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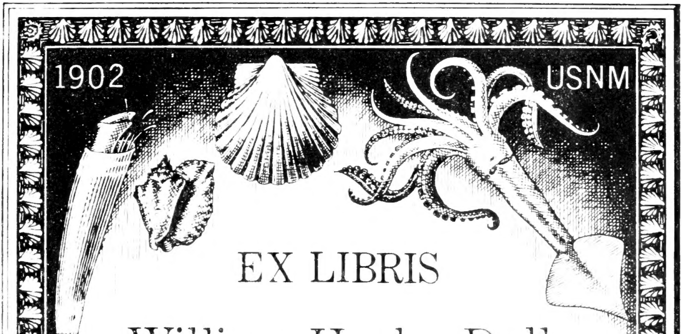
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THE OYSTER, CLAM, AND OTHER COMMON MOLLUSCS.

We feel much indebted to the liberality with which hundreds of specimens of shells of various species for this Lecture were given by the Museum of Comparative Zoölogy, at Cambridge, through Professor Hamlin, and also to Mr. McCarthy, of New York, and Captain Alfred Horsfall, of Steamer Canopus, for the donation of six hundred edible snails from France, the type principally used.

We failed, in the hurry of the issue of the last pamphlet, to acknowledge a similar indebtedness for several hundreds of coral fragments of various species presented by the Museum of Comparative Zoölogy, through the courtesy of Count Pourtales. Figures 1–4 are drawn from nature by Mr. Van Vleck, Assistant in the Museum of the Society; Figs. 30, 32, are from Morse's First Book on Zoölogy; Figs. 27, 28, 34, 37–40, 42, 43, are copies from various sources; Figs. 21–24 are shells drawn from nature by a student, Mr. Edward Warren, of the Institute of Technology, and the remainder are by the author.

If I had written the following pages with the view of making everything perfectly clear and easy to the reader, I should have omitted much which is here given, and missed the object I have at heart, which is to convince teachers that they cannot use any text-book as a basis of good instruction. Either Natural History must be used to lead children to observe the facts themselves, to see for themselves, and to appreciate that seeing is the first step on the road to knowledge, or else it is only one study the more; a little more information, but of no greater value in disciplining the mind than any other mechanical exercise in mnemonics.

In succeeding numbers no attempt will be made to add to what was given in the lectures; what was there brought forward will be sufficient.

Boston Society of Natural History.

GUIDES FOR SCIENCE-TEACHING.

No. VI.

The Oyster, Clam, and Other Common Mollusks

By ALPHEUS HYATT.

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MOLLUSCA.

THE largest oysters * procurable are of course the best for teaching purposes; but small ones can be used, though less effectually.

They should be cleaned with a sponge, just enough to remove the dirt, without destroying the brown, horny skin covering the shell, which sometimes is quite perfect, though generally more or less worn off. They can be killed by laying them in fresh water, which is kept at a blood heat, or about 90° Fahr. This is a slow process, however, twenty-four hours being required sometimes. It may be quickened by nicking or filing the edges until two small holes are opened, admitting the water directly into the interior. It will often be found advisable to put wedges between the valves when they open, after the death of the animal, and leave the shells for some hours.

The first operation is to seek on every shell for the marks left on one of the valves which show where it has been attached to some rock, or stick, or other oyster.†

The greater size and convexity of this valve will at once attract attention; and that it is also the lower

* Cohasset oysters are especially good, and can be obtained from wholesale dealers.

† Occasionally these are wanting, but as a rule they will be found.

valve will presently appear. If all the observations can be made by the scholars themselves, the next step will be to determine whether the valves are open all around. It being determined that they are fastened together, and closed at one end, the nature of this fastening can be investigated. Lead them to try first by pressing on the larger end, and then on the pointed end of the smaller and flatter valve. By this tilting they ought to be able to tell the teacher how wide the oyster can open the valves, and that they are held together by some bond (muscle) existing inside near the broad ends, as well as by a sort of hinge at the closed or pointed ends.

Let them determine for themselves what experiment would be sufficient to prove all these facts. Then, following their suggestions, take off the upper valve and show the position and action of the large muscle (Fig. 1, *ad*), which acts only to close the valves and hold them together in the living animal. It is best for the teacher to have at his disposal an oyster with the muscle alone cut through; and this he can use at this point to show how the hinge can act when not restrained by the muscle. It will be at once seen, that, when tilted, the beak of the upper valve soon comes in contact with the lower, and thus limits the extent of the opening of the valves at the opposite or broad end.

The operation of cutting off the upper valve requires care; but I know from experience that workingmen can be taught to do it successfully in a few minutes.*

* When time is an object, and the scholars numerous, it is advisable to have the muscle cut in all the specimens before-

The knife-blade should be passed between the mantle and the inner side of the upper valve; and when this has been separated, the muscle can be cut loose by the same process, though very slowly and carefully. If this is well done, the muscle will be the only part which has been lacerated; the mantle will be entire throughout, and the hinge unbroken (Fig. 1).*

Thus, when the upper valve is lifted or broken off gently, the hinge will be seen to break just at the edge of the white internal surface. They can then, by probing this and observing it, see that it is not unlike a piece of horn, elastic, and quite capable of acting as a spring to keep the valves open (Fig. 1, *h*).

A piece of bent horn can be used to illustrate this point, though it should not be forgotten that these are distinct, though horny, substances, and derived from far different animals, and that the ligament loses its elasticity when dried.

Replace the smaller valve, and proceed to the more minute study of the structure of the shell itself, which must be clearly understood before any explanation can be given of how it is built by the soft animal within.

Notice, in the first place, how each valve is roughened and encircled by concentric, projecting ridges. The edges of these may be followed back towards the

hand; but the hinge had better be left untouched. In this case the action of the hinge in opening the valve, and of the beaks in limiting the amount of this action, can be just as readily taught, and the function and strength of the muscle in holding them together shown by the teacher with a live specimen.

* It must be noticed, that the lower valve has been removed, and not the upper one, in this figure.

pointed ends, in both valves, and found to enclose less and less space, and to be farther and farther removed from the largest and outer ones. (Fig. 16.) Then, either with the free valve in hand, or upon the lower valve, let them trace the edges of some of the shell-layers all the way around, until they have satisfied themselves that the two inner layers or those by which they can see the oyster is enclosed, were the last ones built by the animal.

These observations can be made intensely interesting, if, after this, they reverse the process, and trace backwards again the lines of the ridges, until they arrive at the smallest and youngest layers at the apices of the valves, and realize that these represent the outlines of the valves which, although now widely separated, were once united and enclosed the oyster when it was a mere baby.

Very often the larger oysters have younger and smaller ones attached to them, which can be compared with the apices of the valves in order to show that the latter unquestionably represent the younger stages of the shell. It is practicable, also, in specimens properly roasted, to split a valve into its constituent layers, and show the imprint of the large muscle of the mantle margin, and the hinge at different stages of growth. Vertical sections through the roasted shells of oysters do not show the general structure very well; but, when made through the living shell, they are very instructive, and in fact necessary to a complete understanding of the structure, For example, to see the proof of how the great muscle moves forward, such a preparation (Figs. 13, 14) should be made. Here we see the past history of the muscle imprinted upon the face of the shell it has travelled over, and learn that the scar is made as follows: First by a discolored area (*bs*), laid down by the mantle in front of the scar, all around the posterior end and sides, but not at the anterior end. That this pigment was deposited in narrow bands just posterior to the great muscle, and on its sides; that this deposit accompanied a series of layers made by the mantle border (*so*), which occupied precisely the spaces between the horny layers (black lines *sh* in Fig. 14); that these interspaces were periods of growth, and the horny deposits periods of rest, from growth; that the muscle remained stationary during the period of rest, and consequently here a deeper furrow was built up, and the spiral changed its direction. Between the periods of rest, or as the shell was building itself outwards, the muscle followed, stopping to rest at short but irregular intervals. The manner of the advance even can be determined by these scars, since the central posterior part bulged out first in the direction of least resistance, and was followed by the sides.

The marks of this progress are the striations (*str*) showing the course of the muscular bundles as they were crowded onwards, and the cross-ridges (*s'*) left by the anterior edge of the muscle, which enable the observer to show in some cases its former position and shape.

This preparation is made by filing on the outer side of the shell, to an appropriate depth, and then striking it smartly with a hammer. The inner deposits usually flake off when this is done, and leave the track of the muscle exposed, as in Fig. 13, showing the long, shallow furrows, the tracks of the bundles of muscles, the transverse furrows and ridges; showing the anterior border of the muscle when taking a comparative rest (probably in winter), and the bow formed by the sides and posterior border at the same time. Here, also, it is proper to notice a fact of great value in the comparative study of shells; namely, that the shell is divided into two regions. These are an outer region, formed by the regularly superimposed and imbricated or lapped layers built by the mantle border and mantle outside of the division line, a continuous thin sheet of shell deposited by the muscles (*ads*), and an inner region deposited by the mantle inside of these limits, and composed of layers which cover up the track, and are built one upon another so as to add considerably to the thickness of the interior.

On the surface of a section it will be seen that there are limited deposits of lime of a columnar structure, as in three such in Fig. 14, *sc*, which are softer, and contain less animal matter than the adjacent parts, and more widely distributed layers. These appear to be due to some cause which irritates the mantle at that particular spot, and causes it to deposit with greater rapidity than usual; at least this seems to have been the cause in several cases observed by me.

An excellent method to pursue in this connection is to induce the children to weigh, and then roast, one of the valves, and observe, subsequently, that the layers of shell retain their form, but peel off readily, and become much lighter in weight as well as more friable.

A little of this burnt shell treated with acid effervesces more readily than when unburnt, and is one of the sources from which lime is obtained for agricultural purposes on the sea-coast, where shells are abundant.

The weight lost remains to be accounted for; and this can be approximately done by suspending a shell of the same weight as the first in about a pint of dilute acetic acid. In the course of a few days the carbonate of lime — the mineral matter which makes the shell so hard and heavy — is dissolved, and there remains the animal matter.

This takes the form of layers of charcoal lying between the lighter-colored layers of lime in shells, which have not been burnt too long, and also as a slight dark stain unevenly distributed, when seen by the naked eye, throughout the layers.*

In both instances, whether the animal matter alone is present, or the lime and carbon, the form is retained. This fact satisfies the scholars that the hardness of the shell and its weight is due to a deposit of layers of mineral matter in close connection with a similar series of layers of animal matter. Having examined the shell itself, the next step naturally is to study the parts of the animal which are associated in building it up, and have left their imprints upon it.†

For this purpose it will be necessary to observe only the upper, exposed side of the soft parts. It will be seen that the oyster itself is inclosed by two leaves delicately fringed on their outer edges, which are dark-colored and double, and of the same outline as the inner white layer of the valve.‡

* Shells which have been bored by sponges or worms will often have the cells or tubes they have made lined with charcoal, derived from the burning of these bodies. In trying to account for the weight of an unburnt or undissolved shell, by adding the weight of the burnt shell or lime to that of the animal matter, when separated by the action of acids, it should be remembered that the burning or the solution is very imperfect, and leaves unchanged foreign substances, also, which ought to enter into the analysis, if exactness is desired, and that carbon exists in both cases, and is weighed twice.

† This is literally the case, since a keen eye can detect the form of the gills, palpi, and body imprinted on the internal surfaces of the valves.

‡ In all these operations and manipulations, where soft parts are to be examined, no great amount of success can be obtained unless the parts are covered by water. This floats them up, and

By careful manipulation, the edges of the leaves which form the mantle can be followed around on their convex edges to where they are joined to each other near the hinge; then back again to where they are again joined by a narrow neck at the outer end of the concave side; and then along the concave side to where they again join near the hinge on this side.

The borders are free and easily lifted, but care must be taken not to cut or lacerate any portion. The border of the mantle is usually narrow in captured specimens; but it can be readily seen that there is a thicker outer portion reaching some distance inside of the fringes. Sometimes the inner side of this border is dark-colored, but often it is not very distinctly marked, though it is an important region for shell-building purposes.

The marks of the border are generally quite easily seen on the inner surface of the valve, and may be detected, either by a difference in color and a slight linear depression, especially in burnt shells, and also by the contour, which is convex, the remainder of the interior of the valve being concave. This portion of the animal deposits the whole exterior of the shell to a considerable depth, as has been described (see, also,

enables one to both see and handle all of them more easily. The inexperienced not only take them out of the water, but indulge in many useless and objectless researches, which disarrange and destroy the parts. Care, foresight, and the necessity of doing everything with a definite end in view, are needed even in the simplest operations of dissection, and can be practically taught in these and all other operations, if the teacher is disposed to make these lessons useful in their broadest acceptation.

Fig. 46). Between this and the body of the animal the mantle is striped with bands of muscles running across the intervening space, and easily detected by their opaque aspect. In the midst of the mantle is seen the large muscle; in the free valve the depression and peculiar marks it makes in the shell; and these are still more distinct in the burnt shells.

The outer layer of the mantle really runs between the muscle and the shell; and it is the surface of this which builds the thin layer of shell secreted over the scar or track of the muscle, and not the muscle itself. This is not organically attached to the shell, but is held in place by the pressure of the surrounding water and air. The movements of the muscle along its track are due, in all probability, partly to the growth of the animal and of the muscle, and partly to the mechanical effect of the swelling and contractions of its transverse dimensions, occasioned by the closing and opening of the valves. These actions would tend to make the muscle move in its bed; and this motion could only take place in one direction,—that of least resistance,—away from the body. Thus, though the oyster prefers to grow to the left, if its bed is not favorable for this direction it grows to the right, and reverses the spiral of the shell.

