XXV.—THE METAMORPHOSIS AND POST-LARVAL STAGES OF DEVELOPMENT OF THE OYSTER.

By John A. Ryder.

Professor Brooks in his elaborate paper on the development of this mollusk, in the report for 1880 of the commissioners of fisheries of Maryland, page 25, observes, in relation to the oldest embryos figured by him (Figs. 44 and 45, Plate VI): "The American oyster reaches this stage in from twenty-four hours to six days after the egg is fertilized, the rate of development being determined mainly by the temperature of the water." He further states, "All my attempts to get later stages than these failed through my inability to find any way to change the water without losing the young oyster, and I am therefore unable to describe the manner in which the swimming embryo becomes converted into the adult, but I hope that this gap will be filled either by future observations of my own or by those of some other embryologist." These remarks applied to the American oyster, *Ostrea virginica.* Since then Prof. H. J. Rice has described what he has called the *proboscis stage* of development of the embryo oyster, said to be assumed after the oldest stages figured by Brooks have been passed over. This stage the writer has never seen, or if it was observed, he has failed to note what has been found by Rice.

The embryo European oyster, *O. edulis*, has been discussed by Professor Huxley,* and his remarks upon the manner of its metamorphosis, on account of their clearness, I take the liberty of reproducing here with some slight verbal changes; I have also borrowed one of his figures in order to make his language more easily intelligible. His remarks are as follows:

"The young animal which is hatched out of the egg of the oyster is extremely unlike the adult, and it will be worth while to consider its character more closely than we have hitherto done.

"Under a tolerably high magnifying power the body is observed to be inclosed in a transparent, but rather thick shell (Fig. 1, L), composed, as in the parent, of two valves united by a straight hinge, *h*. But these valves are symmetrical and similar in size and shape, so that the shell resembles that of a cockle more than it does that of an adult

* In a lecture delivered at the Royal Institution, Friday, May 11, 1883. Published in full in the English Illustrated Magazine for October and November, 1883, pp. 47–55 and 112–121.

oyster. In the adult the shell is composed of two substances of different character, the outer brownish, with a friable prismatic structure, the inner dense and nacreous. In the larva there is no such distinc-

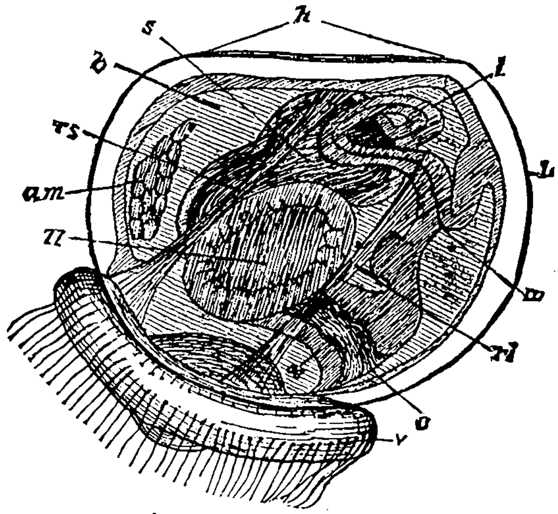

FIG. 1.

tion, and the whole shell consists of a glassy substance devoid of any definite structure.

"The hinge line answers, as in the adult, to the dorsal side of the body. On the opposite or ventral side, the wide mouth *o* and the minute vent *a* are seen at no great distance from one another. Projecting from the front part of the aperture of the shell there is a sort of outgrowth of the integument of what we may call the back of the neck, into a large oval thick-rimmed disk termed the *velum*, *v*, the middle of which presents a more or less marked prominence. The rim of the disk is lined with long vibratile cilia, and it is the lashing of these cilia which propels the animal, and, in the absence of gills, probably subserves respiration. The funnel-shaped mouth has no palps; it leads into a wide gullet, and this into a capacious stomach. A sac-like process of the stomach on either side (the left one *ll* only is shown in Fig. 1) represents the 'liver.' The narrow intestine is already partially coiled on itself, and this is the only departure from perfect bilateral symmetry in the whole body of the animal. The alimentary canal is lined throughout with ciliated cells, and the vibration of these cilia is the means by which the minute bodies which serve the larva for food are drawn into the digestive cavity.

