand, and divided off by a partition into two portions, the anterior containing the shell, the posterior or narrower end the siphons. The animal of the allied *Rocellaria* is similar, but forms no tube, and has the habit of boring into solid rock, shells, and other substances; *R. dubia* being found in limestone, and even granite, on the British coasts.



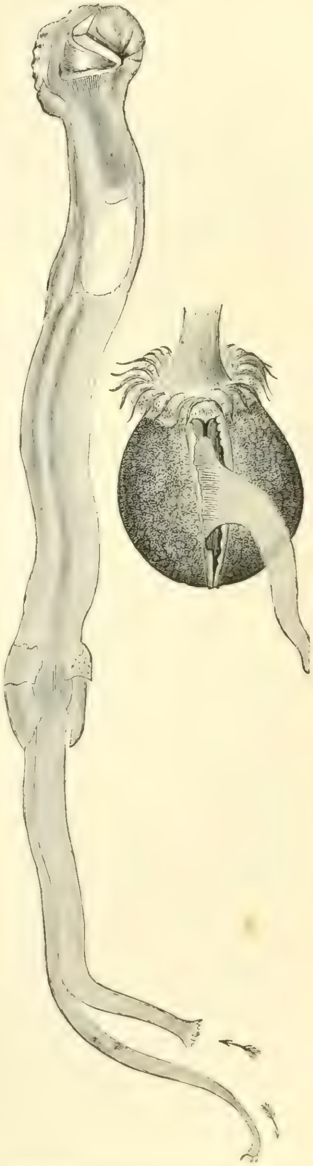
ANIMAL (*a*) AND CASE (*b*) OF *Rocellaria.*

Suborder Pholadacea.

The boring *Pholadidæ* and *Teredinidæ* are the only families contained in this suborder of the group, the former perforating clay, chalk, limestone, and even gneiss. Their shells are always white, thin, but hard and strong, and ornamented with prickly rasp-like sculpture. They gape all round the valves, meeting only at the hinge and the opposite margin. Accessory plates generally occupy the vacant spaces. The valves have no hinge-teeth, and are not connected by a well-defined ligament, like most bivalves. The animals have long united siphons, fringed at the apertures, and enclosed in a tough skin, which is often protected by cartilaginous cup-like processes. In the typical *Pholas* the foot is well developed, and probably forms the principal excavating instrument; the shell being used as a file to enlarge the crypt as the creature grows. *Xylophaga* and *Martesia* bore into floating wood. Species of this family are met with everywhere, and about half a dozen occur on the British coasts. In some parts of Europe *Pholas* is considered


Pholas IN ITS BURROW (nat. size).

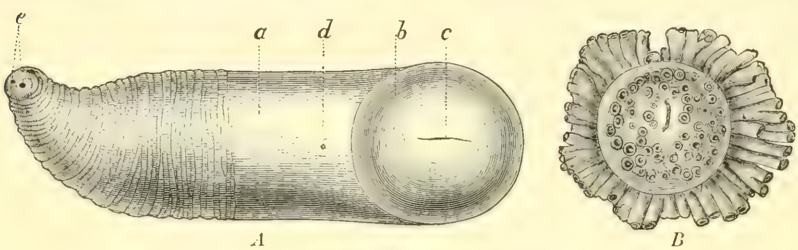
a delicacy, and many species are highly phosporescent. In the second family the ship-worm (*Teredo*) is only too well-known on account of the amount of damage it does to submerged timber. It matters not whether it be oak, pine, teak, or mahogany which it attacks, soon the timber is riddled through and through, and rendered useless. In former times, before the invention of copper-sheathing, immense damage was inflicted upon shipping, and the piles of piers and harbours were constantly having to be renewed through the ravages of this pest. The Dutch have been great sufferers, and at one time such depredations had been made on the piles which support the dykes of Zealand and Friesland as to threaten them with total destruction. The animal is practically nothing more than an extremely prolonged *Pholas*. The siphons are of immense length, in some cases from two to three feet long, united except towards the ends. On the contrary, the body itself containing the principal viscera is small, and protected by a globular, bivalved shell, open both in front and behind. The gills are narrow, elongate, and prolonged into the branchial siphon. The siphons secrete a shelly lining to the burrow, and at the point where they separate there are a pair of calcareous plates, or pallets as they are termed, probably used as a means of defence, in closing the tube after the siphons have been retracted. Ship-worms generally bore with the grain, only turning aside to avoid a knot or any other obstruction; and although their burrows are almost touching, they seldom appear to run into one another. The animal does not feed upon the wood it excavates, but ejects it in small particles through the siphon. The foot is probably the burrowing organ, but the method of excavation is still imperfectly understood. *Hyperotus*, *Nausitoria*, *Xylotrya*, and *Cyphus* are other forms of *Teredinidæ*; the last named constructing a strong, shelly tube, sometimes a yard long, and two inches in diameter, in which the creature lives buried in the sand.



SHIP-WORM (*Teredo*) AND ITS LARVA.

Suborder Anatinacea.

This, the last suborder of the Eulamellibranchiata, contains thirteen families of which only a few are of general interest. Of the *Pandoridæ*, the typical *Pandora* is distinguished by its compressed, internally pearly shell, which is sometimes semi-lunate in form; the right valve being flat, and the left somewhat convex. *P. inæquivalvis* is a common British species. In *Myadora*, an allied genus, the left valve is flat, and the right convex. The species of the third genus, *Myochama*, attach themselves to other shells by their right valve, the left being ornamented with radiating ridges. Among the other families, *Anatina*, *Thracia*, and *Pholadomya* are interesting genera, the last on account of its rarity in the living condition, and its numerous representatives in bygone ages. *Brechites*, or *Aspergillum*, is remarkable, as it is only in the earliest stages of existence that it presents the appearance of a normal bivalve. It subsequently forms an elongate tube, open at one end and closed at the other by a frilled disc full of holes, like the rose of a watering-pot; embryonic valves being embedded in the surface near the rose. The illustration shows the contracted animal extracted from the shell, (*e*) indicating the siphonal openings, (*c*) the mantle aperture, (*b*) the anterior side, (*a*) the mantle, (*d*) foot opening.



Brechites vaginiferus.
A, Animal contracted, withdrawn from shell; *B*, Anterior end of the shell.

Order Septibranchiata.

The members of this group are readily distinguished by the circumstance that the gills are transformed into a muscular septum, extending from the anterior adductor to the separation of the two siphons, and surrounding the foot, with which it is continuous. This septum presents symmetrical orifices. The siphons are sometimes short, or more or less produced. There are two adductors, and the mantle-edges are united at three points. There are two families, namely, the *Poromyidæ* and *Cuspidariidæ*. Of the former, *Poromya* has the siphons short, unequal, separate, and surrounded by a tentacular fringe; each half of the septum having several groups of lamellæ, separated by orifices; the foot being slender, long, and the palpi larger. The shells are often minutely granular and somewhat pearly within. The species are small, few in number, and mostly from very deep water. *Silenia* is a deep-water form, dredged in 1950 fathoms, about eleven hundred miles south-west of Australia, and also in the South Atlantic at the enormous depth of 2650 fathoms. The *Cuspidariidæ* is a more extensive family, and although the species are nearly all small, some are elegant in form, and prettily sculptured. The shells have been classified by characters derived from modifications of the hinge, and the surface ornamentation. The siphons are longer than in the *Poromyidæ* and united with tentacular fringes at the ends; the foot is moderately long and pointed, the labial palpi are rudimentary or wanting, and the branchial septum is pierced with isolated symmetrical orifices. The shells are mostly transversely ovate, and produced posteriorly into a more or less elongate rostrum. They are found in all seas, in depths ranging from a few fathoms to over three miles.

EDGAR A. SMITH.

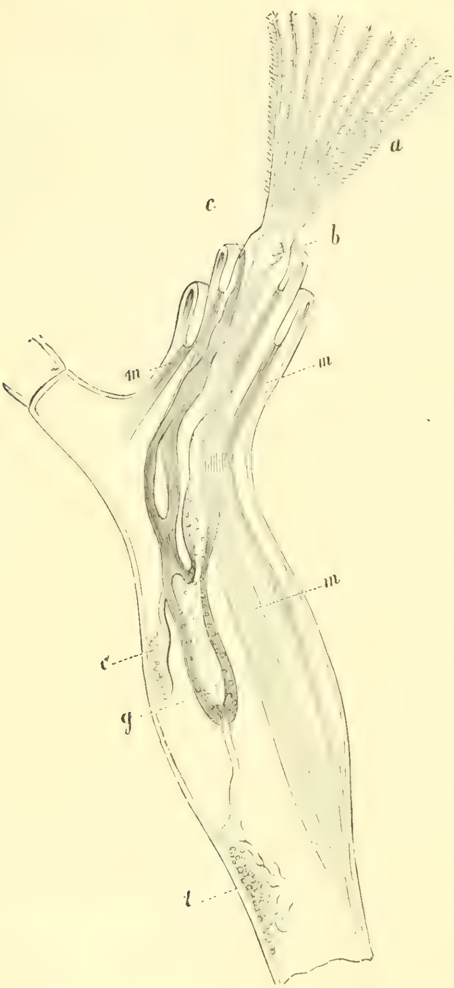
CHAPTER XII.

MOSS-ANIMALS AND LAMP-SHELLS,—Subkingdom **MOLLUSCOIDEA.**

THE exact positions in the animal kingdom of the Bryozoa or moss-animals, and the Brachiopoda or arm-footed animals, which are generally united under the name of Molluscoidea, is still far from settled. The Brachiopods were long placed with the Molluscs, and the Bryozoa with the Corals and Sponges; but fuller knowledge made it evident that the Bryozoa did not in any way belong to the latter. Next, they were classed with the Rotifers, or wheel animalcules, under the name of Ciliata, as a kind of appendage to the worms, while by others they were grouped with the Ascidians. They are here placed with the Brachiopoda, not because the two groups are really related, but simply because they are alike in having no established place in the classification of the animal kingdom. It is true that the Bryozoans and the Brachiopods are sometimes classed together because of the similarity of their development, and also for certain supposed anatomical resemblances between them; but these latter are far from convincing, and the similarity of their larval histories has been disputed.

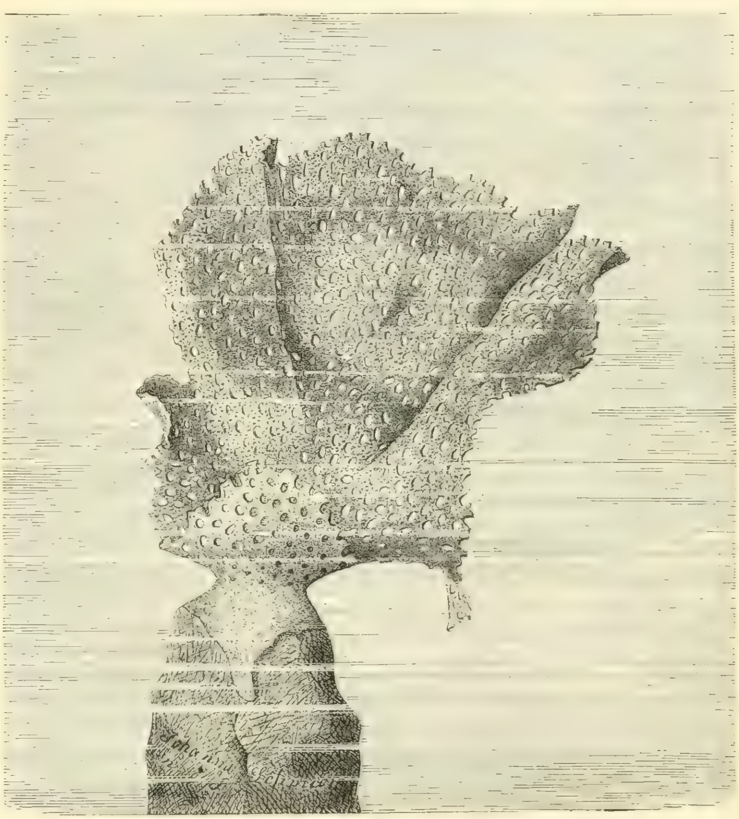
MOSS-ANIMALS,—Class **Bryozoa.**

The moss-animals almost always live in colonies, the individuals of which are joined in a number of different ways to form stocks. The individual animals are small, and the stocks generally also small, never forming anything approaching the masses of substance yielded by those of the corals. The structure of the Bryozoan animal can be studied in the accompanying figure, which shows, greatly magnified, the external outline and the inner organs of a single individual belonging to the stock of a fresh-water form (*Paludicella*) from Belgium. The individual figured has been detached at its base from the one below it, and the one next above is broken off. The body is represented by a chamber or cell, in this case somewhat elongated. Its walls are stiff, except at the anterior end, where they are flexible enough to allow the crown of tentacles (*a*) to be protruded as in the figure, or to be withdrawn by means of muscles (*m*). One of these muscles is seen to be specially powerful, and runs through nearly the whole length of the cell. The mouth is at the anterior end of the body, surrounded by the circle of ciliated feelers or tentacles (*a*). The alimentary canal, which commences with a muscular pharynx (*b*) hangs down in the form of a loop into the body-cavity, the stomach (*g*) being its lowest portion. Its terminal portion runs again towards the anterior end, so as to open not far from the mouth (at *e*). The whole alimentary tube is but loosely fastened to the body-wall, its chief attachment being by means of a single short strand at the end of the stomach called the funiculus, and shown in the illustration. In all adults, two masses of cells are found attached to the wall of the chamber, the upper (*o*) yielding eggs, while within the lower (*t*) the male elements develop. Moss-animals are therefore hermaphrodite, the fertilisation of the eggs being effected by the two elements mingling freely together in the body-fluid. In all essential points, the above description would apply to any one of the seventeen hundred species, fossil and extant, which are known.



SECTION OF AN INDIVIDUAL OF *Paludicella* (highly magnified).

Among the larger colonies may be mentioned certain fresh-water genera, found attached to the roots and branches of water-plants, which may form considerable masses; but these stocks are dull in colour and very inconspicuous, the beauty of the minute individual animals themselves being invisible to the naked eye. Some fairly-sized forms occur also among the marine genera, which are often marked by the great variety and beauty of their stocks. Many of these are delicate branching or tree-like growths some inches in height; take, for instance, the sea-mats (*Flustra*), or again, the still larger and more beautiful lace-corals, Neptune's sleeves, such as are shown on p. 421, which, in spite of their name, are not true corals but bryozoans. The figured lace-coral (*Retepora*) is found in the nets used on the shores of the Atlantic Ocean and Mediterranean Sea. When fresh, the stocks—which resemble a fine, cup-shaped, or folded and frilled piece of lace—seem to be covered by a reddish organic mass, out of which arise the delicate tentacular crowns of the individual animals. These are, however, too small to be seen, except with a magnifying glass. When the soft-parts are removed, the stock is of dazzling whiteness, consisting chiefly of the chalky substance which binds the separate individuals together into a colony. Between the open meshes of the lace-work, multitudes of minute apertures are to be seen, which are the openings of the individual chambers or cells containing the bodies of the animals, and into which they can withdraw their tentacular crown as above explained. Another lace-coral from the Mediterranean is shown on p. 422. It rests upon a branched structure, a common calcareous alga which grows on a stone. The individuals of this genus (*Lepralia*) are arranged in rows, and are further distinguished from *Retepora* and other moss-animals by the fact that the animals occur only on one side of the stock. We mention these lace-corals because of their being comparatively conspicuous; but we might have chosen any other of the many beautiful but less conspicuous forms. On any sea-coast a harvest of them can be gathered in a few days. Certain species are almost always to be found on nearly every leafy seaweed, and where the bottom of the sea is favourable, stones and the shells of molluscs, both full and empty, are covered with stocks of Bryozoa, often only discoverable by means of careful examination with a magnifying glass. Owing to the hardening and frequent calcification of the greater part of the body-wall to form the cell into which the anterior part that always remains soft can be withdrawn, these animals are often found as fossils. The marvellous variety of forms presented by these delicate little stocks is in each case determined by the particular manner of budding. The first animal which, by budding, gives rise to the stock is produced from an egg, and begins to bud as soon as it has become attached. In each family or species the buds appear at special points, and assume definite positions with regard to the parent individual. The smallest variation in this respect causes the profoundest changes in the forms of the stocks produced. Their classification is determined principally by the structure of the mouth and of the tentacle crown, as may best be gathered from a few examples. We take first the subclass Ectoprocta.

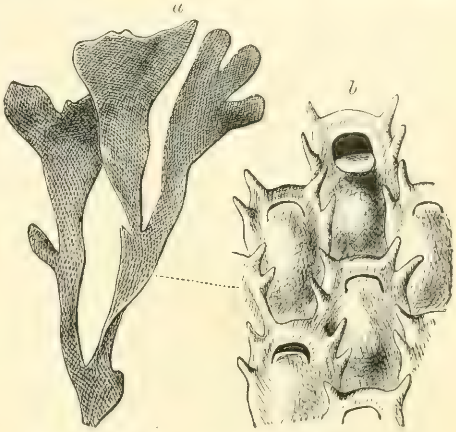


LACE-CORAL, OR NEPTUNE'S SLEEVE, *Retepora cellulosa* (nat. size).

Order Phylactolæmata. Most of the fresh-water moss-animals belong to the order Phylactolæmata, so-called because the mouth is provided with a tongue-shaped lid. The crown of tentacles, which is also a gill, is horseshoe-shaped, and the whole surrounded at its base by an integument forming a kind of calyx or cup. The chambers or cells are either quite soft or else horny, and are thus not found in a fossil condition. Later on in this volume is described a colony of sea-anemones which, instead of being fixed, as are most stocks, are able to travel about; a colony of moss-animals capable of locomotion is figured on p. 425. These remarkable moving types (*Cristatella*) form flattened, elliptical colonies, which creep along on a kind of flat foot, following the direction of the light. The question may be raised as to how the many separate individuals manage to move in the same direction. Even if an external stimulus, such as light, should stimulate the individuals in the same way, this seems hardly sufficient to account for the movement of the colony, without some nervous system connecting the polyps and co-ordinating the movements of the colony. As a matter of fact, such a system does exist. While each separate animal is provided with a nerve-ganglion between the œsophagus and the posterior opening of the alimentary canal (*c* in the illustration on p. 420), and with the nerves necessary for its own individual organisation, the Bryozoan colony, as such, has a special nervous system which is connected with the individual systems, and runs from one to another through the apertures by means of which also the body-fluids circulate throughout the colony. This colonial nervous system no doubt regulates the movement of the stock.

LACE-CORAL, *Lepralia* (nat. size).

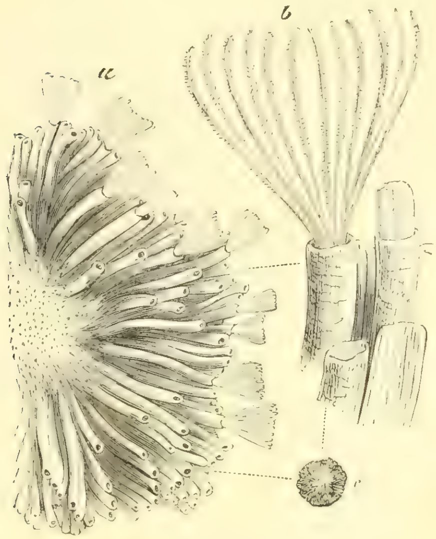
Order Gymnolæmata. In contrast to the Phylactolæmata are the Gymnolæmata, those Bryozoa in which there is no lid to the mouth, and in which the tentacles are arranged in a circle on a disc instead of in the shape of a horseshoe; the name given to such forms denoting the naked condition of the mouth. These naked-mouthed Bryozoans are far more numerous than those with lids to their mouths. *Paludicella*, which is fully described on pp. 419, 420, is one of the few fresh-water forms belonging to this order. Here the crown of tentacles cannot be completely protruded, and thus appears, even when most extended, to be surrounded by a double collar. A numerous group of this order are the marine Chilostomata, or lip-mouthed Bryozoa, of which the sea-mat (*Flustra foliacea*), common in the North Sea, is an example. The magnified cells shown in the illustration represent the harder portion of the animals, into which the soft anterior portions can be withdrawn. The openings through which the tentacles protrude lie crosswise, and each is provided with a lip-like elastic lid. Each individual can thus take refuge within its chamber and close the lid. Other genera which, unlike *Flustra*, have no lid, can close the aperture by means of muscles. The colonies of sea-mats form branched leaf-like lobes very common at the seaside, and often mistaken for seaweed. Each side of the leaf consists of a layer of closely crowded individuals. The cells only partly calcify, so that when fresh they are elastic, and the whole stock remains very flexible. To this suborder belong also *Retepora* and *Lepralia*, above mentioned.



SEA-MAT (*Flustra foliacea*).
a, Stock (nat. size); *b*, Five cells (magnified).

An important rise in the scale of organisation is found in the Gymnolæmata, especially in the lip-mouthed forms, where a marked division of labour takes place; that is to say, the individuals which constitute the stock vary in structure and fulfil different physiological functions. There are structures known as *zoœcia*, *stolons*, *avicularia*, *vibracula*, and *ovicells*, some—perhaps all—of which are modified individuals. The *zoœcia* are the normal individuals of the colony, fully developed for most of the functions of life; respiration, taking in food, and digestion, and no doubt also for receiving sensory impressions. The *stolons* have a much humbler function, but are indispensable for the well-being of the colony. They are rootlike outgrowths of the stock, consisting of very simple individuals which serve for attaching the whole colony to foreign objects, such as stones, shells, etc. The most remarkable are the structures known as *avicularia*, so called because they resemble the head of a bird. The individual is turned into a pair of forceps, of which the large upper blade (very like the skull and upper jaw of a bird) and the smaller lower blade (like the lower jaw) constantly open and shut by means of a complicated arrangement of muscles. These *avicularia* are movably attached by a short neck, and are found near the entrance to a *zoœcium*. They turn from side to side, snapping in all directions, and, no doubt, every now and then catch some of the small worms, crabs, or larvæ which rest on the colony. The victims are held till they decay, and, as they break down, fragments are drawn into the mouth by the water currents caused by the cilia on the tentacles. These dead creatures act as baits, and attract other victims within the influence of the same stream. These also are drawn into the mouth. On account of these peculiar structures, the Chilostomata have been called the bird's-head corallines. Equally interesting again are the *vibracula*, long thread-like structures, attached by short stalks, which keep up a constant whip-like motion. Their function is not clear; but perhaps they may be specialised tactile organs, or may help to drive the minute prey within reach of the nutritive individuals. Lastly, we have the *ovicells*, or egg-receptacles, which are found at the lower ends of the *zoœcia* in the form of bells, helmets, or vesicles. It is uncertain whether these are independent modified individuals or merely appendages of the *zoœcia*, the latter view being the more probable.

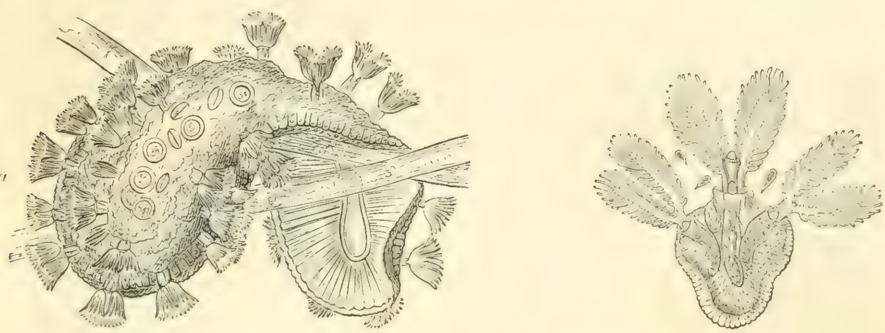
Round-Mouthed Group. Another suborder of the Gymnolæmata consists of the Cyclostomata or round-mouthed Bryozoans. In the tube-like forms (*Tubulipora*), which may be taken as typical of this suborder, the relation between the infolding portion of each individual and the rigid cell differs from that in the Chilostomata; and the aperture of the cell is terminal and wide, passing into the soft anterior end without narrowing. *Tubulipora* is one of the numerous round-mouthed forms, the stocks of which form cup-shaped incrustations, the individuals radiating outwards as seen in the magnified figure (*a*). In Fig. *b*, several cells are still more highly magnified. Fig. *c* shows the natural size of the colony.



Tubulipora verrucosa.

a, Part of a stock (magnified); *b*, A few cells (highly magnified); *c*, A stock (nat. size).

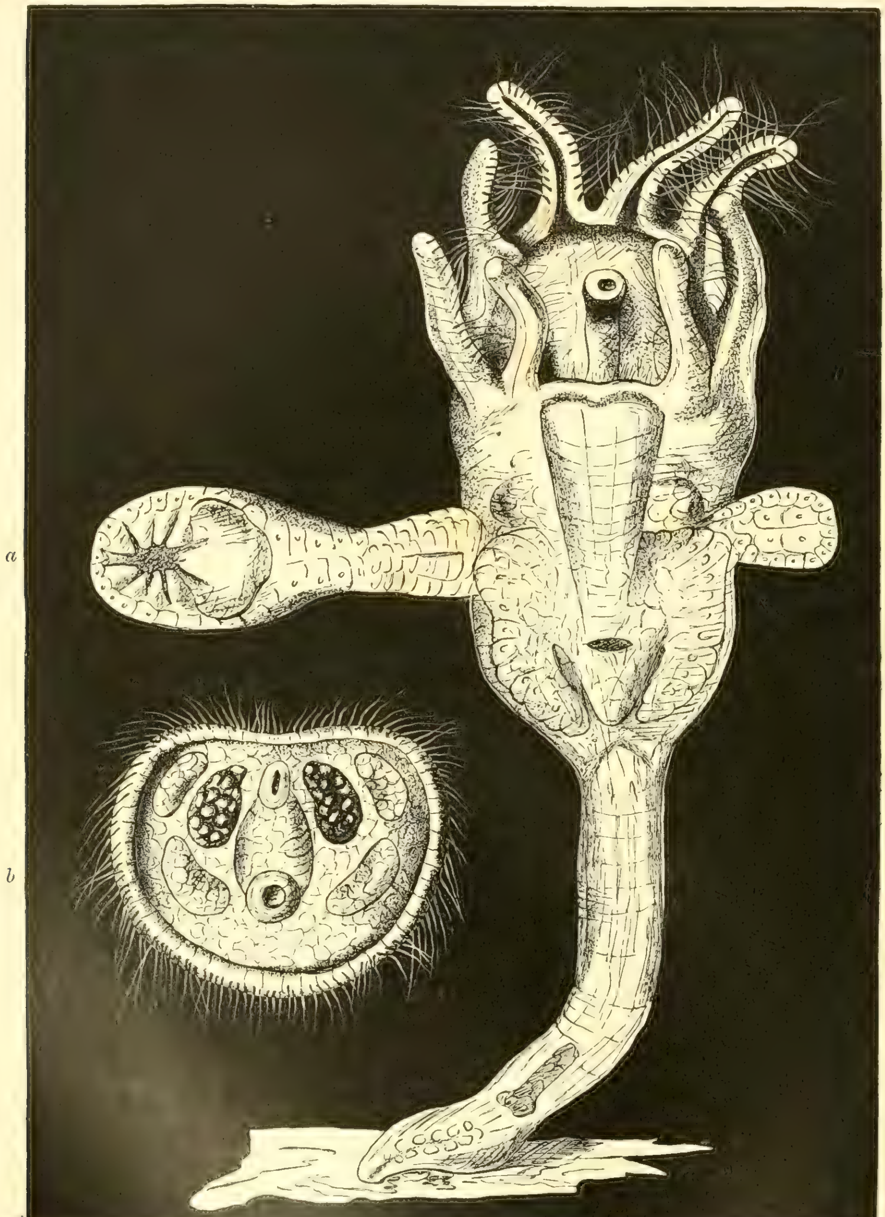
The moss-animals seem to be exceptionally rich in methods of reproduction. There is, firstly, the sexual reproduction above mentioned; secondly, the multiplication of individuals by budding and stock formation; and, thirdly, a peculiar reproduction, found in fresh-water forms, in adaptation to external conditions, enabling the animals to tide over the cold of winter, or the drying up of ponds, etc. This last method deserves description. It is effected by means of germinal bodies, which may be of two kinds. In the genus *Paludicella*, the germs are produced in the course of a few days at the end of September by simple constriction or breaking off of portions of the stock, which then perishes. These detached portions vary greatly in size, and resemble buds of the same size, which latter however remain connected with the stock. They are, in fact, detached buds, called winter-buds, which adhere to the dead remains of the horizontal creeping stem of the *Paludicella* stock, and the next spring either grow out at the same place into new colonies, or are swept away by the water to form fresh colonies at a distance. The other germinal bodies, termed statoblasts, form as cell-masses on the strand known as the funiculus, which holds the stomach in place, also at the end of September. They are round or oval in shape, and become surrounded by a peculiar horny transparent shell, which is brown or yellow in colour, and consists of two valves fitted one upon the other like watch-glasses. A number of these statoblasts may be seen inside the colony in the illustration on p. 425. The edge running round the two valves is often widened and contains small air-chambers, or else horny filaments which stand out radially and have barbed tips. This ring is termed the swimming-belt, and is a hydrostatic apparatus, which supports these winter-buds or statoblasts on the surface of the water. The complicated barbed hooks apparently act as anchors, by means of which the passively swimming statoblasts catch on at points suitable for their development during the course of the next spring. As soon as the time for development comes, the two valves split apart, and the germinal mass emerges from between them. Here, then, we have an alternation of generations. Out of the winter-buds and statoblasts asexually produced individuals arise, which then reproduce themselves sexually, their descendants again yielding winter-germs. The colony produced from the winter-buds may, however, continue for some time to multiply sexually, but in autumn again produces statoblasts. These processes taken together, namely, the growth of a Bryozoan colony by means of the budding of one individual out of another, the detachment of the winter-buds in *Paludicella*, the formation of the statoblasts, and the appearance of eggs, well illustrate the close connection existing between growth and reproduction.



a, *Cristatella* (double the nat. size); *b*, STATOBLASTS OF *Cristatella*, WITH THREE YOUNG ANIMALS (enlarged).

Subclass Endoprocta.

Systematists have hitherto found themselves compelled to add to the Bryozoa, or moss-animals, certain genera whose most striking peculiarity is that the posterior aperture of the alimentary canal lies within the tentacle-crown. These have been called Endoprocta, in contradistinction to the Ectoprocta, in which, as we have seen, the aperture of the intestine (*c* in the illustration on p. 420) lies outside the tentacle-crown. We take, as an example of the Endoprocta, the genus *Loxosoma*, which might well be called the spoon-animal, since, not only in *Loxosoma cochlear*, represented in the illustration on p. 426, but in most other species as well, the side view, especially when the tentacles are withdrawn, strikingly recalls a ladle. The body is attached to a stalk, and its anterior portion carries a circle of from eight to twelve tentacles, provided with double rows of long cilia. The mouth is at the lower edge of the disc which carries the feelers, while the posterior aperture of the digestive tract lies somewhat above the middle of the disc. The thick stalk is well provided with muscles, and is attached by means of its foot or sucker-like end, to the point chosen by the animal, so as to be fixed by the probably viscid secretion of a large pedal gland. The whole animal is more or less transparent, and leads a retired life in the sea, often hidden in the cavities of horny sponges. Although capable of slow locomotion, *Loxosoma* appears seldom to move from the place once chosen. It feeds on microscopic particles, brought by the stream of water kept up in the cavities of the sponge it inhabits. This food is conducted to the mouth by the cilia of the tentacles and by a ciliated furrow round the tentacle disc. The method of reproduction of this animal is remarkable. Two lateral buds are seen on the mother in the illustration on p. 426. The young animals quickly and without any metamorphosis attain the form of the parent, and may, even while attached to her, feed independently, only falling off when mature, and becoming attached in her neighbourhood. This is not, however, the only manner of reproduction. From time to time, without any interruption in the lateral budding, fertilised eggs ascend from the ovary towards the tentacle-disc, and develop into larvæ which in no way resemble *Loxosoma*



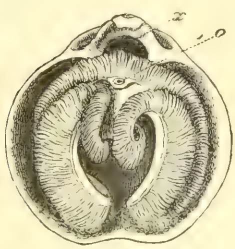
A FIXED MOSS-ANIMAL (*Loxosoma*) WITH LATERAL BUDS (×200). *a*, Stock; *b*, Swarm-larva (×100).

They have flat, almost shield-shaped bodies, surrounded by a ciliated margin. After breaking out through the disc of the mother, at the stage represented in the illustration, they pass through various changes before reaching the adult form.

The Lamp-Shells,—Class **Brachiopoda.**

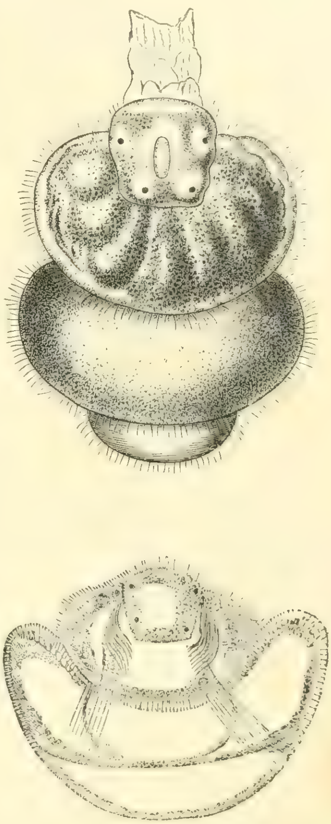
We must now leave the moss-animals, about whose relationship to the rest of the animal kingdom we know so little, and pass on to the equally enigmatical class of the arm-footed animals, or Brachiopoda. The chief structural feature in the Brachiopods which led to their being classed as molluscs, was their bivalve shell. They were therefore regarded as a subdivision of the bivalves. How easily a Brachiopod might be mistaken for a mussel will be understood by the reader who glances at the accompanying illustrations. But whereas the shells of the mussel are at the animal's sides, and close in front, behind, and below, the hinge being on the back, in the Brachiopods one shell is on the back and the other underneath. There are, in addition, other profound differences in the anatomy of the soft-parts. A further argument against there being any relationship between the Brachiopods and the mussels is found in the fact that no intermediate forms exist which could facilitate the deduction of the one class from the other. On the other hand, many zoologists are inclined to consider the Brachiopoda to be modified worms, a view confirmed by their anatomy. Although there is little to record of the activities of these creatures, they are worthy of attention, not only on account of their structure, but also from their extraordinary stability. With regard to this latter point they are almost unique in the animal kingdom (if we omit the lowest unicellular organisms), in having remained essentially unaltered from the earliest geological epochs. They have neither progressed nor degenerated, but have lived on practically at a standstill, so far as organisation is concerned. The period in which they flourished most is now long past. Not only in the number of species, but also in the number of individuals were they once so rich that thick layers of rock have been built up by their accumulated remains. Brachiopods are divided into two orders; those having shells without hinges, and those with shells hinged together. Taking the latter order (Testicardines) first, a few of its most important families may be described.

Hinged Group. At the present time, the most widely spread group are the *Terebratulidæ* or perforated Brachiopods, to which *Terebratulina*, figured on p. 428, belongs. In all species of this family, the dissimilarity of the two shell-valves is strongly marked, one valve being larger than the other, more concave, and perforated at the beak. The hole through the beak in this family resembles in some cases the hole for the wick in an ancient lamp, and has thus led to the name lamp-shells being applied to all Brachiopods. Through the perforation a short sinewy stalk emerges, by means of which the animal attaches itself to submarine objects. The hinge at the beak consists of a pair of teeth situated on the larger valve, and fitting into depressions in the smaller valve. Thus, although these shells do not possess an elastic band or ligament, like that which binds together the shells of a mussel, they are prevented from falling apart. The valves are shut and opened by means of muscles. In consequence of the position of the animal and of its organs, the larger more concave valve has been called the ventral valve, and the smaller the dorsal valve or lid. The most remarkable feature in these ancient forms is the looped calcareous framework attached to the under surface of the lid near the hinge, and running forward towards the gape of the shell. The differences in the forms of this framework are used for distinguishing the families and other subdivisions of the Brachiopoda. Its form and extent can be made out in well-preserved fossil specimens. These two spirally coiled appendages are the "arms," from which the class takes its name, and deserve a little closer description. The illustration below represents the under surface of a valve of the serpent-headed *Terebratula,* near the back of which the mouth opens (*o*). The arms rise on each side of the mouth, run forward, bend back again, to end in an elegant coil. We may compare them to the crown of tentacles and other organs associated with the mouth of many worms, and of the moss-animals, only here they are stiffened by a calcareous skeleton. As can be gathered from their rigid calcareous frame, they are capable of only slight movement, and even their fringes are more or less stiff. As to the functions of these arms, inasmuch as they are traversed by canals, and covered with cilia, we are justified in assuming them to be gills. The animals feed on fine particles brought to the mouth by the streams of water set up by the cilia on these gills. In only one genus (*Rhynconella*), belonging to the family of the *Rhynconellidæ,* do the arms themselves project beyond the shell to seize prey. The alimentary canal is short, and ends blindly at *x*. The body of the animal within the shell is enveloped in two mantle-folds closely applied to the shell; the latter being formed by a secretion from the outer surface of this mantle. Very simple reproductive organs lie in vessel-like widenings of these mantle-folds. The sexes are separate, and may sometimes be recognised by differences in the form of the shell. A pair of membranous funnels, internally ciliated, serve as ducts for the genital products; the free ends of these funnels open into the body-cavity, and conduct the reproductive elements outwards. The resemblance of these funnels to the nephridia of worms, would hardly be enough to establish a relationship between the Brachiopods and the worms. Their relationships rest rather upon the developmental history of the Brachiopods and the transformations they undergo. The first stages in the development of *Thecidium* are briefly as follows. The developing eggs enter a pouch formed by the lower mantle-fold, into which also the two nearest arm-fringes sink. These latter become thicker, their ends swelling to form a pair of pads, round which the eggs group, and to which each embryo is attached by means of a short stalk. The embryo soon resembles a short thick annelid. The upper process from its neck is the stalk by means of which the embryo is attached to the arm-fringe. The small anterior section resembles a head, and carries four eye-spots and a depression, the future mouth. There are two thicker middle segments, followed by a fourth smaller segment, all covered with cilia. In the later development the most posterior part is used for attachment, the head and collar-like ring sink between the upward growing portions of the following ring. These upward growths increase and form the two mantle-folds. These, as above stated, secrete the shell. The illustration (*b*), shows the young *Thecidium* withdrawn into itself, having given up the free-swimming life it led after breaking away from its parent.



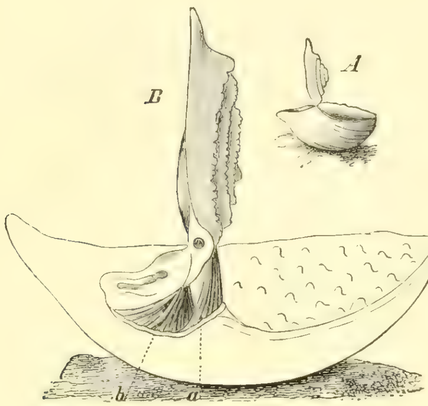
BACK VALVE OF *Terebratulina,* SHOWING THE ARMS.

The developmental transformations of another genus, *Argiope*, are very instructive. Its larva may not only be compared with that of a bristle-worm: it is in reality such a larva. No further development, however, occurs in this direction, but rather a degeneration. It becomes transformed into a creature which has no resemblance to an annelid. The posterior end changes into a stalk, by means of which the animal is permanently attached, while the bivalve shell protects the otherwise defenceless body. In this case we can witness the degeneration of an animal in its own development. It begins as if it were going to be a highly developed worm, which seems to show that its ancestors were once such worms, but it disappoints us; instead of advancing in organisation, it suddenly drops back into the lowly creature described. Off the coast of Norway, the serpent-headed *Terebratulina* is found everywhere in small numbers, at a depth of from thirty to one hundred and fifty fathoms, often attached to the coral *Oculina*. When placed in sea-water, they gradually open their valves; those specimens which remain attached to foreign objects show a great disposition to move about at the ends of their stalks. Detached specimens can be moved about without causing the animal to close its valves. If some of the protruded cirri be touched, they are at once withdrawn and the valves snap together, but soon open again. When the arms are withdrawn the cirri are bent inwards, but when the valves open the former are seen to raise themselves into an upright position; even before the shell was opened a few cirri were often protruded and waved to and fro, as if to ascertain whether any danger threatened. An inflowing current of water can sometimes be observed between the two rows of cirri.



STAGES OF DEVELOPMENT OF *Thecidium* (magnified).

Another form, *Waldheimia cranium*, is found near the North Cape, at a depth of from twenty-five to one hundred and fifty fathoms, attached to stones or barnacles. The calcareous framework in *Waldheimia* is long, and the oral appendages are incapable of movement unless it be at their spirally coiled ends. It has been conjectured that the two coiled ends can be unrolled and rolled up again like the proboscis of a butterfly. These animals are more active than *Terebratulina*, frequently moving about on the ends of their stalks and being more easily alarmed. The cirri do not project beyond the edge of the shell, and are bent back when it is closed. The genus *Thecidium*, whose development is described above, is distinguished by the very peculiar calcareous framework of its arms; one of its few living representatives being the unstalked *T. mediterraneum*, figured on p. 430. In this form the dorsal valve forms an almost flat lid for the much larger ventral valve, and is seen in the figure standing wide open at right angles to the lower shell. The calcareous framework nowhere rises freely from the lid, with which it is connected by a calcareous network. In the section (*B*) given in the illustration we see in the dorsal valve the depression for the hinge on which the valve rotates. The shell is opened by the muscles (*b*) which run from the bottom of the ventral valve to a process directed backward in the dorsal valve behind the hinge. It is closed by the muscles marked *a*, which lie in front of the hinge. The shells of *Thecidium* become attached to submarine objects, and are brought up in considerable numbers by the nets of the coral-fishers between the Gulf of Bona and Cape Rosa, from a depth of from forty to fifty fathoms. The number of specimens of *Terebratula* is small as compared with that of *Thecidium*, twenty to thirty specimens of the latter being often found together. When first caught, *Thecidium* opens its valves very wide, but when isolated and placed in small vessels gapes less widely. The small dorsal valve or lid can be raised to form a right angle with the other valve, but, when the slightest movement is made, it snaps to with the speed of lightning. These lamp-shells are undoubtedly sensitive to light, even a shadow thrown upon them making them close their shells instantly. On account of the wide gape, the inner organs, such as the cirri and arms, can be accurately observed. The inner surface of the shell on which the mantle lies is so dazzlingly white, and the latter so transparent, that the calcareous framework and the prominences on the valve are as easily seen as if there were no intervening mantle. Externally, the shell is rarely white and smooth, being usually covered with plants or animals which have attached themselves to it, and the valves perforated in all directions, chiefly by boring sponges.



Thecidium mediterraneum. *A*, Nat. size ; *B*, Section through the shell (magnified).

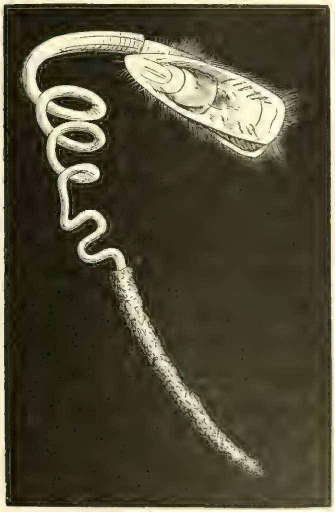
The *Rhynchonellidæ*, or beaked Brachiopods, were extremely numerous in the oldest geological times, but are now only represented by some three genera. The most important genus is *Rhynchonella*, which is one of the oldest and most widely distributed of all known organisms, being found from Silurian times through all subsequent strata. The living *R. psittacea* shows best the characteristic beak-like process of the ventral valve ; the aperture for the stalk being found under this beak. The valves are fastened together as in the *Terebratulidæ*, but the calcareous framework consists merely of two short, narrow plates, which are attached to the smaller valve. *Rhynchonella* is not very numerous in northerly regions, but empty valves are found in mud. Observations on the living animal are rendered difficult by the fact that it is peculiarly sensitive to all disturbance, and closes its valves at the slightest movement. The arm-spirals widen sufficiently to allow the cirri to reach the edge of the shell; the arms do not appear capable of unrolling and protruding beyond the shell. The members of another family of this order of hinged Brachiopods, the *Spiriferidæ*, are rendered very remarkable by the long, spirally-coiled and calcified arms. *Spirifer* was very abundant in the Palæozoic epoch, but died out with the Lias.

Hingeless Group.

The second order of the Brachiopods (Ecardines), or those whose shells are without hinges, consists of but four families, two of which may be briefly described. The unstalked genus *Crania* is widely distributed, both geologically and at the present time. Its structure is so peculiar that it forms a family by itself (*Craniidæ*). The shell is attached to some submarine object by the ventral valve; the dorsal valve is lid-like, and the two valves connected, not by a hinge or interlocking processes, but simply by muscles. The best-known of the four living species (here figured) of the northern seas, is almost always found in company with *Terebratulina*, which, however, it does not follow into the seas of Northern America.

UPPER VALVE AND ANIMAL OF *Crania* (magnified).

The last family to be described, the *Lingulidæ*, is also one of the most interesting. It existed in the oldest fossiliferous strata, and is still found living chiefly near the shores of the warmer seas. It may be regarded as perhaps the very oldest of the Brachiopods. Indeed, if we may look upon the hinge which characterises the other order as a specialisation, the hingeless forms are clearly the older and more primitive. The shell of a *Lingula* is thin and horny, almost flexible, and green in colour. The valves are almost exactly similar, and, as we have seen, they are not hinged together; and, further, they have no processes for the support of the thick, fleshy spiral arms. No living *Lingula* is now found in European seas, but *L. pyramidata* occurs on the American coasts, and another, *L. anatina*, in the Philippines. The stalk of the former, which is nine times as long as the body, does not become attached, but moves like a worm, and again, like certain worms, makes tubes out of sand into which it can withdraw. The *Lingulidæ* generally live in holes in mud, the bottom of which is lined with sand. The shell-covered body projects above the mud to open and feed; on being alarmed, it shuts and disappears below the surface. The cilia at the mantle-edge form a fine sieve which prevents foreign particles from entering the gills. The length of life of *L. pyramidata* is not more than a year. The simplicity of the shell of *Lingula*, which may best be compared with the cartilaginous structures at the anterior end of a chætopodous annelid, and its occurrence in the oldest strata in which Brachiopods are found, seems to justify the conclusion that it stands nearest of all the class to the worm-like ancestor.



Lingula pyramidata (nat. size).

H. AND M. BERNARD.

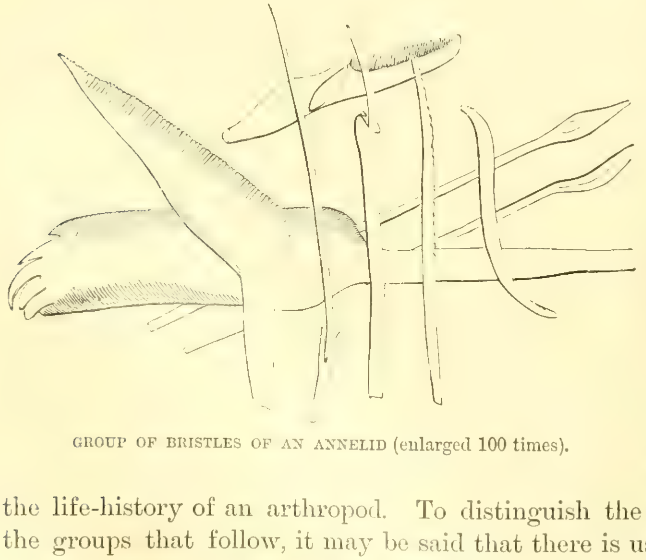
CHAPTER XIII.

The Worm-Like Animals,—Subkingdom **VERMES.**

Although it is convenient to have a single group in which to include the various kinds of worm-like animals, it has been frequently pointed out that there is no natural sanction for such an arrangement, and that it is highly probable they ought to be divided into several subkingdoms. Accordingly, the present division of the animal kingdom must be regarded as a convenient receptacle in which to place such Invertebrates as cannot be readily assigned to any of the other subkingdoms. This being so, it will be evident that it is only possible to describe this assemblage of heterogeneous elements by stating that the various classes into which it is divided resemble each other in the negative feature of not possessing the characters distinctive of any of the other groups.

Bristle-Worms, or Annelids,—Class **Annelida.**

The more highly organised members of this group show unmistakable points of affinity with the arthropods, such as *Apus* amongst the Crustacea, and *Peripatus*, which approaches the Centipedes. It is possible, however, to mention certain characters, which, so far as known, serve to distinguish the bristle-bearing worms from the arthropods. In the worms the jaws, when present, are not modified appendages, but are merely horny skeletal pieces developed from the walls of the front end of the alimentary canal; the appendages, when present, are not segmented, but merely unjointed processes of the sides of the body, and certain parts of the body are ciliated, or beset with fine hair-like threads, such threads being seldom found at any stage in the life-history of an arthropod. To distinguish the annelids or chætopods from the groups that follow, it may be said that there is usually a distinct prostomium, or lobe in front of the mouth, that definitely arranged bristles are implanted in

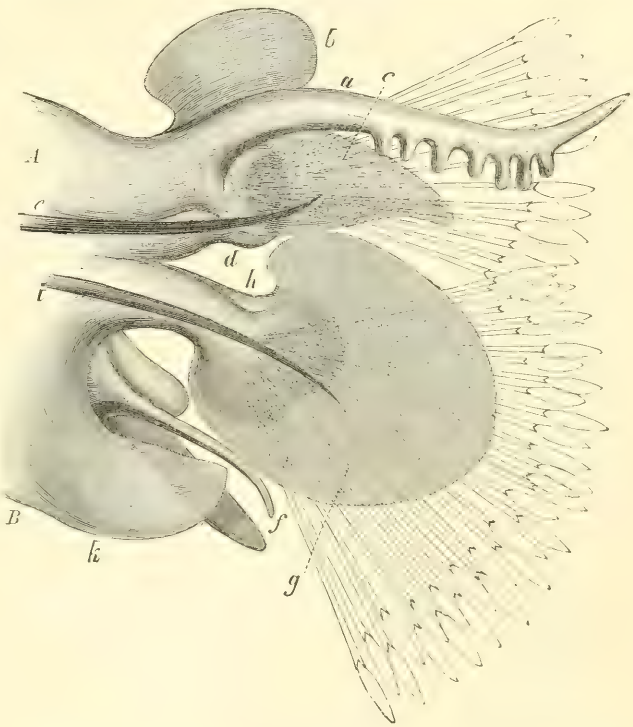


GROUP OF BRISTLES OF AN ANNELID (enlarged 100 times).

the segments of the body, and that the latter are defined externally by transverse grooves, and internally by septa or partitions, which divide the body-cavity into a series of compartments.

Many-Bristled Group,—Order Polychæta.

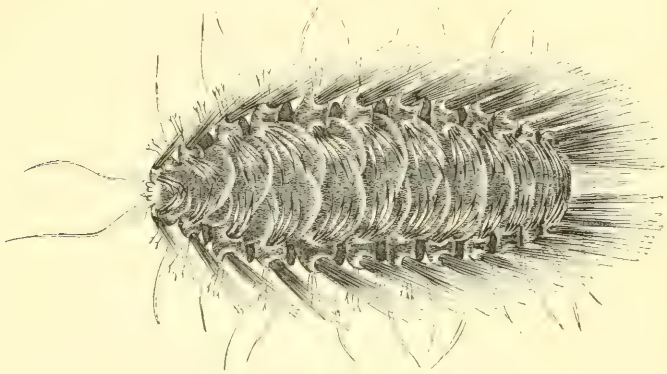
The Annelids of this order live exclusively in the sea, and may be referred to two sections or suborders, the one being the wandering or roving species, which have no fixed abode (Errantia), while the other sedentary forms live habitually in tubes which they construct for the purpose. In the former of these two suborders in accordance with the free roving life, the front end of the body is furnished with a conspicuous lobe, or prostomium, overhanging the mouth, which bears eyes and feelers. Those forms that are carnivorous seize their prey with sharp-hooked teeth, visible at the end of the proboscis. The structure of one of the parapodia is shown in the accompanying figure. It consists of two principal branches, an upper (*A*) and a lower (*B*), each being supported by a long stout bristle (*e*, *i*). The branches are further divided into several well-defined parts. For instance, in the upper there is a conspicuous feeler or sensory cirrus (*a*), and a bilobed leaf-like plate (*b*, *c*), from the lower lobe of which



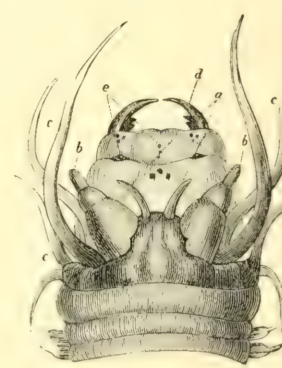
PARAPODIUM AND BRISTLES OF A POLYCHÆTOUS ANNELID, *Heteronereis œrstedi* (much enlarged).

(*c*) projects a cluster of arrow-shaped bristles. Analogous parts may be recognised in the lower branch, *f* being the feelers, at the base of which is the leaf-like plate (*k*); while the larger leaf-like plate (*g*) supports a second and larger tuft of similarly-shaped bristles. A well-known example of this group is the sea-mouse of the British shores (*Aphrodite aculeata*), a broad-bodied, somewhat slug-shaped creature, commonly 3 or 4 inches in length. Like many of the species of marine worms the sea-mouse is ornamented with iridescent hues, revealed by cleansing the skin of the mud and sand with which it is usually coated. The back is furnished with a double row of large overlapping scales, but in the British species these scales are concealed by a close felt of hairs, although in another kind

(*Hermione hystrix*), common in the Mediterranean, this coating of hairs is absent, and the scales are exposed, as shown in the accompanying illustration. In spite of their thick armature of spines, all the sea-mice are greedily devoured by fish of various kinds, such as cod, haddock, and dog-fish. Another well-marked family is that of the *Nereidæ*, in which the predatory character, coupled with ceaseless activity, rapidity, and sureness of movement reaches its highest expression. The head of the particular species (*Nereis incerta*) represented in the illustration shows two pairs of feelers (*a* and *b*), as well as several pairs of longer organs of the same nature (*c*), situated at the sides of the head. On the thrust-out and upturned proboscis may be noticed the two strong, sharp-toothed jaws (*d*) as well as several smaller horny teeth (*e*). In the worm named *Heteronereis*, which is shown at *A* in the next illustration, one of the chief peculiarities is that the segments in the hinder half of the body are not so high as those in front, and that they are furnished with far longer bristles, whereas in *Nereis* all the segments are alike, being constructed on the same plan as those of the front half of the body of *Heteronereis*. The exact nature of the connection between these two marine worms does not appear to be understood. The latter, however, seems to be a stage in the development of the former; but not an invariable stage, since adult examples of *Nereis* produce young sometimes like themselves, and sometimes like *Heteronereis*. Allied to the *Nereidæ* is *Palolo viridis*, of the Samoa Islands. Of this species Stair and Powell write that "every year the animal appears during October and November in countless numbers at different spots on the coast; but the second swarm is even greater than the first. . . . Both swarms seem to make their appearance on the day before the last quarter of the moon, and on this day, but especially on the day of the last quarter itself, the crowd of them is so inconceivably great that the sea, even far from the shore, seems to consist of nothing else. The worms appear with the dawn of light, and their number is at its height by sunrise, but after two or three hours all have vanished." Curiously enough this mass of worms seems to be composed entirely of living fragments, entire examples being never met with.

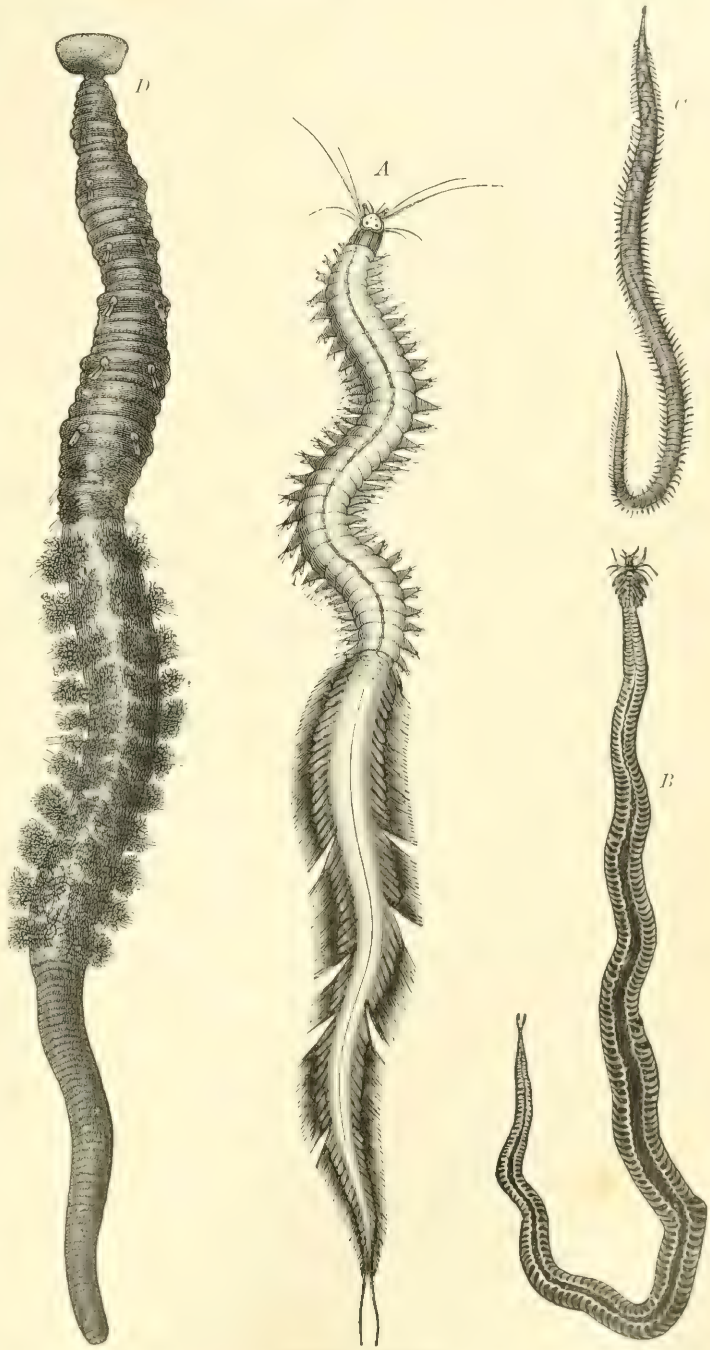


SEA-MOUSE, *Hermione hystrix* (nat. size).