The horny hinge is formed by the area of the soft mantle attached to it. This area is similar in shape, minutely ridged, and, when drawn away, shows the deep brown color of the layer of horn which it is about to deposit. (Fig. 12, *h'*.)

The manner in which the ligament advances is evidently by the building of new layers on the inside, and the wearing off of the old, useless layers on the outside. The broad furrows leading from the hinge to the apex of the valve (*hf*) is the track of the ligament; and often the pieces or strips of the older and half-decayed layers are still attached to the bottom of the furrow, and half fill it, as in Fig. 12, *h''*.

The horny portions are evidently produced around the extreme edges of the mantle margins everywhere, and by the narrow area along the hinge.

The so-called skin or epidermis of the shell, which covers the outer surface of a valve with a continuous layer, can be peeled off, when present, with a knife-blade. It is a horny layer produced by the extreme edge of the mantle, which, in living and fully-expanded animals, are capable of stretching even farther outwards than would be necessary for this work.

The ligament or hinge is continuous, layer by layer, with this epidermis, and is evidently a part of the epidermal secretions, though originating from a distinct region of the mantle.

It is composed of three parts: two external parts composed of loose layers, which are continuous with the horny layers of the edge of the mantle, and a denser, central part continuous with the latter, and of the same striated or columnar structure (Figs. 5 and 12, *h*).

For obtaining a view of other parts, lift the outer part of the mantle on the convex border, and turn it back.

This shows below the four gills (Fig. 2, *g*). The scholars can readily trace these to both ends, and find that they are united along their bases, and terminate both ways; at one end where the leaves of the mantle are united (Fig. 2, *m d*), and at the other where four broad, pointed flaps reach out and embrace their extremities when the animal is in perfect condition and at ease (Fig. 2, *p*; Fig. 12). The fluted or frilled character of the gills, and their serrated edges, can be seen with the naked eye (Figs. 8, *fd*, and 15, and 6'). With a magnifier these flutings can be seen to be covered by a net-work of lines with partially transparent spots between them.

Mix a little indigo with *salt water*, and pour a few drops with a medicine dropper or glass tube on the surface of the gills. If the oyster is living, the particles will be seen to gather into threads, and pass down the surface of the gill to the edge, and over this into a channel along the outer edge (Figs. 7, 8). Here they are joined to a larger thread of food which is moving towards the four pointed flaps. Of course all the minute plants and animals of every kind, of which there are myriads floating in the water where oysters are found, must be acted upon in the same way. They are entrapped in the mucus, which is abundantly secreted by the surfaces of the gills, and moved forward by the cilia or waving hairs which cover the surface with a coat like the pile on velvet. These move so as to force the combined mucus and particles to weave themselves into threads, which are carried forward until they come within the reach of the cilia coating the canals that run along the edges of the gills. These take them up, bind them together, and move the whole forward as four larger threads which are finally received between the two pairs of pointed flaps at the upper end. Each pair of these embrace a pair of the gills with their extremities, and receive the two large threads of food which they have spun.

These flaps may be seen by the naked eye to be roughened by linear ridges on their inner surfaces, which enable them to fit closely where in contact, and also increases the area of surface for the development of cilia. The cilia move up one side and down upon the other of each of the tubes or minute folds on the surface of the larger folds (Fig. 6′), so that all particles are thrown towards the channels between the larger folds, and retained there while being moved towards the outer edge. The operation of feeding may be watched by quite a number of pupils, and readily seen by them.

In nature the outer edges of the flaps are probably joined so as to form a closed canal on either side leading from the gills to the mouth.

In these disturbed specimens, however, the edges are not often so closely fitted, and a considerable part, if not the whole, of the food, brought forward along the gills is carried too far out, or escapes from the incomplete bottom of the covered way, and being caught by the cilia on the outer free edges of the flaps, called palpi, is returned back from whence it came.

A portion, however, may sometimes be followed on its course; and by opening the flaps and dropping a little sea-water, dyed with indigo, the particles may be seen as they are carried off by the cilia, all moving in the direction of the mouth.

The mouth itself is situated in the angle of the flaps or palpi, and deeply buried between them (Figs. 2, 12, 15, *om*), so that it is difficult to get at, and cannot be found unless great care is taken not to tear the parts. Constant failures must be expected, even in such simple operations, until the observer has learned that nature yields nothing but a crop of mistakes to hasty and thoughtless exploration. A single ill-planned cut will generally destroy or mutilate just the part which is being sought for.

In order to carry on these observations properly, the leaves of the mantle must be cut open, so as to expose the flaps of one side.

To do this without lacerating the soft body of the oyster, pass a probe, a burnt match, a straightened hair-pin, a knitting-needle, or piece of blunted wire round the flaps, and hold the mantle out until you see where to slit it open. Then you can readily, with a pair of scissors, remove this entirely from one side, and afterwards the outer flap or palp, the same side as in Fig. 15, *p'*.

When this is done, without tearing the parts, you can be sure of finding the wrinkled cavity of the mouth by bending the end of your probe into a small hook, and pulling gently aside one of the large muscles in Fig. 15, *om*, which run forward on either side, from the bases of the inner palpi or flaps, and form the two sides of that aperture.

It will have been already noticed by the observant, that a certain portion of the blueing, dropped on the gills, disappeared in the interior. This evidently passed through their sieve-like surface, because they also saw it coming out again under the borders of the mantle on the concave side in two streams,—one immediately before and one behind the large muscle. Both of these currents serve to carry off the excretions of the body and the feculent matter from the anus, and are really branches of a stream issuing out of the interior of the gills.

The circulation of water, then, in the oyster, when living, takes place by the entrance of a continuous stream in at the outer convex edges, and its passage through the gills and out on the other side in the manner just described.

In order to understand this, lift with the probe, and cut across that portion of the mantle, on the upper side, which lies loosely between the large muscle and the body, as in Fig. 5.

This operation exposes the thin membrane, which covers the cavity occupied by the heart, and calls attention to the close attachment of the outer lamina of the outer gill and the inner side of the mantle.

It also gives an inside view of the gills, showing that they form a ridged and grated bottom to a cavity running along their entire length.

A little blueing, again placed on the outside of the gills, will now be seen to pass into them, and come out into this cavity with considerable force from a series of tubes in the interiors of the gills. (Figs. 2, *og*, 5, 6.)

In order to expose the gill cavity fully, sever the connection of the outer side or lamina of the outer gill, with the mantle (so as to leave a portion of the base of the gill still attached to the mantle) all around the large muscle, and also anteriorly, until the mantle can be turned back and disposed of on either side, as in Fig. 5, *m'*.

Then, by tilting the gills over towards the convex side, it will be seen that each one is made up of two sides or laminæ, united to each other on their outer free edges, but not on their inner edges; that here the laminæ of each gill are spread apart, and connected only by fleshy partitions, while the adjacent laminæ of neighboring gills approach each other, and join, so as to form three fleshy ridges running the whole length of the gill cavity. (Figs. 6, 7.)

The interior of each gill is divided by numerous fleshy partitions into a series of tubes opening into the gill cavity above. The bases of these partitions cross the openings of the gill at right angles, from one fleshy ridge to the next, so that the bottom of the gill cavity thus formed has the aspect of a grating. (Figs. 5, 6.)

Although most observers will be content to stop at this point, it is to be hoped that those having magnifiers and microscopes will try to go farther into the structure of these curious and complicated organs.

In order to do this, divide a portion of a gill, by cutting the partitions and taking out a piece of one lamina, and lay this under the magnifier in a watch glass, and covered by water.

The inner side (Fig. 8, r'', t'') will be found to be composed of a series of vertical tubes with thick walls.

The vertical tubes are united by smaller horizontal tubes (Figs. 8, 9, $t''+$) at regular intervals, so that here again we see a grating presented in the structure, but this time of small meshes.

If now the focus of the microscope is changed, and the gill is in good condition, and can be stretched open a little, these meshes will be seen to open into semicircular cavities (Figs. 9 and 6′), which show that the vertical tubes lie at the internal junctions of the vertical folds of the outer side of the gill. The infoldings of the outer surface are permanent, and each one corresponds exactly in breadth to the space between two internal vertical tubes (Fig. 11, r'', t'').

On the surfaces of these flutings are numerous smaller vertical folds (Fig. 6′); and these, the most minute folds, are united by cross-bars, with apertures between, so that here we have still another and a very fine grating, and one admirably suited to strain water of food and all large particles. These are shown from the interior also in Fig. 9, *eo*. The course of the water, then, is evidently through these minute, external gratings, first into the semicircular chambers of the interior of the gill laminæ, then through the second grating of the tubes into the large tubes of the gill formed by the partitions, and up through these into the long gill cavity.

The whole of this complicated apparatus is so arranged that not only is great strength and stiffness acquired, but also a very large expanse of thin membrane, behind which the blood passes, and which acts like a veil, keeping the blood in and the water out, but permitting the air in the water free access to the blood.

The act of respiration among marine animals consists simply in bringing the blood in contact with the air in sea-water. This is accomplished when the blood passes through the vessels of the gills, since the thin membrane which surrounds all of them on the inner side of the gill laminæ is permeable to air.

If part of a gill is thrown into a weak solution of caustic potash, the animal matter will disappear, and leave behind a number of long threads. These threads are elastic and horny, and support the gills. They are secreted on either side of each of the minute folds or flutings in the middle layer (Figs. 7, *q*, 11, *eh*); and there are also similar supports to the vertical tubes of the inner surface of the lamina at the junctions of the folds, but much broader than those of the flutings. (Fig. 9, *eh'*.) The mode of circulation of the blood in the gills cannot be described until the larger vessels of the body are understood.

The heart can be exposed by lifting up and cutting away or tearing off carefully the thin membrane enclosing the cavity on the upper side, as in Fig. 2, *h*.

The heart in a live specimen will beat regularly, and the action of the different parts can be observed.

This organ is divided into three parts, or sacs,—one large transparent one, the ventricle, and two smaller, brownish-looking bags, the auricles, only one of which, however, is visible from the side. (Figs. 12, 15, *vr*, *au*.)

First, the auricles are distended with blood,—a bluish, milky-looking fluid, which is received from the gills and mantle. This is forced, by the contraction of the walls of the auricles, into the ventricle, which swells up to accommodate the influx of blood, and immediately thereafter contracts, forcing the contents out into the larger arteries of the body (Figs. 2, 12, 15). The principal vessel of the arterial system may be seen issuing from the ventricle, and penetrating forwards directly into the soft body beyond, while another passes backwards along the inner side of the intestine on to the inner surface of the large muscle (*ad*), which it enters and supplies with blood.

On the way it also branches laterally, giving blood to the whole surface of the intestine and mantle in the regions on either side of the intestine in the neighborhood of and behind the muscle (Fig. 12, *iat*).

The great artery, after it enters the body, throws off three branches to the ventral side (Fig. 12). The first of these passes directly to the viscera on the lower side of the body; the next passes to the intestine, by means of a posterior branch, and then, passing onward towards the great venous sinus and under the intestine again, gives off two branches, one reaching anteriorly to the liver and genital organs, which is cut in Fig. 12, and the other posteriorly to the intestine and genital organs in the region below the great muscle; the third branch, which is severed in Fig. 12, goes to the stomach, intestine, liver, etc., on the right side of the visceral cavity. After giving off these branches, the aorta passes forward through the loop of the intestine (*i*), and supplies this region and the stomach with blood by means of smaller branches. When in the neighborhood of the mouth it sends off a large branch, which passes just posterior to the mouth (*pat*), and supplies the palpi with blood through four secondary branches springing from this arch. A little farther on and a smaller branch (*mat*) passes anterior to the mouth, supplying this region with blood. Just beyond this, in the angle of the mantle, it gives off a branch posteriorly, the mantle-border artery on the dorsal side (Fig. 5, *dma*), and then, turning sharply at right angles (*ma*), passes along the hinge area, and in its course gives off numerous small arteries on either side, which pass posteriorly, and with their numerous ramifications supply the whole anterior portion of the two leaves of the mantle. These last are often quite conspicuous externally, on account of the opacity of the coagulated blood which they contain. (Fig. 5.)

At the ventral angle of the mantle (Fig. 5, *vma*), it separates into two terminal branches, which traverse the whole ventral side, with numerous branches springing out on the ventral side to supply the borders of the mantle.

These are the main channels through which blood is conveyed to the various parts of the body, and most of them may be followed out with the knife.

After passing through the arteries, which divide into smaller and smaller branches as they recede from the heart, the blood is collected in a system of intermediate vessels or spongy cavities (Figs. 12, 7, *v*), and from thence returned either through the gills or directly collected into small branches and returned to the larger veins. In these it flows on its way back to the auricles, from whence it again enters the ventricle, and begins over the course we have described.

The principal vessels of the venous system are not difficult to follow out, even without injections, and may be partly seen by the eye without resorting to dissections.