"There are two pairs of delicate longitudinal muscles, *rs ri*, which are competent to draw back the ciliated velum into the cavity of the shell, when the animal at once sinks. The complete closure of the valves is effected, as in the adult, by an adductor muscle, *am*, the fibers of which pass from one valve to the other. But it is a very curious circumstance that this adductor muscle is not the same as that which exists in the adult. It lies, in fact, in the fore part of the body, and on the dorsal side of the alimentary canal. The great muscle of the adult, on the other hand, lies on the ventral side of the alimentary canal and in the hinder part of the body. And as the muscles, respectively, lie on opposite sides of the alimentary canal, that of the adult cannot be that of the larva which has merely shifted its position; for, in order to get from one side of the alimentary canal to the other, it must needs cut through that organ, but as in the adult, no adductor muscle is discoverable in the position occupied by that of the larva, or anywhere on the dorsal side of the alimentary canal; while, on the other hand, there is no trace of any adductor on the ventral side in the larva, it follows that the dorsal or anterior adductor of the larva must vanish in the course of development, and that a new ventral or posterior adductor must be developed to play the same part and replace the original muscle functionally, though not morphologically.*

"This substitution is the more interesting since it tends to the same conclusion as that towards which all the special peculiarities of the oyster lead us; namely, that, so far from being a low or primitive form of the group of lamellibranchiate mollusks to which it belongs, it is in reality the extreme term of one of the two lines of modification which are observable in that group. The *Trigoniæ*, the arks, the cockles, the fresh-water mussels and their allies, constitute the central and typical group of these mollusks. They possess two subequal adductors, a large foot, and a body which is neither very deep nor very long. From these, the series of the boring bivalves exhibits a gradual elongation of the body ending in the ship-worm (Teredo) as its extreme term. While, on the other hand, in the sea-mussels, the *Aviculæ* and the scallops, we have a series of forms which, by the constant shortenings of the length and increase of the depth of the body, the reduction of the foot, the diminution of the anterior of the two adductors, and the increase of the posterior, until the latter becomes very large and the former disappears, end in the oyster.

"And this conclusion that the oysters are highly specialized lamellibranchs, agrees very well with what is known of the geological history of this group, the oldest known forms of which are all dimyary, while the monomyary oysters appear only later.

"When the free larva of the oyster settles down into the fixed state the left lobe of the mantle stretches beyond its valve, and applying itself to the surface of the stone or shell to which the valve is to adhere,

* The larva of the cockle has at first, like the oyster larva, only one adductor, which answers to the anterior of the two adductors which the cockle possesses in the adult state.

secretes shelly matter, which serves to cement the valve to its support.* As the animal grows, the mantle deposits new layers of shell over its whole surface, so that the larval shell valves become separated from the mantle by the new layers, which crop out beyond their margins and acquire the characteristic prismatic and nacreous structure. The summits of the outer faces of the umbones thus correspond with the places of the larval valves, which soon cease to be discernible. After a time the body becomes convex on the left side and flat on the right; the successively added new layers of shell mold themselves upon it; and the animal acquires the asymmetry characteristic of the adult."

In my article entitled "On the fixation of the fry of the oyster," published in the Bull. U. S. Fish Commission, II, 1882, p. 383–387, I have already described the manner in which the young embryo of *O. virginica* affixes itself by the border of the mantle. Upon comparing the above-quoted description, given by Professor Huxley, of the way in which this takes place in that of *O. edulis*, it will be observed that there is little or no difference in this respect between these two species. I have, however, entered more fully into a description of the manner in which the metamorphosis into the spat shell is effected than was done by Huxley, having indicated in my Figs. 5, 6, 7, and 8 the pecteniform or scallop-like appearance of the shell of the spat in its very young condition, with the dorsally straight-bordered anterior and posterior alæ of the valves which are developed at this time. It is also a very significant fact that the young oyster spat should resemble in its early condition the form permanently assumed by some of its nearest allies, the pectens. And it may be explained only by the well established doctrine that even highly specialized forms tend to reassume during the early stages of their existence the form of the type from which they have been evolved.