HEAD OF *Nereis incerta* (enlarged 4 times).

Two more types of roving predatory worms are shown in the same illustration. Of these, *Phyllodoce laminosa* of the French and English coasts has as many as three hundred to four hundred segments, and may measure as much as 2 feet in length; the parapodia are flattened and leaf-like. During the day these animals lie quietly in their hiding-places, but come forth at twilight to swim about in search of prey, when the whole body, supported and in part propelled by the parapodia, executes the most graceful wave-like movements. *C* shows a species of the genus *Glycera*, a comparatively dull coloured form, which habitually lies hidden in sand. These worms make their burrows by means of their relatively colossal proboscis, which is studded with numerous little warts and teeth. From the genus *Glycera* there is naturally a passage to the sedentary group (Tubicola) of polychætous annelids, and we may take as our first example the sand-worm (*Arenicola piscatorum*), represented of the natural size in *D* of the illustration. This worm reaches a length of about 8 inches. Individuals vary, however, much in colour, according to the nature of the mud or sand in which

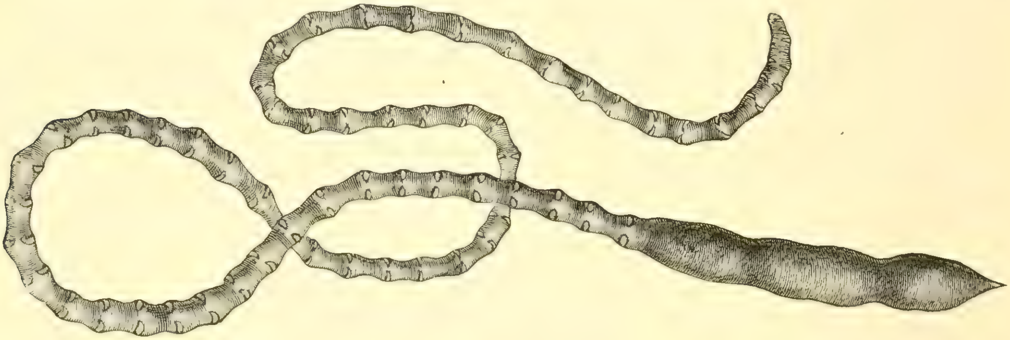


VARIOUS ANNELIDS.

A, *Heteronereis* stage of *Nereis*; *B*, *Phyllodoce laminosa*; *C*, *Glycera*; *D*, Sand-worm or lug-worm, *Arenicola piscatorum*. (All nat. size.)

they are found; those living in clean sand being of a light tint, whereas black specimens frequent slimy sand, strongly impregnated with decaying organic matter. The segments of the body are not all alike; those at the front end being furnished with a few small, widely-separated tufts of bristles arranged in pairs; then follows a series in which the clusters of bristles are large, bush-like, and close together; while the end of the body is cylindrical and without bristles and parapodia. The goblet-shaped organ, shown in the illustration, projecting from the head is the protruded proboscis. This worm, which is found on all the coasts of Europe, is used by fishermen as bait. At low water, on some sandy shores, it may be found in vast numbers.

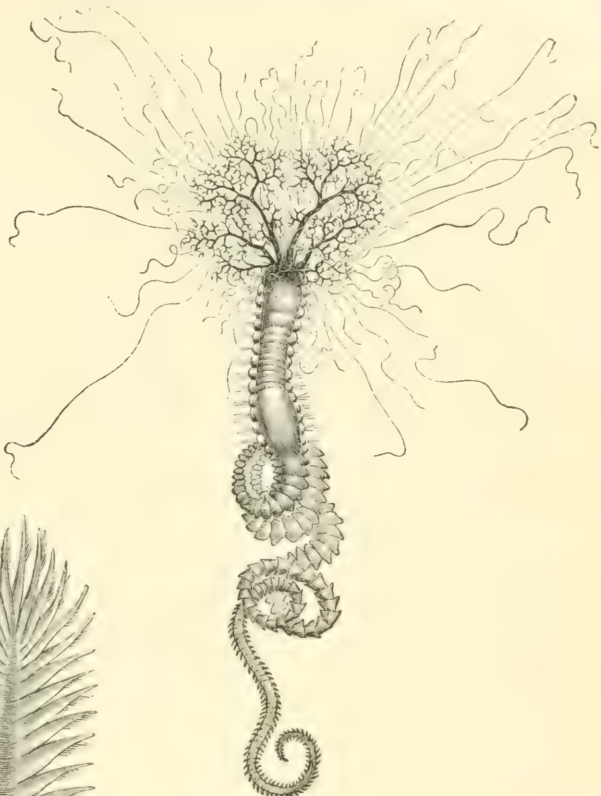
In the family *Clymenidæ*, to which belongs the worm known as *Arenia fragilis*, the body is only divisible into two regions. The fore-part, which is of a dirty red tint, alters its shape greatly owing to the retraction and extension of its



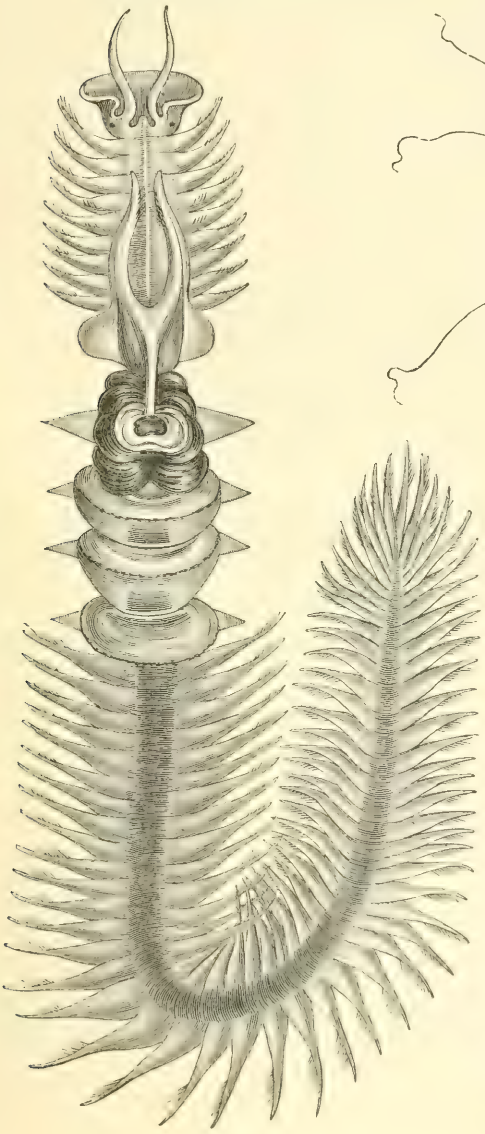
Arenia fragilis (nat. size).

segments; while the exceedingly long and slender hinder part is of a yellowish colour. A remarkable family is that of the *Chætopteridæ*, containing the genus *Chætopterus*, of which a specimen is represented of the natural size in the illustration on p 437. The head is funnel-shaped, with an indentation on its upper side, and from this spring a pair of feelers. The body is marked out into three regions; the most striking being the formation of the five segments which compose the middle region of the body. From the first segment of this area the parapodia stand out like a pair of flat feelers, while the lower branches of these feet are spread like a ruff over the abdominal region. The upper branches of the parapodia of the second segment unite with those of the first to form a dorsal crest, and between these and the lower branches the skin is much swollen and of a violet colour; the following three segments are swollen and have relatively short parapodia. Species of these worms are found on the coasts of Normandy and in the Mediterranean. Like many other marine animals, this worm is phosphorescent, the phosphoric matter spreading like a cloud in the water.

In the next group the gills are in the form of small trees or branches of threads attached to the end of the head; while the mouth is unprovided with either teeth or a proboscis. The creatures spend their days in tubes, from which they can only be extracted by force. In *Hermella* the body ends in a long unjointed, limbless, hairless tail, while the rest of the body bears well-developed bristly parapodia, upon the upper side of each of which there is a tongue-shaped gill. The head is remarkable in that the two large feelers blend



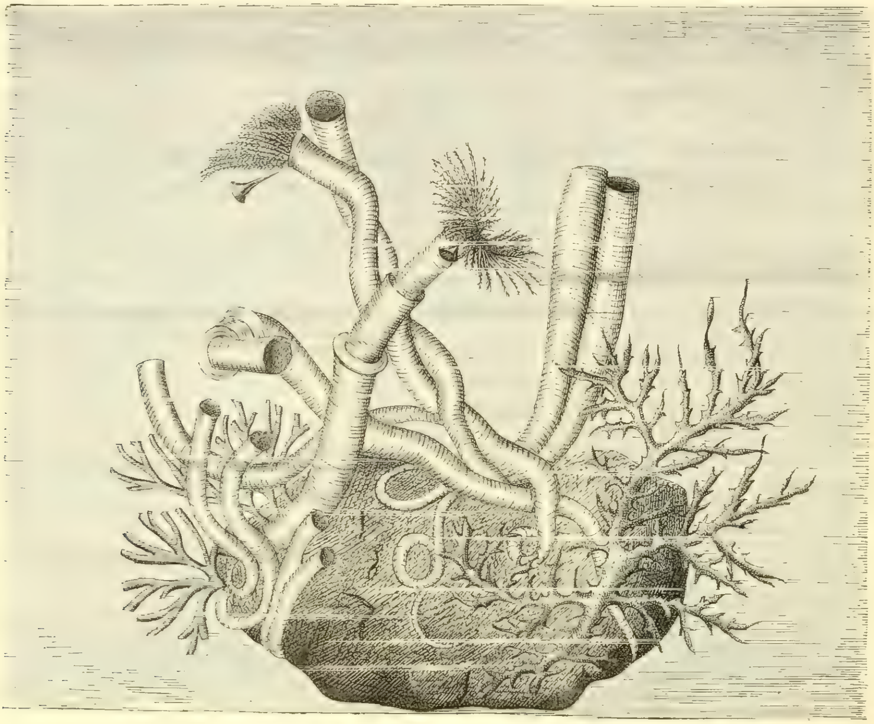
TUBE-WORM (*Hermella*).



Chætopterus.

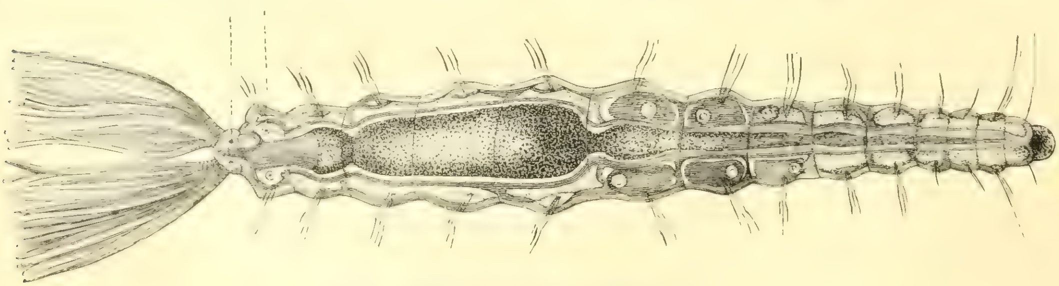
into one and bear a few rows of broad, flat bristles. They are thus converted into a stopper, which closes the mouth of the tube when the worm is retracted. In *Terebella*, forming the family *Terebellidæ*, the tubes are formed of fragments of sand or shell.

In the family *Serpulidæ* the gills are restricted to the fore-part of the body, and the water set in motion by their glistening hairs brings the food to the mouth, which is situated immediately beneath. The head-lobe is blended with the first segment, and not sharply marked off from it, as in most of the worms hitherto described. These animals live in calcareous (chalky) tubes, the apertures of each tube being closed—when the worm has retreated within—by a tight-fitting stopper, formed from a modified piece of one of the gills. The first tube made by the young worm is cylindrical and open at both ends, but as the animal increases in size it enlarges and extends its tube by adding on layers of calcareous matter to the aperture at the head-end.



COMMON SERPULA, *Serpula contortuplicata* (nat. size).

The species of the allied genus *Sabella* exude a gluey substance, and construct a flexible, leathery tube. In some cases these tubes are covered with sand, or pieces of shell, and completely resemble those of the *Terebellidæ.* The species of the genus *Amphicora* may be found amongst seaweed on the coasts of Europe.

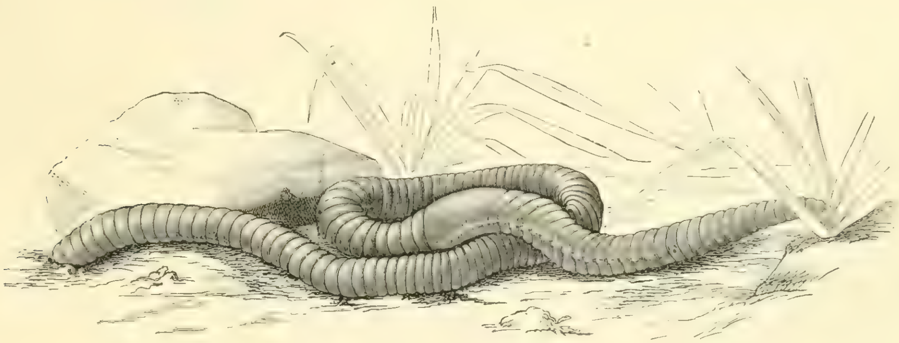


SABELLA, *Amphicora sabella* (enlarged 30 times).

The body is short, measuring less than half an inch in length, and composed of a small number of bristle-tufted segments. Unlike the *Serpulidæ,* the animal habitually leaves its membranous tube in search of food, when it appears as a lively little creature, moving with indifference and facility either forwards or backwards.

SPARSELY-BRISTLED GROUP,—Order OLIGOCHÆTA.

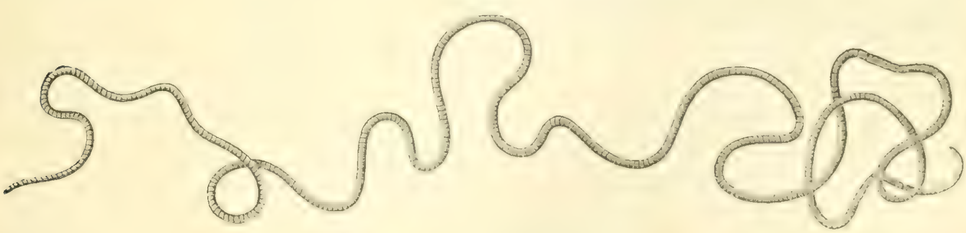
The most familiar representatives of this group are the earth-worms (*Lumbricidæ*), characterised by the numerous short segments of the body, the bullet-shaped, plastic head-lobe, and the hook-like bristles which form either two or four longitudinal rows, and project but slightly above the surface of the skin.



COMMON EARTH-WORM, *Lumbricus agricola* (nat. size).

Apart from certain thickenings of the skin, earth-worms have no special organs of sense, that is to say, neither ears nor eyes, although at the same time they are highly sensitive to the influence of light. Their food consists for the most part of the decaying animal and vegetable matter absorbed from the soil, which they take in large quantities into the alimentary canal; but they also draw into their burrows straws, feathers, leaves, bits of paper, etc., to serve for food. The muscular strength required to overcome such obstacles is often very great, and no one would suppose that a creature so soft, slimy, and to all appearance helpless would be capable of the effort; but the muscular system of these animals is in reality highly developed, as is shown by the strenuous resistance offered to any attempt to drag them from their burrows.

In Britain there appear to be about twenty kinds belonging to three genera, of which the richest in species are *Allolobophora* and *Lumbricus*, *Allurus* including only the square-tailed worm. Earth-worms appear to be spread over all the tropical



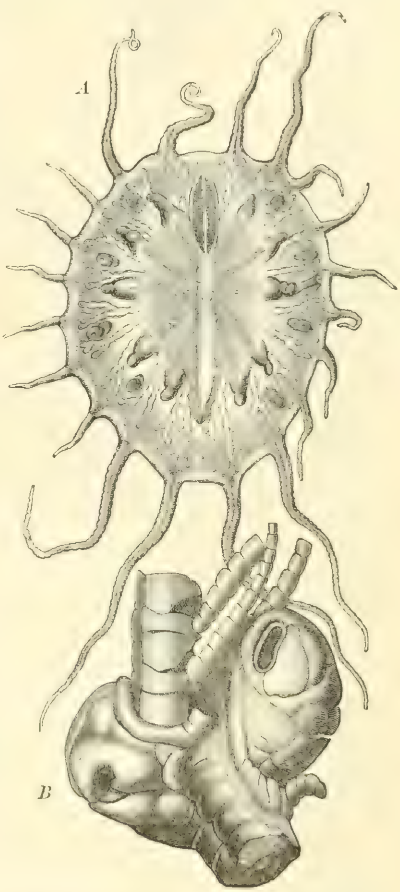
Phreoryctes menkeanus (nat. size).

and temperate parts of the world, and in some countries attain a size far surpassing that of the English species; one of the largest (*Microchæta rappi*) being an inhabitant of South Africa. The average length of this creature is 4 or 5 feet, although it is capable of stretching itself much further, and its width is about equal to that of a man's finger. On account of their burrowing habits, worms are not very frequently seen, although periodically—but only after heavy rains—they come to the surface of the soil in some numbers. Allied to the earth-worms is the rare and extremely slender *Phreoryctes menkeanus*, which lives from preference in wells and shallow water, in which it may be found in the greatest abundance in May and June, disappearing in the winter. Another aquatic member of the group is *Tubifex rivulorum*, a small red, translucent little worm, found abundantly on the slimy bottoms of ditches and brooks. These creatures remain with the forepart of the body stuck in the slime, while the hinder end keeps up a continual vibrating movement. Usually they are so closely packed that the surface of the mud appears to be red coloured, and when startled, the whole throng disappears like a flash into the slime. The clear transparent naids behave in quite a different manner. These animals are also found in ponds and ditches, where they may be seen winding themselves in and out amongst the stems of duck-weed. One of the best known is the beaked nais (*Nais proboscidea*), so called from a feeler-like prolongation of the head, which is furnished with two conspicuous eyes. These worms frequently reproduce spontaneously by fission, and it is not uncommon to see one individual in process of giving rise to several others. Amongst the bristle-worms is placed the family *Myzostomatidæ*, which was long a puzzle to zoologists. The species are all of small size, the largest, *Myzostoma gigas*, measuring only a little more than a quarter of an inch in length. The body is short and oval. Its upper side, which is variously coloured, is covered with fine threads, called cilia, and its edges are prolonged into ten pairs of long, slender, flexible appendages, while below there are five pairs of horny tipped parapodia, and four pairs of cup-like suckers. All the members of this anomalous family are parasitic upon stone-lilies or crinoids, but the degrees of parasitism are various, some kinds wandering freely about their hosts, while others cause those curious swellings which appear upon the arms of the infested animal.

BEAKED NAIS, *Nais proboscidea* (enlarged 10 times).

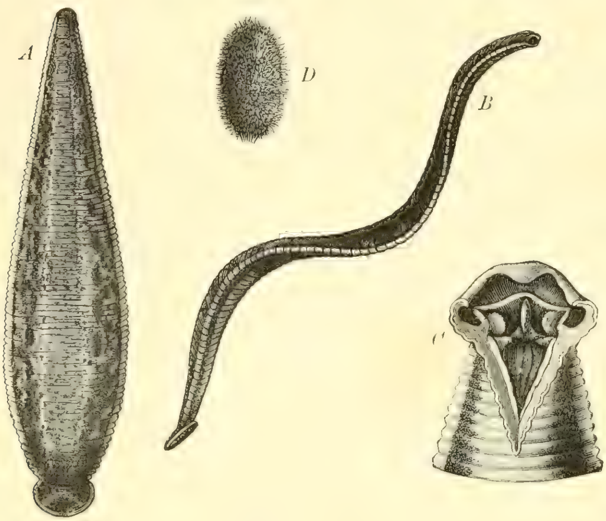
The Leeches,—Class **Hirudinea.**

Leeches are worm-like animals which differ from the bristle-worms mainly in the absence of parapodia, and also of bristles, as well as in the presence of one cup-like sucker at the hinder end of the body, and usually of another at the anterior end. Examination of a leech's body shows that the skin is divided into a number of close-set rings. These, however, are not the true segments; for, as the arrangement of the internal organs shows, a true segment of the body—such, for instance, as have been described in the earthworm or the sea-mouse—is composed of four or five of the dermal rings. The best known example is the common leech (*Hirudo medicinalis*), a species in common use fifty years ago for blood-letting. The body is broadest in the hinder third of its length, and from this point it is gradually narrowed towards the head and tail. The head end is furnished with ten eyes arranged in pairs upon the first eight rings. At the tail there is a large cup-shaped sucker with a narrow neck; there is also a second sucker placed upon the head round the mouth, which is armed with three semicircular finely toothed jaws capable of being worked backwards and forwards like a saw. The alimentary canal is of enormous extent and occupies nearly the entire cavity of the body. Its front part, or œsophagus, is a narrowish tube, then follows the stomach which is expanded into eleven pairs of sacs, the last pair of these being very long and stretching backwards side by side with the narrow intestine, which terminates close to the large cup-shaped sucker. The structure of the organs that have been just described explains the utility of the leech as a blood-letter. The creature adheres to the spot upon which it is placed by means of its front sucker, which has the mouth in the middle of it. The jaws are then brought to bear upon the skin and start sawing their way into it, while the blood that flows from the wound passes into the sacs of the stomach until they are all filled; and since the walls of the body as well as those of the alimentary canal are highly elastic, it is easy to understand how the creature is able to expand to two or three times its normal size. Some of the structural points enumerated above are shown in the illustration on the next page, in which 1 is the alimentary canal, with the œsophagus (*a*) and the sacs of the stomach (*b* and *c*); 2 is the head end showing the eye-spots; and 3 is part of one of the jaws.



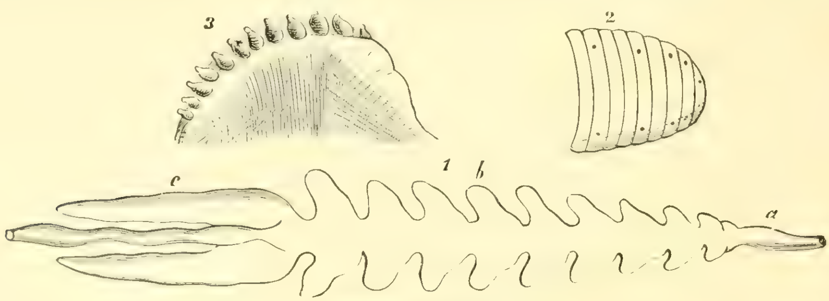
A, *Myzostoma gigas* FROM BELOW; *B*, PORTION OF ARM OF A SEA-LILY (*Antedon*), SHOWING THE SWELLINGS PRODUCED BY *Myzostoma*.

Leeches are found in marshes and ponds with a bottom of mud or clay, and overgrown with weeds. They cannot live long out of water and die as soon as the skin dries, though for some time they may protect themselves from this by the excretion of slimy matter. By day, and especially in warm weather, they swim about with liveliness, but at night and in dark, foggy weather, or on cold days they remain quiet and curled up, and in the autumn they bury themselves deep in the mud. They feed largely upon the blood of fishes, frogs, or mammals, but sometimes, in cases of necessity, devour each other. After pairing in the spring, the suctional leeches bore into the soft spongy ground just above the level of the water, and at the end of July or thereabouts begin to form their cocoons or egg-cases, one of which is shown at *D* in the above illustration. These cocoons are formed of a greenish mucus, or slimy material, and in them from ten to sixteen eggs are laid. The mother then closes the aperture, and over the whole



COMMON LEECH.

A, From above (nat. size); *B*, From the side, swimming (nat. size); *C*, Head cut open to show mouth (enlarged); *D*, Egg-cocoon (enlarged.)



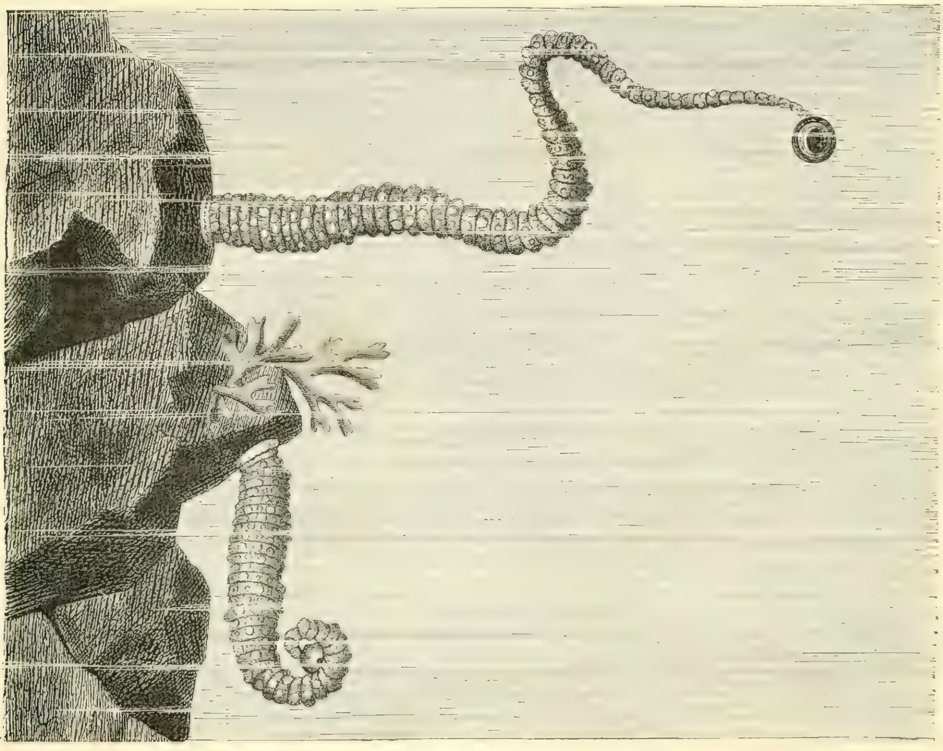
STRUCTURE OF LEECH.

1, Alimentary canal—*a*, Œsophagus; *b*, Saccular stomach; *c*, Last pair of pouches. 2, Anterior end, showing eyes. 3, Jaw.

pours out a whitish saliva-like froth, which upon drying forms a spongy coating to the case. The cocoons are placed in the burrows, and from four to six weeks after the laying, the young creep forth. These are thread-like and clear, but like the old ones in form; and appear to attain their full size in about five years, although they may live as many as twenty.

The colour of the medicinal leech is black above, generally ornamented with pale bands. This species extends over the greater part of Europe, and has been found in France, Germany, England, Russia, and Sweden. Another nearly allied species, *H. officinalis*, which is of an olive-green, unspotted colour, is most abundant in the south and south-east of Europe. Other kinds are found in Morocco, Senegal, India, and North America. In some parts of the tropics, such as India and Ceylon, land-leeches, which abound in meadows and woods, are a terrible plague. They live on grass or trees, are exceedingly quick in their movements, scent prey from a long distance, and troop in numbers to the spot. Hence a person brushing through the jungle becomes covered with them, unless some precautions are taken.

Another well-known member of the group is the horse-leech (*Aulostoma gulo*), characterised by its blackish green colour, the great narrowing of the fore-



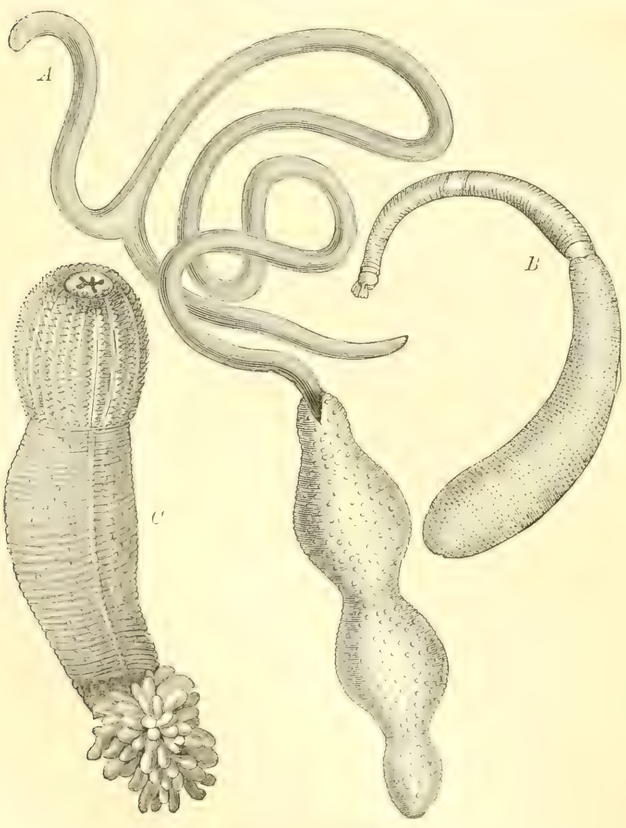
ROCK-LEECH (nat. size).

part of the body, and the presence of only three small teeth in the mouth. Many stories are current as to the dangerous nature of these leeches, and it is even said that nine of them will suck a horse to death; but although doubtless a voracious creature, it is certain that such accounts are fallacious. The horse-leech lives on earth-worms, snails, grubs, and other leeches, and even creeps into the shells of fresh-water mussels, and takes up a lodging there until it has devoured the inmate. Another form that abounds in fresh-water ponds and streams is *Nephelis vulgaris*, which reaches a length of nearly two inches, and has four pairs of eyes and toothless jaws. It appears to feed partly on animal and partly on vegetable food. A second group of the leeches are the *Clepsinidæ*, recognised by the short flat body, which towards the front is usually stumpy, and ends in a seizing disc carrying the eyes. The gullet, which is toothless, can be protruded like a proboscis.

Different species of the genus *Clepsine* may be found on the leaves of water-plants and on the under side of stones. They are grey, yellow, or whitish in colour. Instead of burying their eggs like the medicinal leech, these creatures carry them about, and the young after birth remain some time with their mother. They live principally upon water-snails and young mussels. The engraving on p. 443 represents the rock-leech, *Pontobdella muricata*, remarkable for being an inhabitant of the sea, and also for having the skin covered with warts and knobs. The body, which gradually narrows from the posterior end to the head is of a greenish grey colour, and the anterior sucker large and button-shaped. During the daytime these leeches usually rest partially coiled up, as shown in the lower figure, and firmly attached by their hinder sucker to some rock; but their muscular strength is so great that they are able to maintain themselves extended in an almost horizontal direction, as represented in the upper figure of the illustration. They feed upon skates and other fish.

The Gephyrean Worms,—Class **Gephyrea.**

Gephyreans are marine, cylindrical, worm-like animals, presenting no distinct external segmentation of the body, and possessing nothing of the nature of limbs or gills. The skin is horny, though not calcareous, and often provided with tubercles, hooks, or bristles. The anterior end of the body is furnished with a retractile and sometimes highly-flexible proboscis, at the end or at the base of which the mouth is situated; the alimentary canal either traverses the body from end to end, as in *Bonellia* and *Echiurus*, or is coiled round a special spindle muscle, and returns upon its course to open in the front half of the body, as in *Sipunculus*, *Phascolosoma*, and *Phymosoma*. In the last-named genus the head is furnished with a circle or half-circle of tentacles. The muscular, vascular, and nervous systems are well-developed; the latter consisting of a cerebral ganglion, an œso-



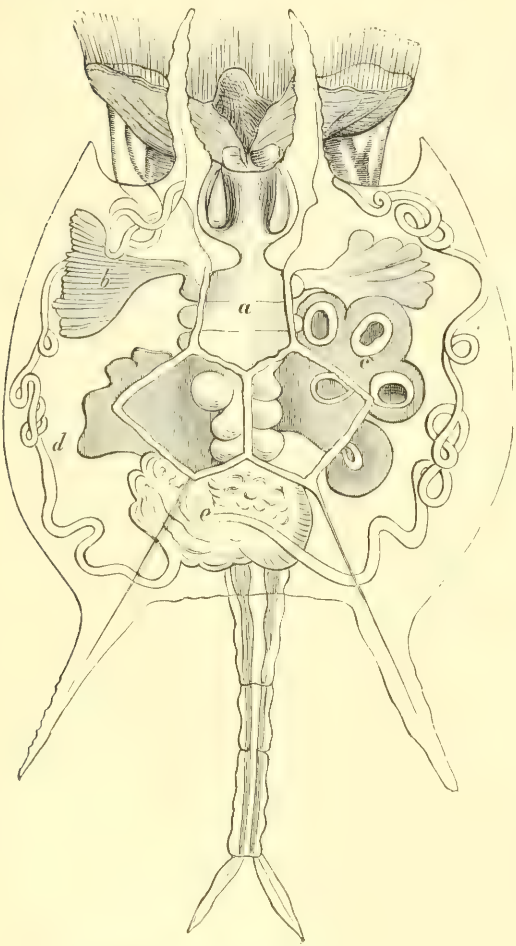
GEPHYREAN WORMS.
A, *Bonellia*; *B*, *Phascolosoma*; *C*, *Priapulus*. (Nat. size.)

phageal collar, and a ventral chord, while the most important part of the vascular system is a dorsal vessel which lies above the alimentary canal. This class contains two orders, named the Achæta and Chætifera. In the former the mouth is placed at the apex of the proboscis, which is retracted by a special muscle as in the Nemertine worms, and the alimentary canal opens posteriorly in the front half of the body. Moreover, as the name of the order indicates, the integument is without bristles. In the illustration on p. 444, *B* represents *Phascolosoma*, one of the genera of the order. Here the narrowed part of the body is the extended proboscis, which is furnished at the tip with a cluster of tentacles. A second family of this order is the *Priapulidæ*, containing the genus *Priapulus*, of which a representation is given in *C* of the figure. In this form the body is short, stout, cylindrical, and furnished at the tail-end with a tuft of oval papillæ. The proboscis, which in the figure is represented as protruded, is short, stumpy, and covered with toothed ridges. The animal is found in deep water in the seas of Northern Europe, living in burrows on the sandy bottom.

The Chætifera, which in some respects approach the Annelids, differ from the Achæta in having the mouth situated at the base of the proboscis, and the vent at the hinder end of the body, as also possessing a pair of large hooks upon the front half of the lower surface. The best known is the genus *Bonellia*, represented at *A* in the illustration on p. 444. The proboscis is of great size, being often many times the length of the body, and is forked at the end. The males differ from the females, being minute,—not more than about one-sixth of an an inch long,—covered with cilia, and living within the kidneys of the females.

The Wheel-Animalcules,—Class **Rotifera.**

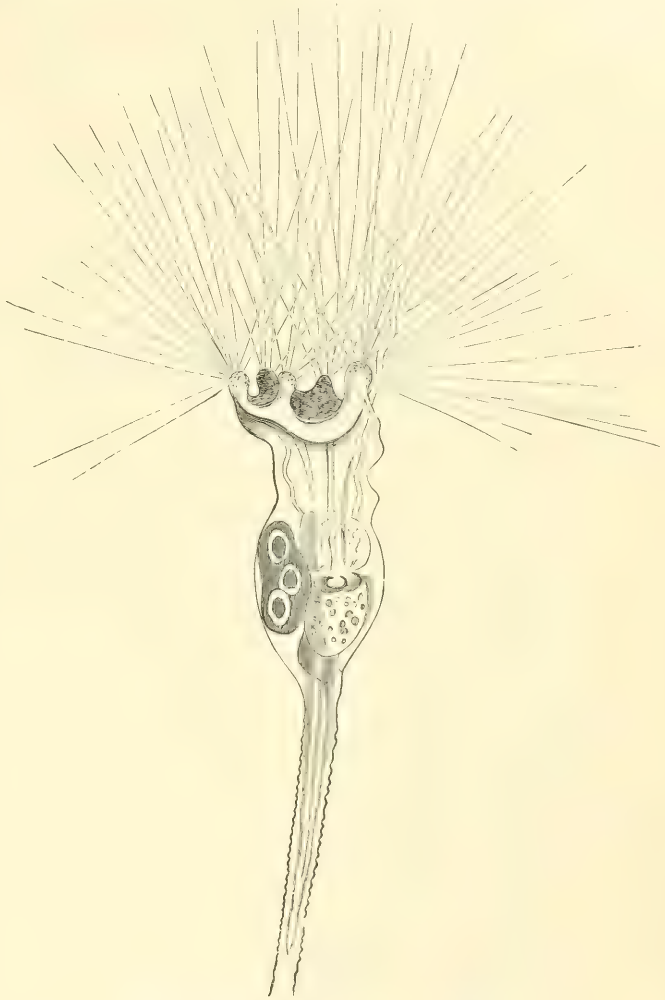
The Rotifera, or wheel-animalcules, are small aquatic animals, varying from an eighth to the five-hundredth part of an inch in length, and derive their name from the circumstance that the circlets of hairs situated on the head give rise, when waving in the water, to the appearance of revolving wheels. The head end of the body is usually broader than the opposite extremity, and terminates in the wheel, or trochal disc, the edges of which are variously lobed, and clothed with the vibratile cilia, or threads. The body, which is indistinctly segmented, is either naked or enclosed in a hard transparent case, or *lorica*, open at both ends, which may be variously sculptured, and armed in front and behind with spiny processes, as shown in the annexed engraving. The posterior end of the body, termed the foot, ends usually in a pair of movable processes, by means of which the rotifers anchor themselves to foreign bodies of various kinds. The mouth, situated in the middle or at the side of the wheel-disc, is a funnel-shaped cavity, leading into a muscular gullet (*a*), provided with a peculiar armature of teeth, which serve to masticate particles of food that are swept into the mouth by the movements of the cilia on the wheel-disc. The nervous system consists of a single large ganglion, situated on one side beneath the disc, and sending forth nerves to the surrounding parts, and sometimes being furnished with one or more eye-spots. In all cases the males are smaller than the females, and further differ in having the alimentary canal aborted and reduced to a solid chord. Wheel-animalcules are divisible into four orders. Of these, the Ploima may be considered the typical order of the class, on account of the numbers of genera, the abundance of species, and the restless energy, perfection of structure, and superior intelligence of its members. Locomotion is effected by means of swimming with the ciliary wreath. The order is divided into two sections, the Loricata, which, as in *Noteus*, represented in the annexed illustration, are protected by an enclosing shell, and the Illoricata, which, as exemplified by *Notommata*, have the integument flexible, and the body not protected in a shelly case. The habits of the group show considerable variation. Many species may be found swimming freely or attached to water-weeds in almost any pond, stream, or stagnant ditch; and others, like *Brachionus*, one of the Loricata, may be seen riding in clusters on the backs and sides of crustaceans. Amongst the Illoricata, *Balatro calvus* — remarkable for having no disc—infests small water-worms, to which it clings by its enlarged foot-processes; and *Drilophagus bucephalus* is parasitic upon a water-worm (*Lumbriculus*), to which it clings, feeding by means of its modified jaws. Other species again form internal parasites, the genus *Albertia* being found in the interior of earth-worms, slugs, and annelids of the genus *Nais*; while *Notommata* may be seen swimming freely within the spheres of the beautiful *Volvox*.



FOUR-HORNED ROTIFER, *Noteus quadricornus* (enlarged 300 times).

The members of the order Bdelloidea swim by means of their ciliary wreath, and creep about like a leech. The foot is telescopically retractile, and ends almost invariably in three toes or claspers. In this group also the mode of life is varied. Most species are free-living, but others attach themselves to various entomostracous crustaceans, and *Callidina parasitica* is always found clinging to the appendages of the fresh-water shrimp and the aquatic wood-louse. A special interest attaches to this group on account of their vitality. If specimens be enclosed in a cell containing a little sand or moss, the contents may be dried over sulphuric acid or heated up to 200° F., or left to the neglected dust of years, and some of the little creatures will revive if a drop or two of fresh water be added to the sand.

The order Rhizota takes its name from its members being fixed when adult, and usually inhabiting a gelatinous tube. The foot is not retractile and ends in an adhesive disc or cup. In the flower-animalcules (*Floscularia*), which may be found everywhere in fresh water adhering to weeds, the edges of the wheel-disc are produced into distinct bristle-bearing lobes; but in the allied *Melicerta* there is no such production of the disc.



FLOWER-ANIMALCULE (magnified 200 times).

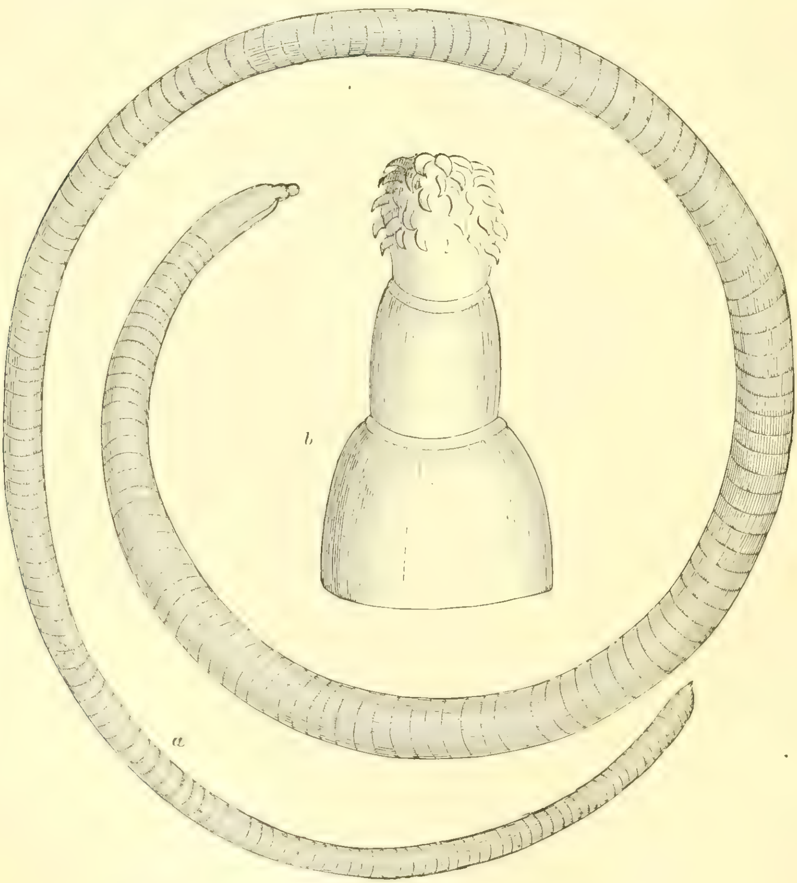
The last order, Scirtopoda, comprises only the two genera *Pedalion* and *Hexarthra*, each of which is represented by a single species. The two resemble each other and differ from all other rotifers in possessing three pairs of limbs, ending in a fan-shaped tuft of setæ. The body is conical with a broad square-cut head, furnished with two wreaths of cilia and a pair of conspicuous eyes. In *Hexarthra*, which bears a strong superficial resemblance to the *Nauplius* larva of some crustaceans, the three pairs of limbs spring from the ventral surface, the first pair being considerably the largest and the third the shortest; but in *Pedalion* they are arranged round the body in pairs, one limb projecting from the middle of the back, another from the ventral middle line and two from each side, the ventral limb being the largest of the six. By means of these appendages the creatures are able to project themselves through the water in a series of jerks. *Pedalion* has been discovered in various parts of England, and *Hexarthra* in brackish water in Egypt. The male of *Pedalion* is a veritable dwarf as compared with the female, the body and limbs being greatly reduced in size, and the latter merely represented by three stumps, each of which terminates in a pair of long bristles.

The Thread-Worms, or Round-Worms,—Class **Nematohelminthes.**

These worms are characterised by having a thread-like body, covered with tough, elastic integument, but usually showing no distinct traces of being divided into segments like those of leeches and earth-worms, and possessing no trace of limbs. The sexes are generally distinct. The group is divided into the three orders Acanthocephali, Nematoidea, and Chætognatha.

Spiny-Headed Thread-Worms,—Order Acanthocephali.

In this order is contained the single genus *Echinorhynchus,* which is appropriately named for animals possessing a protrusible proboscis, armed with several rows of backwardly-directed spines. The chief character in which this order

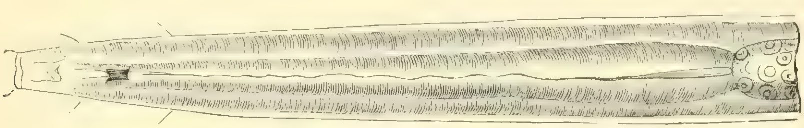


SPINY-HEADED THREAD-WORM. *a*, Nat. size ; *b*, Head enlarged.

differs from the next is the lack of any special alimentary canal and digestive apparatus. In the adult stage the species of *Echinorhynchus* are found in the intestines of vertebrates ; the large species figured above (*E. gigas*) infesting the pig. But in order to reach its final residence in this host, it has to spend its early days in the grub or maggot of the cockchafer and allied beetles. These latter are rooted up and devoured by pigs, which thus unconsciously swallow the worm. Similarly, *E. proteus* of various fish lives in an immature state in the intestine of the water-shrimp, which swallowed it while still in the egg; and *E. moniliferus*, which occurs adult in such rodents as hamsters and voles, lives during the larval state in beetles. Another species, *E. polymorphus*, has to be transplanted from the body of the water-shrimp into that of a duck to reach maturity.

Typical Thread-Worms,—Order Nematoidea.

The illustration showing the growth and structure of one of the thread-worms (*Nematoxys*), an internal parasite of the frog, is intended to show the mode of development typical of the whole group. The egg is elliptical, and contains a mass of granular protoplasm, the external wall of which soon becomes marked out into a layer of large cells. Meanwhile, there appears at the side a distinct notch or nick, which, shallow at first, gradually deepens, until, as shown in the figures, it represents the space enclosed between the head- and tail-ends of the bent-up embryo, which may be recognised respectively by their blunt and pointed



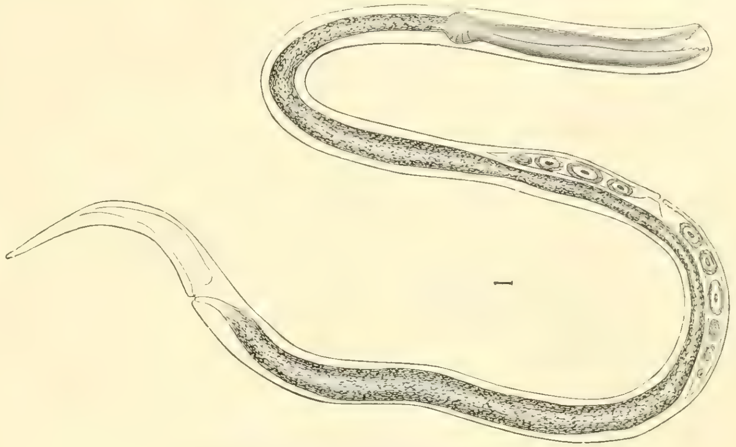
FRONT END OF THREAD-WORM, *Enoplus* (much enlarged).

extremities. The external layer of cells becomes transformed into the cuticle, and the mouth appears as a depression at the end of the blunt head. When the muscular system and alimentary canal are developed, the embryo hatches in the form shown in the bottom right-hand figure. Most of the species lead a parasitic life, chiefly in animals; many, however, are free-living forms, occurring in damp earth, fresh water, and the sea. A genus, with marine habits, has received the name of *Enoplus*, and includes small, slim, transparent creatures, some of which are provided at the front end with isolated bristles (as shown in the illustration above), while many are furnished with a peculiar spinning-gland, opening beneath the tail. According to Schneider, "as soon as the animal has fixed its tail to something it moves on, and draws after it the secretion in a transparent thread, which is often several lines long. One end of this thread sticks fast, and by the other the animal floats freely in the water." The young are found in shallow water, and may be seen crawling on the surface of seaweeds; but the mature animals occur at depths of from two to three fathoms. As another example of non-parasitic species, we may take the common vinegar-eel (*Anguillula*), the magnified figure of which shows that the body is bluntly rounded at the head-end, and narrowed and pointed at the tail. The greater part of the body-cavity is occupied by the alimentary canal, which traverses it almost from end to end. The oval particles contained in two tubes, which unite and open by a common orifice, are the eggs. This worm appears to live both in vinegar and paste, although it does not seem to derive its nourishment directly from either of these substances, but rather from the microscopic fungi growing in them. These worms now appear much rarer in vinegar than former observers have represented; and it is suggested that the reason of this may be that vinegar is no longer made from wine or beer; since, in the vinegar obtained from the two latter, there probably remained much sugar and albumen, which form a favourable basis for the growth of fungi, and therefore for the eels. The maturing and propagation of these animals cannot take place in pure vinegar, but only amongst fungi, where a nitrogenous diet is offered.

DEVELOPMENT OF THREAD-WORM, *Nematoxys* (400 times enlarged).

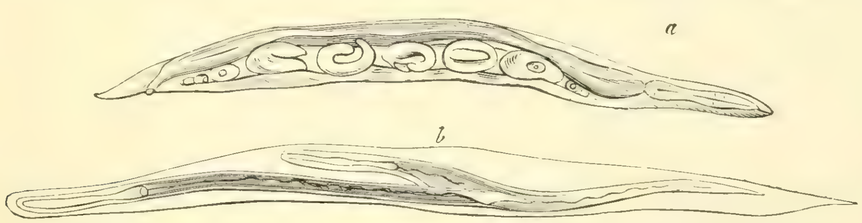
Vinegar now never contains adult eels, but, at most, larvæ and the innumerable little creatures supposed to be seen upon shaking a bottle of vinegar are, for the most part, nothing but the skin-skeletons of these animals. Nearly allied is the wheat-eel (*Tylenchus tritici*), which is the cause of a serious disease to the cereal from which it derives its name. In the ears of wheat affected by this worm the grains are misshapen, blackish, and consist of a thick hard scale enclosing a white powdery substance, composed of the larval forms of the worm. If grain in this state is sown in moist ground, it merely rots; but the larvæ awake to activity, and scatter over the ground in search of another growing blade of corn.

If they fall in with one, they start to creep up it, and mounting ever higher and higher, as the corn grows, ultimately succeed in reaching the summit. They then attack the soft grain, bore into it, and form gall-like swellings, in the middle of each of which there is a larval worm. Here the worms quickly develop to normal perfection, and after the females have laid a large quantity of eggs, both they and the males die. Subsequently the eggs hatch, and the larvæ, which constitute the powdery substance referred to above, make their appearance. Somewhat similar diseases are produced in other grains by members of the same family; and the turnip-eel (*Heterodera*) is very destructive to root-crops.



VINEGAR-EEL (much enlarged).

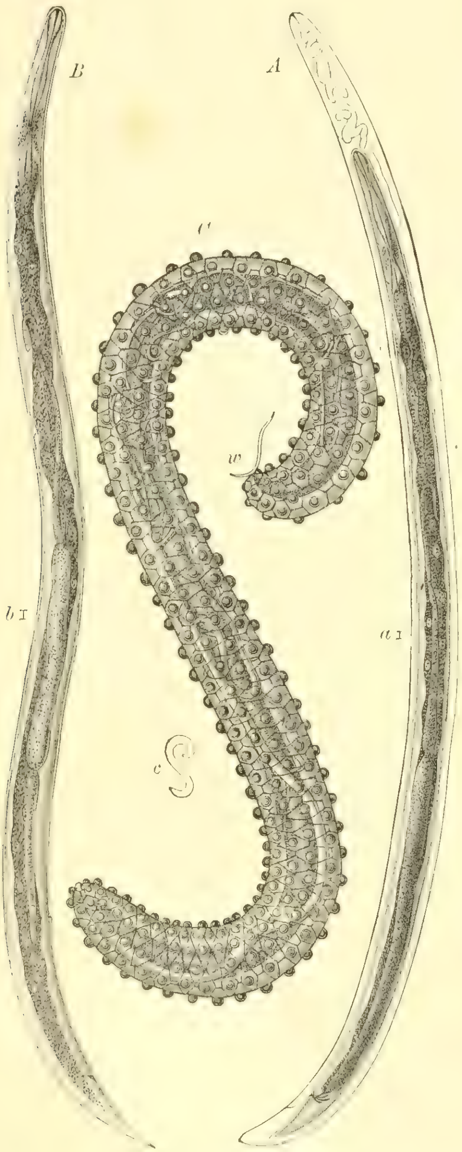
Of the parasitic forms, the genus *Rhabdonema* has a remarkable course of development, one species (*R. nigrovenosum*), which is about three-quarters of an



a, FEMALE OF *Rhabditis*—FORM OF *Rhabdonema nigrovenosum*; *b*, BROOD-POUCH. (Enlarged.)

inch in length, living, sometimes in great numbers, in the lungs of frogs. This species is hermaphroditic, and produces innumerable young ones, which bore their way from the lungs into the alimentary canal of their host, whence they are expelled with the remains of their food. They then develop in a few days into free-living, separately-sexed individuals, bearing a close resemblance to another free-living worm (*Rhabditis*). These individuals breed; the females bear one or two young apiece, and these, after devouring their mother's vitals, and making their escape by bursting through the skin of her body, pass through a frog's mouth into its lungs, and become the hermaphrodite adult. Another species (*R. strongyloides*) is of interest, inasmuch as it is parasitic in man in warm climates.

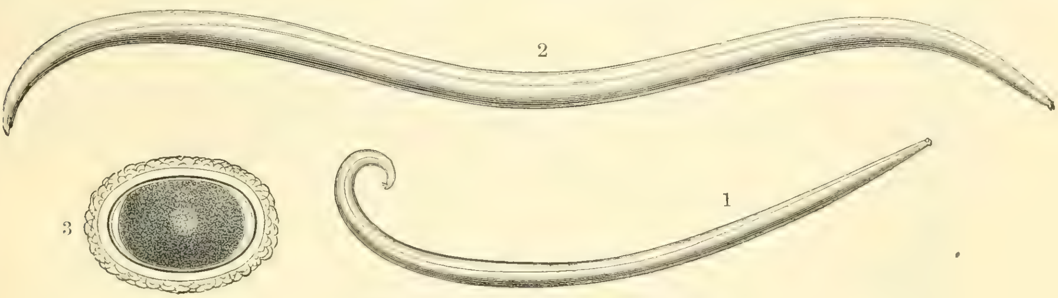
Two more remarkable Nematoids may be mentioned, both of which infest insects. The first of these, *Atractonema gibbosum*, is found in numbers in the body-cavity of the larval and adult stages of the midge; the completely-formed worm reaching a length of nearly one quarter of an inch. Its shape is unusual, on account of the presence of a hump projecting like an excrescence from the surface of the abdomen, some distance from the tail-end. When fully formed, this excrescence amounts in size to half the length of the entire worm, and contains the young, which, after making their escape, undergo a short development in the body-cavity of the midge, then reach the outside, where they are transformed into mature males and females. After the pairing of the sexes, the males perish, but the females again enter the larva and start another cycle of metamorphosis. The second kind (*Sphærularia bombi*), which infests humble-bees, closely resembles the first in development; but the excrescence, or brood-pouch, of the mother-worm is changed into a tube, and ultimately reaches a size from fifteen to twenty thousand times as great as the parent, which dwindles in size in proportion as the sac grows. The life-history of this worm is shown in the illustration, where *A* is the free-living male, *B* represents the free-living female, and *C* is the parasitic female (*w*), with her brood-pouch.



HUMBLE-BEE THREAD-WORM.

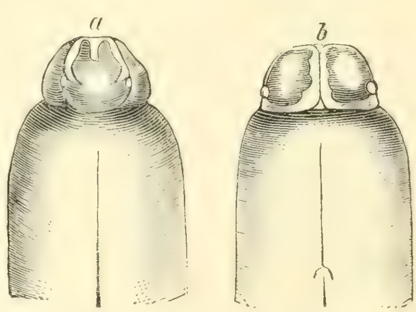
A, Male enlarged; *a*, nat. size.
B, Female enlarged; *b*, nat. size.
C, Brood-pouch of female (*w*); *c*, nat. size.