The best way to study these is, as with the arteries, to start from the part of the heart to which they lead; in this case the auricles. If the oyster has been carefully opened, and the mantle turned back on either side, the auricles may be seen to connect with a narrow, triangular space with thin walls (Figs. 5, 12, 15). This space has two main branches, one leading anteriorly up on to the side of the body (*av*), and the other posteriorly on the inner side of the mantle to the base of the outer gill lamina (*j*). Fig. 6 shows this last and its branches, as well as the anterior one and its branches (*j'*). The anterior one branches near the bases of the gills, and is really the stem into which the venous vessels of the anterior parts of the gills and mantle empty; and the blood, also, from part of the viscera (Fig. 5, *vv*), passes down this main channel to the auricle without going through the gills at all. The posterior vessel and its branches (Fig. 6) connect in the same way with the vessel at the base of the outer lamina of the outer gill, and also pass on beyond this to the outer part of the mantle. The vessels at the bases of the inner gills are connected with that at the base of the outer lamina and mantle by the cross-bars of the bottom of the branchial cavity which contain large tubes (Fig. 6). In these vessels and tubes the blood from the posterior parts of the gills and mantle is collected and transmitted to the posterior venous branch, by which it is taken to the auricle (Fig. 5).

The blood from that region of the mantle immediately above the heart, and just back of the great muscle and body, is collected in a set of branches which distribute themselves over that region, and convey it to the auricle by a vein running close to the anterior edge of the muscle on the inner side of the mantle. (Figs. 5, 6, *z*.)

These veins can usually be distinguished by the clear, transparent look of their walls, and by the way in which they lead to the great sinus in front of the auricle at the ventral corner of the cavity containing the heart. To see the remaining parts of the venous system, dissection is necessary.

Cut off the mantle leaves completely, and then slit open carefully the largest venous vessel (Figs. 5, 6, *x*) at the fleshy junction of the inner laminæ of the middle pair of gills. This will be found to receive, near the anterior end, two large branches running right and left, and other branches from the bases of the palpi. Along the bottom of its channel several large veins from the body and many smaller ones open, which come in some cases from the spongy capillary tissue about the intestine, and in others from the capillary tissue of the more adjacent parts of the body (Figs. 5–7, 12). This is, in fact, the main stem or reservoir of the venous system of the body and viscera, and from this the blood received from all of the regions of the body is thrown into the gills, and then, after being aerated in its passage through the tubes and capillaries, is again collected in the special vessels already described, and passed onward to the heart, mingling, when it arrives at the two main stems of the venous system leading to the heart, with the blood returning from the mantle, and partly also from the viscera.

The blood, after its passage through the fine branches of the arterial system, is passed on into still finer vessels, which form masses of spongy-looking tissue. These minute tubes, or capillaries as they are called, unite into larger tubes, and lead the blood into the larger veins.

To illustrate this, imagine that you had two bushes, each with numerous branches, but the stems hollowed out into tubes of different sizes opening at the ends of the twigs.

Then that there was a great mass of tubes smaller than the terminal twigs of the two bushes, all of these so inextricably interlaced, and communicating with each other by means of intercepting tubes, that the whole mass would look like a great sponge. One bush of hollow tubes could be made to represent arteries; and by connecting the hollow twigs of the former with the tubes of the exterior of the spongy mass, fluid could be forced through the stem into the twigs and fill the sponge. The other could be considered as representing the venous system; and its twigs being connected with the spongy mass, on the side opposite to the arteries, would receive the blood as it flowed through the fine network of vessels in the sponge, and collect it into larger and larger tubes until it reached the stems of the venous system. If now the stems, both venous and arterial, were supposed to be dilated into bags at their largest ends or roots, and these connected together, the arterial bag with the venous, so that the blood would pass from the bag at the end of the venous stem, back into the bag at the beginning of the arterial stem, and commence again to run towards the spongy connecting mass, this would represent the relations of the arteries and veins in the mantle of the oyster, but not in the other parts of the body.

Instead of passing from the spongy masses into the smaller veins, and thence to the auricles, the larger portion of the blood from the spongy masses of tissue surrounding the stomach and intestine (Figs. 7, 12, *v*), from the palpi and from the great muscle, is collected into tubes of greater or less size, and conveyed by them to the median vessel which lies at the base of the two inner laminæ of the gills (Figs. 5–8, *x*). From this numerous tubes branch right and left through the partitions, and open into smaller tubes, which run in the ridges along the bases of the gills on either side, and (*k*) along the junction of the outer laminæ with the mantle (Figs. 6, *r*; 7, *t*). From these vessels it flows into the numerous vertical tubes of the gills (Figs. 7, 8, 11, t''). From these it takes a horizontal course into the depths of the semicircular chambers, and thence, turning vertically again in both directions, passes between the minute openings (Fig. 9, *eo*) of the gills into the smallest of the return vessels. These are in partitions (Fig. 10, r''^{+}) which cut across the folds of the gill, and open into the vertical tubes (r''), which carry it upward to the larger reservoirs in the partitions (Figs. 8, r'''^{+}; 7, r'''), and force it onward through the transverse connecting tubes to the venous trunks previously described at the junctions of the mantle and the gills (Figs. 6, 7, *j*). Here it mingles with the return blood in the vessels *jm*, Fig. 6, from the mantle. The leaves of the mantle undoubtedly also aerate the blood which is carried through them, though probably much less effectually than the gills; and it is probable, also, that the great amount of sea-water taken in by the water vessels also does some of this work, and perhaps mingles more or less with the blood itself.

To this double circle of the mantle and the gills, there must also be added another special system for the great muscle.

A portion of the venous blood appears to return from the mantle in the vicinity of the branchial cavity in two large vessels situated on the interior of the mantle leaves (Fig. 6, *jm'*). These lie on either side, near the bases of the gills, and on approaching the muscle split into two branches, which encircle its edges on the outer convex side, but not on the anterior or concave side.*

From these branches numerous smaller tubes arise which penetrate the muscle, passing into the interior at intervals all the way around.

The aerated blood from the mantle which these convey into the muscle, and the arterial blood from the artery, before described, which penetrates the muscle on the anterior side, is all collected into one large vein on the lower side (Fig. 6, *y*), and emptied into the median vein (*x*).

The extraordinary complication of the gill structure in the oyster makes it an unfavorable type for studying the course of the blood in these organs, but the ease with which the larger arteries and veins can be filled by injections, from the heart or auricular antechamber, makes it available in this respect.

* Here they are replaced by two other of the mantle system of veins (*z*), which go directly to the venous trunks, and empty into the auricles on either side. One thing quite noticeable in these arteries and veins is the effect of pressure upon their size. Thus the vertical tubes carry blood into the gills, are dilated at the bottom where the blood tends to accumulate; the alternate return verticals and the reservoirs in the partitions are dilated at the upper ends from the same cause.

Pecten, the scallop, gives the easiest and best results, besides being essentially typical in gill structure.

The heart is really quite a powerful organ, and acts with considerable power, though rather slowly. Its contraction forces the blood through the arteries, and from thence the same pressure causes this fluid to continue its motion, when collected, into the branchial capillaries and spongy masses onward into the veins on its return to the heart.

The muscles which do the pumping are to be seen by opening the heart. They cross each other in the interior of the ventricle in every direction, near the walls and along the centre, and in the auricles they have a similar distribution, though not so powerful. The auricles and ventricle are furnished with valves, which prevent the return of the blood towards the veins, so that a self-acting pump is formed of three compartments. The two auricles acting as feeders to the ventricle, and the ventricle as the forcing agent from which it is again distributed over the body.

The generative organs (Figs. 12, 15, *w*) are immediately under the mantle, and envelop the viscera all over the body, forming, when gorged with eggs or spermatozoa, a thick, white coating of tumid-looking branches, terminating in little, round sacs, or grape-like bodies, and are a marked characteristic of the external aspect of the body at certain seasons of the year. Upon examination, these are found to be filled with little granules, which are the eggs. The sexes are said to be distinct by some investigators; by others it is affirmed that both eggs and spermatozoa are elaborated in the same canals, and that the oyster is truly a hermaphrodite. This question is not decided, but it seems certain that the organs of generation are similar in all specimens, and that most observers are inclined to believe that the generative organs are filled in some specimens exclusively with spermatozoa, and in others exclusively with eggs. This seems to show that the sexes are distinct in the oysters, though the organs of generation are similar. The orifice for the exclusion of the eggs and spermatozoa is situated at the black mark in Fig. 15, *w''*; and from this a branching tube connects with all parts of the ovary.

Just under the generative organs, and in one place near the mouth uncovered by them, lies the dark, brownish-green liver, composed of grape-like bunches of glands connected by hollow branches, which unite into stems and empty bile into the blind sacs of the stomach (Figs. 2, 12, *l*). Within the liver and generative organs lies the coiled alimentary canal, surrounded by its coat of blood vessels, which in places form a very thick, spongy, investing mass.

The situation of the mouth we know already. The throat, or æsophagus, is very short, leading immediately into the stomach, a large sac (Fig. 12, *st*), with several deep blind sacs, into which the branches of the liver organs empty the bile. The intestine begins at the posterior end of the stomach, and passes first posteriorly between the great muscle and the gills, where it makes a sharp return to the right. From thence it keeps to the right, running dorsally, and passes under the intestine and stomach to the left. Near the mouth it makes a bend to the left, passes under the mouth, and then (Fig. 2) ventrally on the left side, describing a half circle, again skirting the bases of the palpi and the gills.

When far enough around, it reverses the curve, and passes out of the visceral region across the cavity containing the heart on to the dorsal side of the great muscle, where it terminates.

With even such a portion of these facts as may be observed by the naked eyes, without help of the microscope or dissections, a child can be led to see at least the parts of the animal, the work they do, and the relations of the shell to the animal; and also that this is a part of the oyster, and, though a protective covering, neither like a coat or a suit of armor or a house, or any other artificial covering whatever.

Such comparisons are misleading, and should be made only where they are truly applicable, as in the case of the hermit crabs, which seek protection in the shells of dead mollusks and other similar instances.

A very lively interest can be awakened by leading children to observe the symmetrical distribution of the parts in pairs, on either side of an imaginary plane passed through the animal.

If the oyster is held with the pointed end of the shell away from them, the broader ends towards them, the scholars will readily perceive that the mouth is at one end of the body, the anus at the other; the mantle valves symmetrical, one on either side; the palpi and gills in pairs, and so on. They can be brought finally to realize, that, although in many specimens twisted or distorted until all external comeliness of shape is destroyed, the shell is built by an animal with a definite anterior, or forward end, where the mouth is always to be found surrounded by its own peculiar organs for feeding, and an equally well-defined posterior or hinder end, where the terminus of the alimentary canal occurs at the anal opening; that this same soft-bodied creature has also right and left symmetry to its body, like that which we observe in man and all the higher animals;

that all this, and the complicated structure shown by the organs, occurs in a headless animal.*

This last fact has a peculiar significance among Mollusca, and can very properly be made the leading idea in treating of the anatomical structures and the general relations of the different forms comprised within this group, the Lamellibranchiata.

It must not be forgotten, however, that, though headless, they are not deficient in their nervous system.

Some of these nerves can be seen readily enough, as opaque white lines running along the bases of the

* There are certain characteristics of the body of the oysters of the highest interest, which show that the bilateral symmetry of the parts have been modified greatly by the habits of life of the oyster, but which will be better understood after the study of the clam and other forms.

Though the shell is often curved to the right instead of to the left, the animal is found to be in the same position inside the shell. The young shell is usually, also, even in these reversed specimens, curved in the normal way to the left. This reversion occurs only where there is good mechanical reasons for it, where there is no room for proper growth to the left, and so on. The irregularity of the valves is also probably due to the fact that the animal lies quietly on one side, and naturally produces more shell with the mantle leaf, which is not occupied in the opening or shutting of the valve, or in the function of passing the water through the body. In the same way we can account for the soldering of the mantle on the lower side to the body. The former presence of an opening on this side, leading into the gill cavity, is indicated by a depression near the intestine, which is sometimes quite deep. This, and the perfect symmetry of the young while it is a free animal, and of all the Lamellibranchs which are free, clams, etc., shows that all of these irregularities in the symmetry of the sides must have arisen from the mechanical effect of the habit of living on one side.

gills, and from the surface of the large muscle, where there occurs a pair of nervous swellings or centres of distribution of the nervous stems which are united by a cross-bar or nerve. From this pair of ganglia the various nerves radiate out to the great muscle, the mantle, the viscera, and other parts, while two large branches run forward upon either side to the bases of the gills, and bend quickly back again, following the ridge of the base to the posterior end, and giving off a great number of lateral branches.*

A pair of branches concealed in the interior of the body connect this pair of ganglia with another situated under the palpi and near the mouth. These ganglia give off branches to the mouth parts, the foot, mantle, and gills.

Though supplied with nerves to such an extent that each of the papillæ of the fringes on the two edges of the mantle has its own nerves, there are no special organs of taste or smell or sight. Their places are supplied by these papillæ, which are supposed to act as organs of touch, as well also as the palpi. There are no eyes.

The related forms of the oysters are, for the most part, unsymmetrical animals, and have no feet or digging organ for constructing burrows, or siphons for reaching up to the water above if accidentally buried too deep in the mud. The oyster, therefore, unlike the clam, cannot live anywhere below the surface mud, and must lie upon one side. It is, however, when first born, a free, moving animal; and at that time, and for a long

* These are shown as black lines in Fig. 5, *n*.

time subsequently, much more symmetrical than the adult afterwards becomes.

Even such forms as the scallop, which are not only free but capable of migrating at different seasons of the year from deep to shallow water, nevertheless habitually lie on one side, and show the effect of this habit in the inequality of the sides. This animal — Pecten, or Comb-shell, or Scallop — is also remarkable in the possession of a foot, which, however, is not used as an organ of locomotion, and in having a row of eyes situated among the fringes on the edges of the mantle.

These can be obtained of fish-dealers, but they must be cautioned to get them alive and whole, since, when cleaned for sale, everything is thrown away except the large central muscle, which alone is considered suitable for food.