The hinge border of the embryos of both *O. virginica* and *O. edulis* is straight, and in both species there is an umbo developed on both valves of the larval shell during its later stages. This character is also observed in the young stages of native oysters from other parts of the world, as in those from the Pacific, on the coasts of California and Peru. It is therefore very probably characteristic of all of the members of the family.

My observations upon the internal organization of the young spat were made upon some that were removed from the smooth inner surface of the dead oyster and clam shells, which had been sown on the bottom in Cherrystone River, Virginia, by Captain Hine and Mr. W. H. Kimberley in the spring of 1881. A number were removed from such situations without injury, so that I could study them under the micro-

[* The young oyster is not cemented directly to its fixed basis by the calcareous substance of the shell, but by the brown cement substance which is quite apparent on the outer surface of the valves. This layer answers to the periostracum of the adult, and is probably what was really meant by the speaker.]

scope as transparent objects in the living condition, and with the cilliary structures in lively movement and the heart pulsating as though nothing had occurred to injure them.

The shells of the smallest specimens I obtained during the season of 1881 were about one-eighth of an inch in their greatest diameter or about ten times as large as the shell of the fry when it ceases to swim. Since then much smaller specimens have been obtained. Lest any one should suppose that I may have mistaken the young of *Anomia*, or the "silver-shell," for that of the oyster, let me here remark that they are very readily distinguished even when very young. The valves of young "silver-shells" are lustrous, very smooth, and thinner than those of the oyster; the shell of the young of the latter is never lustrous, and is almost always marked with bands of a dark or purple color which run from the hinge in a radial manner to the edges of the valves. There is no mistaking these differences, and only a little experience will enable any one to distinguish the very smallest spat of *Ostrea* and *Anomia* apart.

Another means of distinguishing the spat of *Anomia* from that of *Ostrea* is afforded by two other characters not before mentioned. There is no pigment developed in the shell of the former, while almost invariably in the young oyster a well-marked deep purple streak runs from the hinge-border of the valves to the free-margin, especially in the upper or left one. This streak also usually widens as it approaches the margin of the valve and coincides with the radius of the shell in which the great posterior adductor is developed. This streak is, in fact, in great measure due to the fact that the insertion of the adductor in *O. virginica* is deeply pigmented throughout life, the deposit of color at first shimmering through the thin translucent valves of the young oyster. It is probable that in the spat of *O. edulis* no such purple streak is present on the upper valves, because in that species the insertion of the adductor is rarely if ever pigmented. The purple streak in the upper valve of the spat of *O. virginica* also serves to distinguish which is the posterior or upper margin of the shell, upon mere superficial inspection, inasmuch as when at all well developed it is nearest the posterior margin of the shell. Occasionally spat of *O. virginica* is found in which pigment is almost entirely wanting.

A second character which distinguishes the spat of *Anomia* from that of *Ostrea* is the following: In *Anomia*, when the shell is forcibly detached from the surface to which it is affixed, both the upper and lower valves may be lifted from their nidus; in *Ostrea*, on the contrary, it is only the upper valve which can usually be removed, the lower one being firmly cemented to its surface of attachment. The lower valve of the spat of *Anomia* is never cemented to the surface of fixation, the lower valve of *Ostrea* invariably. The byssal plug of *Anomia* in its spat stage, as well as in the adult, finally perforates the lower valve, and this is the only attachment of the animal to its fixed basis. As elsewhere mentioned by the writer, the lower valve of *Ostrea* may be cemented to its basis of attachment over its entire outer surface till it has attained a size of two inches in diameter.