Of the thread-worms infesting the human body, one of the commonest is *Ascaris lumbricoides*, which is found in numbers varying from one or two only to over two thousand. These worms usually infest the small intestine, but sometimes enter the stomach, or even penetrate into the liver. Large examples reach a length of 6 inches or more, and the females produce about sixty millions of eggs annually. These are naturally dispersed abroad everywhere, and as the young worm retains its power of growth in spite of frost, drought, and, in fact, the most unfavourable circumstances imaginable, and is, moreover, far too small to be noticed, we need not feel surprised at the prevalence of the pest. The form and some of the structural characters of this worm are shown in the two illustrations on p. 453. In the uppermost, 1 is the male, and 2 the female, of the natural size, 3 being the egg, enormously enlarged; the lower illustration depicting the upper (a) and the lower (b) side of the head, with the prominent lips. Other mammals, besides man, are the hosts of different species of *Ascaris*. For instance, *A. mystax* is found in dogs and cats, and sometimes even in man; while *A. lumbricoides* also occurs in swine. A large species, *A. megalocephalus*, the female of which reaches a length of over a foot, lives in horses and cows. A second common parasite of mankind is *Oxyuris vermicularis*, a small, white, sharp-tailed worm, which measures about one-quarter of



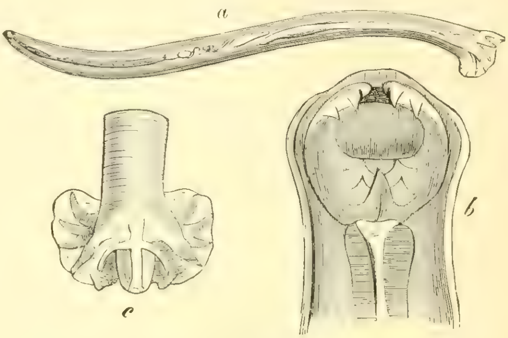
HUMAN ROUND WORM (*Ascaris lumbricoides*).
1, Male; 2, Female. (Nat. size.) 3, Eggs (enlarged).

an inch in length. It occurs abundantly in children and growing people. As, in the case of *Ascaris*, it seems that before development can take place, the egg must pass out of the host, and again make its entry into the alimentary canal through the mouth. These worms are so small and light that, when dried, every current of air will scatter them, and they may make their way into the alimentary canal of their host in connection with almost any kind of food. To the family *Strongylidæ* belongs a dangerous parasite, *Dochmius duodenalis*, occurring in the intestine. It is about half an inch in length. A peculiarity of this species and others of the genus is that the posterior end of the male is furnished with a curious bowl- or fan-shaped ruff, which is often supported by thick ribs (a and c of the figure on p. 454). The gullet, at least in individuals that are still growing, is furnished with strong teeth (b). When this worm appears in masses, it produces the disease known as Egyptian cholera.

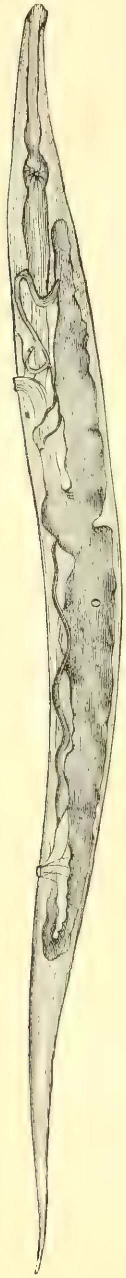


HEAD OF HUMAN ROUND WORM (enlarged).

The accompanying illustration is an enlarged view of the head of *Cucullanus elegans*, a parasite in fresh-water fishes like the perch, and having for its intermediate host the Crustacean *Cyclops*. The worm is about half an inch long, and the aperture of its mouth forms an elliptical case with thick brown walls. The female bears living young, which creep forth from their egg-cases while still within their mother's body, where they may be counted in thousands. Protected by a tough skin, the worms, which have reached the outside world, frequently live for several weeks in the water on the look out for a favourable host. Having come across, and made their way into a *Cyclops*, they undergo various changes, but only reach in this host a length of about one-twelfth of an inch, their complete development only taking place after the swallowing of the infested *Cyclops* by a fish. Another member of the same family is the *Syngamus trachealis*, which owes its double name to the fact that the males and females are found in pairs in the windpipes of various birds. They sometimes occur in such numbers that the inflammation set up by their blood-sucking suffocates their host. The eggs appear to be brought up into the bird's mouth by crowing, or by the choking cough that the presence of their parent causes. They are then swallowed, and pass out through the alimentary canal. As soon as they have obtained sufficient dampness and warmth, they develop in about a week's time into small thread-shaped embryos, with a blunt head and pointed tail. These obtain an entrance into another, or the same bird's mouth with the food, and thence pass into the windpipe.

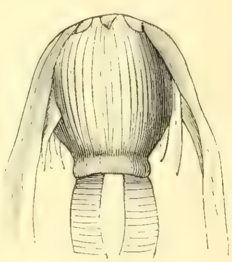


Dochmius duodenalis. *a*, Entire; *b*, Head (enlarged); *c*, Tail (enlarged).



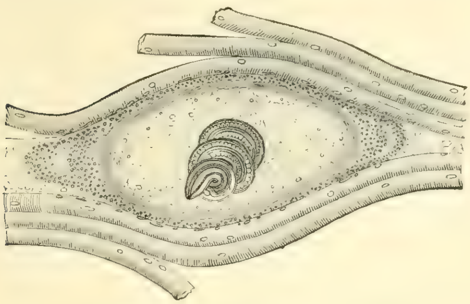
HUMAN THREAD-WORM, *Oxyuris vermicularis* (much enlarged).

Perhaps the most dangerous of all human internal parasite worms is *Trichina spiralis.* In the mature stage these creatures live in the intestines of mammals and birds, where they propagate and gradually perish. The females are about one-eighth of an inch long, and twice the size of the males. In both sexes the mouth lies at the front end of the body, which is its narrowest part; the tail is stumpy, and in the male provided with a pair of short processes. The number of progeny produced by one female may amount to some thousands, and as soon as these are born they make their way into the blood-vessels of their host's intestine, where they are carried by the circulation to some more distant part of the body, and ultimately come to a stop in one of the muscles. Here by feeding they grow in a few weeks to four times their original size, and form between the muscular fibres a great cyst or capsule, in the centre of which the worm lies coiled up in a spiral. It has not been ascertained how long the creature can remain in this immature state, but



HEAD OF *Cucullanus elegans* (enlarged).

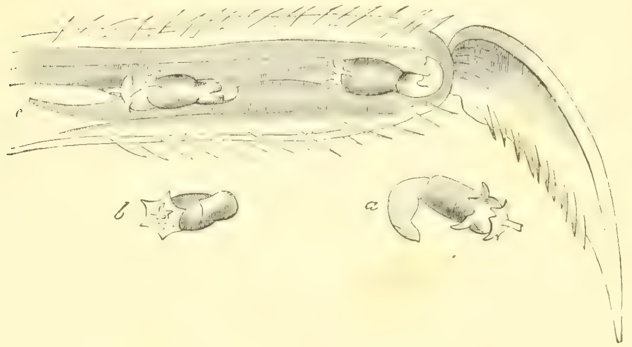
certainly for years, and perhaps decades. It can, however, develop no further until introduced into the intestine of a suitable host. For instance, if the muscles of a pig be infested with trichinas, and eaten in an uncooked state by a human being, the immature worms are set free in the intestine of the new host, where they grow to maturity, and produce young. To the genus *Filaria* belong two other worms parasitic upon man, and the cause of sickness. One commonly known as the guinea-worm, and occurring in the tropical and subtropical countries of the Old World, lodges itself beneath the skin, producing abscesses. It may attain a length of several feet, and the operation of extracting it from the patient demands considerable skill and patience. The second species lives in the blood and lymphatic vessels, and is said to cause elephantiasis. The larvæ are sucked from human blood by mosquitoes. When the insects perish, the worms make their escape into water, where they attain maturity and produce their young, which are subsequently taken into the human body when the water is drunk.



TRICHINOSIS WORM COILED UP IN HUMAN MUSCLE (enlarged).

TRICHINOSIS WORM, *Trichina spiralis* (male enlarged).

The family of hair-worms, *Gordiidæ*, owe their English name to the resemblance that their long, black, slender, flexible body bears to a hair from a horse's mane or tail, and their scientific title, *Gordius*, to the peculiar habit the animals have of tangling and entwining themselves in a way that may be compared to a Gordian knot. The best-known species is *G. aquaticus*, the average length of which is about 4 inches, although specimens three times that length have been obtained. The width of a male is about one-thirtieth of an inch, the females being slightly wider. The prevailing colour is brown of various shades; the males, however, are always darker and more polished than the females, and are often of a deep shining black, while the females vary from light yellow to deep yellow-brown. Upon the middle of the abdomen, both in males and females, runs a long dark streak, visible even in the darkest males. Another mark by which the male may be recognised is the bifurcated tail end. Although living a free life in the adult condition, these worms spend the greater part of their lives, up to the last period, in certain insects. The young hair-worms, as they issue from the egg, are scarcely more than one twenty-fifth of an inch in length, and most curiously shaped; the body being cylindrical, and consisting of a thick fore-part, and a thinner tail-like appendage. Out of the front end of the body a sort of head can be thrust, which is armed with two circles of small hooks, and tipped with a horny proboscis. With these instruments the creatures, in the first place, bore their way through the egg-shell, and, having made their escape, lie quietly at the bottom of the water without appearing to wander in search of a host. Insects, however, in the adult and larval stage abound in most fresh waters, and sooner or later the young worms come across them. They then seek out a soft spot, bore a hole by their apparatus of hooks, and by a series of contractions and extensions of the body force an entrance between the muscle-fibres of the limb, whence they spread into the body-cavity of their host. In the illustration, *a* and *b* show two views of the larva with its armature of hooks, and *c* represents two that have effected an entrance into the foot of the larva of a May-fly. They also infest in this way water-bugs and gnats. All these water-insects, however, are liable to be devoured by fresh-water fish, and by this means the young hair-worms are set free in the intestines of the fish, where they undergo their metamorphosis, and after five or six months pass into the water in the mature form. Nearly allied is the family *Mermithidæ*, containing the genus *Mermis*. Like the hair-worms, they occur both singly or coiled up and entwined with each other. The eggs are curiously constructed, having the form of lenticular capsules, with a pair of tassel-shaped appendages projecting from their flat surfaces. Eggs of *M. albicans* laid in the summer do not hatch until the spring. After remaining a short time in the earth, the young search for insects and larvæ, bore a way into their bodies, where they gradually grow to maturity, and ultimately pass out to lead a free life, when they pair and lay their eggs. They may be found in caterpillars, grasshoppers, and more rarely spiders.

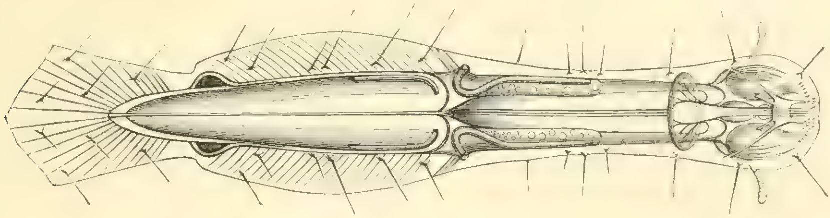


LARVÆ OF *Gordius*—*a*, showing proboscis, and *b*, circlets of hooks on the head; *c*, two examples lodged in the foot of a larva of the May-fly.

EGGS AND LARVA OF *Mermis* (enlarged).

ARROW-WORMS,—Order CHÆTOGNATHA.

The small group of worms included under this heading are of doubtful position. They are glass-like, transparent creatures living in the sea, near the surface of which they swim in numbers. They are most active and vigorous swimmers, as might be expected from their slender build, and the presence of a large horizontal fin at the sides of the hinder half of the body, projecting beyond the tail. The shape of the body and the presence of the large tail-fin suggested the name *Sagitta*. The head is bluntly rounded and furnished with a pair of eyes, a pair of feelers



ARROW-WORM (25 times nat. size).

and an armature of close-set horny teeth, all of which must be of the greatest service to the animal in its roving, predaceous life.

The Nemertine Worms,—Class **Nemertinea.**

All the members of this group are characterised by having the body elongate and flattened, at least on the abdominal side; at the front end there are frequently two clusters of eyes, and two apertures, one of which leads into the alimentary canal, and the other into a cavity containing a peculiar organ known as the proboscis. The latter, which is used as an instrument for prehension, can be thrust out with swiftness to a considerable distance, and in many species is armed in the middle with a sharp spike-like tooth and some smaller ones at the sides, which are brought by degrees into use as the large median one is worn away or fractured. This organ is shown protruded in a small marine species (*Tetrastemma obscurum*) in the illustration on this page, and retracted within the body in the full illustration of the animal on p. 458. The creature thrusts forth its proboscis with lightning speed at passing animals, such as crustaceans. The figure of *T. obscurum* illustrates other characters in the anatomy of these animals. The two swellings situated in the head end and united by a cross bridge constitute the brain or chief centre of the nervous system; running backwards from each to the hinder end of the body is a long nerve-chord, supplying the muscles and other organs of the body. The winding curled tubes, which also run the length of the body, are the so-called water-vessels. These worms, which have received their generic name from the presence of four eyes, are widely distributed, most of the species being minute, and commonly found among seaweed. The worms of this group that have hitherto been discussed have the proboscis armed with stylets, and are consequently called the Hoplophora, or armed nemertines. The second division, namely, the Anopla,—comprising those kinds which have no spines upon the proboscis,—contains some of the largest species of the class, *Meckelia somatotoma* reaching a length of

END OF PROBOSCIS OF *Tetrastemma* (enlarged).

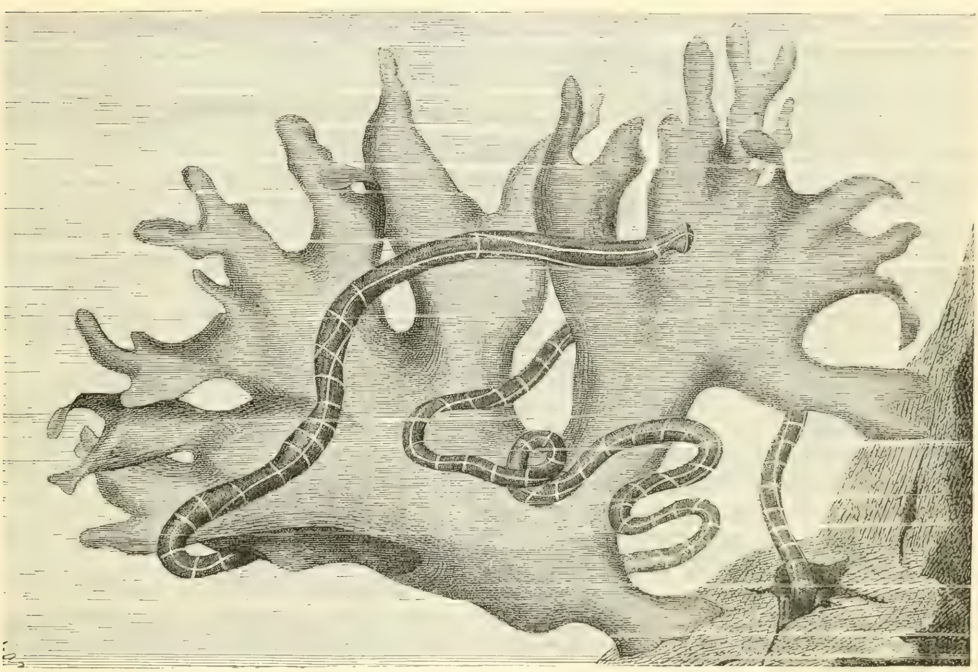
from 3 to over 6 inches. It is a long, flat, whitish-coloured creature, occurring on muddy ground and between the branches of coral; and has received its name from the habit of breaking up into pieces at the least touch. The vitality of the severed pieces is so great that the head end has the power to re-form a new tail, and the tail end a new head, and the intermediate pieces a new head and tail. Another common kind is *Polia crucigera*, so-called because its greenish body is marked with five longitudinal white bands and transverse white stripes, forming together a series of crosses. These worms are long and slender, reaching a length of about 16 inches. The proboscis, moreover, when protruded, adds another 6 inches to their extent. They are found most abundantly in pieces of rock riddled with holes and galleries by boring sponges, and they also intertwine themselves amongst the prongs of branching-corals, as shown in the illustration.

A FOUR-EYED NEMERTINE, *Tetrastemma obscurum* (enlarged).

Most marine nemertines prefer rather shallow water; but some occur at considerable depths; and a pelagic species from the Indian Ocean, originally described as a mollusc, under the name *Pterosoma planum*, is a transparent creature, whose internal organs, especially the chestnut-brown digestive apparatus, are visible through the colourless integument. The body diminishes from the front towards the hinder end, and at the sides is marked out by deep notches into a series of five lobes, of which the first pair are enormously large, and have the form of two semicircular wings. The use of these is doubtless to enable the creature to float or swim in the water. All the foregoing are free living types, but we now come to forms (*Malacobdella*) not unfrequently found living parasitically under the gills of various marine molluscs. In these, the body is short and broad and capable of but little change in shape at its hinder end; it is furnished with a sucking apparatus, by means of which the animal adheres to its host. As stated above, almost all nemertines are of separate sexes; and in some marine species the development of the young is so remarkable that it is impossible to pass it by without notice. The young which issue from the egg are so unlike the parent, that no one would at first sight suppose them to belong to this group. The larva, as shown on p. 461, bears some resemblance to a helmet, and has been named *Pilidium*. This creature, which is covered with cilia, swims near the shore for some time, while the young nemertine is developed inside. As soon as this has acquired its cilia, and attained a certain stage of maturity, it breaks from the pilidium and starts an independent life.

THE FLAT-WORMS,—Class **Platyhelminthes.**

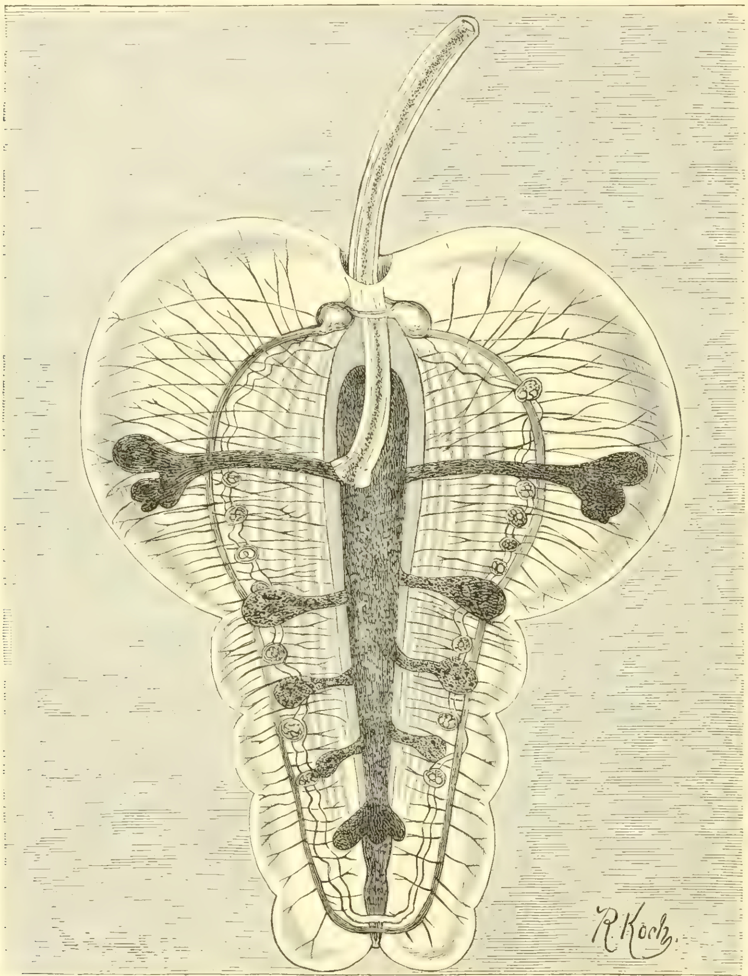
The flat-worms are characterised by the absence of a distinct vascular system, and by the alimentary canal being either absent or with no posterior outlet. A nervous system is developed, consisting either of a network of nerves, or sometimes of a distinct brain and lateral chords. The excretory organs are composed of fine tubules opening to the exterior, and the body-cavity is reduced to a set of slits in the tissues. For the most part the sexes are united in one individual. Sometimes a sexual reproduction occurs, accompanied by an alteration of generations. There are three orders of flat-worms, namely, the tape-worms, the trematodes, and the turbellarians.



CROSS-BEARING NEMERTINE (*Polia crucigera*) ON A CORAL (nat. size).

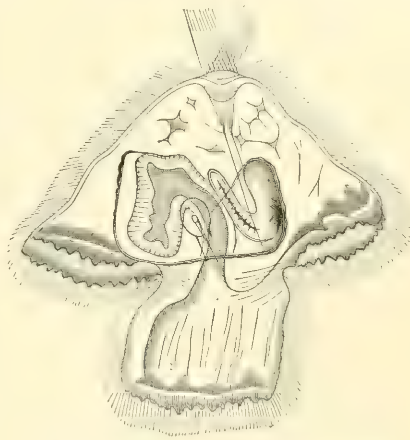
TAPE-WORMS,—Order CESTODA.

The members of this extensive group are internal parasitical worms with the body divided into a number of segments. There is no trace of an alimentary canal, nutriment being obtained by the absorption of juices through the entire surface of the body. The head is furnished with suckers, or hooks, or both, by means of which the worm adheres to the walls of the intestine of the host it infests. The nervous system consists of a ganglion in the head, and a cord on each side. As a well-known example, we may take *Tænia saginata*, one of the human tapeworms; and since its structure and the phases through which it passes in the course of its development are thoroughly known, a detailed discussion of its characteristics will serve as an introduction to the study of the group. In its mature state this worm, which spends this stage of its existence in the human intestines, may reach a length of 5 or 6 yards. Its head is relatively minute, being only about equal to that of an average pin in size, and furnished with four suckers, by means of which the creature adheres firmly to the walls of the intestine. The head is followed by a narrow piece called the neck, which gradually passes posteriorly into the trunk. It is not jointed, but where it merges with the



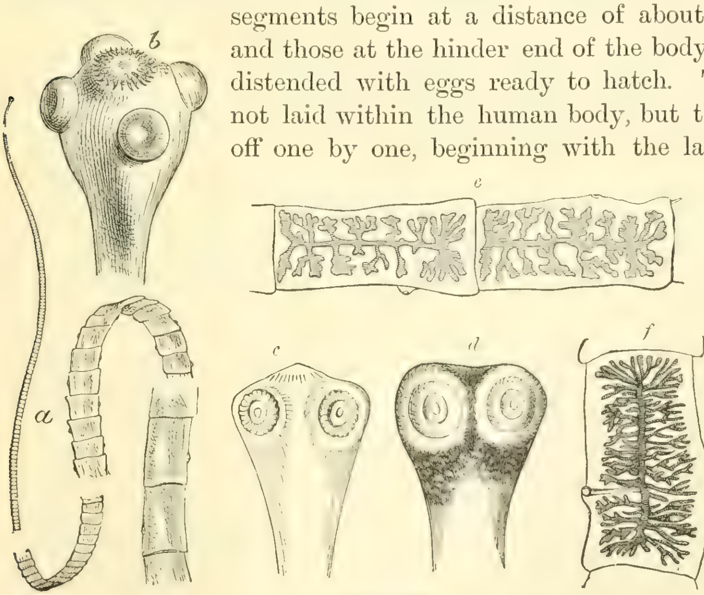
A NEMERTINE, *Pterosoma planum* (enlarged).

trunk it becomes marked by shallow grooves, growing deeper and deeper as they recede from the head, until ultimately they divide up the body into a chain of flattened, square or oblong segments, of which there may be many hundreds. Each segment is called a *proglottis*, the whole series being termed *proglottides*. The muscular system is fairly well developed, and consists of fibres running lengthwise throughout the segments and across from side to side, and of others passing from the upper to the lower walls. By means of these muscles the worm is able to shift at will its point of attachment to the gut, and to lengthen or shorten its body to a very considerable extent. The chief centre of the nervous system lies in the head, and from this portion, which may be called the brain, nerves pass forwards to supply the suckers, while a single stout cord runs backwards on each side to the end of the body, lying close to the edge of the segments.



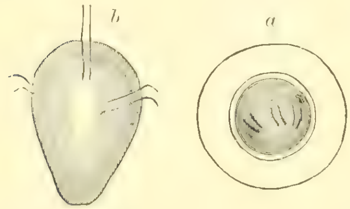
PILIDIUM LARVA, WITH NEMERTINE WORM DEVELOPING INSIDE.

As already pointed out, there is no trace of a mouth nor intestinal canal, although there is an excretory organ, consisting of a ring-shaped vessel in the head, from which four tubes, corresponding in position with the sucker, are prolonged backwards. Two of these soon vanish, but the others lying near the edges of the segments, close to the inner side of the nerve-chords and the longitudinal muscular band, extend to the hinder end of the body, where they unite and communicate with the exterior by a common aperture. At the hinder end of each of the segments these two ducts are united by a third, which runs across from side to side. In addition to these structures, each fully-grown segment contains a complete set of organs for the formation and fertilisation of eggs, of which an immense number are developed. The mature segments begin at a distance of about a foot from the head, and those at the hinder end of the body are the first to become distended with eggs ready to hatch. The eggs, however, are not laid within the human body, but the ripe segments break off one by one, beginning with the last, and pass out of the intestine.



HUMAN TAPE-WORMS.
a Tænia solium (nat. size); *b, c, d*, Head enlarged; *e*, Segments; *f*, Segment of *Tænia saginata* (enlarged).

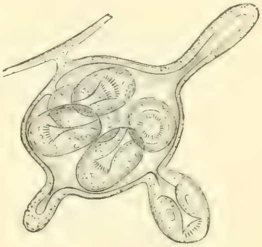
The rupture is effected by the contraction of the muscular fibres, which acts upon the transverse vessel of the excretory system of the segment in front, in such a way that a fresh terminal pore is formed. The ripe *proglottis*, or segment ready for separation, is little more than a sac that is crammed with minute spherical eggs, set free by the bursting of its walls. In this way the eggs, which, on account of their thick protecting shell, are able to withstand the most unfavourable conditions, are disseminated abroad; and, owing to their vast numbers and minute size, some ultimately succeed in making their way in connection with either food or water into the stomach of an ox. Here the egg-shell is dissolved by the action of the digestive fluids, and a small embryo, the *proscolex*, is set free. This embryo is a small round creature furnished with six hooks, arranged in three pairs. Upon this proscolex the gastric and intestinal juices have no effect; but instead of undergoing further development in the alimentary canal of the ox, it bores by means of its hooks into the blood-vessels of its host, and is thus carried by the circulation into the muscles, liver, lungs, brain, or other suitable resting place, where it starts its growth. Here it elongates, and becomes larger, while the hooks drop off and the central portion liquefies, so that a bladder of fluid is formed. When these bladders—which are oval and about a quarter of an inch in length—are found lying side by side between the muscular fibres of beef, the meat is spoken of as measly. The next step is the formation of the head, which takes place in the following way. At one spot on the side of the bladder an infolding of the outer skin takes place, and this elongates until converted into a hollow sac projecting into the cavity of the bladder. At four equidistant points near the bottom of the pushed-in sac the suckers of the head appear. The head therefore is developed outside-in, but subsequently it is pushed out, and the embryo, which in this stage is termed *Cysticercus bovis*, consists of a head, a neck, and a bladder. Beyond this stage the tape-worm cannot go so long as it remains in the body of the ox. If, however, the latter be killed for food, and its affected flesh eaten in an uncooked state, the bladder and neck of the *Cysticercus* are dissolved by the digestive fluids, while the head, which is often spoken of as the *scolex*, fixes itself to the walls of the intestine, its neck gradually elongates, and the body grows and becomes divided into segments, or *proglottides*. Another common tape-worm in Europe is *T. solium*, which is scarcely so long as *T. saginata*, and may be distinguished by the presence of a circlet of hooks on the head in front of the suckers, as well as by the smaller number of egg-sacs in the ripe segments. It has long been well established that human beings share with pigs in the breeding of this tape-worm, the bladder worm stage (*cellulosæ*) being found in one of these quadrupeds, and the cycle of development similar in all respects to that of *T. saginata*. In addition to being found in swine, the bladder-worm stage of *T. solium* also occurs in a few other animals, such as monkeys and dogs; and even in man, if through any accident an egg has been swallowed, the *Cysticercus* duly makes its appearance in the muscles, heart, brain, or eye, and may thus be the cause of very serious consequences. Another tape-worm (*T. cucumerina*), sometimes found in man, frequently lives in



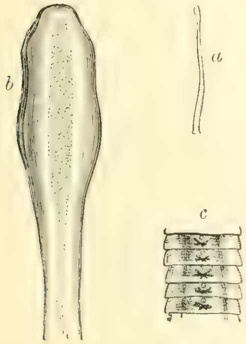
EGG (*a*) AND SIX-HOOKED EMBRYO (*b*) OR *Proscolex* OF TAPE-WORM.

BLADDER-WORM STAGE (*Cysticercus*) OF TAPE-WORM.
a, With head beginning to turn; *b*, With head protruded.

abundance in dogs and cats. Many other tape-worms live in these mammals, one of the commonest infesting the former being *T. serrata*, distinguished by a double row of hooks on the head. In the bladder-worm stage this species lives in rabbits and hares. The commonest form in cats is *T. crassicollis*, which has a large head and a short thick neck, its bladder-worm stage being passed in mice. Perhaps, however, the most important tape-worm of the dog is *T. cœnurus*, interesting on account of the remarkable features it presents in its condition as a bladder-worm, and the serious disease, known as the staggers, which its presence in the brain brings upon sheep. Another pest of much the same nature is the bladder-worm known as *Echinococcus*. The mature worm living in the dog is a small tape-worm, scarcely more than a sixth of an inch in length, and differs from the species hitherto discussed, in that it consists merely of a head, neck, and three distinct segments, of which the third or last becomes ripe and then equals the rest of the worm in length. The head, like that of *T. solium*, is furnished with suckers and hooks, and the embryo which hatches from the egg is armed, like the rest, with six hooks. The bladder-worm stage occurs in both men and pigs, and each bladder becomes the brooding-place of a large number of others. Upon the surface of the bladder several ingrowths are developed, and each of these gives rise to a single head. As many as twelve, fifteen, or twenty may be formed. The bladder, however, sometimes becomes more complicated by the formation, either outwardly or inwardly, of secondary head-producing vesicles, so that the original cyst is enveloped by others which have arisen as its buds. To complete the register of the tape-worms, whose life-histories are bound up with our own existence, the genus *Bothriocephalus* must be mentioned. The commonest species (*B. latus*) is the largest of human tape-worms, and may attain a length of nearly 10 yards, and be furnished with from three to four thousand segments. It may be at once distinguished from the species of *Tænia* by the shape of its head, which is long, flattened, and furnished with a deep cleft or slit on each side. The intermediate hosts of this worm are fresh-water fish. Belonging to the same class as the preceding is the strap-worm (*Ligula simplicissima*), which reaches maturity in the intestine of various water-fowl, but is found in the bladder-worm stage in the body-cavity of whiting, which swallow the eggs expelled from birds. A peculiarity of this worm is, that the segmentation of the body into proglottides does not take place.



Tænia echinococcus (enlarged).



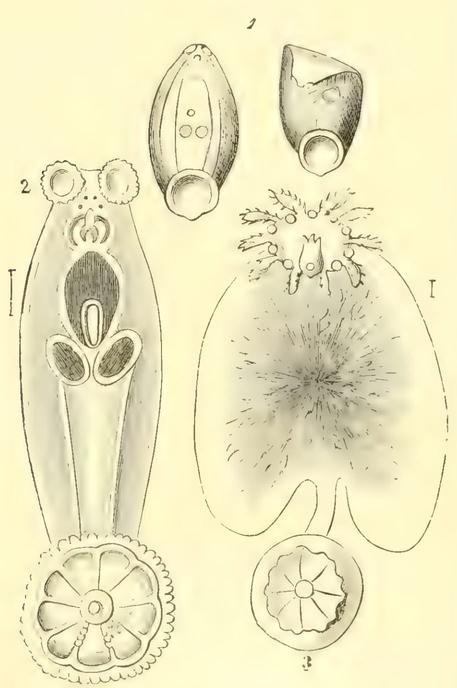
BROAD TAPE-WORM (*Bothriocephalus*). *a*, Head nat. size; *b*, Head enlarged; *c*, Segments.

TREMATODE WORMS,—Order **Trematoda**.

Some of the less highly organised members of the preceding group, namely, those which are not segmented, are nearly related to the present section of parasitic worms. In this class the body is unsegmented, usually leaf-like in form, smooth-skinned, and provided with suctorial discs in the middle or at its hinder end. There is a distinct digestive canal, usually forked, but provided with only one aperture, namely, the mouth. The excretory organs open by one or two pores at the hinder end of the body, and, as in the tape-worms, the male and female generative organs coexist in one individual. Although all are parasitic, the higher members are external parasites, and develop without migration; whereas the lower ones make a complicated migration, with intermediate stages of development, spending their youth in one host, and their maturity in a second.

MANY-SUCKERED GROUP,—Suborder Polystomeæ.

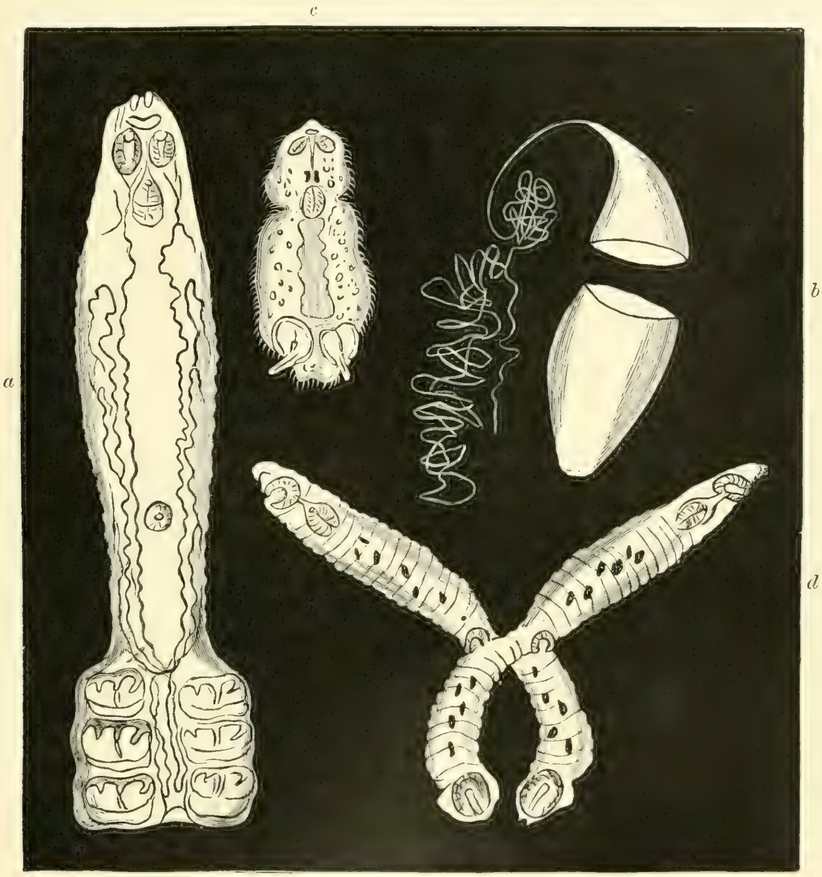
The characteristic feature of this group is the presence in the fore-part of the body of two small sucking-discs, and also of a large one and several small ones at the hinder end, as well as sometimes hooks for clinging. These worms are chiefly external parasites, laying fairly large eggs, and the young develop without an intermediate generation. One of the best known genera is *Epibdella*, in which suckers are placed close to the true mouth, giving the appearance of three apertures of this nature. Fig. 1 of the illustration represents a specimen of one species; in the right-hand figure the head being curled upwards and backwards. The posterior sucker is large and furnished with three hooks; the two anterior suckers are smaller, and behind them is the mouth. This worm is of a whitish colour, and lives parasitically upon plaice and halibut. Nearly related is *Trochopus*, a parasite of the gurnard, represented in Fig. 2 of the illustration, the line to the left hand of the illustration showing the natural size of the animal. On the head, in addition to the two suckers and mouth, are four black spots, lying just in front of the last-mentioned aperture, which are the eyes. The posterior sucker is of enormous size, and rosette or wheel-shaped; it is supported by nine spokes, and surrounded by a fringed border. Fig. 3 of the same illustration represents a species of the allied genus *Cyclatella*, much magnified. This trematode is one of the most striking members of the group. The body is oval, flat, and pure white in colour. At its hinder end it is marked out by a deep notch on each side into three processes, of which the two external ones are wide and lobate, while the middle one forms a slender tail-like appendage, supporting the large circular sucker. This



TREMATODE WORMS.
1, *Epibdella*; 2, *Trochopus*; 3, *Cyclatella*.

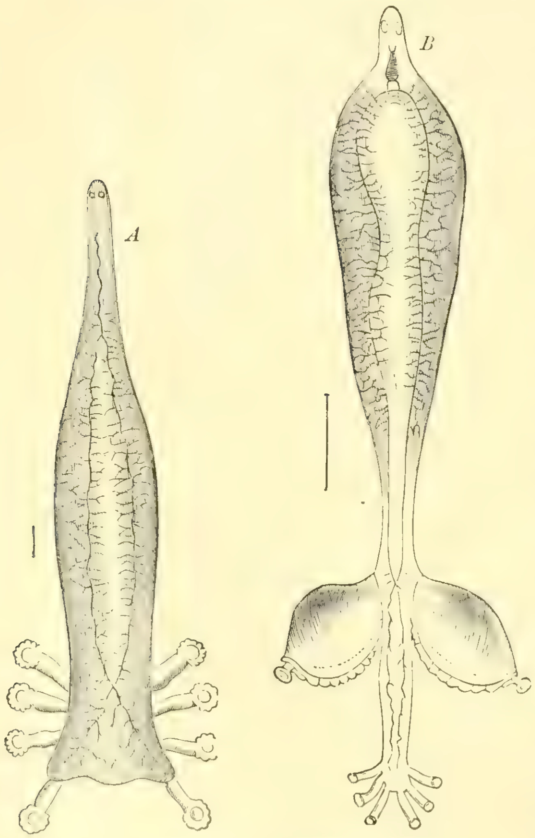
organ is supported by a set of radiating spines, eight in number, and has a soft membranaceous rim. The head is surrounded by a circlet of small feelers. This worm—one of the smallest of its group—lives as an external parasite upon annelids, especially upon tube-making forms, such as *Clymene*.

The worms which constitute a second section of the present suborder differ from the foregoing in possessing several sucking-discs at the hinder end of the body. Among them is a curious creature well deserving its name of *Diplozoum*



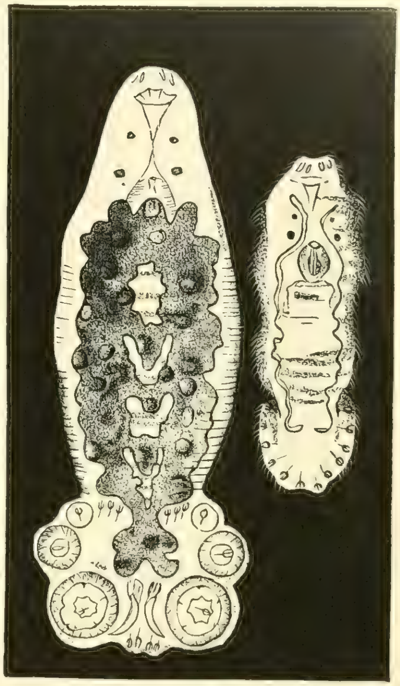
LIFE-HISTORY OF DOUBLE-WORM (magnified).

paradoxum, since it consists of two complete, mature similar halves, each possessing every attribute of a perfect animal (*a*). Each of the pointed front ends has a mouth aperture, and close to it a couple of small sucking-discs; while each individual has a separate intestine consisting of a median tube and innumerable side-branches. At the hinder end of the body are two suckers sunk in a depression, and protected by four hard buckle-shaped organs. The double-worm lives on the gills of several species of fresh-water fish, the gudgeon and minnow for instance. The eggs are elongate and provided at one end with a fine thread-like appendage (*b*). In this egg the young (*c*)—which at the time of hatching is only about one hundredth of an inch—takes about a fortnight to develop. It is covered with cilia, has two eyes, and only a couple of suckers at the hinder end of the body. After quitting the egg the larvæ are very lively and restless in their movements, either gliding slowly hither and thither, or swimming with rapidity. If unable to find the fish in whose gills they are destined to live, they grow feeble and perish; but if successful in making a settlement in their necessary surroundings, they grow into the *Diporpa* (*d*), which is flattened and lancet-like in shape, and bears a small sucking-disc on the under surface, and a conical excresence on the back. After living some weeks or months in this state, and gaining nourishment by sucking blood from the fish's gills, the worms begin to join together in pairs, one specimen seizing the conical excrescence of another by its ventral sucker, then, by means of a truly acrobatic feat, the second twists round until it is able similarly to attach itself to the dorsal excrescence of the first, and in this state an inseparable fusion takes place between the suckers and excrescences involved in the adhesion. Another remarkable trematode is *Anthocotyle merlucci*, parasitic on the gills of the whiting, which is represented in *B* of the illustration. The other worm represented in the same illustration (*A*) is *Dactylocotyle pollacki*, a parasite on the gills of the pollack. Here the slender front end of the body is much longer than in the last, the trunk gradually expands, and is wide and squarely cut at its posterior extremity, upon which are four pairs of long, stout, stalked suckers. The foremost pair of these seem to correspond to the very large suckers of *Anthocotyle*. We now come to two species of the present group of trematodes which, by their manner of life, lead to the second division of the internal parasitic forms. The first of these (*Aspidogaster*), found in the interior of the fresh-water mussels, is little known; but our acquaintance with the development of the second (*Polystomum*) is tolerably complete. This animal, with a roundish body, is less than half an inch in length, and is easily recognisable by the presence at the hinder end of the body of a large wheel-like expansion bearing three pairs of suckers, between the last and longest pair of which are a couple of strong hooks. In the adult stage this worm lives parasitically in the bladder of frogs. It lays its eggs in the spring, and by thrusting itself partially out of the frog's body deposits them in the water. The eggs take from six to



A, *Dactylocotyle*; *B*, *Anthocotyle* (magnified).

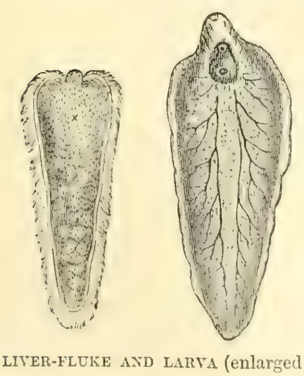
eight weeks to hatch; and the young worm is an active little animal, swimming by means of the cilia with which its body is bordered. It differs from the adult by the presence of the fringe of cilia which extends along the sides of the body from head to tail, and also by the absence of suckers at the posterior extremity of the body. The latter, however, is furnished with eight pairs of hooks, which are retained in the adult. After leading a free life for a short time, the larva attaches itself to the external gills of a tadpole, and speedily loses its clothing of cilia. When the gills shrivel with the conversion of the tadpole into a frog, the larva enters the mouth of its host, and, passing thence into its intestine, succeeds in ultimately making its way into the bladder, where it lives some five or six years before reaching maturity.



Polystomum AND LARVA (magnified).

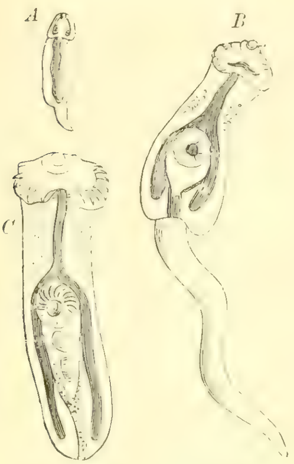
Two-Suckered Group,—Suborder Distomeæ.

The second division of trematodes is distinguished by the smaller number of suckers, the absence of hooks, and the circumstance that all the members of the group are internal parasites, laying an immense number of small eggs; while in the course of their development the young are inhabitants of more than one host. It is evident that parasites living upon the skin or gills of fish, where they are constantly in danger of being washed away, have much greater need of sucking-discs and clinging-hooks than those living within shelter of some internal organ. On the other hand, it is equally clear that the large number of eggs laid by the internal forms, which pass through a complicated metamorphosis, is a means for providing against the remoteness of the chances of the larvæ meeting with their appropriate hosts. Some of these worms are of importance, on account of the destruction they bring upon the hosts they infest. One of the best known is the liver-fluke (*Distomum hepaticum*), found in the mature stage in the livers of sheep. It is about an inch in length, and nearly half an inch broad. The hinder portion of its body is flattened and leaf-like, but the front is thick and conical, and the outer skin is furnished with many backwardly-directed spines. The eggs—of which it has been computed half a million may be laid at a time—pass into the intestine of the sheep by way of the bile-ducts, and thence make their way to the exterior. Many of these eggs fall upon dry ground, where they

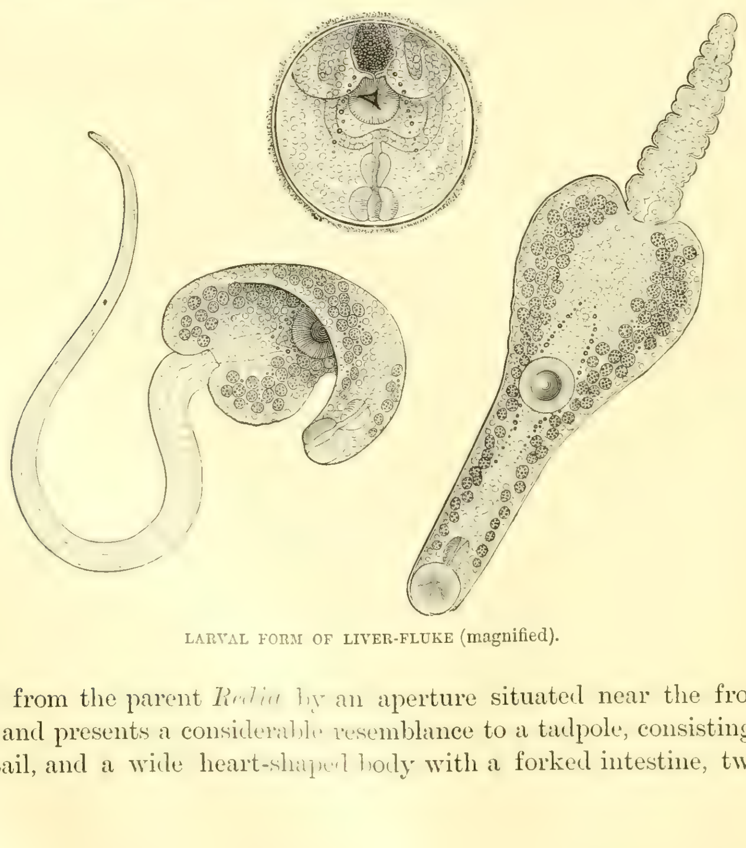


LIVER-FLUKE AND LARVA (enlarged).

perish. Some however, in all probability, make their way into water. When this has taken place, the egg, after two or three weeks, gives birth to a free-swimming, ciliated, conical embryo, provided with a double eye and rudiments of an excretory system. By means of its cilia, this embryo swims rapidly about in search of a particular species of pond-snail. If it fails in its search, it perishes in about eight or ten hours; but, if successful, it proceeds to bore its way into the soft tissues of the mollusc. As soon as it has effected an entrance, it loses its cilia and turns into an oval sac, the *sporocyst*. The latter may multiply by fission, but in any case, in its interior, another organism, called after Redi, its discoverer, *Redia*, arises. This bores its way out of the sporocyst, which closing up again forms another; but if too many are developed they may cause the death of the snail. The *Redia* is cylindrical in shape, and has a distinct mouth and stomach, and in the hinder half of its body there is a pair of bud-like processes, serving as rudimentary feet. The larva in this stage takes up its abode in the liver of the snail, where, in turn, it proceeds to propagate. Its offspring may be a *Redia* like itself but more often it has a different form, and has received the name *Cercaria*.



DEVELOPMENT OF *Distomum echinatum*.


LARVAL FORM OF LIVER-FLUKE (magnified).

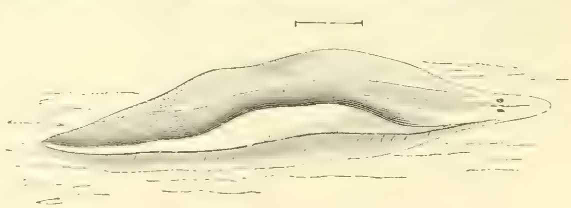
It escapes from the parent *Redia* by an aperture situated near the front end of its body; and presents a considerable resemblance to a tadpole, consisting of a long vibratile tail, and a wide heart-shaped body with a forked intestine, two suckers, and a gland on each side of the intestine. These larvæ make their way out of the snail, but instead of seeking a new host swim about for a time and ultimately settle upon some water-plant, or a blade of grass in a meadow. Here they enclose themselves in a capsule, and await the chance of being devoured along with the grass by a sheep. From the stomach of the sheep they make their way into the bile-ducts, and there develop into the mature stage.

Turbellarian Worms—Order Turbellaria.

Nearly all the worms of this group lead a free life, parasitism amongst them being the exception. They are found either on the land or in fresh or salt water, and have received the name Turbellaria, or whirl-worms, from the whirling eddies of water caused by the lashing of the cilia with which their unsegmented and flattened bodies are covered. In shape they vary considerably, being either short and oval, or long and worm-like. The alimentary canal is almost always well developed, having a distinct mouth, but never a posterior outlet. There are no special respiratory or circulatory organs, the function of breathing being performed by the entire surface of the skin. The nervous system consists of a large double-lobed brain-ganglion, from which, in addition to some branches passing forwards and outwards to supply the head and eyes, two stout cords, one on each side of the body, run backwards to supply the tail.

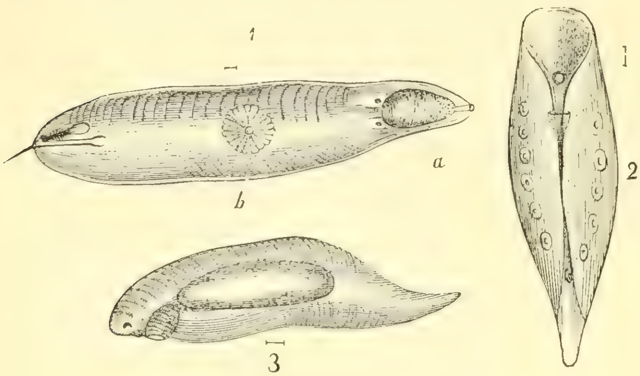
Suborder **Rhabdocœla.**

This group is characterised by the straight and unbranched intestine. A fairly well-known member of the suborder is *Mesostomum ehrenbergi*, a species about half an inch long, found during spring and summer in ponds and streams. The generic name refers to the fact that the mouth, with its muscular gullet, is situated in the middle of the lower surface of the body. Although as transparent as glass and extremely fragile, it is a swift swimmer, moving quietly through the water either by means of its cilia, or by waving the edges of the exceedingly flexible body. It feeds upon fresh-water worms, insects, and crustaceans, its way of overcoming its prey being somewhat curious. The worm converts its body into a cup-shaped hollow, at the bottom of which the mouth is situated, by bringing the two ends close together, and turning over the flexible edges in the same direction. In this manner it envelops its prey, and so deprives it of all chance of escape. It is stated that this and other species ensnare their prey by means of slimy threads. Eggs of two kinds are laid; those found in summer being soft-shelled, while those of winter are protected by a hard and thick coat so as to be able to withstand the unfavourable conditions of this season. An allied species (*M. tetragonum*) is shown in the accompanying illustration.

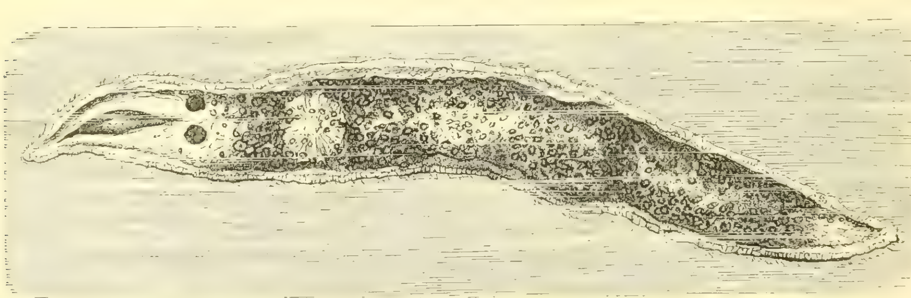


Mesostomum tetragonum.

Upon the narrow and pointed head are the two little black eye-spots. In the genus *Prostomum* the mouth (*b*) is situated in the middle of the ventral surface, as in the last, but the slender and pointed head-end is provided with a distinct proboscis (*a*), which calls to mind that of the nemertines, inasmuch as it is not directly connected with the mouth, and is contained in a special sheath. The posterior end of the body, on the contrary, is thick, club-shaped, and armed with a sharp goad, which seems to be used as an organ of defence. The same illustration shows a species of the allied genus *Vortex,* in which the aperture of the mouth is on the under side, near the front end of the body. This mouth leads into a large oval gullet, communicating with the long sac-like intestine. The black spot in front of the mouth is the eye. In *Schizostoma,* on the contrary, the mouth which is long and slit-like, is situated in front of the two eyes. Some of the allied genera lead a parasitic and not a free life. For instance, *Anoplodium* is found upon sea-cucumbers, and *Graffilla* upon marine gastropods.



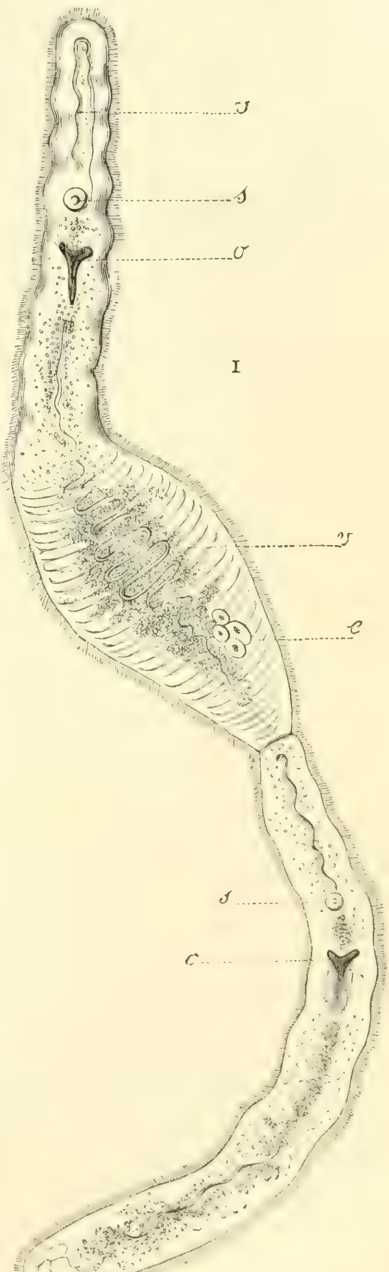
TREMATODES.
1, *Prostomum*—*a*, proboscis ; *b*, mouth. 2, *Convoluta*. 3, *Vortex*.
(Natural size represented by lines.)



Schizostoma productum (enlarged 200 times).

Differing in many important points from the typical Rhabdocœla is the small marine *Convoluta,* shown in Fig. 2 of the illustration, in which the alimentary canal, the excretory organs, and the nervous system have disappeared. Imbedded in the solid tissues of some of the species of *Convoluta* are large numbers of cells containing chlorophyll, or the green colouring matter of plants. These cells are probably minute plants (*Algæ*), which have taken up their abode parasitically in the worm. In addition to the ordinary means of reproduction by sexual organs, some of the rhabdocœlans multiply by division.

The accompanying illustration shows one of these worms (*Stenostomum monocelis*) in process of giving rise to a second individual. In the upper half of the figure (*o*) is the mouth, and (*s*) the auditory organ of the parent; the coiled tube (*v*) being part of its excretory apparatus, and (*e*) some eggs. In the lower half (*o*) is the mouth, and (*s*) the auditory organ of the newly-forming individual. The division may begin successively at several places on the body before the last and oldest bud is attached, so that it results in the formation of a chain of segments lying one behind the other.



SINGLE-EYED TURBELLARIAN, *Stenostomum* (much enlarged).