Fig. 17 gives a general idea of the distribution of the parts and the situation of the eyes (*ey*), which last have lenses and special nerves, and are probably capable of seeing distinctly.

The gills are particularly interesting, because they show the intermediate stage between the single gills of Nucula or Leda, and the completed gills of the oyster, clam, etc. The gills in Nucula and Leda are, in their simplest form, rows of tubes on either side of two fleshy bases or arms projecting from the mantle, as in Pecten, but somewhat longer. Near the foot a section in Leda (Fig. 19) shows that organ (*F*) with its split muscular ridge, effectually used for crawling in the soft mud in which they live,* and the tubes (*g*) on either

* It is thrown out with edges together, penetrating the mud easily, and then quickly spread out as in the figure, taking hold and enabling the animal to move itself rapidly forward.

side. Fig. 20 shows a section of the arm near the end, with the gills reduced to a fleshy ridge on either side. The dotted lines (g^+) show how these gills can be drawn to resemble those of Pecten. Fig. 18 shows an actual section through the free part of the gill-arms and gill-tubes in Pecten. The dotted lines (m^+) here also indicate the mantle on both sides, and the lines (g^+) the way in which the gills of Pecten may be transformed into a resemblance of those in the clam and oyster.

The blood-vessels in the fleshy bases (Fig. 18, *br*) are very simple, one above the other; the uppermost (t') conveying blood to the gills, and the lower (r') receiving it from the gills. On the right, the vessels leading into the gills, and their dilations into partitions, are shown; and on the left the tubes and the vessel into which they carry the returning blood, and which take it to the hearts. The plural is used here, for there are really two of these, consisting of an auricle and ventricle, one either side of the body. The gills are also very interesting, because the cross tubes which unite the vertical tubes internally, as seen in the figure, and the outer membrane of the folds through which the still smaller vessels pass between the apertures, are so very thin and easily ruptured that the vertical tubes separate at a touch, and in many alcoholic specimens assume the aspect of distinct tubes. Fig. 17 shows the gills of one side split into five pieces.

The so-called organs of Bojanus (*u*), which are supposed to excrete from the blood — which passes in great quantities through their walls — urinary products which pass out at the opening marked with a black dot at the posterior end (*u'*), are very large and prominent. The foot has a slight muscular ridge. The peculiar appendage (*bg*) between it and the mouth is a part of the foot; and in the hollow in the young are secreted long threads, like those of the common mussel, with which it anchored itself to the rocks until old enough to break away and take care of itself. The palpi are similar to those of other forms, except just about the mouth, where they are changed into the remarkable branching tentacles (*tp*) shown in the figure. The mantle border is very thick, and has numerous rows of tentacles, especially on the outer part. The eyes are numerous, and between the larger ones are often smaller and more imperfect ones, indicated by black dots. There is a strong muscular border inside (*mm*), attached closely to the shell all around. The generative organs are situated in the foot, and open into the organs of Bojanus.

The movement of the animal through the water is accomplished by the quick and forcible shutting of the valves. This drives the water out in a broad jet, which, by reaction, throws the shell with considerable celerity forwards in whatever direction it may happen to be pointing.

The result of this is in all probability to carry it by an irregular, zigzag line in the direction in which the tide is moving. At least this seems the only reasonable way to account for any definite course being steered by them during their migrations; so that, by selecting their opportunity, they can move towards shallower water, or away from it, at their pleasure. One placed in an aquarium can be made to swim in this peculiar way; and is also very interesting on account of the sparkling aspect of the double row of bead-like eyes and the beauty of the mantle fringes.

The Pearl Oyster, or Meleagrina margaritifera, are often obtainable in curiosity shops or natural history stores. Mother of Pearl is the nacreous layer taken from the inner side of this shell, though other shells also furnish a proportion of this article, — the inside layer being usually more or less nacreous. Pearls themselves are pathological products; and, though common enough among the oysters, not very perfect or valuable when obtained from other forms than the Pearl Oyster.

Imperfect pearls are common in oysters, and in the fresh-water clams of our western rivers; these last are sometimes quite pretty, though very small and irregular. They often have a nucleus of sand or some foreign matter which has lodged between the mantle and the shell. This causes an extraordinary excretion of shelly matter to take place, which ultimately builds itself around the original nucleus in a large number of concentric coats, like those of an onion. Pearls, therefore, are easily injured and dissolved by acids, being of the same structure as the nacreous layers.

The most ancient and successful fisheries are in the Red Sea and off Ceylon, though this species occurs and is profitably hunted for its pearls and shell also at the Society Islands, at Manilla, at Panama, and many other places in tropical latitudes.

It lives on the bottom, in about twelve fathoms, and is gathered by diving.

CLAMS.

The common clam is in many respects a more desirable type to teach this lesson with than the oyster, but it is not so widely distributed, nor so easily obtained in all localities.

There are several species of edible clams quite distinct in aspect and characteristics.

The common soft-shelled clam, Mya arenaria (Fig. 21), is the one best known in New England, north of Cape Cod, and most freely offered for sale in the markets.

In comparing this with the oyster, lay the specimens on one side, and the outlines bearing the same relationship to those of the oyster, as in the diagram (Fig. 16), where the outline of the clam is drawn above that of an oyster, so as to exhibit the contrast of form. It will then be found, as the analysis goes on, that they have been placed with all their organs in a similar position ; but this is a matter the scholars ought to find out for themselves by the examination of the animal.

By an examination of the shell, similar facts to those detailed in treating of the shell of the oyster can be ascertained step by step.

The lines of growth leading back to the beaks and encircling them, the hinge, and so on.

The horny covering is particularly noticeable, clothing the outer edges of the shell, and clinging closely to the exposed fleshy parts, though worn away nearer the beaks by the constant attrition of the sand or sandy mud in which the clam burrows.

In removing a valve observe the same cautions as in the case of the oyster; but observe that here two muscles (Fig. 3, *aa*, *pa*), one at each end, are to be separated from the shell; and the animal also has a thick muscular border to the mantle, as well as smaller muscles near the hinge.

If successfully removed, the clam will appear as in Fig. 3, and by contrast with the oyster the following facts may be elucidated. First, that the mantle is a bag with thick, fleshy borders, which, instead of being free all around, are closely attached. Then, if a probe be passed along the depression which marks the juncture of the fleshy border of one leaf of the mantle with that of the other, it will slip near the larger end into an opening (Fig. 3, *op*). This is the only orifice except the two at the ends of the funnels. The two large muscles, and the thickest muscles of the mantle border and of the base of the funnels, and the impressions they make on the shell, are important. They enable the observer to see at once that the clam builds the shell more with the border of the mantle, than with the part which lies inside of the limits of the impressions made by the muscles, and that therefore a valve is not so thick as in the oyster, and is scoop-shaped in consequence (Fig. 49); in other words, the layers are added very fast in the outer or border region (*es*) of the shell, and very slowly inside (*is*); whereas, in the oyster, the inside is also built up rapidly (Fig. 46).

This also accounts for the fact that the beaks of the valves or the young shells of the clam are apparently closer together, but really quite as widely separated, if the layers are counted, as in the oyster. A marked contrast between the two animals lies also in the differences which may be observed in the marks left on the shell by the muscles of the various parts, particularly of the funnel.

After these general comparisons, the mantle can be stripped off from one side, exposing the parts within. Here similar parts to those of the oyster will be observed (Fig. 4).

The gills, the palpi, the mouth, and the body are similarly situated, but the heart has taken a position such that the intestine passes through the ventricle, instead of back of it.

The gills will be found less complicated than those of the oyster, but much more difficult to understand than those of Pecten. They are free near the mantle for a considerable space, and also around the foot, but united posteriorly to the mantle and to each other in the centre like those of the oyster. In fact, Pecten is by far the easiest type for the study of all characteristics, and if it had been as plentiful as the oyster, I should have been tempted to take it as the type.

If the muscles of the funnel (Fig. 3, *rs*) are lifted, and probes or bristles passed through (as in Fig. 4, *rs'*), it will be found that it is really two tubes soldered together, one leading into the gill chamber, and the other into the gill cavity.

Then, if a live clam be observed, and blueing dropped into the water near the openings of the siphon, the grains will enter the gill-chamber tube, and presently some of them be thrown out of the other. This shows at once that they passed through the gills, and that these siphons are merely prolongations of the mantle, admitting the water into the gill-chamber, and passing it out again across the end of the anus in order to supply food sifted out of the water, and also to carry off feculent matter, as in the oyster. The little muscular junction of the flaps of the mantle at the termination of the gills, the fleshy bar, in the oyster being here, however, prolonged so as to form the partition between the tubes. The mantle edges are joined, and also prolonged so as to complete a tube on either side of the bar.

The foot is a little muscular nub, not usually — except in specimens allowed to die slowly in cold fresh water — so large as in the figure. When alive, this is capable of great extension, and can pass out to a considerable distance through the hole (Fig. 3, *op*) previously described.

If now the symmetrical distribution of the parts are observed, as was done in the oyster, it may be at once seen that the forward part of the animal is not near the beaks, but near the larger end, and the hinder part at the funnel or smaller end, and the beaks or young shells situated on the back.

To finish up these comparisons, place the oyster and clam side by side on their convex edges, which coincide in both, and observe, not only these contrasts, but the equality of the valves of the shell in the clam, which, unlike those of the oyster, are as symmetrical as the internal parts (Fig. 16).

The young of the clam is also free-moving and symmetrical, and we can account for its continuing so only on the supposition that the possession of a foot enables it to maintain an upright position favorable to the symmetrical growth of the parts, instead of being forced either to lie or to swim on one side, like Pecten.

If Mya arenaria cannot be obtained, there are other kinds of clams, which do not differ very much in their more important characteristics.

The triangular-shaped Hen Clam, or Beach Clam, or Hard Shell, Mactra solidissima, is often found in our markets also, and has shorter funnels and a light brown shell, and a larger foot, and, on account of its size, is a very favorable object for dissection (Fig. 24). The tumid, blackish-brown shell of the Cyprina Islandica distinguishes it at once from Mactra; and, although they are often represented as edible clams, they are not considered good eating, and are rarely abundant enough (Fig. 23).

The Quahog, Venus mercenaria, is rare on the coast of New England; and south of Cape Cod it is very abundant, and replaces the Mya arenaria in the markets (Fig. 22). The funnels of this are also very short; and in place of being united, the tubes are partly separated. The interior of this shell is colored violet in part, and formerly served the Indians, when cut into flat beads, for ornament, and also as a medium of exchange or money or ornament, being, in common with the beads of a similar description, cut from the conch shell and other suitable species, called wampum by existing Indians.

The Fresh-water Clam, Unio or Anodon, is a form allied to the clam, and readily accessible to those who live near large ponds or rivers in the interior. The mantle in these is open all around, as in the oyster, but the internal parts and the shell resemble those of the clam. They have a foot, which, however, is used, not for burrowing, but for crawling or rooting to a certain depth in the mud. The shell is held with the beak uppermost, and the mouth or larger end is always directed forwards, and ploughs more or less through the mud, being dragged onward by the long, extensible foot. Thus, although it is headless, like the clam and the scallop, it nevertheless, in all its motions, carries the mouth end forwards as they do; and also, being an upright, free-moving animal, is, like all such, perfectly symmetrical in form and the distribution of the appendages. The manner in which these animals contract and swell the body at will, and the great increase of bulk which they can effect when they wish to protrude the foot or extend the mantle edges, will occasion great astonishment to those who see it for the first time.

This is accomplished by the taking in of sea-water by means of pores, which occur in the skin of the foot, and which communicate with vessels which permeate the interior of this organ, and also the external parts of the body. These are peculiarly large and numerous in the Beach Clam, and can be seen if the foot is inflated with air, or distended by injecting fluid into it in a specimen which has been carefully killed in fresh water, and allowed to lie until all the stiffness of the muscles, occasioned by death, has passed off.

It is not yet settled whether this water system connects with the blood vessels or not; but it is noticeable, that when one of these animals is taken out of water, the fluid expelled from the body is sea-water, more or less mixed with blood.

The number and variety of the kinds of Fresh-Water Clams, Unio and Anodonta, in the Western rivers, is so great that a class may be taught most effectually by their means, not only how to work in the schoolroom, but how to collect and observe out of doors.

These, in many species, have very thick shells, whose structure can be studied with great ease; but the beaks of the shells are almost invariably wanting. The acids contained in fresh water seems to act upon these, which are always exposed above the mud in which the animal lives, eating them away until in some specimens they are almost wholly removed.

The sexes, also, are very distinctly marked, since the females are usually stouter than the males, and have larger gills, especially during certain seasons, when these are filled with the young fry, which are stored away in their interior until they are large enough to shift for themselves.

SNAILS.

The Pteropods, the Butterflies of the Sea, and many other curious and strange forms, such as the Heteropods, might be described in these pages; but the immediate object of the lesson would not be furthered by these digressions, and besides, they are fully treated of in many other books.

It may be well, however, to say that in one division they have shells, and are headless, with broad wings for swimming, — these wings being probably part of the foot, of which also a rudiment is left. Fig. 39 gives an idea of Hyalea, one of these forms. The other division is composed of Pteropods having a swollen extremity like a head, and with a mouth surrounded by tentacles. Figs. 38, 34 shcw Clio, commonly known also as "whale's food." They are all free, swimming animals, living for the most part off shore, and most species come to the surface only at night.