Fig. 2 represents the small spat of which I have just spoken, magnified thirty-two times, and which presents so many peculiarities as compared

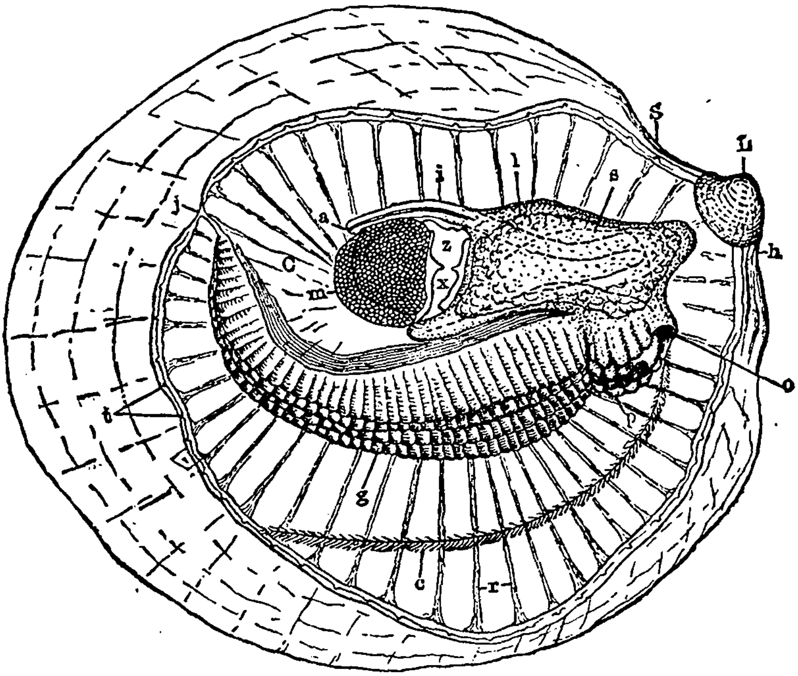

FIG. 2.

with the adult that it will be desirable to describe it somewhat in detail.

The shell in individuals as small as this up to three-fourths of an inch in diameter is nearly always almost round or oval in outline, and very thin, so as to be easily broken with pressure by the thumb or finger. In very young ones, like the one figured, the valves are still transparent, but when a little older they become, first, translucent, then opaque, as they acquire increased thickness. In the case of Fig. 2, the shell, which formerly covered the swimming or fry stage, is attached at the hinge ends or beaks of the valves. It measures about $\frac{1}{90}$ of an inch in diameter, and shows concentric lines of growth, with apparently well developed beaks, or umbos, which are also doubtless present in the young spat of the European oyster at a late stage, or after fixation. Only the larval shell of the right side is indicated at L in the figure; it is permanently fixed to that of the spat shell S, but does not present the microscopic characters of the latter. The former appears to be smooth and concentrically laminated, and not altogether structureless; the latter, under a power of 150 diameters, shows that it is made up of very minute transparent polygonal prisms of carbonate of lime arranged vertically to the plane of the shell; each of these prisms measures $\frac{1}{7500}$ of an inch in diameter, and gives the appearance of an irregular tesselated pavement under the microscope. They are held firmly together by an organic material more or less nearly identical with the hard outer crust of insects. In the latter this material is called *chitin;* in the shell of the mollusk, where it binds the prisms of lime solidly together, it is called *conchiolin.* As development advances the shell is thickened from within by the deposition of lime carbonate on the inner surface of the valves; this lime carbonate is secreted from the blood of the animal and is primarily derived from the food; the organ, which is the effective agent in laying down this deposit, is the mantle, the margin of which is provided with sensitive feelers or tentaculæ as indicated in an undeveloped condition by the small wart-like prominences at the border of the mantle organ at *t.*

The mantle is a highly sensitive structure, and is provided with radiating muscular filaments, *r*, which run through its substance outwards to its margin in every direction. These radial muscular bands are very distinct in the young, as indicated in our figure. In young oysters and "silver-shells" its margin is sometimes seen protruded beyond the edges of the valves, when the animal has its shell open, and is quietly feeding. The mantle covers the right and left sides of the soft body of the oyster like a cloak; the leaves of opposite sides are joined together at the middle line near the hinge *h* and at a point near the ventral hinder end of the body J where the gills *g* end. The extent of the union of the right and left leaves of the mantle behind or below the hinge I have not been able to make out clearly in these young specimens of spat. Only the left leaf of the mantle is shown in Fig. 2.