Suborder **Dendrocœla.**

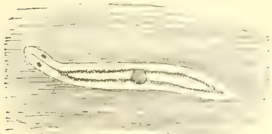
The members of this division differ from the preceding in having the intestinal canal tree-like, or divided into a number of branches. The mouth, which is situated on the inner surface, leads into a muscular and flexible pharynx, capable of protrusion like a proboscis. The body is broad and flattened, usually broader in front than behind, and generally bears a pair of eyes upon what may be termed the head. In the genus *Polycelis*—the species of which occur in meadows and stagnant water—there are a large number of eyes, the broad front end of the body being bordered with from thirty to fifty of these organs. On the other hand, *Geoplana subterranea*, which lives in sandy and clayey soil, in company with earth-worms, upon which it feeds, is entirely devoid of organs of sight. Many members of the group are inhabitants of the land and fresh water, and are collectively termed Planarians. These are often objects of considerable beauty, being both graceful in movement and decked with various colours. The two-striped *Geodesmus bilineatus*, for instance—which has been found in hothouses in Europe, where it has been doubtless introduced from the tropics with exotic plants—is a dull yellowish colour above, but is ornamented with two reddish brown bands, extending on each side of the back, and meeting near the front and hinder end of the body. Another planarian not infrequently introduced into the conservatories of Europe belongs to the genus *Bipalium*; this species

(*B. kewense*) having been first obtained in the plant houses at Kew. It is a striking creature, measuring upwards of a foot in length when fully extended, and

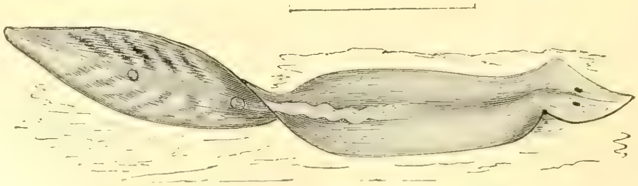
STRUCTURE OF A DENDROCŒLIAN (enlarged 5 times).

having the grey colour of its skin relieved by three dark longitudinal bands running along the back from the head to the tail. It is exceedingly flexible and contractile, looking sometimes short and stout, and at other times long and narrow. The head is susceptible of many changes of form, assuming the shape of a hammer-head or the blade of a cheese-cutter, and the next moment being tongue-shaped. The skin is richly supplied with glands, secreting a sticky slime, by means of which the *Bipalium* is able to ascend perpendicular surfaces, and to lower itself from a high point by letting out a thread of the material. It is said to feed upon earth-worms, and to propagate by division; the tail-end breaking off and growing into a second individual by acquiring a head, proboscis, and intestine. Land planarians are abundant in the damp tropical forests of Ceylon, South America, and Australia; and a rich population of allied forms frequents the sea. One of the most striking of these marine forms is the tufted planarian (*Thysanozoum*), represented in the illustration on p. 473. Here the back is covered with many rows of dark-coloured tufts; the lower surface being pure white, and the head end furnished with a pair of ear-shaped lappets, in which the sense of touch appears to be concentrated. The creature is shown clinging to a

SMOOTH POLYCELIS.
a, The animal; *c*, The eyes.



TWO-STRIPED GEODESMUS (enlarged twice).

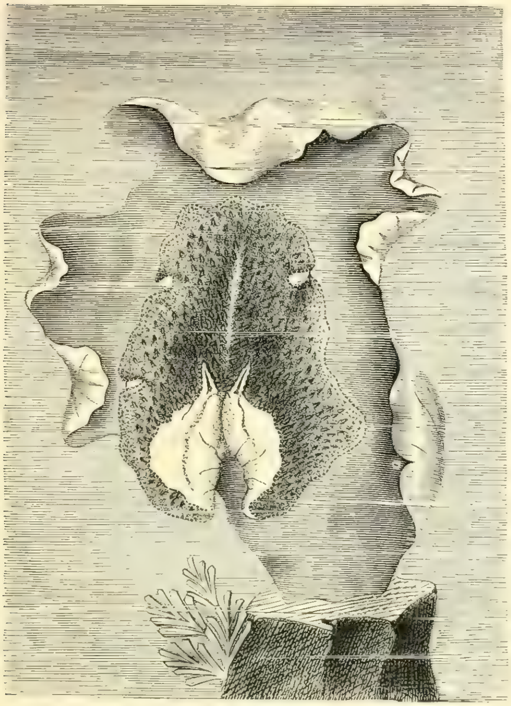


PLANARIAN WORM, *Planaria gonocephala* (enlarged).

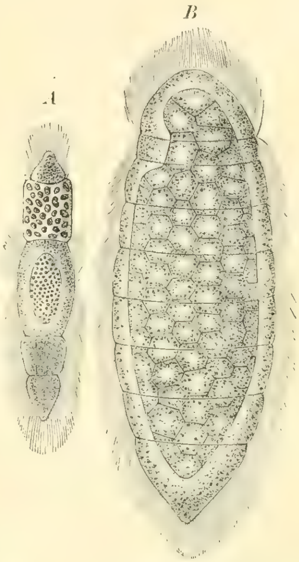
branch of seaweed, with the head elevated so as to exhibit its lower surface, and feeling for a new surface of support. *Planaria gonocephala*, figured above, is one of the land forms. The general structure of the intestine in all the animals of this group is shown in the illustration at the top of the page.

Group of Uncertain Position.

To complete our account of the worms, mention must be made of the parasitic families *Orthonectidæ* and *Dicyemidæ*, of which the serial position is uncertain.

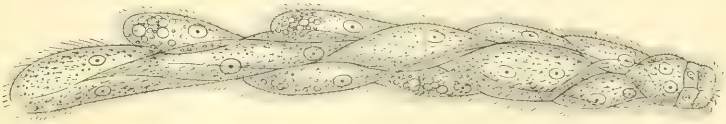


TUFTED PLANARIAN, *Thysanozoum* (enlarged twice).



Rhopalura. *A*, Male ; *B*, Female. (Very much enlarged.)

The members of the former inhabit the body-cavity of certain turbellarian and nemertine worms and brittle-stars. They are minute, segmented creatures, scarcely exceeding the twentieth of an inch in length, and without digestive organs or nervous system, but with the skin ciliated. The males are smaller than the females, being in the figured *Rhopalura* only about half the size of the latter. The *Dicyemidæ* are ciliated, thread-like parasites, varying in length from about a thirteenth to a fifth of an inch in length,



A DICYEMID (enlarged 20 times).

and living in the kidneys of cuttle-fish. The body consists of a central portion, composed of a single long, fusiform cell, around which is arranged a series of whiter cells, partly projecting like papillæ from the surface. At the front end the cells of the external layer form a symmetrical head, by which the parasite attaches itself; but there are no distinct nervous, digestive, or muscular organs.

R. I. POCOCK.

CHAPTER XIV.

Jelly-Fish, Corals, and Sea-Anemones,—
Subkingdom **CŒLENTERATA.**

Few have been able to revel in the exquisite beauty of the southern coral islands, which through thousands of years have been slowly piled up to the surface of the water by the coral-animals. The vivid colouring of the fauna in the lagoons of those marvellous islands is not to be found in European seas, but even in these less favoured climes, any observant traveller, as his ship passes through calm water, may notice lovely creatures nearly related to the corals. Who, for instance, has not seen exquisitely coloured transparent jelly-fish, floating just below the surface, and propelling themselves by alternately expanding and contracting their bells? Or who that has kept a marine aquarium has not admired, as its greatest ornament, the sea-anemones? These animals, the corals, the jelly-fish, and the sea-anemones, constitute the great group known as Cœlenterata. The group comprises all those creatures in which the internal cavity, corresponding with the alimentary canal of other animals, is not a closed canal running through the body, but is commensurate with the whole cavity of the body. Consequently there are no spaces answering to the body-cavity of the Vertebrates, between the wall of the alimentary canal and the outer wall of the body.

A study of the earliest growth of the Cœlenterates has shown that their internal cavities are nothing more than regular radiate outgrowths of the intestine, and, like the latter, come from the primitive intestine of the larva. The result of this development is a condition which does not occur elsewhere in the whole animal kingdom. We have no separate digestive canal, no closed blood vascular system, and no specialised respiratory apparatus. There is only a system of cavities, all in open communication with one another, occupying almost every corner of the body.

Again, the Cœlenterates are radiate in structure, that is, when seen from above, they are typically star-shaped; and if a Cœlenterate be cut across, every horizontal section shows a symmetrical arrangement of the parts around a centre. There are other radiate animals, such as the Echinoderms, but while in these five is the fundamental number of rays, in the Cœlenterates the rays are often far more numerous, being some multiple of four or six. Again, while the skin of the former is almost always modified into a skeleton, or is thick like leather, leathery skins are the exception in the latter. When the Cœlenterates do form calcareous skeletal structures, these are quite different from the tests of the sea-urchins; and, in all cases, the anterior end of the body, crowned with one or more circles of tentacles, remains soft and flower-like. The most highly developed of the free forms, how-

CTENOPHORES

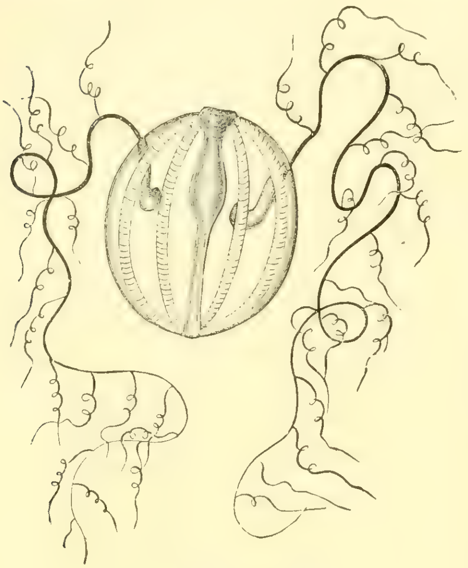
ever, such as the sea-anemones and the jelly-fish, have no hard skeleton at all, but are amongst the most delicate and beautiful objects in the realm of living nature.

In spite of the variety of forms to be found, the Cœlenterata are almost as incapable of higher development as the Echinoderms. Like the latter, they have failed to make any way in fresh water, not to speak of the land. A few free-swimming jelly-fish, a minute attached polyp, and some degenerate sponges are, indeed, found in fresh water, but these can hardly be looked upon as successes. While, at present, it is not easy to connect the Cœlenterata with any other group, inasmuch as they appear to stand without any near relatives among the higher animals, they have a special interest, since they are considered to represent a stage in the development of animal life through which all the higher forms have passed. Some simple form of Cœlenterate may have given rise to all the higher animal forms, the modern Cœlenterates—the sea-anemones, corals, etc—being those descendants of the primitive simple form which have retained the original type of organisation almost unchanged.

The Ctenophores,—Group Ctenophora.

Although all are agreed that the so-called Ctenophores are members of this subkingdom, their exact position is not clear. The Ctenophores are glassy, transparent creatures, either shaped like apples, melons, or Phrygian caps, or else forming bands, often a yard in length, and thickened at the middle. Several types are shown in the coloured Plate. The marvellous transparency of all but one (*Beroë*) is specially remarkable. They inhabit the open sea, or are driven by currents and winds near the coast and into harbours. Their position in the water is usually more or less vertical, the mouth being turned downwards. The organs from which this group takes its name are the ribs, which either run from pole to pole, or else only for certain distances along the meridians, which are often symmetrically arranged. These ribs consist of rows of short transverse combs, each being formed of a row of cilia. The cilia forming a comb are connected together at their bases, but are also capable of independent movement. As they wave to and fro, they constitute what is called a swimming or rowing plate. The activity of these rows of plates depends upon the will of the animal, which can move either the plates of a single rib, or all the ribs together; this latter movement resulting in slow locomotion in the direction of the apical pole, *i.e.* the pole turned away from the mouth. The body is capable of various swift, light, and graceful movements, for in addition to the rowing plates there are other structures, such as the oral umbrella and the capturing filaments or tentacles, with their hair-like branches. These tentacles, which are attached like arms at the sides, are capable of erection, or of withdrawal into pockets. There is great variety in the development of these accessory organs of locomotion. For instance, the *Cydippidæ* have only arms, which, with their branches, serve for capturing food as well as for steering. In other orders, vertical, oar-like, dermal folds stand out from the body, by means of which the movements become more rapid and energetic. Some species of *Eucharis*, by suddenly shutting up the oral umbrella, can jerk themselves forward; and when successive jerks of this sort cause the body to move with greater speed than usual, the arms are withdrawn into their pockets or stretched backward like a rudder. This power of free locomotion necessitates some regulating organ, so that the desired direction or position of the body may be maintained. Such an organ exists at the apical pole of the body, and may be described as consisting of a small weight borne on springs, by which the oscillations of the body or deviations from the line of movement can be instantly felt.

The ventrally placed mouth is like a large slit between the folds of the umbrella, and leads into a stomach which is either tubular or flattened. The food is digested in this stomach, the indigestible parts, mixed with mucus, being again ejected through the mouth. The upper end of the stomach is in direct communication with a funnel-shaped space of variable width. From this funnel-like cavity canals arise, which branch and run below the outer surface, following the lines of the ribs. This funnel further possesses an aperture of its own, opening on the exterior, in the region of the apical pole. Within the funnel is found a fluid substance containing particles of the food-pulp drawn in from the stomach, but consisting chiefly of water, taken in voluntarily; this fluid being kept in motion by ciliary action through the canal-system. Although water is also sometimes taken in through the proper apical aperture of the funnel, this aperture seems principally to serve for the ejection of the fluid when of no further use. It is then also mixed with waste matters from the body. Stinging-cells, such as occur in the next group, have as yet been found in only one species of Ctenophore (*Haeckelia rubra*), and then only in small numbers. Instead of stinging-cells, the Ctenophores have adhesive cells, or small hemispherical knobs found on the tentacles or capturing filaments; these being provided with elastic, spirally-coiled stalks, but containing no poison. These knobs are beset with sticky globules, to which small animals, such as minute crustaceans easily become attached. If the prey attempt to escape, the spiral thread by which the knobs are attached becomes stretched. When the thread is withdrawn, it more or less entangles the victim, and, being like the knob, provided with a great number of sticky particles, renders escape impossible. These structures are very different from stinging-cells, which are useless to an animal after having been once employed. An adhesive cell or knob can act apparently any number of times, being each time drawn back by the spiral thread to its former position.



CYDIPPE (nat. size).

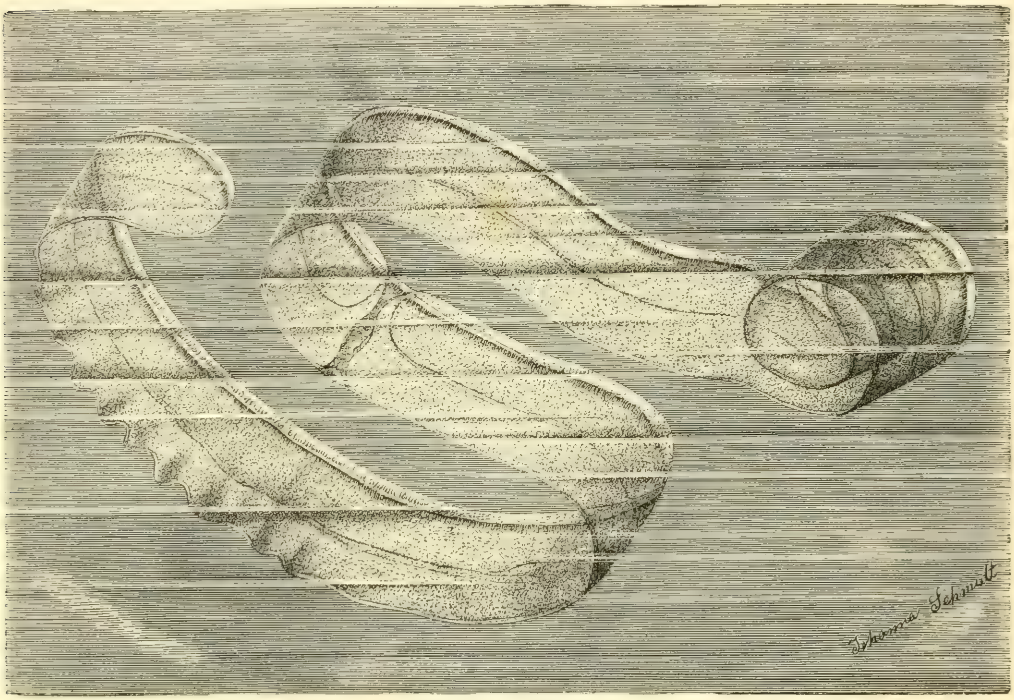
Ctenophores feed upon all kinds of small pelagic animals, especially Crustaceans, while they themselves fall a prey to the disc-shaped jelly-fish and anemones. Ctenophores may continue to grow, if uninjured, almost indefinitely, or as long as life lasts. Storms, however, destroy them. The largest specimens are, as a rule, found in waters sheltered from the wind. They are to be seen throughout the whole year, but are most plentiful during the spring months, and become rarer towards summer, when some species, such as the Venus' girdle, almost completely disappear. In the early autumn, however, great swarms appear, especially of *Cestus* and *Beroë.* After a spring of active fertility, the larvæ, at the beginning of the hot months, sink down to greater depths, where they grow into adults, and come to the surface again in swarms in autumn.

Insignificant as these delicate creatures may appear, they delight the eye, both while living and after death, by their luminosity. This is principally displayed in the walls of the canals below the ribs. It is a curious fact, and one unique as regards luminous marine animals, that Ctenophora, after being exposed for only a short time to the light of the sun or the moon, or to artificial light, when suddenly brought into a dark room, are incapable of giving light. Allman is of opinion that the *Beroidæ* and their broods must be regarded as the principal source of marine phosphoresence on the English coast.

The Ctenophora are hermaphrodite; sexually mature animals of many species being found throughout the whole year, while others occur only in spring, summer, or winter. The young pass through a metamorphosis, or have larval stages which precede the definite form. In at least one species (*Eucharis multicornis*) sexually mature larvæ, or larvæ which are capable of reproduction as such, also occur; these, when completely developed, become once more capable of reproduction as adults;—a method of multiplication which has been called dissogony.

The most interesting, if not the most beautiful, of the Ctenophora are the *Beroidæ,*—shown in the coloured Plate,—which resemble Phrygian caps in shape. In section, they are oval; the mouth is wide, and they have no capturing filaments or tentacles, and therefore no adhesive cells. They attain a size of 8 inches, and are of a delicate red colour, which appears marbled. This appearance is due to the branching of the eight principal canals above described, the ramifications forming a network. *Beroë forskalia*, shown in the Plate, is found in the Mediterranean. The *Beroidæ* are carnivorous, feeding on their own relations of other genera. On one occasion, a large *Eucharis* was placed in a basin with a *Beroë forskalia*, not half its size, in a fasting condition. The latter, attracted by its wonted food, began swimming round the *Eucharis* in large circles, with wide open mouth. On approaching its victim, it darted at it, and seized it. The swimming-plates of the *Eucharis* beat helplessly, when, to the astonishment of the observers, this large creature was completely mastered by the *Beroë,* which in less than a quarter of an hour succeeded in swallowing its victim, and, distended like a balloon, lay at the bottom digesting it.

The *Cydippidæ* are conical, or barrel-shaped, with the ribs uniformly developed, and two opposite tentacles, one on each side. The beautiful creature figured in the Plate is *Hormiphora plumosa* from the Mediterranean. The remarkable Venus' girdle (*Cestus veneris*), shown in the annexed illustration, is so called because the body is lengthened out sideways like a ribbon, so that the mouth is found on the under edge of the ribbon half-way along it. This girdle-shaped, transparent creature, iridescent in the sunshine, is a dazzling sight. The ribbon is edged with cilia, corresponding with the ciliated combs of the body proper. An additional charm is added to this beautiful form by its lively graceful movements, the ribbon assuming all possible curves. If roughly touched, it rolls up spirally, beginning at one end. When undisturbed, its ribbon-like outgrowths are sometimes stretched out, sometimes more or less rolled up, or else the one is rolled up and the other extended. It can, like other Ctenophora, keep itself in motion by the mere play of its cilia, but it also uses the undulating movements of its ribbon-like body. The transformation of the larva after leaving the egg is complicated. The



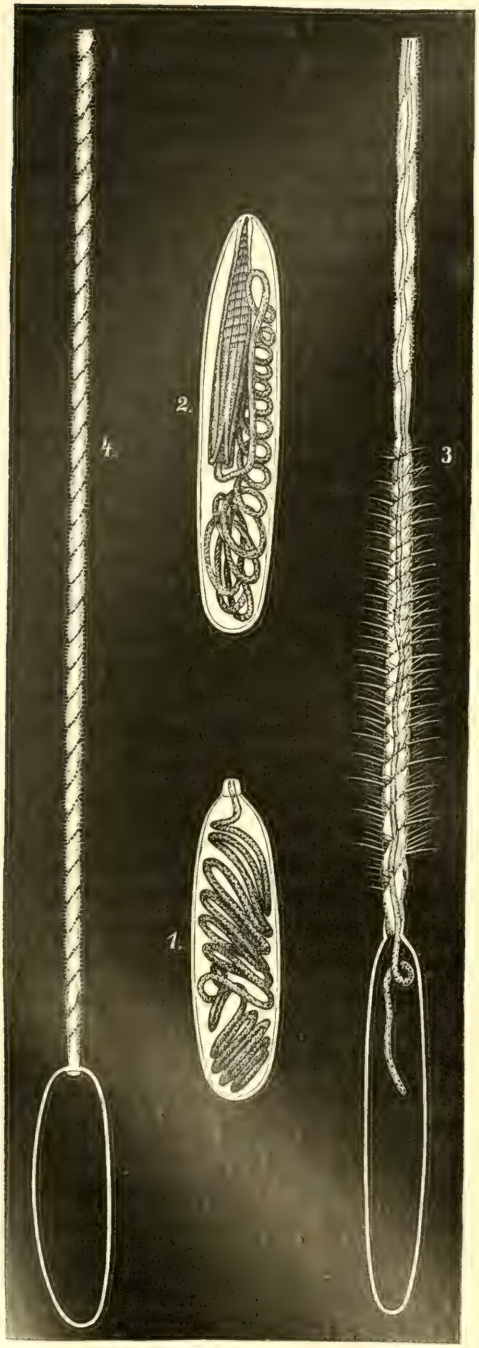
VENUS' GIRDLE ($\frac{1}{2}$ nat. size).

young larva is shaped like a balloon, and possesses two principal tentacles provided with lateral filaments; it has further, on each rib, four to five swimming-plates. At this stage this larva resembles the adults of some other species of Ctenophora, and only by degrees, after passing through many other stages, assumes the form of the girdle.

Stinging Series,—Group Cnidaria.

The Cnidaria, or stinging Cœlenterates, which comprise the sea-anemones, corals, jelly-fish, and the little hydra of English ponds, receive their name from the so-called stinging-capsules, found in their skin, which may be regarded as the homologues of the adhesive cells of the Ctenophores. Before describing these offensive and defensive weapons, it is necessary to obtain some idea of the animals which use them, these Cnidarians having departed less from the simple Cœlenterate type than have the Ctenophora, in which this type is much disguised. Imagine, then, a long footless stocking, sewn up at each end. By thrusting one-half of this stocking into the other half, there would be obtained a long bag with a double wall. Suppose this bag fixed by its blind end to the ground, while the open mouth-end stood up in the air, to catch anything that fell into it, and then suppose that, close round the mouth, the double wall grew out into arms or tentacles, which could catch anything passing and draw it into the mouth, then we should have a structure somewhat resembling the fundamental form of the Cœlenterata. But it must further be supposed that the two woollen walls of the stocking are replaced by two layers of living cells, so that the outer one forms the skin, which is armed with the stinging-cells, while the cells of the inner layer are hungry creatures waiting to digest anything digestible which comes down into the bag. This is still not enough, as the whole animal must be able to move its tentacles, and to stretch or contract its body; so that between the layers there is a special gelatinous layer in which run muscle and nerve fibres. Further, in order that the tentacles, when they seize a passing animal, may have no trouble with it, but may be able to bring it to the mouth as easily as possible, they are thickly covered with batteries of stinging-cells. But how, it may be asked, can we get the beautiful bell-shaped jelly-fish from such a creature? The imaginary animal just described was fixed to the bottom of the sea, or to weeds and stones under water, and here it would grow. But there is a law of life that, after a certain size has been reached, further growth does not add to the animal's stature, but takes the form of buds, which may either be cast off as eggs to hatch and develop elsewhere, or may remain attached to and branching out from the parent animal. Both these processes take place in the simple Cnidarians. Some branch and rebranch to form beautiful trees, or stocks, made up of living animals. Now if all these animals were to drop eggs which fell to the ground to grow up around the parent stock, so fast would they grow that they would soon be killing one another through overcrowding. Hence it has come to pass that in many forms only a certain number of the animals forming a stock produce eggs, and these are able to break away and swim off with their load of eggs, to drop them far away. In this way, swimming-bells have been produced, originally only as carriers for scattering eggs broadcast, just as many trees have arrangements for scattering seeds as far as possible from the parent stem. From this beginning, all the race of jelly-fish appear to have sprung. The free-swimming life offered new fields for catching food. Myriads of small creatures swim near the surface of the water; the Cnidarian fixed to the bottom of the sea may stretch its arms in vain for these, while the free-swimming bell can go amongst them and follow them along the surface currents, feeding as it goes. Hence, while the eggs of many jelly-fish when dropped develop first into fixed tree-like stocks, which, when grown, let loose another swarm of jelly-fish, the eggs of others, as if to save time as it were, and impatient of the fixed tree-like stage, hatch out at once as young jelly-fish, which rise at one bound to all the free-swimming privileges of their immediate parents.

The former process is termed alternation of generations; the egg producing a stock, which is one generation, the stock producing a jelly-fish, which is a second; and these two alternating. In the latter case, when a jelly-fish produces a jelly-fish, one generation—the stock—has been suppressed. This is important, since there is evidence that this alternation of generations was, and indeed still is, widely spread in both the animal and the vegetable kingdoms. It is however, as a rule, suppressed, as animals rise in the scale of organisation. The Ctenophora are a highly developed group in which this alternation of generations has been suppressed.



STINGING CAPSULES.
1, 2, With retracted filament; 3, Partly protruded; 4, Fully protruded. (Highly magnified.)

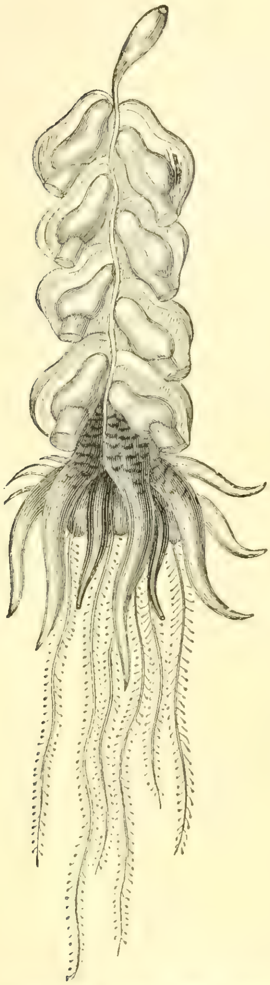
One word as to the changes necessary to turn the simple Cnidarian above-described into a bell or umbrella-like jelly-fish. The principal change is in the gelatinous layer between the outer skin-wall and the inner stomach or digesting layer. This middle layer develops into an enormous mass of glassy jelly of such a shape that, instead of the body being long from the mouth (oral pole) to the bottom of the sac (aboral pole), the animal is umbrella-like, the mouth being under the bell, while the top of the bell corresponds with the old base by which the parent polyp was attached to the ground.

Before taking the principal forms assumed by the Cnidaria, and briefly describing their relation to one another, the stinging-cells and batteries claim attention. These cells, though all microscopical, vary considerably in size, without their structure being essentially affected. The surface protoplasm of the cell is modified into a tolerably firm shell, enclosing an oval or cylindrical vesicle. Closely associated with this structure is a pointed process, standing up far above the level of the skin, known as the cnidocil. Within the vesicle is found, either spirally rolled or in an irregular tangle, a long filament, or hollow tube, which is a prolongation of the vesicle, but turned outside in. This tube, which is more than twenty times as long as the cell, is pointed at the tip, and almost up to the tip beset with two rows of fine, spirally-arranged, barbed hooks. When the cnidocil is touched or irritated, this filament is violently shot forth, being turned inside out like the finger of a glove.

So long as the thread remains rolled up within the vesicle, the barbed hooks are, of course, in the tube, but when it is shot out, they come on the outside. The rolled-up thread appears to be filled with some poisonous substance, which, when the tube is shot out, is ejected over the spot where the point strikes and wounds. It has been asserted that in many, probably in all, Cœlenterates, muscle and nerve elements occur below, and are associated with, the stinging-cells. The action of these stinging-cells is perhaps as follows. The cnidocil is touched by some passing object, and conveys the stimulus which leads to the violent contraction of the distended vesicle. This forces out the tube which is lying in it, in the manner described. A simple touch is, however, not enough to cause the cell to be discharged, otherwise such discharge would take place when the animal knocks against a stone, or when the tentacles, being withdrawn, touch the body. We must assume that the Cnidaria are able to distinguish between the various stimuli received from contact with other bodies. The stinging-cells are very often grouped together to form so-called stinging-batteries of various sizes. Dr. Möbius writes that as soon as the capturing arm touches the passing victim, the long filaments are shot out of the stinging-capsules, penetrate or adhere to the animal and detain it. Unless the prey is stronger than its attacker, it cannot escape. New filaments are being continually shot out at it as it is slowly drawn in towards the mouth; even within the body-cavity similar stinging-cells are found in the skin. The greater the struggle, the larger the number of capsules discharged, in order to hold the prey.

THE JELLY-FISH AND THEIR ALLIES,—Class **Polypomedusæ.**
Order SIPHONOPHORA.

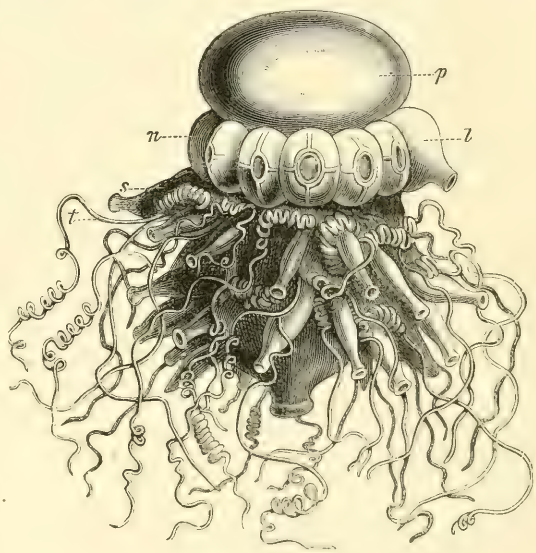
We have already described the swimming-bells of the jelly-fish as the highest development of the stinging group. The Siphonophora, as represented by the Portuguese man-of-war, are, in their turn, the highest development of the swimming-bells. They are, in fact, colonies of bells, joined together in almost every possible way, and showing extraordinary modifications of individuals in the interests of a division of labour. For instance, some of the bells do nothing but row the colony along, others feed the colony, others are guards, and yet others produce the eggs. As our first example of the group, we may take the creature known as *Physophora*, which consists of a long tube or central axis, surmounted by an individual which is nothing but an air-vesicle for holding the colony in an upright or a sloping position in the water. Below the air-vesicle come two rows of bells, which bring about by their contractions the movement of the whole colony. These rowing-bells force the water out of their cavities, and thus propel the colony. Below these, again, comes a circle of extremely mobile tentacles, which may perhaps be the tentacles of vanished bells. Among these tentacles are hollow structures, open at the end, which are the feeding-bells, now reduced to sucking-tubes, or stomachs, each of which endeavours to seize and digest for itself whatever in the shape of food (chiefly small crustaceans) is brought to it by the long capturing filaments and their branches, armed with stinging organs. The colourless blood and nutritive fluid prepared by these two stomachs serve for the nourishment of the whole colony, and are carried to the various parts through the axial tube above mentioned. In the illustration, which has been chosen on account of its comparative simplicity, no reproductive or egg-bearing bells are shown. When present in the *Physophora*, these appear like clusters of grapes; in other genera they are capsules; in others, again, they may be actual swimming-bells, which become detached, and lead an independent life. This fact is of importance in helping us to understand this complicated organism. It shows that the *Physophora* is not a single animal, but a stock or colony. Of this there is evidence in the rowing-bells, as well as in the two, three, four, or more sucking-tubes, with distinct mouths and stomachs. And, lastly, we have the reproduction brought about, in some cases, by detached jellyfish-like individuals. All the parts of the organism form a whole in a physiological sense; they belong to one life, and many are so modified as no longer to appear as individuals. But, on the other hand, some of them are fairly independent, and, when they take the form of medusæ, they are so highly developed that their individuality is at once manifest. We must, therefore, regard a Siphonophore as a colony of highly-modified individuals, which—owing to the fact that these individuals differ greatly in form and function—constitute what is termed a "polymorphous colony."



Physophora, WITH TWO ROWS OF SWIMMING BELLS (nat. size).

One of the most beautiful and most dangerous of the Cœlenterata belongs to the Siphonophora. This is the so-called Portuguese man-of-war (*Physalia*), several species of which are found in the southern seas. The air-bladder at the top of the stem is a large, oval vesicle, which projects above the surface, lying horizontally on the water. It is drawn out into two points at opposite poles. A comb runs lengthwise and somewhat slantingly along the top of it. From its lower side, nutritive polyps, feelers on which the genital products develop, and very long tentacles hang down side by side below the surface of the water. Another strikingly beautiful species found in the Mediterranean is *P. pelagica*. Lesson writes that these creatures "shimmer with the most splendid colouring. The air-bladder and its comb look like molten silver, adorned with light blue, violet, and purple. The small thickenings on the keel of the comb are of a vivid carmine, while the appendages are of a wonderful, delicate, ultramarine blue." The English name is happy, as it indicates the latitude in which the traveller from Europe first meets with it, its ship-like appearance on the surface of the water, where it uses its comb as a sail to catch the wind, and its ample provision of weapons. The tentacles of the *Physalia* are stiff with batteries of stinging-capsules, and those who are careless enough to touch them will repent. Meyen relates that during the first voyage round the world made by the ship *Princess Louise*, a sailor jumped into the sea to capture a large *Physalia.* As he seized it, the animal enveloped him in its long filaments, stinging him so terribly that he cried out for help, and was hardly able to swim back to the ship to let himself be hoisted up. Severe inflammation and fever followed, and his life was for some time despaired of.

During the *Challenger* expedition, deep-sea Siphonophora of a remarkable kind were brought to light. The most interesting belonged to a new family, the *Auronectidæ.* The colony, instead of being a long string of individuals, is here thickened and shortened so as to be oval or round. It consists of a hard, cartilaginous mass, traversed by a close system of branching canals. The upper part of this mass is a large, round, hollow air-bladder (*p* in the figure). This pneumatophore is surrounded by a circle of large, round swimming-bells (*n*), one of which (*l*) is modified in a remarkable way. It is not, like the rest, quite hollow, but is traversed by a narrow canal attached to its walls by strands of gelatinous tissue. The free end of the canal opens outward through a short tube, while its attached end enters the great bladder of the pneumatophore. This specially modified rowing-bell has been called the aurophore, since it appears to regulate the quantity of air in the air-bladder. In order to sink to a greater depth, the *Stephalia* has only to contract its pneumatophore, discharging the air through the lateral canal. When the animal rises, the aurophore probably secretes a gas which fills the pneumatophore again. The lower end of the colony is occupied by a large feeding or nutritive polyp, and at its sides there are several rows of smaller nutritive polyps (*s*), each of which, at its base, carries a capturing filament (*t*), and at its side grape-like clusters of reproductive bodies.



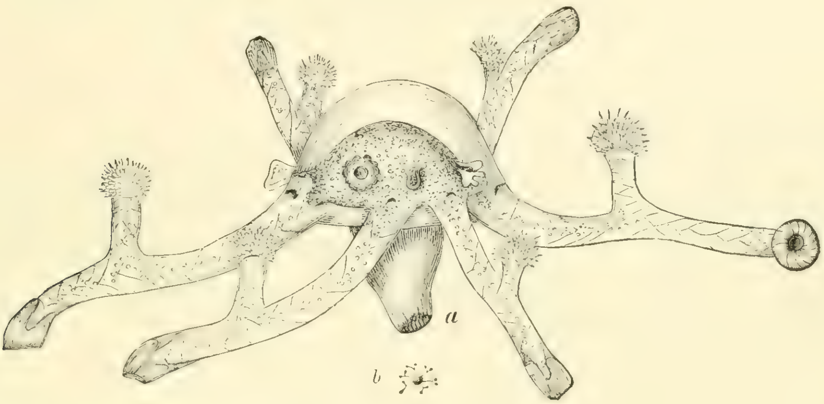
Stephalia (nat. size).

The Siphonophora, as a rule, require frequent changes of depth. It does not appear that exclusively deep-sea forms are to be found in the Mediterranean, but that all Siphonophora under certain circumstances and at certain seasons appear at the surface. Many pass through their larval development at a great depth, and the young *Physophora* larvæ found at the surface in the spring descend to greater depths at the commencement of summer, and only return, when their metamorphoses are complete, to develop into sexually mature animals. In the *Physophoridæ* we had the different individuals in a long series. In the *Auronectidæ* we found them arranged in a compact mass; and, lastly, in the *Velellidæ*, the body is flattened out to a disc, which is traversed by a system of canals. On this disc lies the similarly shaped pneumatophore, which is also traversed by concentrically arranged canals opening outwards. The polyps hang on the lower side of the cartilaginous disc, a large nutritive polyp occupying the centre, surrounded by concentric circles of smaller nutritive polyps. As in the *Auronectidæ*, these polyps carry at their bases genital clusters, but no capturing filaments. The tentacles are arranged round the margin of the disc, and are very short. The genus *Velella*, one species of which is frequently found in the Mediterranean, has an irregular oval disc, surmounted by a sloping comb, which acts as a sail. These animals, which are of a deep indigo colour, are often found in swarms.

Order Hydromedusæ.

Having considered the complicated colonies of swimming-polyps constituting a Siphonophore, the individuals of which have each been simplified for the performance of a limited number of duties, we turn to the solitary swimming-bells, each one of which forms an individual competent to perform all the many functions required in its struggle for existence. There are hosts of these bells, of almost all sizes, some being large and beautiful, but dangerous to touch, while others are quite minute creatures, which have to be examined under the microscope. In regard to these swimming medusæ, it has been already mentioned that they were primitively individuals broken loose for a free-swimming life in the open sea from a stock attached to the ground at the bottom. The eggs of some of these forms have now given up passing through the attached stage, and hatch out at once as young medusæ. Now, examination has shown that this host must be divided into two groups, having remarkable differences, the one being called the Hydromedusæ, and the other the Scyphomedusæ. The two came from two different kinds of attached stocks, and consequently, as free-swimming animals, in spite of their general resemblance to one another as jelly-fish, each has organs which the other wants. Taking the Hydromedusæ first, as closest to the Siphonophora, we describe a few in detail, in order to give a clearer idea of the alternation of generations.

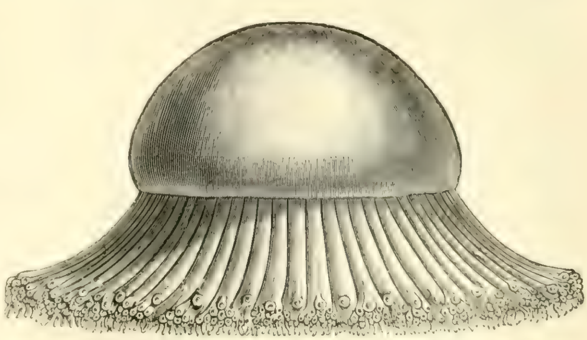
Among the Hydromedusæ there are the following different life-histories. Beginning with the highest, we have—(1) jelly-fish alone, the eggs of which have given up forming stocks, but hatch out jelly-fish; (2) jelly-fish, the eggs of which still form stocks, some individuals of which swim away as jelly-fish; (3) stocks in which the sexual individuals do not swim away as jelly-fish. We need not here describe any of the medusæ in detail, since the much larger jelly-fish of the Scyphomedusæ will claim our attention presently, but two remarkable forms, which have taken to creeping on the ground, deserve attention. In Dalmatia, on seaweed, a delicate, pale object can often be discerned with a magnifying-glass creeping laboriously about on its long arms. If detached from the seaweed, it falls to the bottom, as it is unable to swim. In each point of its structure this animal is a medusa, related to the genus *Eleutheria*, or *Cladonema*, but still further removed from the ordinary medusa in one respect, since the *Cladonema* alternately swims and creeps. This creeping medusa (*Clavatella prolifera*) has six arms, the tips of which are provided with true suckers. On these it walks, as on stilts, while from each arm a short stalk rises, the swollen end of which is beset with stinging-capsules. The very extensile mouth-tube moves about tentatively, and easily seizes upon the small crustaceans to be found upon the seaweed. Just above the base of each arm lies a horseshoe-shaped eye-spot containing a well-developed lens, but so far the nerve belonging to a true eye has not been discovered. Somewhat higher up, between every two arms, a bud is to be found. None of the



Clavatella (*a*, magnified ; *b*, nat. size).

specimens of a certain size examined in May were without their six buds, these being at such different stages of development that their gradual growth could be clearly traced. On the riper buds the rudiments of a second generation of buds were to be seen. Multiplication by budding has been observed in other medusæ, and it is from such budding medusoid colonies that we may perhaps deduce the remarkable swimming colonies of the Siphonophora. As a rule, however, all medusæ multiply sexually by means of fertilised eggs; even the *Clavatella* at other seasons lays eggs.

Creeping medusæ are also found in deep seas, although their presence at great depths would hardly be expected. Haeckel remarks that "few animals appear less suited for deep-sea life than the medusæ, with their soft, mucilaginous, watery bodies, and their singular methods of swimming; nevertheless, a few species sink down to great depths." One of the most interesting forms adapted for deep-sea life is the *Pectis antarctica*, belonging to the family of the *Pectinidæ*. This animal is remarkable for its sucker-tentacles, which stand in numbers round the margin of the firm cartilaginous disc (these in the illustration are represented in a contracted condition). These tentacles bear a great



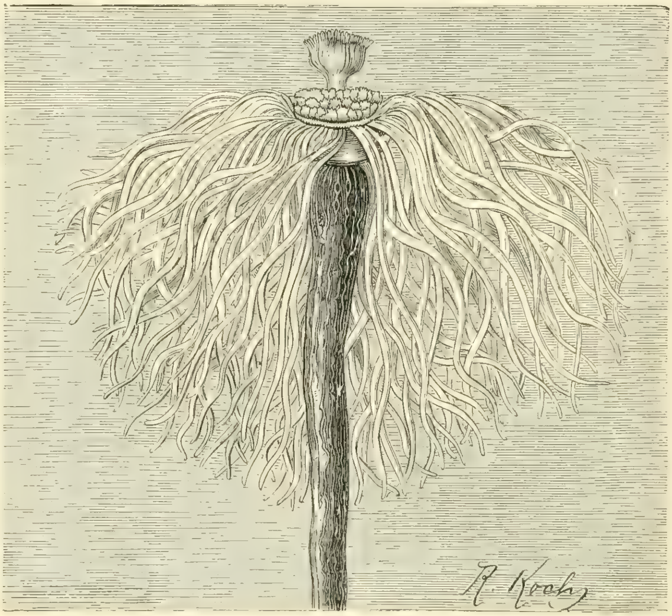
Pectis (nat. size).

resemblance to the tube-feet of the star-fishes, being very elastic and contractile, and carrying a sucker at the tip. They are used in the living state for attachment, and for creeping in the manner of a star-fish. The disc of *Pectis* is about 1½ inches in diameter.

Of the forms among which the reproductive individuals swim away as jelly-fish, we may take as an example *Corymorpha nutans*. In this creature, between the five individuals grouped together in the illustration, five small creatures, each provided with a filamentous appendage, are to be seen swimming, which are the medusæ belonging to this animal. Each egg of these minute medusæ, which are no larger than in the illustration, develops into a ciliated larva, which, sinking to

Corymorpha, WITH DETACHED MEDUSÆ.

the bottom, grows into an attached *Corymorpha*. The illustration shows these animals, which in the polyp form are always single, of the natural size. Unlike most animals of this sort, they do not attach themselves to seaweed or stones, but live on fine sand, into which they sink the posterior end of the stem. Numerous thread-like appendages of this buried part penetrate the sand in all directions, thus firmly attaching the animal. The mouth at the anterior end is encircled by tentacles, a second circle of tentacles surrounding the widened part of the body which contains the stomach. Immediately above this latter circle, the buds stand in clusters; in summer they are found in all stages of development, and even while attached to their stalks assume the complete structure of a medusa. They move their umbrellas actively, break loose, and thus complete the circle of development or alternation of generations. *Bougainvillea ramosa* is another form in which, owing to the stock being branched, the division of labour is even more clearly seen; some of the individuals are feeding and some are reproductive, these latter turning into swimming-bells, and breaking loose. Both these forms are small, as indeed are the great majority of the hydroid stocks, but whole forests of hydroid-polyp stocks may be seen on the reefs in the Pelew Islands, almost as tall as a man, and with roots three or four inches in diameter. A bather, entering such a forest, is terribly stung, the pain lasting for hours. A solitary form (*Monocaulus imperator*)—the upper portion of which is here figured—nearly related to *Corymorpha*, and found in the Northern Pacific, attains still larger proportions. These animals, brought up during the *Challenger* expedition from a great depth, were more than two yards in length, with a proportionate diameter.



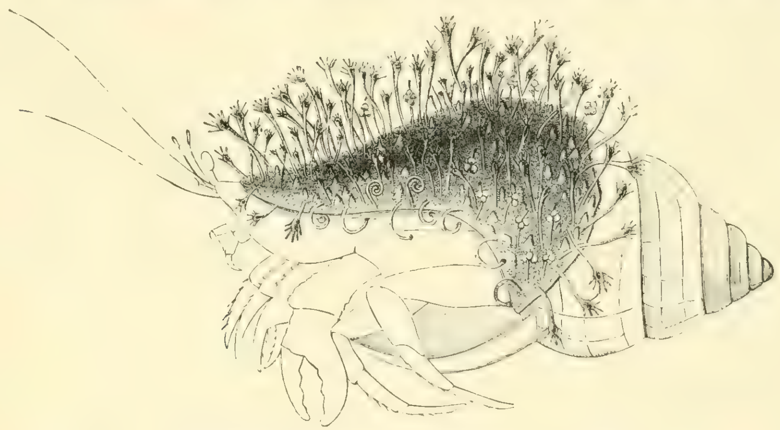
Monocaulus, UPPER THIRD (much reduced).

As examples of stocks of which the reproductive individuals do not swim away as jelly-fish, we may select the pretty, feathered, plant-like creatures found along the sea-shore, which are often thought to be plants but are really animal colonies, well-known types being *Sertularia* and *Plumularia.* In these cases, in addition to the nutritive individuals, there are the egg-bearing individuals which never turn into free-swimming medusæ. In saying this, it must be left undecided whether these colonies are degenerate, that is, were once capable of producing medusæ, but have now lost the power; or whether they are in a lower stage of development, above which they have never risen. One small form which is not branched and feathered is *Hydractinia echinata*, found in the North Sea and on the English and Norwegian coasts, where it attaches itself to gastropod shells, inhabited by hermit-crabs. The polyp probably profits by changes of place for feeding, or else for some other reason adapts itself to the restless life of the crab. The part of the stock common to all the individuals is the skin-like portion which adheres to the surface of the shell or other object to which it is attached. This skin is raised up into spiny prominences, as shown in the figure on p. 488. A horny layer occurs in this integument, similar to that of which the single tubes consist. The nutritive canals running down the stems of the polyps are continued into this membrane, promoting its life and growth. In such a stock there are never more than two kinds of individuals; namely, the nutritive individuals, distinguished by their long tentacles, mouths, and digestive cavities; and the reproductive individuals, male or female. These latter have no mouths, and are supplied with food through the system of canals running to them from the nutritive individuals. These reproductive individuals, instead of tentacles, carry at their tips a circle of stinging-batteries for the protection of their eggs, which are enclosed in capsules clustered together round the stalk a little way below the tips. The ciliated larvæ emerging from the eggs swim away, and eventually become attached and found new colonies. The egg-capsules in no way recall medusæ, but all medusæ which pass through a polyp-like intermediate stage also pass through the simple capsule stage.

GROUP OF A FEMALE STOCK OF *Hydractinia echinata*.
a, Nutritive individuals; *b*, Female individuals. (Enlarged.)

Two more of the Hydroid stocks are worth mention, since they secrete masses of carbonate of lime out of which the animals protrude like corals, which indeed they were thought to be. This error was made because only the massive skeletons of the Hydrocorallia—as they are called—and not the living animals were known. Instead of the horny, often delicately branching integumentary skeleton usually found in the Hydroid polyp stock, that of the Hydrocorallia contains ninety-seven per cent. of carbonate of lime, and forms rough, solid-looking masses, with lobed processes or bosses like those figured on p. 490, or else (*Stylasteridæ*) branches, like the precious coral of commerce. The whole surface can be seen even with the naked eye, but still better with a lens, to be covered with small pore-like apertures. Closer examination shows that these are of two sizes, a larger central pore being surrounded by an irregular circle of from five to eight smaller ones. The mass of the colony is traversed by an irregular system of numerous branching canals of different sizes. In vertical section, indistinct layers can be seen running almost parallel with the outer surface.

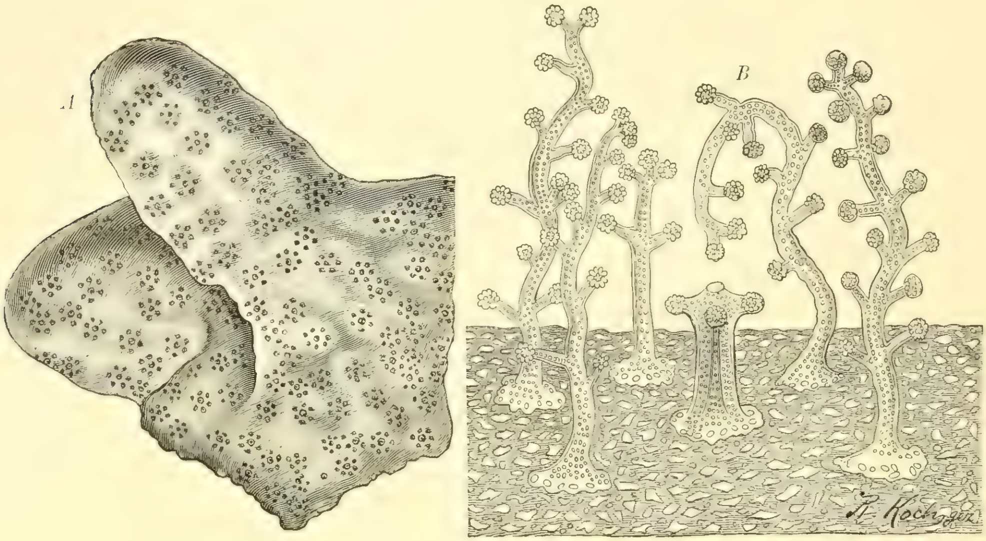
These form the floors of the polyp-cavities. Only in the outermost layer of the stock is there life, the inner mass being composed of dead skeleton. In this living layer there is a close network of soft branching tubes, from which rise the small polyps, the bases of which are connected together by this network. The polyps lie in cup-like depressions, and, when undisturbed, project outward through the pores, retreating instantly at the slightest disturbance. The polyps, like the pores, are of two sorts. Those inhabiting the larger pores are short and thick, with four short tentacles, resembling stalked globules, surrounding a comparatively spacious mouth. The polyps protruding from the more numerous smaller pores, which surround the large ones, are much longer and have no mouths. Each of these ends in a simple knob, below which, at intervals, and generally alternately on one side and the other, short simple branches are given off. The central polyp remains quite still, but those which surround it are constantly in undulating motion, often bending down to the mouth of the central polyp, which they appear



STOCK OF *Hydractinia* ON A SHELL OF THE WHELK INHABITED BY A HERMIT-CRAB (nat. size).

to be feeding. Here, again, there is division of labour in an animal colony, the larger central polyp provided with a mouth being the feeding individual, while the mouthless nutritive individuals catch the prey. The smaller polyps also probably defend the colony, being far better armed with stinging-capsules than the larger polyp. The knobs with which the tentacles end are stinging-batteries. The manner of reproduction of the Hydrocorallia—which are tropical animals and assist in building up the coral-islands—is not yet known. They grow upon rocks or dead corals, often covering the skeletons of sea-fans (*Gorgoniidæ*), and are even found in the Bermudas on old bottles thrown into the sea. In the latter case the lower side of the stock is quite smooth as if polished, and reproduces exactly the surface of the glass with all its markings.

There are two families of these Hydrocorallia, as they are called, namely, the *Milleporidæ* and the *Stylasteridæ*. They are of great interest as illustrating the marvellous adaptability of living forms. While the true corals, which are polyp-colonies somewhat differently organised from these hydropolyps, secrete great masses of solid rock, we find two small families of minute hydropolyps also building up hard coral-stocks. This phenomenon is called convergence; two different kinds of animals, starting from different points, become adapted to similar conditions of life, and eventually come superficially to resemble one another. Just as these hydropolyps forming coral were long thought to be true corals, so many other animals have, on account of their resemblance, been classed together which are now known to belong to different groups.

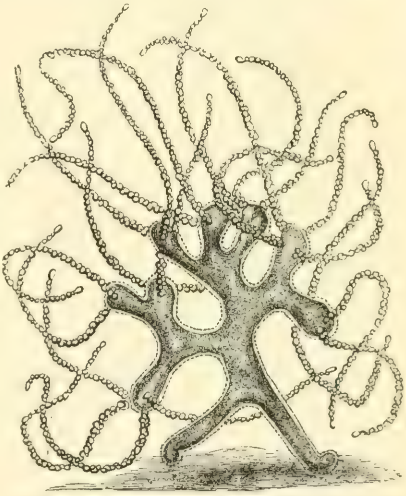


MILLEPORA.

A, Part of a stock with the polyps withdrawn (slightly magnified); *B*, Five peripheral nutritive individuals round a central feeding individual (highly magnified).

Fresh-Water Forms. Two other Hydroid polyps which live in fresh water, while all the rest are marine, deserve mention. Of these, *Cordilophora lacustris* forms branched trees from one to three inches high, rising from a network of roots attached to stones, wood, mussel-shells, etc. The whole stock—except the club-shaped heads of the individual polyps, which are provided with proboscis-like mouths and irregularly-branched thread-like arms—is covered with a delicate horny envelope. In these stocks, which are of a red-grey colour, the sexes are separate. Until the middle of the present century, the *Cordilophora* had only been met with in brackish water on the coasts of Europe and of North America. After that it appeared from time to time in the lower courses of rivers, such as the Thames, the Elbe, etc., and now it has found its way far inland both in the Old and New Worlds. It occurs in the Saale, near Halle, and is specially plentiful in the slightly brackish lake of Eisleben. In Hamburg it has in some places invaded the water-pipes supplying the city, developing in them to such a degree as actually to stop them up. This history of the migration of *Cordilophora* is instructive in helping us to understand the rise of at least a part of the fresh-water fauna. In this case, within our own experience, an animal inhabiting brackish water has in a few years become so adapted for living in fresh water as to be considered altogether a fresh-water form, without the least apparent change in its organisation. Whether a change in organisation would not gradually take place in the course of many years is, of course, another question, which for the present is unanswerable.

In the *Hydra* we have a hydropolyp much better known and much more specially adapted to its habitat than the *Cordilophora*. These hydras, which are from one-eighth to one-third of an inch in length, form simple stocks of one or two branches, and as often as not are found single. They almost exactly resemble in form those polyps of the *Hydractinia* which are provided with a circle of tentacles. The water of stagnant pools or ponds in which water-plants are abundant will almost always yield one of the three species of the fresh-water hydra, if the water-plants be left undisturbed in a vessel. The little creatures often leave the weed and attach themselves to the sides of the vessel, where they can be examined with a lens. When undisturbed, the polyps begin to extend and spread out their six or eight tentacles like fine threads. Small creatures, coming in contact with these tentacles, remain attached to them, caught and held by the stinging-threads, whereupon the tentacle contracts, bringing the prey to the mouth, which is capable of great extension. Besides the large stinging-cells which shoot out long poisonous threads, paralysing and holding fast the small creatures that happen to come too near, the hydra also possesses a smaller kind of cells with smooth threads which are not ejected by the stimulus that leads to the ejection of the long threads. Jickeli, who closely investigated this matter, came to the conclusion that the small cells were modified for an entirely different function. However small the little crustaceans paralysed by the hydra may appear to us, relatively to the hydra they are enormous, and, on being stung, would sink heavily to the bottom. Jickeli's observations led him to think that the smaller capsules act as buoys to neutralise the action of gravitation. Indeed, when we remember how far removed tentacles are from being hands, we can understand how much more easily a victim could be got into the mouth if it floated helplessly near, than if it tended at every moment to sink like a stone. The hydra usually multiplies by means of buds which grow out of the body. The offspring often remains attached to the mother until it, in its turn, has given rise to one or two buds. Single eggs, however, develop from time to time in the body-wall beneath capsule or wart-like prominences.



HYDRA MONSTER, ARTIFICIALLY PRODUCED (5 times nat. size).

The astonishment of the naturalist Trembley, when he discovered that a hydra cut in pieces was not destroyed, but that the pieces were capable of developing into new individuals, was great. He thought that if the hydras were plants, pieces cut from them would, like young shoots, be capable of further growth. But he had, meantime, come to the conclusion that they were animals, and according to the ideas of the time it was an unheard-of thing that new individuals could grow from cut-off pieces. And thus commenced his experiments of cutting up hydras, which excited the liveliest interest among naturalists in the middle of last century.

The hydra is also remarkable on account of its capacity for regenerating lost parts of the body. Thousands of hydras have been cut up in all possible ways, grotesque monsters being produced of which drawings were made. Trembley also made attempts to turn the hydra inside out, like the finger of a glove. His first experiments of this sort with fasting animals were not successful, but he succeeded with others which had been well-fed. Animals thus treated often succeeded in returning to their natural condition.