Common snails can be easily procured in damp, shaded places, and in the woods; but the best specimens are the edible snails, imported to New York from France, and our common garden snail. They should be drowned by immersion in fresh water under a close cover.

In this situation they die slowly, and apparently with as little pain as possible. The parts are distended with water, and in good condition for examination. The pupil will naturally observe with curiosity the coiled shell, and the large crawling disc or foot.

These observations, in fact, ought to be made upon a live snail, and repeated upon the dead ones, which will then be better understood, and studied with a more lively interest.

The shell, in the first place, will be seen to be brownish, or of various colors, on the outside, and the fact that this coloring resides in an external horny layer, like that of the oyster and clam, established by scratching it a little with a knife.

The opening of the shell will be found to be entire, like the flaring mouth of a trumpet; and thus, if there is an empty shell, also, which can be examined, attention can be called to the difference between this single shell, which is like a cone coiled into a spiral, and the two valves of the Lamellibranchiata. The names "univalve" and "bivalve" are often applied to the snails and oyster in popular literature without any adequate appreciation of their real meaning. The snail shell (Fig. 48) does not correspond to one valve of the oyster, as formerly supposed, but to both valves. It differs principally in not being split into two valves, and is built up by layers around one centre as apex instead of two beaks. In order to appreciate this, begin at the opening and trace the edge of the layers across and around the tube. (Figs. 30–32, from Morse's First Book in Zoölogy.) Then proceed, as in the oyster, back to the beak or apex. This represents the young, and has also another marked characteristic. A little, smooth, bag-like shell lies here, and this was the protective covering of the very young animal.*

The opening of the shell is bordered, and, in a living animal, covered in by a thick, fleshy rim, which is the mantle border; and this, as in the clam, is closely attached to the shell, and is the part which builds the layers just observed (Fig. 25).

The foot projects out of the opening, and it is easy to see that it is a curiously-formed portion of the mantle itself, since they are continuous. The mantle border merely folds inwards, just inside the rim of the shell, and immediately comes out again to form the foot.

There is, however, a hole on one side (Fig. 25, 30, *op*), the breathing orifice. This, in the living snail, may be seen to open occasionally and admit air.

A very interesting series of observations may be made upon fresh-water snails, which can be collected on plants and stones along the borders of ponds and quiet waters.

* In the Mollusca, the shell begins with a disc, which partially divides, forming two valves in the young of the Lamellibranchs, but continues single, and is built out into an egg shape, and then a cone-like tube, in the young of the snails or Gasteropods. Fig. 31 is made from one in which the egg form is already attained, and can be compared with the apex of Fig. 30, *apx*.

Many of these breathe the air, though they live in the water.

Those which breathe the air (Lymnea) come to the surface for that purpose, and may be observed opening the orifice described above, in order to fill the air sac or lung. This serves them while under water until they rise again for a new supply.

Among these true air-breathing snails, there is no special provision for closing the shell. The animal can double up and withdraw its foot inside; and in winter the land Pulmonates, as part of the air-breathers are called, close the aperture often with five successive partitions formed of mucous. These dry into a hard, dense membrane, and keep out the cold and marauding insects, etc. The foot destroys these on the return of spring. Snails protect themselves in this way from excessive dryness also, and in the tropics during the extreme heats of summer. The water-breathers, which have branchiæ for that purpose, must not be confounded with these, and can always be distinguished by their remaining below the surface; and they also have an operculum, or little plate, on the foot, which they use to close the aperture of the shell when they retire within; and the mouth on a sort of proboscis, as in most of the marine forms, to which they are more closely allied than to the true air-breathers with which they live. Fig. 30 shows a specimen of the genus Paludina expanded, and Fig. 32 one contracted.*

The foot itself is a most interesting region for general examination.

The peculiar motions of the land snails as they crawl, — the head part always in front; the feelers stretching out to touch everything, the pair above look-

* See also, for other figures and a fuller account, Morse's First Book in Zoölogy.

ing out for danger, and the lower ones for food; the tiny black dots on the ends of the upper pair, which, however, never seem to see as much as they feel; the motions of the mouth scraping up food; and, finally, the division of the foot into head part and crawling disc, — can all be easily seen. (Fig. 25.)

The long trail of slime left by the crawling disc, and shining aspect of the skin, covered with mucous, are also characteristic of snails.*

If the foot is observed while crawling on a piece of glass, or at the surface of the water, it will be seen to roll on in little waves.

The action is that of an elongated sucker, which is applied closely to the surface, and is held there by the pressure of the excluded air or water, but which is capable of lifting parts or strips of its own substance in rapid succession, and pushing them forward in the form of waves. All of these peculiarities afford a fine opportunity for making comparisons with the oysters and clams, etc., the Lamellibranchs, whose structural inferiority to the snails is thus easily pointed out.

An examination of the mouth should be made, and also of the broad, hard upper jaw. This, if taken out and placed under a magnifier, will show a sharp, serrated edge; and if snails are watched, especially Lymnea, in a water-tank or aquarium, which has been kept a week or so with a few water-plants in it, they

* It is this function which makes dry sand, ashes, or dust, or any irritating substance, the deadliest means of destroying snails, since they become at once covered with the particles, and excrete great quantities of mucous in their efforts to get rid of them, until they die from exhaustion.

will be seen scraping surfaces of the glass, and swallowing the green growths which they have taken off.* Often the land snails will in this way destroy the surface of a paper-box if confined in one. Their favorite food is wet bran or leaves of different kinds of plants, though they will also eat animal food with avidity. They can be successfully kept in earthen pots on bran, if this is dampened, and a small piece of sponge introduced to maintain the moisture. The bran must be changed frequently, and only a few kept together. Leaves, also, of various kinds, lettuce and cabbage, etc., can be used to feed them, and they will live well in Wardian cases.

The strong jaw in the upper part of the mouth works down and back over two cartilaginous pieces, one of which is shown in Fig. 26, *car*. Just below these is the true mouth, and in the back part of this the tongue. (Fig. 26, *to*). This consists of an inner, stiff, cartilaginous part (Fig. 26, *car*), which supports a membrane carrying upon its outer surface a broad band of very small but numerous teeth. These are in rows, and slant so as to have their points directed inwards. This whole apparatus is moved forwards to the opening of the mouth, becomes stretched by this, and the teeth erect and in proper position to receive the coarse pieces cut off by the jaw. These it rasps into smaller pieces against the top of the mouth and under side and edge of the jaw, and passes them backwards into the throat, the whole operation being performed by the aid of numerous and powerful muscles. In moving for-

* They are particularly useful in aquaria in keeping the surface of the glass clear and clean on the inside.

ward again, the slanting teeth are cleaned of whatever they had on them, and leave it to be swallowed by the throat. The teeth are worn out very fast by this operation in front, and the band of membrane carrying them moves forward, bringing up fresh teeth. In order to keep up this supply, there are new rows being continually formed in the rear. These grow in a sort of pocket behind the tongue, and around a core, which is figured in Fig. 26, *co*. This figure shows below at *rd* the inner side of a number of rows, which are formed or forming lower down out of the surface membrane of the core.

The lips on either side of the mouth, and the deep incision between the head and the crawling part of the foot, are also noticeable.

Into the latter opens (*gdo*) the long glands of a yellow color (*gd*), which secrete a large portion of the mucous used by the animal to smooth its path over all surfaces, and, as a lubricator, to render its motions easier by excluding the air more effectually. Some snails and slugs have other openings in the foot for excreting mucous, which dries so rapidly, and becomes so tough, that they can suspend or lower themselves from the branches of trees by its means, as the spider does with its thread, which is also only hardened mucous.

Those who wish to go beyond mere externals will find it necessary to put some of the killed specimens into very dilute acetic acid. This will act upon and dissolve all the exposed parts of the shell, and leave the brown, horny skin entire, if the acid has not been too strong, and effervescence too violent.

Inside of this skin will be seen the mantle, which lined the shell, filled with various internal organs (Fig. 25, *op*). Inflate the air sac from the orifice, and observe the large blood vessel (*j*) leading to the heart, and its network of branches which convey the blood from the whole surface, and expose it to the air within this lung-like cavity.

Cut open the air sac by introducing the point of the scissors at the orifice. The network of blood vessels can be more closely examined by holding the mantle up against the light, and by examining a piece under a magnifier.

It will then be seen (Fig. 25) that each of the larger branches leading to the heart has a vessel (*k''*) from the border of the mantle between it. This terminates in a point, but communicates by numerous transverse tubes, which can be seen by the naked eye, with the vessels (*j*) carrying the blood to the heart. These carry a part of the blood,* aerated by its passage through them, from the mantle border to the heart, from whence it is distributed over the bódy. The beating of the heart, and the course of the blood vessels, can often be seen from the exterior in live snails when the shells are thin. It is concealed on the left side in Fig. 25, but is seen in position in Fig. 27, *vr*, *au*. The arterial vessels (Fig. 27, *art*) which convey the blood from the heart are behind, and can only be followed by injection and dissection. They empty into the great cavity of the foot, and into the spongy mass forming the face or disc below, and also into the other cavities of the body, which are more or less filled by blood. From these it is forced onward into large veins (*k'*), which collect it finally into the mantle border or pulmonary vessel above described, and from thence it passes through the gills to the auricle of the heart (Fig. 27).

The arrangement of the pulmonary veins (Fig. 25) are

* A portion of the blood is carried directly to the auricle without passing through the lungs or gills.

The arrangement of the pulmonary veins (Fig, 25) are so easily made out, and so simple, that it is a very fine illustration of the relations of the arterial and venous systems. These essentially consist of two parts, which I have described as resembling two bushes with their branching heads connected by a spongy mass of interlacing vessels in the body of the oyster, and in some parts of the snail, and in the gills by tubes.

The general course of the arteries and veins is shown in Fig. 27, Paludina, a water-breathing form; the arteries and the ventricle of the heart are shaded; the veins, the branchial tubes, and the cavity of the body in which the blood collects, are left blank. The fluid passes from the foot cavity into the opening of the large vein (*k'*), and from other veins (*k*) into the large vein (*k'*), and through the branchiæ to the vein (*j*), and then to the auricle. This, of course, opens into the ventricle (*vr*), and begins its redistribution in the arteries (*art*). In order to expose the internal organs, more than one animal is necessary.

Open the foot of the snail (Fig. 25) by splitting along the middle line of the bottom. Before the thick, muscular layers are cut through, the yellow double line of the mucous gland (*gd*) will be seen. The large mass of the foot ganglion (*n'*), with its radiating branches, next comes into view in the interior. The branches from this leading forward to other ganglia (*n*) above the throat are also visible.

On the right side is the swollen bag (*sac*) containing the dart; and, attached to this, the long penis (*pn*) with its ducts; and on the other side of these the oviducts (*ov*) leading to the ovaries, — a complicated apparatus, which we have not space to describe.

The snail is, therefore, both perfect male and perfect female, but self-impregnation does not take place. Two individuals, as a rule, conjugate in the production of offspring, and mutually impregnate each other.

The black tubes of retracted tentacles are also visible, but better seen from above, as described farther on. The throat, as a muscular bulb, with its continuation in the flattened, thin-walled tube of the alimentary canal, is also better seen from the upper side. The generative organs are thrown out of place in Fig. 25. They really cover the intestine, and crop from view, and have to be treated in this way to give a view of these parts.

Slit open another specimen on the upper side, beginning between the tentacles.

Lying above the other organs are the two inverted tubes of the upper pair of tentacles, distinguished by their dark-colored interiors; and below them, but partially hidden, those of the lower pair; both of these are exserted in the figure, however. Just around the throat the nervous collar and its ganglia show plainly.

Slit open the throat, or slice a head in two after hardening it in alcohol, and notice the two cartilages upon which the tooth or jaw rests, and the slightly-roughened tongue behind, with its horny surface (Fig. 26).

Introduce a probe into the throat and alimentary canal, and observe how the motion of the tooth in scraping surfaces would at the same time place food within the reach of the lips, and the tongue, by moving back and forth, would help to comminute the food. Follow the alimentary canal backwards, and notice at the same time the ovaries, and how they run back into the spire, and the other generative organs attached to the sac of the dart on the right side. The alimentary canal will be found to expand into a large so-called crop underneath the pulmonary sac; and after that it passes directly onward into the spire to *st*, where the true stomach occurs. Then, turning abruptly down, it crosses around to the point *i*, and making the bend as in the figure, returns around the spire to *i*; and from thence again circles around to *i*, and passing along the floor of the pulmonary sac, terminates at the anus (*an*), alongside of the pulmonary opening in the thick border of the mantle. Between the bends of the intestine are the brownish masses of the liver (*l*), and at *gav* is a mucous or albumen gland belonging to the generative apparatus, of which the larger portion is hidden in the spire. Do not tear the internal organs apart, but carefully skin the mantle from the spire, and observe their relative positions and connections. After this they may be carefully separated with a sharp knife.

When this has been done, and the connection of the alimentary canal and liver tubes traced, it will be easy to follow the intestine with the scissors along its posterior part, where it is imbedded in the wall of the pulmonary sac, until it opens in the angle of the orifice.

Cut away entirely the tube of the œsophagus or throat, and the large muscles accompanying it. This will expose the upper side of the mass of ganglia below, or the pedal ganglion, as it is called. Close observation of the top surface of this will exhibit a peculiar disc or space filled with yellowish granules. This is the rudiment or essential part of an organ of hearing; namely, a sac filled with small calcareous particles.

The capsule of the otolith, or rudimentary ear, is also shown in Fig. 27, *ot*, projecting in this case from the surface of the ganglion.