The gills *g* of the spat are well developed at this early stage, and extend between the right and left leaves of the mantle from the palps or lips *p* to the point *j*. They are much like the gills of the adult, but above them the upper gill chamber is wider, and the cloacal space C, which lies between the adductor muscle *m*, the hinder part of the gills and the leaves of the mantle at the sides, is remarkably spacious. The gills are at this stage already very evidently of the type seen in the adult; they are really four elongated pouches suspended between the leaves of the mantle with vertical rows of pores arranged in the furrows on their surface; these pores convey the water into the hollow gills, from which it passes through rows of large holes above into the upper gill chamber and out by way of the cloaca C.

In the spat, I also find in the course of more recent studies that there is a very delicate branchial skeleton formed of very fine quadrangular meshes of a chitinoid substance, which, as in the adult, serves to give support to the soft tissues of the gills. Whether there is present a delicate thin membrane in the skin covering the mantle of the spat, composed of very fine interlacing fibers, as in the adult, I am unable to state.

The palps or lips of the young spat at this stage are not at all like the palps of the adult. They are much shorter, as indicated at *p*, but the upper or anterior lip passes like a hood in front of the mouth *o*, and the lower, hinder, and inner one bends backwards on either side behind the mouth. In the adult, the inner surface of the outer pair of palps or upper lips are furrowed with numerous shallow grooves; in the lower lip the outer and upper surfaces are so furrowed. In the young, a different state of affairs exists. Here furrows can scarcely be said to be present; but the lips are apparently divided into more or less distinct conjoined parallel lobes; their number, unlike in the adult, is also very few, or about 4 to 5. I have counted over one hundred folds and furrows on one side of the lower lip or palp of the adult: we would naturally expect to find them fewer in number on the same parts in the young animal.

At the hind or ventral borders of the palps their edges seem more or less nearly continuous with the gills, and, as there are four of the latter as well as four posterior ends to the lips, it would appear probable that both palps and gills originated from very nearly the same primitive structure. That is, suppose the four folds or rows of branchial processes of which the gills are formed were at first developed from a tract of epiblastic tissue, or the skin-layer proper, from which the palps also are differentiated, and it is possible to conceive of them as having been developed from nearly the same type of rudiments, that is, longitudinal folds of epiblast which were at first continuous.

The mouth of the spat in Fig. 2 opens downwards and not so directly forwards or dorsally as in the adult. This fact, taken in connection with the singular change of place undergone by the mouth in its passage from the fry stage to that of the spat, is significant and will be discussed farther on.

The ciliated band *c* in Fig. 2 gives an ideal representation of the way in which the cilia on the inner surface of the mantle are arranged and how they may be brought to act in conveying the food to the mouth *o*. The gills also are of course clothed with cilia, as in the adult.

The course of the intestine *i* is very much the same as in the adult; the vent *a* lies just over the adductor muscle *m*, and the stomach *s* is enveloped by the brown liver *l*, which appears to constitute the principal portion of the body-mass, exclusive of the intestine and stomach, at this stage. The heart is divided into a pair of auricles, *x*, below and a medially divided ventricle, *z*, above, and like the heart of the adult, lies in a crescent-shaped heart-cavity. Where the intestine returns and bends sharply backwards on itself above the mouth, there is a rounded projection of the body-mass forwards, which is not seen in the adult.

The most striking changes in the relations of the intestine after the larval condition is past and that of the young oyster has been assumed as spat, may be observed upon comparing together Figs. 1 and 2; Fig. 1 shows a larva viewed from the left side; Fig. 2 represents the spat as seen from the right side, but in both the course of the intestine is displayed. In Fig. 1 the single loop of the intestine *i* does not extend nearly as far forward anteriorly as in Fig. 2, it is therefore evident that during the metamorphosis this loop is prolonged so that in the adult it actually crosses the gullet, but the intestinal canal as a whole remains flexed upon itself in much the same manner from the later larval stage onwards with its anterior flexure thrown forward over the left side of the stomach. The posterior end of the stomach, together with the first flexure of the intestine is afterwards considerably depressed, while the œsophagus is thrown upwards and between the first flexure of the intestine and the rectum, the permanent posterior adductor muscle *a* (Fig. 2) is developed, very probably from wandering cells which have dehisced from the visceral cavity or blastocœl of the embryo.