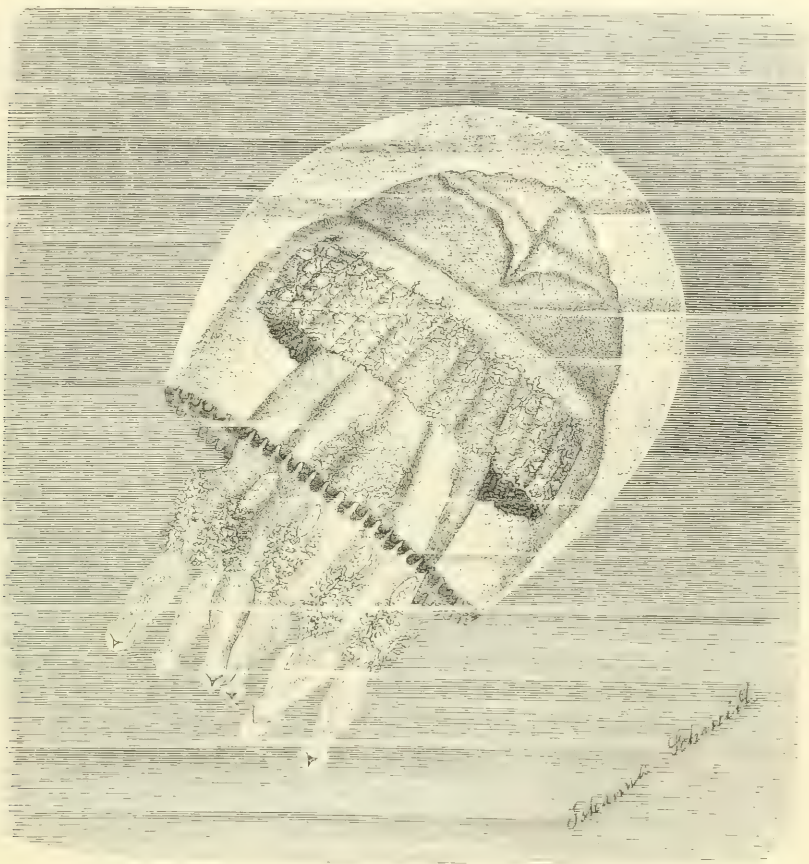
The formation of buds was watched with care by Rösel, who did not fail to notice that the digestive cavity of the young polyps, growing out at various parts of the parent animal, even when provided with functional mouths and arms of their own, still remained in open communication with the digestive cavity of the parent.

Order Scyphomedusæ.

In the Scyphomedusæ we again have free-swimming jelly-fish, stocks developing into jelly-fish, and persistent stocks which never form jelly-fish. Whereas in all the Hydromedusæ the mouth opens directly into the stomach, in the Scyphomedusæ, and their attached and related forms, the skin round the mouth has been drawn in to form a tube which opens some way down into the stomach; the drawing-in of this mouth-tube, or œsophagus, having led to the formation of ridges on the wall of the stomach, which hold the inner end of the tube in place, as shown in the illustration of *Monoxenia*, on p. 496. Although this does not appear important, it indicates a higher specialisation.


Chrysaora (nat. size).

Taking first the free-swimming jelly-fish, the larger and more characteristic forms are distinguished by their delicate colouring. The yellow and yellowish red *Chrysaora ocellata* are seen floating past in thousands off the southern coast of Norway. The western harbours of the Baltic Sea, after continuous northerly winds, are often filled with whole banks of the blue *Aurelia aurita*, and the splendid *Rhizostoma* are constantly to be met with in the Mediterranean and Adriatic Seas. On a fine spring day they are almost always to be found on the shore, where these large, reddish blue, living hemispheres are wrecked, and soon melt away. Indeed, the bodies of all jelly-fish contain so large a proportion of water that when a tolerably large specimen is laid on blotting-paper it evaporates, leaving no other trace than its outline on the paper. In these medusæ—which are well known to all who dwell on the coast, and range from one to seven inches in diameter—we have the most highly-developed of the simple Cœlenterates. Their body consists for the greater part of the circular umbrella, the margin of which is notched all round so as to hang down in large or small lobes. There are also, along the margin, from four to eight or more eye-like spots, and extensible filaments. At the centre of the lower side of the disc is the mouth, which in some forms lies at the end of a projecting stalk, and is almost always surrounded by several thicker folded processes for the capture of prey.

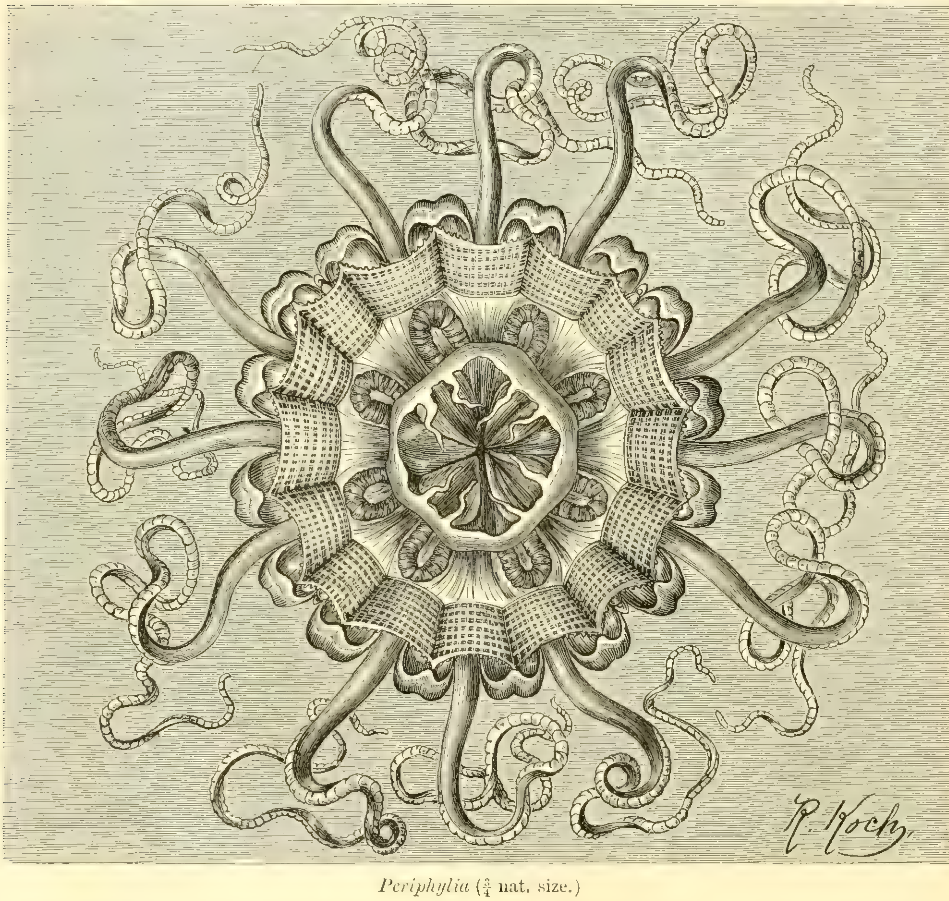


Rhizostoma.

In some cases the folded edges of these ribbon-like arms fuse together, leaving only small sucker-like apertures. Canals run from the sac-like cavity representing the stomach to the edge of the disc, where they enter a circular canal, often provided with apertures. The similarity between this apparatus of digestive canals, and the arrangement obtaining in the Ctenophora is then evident. The reproductive organs lie either in special sacs round the stomach, or merely in widenings of the canals. The surface of the skin is provided with innumerable microscopically small stinging-capsules, and, thus armed, these so-called Disco-medusæ float about in the water, their bodies being but little heavier than the water itself. Indeed, the common blue medusa (*Aurelia*) is slightly lighter than water, whereas most of these jelly-fish are somewhat heavier than that element, and sink during the pauses in their contraction.

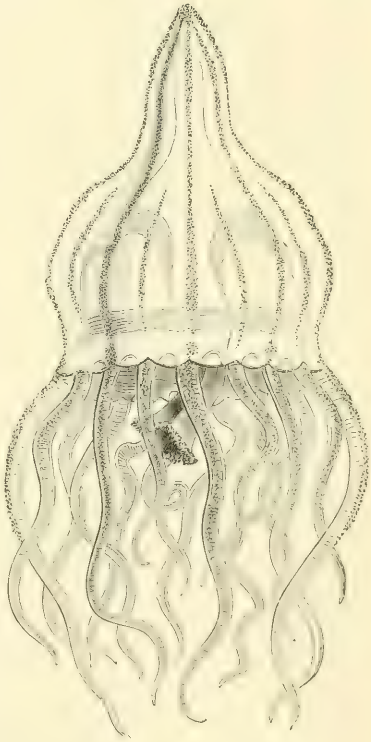
Discomedusæ are also found in the deep sea, one form of a delicate violet, with darker tentacles, being the so-called *Periphylia mirabilis*, figured below, which was dredged from a depth of over six thousand feet during the *Challenger* expedition off the coast of New Zealand.

These beautiful quiet creatures, themselves apparently so harmless, are not



Periphylia (¾ nat. size.)

exempted from the struggle for existence. Not infrequently, small Crustaceans belonging to the orders Isopoda and Amphipoda, related to the wood-lice and sandhoppers, become parasitic upon them, and many genera are attacked by a small species of fish. These fish collect in small companies under the umbrella of their prey, eating its arms, and especially their stinging-capsules, which do not appear to injure them. Although some of these splendid forms develop directly as jelly-fish from the egg, the great majority commence life as attached polyps, so that we have here again another instance of alternation of generations. The sexes are usually separate, and from the egg arises a ciliated larva, which is oval, hollow, and somewhat flattened, recalling the shape of a locket. This is the so-called *planula*, which for a time swims about, then attaches itself firmly by the end of its body and becomes pear-shaped, the stalk of the pear being represented by the attached end; a horny envelope is then secreted over the whole surface, the mouth breaks through the free end of the central cavity, four tentacles appear, and we have a four-armed polyp or *scyphistoma*. The tentacles increase in number, and the *scyphistoma* can produce at its base a number of young polyps which again can multiply by division. At a certain period, this method of multiplication by budding of the polyps from the base ceases, and each *scyphistoma* divides up in quite a different fashion. The polyp becomes horizontally constricted in several places, until it appears like a number of cups placed one inside the other; this is called a *strobila* (pine-cone). When ready, the top cup breaks away, turns over, and swims as a young form of medusa, called an *ephyra*, which gradually acquires the shape of the perfect discomedusa. We thus have here an alternation of generations in which a sexual medusa-generation is succeeded by an asexually-reproducing polyp-generation, this again being followed by another medusa-generation.

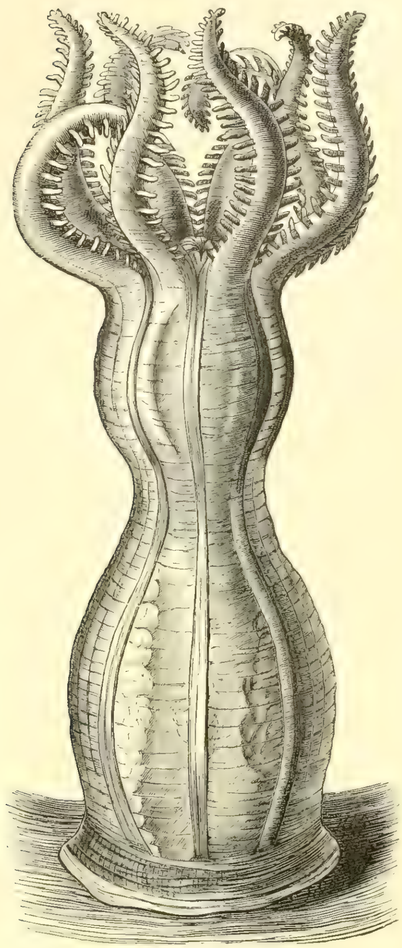


Tessera (20 times nat. size).

In relation to these, and constituting a kind of transition form connecting the Discomedusæ and the polyps, are the Calycozoa, or cup-shaped medusæ, which either swim about freely or are attached by their apices, where the firm gelatinous disc attains its greatest thickness. At the margin of the disc, these forms carry eight to sixteen arm-like processes. In the attached forms (*Lucernaria*) the ends of these processes are provided with short tentacles, occasionally broadened into discs and used for attachment, and also with stinging-capsules. The Calycozoa may leave their place of attachment and swim about for a time, with a rotatory motion, and then again settle down. *Lucernaria* has been found as deep as three thousand three hundred feet, but appears to prefer to settle in shallower water. The nearest relations of *Lucernaria* are the *Tesseridæ*. These creatures are small and swim about freely, having an elegant long bell-like shape. The edge of the disc is drawn out into alternately longer and shorter arms, eight to sixteen in number.

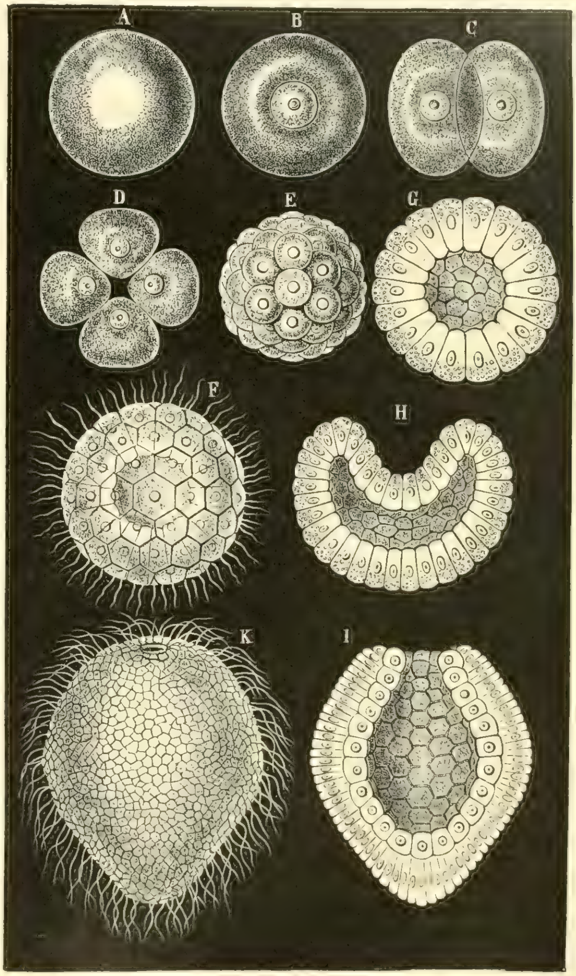
The Sea-Anemones and Corals,—Class **Anthozoa**.

We turn from the free-swimming Scyphomedusæ to the permanently fixed polyp forms, namely, the sea-anemones and corals; the latter of which leave behind them monuments compared with which the pyramids sink into insignificance. Wherever these often minute animals settle, they build up great masses of rock which may form part of the solid ground of the globe. Although Aristotle and his contemporaries recognised the sea-anemones as animals, almost two thousand years elapsed before corals were considered to be related to them. In describing the development of a small coral discovered on the Arabian coast, and named *Monoxenia darwini*, Haeckel states that the polyp, which is one-eighth of an inch long, is of strictly radiate structure, the mouth, which lies at the upper end of the cylindrical body, being surrounded by eight feathered tentacles. It is attached to some substratum by means of a flexible disc at the opposite end of the body to the mouth. It is clear that it has no hard skeleton, as the shape of its surface is changeable; and its internal structure must be shown by transverse and longitudinal sections. The development of *Monoxenia* commences with the egg repeatedly dividing into many parts (*C*, *D*, *E*). This process, which is common throughout the animal kingdom and is called egg-segmentation, in this case proceeds so simply and regularly that it ends in the production of a hollow sphere enclosed by a single layer of cells (*G*). Each cell sends out a long cilia or whip-like process (*F*) by means of which the larva turns about and swims in the body-fluid of the parent polyp. One-half of the sphere now becomes infolded into the other half (*H*), and forms what is called a *gastrula* (*I*, *K*). The term gastrula has taken a great place in zoology in recent years, since the Russian naturalist, Kowalevski found that many different classes of animals, in developing from the egg, passed through such a stage. Haeckel, generalising from these facts, invented his Gastrea theory, according to which all animals in which the gastrula stage occurs must have been descended from a common primitive form, Gastrea, which has, however, in its simplest form long been extinct, but of which the Cœlenterates are the closest modern representatives.



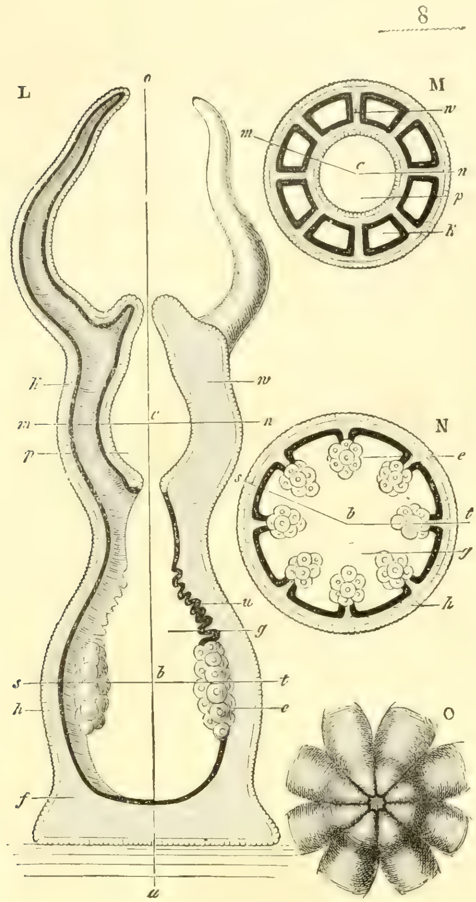
Monoxenia darwini (highly magnified).

The gastrula of *Monoxenia* is of the simplest kind, the infolding being complete, and the larva forming a sac, whose walls consist of two layers of cells, or germinal layers, an outer *ectoderm* and an inner *endoderm* (see section given in the illustration). The transition from the flat dish-shape (*H*) to the sac with a narrow mouth is at once clear, and the knowledge that all the Cœlenterates proceed from a similar larva, and that all the complications of their various systems are developed from such a simple gastrula, throws much light on their anatomy. During these transformations, the endoderm, whose cells multiply, continues as an uninterrupted lining to the stomach and its appendages, while the ectoderm yields the constituents of the skin. A third intermediate gelatinous layer, the *mesoglœa*, arises between the outer and inner layers; in this, muscles and connective interstitial tissues appear. The chief part of the jelly forming the great umbrella of the Discomedusæ consists of this mesoglæa. In the mesoglæa of one division of the corals the calcifications take place. These internal calcifications play, however, but a very small part in the great rock-making activities of corals as a whole, the most important calcifications being external. Returning to Haeckel's account of *Monoxenia*, although the transition from the gastrula larva to the adult animal has not been observed, there can be no doubt as to how it takes place; all the transformations having been watched in other species. The larva attaches itself with the end opposite to the mouth, the cilia disappear, and after the mouth-tube (p) has been formed by the folding in of the anterior end along the longitudinal axis of the body (L, o, a), and has thus become marked off from the stomach (g), the eight hollow tentacles rise round the mouth as outgrowths of the body-cavity, or as direct continuations of the stomach. Like all other corals, *Monoxenia* periodically multiplies by means of eggs which arise either in the walls of the radiating stomach partitions (or septa), or on their free edges, and have to be ejected through the mouth, as development does not in this case take place within the digestive cavity of the parent polyp. As a rule, the polyps are either male or female, but in stock-forming species individuals of the two sexes may be mixed. Hermaphrodite individuals are less frequent.



STAGES IN DEVELOPMENT OF *Monoxenia darwini* (highly magnified).

Monoxenia may be taken as the simplest type of the regularly radiate polyps; in all radiate animals the different organs being repeated in regular rings round the central axis. *Monoxenia* and similar animals are considered simple, because the repeated organs develop similarly and simultaneously, and are comparatively few in number. The mouth, too, is circular. In many other polyps, however, the regularly radiate type is slightly departed from; the mouth, instead of being round, forming a long slit, while there is a tendency for the originally radiate animal to become bilateral. From this account of a simple polyp, it is easy to understand what kind of animal it is which makes coral; and our readers, if they have not already done so, will give up speaking of "*insects* building up the coral-reefs." It is, however, by no means all such polyps that form coral, nor do those which form it produce it always in the same way. Numbers of polyps, such as the beautiful sea-anemones, never produce any hard substance, but remain soft and delicate, though dangerous, at least to small animals, because of their stinging-cells. Many of these soft sea-anemones are highly specialised creatures, as may be seen from the coloured Plate; but those which secrete coral are generally simpler, and smaller, and grow in vast colonies. It is the accumulation of all their little contributions of coral which, in the process of time, build up islands or even continents. In regarding coral animals as reef-builders, we may leave out of account, as unimportant, those which form hard spicules within their bodies, and consider only those which perform most of the work. Imagine a crowd of small animals like sea-anemones fixed to a rock, each one secreting a layer of carbonate of lime between itself and the rock, and this layer becoming thicker and thicker till each polyp rises on a little pedestal. There is probably a race between them, as there is among trees in a forest, which shall reach the highest to get most of the food as it passes by on the currents in the water. Now, it is obvious that a crowded colony of polyps like this would in a short time add a thick layer of solid carbonate of lime to the rock on which they first settled, and this is, in brief, the principle of reef-building. As a matter of fact, however, it is



Monoxenia darwini (magnified).

L, Longitudinal section, on the left, through one of the interseptal cavities, on the right through one of the partition walls; *M*, Transverse section through the line *m n*; *N*, Transverse section through the line *s b t*; *O*, The eight-lipped mouth-aperture, with the bases of the arms; *a b c o*, Principal axis; *p*, Pharyngeal cavity; *g*, Digestive cavity; *k*, Divisions of the digestive cavity; *w*, Radial septa or walls dividing up the digestive cavity; *e*, Masses of eggs; *u*, Mesenterial filaments; *f*, Masses of muscle and connective tissue.

not quite so simple. The layer each polyp secretes is not a smooth flat disc, evenly secreted by the whole surface of its foot. Some parts of the foot secrete more than others, hence those parts rise up as spines, walls, and rings, which protrude into the body of the polyp without, however, breaking through the skin. These probably help to fasten the polyp to its pedestal, and prevent it from being swept off by strong currents. The figure on p. 505 is a good illustration of one of these plates. Each genus of corals has a pattern of its own, each one perfect and beautiful in its way, and it is frequently a puzzle to discover how it is made. When a crowd of polyps grow in contact, their pedestals will also grow in contact and form continuous masses; this growing in contact being ensured by their ordinary method of multiplication. For a coral-polyp does not have to wait until another takes up a position beside it, but as soon as it can feed freely, it begins to bud or divide, producing a number of young polyps close around it. These also bud in their turn and are soon surrounded by young polyps, and in this way such compact colonies are formed that it is a struggle among the inner ones to avoid being suffocated. We thus have densely crowded colonies of polyps struggling upwards, each individual secreting a more or less beautiful and complicated pedestal. The pedestals are fused together in a hundred different ways, and from these different patterned pedestals, with their various ways of fusing together, are produced the almost countless different kinds of coral which together build up coral-reefs.

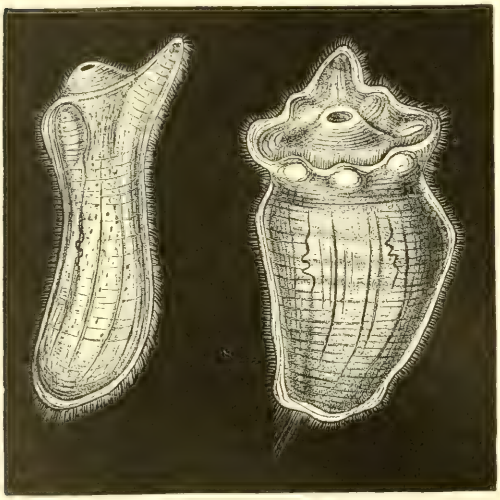
In a growing polyp-stock the individuals usually remain in organic connection, that is to say, each first provides for itself, and then shares its superfluity with the others, sometimes by means of a continuous reticulated system of canals running from polyp to polyp, perforating the stony substance which often separates the members of the one stock from another. The whole stock may thus be physiologically one creature with many mouths. Where, however, the secretion of the pedestal is very rapid and the budding very slow the polyps may separate, each standing at the end of a branch; the illustration of *Caulastræa* showing an example of this. It will be understood from this description that only the layer of growing polyps with their intercommunications can be spoken of as living; and as this layer rises higher and higher by secreting fresh layers of carbonate of lime, the living linings of the communicating canals are either withdrawn or die away, and all beneath the living layer is mere dead matter built up and left behind by the coral animals.

OUTLINE OF *Caulastræa* (nat. size).

Before passing to our survey of the corals themselves, two other points deserve attention. Not all corals form stocks. Some remain single, like the mushroom-corals (*Fungidæ*), which grow to a very large size with a heavy solid skeleton; and although these form new polyps by budding, the latter become detached and live as solitary individuals. Again, although coral-reefs are due to the great power of multiplying by division or budding, yet all corals, so far as is known, also at certain times produce eggs. The further development of these eggs gives rise ultimately to a small polyp, which settles down and commences to secrete its pedestal and then to bud, thus starting a new coral-stock.

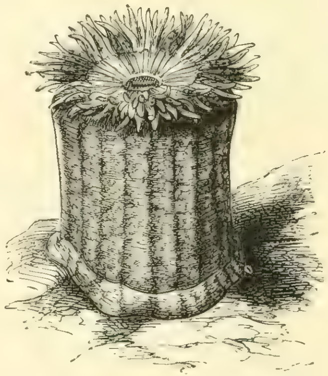
Six-Rayed Polyps,—Order Hexactinia.

This name must not be taken too strictly. It is true that it was applied in good faith, because it was believed that this order always had exactly six or some multiple of six as the number of the tentacles; but corals are tied by no such rigid rules, and all we can say is, that the number of tentacles in this order generally approximates to some multiple of six. Among the Hexactinia the sea-anemones take the first place. They spread over all seas, being especially plentiful in the temperate zones, near the coast, at depths which bring them within the reach of every observer. They are distinguished by their solitary manner of life, their size, and their vivid and usually beautiful colouring. The skin is firm and leathery, and often covered with warts. It does not secrete any calcareous skeleton either inside or outside, so that the animal is soft and capable of great contraction and changes of shape. Most sea-anemones use the basal disc for attachment, and can move from place to place by means of it, but a few species bore into sand with the posterior end of the body, or else secrete or build a sheath which they inhabit. In our coloured Plate are depicted, in their natural brilliant colours, a number of sea-anemones living in the Naples aquarium. To the left, in the foreground, are two examples, one extended and the other contracted, of the red *Actinia equina*, which varies greatly in colour. In the centre of the group, somewhat to the left, there is an extended specimen, and near the right edge a strongly contracted specimen of the lovely green *Actinia cari*. Other beautiful forms are found in the two striped anemones, *Ragactis pulchra* and *Cereactis aurantiaca*. The sun-anemone (*Heliactis bellis*), again, varies greatly in colour but is always elegant, and the same may be said of the trumpet-anemone with spotted tentacles (*Æptasia mutabilis*). In the foreground at the centre a hermit-crab is seen carrying with him his guest, the cloak-anemone (*Adamsia palliata*). A less conspicuous anemone (*Eloactis mazelii*) is provided with somewhat long cylindrical tentacles. The *Anemonia sulcata* lets its tentacles float gracefully, while the vestlet (*Cerianthus membranaceus*), of varying colour, hungrily stretches out its arms in all directions. *Bunodactis costæ*, which is covered with warts, is no less voracious, but with apparent apathy allows its tentacles to droop around it.



LARVÆ OF SEA-ANEMONE (magnified).

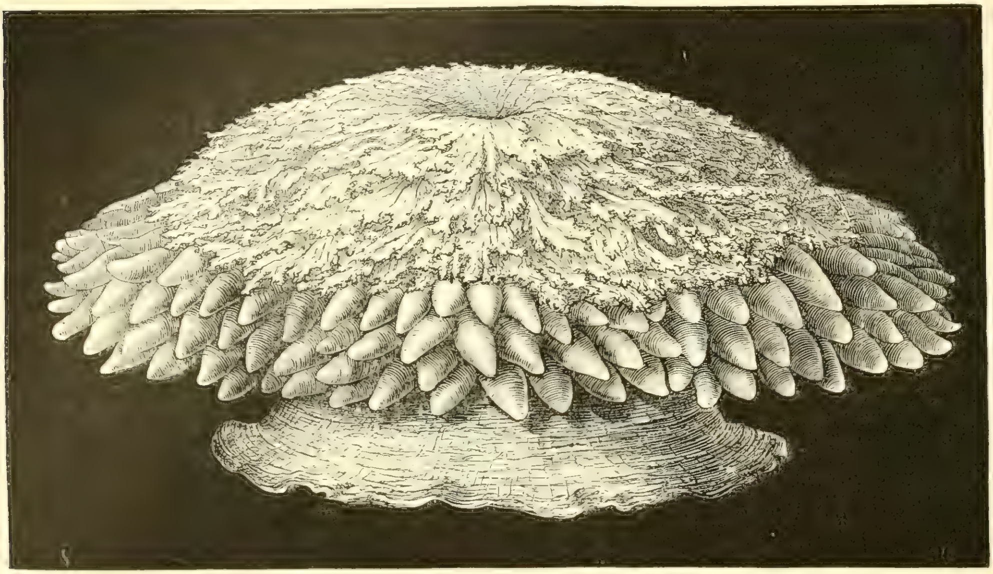
These quiet, externally beautiful, and apparently harmless creatures are in reality extremely voracious, devouring large pieces of flesh, and sucking down mussels and oysters. When fed in an aquarium, the long grasping tentacles greedily surround the food, such as morsels of flesh, small fish, or crabs, given to them, and convey it to the mouth; not merely are the juices sucked out, but the flesh itself is digested, only the fat being rejected. Well-fed anemones change their skin frequently, no doubt because of their quick growth. During this process, they remain closely contracted, expanding again after it is completed; the shed skin forming a loose, dirty-looking girdle round the base of the foot. Anemones only settle in places where the currents bring them the animal food they need; and are most plentiful where the current is strongest, as, for instance, at the entrance of harbours or on rocky coasts. Some species are in the habit of settling on other animals whose requirements make them frequenters of disturbed waters, hermit-crabs being especial favourites. Certain species again, such as the large yellow-and-brown-striped *Actinia effœta* (see illustration below), are indeed always found fixed upon the shells inhabited by these crabs, the one mentioned being generally found with *Pagurus striatus*, a large Mediterranean crab which inhabits whelk-shells of suitable size. Two or three of these anemones often settle on one crab, which does not seem to be at all incommoded by his burden, while the former profit in the matter of food by the wanderings of their host.



A SEA-ANEMONE, *Actinia effœta* (nat. size).

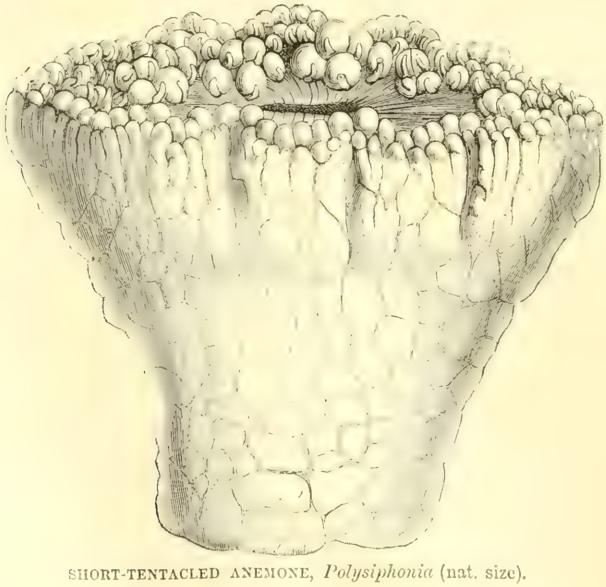
On account of the ease with which anemones are kept in captivity, their manner of reproduction has been well observed. With rare exceptions, they develop from eggs. Dalyell kept one for six years, and reared from it upwards of two hundred and seventy-six young ones. Two of these young lived for five years, producing eggs at ten or twelve months old, which hatched a couple of months later. He saw that the ciliated, infusorian-like larvæ (see illustration on p. 500) settled down on the eighth day, losing their cilia, the first tentacles appearing during the process of attachment. Young anemones often pass through their whole development within the body-cavity of the parent. Even in a free condition sea-anemones can easily be studied. Gosse has well described the many British species, and Lacaze-Duthiers has given a still more detailed account of several kinds studied in connection with their development. He gives many details of the common European *Actinia equina* found along the coasts of the English Channel in all rocky parts at low-water level. Its colour varies between scarlet, rose-red, dark red-brown, and olive-green, a distinguished characteristic being a circle of beautiful blue warts below the tentacles.

Most anemones are provided with several circles of more or less similar cylindrical tentacles, but there are some specially beautiful species which, besides tentacles of the usual shape, have, either within or outside of the circle of ordinary tentacles, lobed or leaf-like tactile and seizing organs. These belong to the family of the *Crambactinidæ*. The beautiful *Crambactis* from the Red Sea, shown in the illustration, has, immediately round the mouth, several circles of delicate grasping tentacles, shaped like curly cabbage or endive leaves. Below these comes a circle of numerous thick arms altogether unlike the others, being rough-skinned, and of a simple spindle shape, the body itself forming a thick disc. All the tentacles of



ENDIVE-ANEMONE, *Crambactis* (somewhat less than nat. size).

the sea-anemones are hollow, with a fine aperture at the tip, through which, when the animal contracts, the water contained in the body-cavity can be expelled, but in the deep-sea forms these organs are very curiously modified. For instance, in the genus *Polysiphonia*, here illustrated, the tentacles are short and unsuited for catching and holding prey; but the aperture at the tip is large, and through it flows in water containing organic detritus which can be used as food. The allied *Sicyonis* has sixty-four wart-like tentacles with wide apertures standing in a double circle round the mouth, and in *Liponema* the body-wall is perforated by several hundred apertures leading into the digestive cavity and corresponding to the tentacles.



SHORT-TENTACLED ANEMONE, *Polysiphonia* (nat. size).

Although most members of the group arise as single individuals from eggs, some multiply by the detachment of small pieces from the pedal disc. Fischer observed this process in the translucent anemone (*Sagartia pellucida*) on the French coast. The pieces detached on the 23rd of August had, by the 7th of September, developed into small individuals with fifteen or sixteen tentacles. Multiplication by fission seems common in several species, such as *S. ignea*, and always ends in producing single individuals. Sea-anemones sometimes, however, form stocks, but are then no longer called *Actinia* but *Zoantharia*. Such stocks are not very numerous, but some species can be found on European coasts. The genus *Zoantharia*, in which the separate individuals are united by a creeping branching root, is distinguished from *Palythoa*, in which the common stock resembles a root-like crust, on which the polyps form irregular groups of various sizes. A peculiarity common to the two genera is the incorporation of hard particles of the most different kinds—sand, sponge-spicules, pieces of shell or coral—into the body-wall in large quantities. The walls in consequence become so firm that the exact form of the polyp is retained in dried specimens. The species of *Palythoa*, although unattractive when in spirit, are of a sulphur yellow, and beautiful when alive in an extended condition. The most interesting species is *Palythoa fatua*, which is always found growing on and in one of the most curious of sponges, the Japanese glass-sponge (*Hyalonema*). Here the surface of the stalk, that is above the portion embedded in the mud, is covered with a warty crust belonging to this *Palythoa*. All the specimens of this Japanese sponge in European museums in 1860 had their stalks overgrown with the *Palythoa*, while many had their bodies also covered with another polyp which, however, settled singly and, fortunately for the sponge, did not form a sandy crust. The illustration represents a specimen of this beautiful glass rope-sponge, its body pitted all over with holes in which small Anthozoa once lived, and its stalk coated with the sandy crust of the stock-forming *Palythoa*. The former, having no skeleton, dry up entirely; no traces of them being found in dried specimens of the sponge except the holes they lived in. Unlike a parasite, the polyps do not feed upon the juices and soft-parts of the sponge, nor indeed do they share its food, but simply settle upon the sponge and feed upon the food that

PARASITIC ANEMONE (*Palythoa*) ON STALK OF GLASS-ROPE SPONGE (⅓ nat. size).

The holes on the body of the sponge are formed by anthozoans.

may chance to come within reach. It is interesting to note that a *Palythoa* closely related to the Japanese form occurs in the Adriatic, and is also attached to sponges, scarcely a single specimen of the sponge in question being found without its polyp guest. The larvæ hatched from the eggs of the *Palythoa* evidently perish unless they meet with one of these sponges; but the manner in which they find and recognise their particular host is quite unknown. Other species of *Palythoa* found on the American coast settle on the shells inhabited by hermit-crabs, covering the shell as an uninterrupted mass several lines thick, and the individual polyps rising to about an equal height above the general mass. The shell becomes disintegrated beneath this cover, and the polyp-stock then remains as the only covering to the crab. In this case there is mutual advantage, for the crab is covered and protected by the polyp-stock, while the polyp profits by its wanderings and enjoys constant change of water and new fields for food.

Palythoa axinellæ (somewhat less than nat. size).
The small dried-up polyps are seen adhering in groups to the branching sponge.

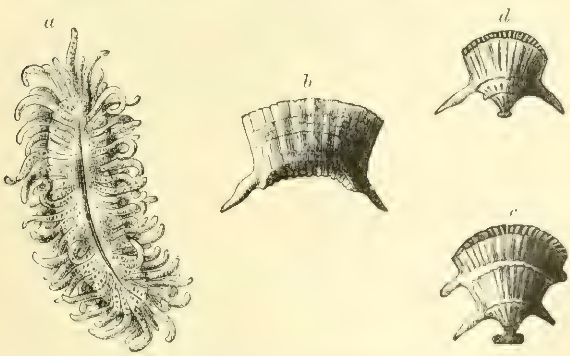
An extraordinary form, very nearly allied to *Zoantharia*, has been described under the name of *Polyparium ambulans*, and is found in the strait dividing the island of Mindanao from that of Billiton. It consists of a colony three inches long and six wide, flattened from above downward, and therefore more or less ribbon-like; and the anterior cannot be distinguished from the posterior end. The upper surface of the colony is covered with peculiar polyps shaped like chimneys, the base being much wider than the top, which carries a round aperture. Each polyp is extremely minute, and has no tentacles. They stand in irregular transverse rows of from five to eight, differing in age and therefore in size; the lower side, on which the colony rests, being beset with protuberant suckers. These also differ much in size, but stand in regular rows divided by furrows, and serve for attaching the colony, and also enable it to creep. The colony can even be seen slowly climbing up and down small stones. The polyps have no septa in the digestive cavity, the inner side being quite smooth; and the lower end of each is not closed, but communicates with a large cavity running along the whole colony, and divided at regular intervals by partitions.

True Corals.

From the foregoing observations it will be seen that in the soft division of the Hexactinia, or six-rayed anemones, there are both single individuals and colonies of individuals joined together to form stocks; and there is also the same diversity in the skeleton-producing division—the corals proper, where we have both single individuals and stocks. Whereas however, in the soft division, the simple individuals are the more numerous and the colonies comparatively rare, among the corals the opposite is the case, the colony-forming types presenting almost innumerable varieties. This is not difficult to understand, since the soft anemones cannot well form complicated colonies, whereas the skeleton-forming polyps, by combining their skeletons, can build complicated structures, in order to raise themselves into more advantageous positions. We have first, then, to consider those corals which do not typically form stocks, but remain at the stage of a simple sea-anemone, only with a rigid, calcareous skeleton supporting, and no doubt protecting, them in different ways. All the corals found in British seas are (with the exception of the so-called tuft-coral) single, and generally very small. As an example of a regular, circular, solitary coral, we may take *Thecocyathus cylindraceus*, the skeleton of which is shown in the illustration. The animal when expanded fills up the central depression, but when, on expelling the greater part of the watery contents of its cavity, it contracts, the whole body seems to sink into the hollow cup formed by its skeleton. In the illustration we see only the outer wall and the top of the ring of septa, which are solid vertical plates, rising up from the pedestal secreted by the foot and radiating outwards in all directions. Two other solitary corals are worth describing, as they show certain interesting specialisations. Both of them may increase by budding, that is, by the method which, in colony-forming corals, leads to the formation of stocks, if the buds remain attached to their parents. When, however, solitary corals bud, the buds fall off, and lead solitary lives like their parents.

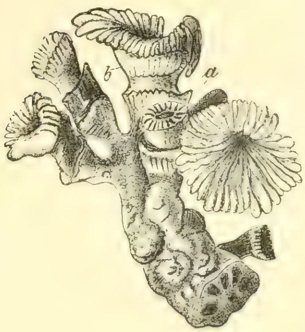
A SIMPLE CORAL, *Thecocyathus* (nat. size).

Most of the numerous species of the scarlet crisp-corals (*Flabellum*) are individuals, and are characterised by the slit-like form of the mouth. At *a* in the illustration the living animal is seen from above, while *b* shows a side view of the skeleton, which is attached. It resembles a pair of fans fastened along their edges; and just inside the outer edges of the fans is the row of tentacles. The whole animal is as if the upper end of a circular polyp had been squeezed, so that the mouth-area, instead of being round formed a long oval (*a*). An interesting case of budding occurs in these corals, the buds falling off. In the illustration, *c* shows the bud growing out at the top of an individual like *b*. In this budding condition the coral might pass for a different species of *Flabellum*. The bud, however, ultimately falls off (*d*), but instead of becoming attached, is swept by the waves into some rocky fissure, where it spends the rest of its life. Besides the fact that it remains unattached, this bud differs from its attached parent in a far more important respect. It can produce eggs, which the fixed coral can not do, so that we have here another case of alternation of generations. Out of the egg comes an attached form, which buds and produces the free unattached form, which again produces eggs, and so on. The predominating colour of this species is a beautifully intense and yet transparent red, the mouth-disc having almost always broad bands of darker red, most marked in the paler specimens.

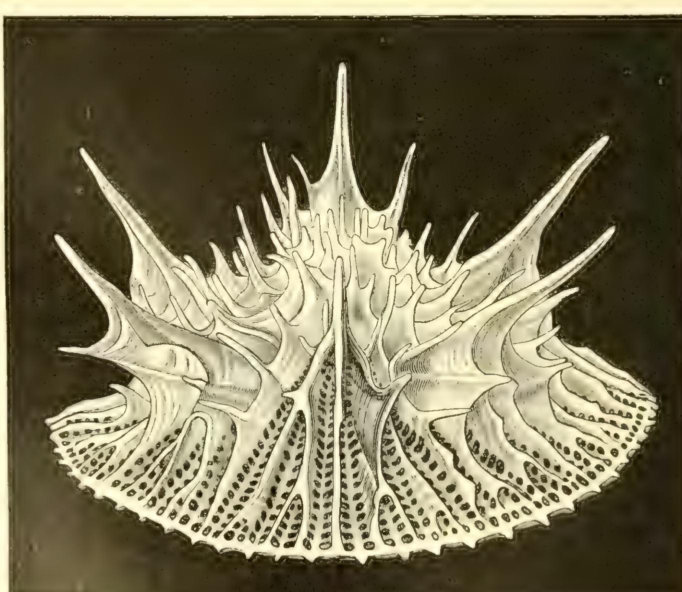


SCARLET CRISP-CORAL, *Flabellum* (nat. size.)

The mushroom-corals (*Fungiidæ*) are another remarkable group of solitary forms, taking their name from their resemblance to the head of an expanded mushroom turned upside down. Turning to the figure of *Thecocyathus* (on p. 505), and imagining the circular wall pulled down all round, and drawing down the septa so that they radiate outwards, some idea of a *Fungia* may be obtained. Their skeletons are remarkable objects, which no one, at first sight, would in any way connect with a sea-anemone. Although the mushroom-corals are considered to be individuals, reproducing themselves by means of eggs, both budding and division into halves occur exceptionally; in the former case the buds sooner or later becoming detached. In some there is an alternation of generations, leading to the formation of compound stocks. In the illustrated form true mushroom-corals are produced at the ends of the branches; at *a* one has become detached, and the others are in different stages, the youngest being nearly cylindrical, like a typical polyp, whereas the older ones spread out like a typical *Fungia*. When a bud has fallen off, the stem seems capable of developing another. This is the asexual generation, reproduction by eggs being the sexual generation. Lastly, certain solitary corals have recently been discovered in the deep sea, where, on account of the presence of carbonic acid in sufficient quantities to make itself felt, there is little lime. On this account the calcareous skeleton is generally distinguished by great delicacy. A deep-sea coral with such a delicate skeleton (*Leptopenus*), found off the east coast of South America at a depth of over a mile, is shown in the illustration. Its pedestal is formed of a delicate network with fine rays or spokes, connected together in a regular manner by transverse supports.

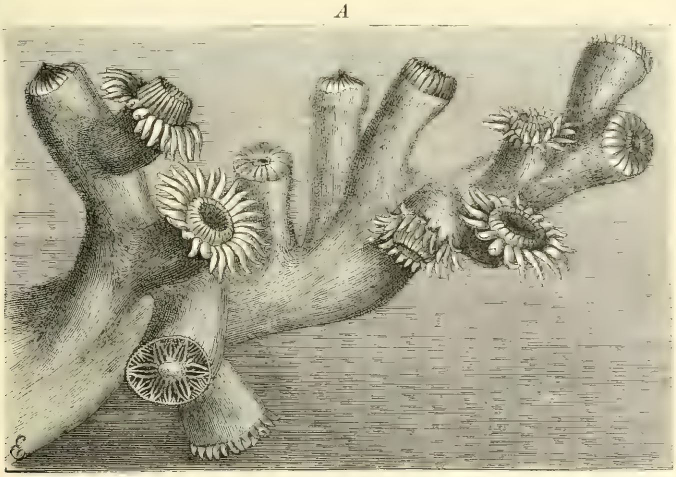


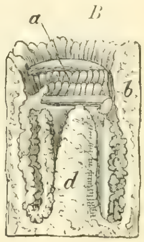
MUSHROOM-CORAL BUDDING AND FORMING A SMALL STOCK (nat. size).



A DEEP-SEA CORAL, *Leptopenus discus* (nat. size).

Plentiful as are the solitary corals, they are surpassed in number by those which form compound stocks; that is to say, in which the buds do not fall off but go on budding till coral-islands and barrier-reefs are built up. As it is impossible to give here more than a very few illustrations of the many different ways in which the coral-stocks grow, we can only select a few types. In *Dendrophyllia*, as shown in the illustration, we have a tree-like growth; each polyp secreting a solid pedestal for itself, and living in a depression in the top. This is shown in the section *B*. Into this depression the soft animal

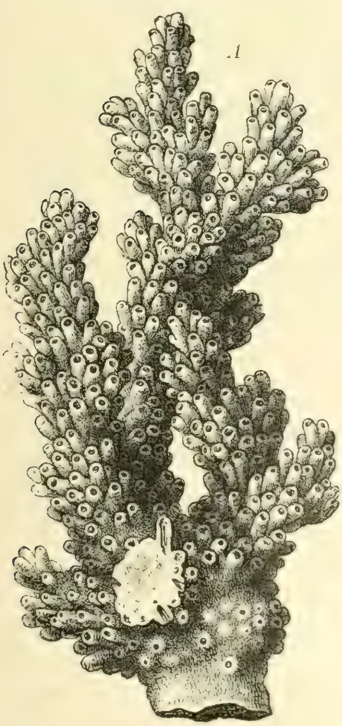


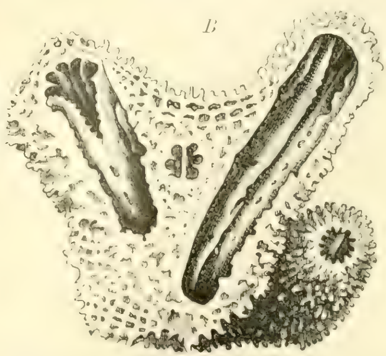


A BRANCHING CORAL, *Dendrophyllia*.
A, Terminal branch of a stock (nat. size); *B*, Longitudinal section of a single polyp (magnified).

can withdraw at the approach of danger, drawing all its tentacles (which also contract) down to *a*. The space occupied by the animal is not very roomy at the best, and it is further limited both by a great columella *d*, rising up in its interior, and by the solid septa *b* projecting into it all round. It must not be forgotten that these parts are not in the animal but outside of it, and as they are secreted they push the skin up and never penetrate into the tissues themselves. These polyps bud at intervals, the apical polyp most frequently; and the result is a simple branched stock, as seen.

A different kind of stock is developed when the polyps produce many buds, as in the madrepores. In these delicate stocks, selected polyps spring up above the rest, and their sides become covered with small buds. Space would obviously not permit all these small buds to bud again in the same manner. A few favoured ones, however, which have sufficient room next spring out and become covered again with small

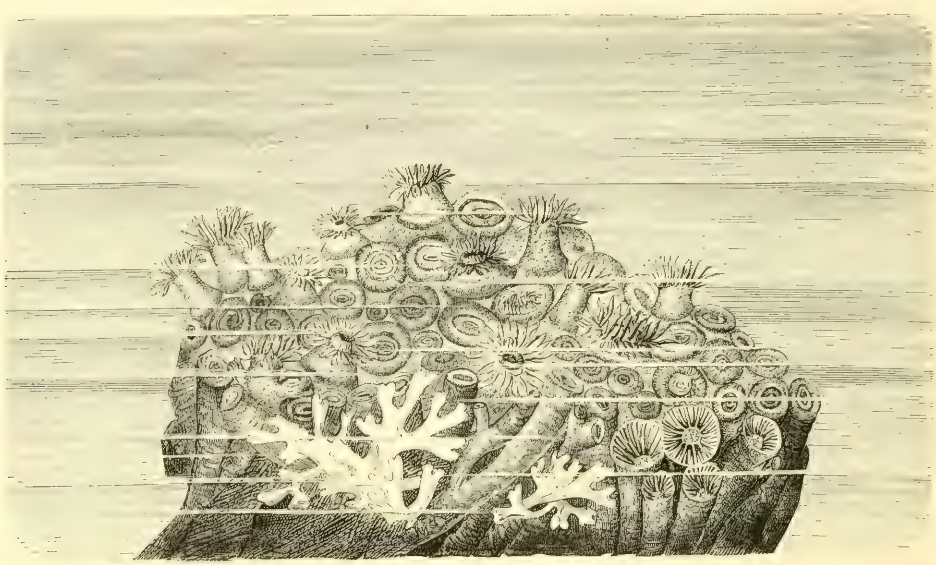




A MADREPORE CORAL (*Madrepora verrucosa*).
In the section *B* the canals which connect the polyps through the stony skeleton are seen.

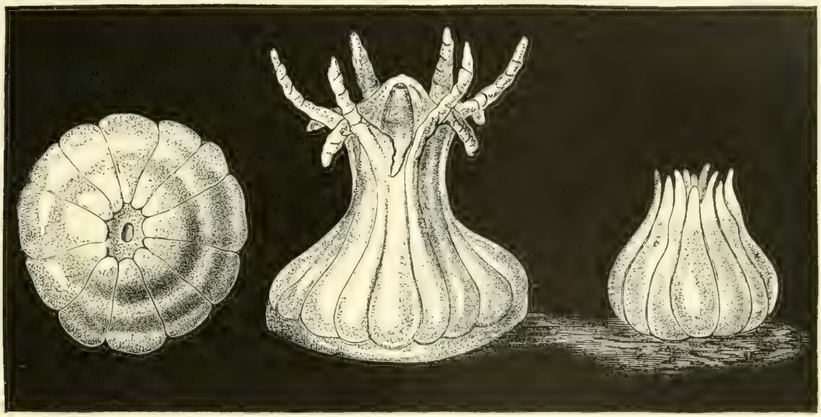
buds. Each bud is a living, feeding, coral-animal, surrounded by its crown of tentacles. These madrepores play no small part in building up coral-reefs, and the many different elegant forms which they assume (while keeping to their method of budding) is astounding. Some corals, again, do not form true branches, but may cover the ground like a field of corn,—a good example of this type being found in *Cladocora cæspitosa*, which inhabits the Mediterranean and Adriatic seas. Here the single individuals form somewhat long tubes, and the buds arise laterally at the lower end, then bend upward and grow alongside of the parent, without any further connection or fusion. The spaces between the different rising polyps are not filled in with secreted hard matter, but the latter grow up side by side free. The stock, therefore, is easily broken. This coral flourishes extraordinarily in many places, covering areas of over one hundred square yards, with a growth of a foot in height.

The method of growth just described is shown also by another and quite different coral, *Astroides calycularis*. As in *Cladocora*, just described, the single



A MASSIVE CORAL, *Astroides* (nat. size).

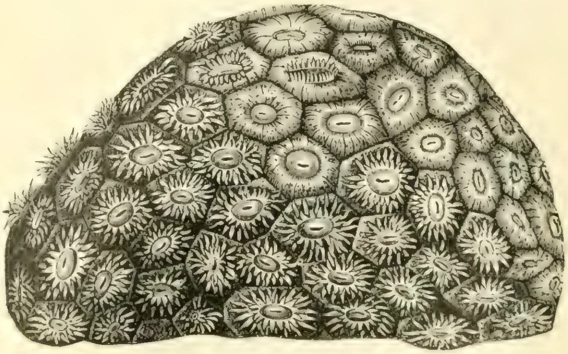
polyps, with their calcareous tubes or pedestals, are not fused together by any cementing substance. The yellowish red polyps are seen standing out a great height above their cavities, much more so than is usual in corals. The larvæ of these corals leave the egg while still in the large, chambered body-cavity of the parent, where they swim about for a time, till they escape through the mouth. They are long and worm-like, and slightly thicker at the posterior end, but may change considerably in shape. They swim about rapidly by means of their covering of cilia, the thicker end being foremost. The mouth appears at the thinner end soon after the larva leaves the body of the parent. Its free-swimming life has been known to last as long as two months; but under natural conditions it would probably be shorter. A strong sirocco had a marked effect upon the larvæ, which seemed to become exhausted, contracted, and became attached. The transition from the worm-like larva to the polyp takes place as in the anemones. The thicker end of the body is pressed against a hard rock, and the whole contracts into a thick, round disc; while longitudinal furrows become visible at the upper pole, where the mouth sinks deeper. At the ends of these furrows the twelve tentacles appear. The accompanying three illustrations show the stages which



DEVELOPMENTAL STAGES OF *Astroides calycularis* (magnified 24 times).

follow in rapid succession, resulting in a form almost exactly like a young sea-anemone. It has, however, already commenced to secrete its calcareous skeleton. This is not formed as a connected whole, but begins as a number of separate centres of secretion between the polyp and the substance to which it is fixed. These meet and fuse, till gradually the skeleton is produced. The polyp commences to bud, and the buds develop their skeletons, the whole together forming a stock like that shown in the illustration.

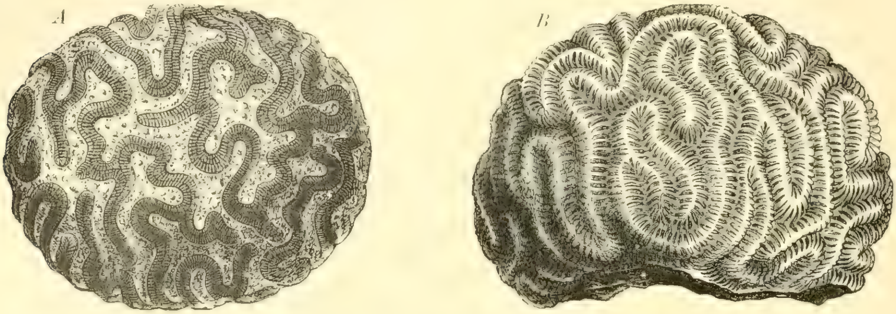
The star-corals, which are some of the principal reef-builders, do not branch, but form great solid mounds; the polyps being all cemented together, and the budding so arranged that the whole colony forms a thin, living layer or covering to the mass it and its parents have built up; all but this thin layer on the surface being dead coral. The illustration given is of *Astræa pallida*, a species which appears as a rounded mass, with flat base, and the individuals being quite distinct from one another, although their outer walls are in contact. Those on the top and to the right of the figure are represented in a contracted condition, and the rest with expanded tentacles. None of the individuals here seen are in the act of dividing; and the genus is characterised by the fact that the bud-



A STAR-CORAL, *Astræa* ($\frac{1}{2}$ nat. size).

ding polyps separate from one another completely, forming so many distinct individual polyps.

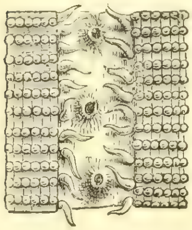
In the brain-corals, or *Meandrina*, we have animals budding, but not com-



A BRAIN-CORAL.