The eye (*ey*) can also be readily dissected out, and the parts examined. It consists of a lens, a black floor or retina, and a large nerve distributed over its lower part, outside of the retina.

The nerve of the eye penetrates the retina or black layer in the vertebrates, and spreads itself out on the bottom of the capsule inside of this layer. This peculiarity has no parallel in the structure of the Molluscan eye, with the exception of the singular form known as Onchidium. This animal, a naked marine species, a degenerate form of land mollusc, has a number of eyes gathered in groups upon the skin of the back; and each of these, as Semper has shown, has the peculiar structure of the vertebrate eye;

whereas the eyes on the tentacles in the same animal are purely Molluscan in their structure.

The Gasteropoda have no organs of smell, though it is well known that they seem to seek and find food by this means. Perhaps some part of the moist, exposed skin, which is supplied with nerves, acts in this way, since it is well known that, besides the nerves, moisture and air are necessary to this function. Let the scholars hold their breath and drink anything, they cannot taste it until they draw in a current of air over the tongue, unless it is exceptionably bitter, or astringent.

The common Garden Slug, Limax maximus, which may be procured for a trifle from any horticulturist, is also an air-breather (Fig. 29).

Observe in this the saddle or fleshy cushion (*m*) on the back, the orifice on the right side as in the snail, and the similar way in which it opens to admit air (Fig. 29). This saddle is all that is left to represent the mantle. Open it with a sharp-pointed knife or scissors, and you will find a little horny disc inside (Fig. 52). Hold this up against the light, and it will show the usual concentric lines of growth. It is in fact a flattened shell, one which has retained the character of the young or embryonic shell plate, and which, instead of being externally covered only by the epidermis, has been enveloped during growth by a fold of the mantle enclosing it completely in the adult.*

Further dissection will show similar organs to those described in the snail, but all of these are concentrated in the crawling disc.

* Above Fig. 52 is shown an imaginary section through a slug at this point.

The natural order of arrangement, if followed, would have placed the marine gasteropods between the Lamellibranchs and the air-breathing or pulmoniferous gasteropods. The prominent characteristics of these being, that while they are univalves, like the Pulmonifera (snails), they have organs for breathing the air in water instead of lungs, or pulmonary sacs, as they ought to be called. These organs, though not similar to the gills of the Lamellibranchs in appearance, are in reality quite similar when viewed from an analytical point of view. The gills of the Lamellibranchs are tubes united in sheets in the oysters,* but in the marine snails they are commonly in the shape of free, floating fringes of tubes, or rows of projecting plates, thus exposing a much greater surface to the water than if only one side was uncovered (Fig. 27).

When a shell is present, it is always contained, either in a hollow of the mantle lying under the shell, or above in the fold between the creeping disc and the mantle border, as in the Limpet, Patella † (Fig. 50). In all of these animals the heart receives the blood from the gills in front, as described above, and sends out the great artery (aorta) behind; and they are called

* In several types this is not so complete, and they are more or less free and disunited, but still maintain the complicated folds and aspect of the Lamellibranchs, as has been described above.

† The species on our coast belong to Acmea and other genera, which have the gills in plumes, situated in the mantle cavity above the head, though their shells (Fig. 35) are similar to those of Patella, and were formerly described under that name.

Prosobranchiates in consequence, because, in almost all, the branchiæ are also situated in front of the heart, as in those described above. Chiton is a notable exception to this law, the heart receiving the blood and distributing towards the front, as it is also in the shell, which is divided across the back into numerous overlapping plates, giving the whole animal the aspect of a worm on the back. The foot, however, underneath, always enables one to tell that it is a Gasteropod. The shells of the marine and fresh water and land shells of this group are often conveniently distinguished as Siphonated and Holostomated, meaning siphon lipped and entire lipped. The former (Figs. 37, Columbella; 40, Rostellaria) have a fold of the mantle pushed out into a tube, through which water is drawn into the gills; and a canal in the aperture of the shell, often very long, and sometimes a mere notch on the left side, holds this, and the latter (Figs. 35, Acmea; 36, Crepidula; 30, 32, Paludina) have not this notch.

The Siphonated Molluscs are generally carnivorous, and the Holostomated vegetable-feeders; but there are so many exceptions to this rule, that it cannot be safely applied to any one species whose habits are unknown.

Besides the Prosobranchiates, there are other forms usually classified under the name of Opisthobranchiates, because the heart, when it is present, receives the blood from behind, and sends it out through the aorta in front. These are all marine, and though the shell is quite fully developed in some species, most of the forms have it in a rudimentary condition, or absent. The mantle, also, is frequently absent, and the branchiæ wave above the back, free and uncovered in these last (Fig. 28, Eolis), though more or less protected in the others. Notwithstanding this fact, they have a shell and an operculum in the young, as have all others. Fig. 31 is the young of Dota coronata, which moves freely about by means of the ciliated lobes (*vel*) ; has a foot (F), which secretes the operculum (*opr*), eyes, and a mouth, with an oval shell (*apx*) below, into which it can be withdrawn when alarmed.

It must not be imagined that I have attempted to give any adequate idea of the different forms of the Mollusca. The foot, for example, may be almost obliterated in some forms, and in others suffer the most extraordinary modifications, fitting parts of it to be, not only the ordinary walking apparatus here described, but a swimming organ (Fig. 38, 39), a climbing and leaping organ (Fig. 40), and so on, sometimes split longitudinally, sometimes transversely, sometimes a mere lump or plug, and in other cases reduced to a secreting gland.

CEPHALOPODS.

The principal forms of this class of the Mollusca can barely be mentioned, though the author feels that this omission is the sacrifice of an opportunity, which may never recur, of putting before teachers the results of special researches upon one of the most intensely interesting of the problems which bear upon the laws of heredity among animals.

NAUTILI.

The Nautilus is extremely interesting, both on account of its chambered shell, and because the few species which remain among the western Pacific islands and Indian Ocean (East Indies) (N. pomp.) are the last remnants of a host of extinct types which peopled the sea in geologic ages.

This shell is frequently seen in the shops, but should be split open on the lapidary's wheel, in order to show the structure of the internal chambers, and the long connecting-pipe which unites them.

The various forms of these shells and of the animal are described in all general works on the Mollusca; and it is merely necessary to notice that the shell is turned or built in a direction which reverses that of the internal pen or shell of the Squids (Fig. 41) and Cuttle Fishes; and, like the Argonauta (Fig. 43), has the funnel and the ventral part of the body turned to the outside. This is directly the reverse, also, of the position of the animal in the shell among the Gasteropoda.

SQUIDS AND OCTOPUS.

These remarkable forms can only be mentioned, but they are too important and interesting to be skipped entirely.

The body consists of a fleshy bag, hollow in front, and surmounted by a head, furnished with large eyes, and a circle of tentacles or arms surrounding the mouth, which is situated in the forward end (Fig. 41). Inside of the mantle, on the dorsal side, is a long, horny shell, or pen, as it is called.

The mouth has powerful jaws of horn, formed like a parrot's beak, and also teeth inside, situated upon the tongue. The arms are covered with sucking discs, so that they can firmly fasten themselves to their prey, and hold it down to the mouth for the beaks to tear and cut up at their pleasure.

The breathing organs are gills exposed to the water in the mantle cavity, into which opens the intestine and the peculiar gland known as the ink bag, and the generative organs.

The nervous ganglia are very highly organized; and, though they are strictly molluscan in general structure, have a brain case, or sort of cartilaginous skull,* which has been erroneously compared with that of a vertebrate. The eyes are huge, in comparison with the head, and perfect, set in remarkably deep sockets, and have in some species eyelids. Near the upper end (*ey'*) is an opening, *supposed* to be for the excretion of tears, or some sort of lubricator for the surface of the eyes; and in the figure this is accompanied by a notch like the lacrymal sinus in vertebrates. Below the eye is a pit, very small in the species figured (Ommastrephes), and hidden by the mantle, but in others quite large, and plainly visible, supposed to be an organ of smell. In Octopus, the devil-fish, and in Nautilus, this hollow is capped by a sort of short tentacle or fleshy tube. The ear is internal, and situated in the brain case, on the lower ganglia, but has not been proved to connect with the exterior, though there is a partial canal like the inner part of an external ear.

The Squid, or arrow-fish, is common on our shores. Their mode of progression is backwards towards the hindmost or pointed end, instead of the head, — a most

* These and many other forms can be obtained from fishermen. Mr. Vinal Edwards, of Woods Holl, Mass., deals in these and other animals for the use of naturalists.

unexpected interruption of the line, which is indicated by the motions of the body in Gasteropods, which move head-end foremost, and the Lamellibranchs, which, with equal discretion and effect, hold the mouth-end foremost. The fact is, that the situation of the organs, and the shape, make it more convenient for the Cephalopod, like the Lobster, to back out of a scrape than to run away from it. The so-called funnel is a tube leading into the mantle, which is also open at the neck (*on*). The water is admitted or sucked in by expanding the mantle. The rim of this then closes against the neck, the powerful muscles in the walls lower down, contract, and the confined water is driven in a powerful jet out through the funnel, driving the animal back by its reaction. The Nautilus, Argonauta (Fig. 43), Octopus (Fig. 42), and all the Cephalopods move this way; and some, which have webs between the arms, use these also, opening and shutting them like an umbrella.

The fins (Fig. 41) in the Squid are also used in locomotion, though they can only keep the body in position, and move it slowly forwards, if necessary.

A favorite mode of locomotion with Octopus, or devil-fish, is to walk or crawl on its arms, the round body above, as in Fig. 42, though it also swims like the other forms.

The ink bag in the interior is filled with an intensely black secretion. This communicates with the mantle-hollow by a tube opening at the base of the siphon, and when frightened by sudden danger, they squirt out a portion of this through the siphon, forming a dense cloud, blinding their enemy, and concealing their own simultaneous retreat. This excretion, when dried, smells like India ink or Sepia, and may be used as a pigment, though this color is often made artificially.

Cuttle-fishes are flatter and broader bodied than Squids, and have, in place of a horny pen, a curious structure. Buy a cuttle-fish bone, and you can see readily that the outside is not bone, but a hard shell, and the inside filled with a curious chalky deposit in layers, but in no respect resembling a bone. The Squids and Cuttle-fishes have ten arms around the mouth and side fins. The eight-armed Devil-fish, Poulp, or Octopus, is found on our coast, also, but only of small size, and in deep water.

The Argonauta, about whose beautiful shell so many popular traditions have been woven, crowns this group in a becoming manner.

And as many of the popular books are in error about the last named, it may be as well to mention, that the Argonauta never sails on the surface with its outspread arms, but prosaically swims, squirting its way backwards like the Squid.

But while we have lost the tradition, we have gained something of more value, — the knowledge that this is not a true shell fastened to the body by muscles, but an excretion, partly of the mantle, and of the edge of the mantle, and of the great sail-like arms, which are thrown backwards over and closely envelope the shining white surface; and that it is simply a lovely case built by the female to protect herself and the large bunches of eggs which she carries.

Fig. 43 shows the female, with six arms extended, in the act of swimming backwards; one of the other two arms, with its broad membrane, is shown as a surface (*am*), covering up all of one side of the shell, except a small part of the spiral and opening, out of which projects a part of the eggs. The male is naked, much smaller than the female, and, like the Octopus, has no internal or external shell.

Some of the Cephalopoda reach an enormous size. Prof. Verril describes the gigantic Squids of our coast, one of which was on exhibition in Boston not long since, measuring 9.5 feet from tip of tail to the base of the arms; arms 11 feet, and longest arms 30 feet.

These, and the gigantic Octopi of the tropical seas, have given rise to the tradition of the Kraken.

In the Marine Chapels along the coast of Europe, figures of huge Octopi, clasping large ships with a frightful perplexity of arms, some curled even around the royal yards, are not uncommon. We have no means of ascertaining how much truth there is in these representations, which are doubtless exaggerations, but that the Sperm whales feed on very much larger forms than any yet described, seems probable.

To complete this hasty sketch, it is necessary only to state that the sexes are distinct; and that, while reproduction in some forms takes place by direct conjunctions, as in Squids; in others, as in the Argonauta, one of the arms becomes loaded with spermatozoa, and breaks off, finding its way into the mantle of the female. When first found, it was regarded as a parasite, and described as a distinct, worm-like animal, under the name of Hectocotylus.

The obvious fact, which strikes the observer in looking back over the various forms passed in review, is the almost constant presence of the mantle employed to protect both the viscera and breathing organs when fully developed, and, when reduced to a small size, still covering the breathing organs. The shell is present in nearly all instances wherever the mantle itself is found; and it is invariably found in the young, even of the naked marine Mollusca, Nudibranchs.

The foot may be said, perhaps, to be more constant than the mantle.

The general plan of the molluscan body seems to be, therefore, that of a fleshy bag or sac, containing the viscera, which is normally divided or constricted, so as to form two regions, — the mantle region and the foot region, — though either one or the other of these may be absent. The modification of the body observable in the different groups can all be reduced to different expressions of these two combined in the higher groups, with a tendency to transform the mouth end into a true cephalic or head region.

The Lamellibranchs are flattened bags, cleft at either end, with the foot projecting from the centre.