Upon comparing the two figures it would appear as if the mouth *o*, Fig. 1, together with the œsophagus and forepart of the stomach, would have to be rotated through an angle of nearly ninety degrees in order to bring it into the relation with the hinge *h*, as shown at *o*, in Fig. 2. This alteration in the relative positions of the viscera during the passage of the larva into the adult condition is one of the most striking changes which occur during the metamorphosis.

One of the most conspicuous differences between the symmetrical larva and the young spat is the absence of gills in the former and their presence in the latter. These grow out as blunt fleshy processes, behind the mouth *o*, and in front of the anus *a* (Fig. 1), after a pallial sinus has been formed in that position. Sections which I have prepared of very young spat seem to show that the development of the branchiæ is not completed until some time after the fixed and spat stage has been assumed. Cross-sections of very young spat one-eighth of an inch in diameter show only two gill pouches developed posteriorly, instead of four, as in the adult; this would indicate that the outer gill pouches are formed during the young condition of the spat, and some time after the symmetrical larval condition has been passed. As far as the branchial system is concerned it therefore appears evident that it is completely developed after the true larval condition is over, and the metamorphosis is otherwise complete.

The liver, according to the testimony of a number of investigators, arises as a pair of hollow outgrowths on either side of the stomach. It seems therefore to develop from bilaterally symmetrical rudiments like the shell, and that its subsequently more complex structure is a result of secondary or later processes of growth, affecting mainly the walls of the original right and left hepatic lobes. These hollow lobes seem to arise rather from the lower lateral portions of the gastric dilatation of the alimentary canal of the embryo, and traces of this original symmetry are not wanting when we come to observe the relations of the hepatic structures to the stomach in the adult, which is very apparent when cross-sections are examined. While there seems to be only two hepatic diverticula in the embryo, from the alimentary canal it is evident that the liver in the adult opens into the gastric cavity by way of four principal ducts, one pair being more anterior in position than the other; this may be a result of the transverse division of the primitive ducts, just as the lobules of the liver are multiplied by the upgrowth of folds on the walls of pre-existing follicles, by which the latter are again and again subdivided and multiplied in the course of further growth. The hepatic tissues are most extensively developed below and at the sides of the stomach in the adult, sparingly at the upper part of its sides, and are altogether wanting immediately above it along the median line. Together with its increase of size the number of its follicles increases very greatly so that there may be thousands in the adult, whereas there were at first but two in the embryo.

Cross-sections of the soft parts of the young spat show the hepatic follicles proportionally larger than in the adult, but far less numerous, there being at most not over a few dozens present in spat of the size shown in Fig. 2.

The connective tissue also, which forms so large a proportion of the soft parts of the adult, is very sparingly developed in the spat, of the size here figured. In the young larva the connective tissue appears to be represented only by a few multipolar cells and the cells which enter into the formation of the anterior adductor and retractor muscles of the velum. In the spat there does not appear to be any connective tissue or mesoblast between the liver follicles (hypoblast) and the mantle (epiblast), which forms the integument or body walls of this stage. The development of connective tissue in such quantity as is found in the adult therefore occurs during the time intervening between the development of the earliest condition of the spat and the stage of growth reached within the next following twelve months. In the course of its development the connective tissue remains in part spongy, and has a lacunar structure in some parts, but in certain parts of the body-mass its component cells enter directly into the formation of the walls of the principal vessels which are devoid of an endothelial lining. As the stratum of connective tissue increases in thickness, the organs of epiblastic origin, the mantle and gills, and those of hypoblastic origin, the alimentary canal and its appendages, are more widely separated from each other by it.

The vascular system and heart both originate from the connective tissue or mesoblast. In the youngest stages of the larva there is no heart developed, and inasmuch as the walls of the vessels traversing the body-mass in the adult are formed of connective tissues alone, there can, of course, be no vessels developed in the larva, where the connective tissue is still practically undeveloped as a discrete layer. The colorless blood-corpuscles of the oyster are also probably not developed in appreciable numbers until after the true larval stage is past.