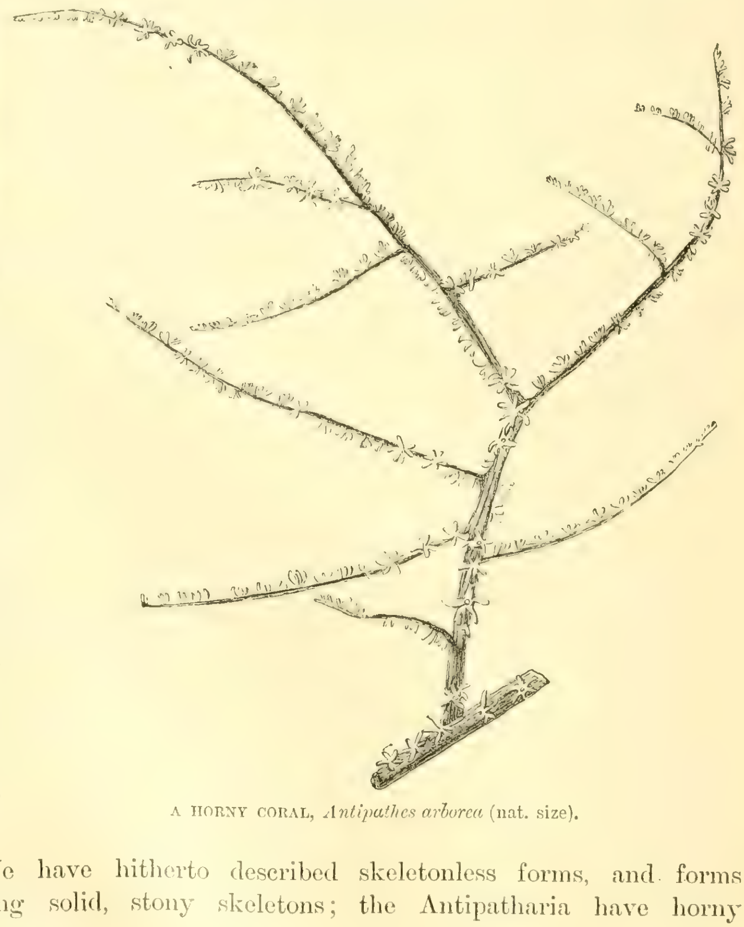
A, Stock with the soft-parts ; *B*, Skeleton. (Nat. size.)

pletely separating. No hard wall grows between the bud and its parent, although such separate the polyps less closely related. We thus get a system of valleys



THREE MOUTHS, WITH TENTACLES AND DIVIDING WALLS OF BRAIN-CORAL.

with rows of mouths, belonging to the polyps, which have budded off from one another. The valleys are bounded on each side by the hard walls separating them from similar valleys containing similar series of polyps. The three illustrations will enable the reader to understand this brief description.



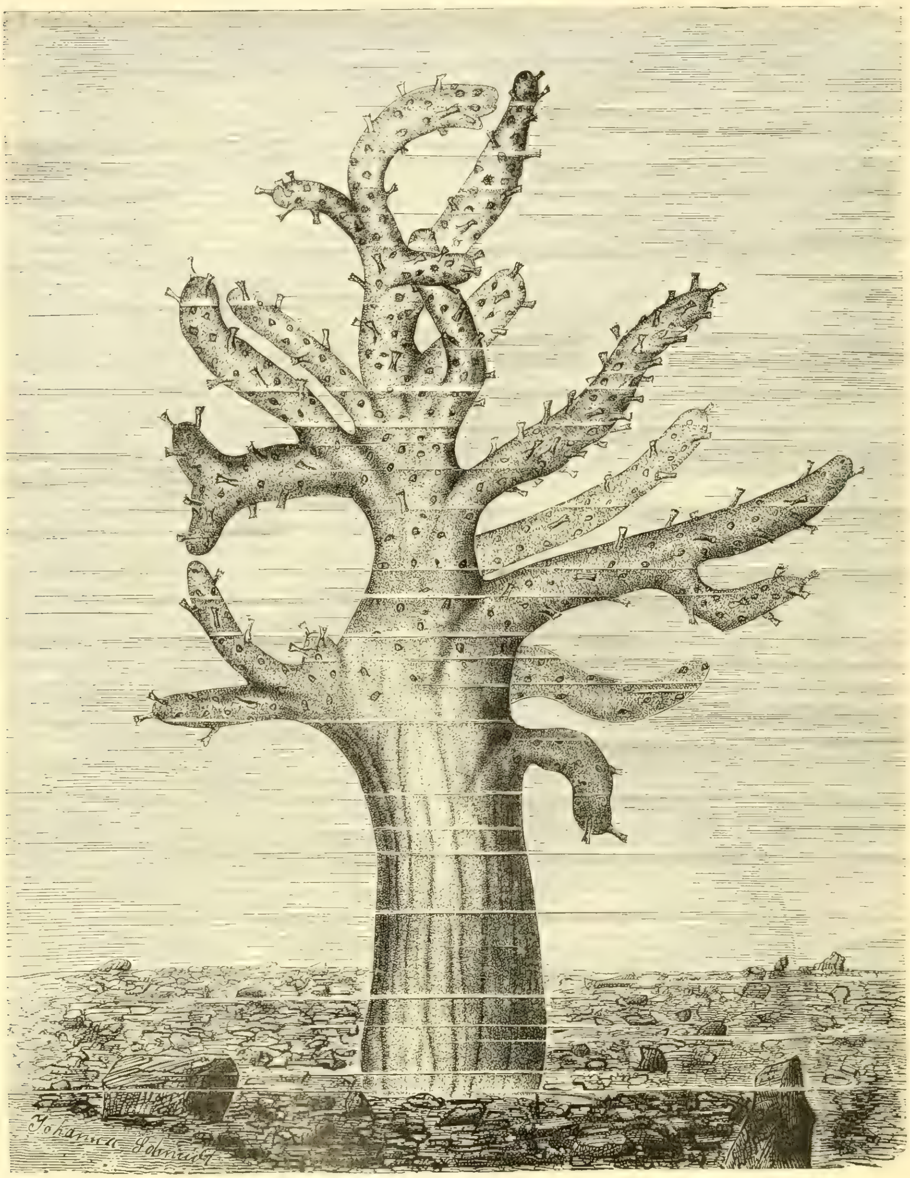
A HORNY CORAL, *Antipathes arborea* (nat. size).

Horny Corals.

We have hitherto described skeletonless forms, and forms secreting solid, stony skeletons; the Antipatharia have horny skeletons, the method of secreting which will be described when we come to the horny skeletons of the next group. The polyps have only one, instead of several rows of tentacles, and in most of them the tentacles are six in number. They form compound stocks, looking like delicate shrubs, with long branches, from which the polyps project, these branches being supported by a flexible horny axis. In the Fiji Islands a stock three feet high, with a stem half an inch in thickness, has been found. The general form of the whole stock, the brown colouring, and the small, thick tentacles of the little polyps are not attractive.

The Eight-Rayed Polyps,—Order Octactinia.

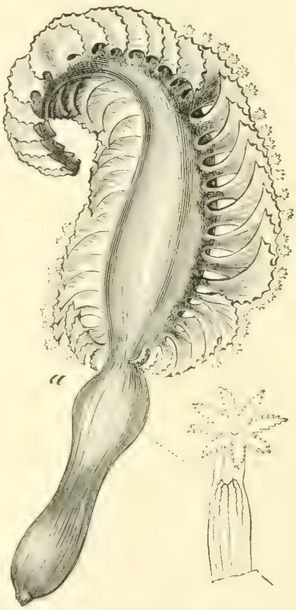
Although this second order of the corals contains a variety of forms, the appearance of the individual animals is more or less uniform, the number of tentacles being always eight. The tentacles are not hollow, but are usually somewhat flattened and notched round the edges like delicate leaves. These corals form stocks which are sometimes knobbed or lobed, and sometimes resemble a hand or tree with simple branches. The individuals of the stock are usually small and rise like minute white blossoms above the soft fleshy surface of the stock, which has a peculiar reddish yellow glistening appearance. The stock attaches itself by means of a stem, or else rests loosely in the sand, generally at a moderate depth. These corals secrete carbonate of lime, but in no case in the same way as do the true corals or the hydrocorals. In both these latter the solid skeleton is formed by the outer skin, while in the present group the secretion takes the form of minute calcareous particles of definite shape scattered about between the outer skin and the lining of the body-cavity. These spicules never fuse together to form solid continuous masses, but may, nevertheless, be present in sufficient quantities to give the lower part of the body a certain degree of rigidity. When fresh, the stocks show some elasticity and turgescence. When removed from the water the whole stock contracts strongly, but swells out again if placed in an aquarium, where it may live for weeks or months, although the great swelling of the lower part shows that its condition is abnormal. A tendency to form a stem is also common. The illustration on p. 512 shows an alcyonarian, as these corals are called, with its lower part modified into a stem free from individual polyps; while the next figure exhibits a representative of another family, the sea-pens (*Pennatulidæ*), which also form stocks divided into a polyp-bearing area and a stem resting on the sea-bottom. In one of the simplest forms of the sea-pens (*Veretillum*) the upper part is simply surrounded by polyps, and the lower a cylindrical stalk. A stock of this last-named type may lie for two or three consecutive weeks like a wrinkled turnip at the bottom of an aquarium, with all its activities suspended; no individual polyp appears; no food is taken in, and the circulation of water, necessary for the life of the stock, does not take place. After a time, however, the fine pores begin to take in water again, the surface becomes smoother, and gradually, as the individual polyps appear and stretch out their tentacles, the colouring of the whole stock becomes more vivid and more delicate. The stock lengthens and thickens, and the white crowns of tentacles stand out in dazzling contrast to the red of their bodies and of the common trunk. The foot swells out like an onion and becomes transparent, curves, and sinks into the stand; and the stock, which during its period of inactivity lay prone on the ground, assumes an erect position. In these sea-pens



AN ALCYONARIAN CORAL, *Alcyonium* (nat. size).

the parts of the stock may be compared with the parts of a feather, the whole being bilaterally symmetrical, and the single polyps being carried on the leaf-like lateral appendages of the stem. The sexual animals, which are provided with all the organs necessary for a polyp, take in the food and reproduce themselves. The other less perfect brethren, called zooids, although more or less resembling these, have remained at a lower stage of development, are smaller, and have neither tentacles nor reproductive organs. These zooids appear to perform only one function, namely, to pump water through the body of the stock. In this important work the higher individuals no doubt assist, as indeed in most alcyonid-stocks they alone must do the work, there being no such specialised pumping-polyps.

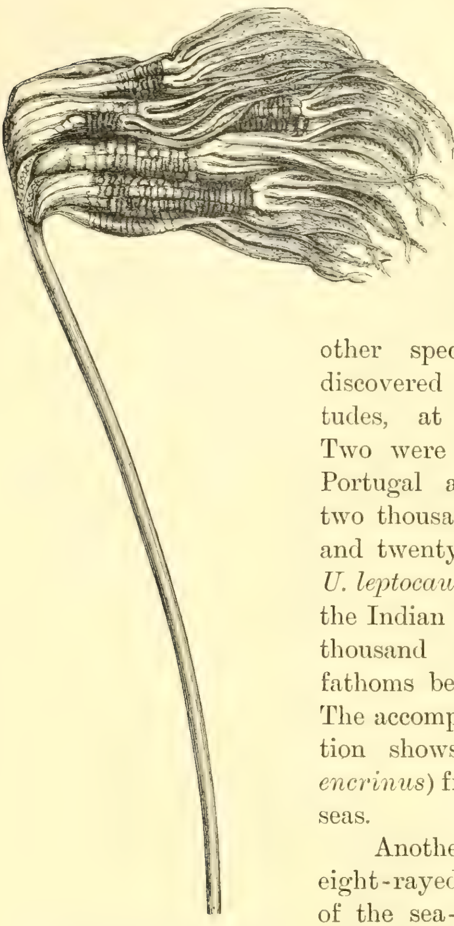
In addition to the small, isolated calcareous particles already mentioned within the bodies of the individual polyps, sea-pens have a further support in the form of a calcified and often flexible axis, entirely concealed in the stock and pointed at the two ends. The accompanying illustration represents *Pteroides spinosa,* in which the polyp-bearing leaves are supported by a number of calcareous rays which project at the edges as spines.



A SEA-PEN, *Pteroides spinosa* (¼ nat. size).
a, A polyp (somewhat magnified).

The best known of the sea-pens is the phosphorescent *Pennatula phosphorea* of the Mediterranean and the Atlantic. In this form the capacity for giving light is not possessed by the whole surface of the stock, but only by eight band-like organs on the polyps themselves, the upper ends of which surround the mouth like papillæ, while their lower parts run down over the stomach. These bands are filled with cells containing fatty spherules, to which the phosphorescence is confined. The fact that these luminous bodies have been found in all parts of the stock is explained by the liability of the bands to be injured, the least pressure causing their contents to escape. Specimens which have been roughly treated when captured and have strongly contracted, as also those which have been kept for any length of time in small vessels and have become dropsical, are incapable of giving light. The phenomenon is only observed in freshly-caught and little-disturbed animals. Very slight irritation, such as is produced by tapping on the glass of the aquarium, is enough to call forth flashes. If the animal is taken in the hand, either in or out of water, still brighter luminous spots and streaks are seen. Repeated careful experiments have revealed the fact that the streams of light follow regular courses. There are two kinds of streams; the one connected with the polyps proper, and visible on the dorsal side of the feathers, and the other connected with the zooids, and appearing on the lower side. The two streams appear at the same time, as a rule, but either the one or the other may, without any apparent reason, arise independently. It can be shown that the direction taken by the streams depends on the part to which irritation is applied.

The higher forms of the sea-pens, or those which actually resemble feathers, are not found in deep water, none being recorded to exist below six hundred fathoms. Deep-sea forms have, however, been found; these being related to *Umbellula grœnlandica,* which has long been well known. As early as the middle of last century, when the presence of animal life at great depths was quite unknown, two specimens were brought up from a depth of two hundred and forty fathoms, sixty miles from the coast of Greenland. The polyp-stocks consisted of a long, thin stem, ending in a bundle of polyps. The larger specimen was two yards long.



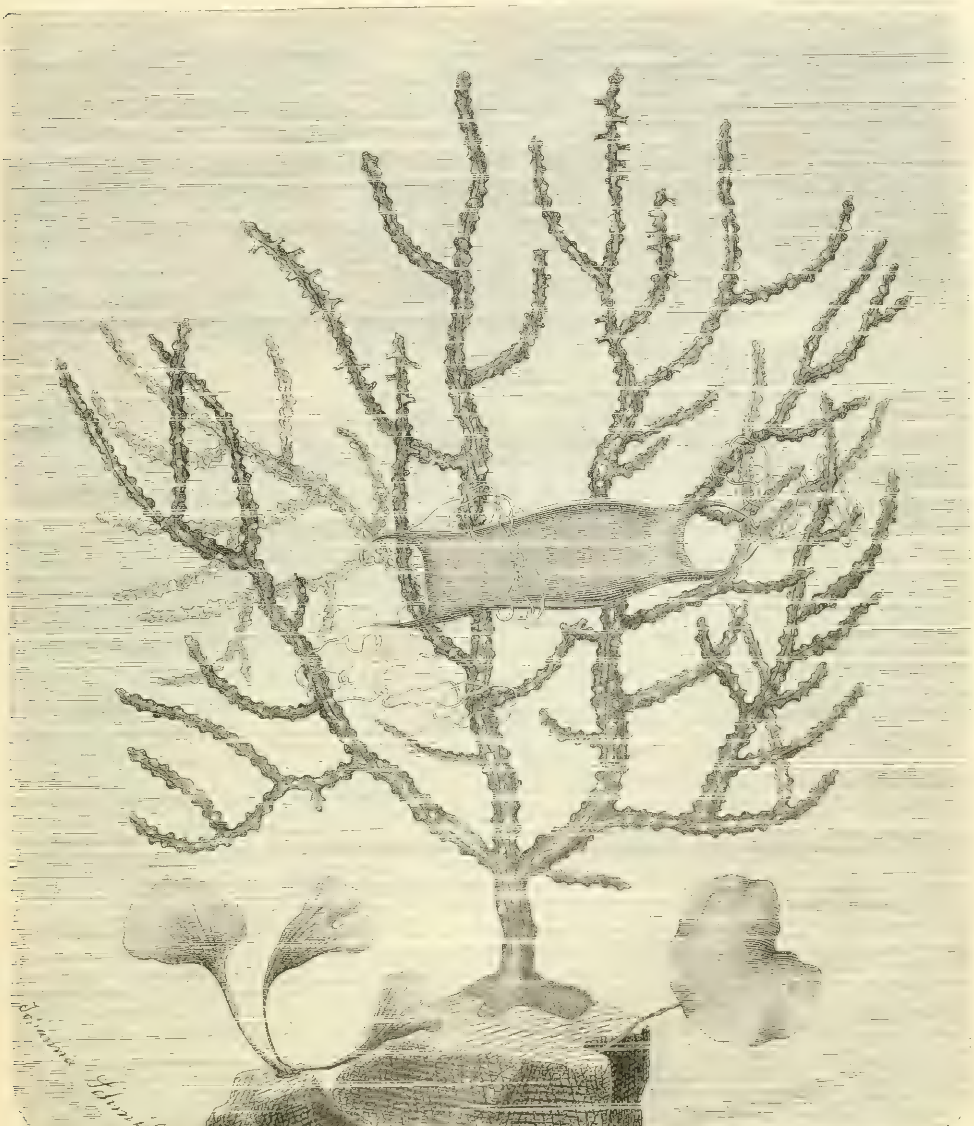
Umbellula thomsoni (nat. size).

These two specimens, soon after being described, were lost, but a very similar form (*U. thomsoni*) was obtained during the *Challenger* expedition; and other species have been discovered in various latitudes, at great depths. Two were found between Portugal and Madeira, at two thousand one hundred and twenty fathoms, while *U. leptocaulis* was taken in the Indian Ocean, some two thousand five hundred fathoms below the surface. The accompanying illustration shows a species (*U. encrinus*) from the northern seas.

Another family of eight-rayed corals is that of the sea-fans, or *Gorgoniidæ*, of which the beautiful, horny, tree, and bush-like growths give no idea of the living coral. In order to gain an idea of the latter, we must picture these trees thickly covered with beautiful eight-rayed anemones. As in the case of ordinary corals, the polyps secrete the horny branches beneath their bases, and on these they rise in gracefully branching colonies. All the sea-fans are attached, and branch in the most various ways, some in all directions, others only in one plane; in some cases simple branches run out at an angle or spirally, forming fans or nets, etc. In most, the axis is horny and flexible, and they might be called horny corals, but single calcareous particles are enclosed in the axis, and its soft covering is crowded

Umbellula encrinus (nat. size).

with them. The different kinds of these particles, found in different species, are of great importance in classification. One of the most common of the group is *Gorgonia verrucosa,* found in the Mediterranean, and here illustrated. A shark's egg is shown in the illustration attached to the coral by means of its



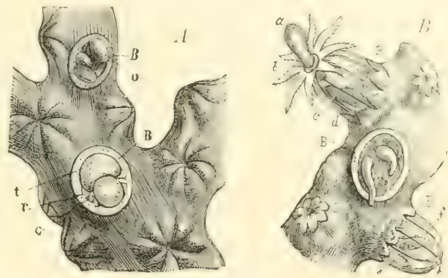
A SEA-FAN (*Gorgonia verrucosa*), WITH A SHARK'S EGG FIXED TO ITS BRANCHES (nat. size).

appendages. The soft covering of this *Gorgonia* is white. These animals occupy no very important place in the economy of nature; but several gastropods seem to attack the polyps, and brittle-stars climb up the branches in search of food. A beautiful form is *Isidigorgia*, resembling a corkscrew with a long spiral. It sends off at right angles to the principal axis, and at short intervals, delicate branches, so that the whole structure looks like a spiral staircase constructed of fine cord. The accompanying illustration shows an allied form (*Streptocaulus*) of the family *Chrysogorgoniidæ*, as yet found only in the Western Atlantic. The simple or branched colonies are as thin as horsehair, and the delicate axis has a golden sheen, with a beautiful display of colours.

CORKSCREW SEA-FAN, *Streptocaulus pulcherrimus* (nat. size).

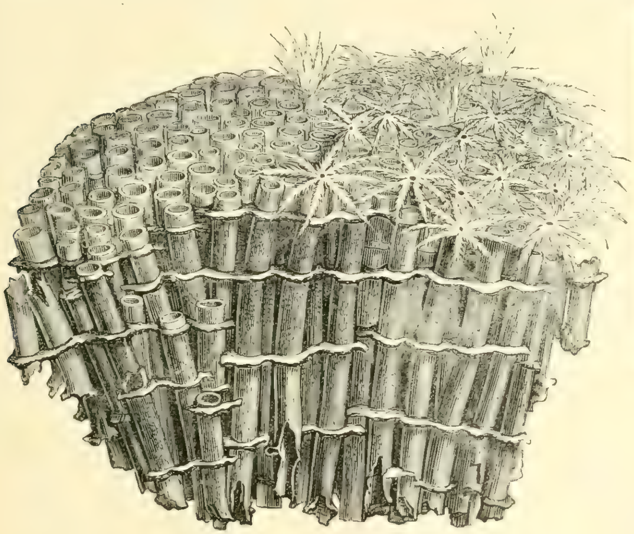
The genus *Isis*, the stock of which is partly horny and partly purely calcareous, forms a transition between the above and the red coral (*Corallium rubrum*). In the latter the axis is calcareous, and built of numerous fine layers, the microscopic structure of which is so definite that a connoisseur can detect false from real coral. The fresh axis is covered with fine longitudinal furrows, in which run the deepest of the canals connecting the polyps with one another. The stocks, as a rule, consist either purely of male or purely of female individuals, although occasionally the two sexes are found on one and the same stock, and even individual polyps which are both male and female sometimes occur. In the illustration, a slightly magnified branch of a stock is represented, with several retracted polyps and two cut open. In the upper exposed calyx (*o*), eggs are seen, while the lower (*t*) contains a large male vesicle, and at its side an egg (*o*). After hatching, the ciliated larvæ leave the egg while still within the chambered cavity of their parent (*B*). Two of the long worm-like larvæ (*f*, *g*) can be seen in the illustration through the delicate body-wall of a polyp whose tentacles are retracted, and others are visible in a cell which has been cut open. In the uppermost cell a larva (*a*) is seen in the act of passing out through the mouth (*b*). The red coral is found only in the Mediterranean and Adriatic seas; the most noted coral-fisheries being carried on off the Algerian and Tunisian coasts, at depths of forty to one hundred fathoms. The coral obtained in these fisheries varies greatly in value. The price of the broken pieces, often perforated by worms and sponges, is from five to twenty francs the kilogramme (2 lbs.); good coral fetches from forty-five to seventy francs, while choice thick coral, especially the rosy red kind, is bought at from four hundred to five hundred francs the kilogramme. Such pieces as are black, either superficially or throughout their whole thickness, are sold separately at from twelve to fifteen francs the kilogramme; these are not of a different species, but, having long been covered with mud, have changed colour as a result of chemical changes. The coral is made into articles of ornament both in Paris and Marseilles, but the chief industries are in Naples, Leghorn, and Genoa.

We conclude our description of these eight-rayed corals with the organ-pipe corals (*Tubiporidæ*), a family consisting of the one genus *Tubipora*, the members of which are neither numerous nor varied. The individuals resemble in form, in the number of their delicate tentacles and in their soft anterior body, the other living members of the order. In the structure of their skeleton they are, however, unique among extant corals, and recall certain extinct forms. Each individual secretes a smooth-walled tube, without calcification of the vertical septa. These tubes, which, like the pipes of an organ, stand almost parallel, are united to form a stock by means of transverse platforms. These latter do not, however, correspond with the inner transverse partitions (*tabulæ*), by means of which the upper living part of the tube is from time to time cut off from the dead part below. The transverse platforms are neither regularly parallel nor continuous; nevertheless they do indicate in a general way stages of growth. They are very richly provided with nutritive canals, and are of special importance for the whole stock, inasmuch as the young individuals bud out from their surfaces. As the longer tubes grow, the intervals between them increase, and as soon as there is room enough for a new polyp, one buds out from the platform. Division of the individuals or formation of buds from the tubes themselves does not take place in this family.

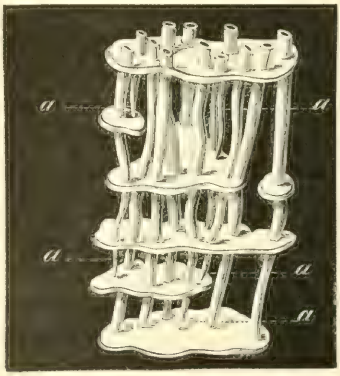


RED CORAL.

A, Part of a stock with retracted polyps, two have been opened (magnified); *B*, With polyps more or less extended; a larva (*a*) seen in the act of emerging through the mouth of the uppermost polyp.



ORGAN-PIPE CORAL, *Tubipora* (nat. size).



STRUCTURE OF ORGAN-PIPE CORAL.

a, Starting points of new individuals (nat. size.)

Coral-Reefs and Islands. Having described a few typical corals, and explained their general structure and characters, some mention must be made of the importance of these creatures in the economy of nature. Whereas most forms of animal life, in passing at death into their elementary constituents, leave no visible traces of their existence, the corals, or at least the numerous reef-making forms, build monuments which last for hundreds of thousands of years, and may be said to attain their greatest importance in the influence they exercise upon the life and development of the human race. Professor Haeckel has described the magical effect of a first sight of a shallow coral-reef, enjoyed by him on the coasts of the Red Sea, where a long bank of coral runs parallel to the shore. The waves break upon these barrier-reefs, the uneven edges of which lie just below the surface of the water, and their position is thus clearly marked by the line of surf produced. The outer side of the reef, which is exposed to the full force of the waves, descends steeply, but the inner side, washed by comparatively quiet water, slopes gently down; the canal formed between the reef and the coast being as a rule so shallow and calm that the full splendour of the garden of corals at its bottom can be seen through the limpid water.

All reef-forming corals inhabit waters which in winter do not sink below a temperature of 68° F., the maximum summer heat in the Pacific Ocean being 86°. Two lines to the north and the south of the Equator, which would connect points where the winter-temperature does not sink below 68°, waving in and out according to the currents, would enclose the zone of the reef-forming corals. Most of the stock-forming corals described above live exclusively within these limits of temperature, a fact that explains their rare occurrence in the Mediterranean, which is so favourable to other forms of animal life. The richest coral regions lie in the middle hottest zone, that is between 15° and 18° north and south of the Equator, where the temperature does not fall below 72° F. The Fiji Islands fall within this region, and possess reefs extraordinarily rich in corals. The star-corals and brain-corals there reach their greatest development, while the madrepores are found as bushes, cups, or leaves, the latter often attaining a breadth of over six feet. In the Sandwich Islands, which lie outside of the hottest zone, the corals are less luxuriant and varied. The genera of corals found in the Indian Ocean and the Red Sea, as well as on the coast of Zanzibar, are essentially the same as those in the Pacific. The corals of the Gulf of Panama, although not in the hottest zone, have the character of the Pacific corals, and are different from those of the West Indies.

When the two Fosters and Cook discovered the coral islands of the South Sea, they were of opinion that the minute creatures to which these owe their origin began to build at unfathomable depths, gradually bringing their structures up to the surface of the water. They thus thought that the same species were able to live at different depths. Recent researches have disproved this; and we now know that although many different animals live at enormous depths, all such are specially adapted to the conditions of life at those depths. Animals adapted to life at a great depth cannot exist at the surface. The number of deep-sea polyps is small, and among them there are no species forming reefs; and authorities are now agreed that reef-building corals can only live at moderate depths and within certain latitudes. One of the principal requirements is pure sea-water, some species flourishing in the canals between the reefs and in the shallower water of the lagoons, whereas others require the open sea. Corals never flourish in impure water or on sandy or muddy coasts. They are not found at the mouths of rivers nor in excessively salt water; abnormal heating of the water of the lagoons also may cause their death. The dead portion of the stocks, and also, at times, that part which contains the living animals, suffer continually from the action of boring-worms and molluscs, while the boring-sponges cause still worse injuries. In addition to these foes, which tunnel through and help to disintegrate the skeleton of the coral-stocks, other enemies prey on the living polyps. These latter are richly provided with stinging-cells; and an unwary fish touching one with its lip is sure to be stung. Nevertheless, the greediest devourers of corals are certain fish which have acquired horny beaks like those of a parrot. These parrot-fish live by browsing on the living flowers of the coral-garden, having jaws which are untouched by their stings.

Certain tube-dwelling worms and cirripedes (*Balanus*), on the other hand, penetrate the living coral without injuring it. They attach themselves to the surface of a coral-stock on leaving the larval condition, and gradually become embedded in the growing stock. Some *Serpulidæ* also grow with the stock, their tubes reaching far into it, and their elegant crown of gills, when unfolded, adding to its beauty

The rate of growth of various corals has been investigated by Dana and others. Although Darwin doubts the statement that the copper plating of a ship in the Persian Gulf was covered in twenty months with a crust of coral two feet thick, the rapidity of their growth is proved by other observations. As early as 1830 Allen sank a number of pieces of coral in the month of December on a bank about a yard below the surface of the water on the coast of Madagascar, and found, the next July, that they had almost reached the surface and had attached themselves firmly. In Hayti a growth of three to five inches has been observed in three months. A stock of labyrinthine brain-coral was found to increase 11½ inches in diameter, and 4 inches in height in twenty years. On a ship, wrecked in 1792 and discovered in 1857, a madrepore was found which had reached a height of sixteen feet, *i.e.*, had grown on an average three inches yearly, whereas massive coral-stocks in its neighbourhood showed slower growth.

The foregoing facts as to the life of the corals themselves sink into insignificance in comparison with the results of their mode of life in the formation of coral-reefs and islands.

Coral-reefs are banks of coral-rock in the sea along the coasts of tropical countries. At high tide the reefs are usually under water, but at low tide are visible as wide, flat, naked expanses of rock, just above the level of the water, in marked contrast to the precipitous coasts of the islands they surround. At high tide the only sign of the presence of a reef is a line of breakers, which often extends for many miles at a distance from the land, a retreating wave only occasionally revealing a small portion of the rock. A small island may be surrounded by such a reef, the annexed illustration showing a typical tropical island thus encircled. On the right side the reef forms a girdle stretching round the coast, and appears like a continuation of the land. This fringing-reef is also found on the left side, but beyond it, separated by a channel, is the barrier-reef. At one point the land is seen to dip down precipitously into deep water, and here, on account of the depth of water, the reef is wanting. The barrier-reef also is broken through at one point, forming the entrance to a harbour, such as is often found in reef-surrounded islands. Many islands are bordered by a reef which protects the land from the sea like a mole. The barrier-reef may occasionally be ten or fifteen miles from land, and enclose several high islands. Various forms of reefs are found between the two extremes presented by such a barrier-reef and the simple fringing-reef.

The channel within the reef at low tide is sometimes hardly deep enough for navigation, or else it is blocked by masses of coral which render its passage dangerous. At other times a reef encloses miles of open water, ten, twenty, or forty fathoms deep, but not free from hidden sources of danger; masses of living coral, from a few square feet to several square miles in extent, rising from the bottom. In the Fijis all these kinds of channel formations occur.

The extent of the reefs, which include scattered banks and masses far below

ISLAND WITH FRINGING- AND BARRIER-REEFS.

the surface of the water, varies greatly. On some coasts there are merely scattered groups or mounds of coral-rock, the tips of which project as rocks; while, on the other hand, to the west of the Fijis there is an area covered with reef of about three thousand square miles. Other reefs are one hundred or one hundred and fifty miles long, and the Australian barrier-reef attains a length of one thousand two hundred and fifty miles.

Passing from such a tropical island girt with coral-reefs, we come to what is more especially known as a coral-island proper, or atoll, which may be described as the encircling reef without any island to encircle. It surrounds a calm lake of blue water, in striking contrast to the restless ocean outside the solid circle. The ring of solid reef in this case is usually only one hundred to two hundred yards broad, and at some parts so low that the waves break over it into the lagoon. At other parts it is covered with tropical vegetation, but it rarely rises more than three to four yards above high-water mark. Seen in the distance from a ship, a coral island looks like a row of dark points, which are the tops of the cocoanut-trees first seen above the horizon. On nearer approach, the lagoon with its green border is a wonderfully beautiful sight. Outside of the reef is the heavy surf, and within the white coral strand, the thick band of verdure, and the enclosed lake with its minute islands. In colour, the water of the lagoon, where it is deep (ten to twelve fathoms), matches the blue of the surrounding ocean, but delicate apple-green and yellow tints mingle with the blue wherever the sand or coral-rocks approach the surface. Although the girdle of reef covered with vegetation occasionally surrounds the lagoon, it is more often broken up into a ring of separate islets of various sizes; between some of which navigable channels are found, giving admittance to the lagoon.

The submarine fields of living coral spread along the coasts of the islands and the mainland. Just as the accumulated remains of the primitive forests add layer after layer to the soil, so the coral-reefs are added to by the breaking down of old corals, by the shells of bivalves and of other organisms. These fragments keep filling up the spaces between the separate living stocks, so that the level of the reef is constantly rising towards the surface. The currents and waves also take part in the building up of the reef. Masses of coral of all sizes, from great boulders to minute sand grains are broken off by the waves, and are cast upon the reefs, and then rolled about until quantities of fine detritus are produced, which, as calcareous

CORAL-ISLAND OR ATOLL.

mud, serves as a cement to bind the larger blocks together. A constant process of destruction goes on; some of the detritus being washed over the reef into the lagoon or canal, and some filling the spaces between the corals along the edge of the reef, while the rest remains upon the surface.

The layer of dead coral-rock forming the foundation of the reef is bordered by living coral. While this living coral is always extending the reef horizontally, the waves are piling up the dead masses vertically, till they rise above the surface of the water. Thus dry land begins to form, and by degrees islands arise well out of the reach of the waves. The ocean is thus the builder of the coral-island as it appears above the waves, the material having been supplied in the first place by the coral-animals. The moment the island is above water, plant seeds reach it from distant lands, and ere long cover it with vegetation. The accompanying section of a coral-reef shows the slope of the reef, both towards the lagoon on the right and the open ocean on the left. At *b–c* is the steep slope from shallow water to the land level on the outer side, and at *d–e* the gradual slope on the inner side. The latter slope is then continued at almost the same angle (*e–n*), the quiet water not disturbing the slow accumulation and growth of the lagoon or canal shore. On the outer side of the reef, however, a broad terrace (*a–b*), succeeds the steep slope, and surrounds the land which has risen above the sea, this terrace being exposed at low tide.

We have still to mention some of the causes of modification in the form and growth of the coral-reefs. The presence of harbours in reefs and atolls can, as a rule, be traced to the tides and to local ocean currents. There is generally an outflow through the canals and openings in the reefs. This is apparently due to the fact that water is constantly being thrown by the larger waves over the lower portions of the reef into the canal or lagoon, and seeks either to escape as an under-current in opposition to the flood-tide, or else strengthens the ebb-tide. These and other similar disturbances of the water in the canals bring with them much coral detritus, and render the bottom altogether unsuitable for the growth of corals. Where such currents are strong, they keep the canals clean and open. The action of the oceanic currents is often increased by the fresh waters coming from the central islands, and harbours are therefore very often found at the mouths of valleys and of their small streams. The influence of the fresh water itself on the

SECTION THROUGH A CORAL-REEF.

corals is not so great as is usually assumed, chiefly because it, being lighter than salt water, flows away on the surface of the latter and hardly touches the animals which grow below the surface.

The form of the reef is again largely influenced by the form and constitution of the sea-bottom. Where deep submarine fissures occur, dipping down below the level at which the corals flourish, no reef can be formed, as also in places where firm ground alternates with sand and mud. All irregularities in the outline of a reef or an atoll, and the formation of harbours in coral islands, can thus be simply explained.

The most important point which needs elucidation is why some reefs encircle islands as a fringe extending from the shore, while others run parallel with the land, no longer touching it; others, again, forming circular lagoons with no island at all in the middle. This was the question which puzzled the first discoverers of reefs, and at one time it was supposed that instinct guided the animals in giving their structures the form best suited to withstand the force of the waves. According to another hypothesis, put forth by Steffen in 1822, the reefs represent the summits of volcanic mountains, the crater being filled by the lagoon, while the channels through the reef indicate the points at which the edge of the crater was destroyed by outbursts of lava. This superficially plausible view was disposed of by Darwin thirty years ago. He argued that the volcanic cone thus assumed must either once have stood upon dry land and then have been submerged, or else must have been formed beneath the sea. In the former case, the crater would in almost all cases have been destroyed during the gradual sinking; while the formation of craters by submarine eruptions and their subsequent elevation is hardly conceivable.

This hypothesis further requires the assumption that immense numbers of volcanoes must have arisen over a limited area, and a still more improbable supposition, that all these volcanoes rose to almost the same level, seeing that the coral animals occur only within a depth of about twenty fathoms. Craters nearly fifty miles in diameter must be assumed to have existed, and others of twenty to twenty-five miles must have been frequent. For these and other reasons, the volcanic origin of coral-reefs was rejected. It is obvious also that the same objections dispose of another hypothesis, namely, that nonvolcanic summits and banks of equal height were the foundations on which corals built.

Darwin believed that all forms of reef arise by the gradual sinking of the land they surround. This theory has been confirmed in all essential points by Dana, and recently by Langenbeck. Other authorities have, however, differed.

The condition of the reefs attached to the Fiji Islands illustrates Darwin's theory of subsidence. The Goro Reef lies close to the land along whose submarine coast it grows. The Ango reef is of the same nature, but lies further from the land, having a channel between it and the shore, and forms what is called a barrier-reef, which name denotes merely difference of position, not of kind. The barrier-reef of the island of Nanuku encloses a large stretch of sea, the islands within it being nothing else than the rocky summit of a mountain. Darwin's theory gives an explanation of these differences. If, for example, the island of Ango were very gradually to sink, two things would happen,—the island would disappear little by little, while the reef would remain at the surface of the water, that is, so long as the land did not sink faster than the corals could build. When the subsidence had gone so far that only the last mountain summit remained above water, the condition found in the island of Nanuku would be realised. Instances are also found in the Fiji islands of the intermediate stages, where only a single mountain ridge and a few isolated peaks remain above water.

It is a known fact that large countries, such as Sweden and Greenland, are in the act of sinking, and we also have direct proofs that reefs and their islands have subsided. The depth of a reef, although not directly measurable, can be approximately estimated, and must in many cases be at least three hundred yards. Since the living portion of a coral-reef cannot reach more than eighteen to twenty fathoms, such a depth of reef can only be explained by the sinking of the land on which it stands. If, instead of sinking, the land rises, the reef would be lifted out of water; raised reefs three hundred feet high being known. This enormous thickness of reef can hardly be explained without a previous subsidence, inasmuch as such a height is greater than the known depth at which corals can live. The assumption that many reefs are the consequence of simple subsidence thus appears highly probable.

The accompanying diagrammatic section (p. 524) through an island and its reef illustrates the action of gradual subsidence. The island at the water-line (*I*) has a simple fringing-reef (*f f*), a narrow rocky terrace at the level of the water, which first descends very gradually and then more steeply. Supposing the island to sink to the level (*II*), what would happen? While the land has sunk, the reef has risen, and there is a fringing-reef (*f′*) and a barrier reef (*b*), with a narrow channel (*c′*) between them. A further subsidence to level (*III*) greatly increases the width of the channel (e''). On the one side (f''), the fringing-reef is retained, while on the other it has disappeared, a fact due to currents and other such agencies. Finally, when the water is at the level (*IV*), two rocky islands are visible in a large lagoon surrounded by the reef (b''' b'''), with two small reef-islands (i''' i''') developed on

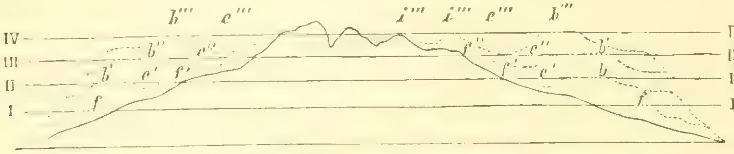
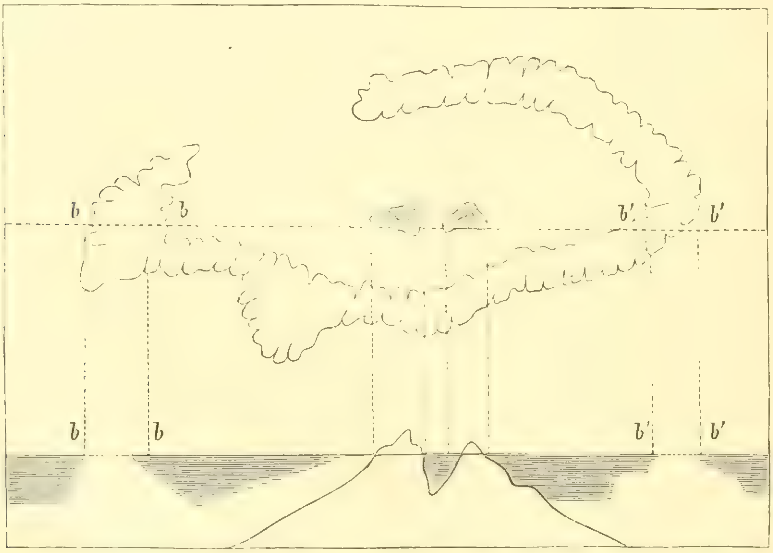


DIAGRAM EXPLAINING THEORY OF SUBSIDENCE.

mountain-peaks which have disappeared below the surface. The coral-rock has greatly increased in thickness, and almost entirely covers the former island.

Such an ideal section corresponds exactly with the reality. In the following illustration the outline of the island of Aiva, one of the Fiji group, is given. In the lagoon there are two islands resembling the summits of mountains, just as in the diagram. The exact altitudes and depths are unfortunately not known, but it will be seen how well the theory of subsidence appears to explain the conditions.

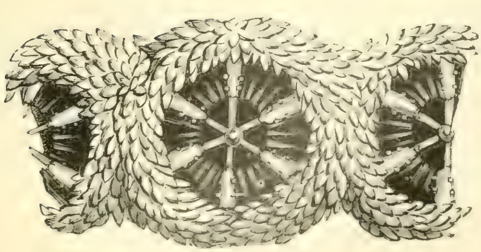
The chief objections which have been made to this theory of subsidence are



OUTLINE OF THE ISLAND OF AIVA, WITH PROJECTED SECTION.

the following. The simultaneous occurrence of atolls, barrier-reefs, and fringing-reefs in neighbouring regions does not coincide with the theory, nor does the appearance of atolls and barrier-reefs in regions in which recent elevation of the land has been proved. The discovery of extensive submarine banks of sediment formed of the calcareous portions of foraminifera, deep-sea corals, molluscs, etc., makes it possible to explain the formation of atolls and barrier-reefs without the help of subsidence, this explanation being more probable than that involving the sinking of extensive areas of land. The formation of atolls can be explained by the better growth of the corals on the outer edges of the reef which are most exposed to the action of the surf, and the sweeping of the coral material out of the lagoon through the agency of oceanic currents, and the dissolving action of the carbonic acid contained in the sea water. The deep canals which divide the barrier-reefs from the neighbouring mainland are formed in the same way. The enormous magnitude of the reefs which the theory of subsidence demands is nowhere realised. Neither among modern reefs nor among geological formations do we find any traces of such gigantic masses of coral-rock. We are thus in face of a fascinating and important scientific problem, which still remains to be solved, a problem which was long thought to have found its solution. After Darwin's and Dana's subsidence theory had been generally for many years accepted as beautiful and completely satisfactory, we are told that it is not always applicable, and that much simpler causes suffice to explain the phenomena. It is obvious, then, that we have an ample supply of possible explanations of coral-reefs, and it is most probable that among the many scattered reefs in the world, in one case one set of factors have played the chief part, in another case a slightly different set, and further, a detailed and exhaustive study of any particular reef would probably reveal natural processes of no small importance which have not as yet been taken into account.

H. and M. BERNARD.

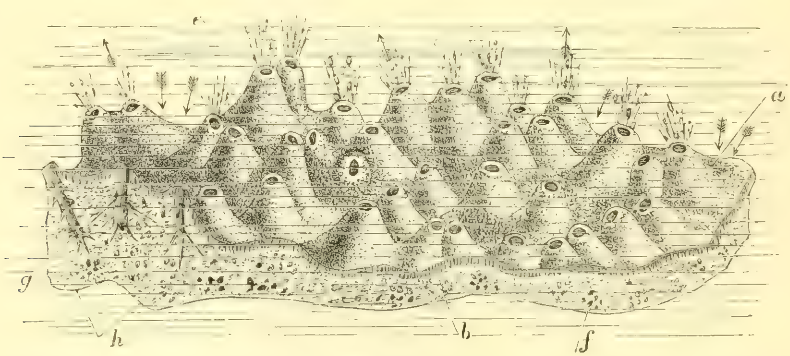


MOUTHS OF MADREPORE.

CHAPTER XV.

The Sponges,—Subkingdom **PORIFERA.**

Characteristics. There are about two thousand species of sponges known, which range in size from a pin's head to masses several feet in height, and vary in weight from a grain to over a hundred pounds. They assume an endless variety of shapes, such as cups, vases, spheres, tubes, branched tree-like growths, etc., but are often shapeless. When alive, they are of all colours, and their consistency may be soft and glutinous, fleshy, leathery, or stony. They are found in all seas, and in all depths from the shore margin to several miles deep, and certain species occur in fresh waters all over the globe. About three hundred species have been found round the coasts of Britain. Aristotle was the first to give a scientific account of sponges. He considered that they were either animals, or organisms transitional between plants and animals, and that they possessed sensation, since they shrank when torn from the rocks. He classified the kinds then known, and asserted that the animals often found in the cavities of sponges were intruders, and did not make the sponges; further, he distinguished the



BREAD-CRUMB SPONGE, SHOWING CURRENTS ENTERING SURFACE AND LEAVING BY OSCULES.

large holes on the surface of certain species from the small ones, and thought that water was sucked in by the former.

From the time of Aristotle till 1762 little was recorded, but in that year Ellis published his observations on the bread-crumb sponge, a British species forming fleshy masses or crusts of a yellow or greenish hue. This sponge envelops the stems of seaweeds, or encrusts rocks and stones; when growing on seaweeds it forms cake-like masses with a level surface, but when encrusting rocks the surface is covered with small cones resembling miniature volcanic craters. The surface between the craters exhibits a very fine gauze-like pattern; and, by careful inspection, groups of minute pores will be seen perforating the meshes. The large holes at the summits of the craters are termed oscules, and the small ones on the general surface, pores. Ellis, who put some specimens in a glass vessel of sea water, wrote that "We could plainly observe these little tubes to receive and pass the water to and fro"; and further, "The sponge is an animal whose mouths are so many holes or ends of branched tubes opening on its surface; with these it receives its nourishment, and by these it discharges like the polyps its excrement." Ellis's observations were erroneous in one important point. The water always passes out of the large orifices, and is not passed in by them. It is true that while the torrent is gushing out of the centre of an oscule, there is a slight passive return current at the margin. Ellis attributed the current to the contraction of the walls of the canals. He found that the current continued in the absence of any worms or crustaceans in the body of the sponges.

a, FLAGELLATED CHAMBER OF BREAD-CRUMB SPONGE, SHOWING COLLAR-CELLS; *b*, FLAGELLATED CHAMBER OF FRESH-WATER SPONGE. (Both figures 1600 diameters.)—After Vosmaer.

Our knowledge of sponges really begins in 1825 with the observations of Grant, who examined a fragment of a living branch of a branching-sponge. On bringing one of the large apertures on the side of the branch fully into view, he beheld this living fountain vomiting forth from a circular cavity a torrent of liquid matter, and hurling along in rapid succession opaque masses, which it strewed everywhere around. After many experiments, Grant convinced himself that a current flowed out of all the large orifices, and not into one and out of another. He also rubbed powdered chalk on the surface of a bread-crumb sponge, and saw particles which clogged the margins of the minute pores on the surface driven into the interior; and thereby demonstrated the passage of currents into the interior through the pores. The origin of the sponge-fountains was now traced. In all sponges currents of water pass into the body through pores, and out again by one or more ways different from those by which they entered. To ascertain the cause of the currents, it is necessary to examine the anatomy of the sponge. A thin skin, which can be peeled off, is separated from the body by numerous minute supporting pillars. On cutting into the sponge, large canals are seen passing down from the oscules and branching into the body, and much narrower canals from the groups of pores in the skin. The channels from the pores divide up into minute lacunar spaces, or canaliculi, which finally communicate with the interior of small, spherical, flagellated chambers, whose walls are perforated by pores. Each of the chambers is the five-hundredth of an inch in diameter, and groups

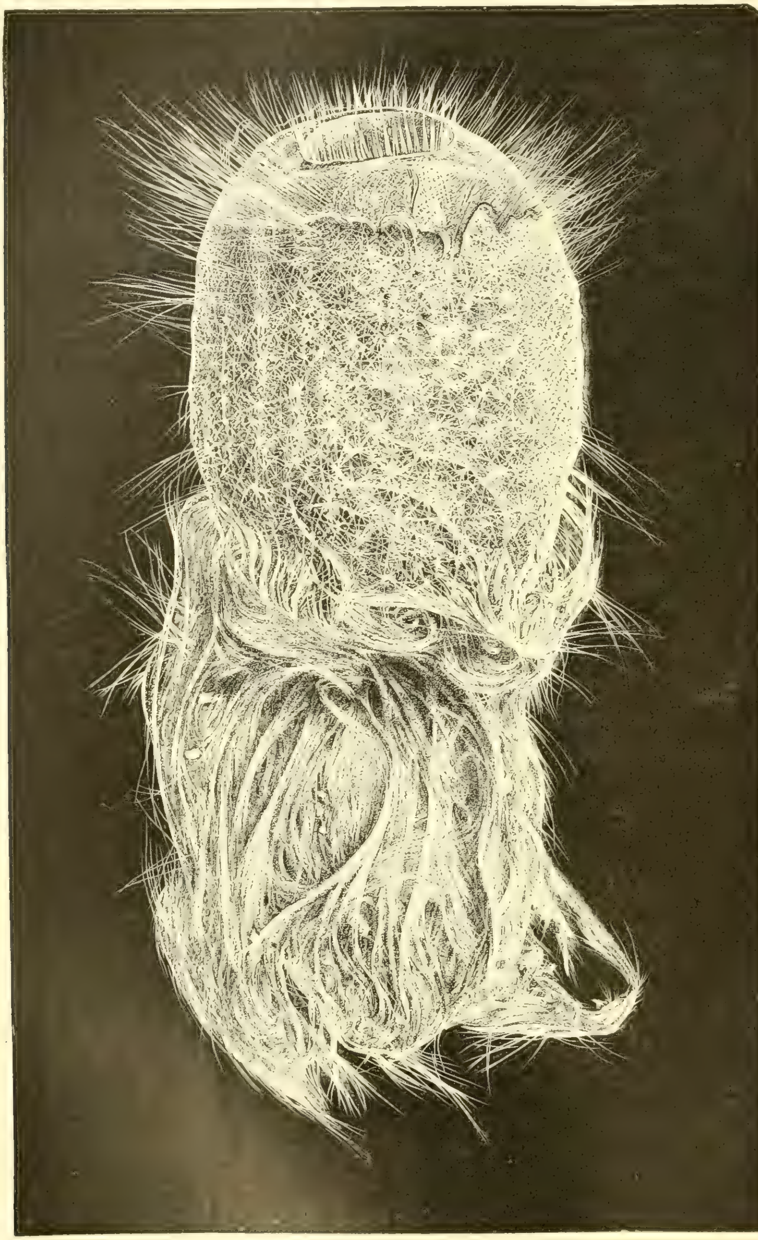
SPONGES GROWING ON SEAWEED. *a*, *b*, Two of the Desmacidine group; *c*, *Spongeldia*. (Nat. size.)

of them open each by one wide orifice into a common space, or canaliculus, which joins with others to form canals terminating in large oscular canals.

The walls of the canals are lined with flat-cells, but in the flagellated chambers the lining cells are more or less cylindrical, and each is provided at its free end with a whip-like appendage, or flagellum; and, further, the upper margin is expanded into a thin hyaline collar, so that the whip appears to rise from the centre of a basin or funnel. The currents of water traversing the body of the sponge are kept up by the movements of the flagella of the collar-cells. The flagella beat the water in the flagellated chambers into the rootlets of the canals leading to the oscules. To replace this, water flows into the flagellated chambers from the rootlets of the canals passing down from the groups of pores in the skin. The currents entering the sponge bring in oxygenated sea-water, and minute food particles such as diatoms, infusoria, etc; the currents from the oscules contain an excess of carbonic acid, of waste products resulting from vital activity, and indigestible remains. The cells lining the canals effect the exchange of gases, and take up food-particles.

At present, too little is known as to the physiology of digestion in sponges, to permit of any definite statements being made. In some sponges, which have been fed with carmine granules and then killed, the collar-cells have been found loaded with granules; in others, again, the flat cells lining the subdermal cavities have been found gorged with the carmine. A terminal cluster of flagellated chambers in the bread-crumb sponge may be compared to a hollow mulberry, reduced to its skin but retaining its shape; each swelling represents one flagellated chamber, opening by one wide orifice into the common central space which is continued into the stalk. A grape-like cluster of mulberries would convey some idea of the arrangement of the canals, in which the hollow main stem represents the terminal oscular canal. Further, each swelling on the surface of the mulberry is perforated by several round pores, termed *prosopyles* (entrances). Another call on the reader's imagination must now be made. The openings of the infoldings on the surface are closed over by a membrane perforated by pores. Suppose the mulberry cluster to be immersed up to its stalk into a skin-bag of jelly, and the skin to be tucked in and folded so as to form channels or canals branching and diminishing in size, till they abut on to the surface of the mulberries. Again, suppose the bag to be immersed in water which, by some means, is made to enter the walls of the bag and come out at the stalk. The current will pass from the pores in the skin, then along the channels till it reaches the pores or prosopyles on the surface of the mulberries, through which it passes, and proceeds to the stalks and main stem. The system of canals from the skin pores to the prosopyles is termed incurrent, and that from the cavities of the mulberries to the orifice at the top of the stem out-current. This structure is shown in the illustration, but the representation is extremely diagrammatic. In a thin section of *Halichondria* one sees a labyrinth of in-and-out-current canals and spaces together with small flagellated chambers; of the latter, often only one or two open into an out-current space or rootlet.

The jelly mass, which in the model supports the hollow mulberry cluster and the channels from the outer skin, would of itself form an inefficient support, so we must add to it a scaffolding of rods and bars or tough horny fibres; the common bath-sponge skeleton, and the skeleton of the Venus' flower-basket are the horny and flinty scaffoldings supporting the soft tissues together with the flagellated chambers and the channels which lead to and from them in the living sponges. The fleshy or jelly substance of sponges is termed mesoderm (middle layer), because it is situated between the collar-cells, which constitute the endoderm (inner layer), and the layer of cells on the outer surface, or ectoderm (outer layer). The usually flat cells of the ectoderm are now considered to be simply a superficial layer of mesoderm cells, and not to constitute a special



CARPENTER'S GLASS-SPONGE, *Pheronema* (nat. size).

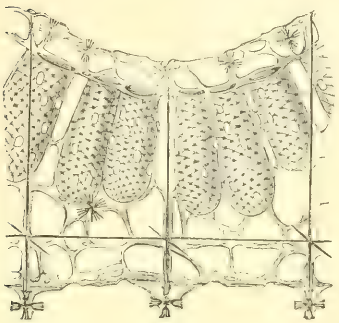
separate layer distinct in itself. Whether this be the case or not, the terms mesoderm and ectoderm may be conveniently retained here. The ground-substance, or mesoderm, contains cells of various kinds, namely, irregularly-shaped cells with slender branching processes, which unite with those of other cells to form a network; wandering amœboid cells, probably concerned with digestion, distribution of nutriment, and excretion; skeleton-forming cells, which secrete lime, or flint spicules, or horny fibres; contractile muscle-cells, possibly nerve-cells; and, lastly, male and female reproductive cells. The cells with the slender processes secrete the gelatinous ground-substance, which may be compared to the material forming the umbrella of jelly-fish.

The varying consistency of sponges, which may be soft, stony, leathery, horny, etc., results from the amount and kind of material secreted by cells of the mesoderm. In the Venus' flower-basket, these cell architects form large spicules of silica which are joined into a trellis. In the living bath-sponge, groups of cells congregate in the ground-substance, and secrete a network of cylindrical fibres of horny material. In calcareous sponges, the skeleton-cells form spicules which nearly always remain separate, and are always beautifully adapted for purposes of support. In addition to forming a support, the skeleton spicules, in many cases, afford a means of defence against small animals by forming spikes in the canals, or on the surface; and, further, it is improbable that any fish would repeat the experiment of eating a siliceous sponge.

To return to the bread-crumb sponge. A dried specimen can easily be crumbled into powder, in which can be seen numerous glassy spicules, pointed at each end, and about an eightieth of an inch in length. The spicules, which are unaffected by most of the strong acids, are composed of silica, and are allied in composition to flint and opal.

Each needle is made up of concentric laminæ of silica, deposited round a fine central axial canal containing a thread of organic matter, and each is formed in a cell of the mesoderm. In this sponge the needles are separate, and scattered with scarcely any regularity in the ground-substance, excepting at the surface, where bundles of needles are joined by their ends to form the gauze-like network. In many sponges the rods or bundles of rods form a regular scaffolding.