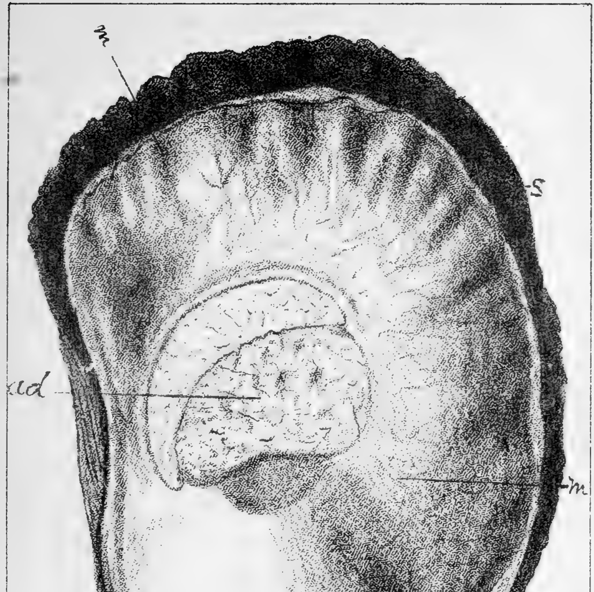
A cloth model can be made to show this, with the foot in the centre, and the breathing organs, as folds of the mantle, disposed on either side. Fig. 44 shows a section of such a flattened bag, and Fig. 45 a side-view of the same, the position of the alimentary canal and ganglia and nerve circle being also roughly indicated. The branchiæ are reduced also to their simplest form, as two lateral arms bearing two rows of tubes. This can be supposed to be bent together, inclosing the foot and gills; and then, if to this the shell is added, in the shape of a piece of pasteboard properly drawn, and the ends of the bag represented by dotted lines in

Fig. 47, the result is a fair presentation of the Lamellibranch. Imagine this bag or mantle in one piece, slightly conical in form, the foot changed to a broad, flat, crawling disc, and the gills arranged in rows of plates on the side, as in Fig. 50, and the result is Patella, a Gasteropod, of which a section is shown in Fig. 51. Elongate the cone and shell, twisting it into a spiral, and carry up the fold at the mantle border into a deeper pouch, protecting the breathing organs, and we have a coarse model of the Marine Snail (Fig. 53). Reduce the cone in size to a mere patch on the back of the foot, or finally abolish it altogether, and we have first Limax (Fig. 54), and then the Nudibranch* (Fig. 28).

* This is, therefore, a form which has retrograded or lost the normal characteristics of its type more even than the Limax, since one region of the body has wholly disappeared. To this may be added another curious but instructive instance. There are but few parasitic Mollusca, but among them is one originally supposed to be a worm, and found in the interior of Holothurians (Huxley's Anatomy of Invert., p. 440.). This can be truthfully said to present none of the characteristics of the type in the adult, but the embryo is a true Mollusc, having even the shell gland and shell. No other inference is here possible, except that the mode of life, as a parasite, has effected this remarkable retrogression by which the animal in course of growth has lost that which fitted it to live in the external world, and changed so completely as to present a singular resemblance to a worm. I say a resemblance, because it is not changed into a worm, but into the close semblance of one; for the worms themselves have a plan of structure of their own, to which this cannot be referred. The illustration is brought forward merely to show the futility of using word-bound definitions, since all structures are liable to the most fundamental changes whenever the conditions of the surroundings of existence are fundamentally changed.

Carry the cone of the mantle out straight, as in the Squid (Fig. 55); turn the hinder end of the foot forward, and bend the edges outwards until they meet, so as to form the tube for ejecting water; enlarge the eyes, making them lateral, and seated on the sides of the head, as they are also in many Gasteropods; produce parts around the mouth into numerous tentacles, and the result is an image of the Squid. But in this last transformation the mantle hollow, the gills, and the opening of the intestine have shifted from the dorsal to the ventral side. This has caused many naturalists to suppose that the Cephalopod was really itself a reversed animal; whereas the nervous system, the eyes, the tongue, and intestine show that it is the mantle hollow and accompanying organs which have shifted place.

In this coarse way we can show that the elements of the structure are after all the same in all Molluscs; but here must be repeated the caution given in No. V. These processes are not nature's processes; they do not show how she has modified animals, but how we can explain by artificial means certain relations of parts, certain homologies, and certain changes which have taken place through the action of other and more natural agencies.



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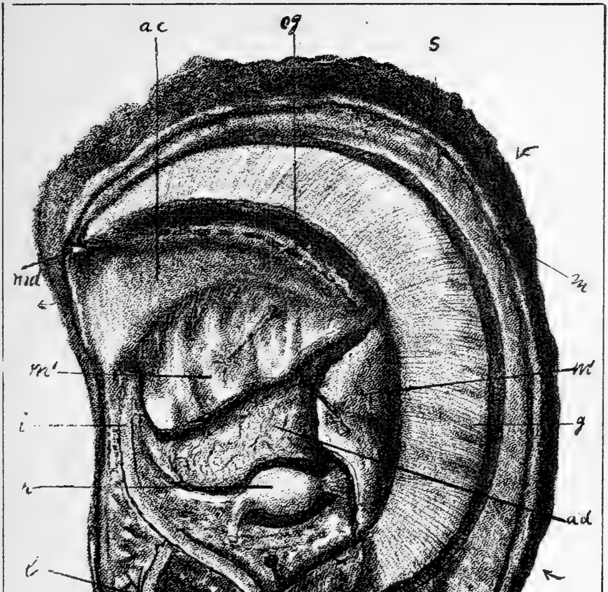

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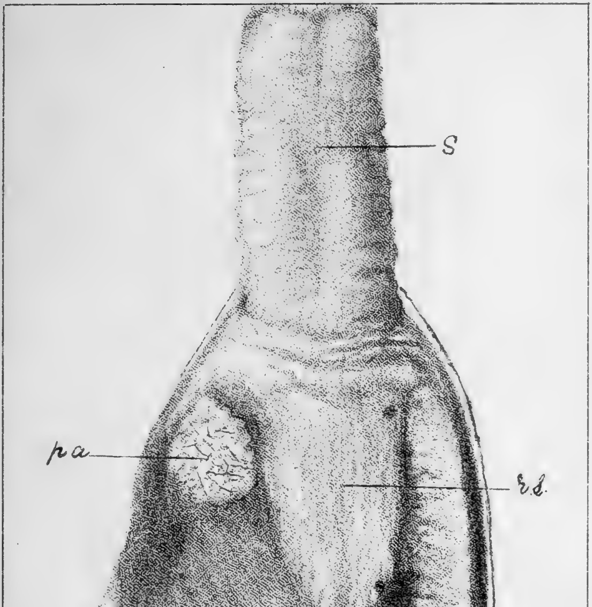
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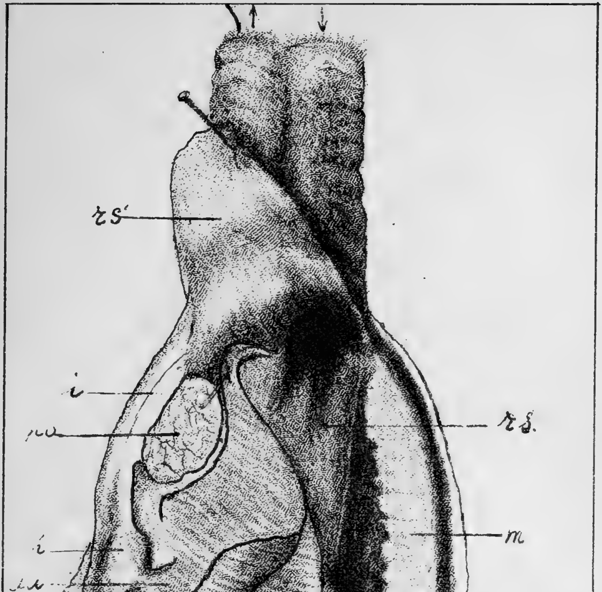
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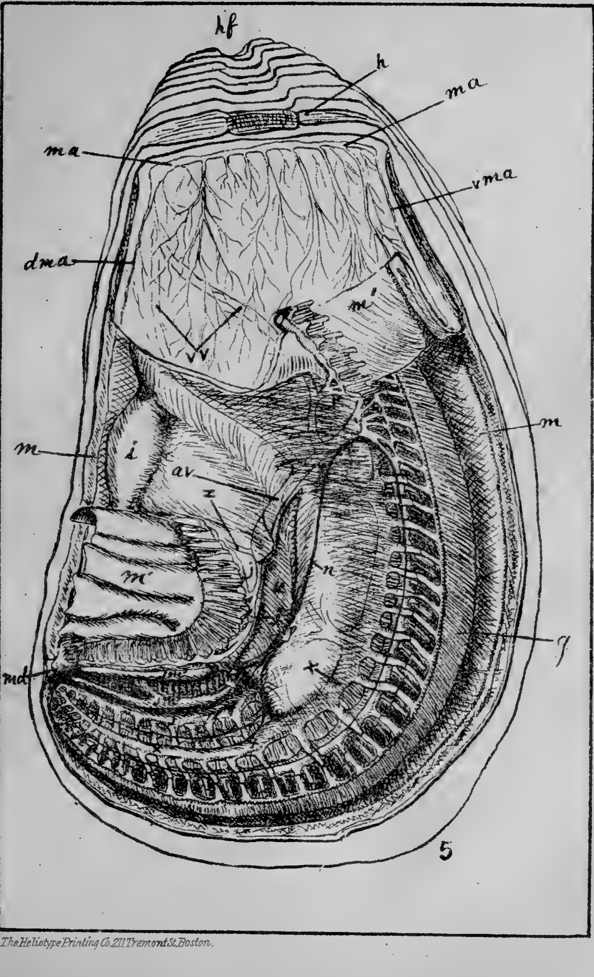

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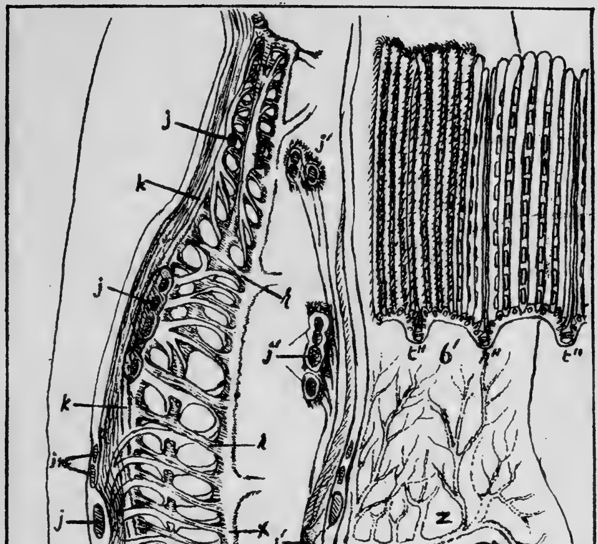

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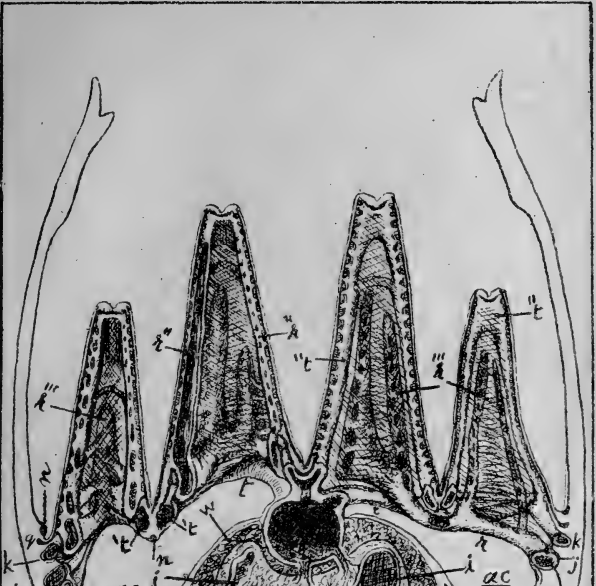
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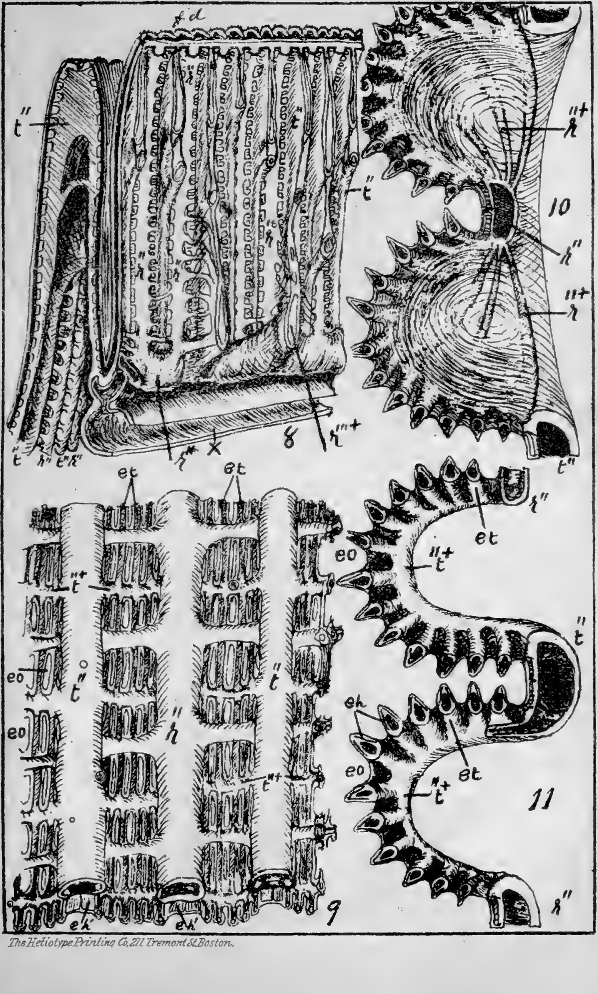