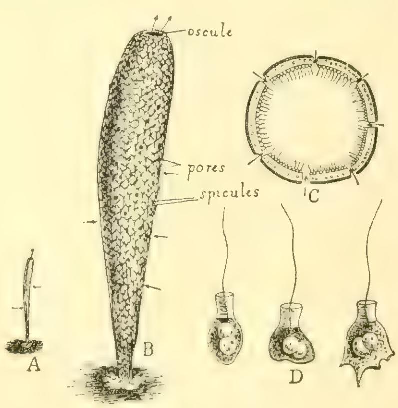
Reproduction. As regards the modes of reproduction, both male and female cells are found in the mesoderm, either in the same or in different specimens. The male cells in sponges generally give rise, by division of the nucleus, to masses of spermatozoa, each of the latter possessing a conical head and a long vibratile tail. The ova appear as large rounded cells, which, after fertilisation, undergo segmentation or division, first into two cells, and each of these again into two, and so on, until a mass of cells results, two kinds being present, one forming an outer layer covering the other. The outer layer of the now egg-shaped embryo, excepting at the narrow end, is composed of long, narrow, cylindrical cells, provided with cilia; and the inner mass is composed of large granular cells. The embryos appear as minute oval bodies, about the size of a pin's head. If a bread-crumb sponge be cut open in the autumn, they will be seen as bright yellow spots in the body-substance. By keeping specimens in a vessel of water, and examining them daily, the embryos will be observed being driven out of the oscules, and swimming about with the broad end forwards. After from twenty-four to forty-eight hours of independent roving existence, an embryo fixes itself by its broad end, and becomes flattened. By a remarkable transformation peculiar to sponges, the large granular cells of the interior burst out and grow over the outer flagellate layer of cells, and the latter become the collar-cells of the adult sponge. A minute sponge with one oscule results from the development of the fertilised ovum. An extensive crust with numerous oscules may be regarded either as a colony in which each oscule represents an individual, or simply as one individual in which the growth of the body necessitates the formation of new channels for the conveyance of food materials.



SECTION OF WALL OF VENUS' FLOWER-BASKET, SHOWING SOFT PARTS.—After F. E. Schulze.

We are now in a position to answer the question, What is a sponge? It is obviously a living animal organism. The next question—the position of sponges in the animal kingdom—is not settled. All are now agreed that sponges come somewhere between the Protozoa and the rest of the animal kingdom, or Metazoa. It is accepted that sponges cannot be classed with Protozoa, for the embryo consists of definite groups of cells giving rise to distinct tissues. Some zoologists class sponges with the Cœlenterata. The opinion here adopted is that sponges form a special subkingdom—Porifera.

The bread-crumb sponge has been selected as an example for explaining the nature of sponges, because of the historical facts associated with it, and its occurrence round the British coasts. Its anatomy is, however, somewhat complicated; but there are other simple forms, the study of whose structure renders it possible to trace the path of development along which the more complex forms have proceeded. One of the simplest of sponges is *Ascetta primordialis*, found on seaweeds in the Mediterranean; in its simple unbranched condition it forms a minute white sac about a twenty-fifth of an inch in height, opening above by a wide round oscule, and narrowing below to a stalk. The walls are very thin and perforated by pores, through which water passes into the interior. The walls of the sac are composed of two layers, an inner lining of collar-cells, and an outer layer, consisting of a gelatinous matrix containing amœboid cells and transparent three-rayed spicules of carbonate of lime. A canal-system can hardly be said to have arisen since the walls of *Ascetta* are thin and not folded. The spicules support the walls and serve as a framework for the pores. By eliminating the spicular skeleton, and by supposing the tube or vase to be more globular, we obtain the "olynthus-form" which has been regarded as the hypothetical ancestor of all sponges. A canal-system arises when the walls grow thick or form folds or give off pouches or tubes. The folds or pouches may

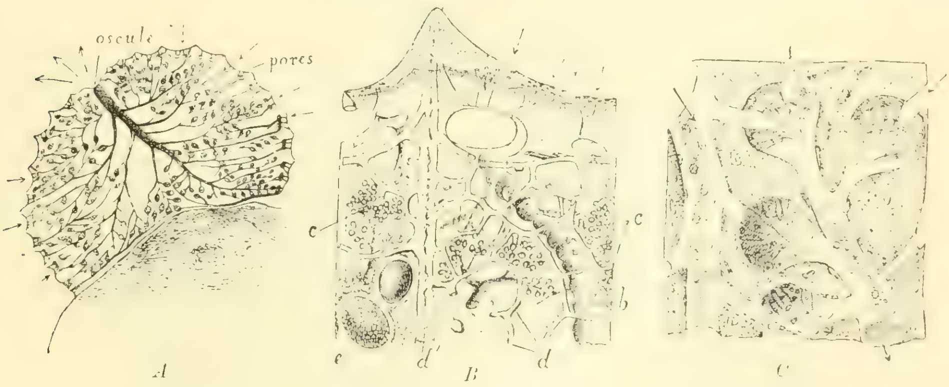


AN ASCON SPONGE.

A, Magnified 20 times; *B*, 80 times; *C*, Transverse section; *D*, Collar cells. (Magnified 700 times.)

be so close to one another that the spaces between and outside of them form channels, which are incipient in-current canals, the spaces in the inside or lumen of the folds forming the out-current canal-system.

The common ciliated sycon, a calcareous sponge found on seaweeds round the British coast, forms a white sac about an inch in height, and with a crown of glassy bristles round the orifice. The vertical cavity of the sac is surrounded by a wall of closely packed horizontal tubes, opening at their inner ends into the central cavity, but externally ending blindly. The central cavity of the sac is lined with flat-cells, and the radial tubes with collar-cells; and the walls of the tubes are perforated with small pores. Here the spaces between and outside the densely packed tubes are the in-current canals. In an equally common British sponge, *Grantia*, which forms small flat white bags, a rudimentary cortex covers the outer ends of the tubes. In *Grantiopsis* the cortex becomes quite thick. In more complex stages the radial tubes branch; and, finally, the collar cells clothe only the ends of branched tubes, thus giving rise to more or less spherical flagellated chambers. As the radial tubes become more branched, and the



TOILET-SPONGE.

A, Diagram of canal system. *B*, Section showing *a*, pores ; *b*, canals ; *c*, flagellated chambers ; *d*, skeleton-fibres ; *d'*, main fibre ; *e*, embryo eggs. *C*, Flagellated whip-chambers. (Highly magnified.)—After F. E. Schulze.

mesoderm thicker, so the passages or in-current canals from the outside of the sponge to the outside of the radial tubes become more complicated. Common siliceous sponges develop in a different manner from the above-described calcareous ones, namely, from a hollow conical sac open at the top, and with a flat base; the spherical flagellated chambers at a very early stage forming a mammillated layer in the walls. *Plakina*, one of the simplest siliceous sponges, encrusts stones with a fleshy crust, consisting of a sac with a flat base attached to the stone, and with the rest of the walls forming simple folds. The spaces between and outside the folds form the in-current, and those in the lumen of the folds the out-current channels. Each of the flagellated chambers in the walls of the folds communicates with the in-current spaces through several pores, and opens into the out-current spaces by one large pore, the currents of water passing out by the central oscule.

The fine toilet-sponge possesses a more developed canal-system. The in-current and out-current parts of the water-bearing system are more definitely "canalised," and may be compared to the roots of a tree which divide into finer rootlets. The flagellated chambers form a convoluted cordon between the rootlets of the two systems. In the sea-kidney sponge of the Mediterranean the specialisation is carried to a still higher stage, each flagellated chamber being isolated from the rest, and having a slender canal leading to it, and one leading from it.

The soft tissues permeated by canals require a supporting scaffolding or skeleton, and in nearly all sponges it is the function of certain cells in the mesoderm to secrete skeleton-material. A few sponges possess no skeleton whatever, excepting the gelatinous ground-substance; in some also the skeleton is mainly or entirely composed of foreign particles of sand, spicules of other sponges, skeletons of Radiolaria or Foraminifera. The vast majority form in the ground-substance a skeleton which is composed of spicules of silica, or carbonate of lime, or of horny fibres. The sponges whose skeleton is composed of calcium carbonate form a distinct class—the Calcarea. Of those which secrete a siliceous skeleton, the glass-sponges form a second class distinct from the rest of the siliceous sponges. All the rest, including by far the largest number, are included under a third class, the common sponges (Demospongia).

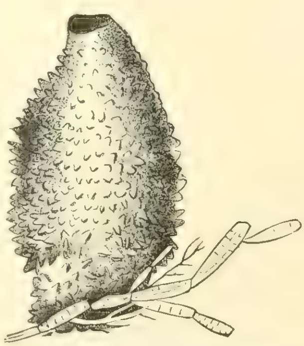
THE CALCAREOUS SPONGES,—Class **Calcarea.**

In this group the skeleton is formed of spicules of carbonate of lime, shaped

A CALCAREOUS ASCON SPONGE, *Leucosolenia* (magnified 4 times).

like three-rayed stars, four-rayed stars, or needles. The triradiate occurs most frequently in its typical form, the three rays being equal, in one plane, and forming an angle of 120° with each other. The spicules are transparent and glassy when viewed separately, but white and opaque in mass. On placing a calcareous sponge in acid, the skeleton dissolves away with effervescence. The class is divided into two groups, namely, the Homocœla and the Heterocœla, in the former of which the collar-cells line the whole of the interior of the simple or branched sac; while in the latter they are confined to the radial tubes, or the ends of branched radial tubes or canals, the gastric cavity with a part of the canal system being lined with flat cells. The simple ascon sponge (*Ascetta primordialis*) forms a minute stalked sac open above, and with its thin walls perforated by pores and supported by triradiate spicules; the whole interior being lined with collar-cells. The simple sac may give off a stolon, whence arise other sacs, or it may branch, and the branches again divide forming a tree-like growth; or, lastly, the branches may join together and form a complicated meshwork of sacs or tubes. The allied *Leucosolenia*, shown in the illustration, is a branched ascon found on seaweeds in the form of clusters of small white tubes.

The ciliated sycon (*Sycandra*) and *Grantia*, are common among seaweeds and in rock-crevices on the British coasts; both sponges are sycons, *i.e.* with tubes radiating out horizontally from a central cavity, and in both are present the three kinds of calcareous spicules (needles, three-rayed, and four-rayed forms). The walls of the ciliated sycon are made up of closely-packed tubes, lined with collar-cells and opening into the vertical gastric cavity. Rows of three-rayed spicules, arranged in regular series, support the walls of the tubes, the blind ends of which are protected by tufts of needles; a layer of four-rayed spicules lines the walls of the central cavity, the fourth rays projecting inwards and upwards into the cavity so as to form a wall of spikes. When the current is flowing from the interior the crown of needle bristles round the oscule is expanded, but when the sponge is inactive the bristles fall together and cover the oscule. *Grantia* lives on seaweeds or hanging down from rocks, and several specimens are usually found together. They resemble small white leaves, or flat bags, averaging about an inch in length and one and a half in width, though sometimes much larger. When quite young and small they possess only one oscule, but larger specimens possess several on the thin margins. When the sponge is active, the flat leaf fills out like a small paper-bag. The leucons usually possess tubular or hollow knob-shaped bodies with thick walls, in which ramify a double system of canals, in-current from the surface to the flagellated chambers, and out-current from the latter to the gastric cavity.

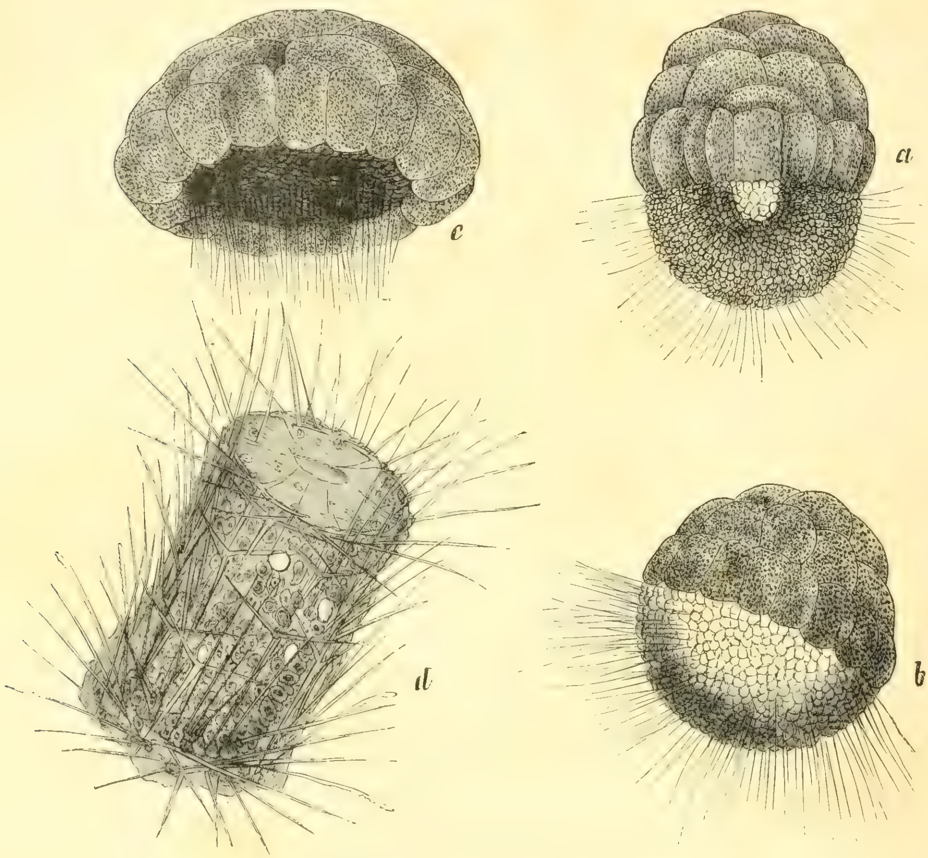


A CALCAREOUS LEUCON SPONGE, *Leucandra* (nat. size).

On making a section or teasing a fragment of a calcareous sponge in the spring, the minute embryos will often be seen. When the embryo leaves the parent sponge, it consists of an extremely minute oval cyst or vesicle (v) with a small central cavity, and is formed of two kinds of cells. The anterior half, or the part in front when the embryo is swimming, is composed of a number of long prismatic cells, each carrying a vibratile flagellum. The hinder end is composed of a smaller number of large rounded granular cells without flagella.

After the larva has swum about for a time, it becomes broader in the equatorial zone (*b*). The fore-half broadens out more and more till it forms a flat lid on the hinder hemisphere. Finally, the small cells lose their cilia and become completely invaginated into the interior of the large-celled hemisphere, which now resembles a cup with a double wall (*c*).

There are thirteen British species of Calcarea, and over two hundred from all



DEVELOPMENT OF *Sycon raphanus* (all figures enlarged).

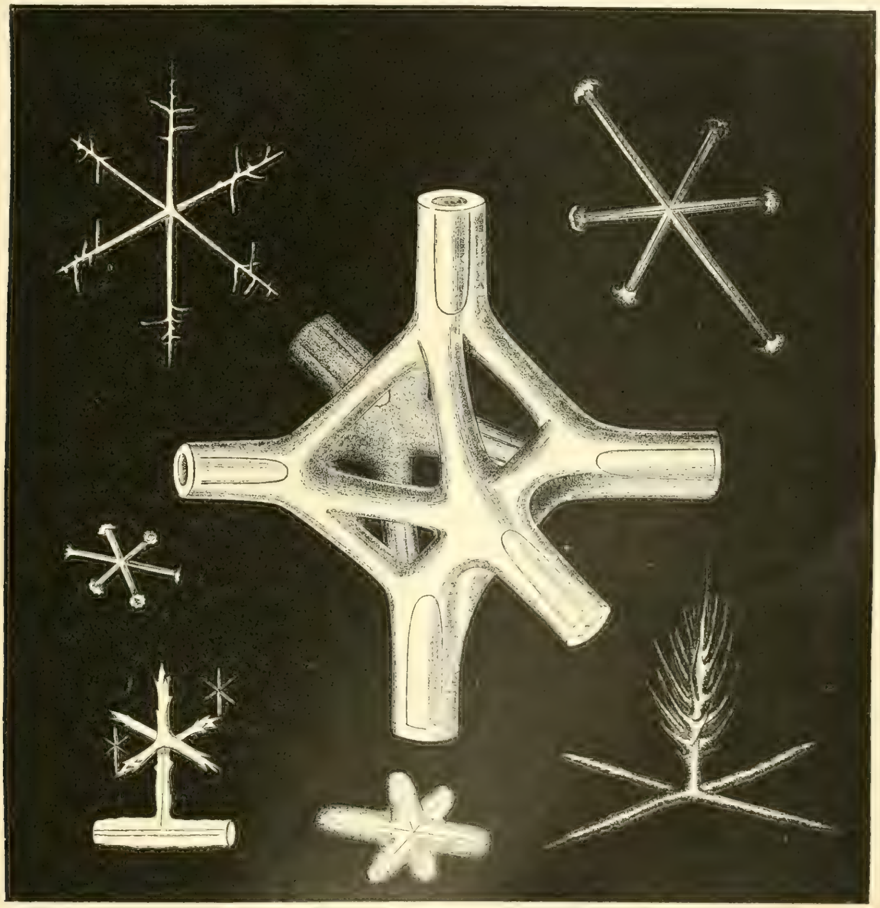
parts of the world. They are almost confined to shallow water, the greatest depth from which they have been obtained being four hundred and fifty fathoms. Calcareous sponges prefer shade and avoid light, and are chiefly found in caves, under stones, in shells, or in the shade of dense thickets of seaweed.

Six-Rayed, or Glass-Sponges,—Class **Hexactinellida.**

In the sponges of this group the skeleton is built of spicules with three axes and six rays, intersecting one another at right angles through a common centre. A second characteristic consists in the comparatively simple arrangement and large

GLASS SPONGES

size of the thimble-shaped flagellated chambers, which attain an average length of $\frac{1}{250}$ of an inch in *Euplectella*. Leaving out of consideration the skeleton, the soft tissues typically form a tubular sac open at the top, and, with the walls, formed of five layers, an outer dermal and an inner gastral membrane with a layer of flagellated chambers suspended between and supported by subdermal and sub-gastral networks of fibres; the direction of the water current being always from the dermal to the gastral surface. The six-rayed spicule is the form best adapted to



SILICEOUS SPICULES OF SIX-RAYED, OR GLASS-SPONGES; IN THE CENTRE AN EIGHT-SIDED INTERSECTION NODE OF A FOSSIL VENTRICULITE SPONGE.

support a soft walled sac of this description, one axis being vertical to the walls, and the other two tangential; the rays of each spicule uniting with those of adjoining spicules to form a framework. The typical spicule has six equal rays at right angles to each other, with an axial canal in the centre of each. When four of the six rays disappear, leaving only a glassy rod, the history of such a spicule is betrayed by the presence of a minute cross, which is all that remains of the axial canals of the atrophied rays. Endless modifications of the typical form may occur. One or more of the six rays may develop more than the rest; one or more may be suppressed, resulting in the formation of five-, four-, three-, two-, or one-rayed spicules. Again, the simple principal rays may branch or give off tufts, which may be pointed or end in discs. Further, the rays may be curved, or become beset with spines. The spicules either remain loose and separate in the soft tissues or become joined by apposition and intertwining, or by fusion of rays by means of layers or bars of siliceous cement.

The glass-sponges are divided into two groups, the Lyssacina and the Dictyonina. In the former the spicules are loose and separate, fusion when present occurring in the older parts of the sponge; in the latter the principal spicules form a solid framework even in the earliest stages of growth. *Bathydorus*, a Lyssacine sponge, which has diverged but slightly from the simple sac form, was dredged from two thousand nine hundred fathoms in the North Pacific, and forms a soft thin-walled tube about seven inches in height and two inches in diameter. In the Venus' flower-basket (*Euplectella*), shown in the central illustration of the coloured Plate, there are certain modifications of the simple sac type. Firstly, there is a lid at the top, and further, the walls of the tube are perforated by large round holes about one twenty-fifth of an inch in diameter. The water can thereby pass direct from the outside into the gastral cavity or lumen of the tube; each aperture is surrounded by an iris-like membrane which can probably close the orifice. These parietal apertures, in the whole thickness of the wall, must not be confused with the very minute in-current pores through which the water passes into the sponge-substance. In life, the glassy framework — frequently seen as an ornament — is covered with the brownish gelatinous flesh. The glassy skeleton forms a curved tube from 10 to 18 inches in length, shaped like a cornucopia, the curve taking place at the junction of the lower and middle third. *Euplectella oweni* from Japan, which closely resembles *E. aspergillum*, forms a straight cylinder, devoid of the collar round the lid and without ridges on the walls.

The glass-rope sponge (*Hyalonema*) of Japan belongs to a group of Lyssacine sponges, characterised by the possession of amphidiscs, spicules with a straight shaft, at each end of which is a large toothed disc, resembling the ribs of an umbrella. The spicules are sometimes large enough to be visible to the naked eye, and vary in different species from the hundredth to the twenty-fifth of an inch in length. The rope was first brought to Europe about 1830, and for years formed the subject of controversy as to its nature. The Japanese glass-rope sponge forms a solid-looking, ovoid, thick-walled cup, the top of which is closed by a thin sieve-like lid with an imperforate cross-shaped area. From the lower end of the body arises the long siliceous glass-rope, composed of twisted strands of spicules which anchor the sponge in the mud. For a varying distance below the body, the tuft is invested by a parasitic zoophyte. A transverse section of the cup shows a cavity, in the centre of which is a spike which is the upper end of the glass-rope projecting into the interior. From the central spike septa radiate; these are convex along their upper margins, and attached at their ends to the imperforate bands on the operculum. The walls contain the much-folded layer of flagellated chambers.

The spicules of the tuft are pointed at the upper end, and terminate below in minute four-pronged anchors. Many of them are marked with a spiral ridge, minutely serrated on the upper edge, and thereby offering resistance to the uprooting of the tuft from the mud. The length of specimens varies from 20 to 30 inches.

The Japanese species is obtained from off Tokyo, from a depth of three hundred and forty-five fathoms, and is fished for with long lines, weighted and provided with hooks, which are dragged along the bottom. Eighteen species have been obtained from the Atlantic, Pacific, and Southern Oceans, from depths ranging from a few hundred up to two thousand five hundred and fifty fathoms. The allied *Semperella*, shown in the right-hand illustration of the coloured Plate, occurs in one hundred fathoms off the Philippines. It forms a subcylindrical stock, about 12 inches in length and 2 inches thick, terminating in a dense tuft about 3 inches long. The lace-like skin covers a complicated labyrinth of tubes. Another Philippine form (*Polylophus*), represented in the bottom right-hand corner of the same Plate, has small thick-walled hemispherical cups, with tufts of spicules growing from conical projections on the walls, and passing down to form root-tufts. This sponge is remarkable for producing buds, which become detached and develop into complete sponges. In the middle of the lower part of the Plate is shown a species of another genus, known as *Periphragella*, from Japan, which forms a curved funnel, on the outer wall of which is a network of tubes which have branched off from the main body. In *Farrea*, seen in the left-hand bottom corner of the Plate, the body is formed of forking branched glassy tubes, the walls of which consist of spicules whose rays have fused into a rigid framework. *Sclerothamnus*, from three hundred and sixty fathoms off Timor, is a remarkable Dictyonine sponge, which forms a bush two or three feet in height, with the branches marked with a spiral band.

Another beautiful type is Carpenter's glass-sponge (*Pheronema*), shown in the illustration on p. 530, which consists of a thick-walled cup, narrowed at the orifice, and giving origin below to a thick root-tuft of spicules; the first specimens were dredged from a depth of five hundred and thirty fathoms off the Faroe Islands.

Glass-sponges, with one or two exceptions, have been obtained in deep water, from ninety to two thousand nine hundred fathoms. Previous to the deep-sea dredging expeditions, specimens had been found in only a few localities, and the procuring of them had been due more or less to accident. Thus the Japanese fishermen, while in quest of deep-sea fish, brought up glass-ropes, which became marketable commodities. Similarly, the Malays found it would pay to explore for submarine treasure, and constructed their bamboo dredge.

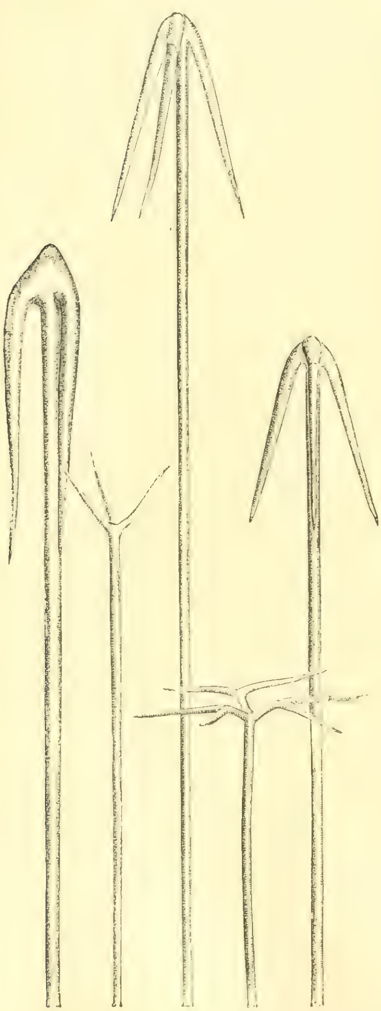
Fossil Hexactinellida are found abundantly in the Chalk. The *Ventriculites*, found in Chalk flints, are the skeletons or casts of glass-sponges.

THE COMMON SPONGES,—Class **Demospongia.**

The common sponges include all those which do not come under the designation of calcareous or glass-sponges. A negative definition is unsatisfactory, but it is difficult to frame a positive one which will apply to all divisions of this class. Most common sponges are siliceous, while such as are horny are probably derived from siliceous types. They are divided into four orders. In the first or four-rayed sponges the spicules typically possess four axes and four rays, and resemble caltrops. The fleshy sponges, with little or no skeletal structure, form a second group; while a third group includes the monaxonid or uniaxial sponges, with the skeleton typically built up of needle-shaped spicules, with one axis. The horny sponges form a fourth group.

Four-Rayed Sponges,—Order Tetractinellida.

In this order the siliceous spicules of the skeleton have four axes and four rays, and typically are shaped like caltrops. The typical form undergoes numerous modifications, one of the commonest consisting in the lengthening of the vertical ray, and the bending of the other three rays towards the long shaft, an elegant anchor-shaped spicule resulting. The anchor form may, however, have originated from the branching of a uniaxial or rod-shaped spicule, and not from the alteration of a four-rayed caltrops form. The three prongs of an anchor may point downwards, upwards, or horizontally outwards, and in the last case they are frequently forked. The Lithistida (stony sponges), one of the groups into which the order is divided, are characterised by the presence of peculiar spicules, known as desmas, in which a minute rod or caltrops is surrounded by concentric layers of silica; at the margin of the plate or disc thus formed, branched and often tuberculated processes are given off, which usually join or interlock with those of other spicules to form a dense stony skeleton; but sometimes the desmas are not linked together, and the lithistid sponge is quite soft. In addition to the larger forms of spicules, such as anchors, which form the skeleton, there are minute, coiled, spiral, or stellate spicules scattered in the flesh. A well-developed crust is frequently present; and in *Geodia* the crust is composed of solid siliceous globules packed into a layer, beneath which lie the anchors with the prongs next the crust, and the long pointed shafts passing in centripetally. The four-rayed sponges are divided into the groups Choristida and Lithistida. In the former the spicules are loose and separate; and in the latter desma spicules are present, and usually fused or interlocked so as to form a stony skeleton. The Choristida frequently form yellowish white, leathery, nodulated cakes, plates, and crusts. The Lithistida, or

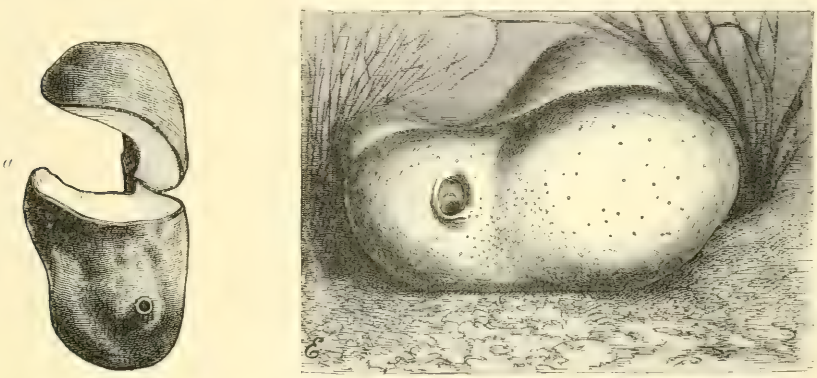


SILICEOUS SPICULES OF FOUR-RAYED ANCHOR SPONGES (magnified 200 diameters).

stony-sponges, are usually brittle and friable, or of stone-like hardness. The four-rayed sponges belong mostly to shallow water, but a few specimens have been obtained from depths of nearly two thousand fathoms.

THE FLESHY SPONGES,—Order CARNOSA.

These form a small group of uncertain systematic position, their chief features being the possession of a tough rind, enclosing a softer pith, the absence or slight development of a skeleton, and the highly-developed canal-system. They appear to be related to the four-rayed sponges. The soft pith contains the flagellated chambers and the canals leading to and from them. The genus *Chondrilla* possesses isolated siliceous spiny spheres, especially situated along the courses of the canals and beneath the rind. The allied *Chondrosia* of the Mediterranean takes the form of



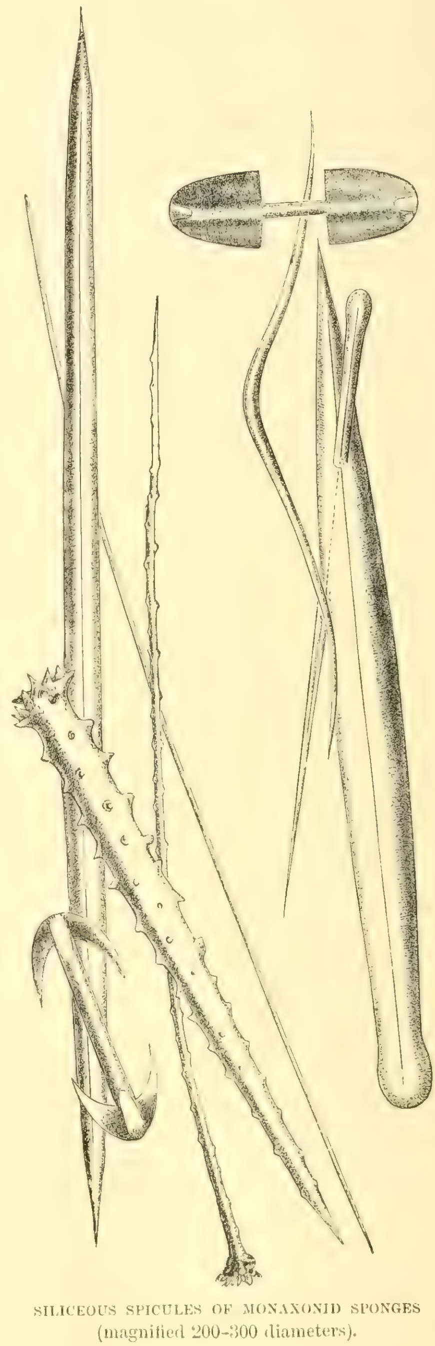
SEA-KIDNEY LEATHER SPONGE (*Chondrosia reniformis*). *a*, Specimen cut open.

leathery knobs or cakes with a slimy surface. The usually solitary oscule is irritable, and contracts slowly when the sponge is taken from the water. Fishermen call this sponge, sea-flesh or sea-kidney. The ground-substance contains no skeleton of silica or horny material; and the in-current and out-current canals form two sets of tree-like branched systems with the flagellated chambers interpolated between the final twigs of each.

SINGLE-RAYED SPONGES,—Order MONAXONIDA.

These sponges are those most frequently met with on the British shores and in shallow water throughout the world. The skeleton is mainly built up of uniaxial siliceous needles or rods, which may be isolated and scattered, or united into bundles by the horny cementing substance, spongin; while the bundles may be joined in various ways to form scaffoldings for the support of the soft parts. The spicules are shaped like spindles. In addition to the large spicules forming the bulk of the skeleton, and on this account called skeleton-spicules, in some groups minute forms abound in the soft substance, and are termed flesh-spicules. The latter are frequently shaped like buckles or double anchors, with prongs at each end. A transition can apparently be traced from this group to the horny sponges; the siliceous needles becoming less numerous and the horny substance more abundant, till, in the true horny sponges, such as the toilet-sponges, the skeleton consists entirely of horny fibres. The ocellated *Chalina*, frequently cast ashore round the British coasts, exhibits an intermediate condition between the siliceous and horny forms. By teasing out and examining a few fibres under the microscope, a fine core of siliceous spicules will be seen in the axis of each thread of spongin.

A SINGLE-RAYED SPONGE, *Axinella* (nat. size).

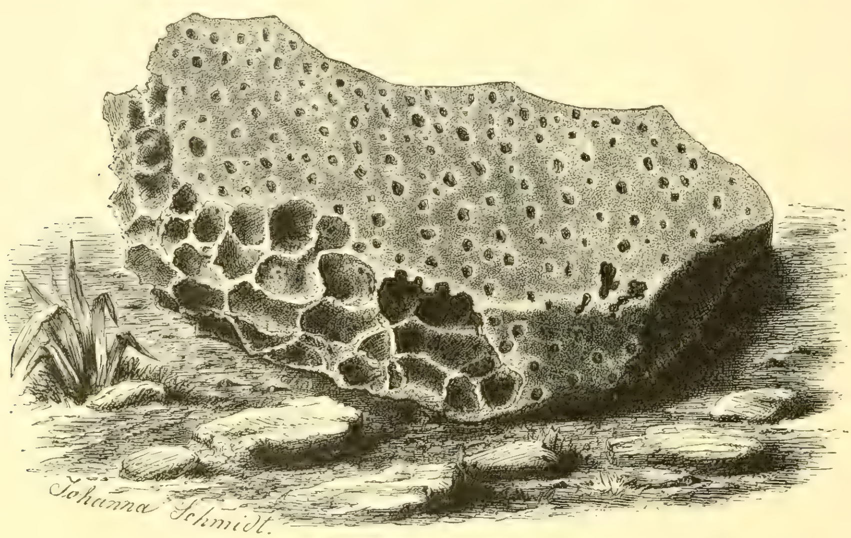


SILICEOUS SPICULES OF MONAXONID SPONGES (magnified 200–300 diameters).

The illustration on p. 528 represents a group of sponges growing together. Near the base of the black seaweed on the stone there arises the much-branched Desmacidine sponge, so called from its buckle-shaped spicules; while from the left branch of the former grows a flat alga encrusted by another sponge of the same order, and of a dull yellow colour; and at the top of the colony is the violet *Spongelia*. The illustration to the left represents another sponge of this group (*Axinella*), common in the Mediterranean. In life this sponge is of a yellowish colour, and the oscules present a radiate arrangement like the polyps of a branch of fan-coral. The illustration on p. 543 illustrates a sponge dredged by the *Challenger*, and known as *Esperiopsis challengeri*, from six hundred and thirty fathoms, east of the Celebes. The largest specimens are about 8 inches in height. From a solid, strong stem six or seven stalks are given off at gradually increasing intervals from below upwards, and each bearing a hemispherical cup or ladle, convex outwards. The in-current pores are on the concave, and the out-current on the convex surface. To this order belongs the Neptune's cup sponge (*Poterium*), attaining a height of 3 or 4 feet. It includes also the boring-sponges (*Cliona*), in which the skeleton consists of scattered pin-shaped spicules. To compensate for the inefficient support, the sponge excavates into limestone, chalk, or shells. Great importance is attributed to the destructive power of these sponges by Prof. Schmidt, who points out that considerable portions of the coasts of the Mediterranean consist of limestone, the disintegration of which has been greatly hastened by the operation of boring-sponges. In many parts the outlines of the coast have consequently been much altered, and along the Dalmatian shore, for a distance of a thousand miles, one may find the beach thickly strewn with stones completely riddled with the holes made by these sponges, as shown in the illustration on p. 544. The causes of this property of the burrowing-sponges are not known; but there are two theories, mechanical and chemical. According to the former, the sponge bores by means of the grinding of its siliceous spicules against the softer limestone. The action would be assisted partly by the action of the contractile substance of the sponge-body, and partly by the currents of water traversing the canals. On examining the galleries of a shell or piece of limestone with a lens, the surface is seen to be pitted with minute hemispherical cavities, giving rise to a finely shagreened appearance. The shagreen surface is characteristic of the action of a burrowing-sponge, and serves to distinguish the cavities and hollows due to the sponge from those caused by worms, molluscs, or the action of water. Certain minute five-sided plates were formerly supposed to assist in the excavating process, but are now known to result from the breaking down of the organic layers of the shell. On the other hand, the advocates of the chemical theory attribute the excavating properties to the secretion of carbonic acid by the sponge, which is thus enabled to dissolve the carbonate of lime of the shell or limestones; but an objection lies in the fact that carbonic acid is incapable of dissolving the organic plates of shells. Recently it has been urged that the power of contractility possessed by the sponge is a powerful aid in the work of excavation. Burrowing-sponges are a trouble in oyster-culture, and it is suggested that at the time when the free-swimming sponge-embryos are formed, a bank of old shells should be placed between the oyster-beds and the tide. The bank would filter off the embryos, which would grow in the old shells, and be subsequently destroyed by immersion in fresh water. A figure of a fragment of limestone thus perforated by sponges is given on the following page.

Esperiopsis challengeri (½ nat. size).

Fresh-Water Sponges. To the group under consideration belong the fresh-water sponges (*Spongillidæ*), which live in ponds, canals, lakes, and rivers all over the world; and have been known to infest the pipes supplying a city with water. The two commoner British species (*Euspongilla lacustris* and *Ephydatia fluviatilis*) grow on the piles of bridges, the sides of locks, the stems of water-weeds, or form crusts on the bed of rivers. *Euspongilla* forms bright green crusts, from the surface of which long, simple, or branched stems arise; or the surface of the crust may be simply conulated. This green colour is due to granular bodies which crowd the cells near the surface of the sponge. Some naturalists consider these bodies to be chlorophyll granules similar to those of plants; others regard them as single-celled algæ. The chlorophyll, in the presence of sunlight and water, splits



LIMESTONE BORED BY SPONGE.

up the carbonic acid evolved by the sponge into carbon and oxygen, the latter being used by the sponge for respiration. Fresh-water sponges growing in shady places are of a pale grey or yellowish white colour; and when bright green specimens are kept in the dark, they lose their green colour. The surface of a fresh-water sponge is covered with fine pores, while here and there a few large oscules are visible. From the pores fine in-current canals pass down to the flagellated chambers, and from the latter proceed the rootlets of the out-current canal-system. With a lens the spindle-shaped siliceous spicules of the skeleton can be made out. They are about one-fiftieth of an inch in length and unite in bundles which partly surround the canals, and are partly scattered irregularly in the ground substance; with the naked eye the bristling points can be seen projecting from the surface. If a specimen be examined in autumn, there will generally be found crowding the meshes at the base of the crust a number of small yellow spheres, about one-twelfth of an inch in diameter, known as gemmules. They possess a firm shell, with a small circular pore at one spot covered only by thin membrane. A gemmule is a kind of internal bud, and is capable of developing into a new sponge.

When the season unfavourable to the life of the sponge arrives, a number of wandering cells collect together into a mass which becomes coated with a horny covering. Outside this a layer of siliceous spicules is secreted. In *Ephydatia* these spicules are, from their peculiar shape, termed amphidiscs, two toothed discs being united by an axle, the layer of amphidiscs being arranged with the axles vertical to the surface of the gemmule. In the succeeding spring the cellular mass in the interior bursts out through the pore, and develops into a sponge. The gemmule-spicules of *Euspongilla* are shaped like curved needles pointed at each end, and with a granular surface. Gemmules are formed, but apparently only rarely, in a few marine sponges, such as *Cliona* and *Chalina oculata.* These bodies are formed also by the fresh-water Bryozoa. In addition to this asexual or vegetative formation of gemmules, fresh-water sponges also form ova and spermatozoa. When the ova are fertilised they undergo segmentation, and form oval ciliated embryos which are about one-seventh of an inch in length, and are easily to be seen swimming about in a glass vessel of water. They swim with the broad end forwards; the anterior upper half is dark and semitranslucent, the posterior lower half glistening white and opaque.

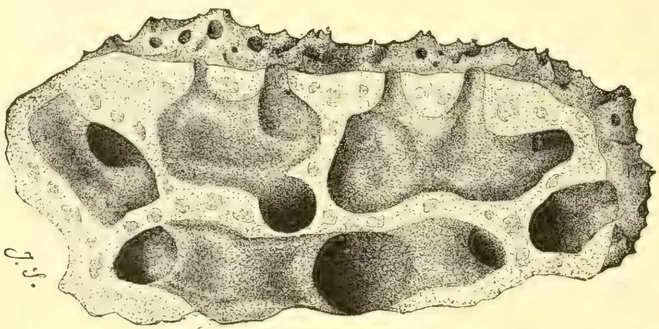
EMBRYO OF A FRESH-WATER SPONGE (magnified 100 diameters).

Horny Sponges,—Order Ceratosa.

In this group, of which ordinary toilet-sponges furnish examples, the skeleton is chiefly composed of fibres of a horny substance, termed spongin, and allied in composition to silk. In the toilet-sponges the fibres of the skeleton form a close felt-like network of soft elastic texture; but some horny sponges are hard and brittle, and others of the consistence of indiarubber. In most of the group foreign particles, such as grains of sand, or siliceous spicules of other sponges, are present in the fibres; and in some the foreign bodies form a thick core covered with a thin coating of spongin. Even in the softest toilet-sponges foreign particles are included in the main fibres. The large purple fan-shaped *Ianthella* from North Australia belongs to this group: also *Luffaria archeri* (Neptune's trumpet) from Yucatan, forming a magnificent cornucopia, five feet in length. *Darwinella* possesses peculiar horny spicules.

Toilet- and Bath-Sponges. The sponges commonly seen in shops may be arranged under three species, all of which occur both in the Mediterranean and West Indies, namely, *Euspongia officinalis*, variety *mollissima*, the fine turkey- or toilet-sponge; *E. zimocca*, the hard flat disc-shaped sponge; and *Hippospongia equina*, the common bath-sponge or horse-sponge. Under these species are included a large number of "varieties" and "grades," classified according to form, quality of texture, colour, locality, etc. The sponge-merchant can define the exact locality whence a specimen came, by observing the presence of characters which the naturalist would not regard as specific. The merchant classifies his material into grades, and uses names expressing the locality, texture, etc. The softest and finest is the Turkey cup-sponge, which usually forms deep or shallow cups. The whole outer surface of the dense horny network is covered with minute holes, which correspond to the groups of in-current pores; in the cavity of the cup are a few large holes about three-eighths of an inch in width, distributed irregularly or with a tendency to a radiate arrangement. The large holes are the oscules or out-current apertures. The second species is the zimocca, or hard-sponge, typically forming rounded discs, convex below and flat at the top. The pores are arranged on the outer side or margin, and a number of oscules cover the flat upper surface. The texture is denser and less resilient than that of the toilet-sponge, which it somewhat closely resembles. The microscope shows the cause of the denseness to lie in the thickness of the fibres composing the skeleton-network.

The common bath-sponge, or horse-sponge (*Hippospongia*), presents such wide differences from the first two forms, that the naturalist places it in a different genus. The holes on the surface of the loaf-shaped hemispherical mass do not correspond to those in a toilet-sponge. The in-current and out-current orifices are in

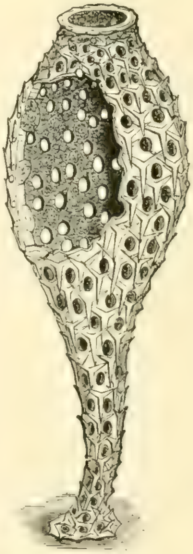


SECTION OF COMMON BATH-SPONGE.

the walls of the wide canals which permeate the whole sponge-body, so that the bath-sponge is really composed of much folded layers, or lamellæ, with the canal-system in the thin walls of the lamellæ. The large holes on the surface are "pseudoscules," and the tortuous passages into which they open are "vestibules" to the true pores, which can be seen on the walls. The pores corresponding with those on the outer surface of a toilet-sponge may be deep in the interior of a bath-sponge. The elephant's ear-sponge from the Adriatic is a variety of *Euspongia officinalis*. It forms a huge lappet, the edges of which may unite to form a funnel-shaped cup two or three feet in height; the pores are on the outer side, and the oscules in groups on the inner. Cut up into flaps a few inches square, these sponges are useful for house-cleaning, etc.

Many of the commoner kinds of sponges, termed hard-head, reef, etc., come from the West Indies, and are included under *E. zimocca*. The bath-sponge is less durable and more easily lacerated than the toilet-sponge, and has more foreign particles in the fibres. In their natural condition toilet- and bath-sponges look very different from the sponges in daily use. On seeing sponges in their natural state, one wonders how it was discovered that they formed skeletons possessing such useful qualities. A sponge living at the bottom of the sea appears as a shining, blackish, fleshy lump, which cuts like raw meat, no trace of the horny network being visible. The discovery would probably result from finding cast up specimens with the skin and flesh partly rotted away from the more durable skeleton. A toilet-sponge when alive is a blackish, cup-shaped fleshy mass, with its surface covered with minute conical elevations. In the hollow of the cup are the oscules, which appear smaller than in the skeleton, and are capable of dilating and contracting. During life currents rush out of these holes. On the outer surface of the sponge, by very careful inspection, sieve-like groups of pores will be seen in the skin, between the conical elevations.

When a living sponge is torn or cut, a good deal of glutinous substance flows away. The dark skin covers a light yellow fleshy substance, in which the canals leading to the oscules are conspicuous. The walls of the canals are greyish, some being filled with mud, others containing a marine-worm or crustacean, others, again, being empty. The skin-pores open into subdermal spaces beneath, and from the floor of the latter canals branch into the body-substance. The smallest canals finally open into minute pyriform flagellated chambers; and from each of the latter there arises a rootlet of the out-current canal-system. What is commonly known as the sponge forms a supporting network of fibres in the gelatinous ground-substance, the horny skeleton forming a kind of scaffolding. The fibres are yellowish and translucent, and built up of concentric layers surrounding a thin axial thread. Foreign particles, such as sand-grains, flinty spicules of other sponges, etc., are included in the main fibres. Each growing fibre is surrounded by cylindrical cells which secrete it. When a fresh batch of cells secretes a new layer, foreign particles on the surface of the fibre become included within the new coating. The embryos are minute oval bodies, which swim by means of their cilia, and lead an independent life for a day or two. They then settle down by becoming fixed at one end, and develop into sponges.



Ascetta primordialis.
After Haeckel.

In addition to sexual reproduction, there is also vegetative propagation. This characteristic has been made use of for cultivating sponges by cuttings.

Sponge-Fishing.

Sponges are found in depths ranging from two to one hundred fathoms, and the methods of collecting depend both on depth and locality. Off Dalmatia the primitive method of harpooning is still employed. Two men go out in a small boat; one rows, the other leans over the edge holding a long fork. If the water ripples, the rower throws in a half circle in front of him a few pebbles dipped in oil. The Greeks employ a submarine spyglass, which simply consists of a pane of glass let into the bottom of a tube or bucket. By this means they do away with the effect of the surface ripples. In the Levant in depths of five to fifty fathoms divers are employed, either naked or provided with a diving-dress. In the former case, the diver, with a bag round his neck, takes hold of an oblong white stone, with a cord attached; he breathes vigorously for a few minutes, and plunges in head foremost, holding the stone in front of him. He can only remain at the bottom at the utmost for three minutes, during which time he hastily snatches up the sponges, puts them into the bag, pulls the cord, and is drawn up. After the first descent of the season he comes up with his nose bleeding. If this does not take place it is considered a bad sign, and the diver will not consider himself fit to continue the work. Divers with dresses can remain for an hour in depths of from five to fifteen fathoms, but only for a few minutes in from twenty to fifty fathoms. In depths over fifty fathoms a drag-net is used, either from a vessel or hauled along from the shore. The net is fixed to a frame six yards in length and one yard in height; this is composed of camel hair, and has four-inch meshes. The sponges are taken ashore, pressed, squeezed, and rinsed, till the dark skin and fleshy glutinous substance has been got rid of, or they are exposed for a short time, and placed in a staked enclosure under water; in a few days the soft animal substance is trodden out, and the specimens are strung up to dry.

In a map of North America, the tongue-like peninsula of Florida will be seen projecting between the Atlantic and the Gulf of Mexico. The tongue extends beneath the sea as a submarine plateau, on which coral-reefs have formed, parallel with the southern and western shores of the peninsula, but separated from the mainland by shallow channels. From the point of the tongue extends a chain of small islands, or "keys," formed from coral growth and its fragments. The plateau forms a south-eastern expansion, the Great Bahama Bank, which sinks along its eastern margin by a stupendous declivity of over ten thousand feet to the great depths. The reefs on the plateau form rich sponge-beds, extending over an area of several thousand square miles. Previous to 1840 the existence of these valuable submarine beds was unknown. Now they afford a means of livelihood to many thousands of men, and nearly a thousand vessels are employed in collecting the crops.

The origin of the sponge-fisheries in the West Indian region was due to an accident. Previous to 1840 all the sponges of commerce came from the Mediterranean. In that year a member of a Paris firm of Mediterranean sponge merchants was wrecked on one of the Bahamas, in the course of a passage from Jamaica to Europe. He noticed that a great number of sponges were in use among the inhabitants, and was told that they were obtained from the waters round the island. On his return to Paris he arranged for consignments, and thus the Bahamas trade became established. In 1849 a cargo of sponges from Key West, Florida, arrived in New York, and was about to be thrown away as unsaleable; the cargo was purchased, however, by a firm, which established a branch at the new locality, and thereby founded the Florida trade.

When the inhabitants of the Bahamas and the Florida Keys found it would pay to collect sponges, their spirit of enterprise was awakened, and putting off in search, they continually found reefs overgrown with crops. Gradually the vessels increased in number and tonnage, till the fleets amounted to seven or eight hundred craft, mostly schooner-rigged, and of from five to twenty-five tons burden. All over this region one method alone is in use, that of hooking the sponges up with a three-pronged fork provided with a very long wooden handle. Each boat carries a varying number of small dingheys. Two men are apportioned to a dinghey, one for sculling, the other for hooking. The hooker leans over the side, and views the surface of the reefs through a sponge-glass. Great skill is required in sponge-fishing; indeed, the difficulty of hooking up a small dark object in twenty or thirty feet of water, and often in a strong current, can be imagined. Once a week the fleet returns to some selected locality to unload its cargo into a crawl,—a staked enclosure covered with a few feet of water. The preceding week's catch, with the skin and fleshy matter almost rotted off, is now beaten, squeezed, hung in strings to dry in the sun, and finally packed in bales, and sent to Nassau and Key West. Sponges used to be sold by weight, but owing to the tendency to absorb moisture, and to the prevalence of the fraudulent practice of weighting them with sand, they are now valued according to size, shape, quality of fibre, etc. The fine toilet-sponge is found chiefly along the eastern shores of the Mediterranean, from Trieste round by the Levant to Tripoli. The distribution of the bath-sponge extends from East Greece, along the Levant and the North African shore, and the zimocca-sponge from the Levant to Tripoli. Good qualities of commercial sponges grow in the Red Sea; the Great Barrier Reef off the north-east of Australia would probably yield a large supply. The bulk of the harvest of sponges from Bahamas and Florida consists of common bath-sponges.

R. KIRKPATRICK.

CHAPTER XVI.

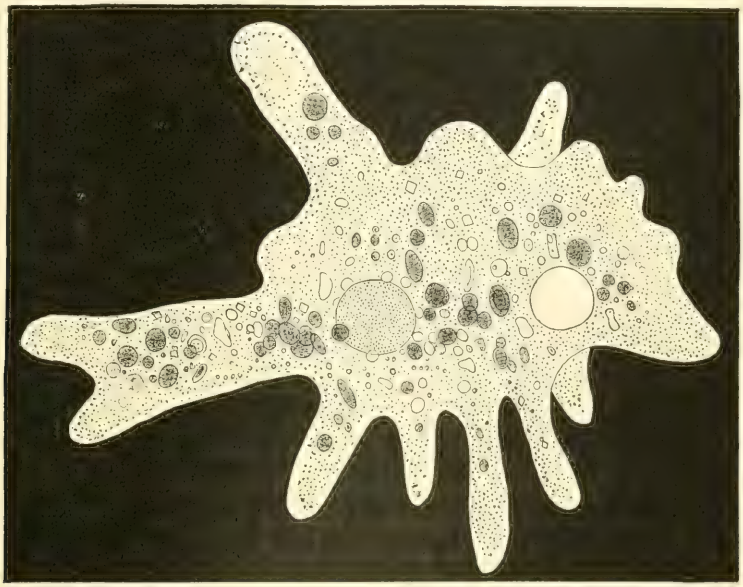
The Lowest Animals,—Subkingdom **PROTOZOA.**

Characteristics. The lowest animals belong to a world invisible to the naked eye, a world whose very existence was unknown two hundred years ago, despite the fact that its inhabitants abound on every side. In 1755 Rösel von Rosenhof saw sticking on the side of a glass vessel of water and weed a tiny particle of jelly, the movements of which attracted his attention. "It fastened itself," he writes, "on the side of the glass; and since, like animals, it moves, although very slowly, from place to place, and thereby continually alters its form, and as I frequently examined the water with a magnifying-glass, the creature was necessarily discovered; as soon as I touched it, it contracted itself into a sphere and

PROTEUS ANIMALCULE.

The same animal in different shapes. (Magnified 600 diameters.)

fell to the bottom." Rösel removed the specimen to a watch-glass, and observed it continually changing its shape. In consequence of this peculiarity, he named the animal "the small Proteus" after the monster of fable. Later the animal was named *Amœba*, as the name *Proteus* had been bestowed on another animal. An amœba is composed of a small particle of living substance, called protoplasm, and resembles a tiny blob of jelly, which continually but slowly changes its shape. The amœba is generally found on the ooze of ponds, or the under surface of the leaves of aquatic plants, but especially amongst conferva, in clear gently flowing water. When first caught, the animal will appear as a tiny yellowish semitranslucent globular speck, about one-hundredth of an inch in diameter; presently it becomes beaded with rounded projections, some of which grow longer at the expense of others and of the body, and may give off one or two branches. By the projection of these processes, or pseudopods, the amœba moves along in the direction of the longer ones. "Sometimes," writes Leidy, "the animal creeps onward in a flowing manner with comparatively simple cylindroid form, occasionally emitting a single pseudopod on one side or the other. More commonly, in movement, it assumes a dendroid or palmate form, or sometimes, diverging from the directly onward course, it becomes more radiate in appearance. Not unfrequently it assumes more or less grotesque



PROTEUS ANIMALCULE, (highly magnified).

shapes, in which almost every conceivable likeness may be imagined." The body, of the amœba is full of granules, which render it semiopaque, with the exception of a thin clear outer hyaline zone, and near the centre is a globular or discoid body, known as the nucleus, composed of a denser protoplasm than that which surrounds it. Division of an amœba into two is preceded by division of the nucleus. Near the latter is a clear spherical space—the contractile vacuole—which gradually expands, rather suddenly collapses, and reappears at the same spot, the systole and diastole being slow and continuous. The contractile vacuole contains a clear liquid, which is expelled on the collapse of the vacuole. This organ probably serves the double function of respiration and excretion. The amœba is omnivorous, but is chiefly vegetarian, and browses on tender leaves, or feeds on diatoms and other algæ; it surrounds the food-particle or organism with the protoplasm of its body or of a pseudopod, and the ingested particle sinks in, surrounded by a zone of water; frequently there are several food-balls in the body of the animal. The food can be taken in, and the remains ejected at any point, but the latter frequently appear to be cast out at one spot behind the nucleus and contractile vacuole. The animal reproduces by dividing into two halves, each containing a portion of the original nucleus and a contractile vacuole, and each growing to the size of the original. A unit particle of protoplasm capable of carrying on the functions of life, namely, nutrition and reproduction, is termed a "cell." Formerly, a unit of this nature was supposed to be a sac or vesicle, hence the name "cell," which is retained, though many cells are solid and without a definite wall. The Protozoans are animals consisting of a single cell, or colonies of cells. In the latter case each cell is more or less independent of the others, and capable of carrying on all the functions of life. All animals above the Protozoa are composed of many cells united into a whole, in which there arises the principle of division of labour.

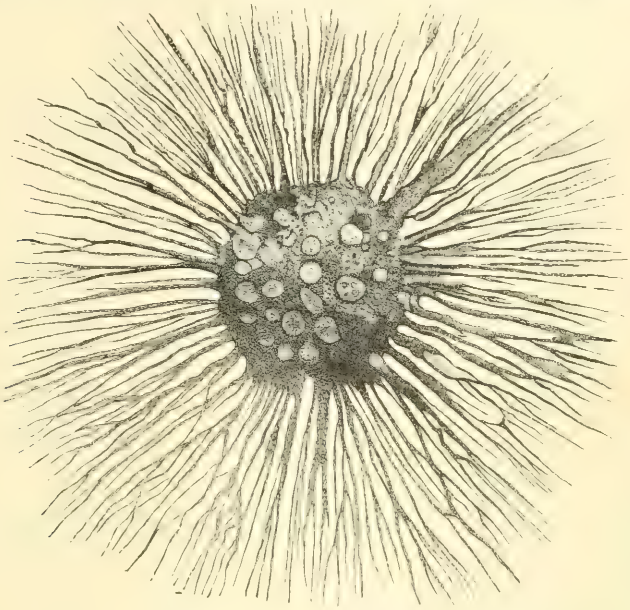
The Protozoa are divided into two groups, the Rhizopoda and the Infusoria; in the former the body-substance is of more or less uniform consistence, and can extend itself from any part of the surface in the form of pseudopods; whereas, in the latter, the outer layer is firmer and denser than the inner, and the animal has a more or less definite shape. In place of pseudopods, the Infusoria develop on their surface one or many fine processes in the shape of cilia or flagella, which set up food-carrying currents, converging towards a definite mouth, and which enable the animals to move rapidly about, when they are not fixed.

The Root-Footed Group,—Class **Rhizopoda.**

The simple organisms of this class take their name from their power of protruding from the body the processes known as pseudopodia, which are often branched like roots of a tree, and by means of which they creep about. The group includes the amœbas, the foraminifers, the sun-animalcules, and radiolarians. In the first the pseudopodia are simple and lobose; in the second they are slender, confluent, and reticulate; while in the two last they are simple, radiating, and somewhat stiff.

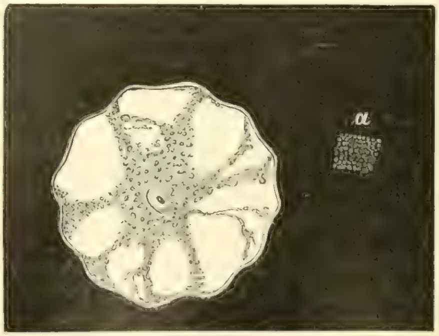
The Amœbas,—Order Lobosa.

The chief character of this group consists in the usually broad lobose simple form of the pseudopods, which flow out from the body in the shape of finger-like processes. The simplest forms are apparently without even a nucleus, and on this account have been separated from the rest as the Monera. As the first representative of the group, we may take the form known as *Protomyxa,* which forms minute orange-coloured particles of jelly creeping over shells, and consists simply of protoplasm containing granules, oil-globules, and food-particles. Occasionally a specimen retracts all its pseudopodia, some of which are broad and others slender, and becomes a quiescent sphere, the contents of which break up into numerous portions, each of which forms a new individual. The amœbas are divided into two groups, the shell-less (Nuda), and the shelled forms (Testacea). The common amœba, which has been described above, belongs to the former group, as also does *Pelomyxa*, a large species found in the form of little white ovoid masses, about the size of a pin's head, creeping on the mud of stagnant ponds; in this animal there is a definite fore-part and hind-part, the broader end of the ovoid mass being in front. The figure represents the capsuled animalcule (*Arcella*), common in pools, especially where there is bog-moss. The brown horny shell is marked



ORANGE-COLOURED PROTOMYXA (magnified 140 diameters).

with a finely faceted pattern, and is shaped like a dome with a flat floor; in the centre of the floor is a circular hole, through which short lobose pseudopods emerge from the body in the interior of the dome-like box. *Arcella* is capable of secreting vesicles of air in its body-substance, whereby it is enabled to rise. In *Euglypha* the shell is sac-shaped, with a jagged free margin, and the surface covered with regular overlapping scales. In *Difflugia* the shell is strengthened by the addition of foreign particles. Amœbas are cosmopolitan; occurring in sea and in fresh water, and a few living in mosses or damp earth. Certain forms of dysentery are said to be due to amœbas, or at least to amœba-like phases in the life-history of other Protozoa.

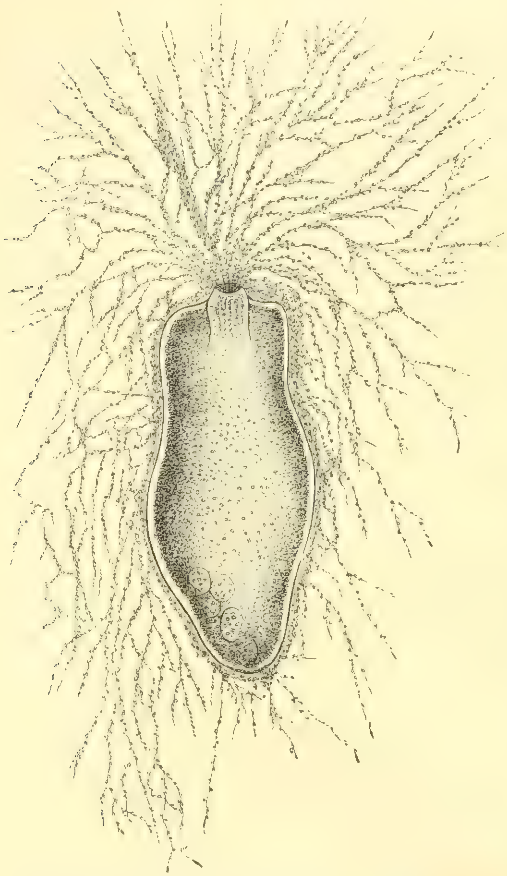


YOUNG CAPSULED ANIMALCULE, SEEN FROM ABOVE (magnified). *a*, Fragment of Shell (magnified 600 diameters).

The fungus-animals (Mycetozoa), are claimed both by botanists and zoologists. The best known species is the flowers of tan, found in tan-yards, in the form of large creeping masses of naked protoplasm, known as plasmodia. Cakes of protoplasm become segregated from the main mass, and break up into amœba-like spores, which again fuse to form plasmodia.

Order Foraminifera.

If shelly sea-sand be looked over with a lens, there will often be seen tiny shells no bigger than the grains of sand amongst which they lie. The specimen illustrated on p. 558, and whose shell is about one-twentieth of an inch in diameter, was originally named the spiral nautilus, with crenated joints. Another kind (*Miliolina*) occurs in the shape of porcelain-like oval shells, one-twentieth of an inch in length, with about five visible segments, arranged somewhat like a string of sausages wound round each other not quite in the same plane. Foraminifera are rhizopods whose simple sarcode-bodies emit slender branching pseudopods, and which form a shell of membrane, of foreign particles of sand, etc., of carbonate of lime, or, in rare instances, of silica. The order is divided into two groups, the Imperforata and the Perforata; in the former of which the shell possesses only one or a few comparatively large apertures, whereas in the latter, in addition to its main opening, the shell has its walls perforated all over with small pores through which pseudopods can be emitted.

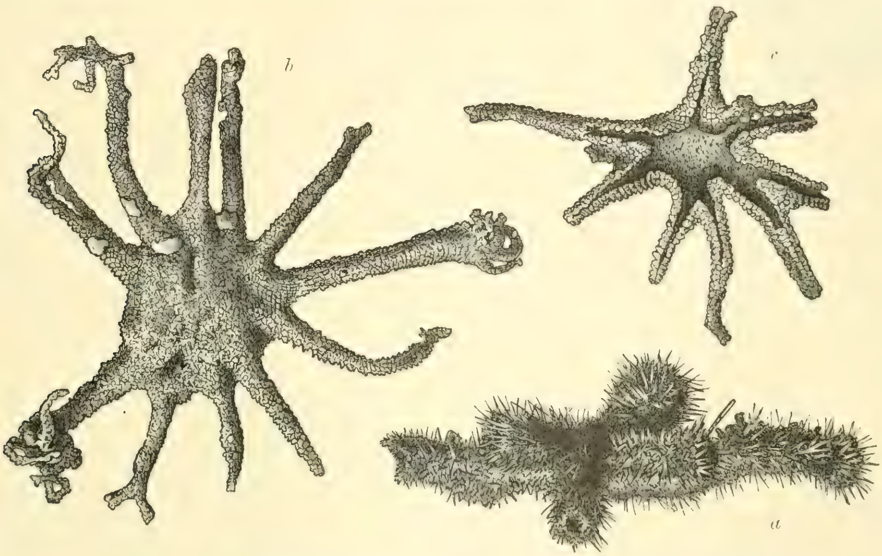


EGG-SHAPED GROMIA, *Gromia oviformis* (magnified 600 diameters).

The Imperforata form shells of membrane, agglutinated particles of sand, mud, sponge-spicules, etc., or of carbonate of lime; the vast majority of the Perforata form shells of the last-named material. The imperforate shells of carbonate of lime often resemble milk-white porcelain; whereas the perforate shells, especially in early stages, have a glassy appearance.

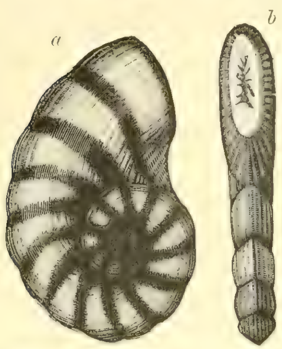
Gromia is found both in fresh and brackish water and in the sea in the form of minute, oval, egg-shaped bodies about one-twentieth of an inch in length, fixed on tufts of corallines, or loose in the sand and mud. At first there appears to be nothing remarkable about the tiny oval mass resembling the egg of a zoophyte; but presently from the opening at one end of the membranous sac or shell granular threads of sarcode creep out and become fixed on the glass slide; slender trunks of sarcode extend themselves, and divide into finer and finer branches, which reunite to form a network of streaming granular filaments ever changing in form, and which may extend to six or eight times the length of the body. Every fibre exhibits an up and down stream of granules suspended in clear hyaline sarcode. A diatom, infusorian, or other edible prey, coming in contact with the pseudopods, is covered with a mass of protoplasm formed by fusion of several filaments, drawn down to the mouth of the shell and engulfed. *Gromia* moves by means of its pseudopods, which fix themselves and draw the body along. When alarmed, the animal withdraws into its membranous test.

The sandy Foraminifera, which are mostly deep-sea types, are composed of masses of sarcode, sometimes of considerable size, which form shells or cases of agglutinated mud, sand-particles, or sponge-spicules. They frequently attain a



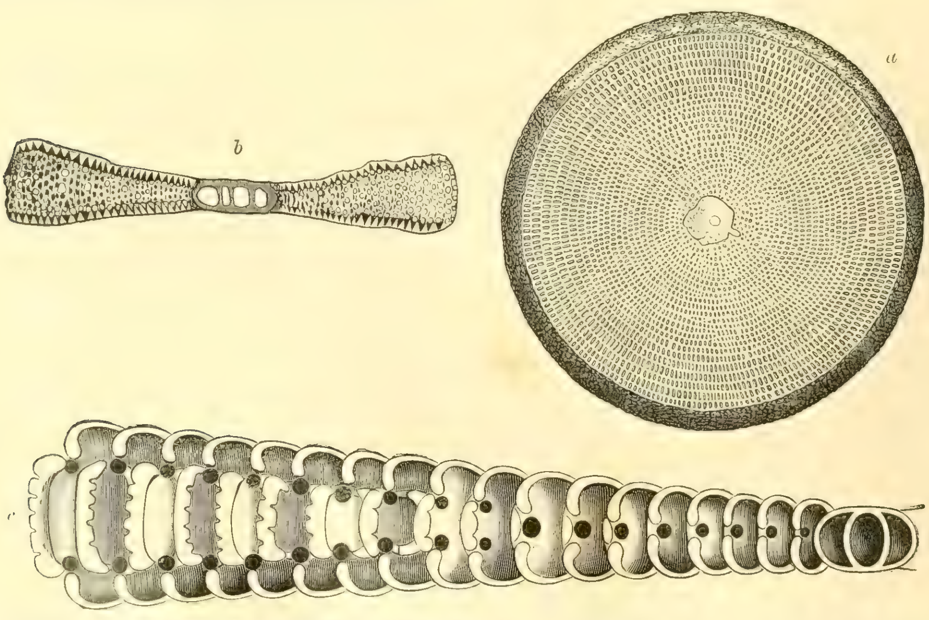
a Hyperammina ramosa; *b* and *c*, *Astrorhiza limicola*; *b*, Entire; *c*, Cut open.

large size; for instance, *Bathysiphon*, from the Atlantic and also from fourteen hundred and twenty-five fathoms off Amboyna, forms a slender annulated tube, two inches in length, and open at each end, the walls of the tube being composed of cemented sponge-spicules. *Haliphysema* is found in shallow water in the North Atlantic in the form of minute club-shaped bodies, one-twentieth of an inch in height, with the narrowed lower end attached by a disc to zoophytes, etc., and with the surface bristling with sponge-spicules. *Hyperammina*, generally distributed in from sixty to three thousand fathoms, makes a test of cemented sand-grains and sponge-spicules, at first forming a globular chamber with a long branched neck, the branches of which again branch. *Astrorhiza* forms stellate single-chambered shells of fine mud, slightly cemented, and lined inside by a smooth membrane; at the ends of the arms are large openings for the pseudopods; the diameter of the disc is about one-fifth of an inch, and that of the entire shell about half an inch; the animal lives in comparatively shallow water (about twenty fathoms), in the North Atlantic. Certain other sandy species are characterised by the regular form of their shells, which resemble those of calcareous species. The imperforate calcareous species are usually milk-white. The shell possesses only one or a few apertures. The seedlet miliolina, previously referred to, is one of the commonest species; it has a world-wide distribution from the shore to three thousand fathoms. The terminal opening of the last and largest segment is guarded by a branched tongue-like process. The Miliolite Limestone of the Paris Basin is composed almost entirely of the shells of *Miliolina* and other Foraminifera. A considerable part of Paris is built of this stone, in which the tiny miliolinas can be distinctly seen with the aid of a lens. The porcellaneous *Peneroplis* forms a spiral, with a slit in the last-formed segment, through which the protoplasm of the body can be extruded.



Peneroplis pertusus. a, Lateral view; b, Front view. (Magnified.)

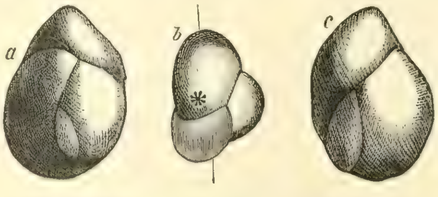
Orbitolites, one of the Imperforata, forms discs from one to two inches in diameter. The shell is composed of a central coiled chamber, followed by concentric circles of chambers, the pores for the emission of pseudopods being situated on the edge of the disc. The different species of *Orbitolites* form an interesting series, illustrating transitions from a simple to the most complex type. In a vertical section of the disc of the figured species the innermost chambers exhibit the simple type, later formed ones the intermediate, and the outermost series the highest type and the greatest differentiation of structure.



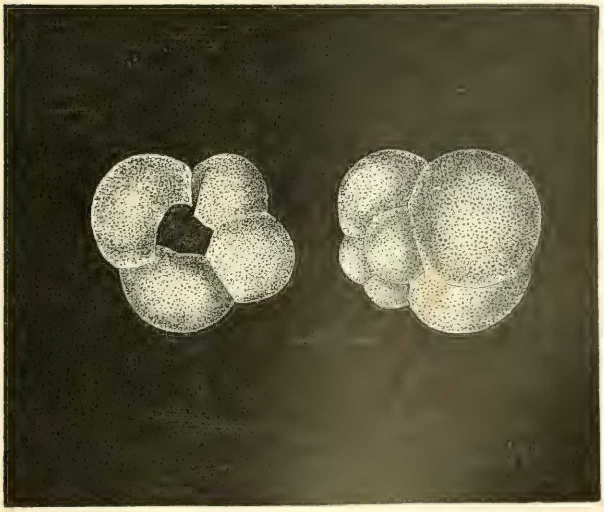
Orbitolites. a, From above; b, Transverse section (nat. size); c, Diagrammatic figure of section of *Orbitolites complanatus,* illustrating the transition from the simplest to the most complex type of structure.

The shells of the perforate Foraminifera may be constructed of only one, but most commonly of many, chambers, arranged according to various plans. The simplest type with one chamber (*Lagena*) is shaped like a Florence oil-flask; in many-chambered forms the segments may succeed one another in a straight line or in a spiral, and the coils of the spiral may or may not be in the same plane; or, again, the segments may form alternately on each side of a long axis.

In *Polymorphina communis* the segments are combined in a somewhat obscurely spiral arrangement. In the Foraminifera group a number of forms have arisen exhibiting an extensive series of variations on a few simple types, and showing transitions between forms which at first seemed distinct. The majority of species live at the bottom of the sea, but some are pelagic, and occur in abundance on the surface. Among the latter, *Globigerina* is one of the most widely distributed. Its shell is about one-fortieth of an inch in diameter, and usually composed of seven globular chambers, arranged spirally in such a manner that all are visible from above, but only the last four from below. Each chamber opens by a crescentic orifice into the depression in the middle of the lower surface. Perfect specimens bristle with long slender spines. The pores afford passage to the pseudopods which stream along the spines. In life, the shell is sunk in the midst of a bubbly sphere of protoplasm, which serves as a float. The investigations of deep-sea expeditions have brought to light the fact that the floor of the ocean, at depths between five hundred and two thousand five hundred fathoms over vast areas, between 110° north and south of the Equator, is formed of a pinkish white mud, containing on an average about 60 per cent. of carbonate of lime. The presence of this material is mainly due to shells of Foraminifera, especially *Globigerinidæ*, and, to a small extent, to the remains of minute pelagic algæ, known as coccospheres and rhabdospheres; the broken fragments of the latter in the shape of discs and rods being termed coccoliths and rhabdoliths. Over the greater part of the floor of the Atlantic, and over immense tracts in the Western Indian Ocean and Pacific, over areas comprising in all about fifty millions of square miles, the ocean-bed is formed of Globigerina ooze. Chalk is mainly composed of the skeletons of *Globigerinidæ*, coccoliths, etc., and, in fact, resembles Globigerina ooze.

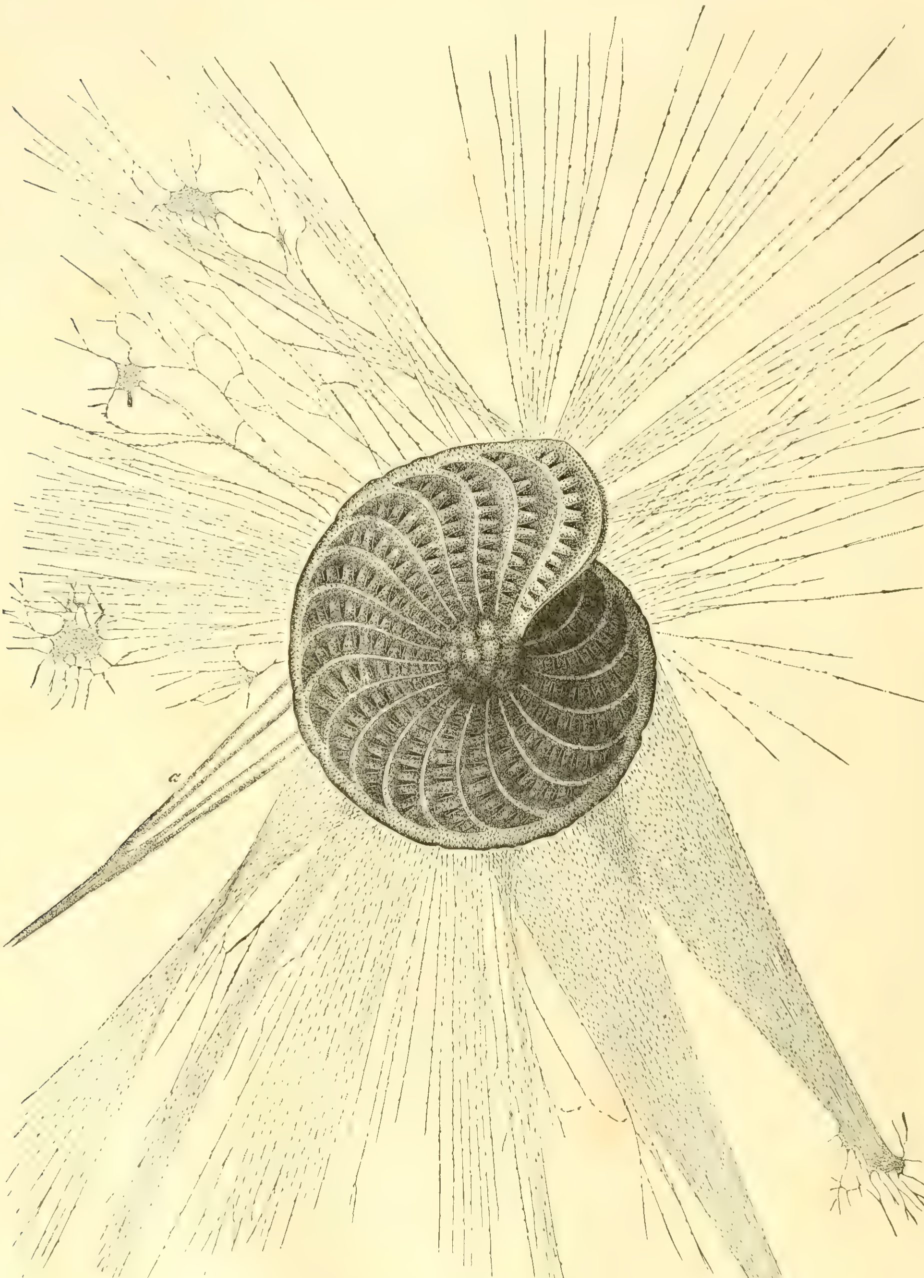


Polymorphina. *a, b, c,* From different aspects (magnified).



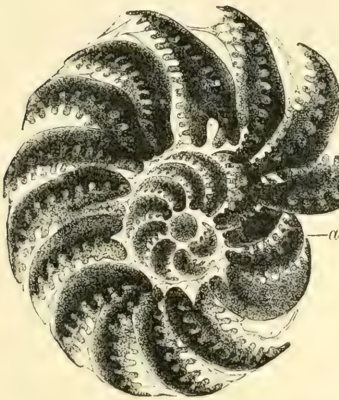
SHELLS OF *Globigerina* (much magnified).

The question whether the *Globigerinidæ*, which make up the bulk of the ooze, live at the bottom as well as at the surface, has given rise to much discussion. Dr. Murray has come to the conclusion that pelagic species do not live near



Polystomella (magnified 200 diameters).

the ocean floor. His opinion is partly based on the fact that the area of Globigerina ooze coincides with the area of surface temperature at which Globigerinas are found to exist. When the surface water is too cold for surface Globigerinas, no Globigerina ooze is found below. Numerous species of Foraminifera, which live only at the bottom, and are never found at the surface, contribute a small percentage to the composition of the ooze, the bulk of which is, however, formed of organisms which have rained down from the surface. The deposits occurring in depths over two thousand five hundred fathoms do not contain calcareous matter. The rain of Foraminifera skeletons falls down from the surface as over the areas of lesser depth, but the shells are dissolved before they reach the bottom, apparently by the excess of carbonic acid in the deep zones of the ocean. Here the ooze is formed of red clay,—a material probably resulting from the disintegration of volcanic remains, pumice, etc., and almost devoid of organic traces. This deposit extends in its more or less unmixed condition over an area of about fifty-two millions of square miles, and is also present in varying proportions in Globigerina and other oozes. In from three to four thousand fathoms in the Eastern Indian Ocean and in part of the Central Pacific, over a total area of about two and a quarter millions of square miles, the deposit contains a large percentage of siliceous skeletons of Radiolaria, and is termed Radiolarian ooze. Beyond the northern and southern boundaries of the Globigerina ooze, in the Arctic and Antarctic Oceans the deposit consists of a fine, white, chalky-looking siliceous mud, with a green tinge in the shallower depths, mainly composed of the frustules of Diatoms.

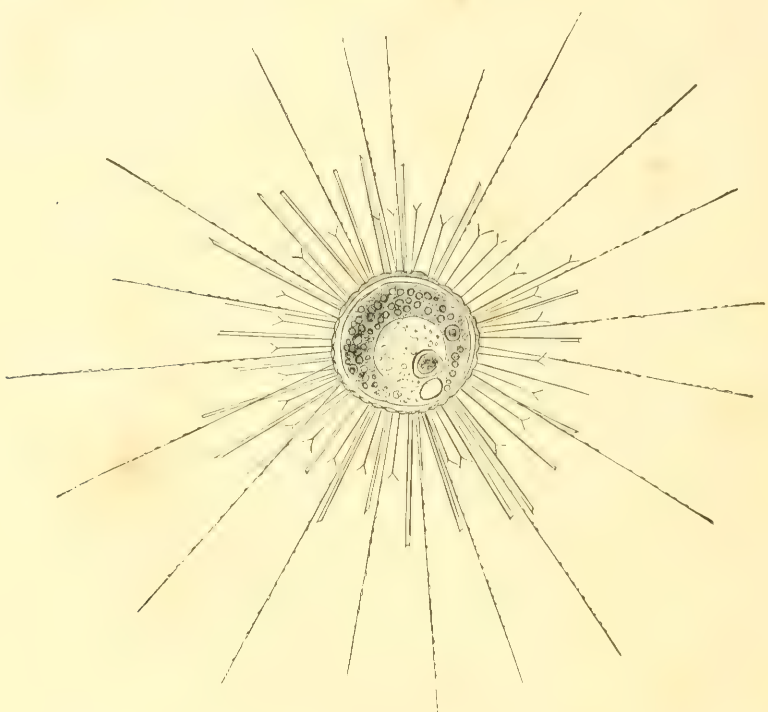


SARCODE BODY OF *Polystomella* AFTER SHELL HAS BEEN DISSOLVED IN ACID. *a*, Nucleus (200 diameters).

The figured *Polystomella*, which belongs to the Nummulite group (so named because some of the species resemble coin-like discs), is cosmopolitan, ranging from the shore-zone to abyssal depths. Only the last convolution of the spiral series of chambers is visible, a section of the shell revealing one or two more coils completely invested by the outer; the radiating lines mark the divisions of the chambers, and on the last partition of the last chamber is seen a series of minute pores. The second figure shows the sarcode-body of a nearly related species, whose shell has been dissolved by acid; the nucleus (*a*) being visible in one of the segments. Nummulitic limestones which cover an immense tract, extending from the Pyrenees, along Southern Europe and North Africa, through Asia Minor to the Himalaya, are composed of the shells of an allied genus (*Nummulites*). As these rocks belong to the Tertiary epoch, and form some of the highest Himalayan peaks, they indicate how recently these mountains have been elevated.

SUN-ANIMALCULES,—Order HELIOZOA.

These animalcules are inhabitants of fresh water; their chief characteristic, and the one to which they owe their name, being the possession of long, slender, somewhat stiff pseudopods, which radiate from all parts of the spherical body, like sun-rays, as represented in pictures. The common sun-animalcule (*Actinophrys*) forms a tiny translucent spherical globule, bristling with pseudopods, and about $\frac{1}{250}$ of an inch in diameter. The pseudopods appear stiff but are quite flexible, and the body contains several clear vesicles, one of which is usually half emerged from the body and on the point of bursting; the nucleus being in the centre of the body. The animal can move over a hard surface by the alternate relaxation and stiffening of its pseudopods, and sometimes so quickly that it appears to run like a spider. When a pseudopod touches some small organism, the latter seems to become paralysed, the pseudopod approximating itself and its prey to the body, which sends up a

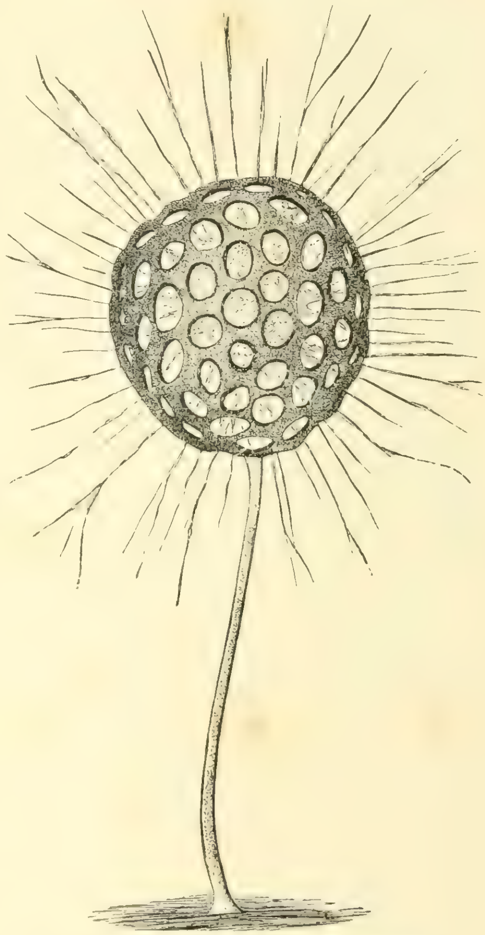


GREEN SUN-ANIMALCULE, *Acanthocystis chætophora* (highly magnified).

lobe wherein the organism is enveloped. Reproduction commonly takes place by simple division of the animal into two. The common sun-animalcule occurs abundantly amongst the weeds in clear pond-water. The green sun-animalcule (*Acanthocystis*) figured above is provided with a skeleton composed of fine siliceous rods or rays, the inner ends of which, buried in the body, are tipped with little discs, the outer ends being either simple or forked.

In another species the siliceous needles are arranged tangentially; further, the skeleton may be formed of a siliceous latticed sphere, as in the lattice-animalcule (*Clathrulina*), which grows fixed to aquatic plants by the base of a long flexible stalk. The body sends its long slender pseudopods through the meshes of the lattice; the total length of the animal is about $\frac{1}{200}$ of an inch.

Sun-animalcules often form colonies which result from the buds or the products of division remaining in contact and partly attached. The most likely places to find sun-animalcules are pools in the woods, where the bottom is covered with dead leaves, and among aquatic plants in ponds.



LATTICE-ANIMALCULE, *Clathrulina* (magnified 350 diameters).

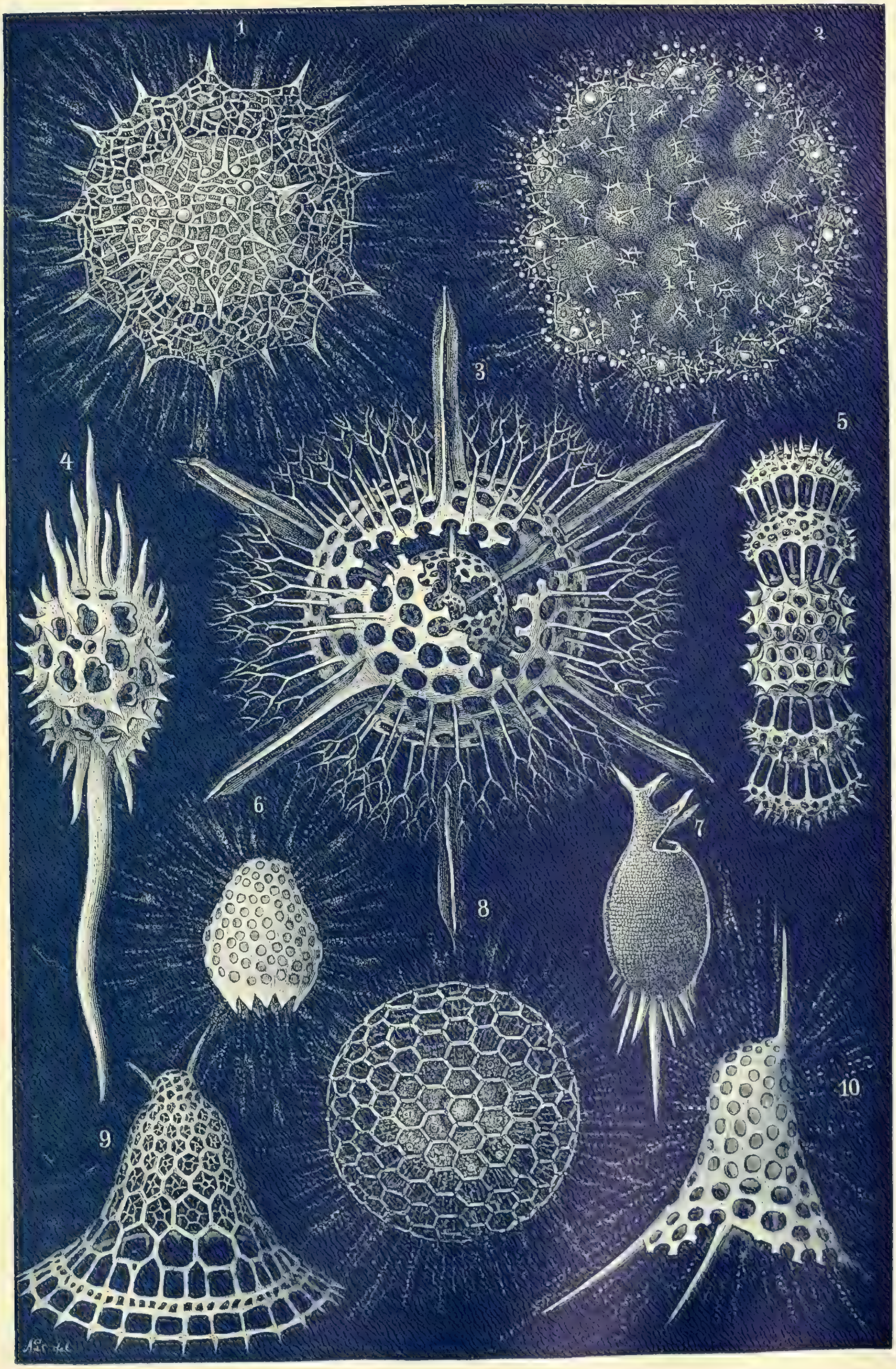
Order Radiolaria.

Both alive and in the form of their skeletons many of the radiolarians are surpassingly beautiful. Floating on the surface of the ocean, their tiny spheres or pyramids of translucent jelly glow with rich tints of crimson, blue, or yellow. They are all marine, and live in zones from the surface to several thousand fathoms. Many of the surface forms avoid a strong light, and only appear after sunset. Certain species which live in depths below one hundred fathoms, and whose bodies contain a dark green or black pigment, are probably phosphorescent Radiolarians are usually known by the flinty skeletons formed by many of them; yet it is not this feature which separates them from the other orders of rhizopods, but the possession of a membranous central capsule in the centre of the body and surrounding the nucleus. The body-substance outside the capsule is highly vacuolated in many species, and especially in surface forms. A few are without a skeleton, and consist of small spherical or oval masses of soft gluey protoplasm, with slender radiating pseudopods, and one or several central capsules; the presence of more than one of the latter indicating a colonial form of growth. In a few species the skeleton is formed of a glassy-looking horny substance, termed acanthin, arranged in the form of radiating spines.

The vast majority of species secrete a siliceous skeleton which assumes an endless variety of forms, such as trellis-work spheres, concentric spheres or boxes joined by radiating spines, helmets, baskets, lanterns, bee-hives, discs, rings, etc. Haeckel has described over four thousand species, and possibly as many more could be added to this number. Radiolaria are divided into two groups; in the first of these there is either no skeleton or one of silex, while in the second the skeleton is formed of radiating spines of a horny nature. The first group is subdivided into three sections, according to the characters of the central capsule. In the first section the capsule is spherical and uniformly perforated by numerous small pores; in the second conical, with a perforated sieve-like floor area below; and in the third it has one main aperture and one or a few accessory ones, and is surrounded by a dark pigment. In the forms with a siliceous skeleton the geometrical pattern of the skeleton conforms more or less to the shape of the central capsule, being either spherical or conical. The central capsule is regarded as being homologous with the calcareous shell of Globigerina. Reproduction takes place by simple division into two, or by the breaking up of the body-substance into oval spores, each provided with a flagellum or whip. Two spores, which may be of similar or of different size, fuse together; the resulting individual growing into an adult radiolarian. Certain yellow corpuscles present in the outer part of the body of surface radiolarians are unicellular parasitic algæ, which can be separated and cultivated independently of their host. The radiolarians live floating at all depths. Some forms are abyssal, living in depths of one thousand to two thousand five hundred fathoms. Over certain areas in the Central Pacific and the south-eastern part of the Indian Ocean the ooze forming the ocean-bed is chiefly made up of their skeletons, sometimes to an extent of eighty per cent. of the deposit, which has hence been termed radiolarian ooze. The chalky-looking rock, known as Barbados earth, a Tertiary formation, is composed almost entirely of skeletons of radiolarians. Somewhat similar deposits exist in the Nicobar Islands, in Greece, and in Sicily. Fig. 1 of the Plate shows the elegant lattice sphere of *Rhizosphæra*. Fig. 2 represents *Sphærozoum*, whose skeleton consists of loose spicules, arranged tangentially. *Actinomma* (Fig. 3) possesses three concentric lattice-spheres, joined by radiating spikes. Fig. 7 represents a deep-sea form (*Challengeria*), whose oval case is formed of a regular, very fine-meshed network. Fig. 8 depicts the elegant lattice-sphere of *Heliosphæra*; while *Lithomespilus*, *Ommatocampe*, and *Carpocanium* are shown in Figs 4, 5, and 6, and *Clathrocyclas* and *Dictyophimus* in Figs. 9 and 10.

The Infusorial Animalcules,—Class **Infusoria.**

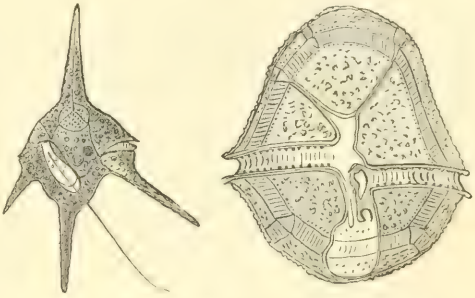
The name Infusoria, which came into use a hundred years ago, was applied to certain tiny living specks which appeared in infusions of hay, etc. The animalcules so named were classed with the worms and radiated animals, or zoophytes. As the microscope improved, infusorians were found to possess a considerable amount of structure. Ehrenberg attributed to them a highly complex organisation, supposing them to possess intestines, nervous system, etc. Later observations negatived these views, and showed them to be animals formed of one cell or composed of a colony of one-celled individuals. It is true that this cell, or unit-mass of protoplasm, may show a wonderful amount of differentiation, what with its nucleus, contractile vacuole, mouth and gullet, its variously arranged cilia or flagella, its contractile fibres, its separation into an outer denser and an inner more fluid protoplasm, and its horny cups, stalks, etc. Most of the species here described live in ponds and ditches, the larger forms preferring clear to stagnant and muddy water.



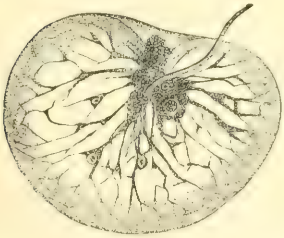
RADIOLARIANS.

FLAGELLATED INFUSORIANS,—Order FLAGELLATA.

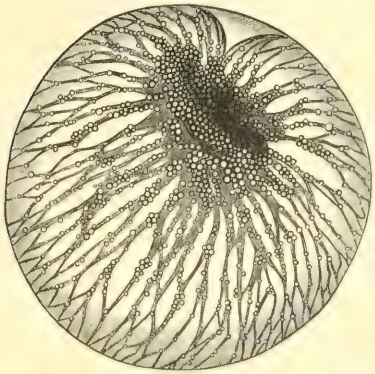
The characteristic of the group is the possession of one or two flagella, or small whip-like appendages, at the base of which is an opening in the denser surface-layer of protoplasm; a nucleus and contractile vacuoles are present, and frequently a brilliant red spot of pigment, known as the eye-spot. The Monads, which are the simplest members of the group, are common in fresh water and in infusions; typical forms consisting of a spherical or oval cell provided with a flagellum. Some species contain chlorophyll, and are claimed by the botanists. The common *Volvox*, for instance, which forms a green-coloured, spherical colony of monad cells has been described as a plant and also as an animal by botanists and zoologists respectively. The animal and vegetable kingdoms converge downwards towards a common point, at which it is difficult to say whether the manifestations of the physical basis of life—*i.e.* protoplasm—are such as we ascribe to plant life or to animal life. In the case of *Volvox*, the presence of chlorophyll would at first sight seem to stamp the organism as a plant; but the phases of life-history are rather those of an animal organism. The collared group possess cup-like collars, and they frequently secrete horny receptacles or cups, which may form elegant tree-like colonies.


MAIL-COATED FLAGELLATA (highly magnified).

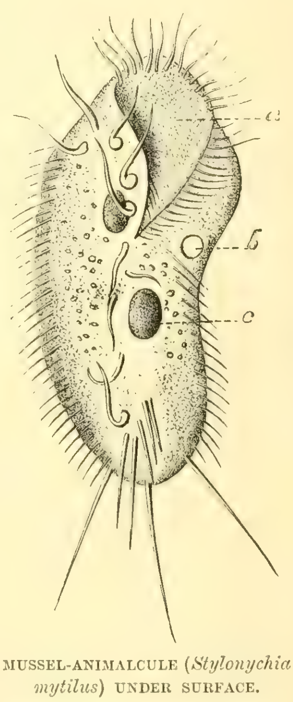
The mail-coated group are of very varied form, the body being often prolonged into long spiny processes. From the presence of cellulose in the cell-wall, and of chlorophyll in the body-substance, the proper position for these organisms would appear to be the vegetable kingdom, but taking their general life-history into consideration they may be regarded as animal organisms. They possess two large flagella which fit into grooves. *Ceratium tripos* (often looked upon as an alga), which sometimes forms chains of twenty or more individuals, is phosphorescent.


PHOSPHORESCENT ANIMALCULE, *Noctiluca* (magnified 150 diameters).

On calm dark nights during the summer and autumn the surface of the sea is occasionally seen to be pervaded by a beautiful bluish or greenish luminosity. The appearance of the phosphorescence is somewhat capricious, but it will best be seen on calm warm nights when there has been a gentle sea-breeze for several days. This strange phenomenon has attracted attention from the earliest times, but it was not till the middle of the last century that the cause was discovered. The luminosity is in most cases due to the presence of multitudes of tiny jelly-spheres, each smaller than a pin's head. On taking up a tumbler of the sea water, the spheres frequently form a thick layer at the surface. By separating a few of the organisms on blotting-paper, the light emitted will enable one to see the time by a watch, at a distance of a foot or more. A few organisms swimming or floating about in plenty of sea-room in a tumbler of water, will not become luminous unless the water be shaken about, but when crowded together, they become diffusely luminous, owing to mutual jostling and irritation. The luminosity in an individual sphere, which should be inspected with a lens, may appear as a sudden, generally diffused flash, followed by darkness or by less intense light, or again, in the form of brilliant points of light. The name of the organism, which belongs to the flagellated infusorians, is *Noctiluca*. The body forms a peach-shaped cyst, about one-fiftieth of an inch in diameter, and with a tough membranous wall. A groove on the surface sinks at one end into a funnel leading into the interior. From the interior of the funnel there arises a large transversely striated flagellum, or proboscis, by means of which the animal swims, and there is also in the same place a fine whip-like flagellum. At the apex of the funnel there is a mass of sarcode, which extends itself as a wide-meshed, highly-vacuolated network, to the inner wall of the cyst, where it forms a thin layer, whence the phosphorescence emanates. *Noctiluca* multiplies by dividing into two, or by becoming encysted, after drawing in its flagella, and breaking up into numerous ciliated helmet-shaped "swarm-spores." Frequently two organisms fuse into one which may then divide up into spores. *Noctiluca* is found only in waters near land, the related forms met with in the open ocean belonging to the genus *Pyrocystis*. In one of the species of the latter the body is spherical, about one-thirtieth of an inch in diameter, and without the big flagellum. The phosphorescence, which in each individual chiefly emanates from the nucleus, is displayed on the ocean surface on calm nights in the Tropics. Prof. Butschli regards this species as an encysted or resting phase of the common form. *Noctiluca* occasionally swarms in such abundance as to give in daytime a reddish or yellowish hue to the surface. When the sea is rough, the organisms are dashed below the surface, and do not form a sufficiently continuous layer to give rise to much luminosity, and when the wind is off shore they are blown out to sea.



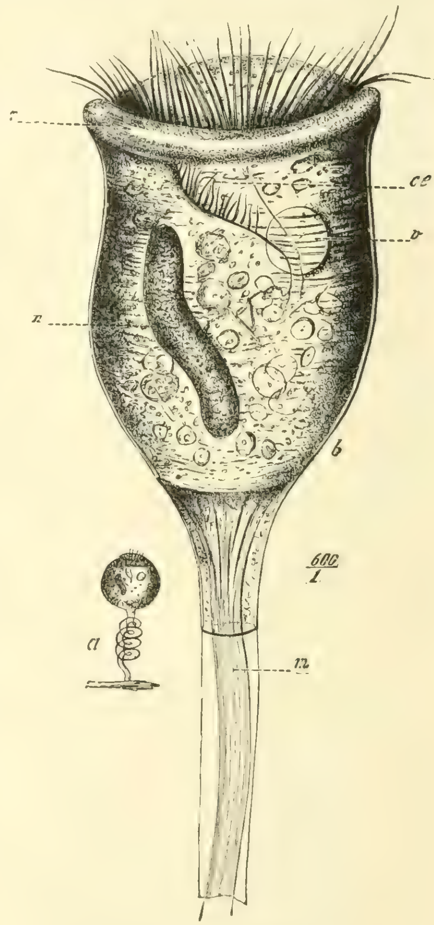
Pyrocystis (magnified 100 diameters).



MUSSEL-ANIMALCULE (*Stylonychia mytilus*) UNDER SURFACE.

a, Mouth ; *b*, Contractile vacuole ; *c*, Nucleus. (Magnified 150 diameters.)

Among the Flagellata are included certain parasitic organisms, which, owing to their being immersed in nutrient fluids, are not compelled to seek further for food, and do not possess flagella. The *Gregarina*, living in the intestine of the lobster, is an elongated worm-like organism about two-thirds of an inch in length; it multiplies by becoming a spherical cyst, the contents of which break up into minute spore-like bodies with spindle-shaped cases, which are set free on the bursting of the cyst. Each of the spore-bodies also ruptures and liberates an amœba-like organism, which ultimately develops into an adult gregarina. Another species of gregarina lives in the intestines of the earth-worm. The Sporozoa are oval or spherical monad-like bodies, but without flagella, and live as parasites in the cells of plants and animals. Cancer and certain forms of malaria have been attributed to the presence of organisms of this nature in the fluids and tissues of the body.



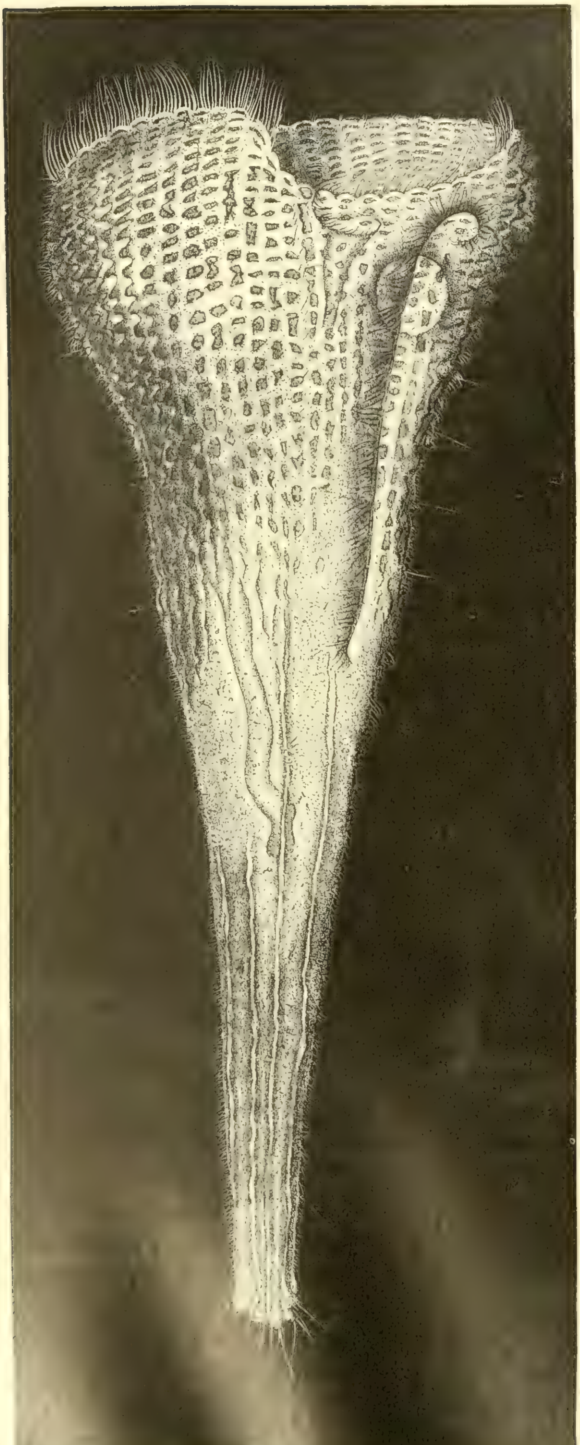
BELL-ANIMALCULE (*Vorticella*).
a, Slightly magnified; *b*, Magnified 600 diameters; *n*, Nucleus; *m*, Muscle-band.

CILIATED INFUSORIA,—Order CILIATA.

NODDING BELL-ANIMALCULE, *Epistylis* (nat. size = $\frac{1}{250}$ inch).

The organisms of this group are provided with cilia, limited either to the under side of the body, or forming a circle or spiral at one end, or arranged uniformly over the surface. Cilia are slender hair-like processes of the body, which move by bending and straightening themselves in unison; flagella are larger whip-like organs, and act more independently, the range of motion is not so restricted, and there are usually only one or two present on a cell. A few typical and common species are described.

The mussel-animalcule (*Stylonychia*), common in stagnant water, has the flattened oval body one-hundredth of an inch in length; on the under side is a ring of cilia, and at one end a funnel-shaped depression or mouth (*a*) with ciliated margin, leading through the dense outer protoplasm into the more fluid inner mass. The two dark oval bodies (*c*) are nuclei, and the clear spot (*b*) is the contractile vacuole which contracts rhythmically once in about every ten seconds. The creature can stalk along on the large bristle-like processes, in addition to swimming by means of its cilia; the



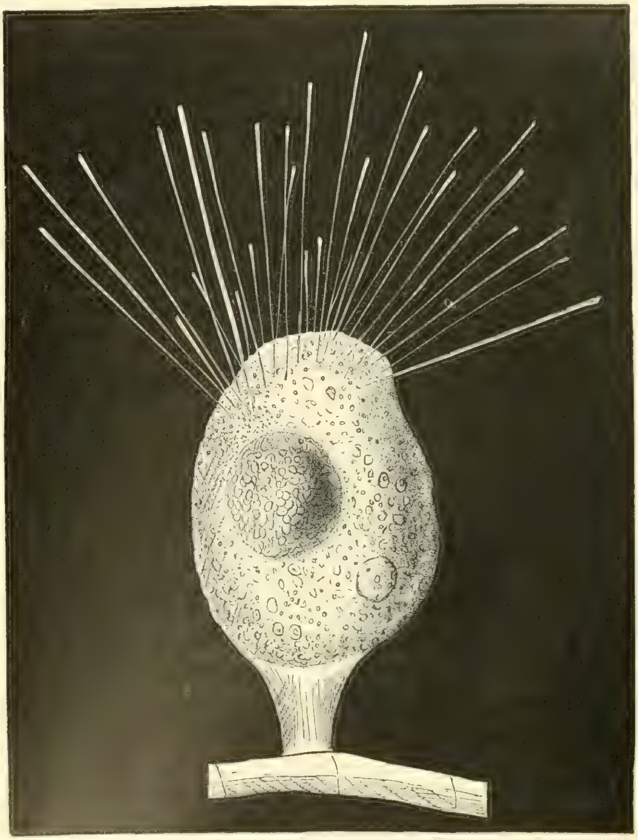
[illegible] TRUMPET-ANIMALCULE, *Stentor* (magnified 200 diameters).

oral cilia set up currents which converge to the mouth-funnel, and carry in other infusoria, diatoms, etc.

The bell-animalcules usually possess stalks, and are either solitary or form branching colonies. *Vorticella*, whose outline is like that of a wine-glass, is provided at the rim with an incomplete circlet of cilia, one end of which passes down into the mouth-funnel at the margin (*r*) of the disc; the stalk contains a contractile band (*m*) which produces a rapid jerking motion by throwing the stem into coils; in the body-mass lie the nucleus (*n*) and contractile vacuole (*v*). Reproduction takes place by transverse division into two. Ehrenberg observed twelve individuals to originate from one within twenty-four hours, so that, calculating on this basis, one million individuals would be produced within twenty days. The common-branched bell-animalcule (*Carchesium*) divides more rapidly, namely, once in an hour; each again being soon ready for division, so that one thousand could arise in ten hours, and a million in twenty hours; but, as a matter of fact, only two hundred have actually been observed to have been formed in one day, owing to the intervals between successive divisions becoming longer. The vigour of the exhausted stock becomes rejuvenated, however, by the fusion or conjugation of two individuals into one.

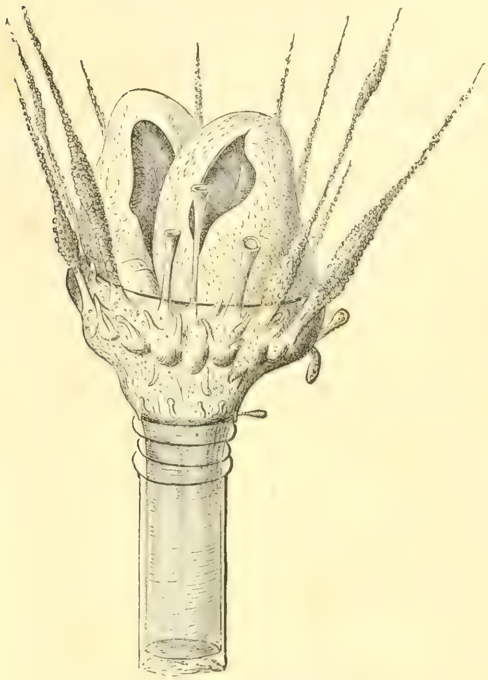
The nodding bell-animalcule (*Epistylis*) forms little branching colonies growing on Conferva in stagnant water. When the animal is disturbed, the heads droop down towards the stalks. One of the forms most frequently met with is *Carchesium*, whose tiny branched tree-like colonies resemble moulds; but a few moments' inspection will undeceive the observer, for the little white globular stalked heads will be seen to be drawn down towards the base of the colony with a rapid jerking movement.

The trumpet-animalcule (*Stentor*) is of comparatively large size, being about one-twenty-fifth of an inch in length when extended. It is usually to be found fixed by its pointed end on the under side of duckweed Its form continually alters from a small knob when contracted, to a trumpet-shaped body when extended; and when in motion its shape continually changes, being in turn ovoid, pyriform, or even spherical. The surface is corrugated and covered with rows of cilia, by means of which the animal swims about. The long cilia at the upper part form a spiral, within the upper margin of which lies the mouth-slit. The mouth opens into a funnel, leading into the sarcode of the interior. The contractile vacuole lies to the right of the mouth-slit, and the nucleus forms an elongated beaded band along the length of the body. The ridge of cilia passing down vertically is the mouth-fringe of a new animalcule about to be formed by division. A cleft sinks in obliquely at one side of the ridge which assumes a wavy outline and later a spiral; the cleft sinks, till two complete animalcules are formed, with one-half of the nucleus, and a contractile vacuole in each. New individuals may also arise by the budding off of tiny ciliated embryos from the nucleus. The species of trumpet-animalcule most commonly met with is of a brilliant green colour; frequently clusters of them are found clinging by their pointed ends to the stem of a water-weed. A specimen has been cut into three parts, care being taken to leave a fragment of nucleus in each, with the result that each part has repaired itself into a complete animal; the central part, for instance, developing a head and a tail-end.



MARINE ANIMALCULE, *Acineta* (magnified 600 diameters).

The spiral-mouthed animalcules (*Spirostomum*) are among the largest of the class, and visible to the naked eye, especially in sunlight, as slender golden threads about one-tenth of an inch in length. The body is cylindrical, and the surface covered with rows of cilia; the mouth-slit extends along half the length of the under side, and is bordered on its left side by a fringe of long cilia. The animalcule is frequently twisted on its long axis, the mouth-cilia forming a spiral; multiplication takes place by transverse fission through the middle.

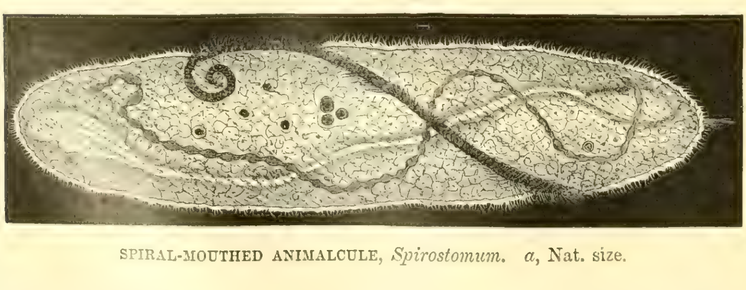


BUD-BEARING ANIMALCULE, *Hemiophrya* (highly magnified).

The curious marine animalcule *Acineta* is probably related to the ciliated infusorians. The stalked club-shaped body is usually fixed on sea-weeds or Bryozoa. From the upper end a number of straight sucker-like tentacles proceed; a nucleus and also clear vesicles are present in the body-substance; and the embryos are ciliated.

The bud-bearing *Hemiophrya* is also a marine-animalcule; it possesses a few suckers and a larger number of longer prehensile tentacles; on its margin several buds are formed, each containing a process of the nucleus, and the young forms when liberated are ciliated on their lower surface. The long tentacles capture and disable the prey, and bring it within reach of the suckers, which then surround and dissolve it, and finally appear to pump the newly-acquired nutriment into the general body-substance.

R. KIRKPATRICK.



SPIRAL-MOUTHED ANIMALCULE, *Spirostomum*. *a*, Nat. size.

INDEX.

VOL. VI.

PRINTED BY MORRISON AND GIBB LIMITED, EDINBURGH.