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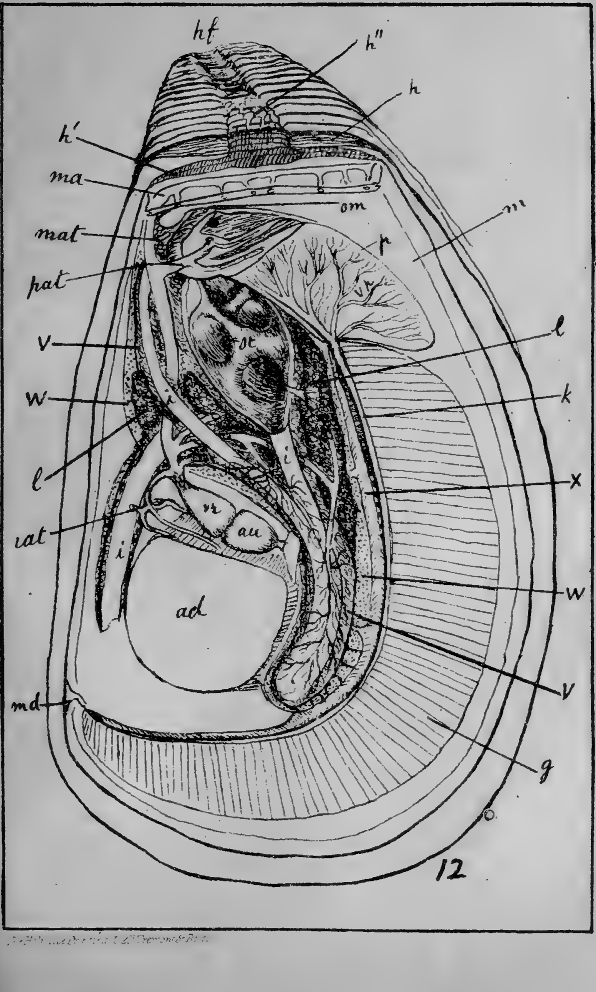

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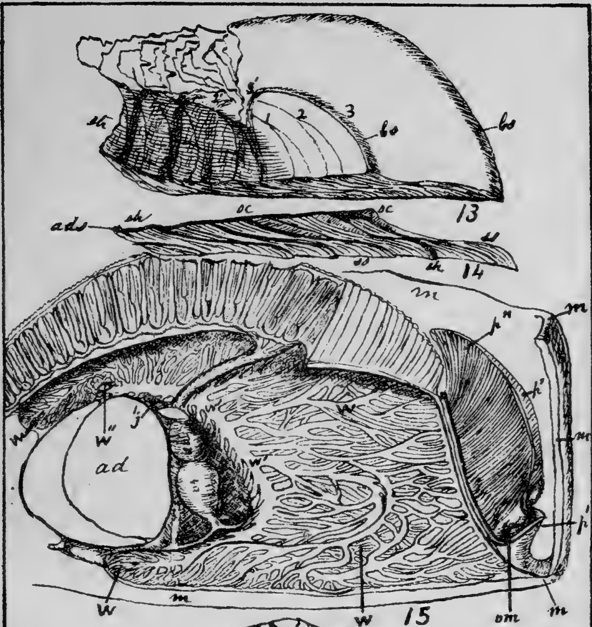

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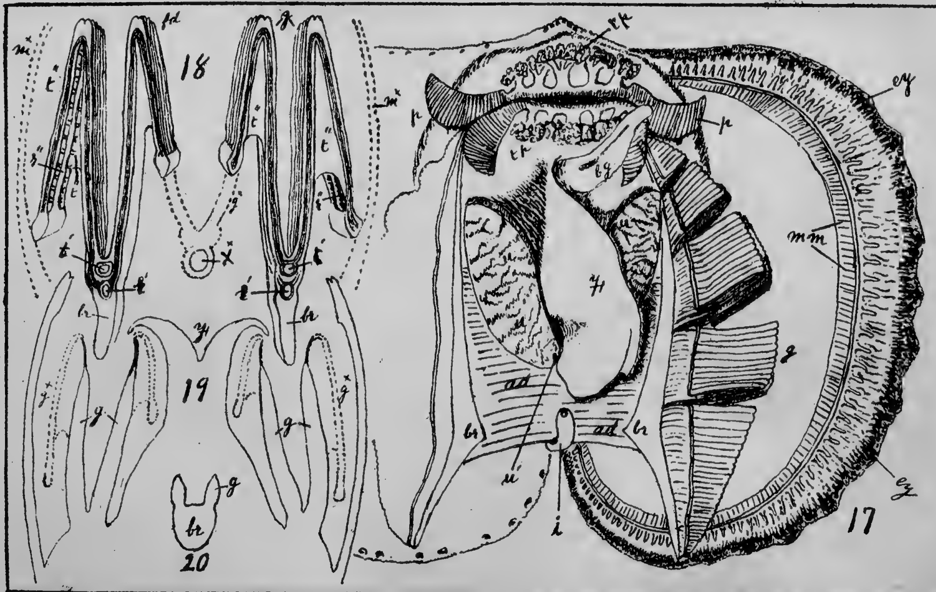

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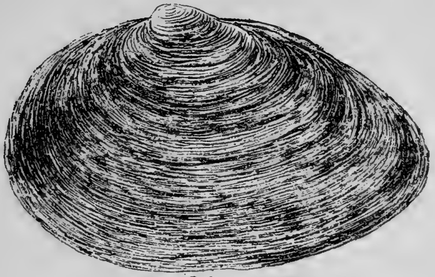

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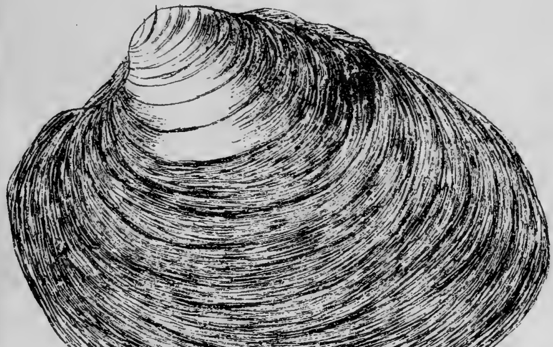

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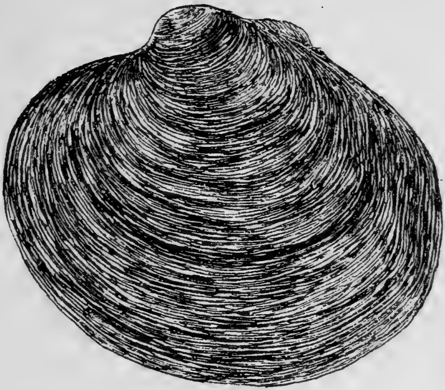

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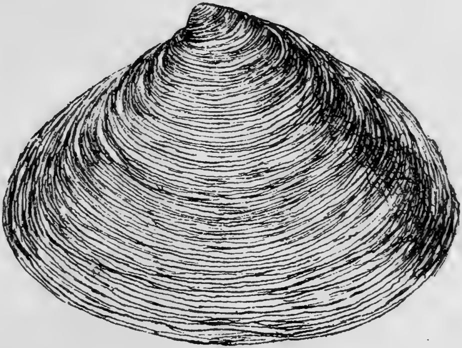

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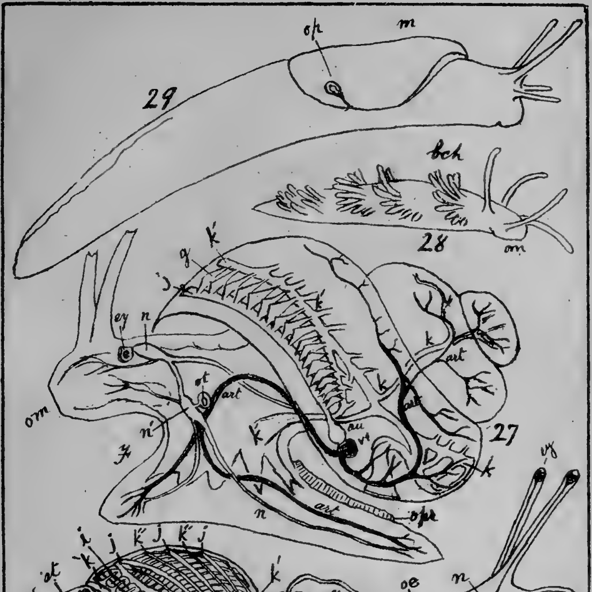

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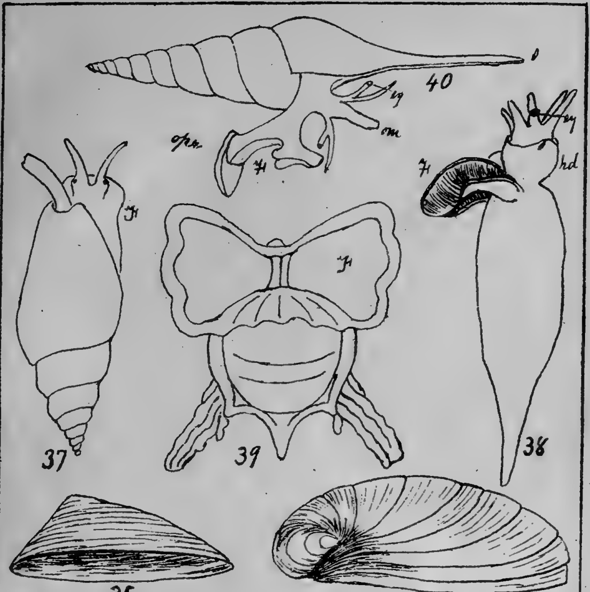
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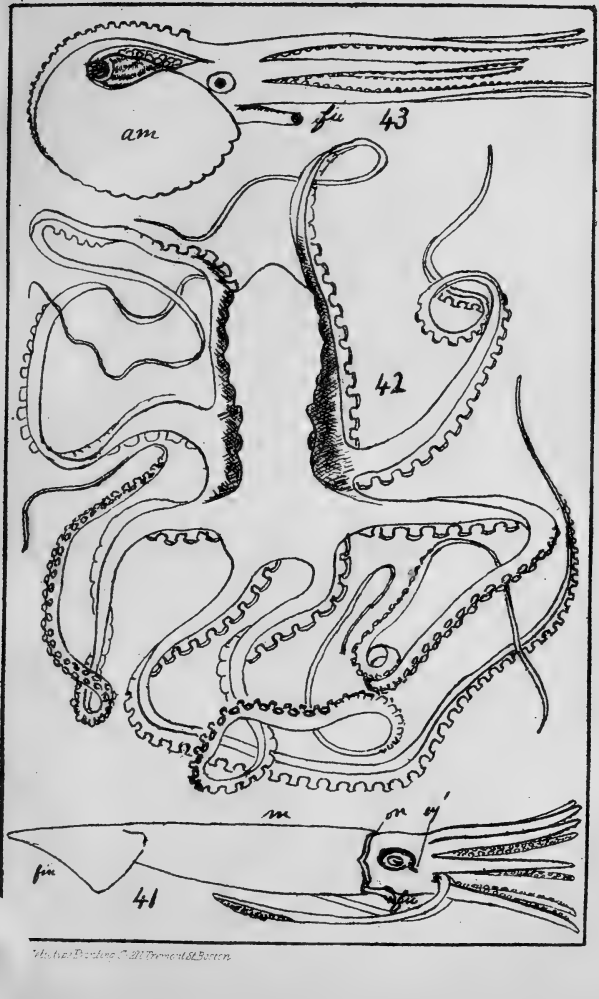
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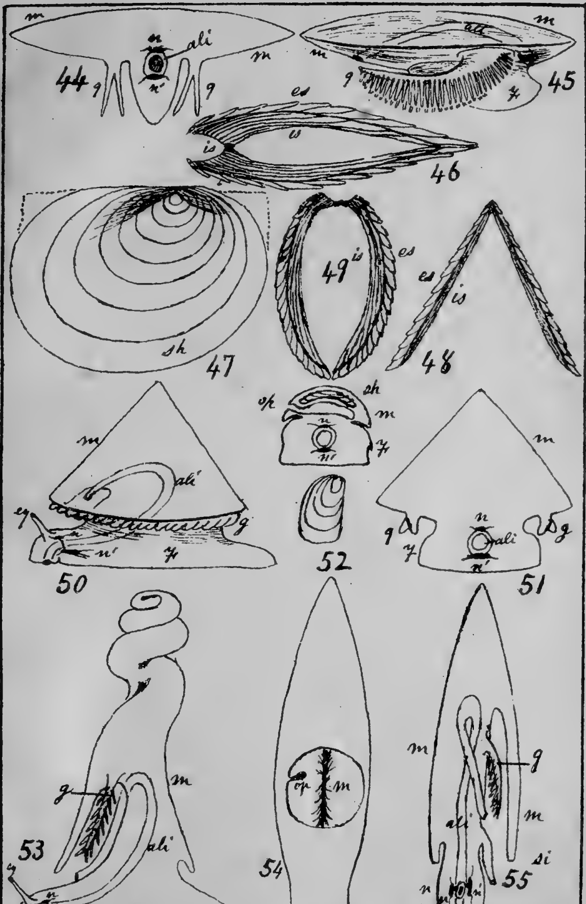

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