The intestine of the larva is a simple internally ciliated tube; indeed the entire alimentary canal appears to be ciliated from the mouth to the vent, and, as in the adult, there do not appear to be anything like unstriped annular muscular tissues developed around the intestine so as to produce anything comparable to the peristaltic action of the intestine observed in worms, arthropods, and vertebrates; the food is carried into digestive tract and the excrements out of it by the action of the cilia alone.

The intestine of the spat long before the stage here figured has been reached already contains food or its indigestible remains, but the longitudinal fold found in the intestine of the oyster, as well as in the intestines of many other lamellibranks, is but feebly developed in the hind gut of young oyster spat. It is, however, present as a pretty well marked ventral ridge or slight induplicature of the intestinal wall, but it is evidently not clearly folded inward upon itself, as in the adult, until the animal is much older than the stages studied by the writer.

The retractor muscles of the velum in the larva do not appear to be homologous with any of the muscles of the spat or the adult, and are analogous only to the radial muscular bundles *r* of Fig. 2. These radiate from around and near the insertions of the great posterior adductor *m*, and are most strongly developed in the posterior and ventral halves of the mantle-lobes (in Fig. 2 these radiating pallial muscles are perhaps too strongly indicated about the hinge-border of the young animal). The retractors of the velum appear to traverse the blastocoel in the embryo. The pallial retractors, on the other hand, are embedded in the connective tissue of the mantle next to the outer epithelial covering or epidermis. The radiating pallial muscles become more complex with advancing age, and as the adult condition is approximated, and while there is a decided thickening of the margin of the mantle in the spat there is not as strong a development of the marginal muscle as in the adult. In the adult the radiating pallial muscular bundles also repeatedly divide as they pass towards the margin of the mantle, a trait which they possess to a much less marked degree in the spat. The radiating and marginal muscles have their fibers very much interlaced, so that a very complex arrangement of the muscular fibers is finally developed at the edge of the mantle.

The fringe of the tentacles along the border of the mantle of the spat is also much less strongly developed than in the adult. They are, in fact, in the young spat mere papillary elevations, as shown in Fig. 2, and at first there appears to be only a single row of them, whereas there are two rows in the fully grown animal. As the animal increases in size these marginal tentacles of the mantle also increase greatly in length until they become finger-like in form, with a usually more or less well-marked purplish coloration throughout their epidermis and about their bases. In cross-sections through the soft parts of the young spat the margin of the mantle is grooved the same as in the adult. The two marginal ridges are evidently the rudiments of the two rows of tentacles in the adult.

The extent to which the right and left mantle leaves are united dorsally I have not made out accurately, but it is evident that they are joined together for at least the length of the straight hinge of the larval shell. The development of the cucullus ventrally, and the velamen dorsally, evidently must occur after the transformation of the larva into the condition of spat.

Davaine makes the statement that the velum appears to drop off some time about the end of the larval period. Gerbe, on the other hand, asserts that the velum is transformed into the palps. There are marked discrepancies between the figures of oyster embryos which have been published by various authors; for instance, in Fig. 1, from Huxley, the intestine arises from the end of the gastric dilatation of the alimentary canal, but in Horst's figure of the same stage it is shown to arise from the middle ventral part of the stomach. In other respects the figures of these authors agree pretty closely; Môbius also represents the intestine as arising from the middle of the under side of the stomach in the embryo, and approximates the mouth and vent more in his figure than do the two preceding authors. He also indicates the presence of a third strong retractor muscle which takes its origin from near the hinge and is inserted into the body-wall near the vent. Davaine's interpretations of the form, course, and relations of intestinal canal again differ somewhat in detail from all of the foregoing, as is shown by his figures. The figures given by Coste and Gerbe agree pretty closely; both represent the intestine as arising from the posterior extremity of the gastric dilatation, but again differ from the other authors in the way in which they represent the insertion of the retractor muscles into the velum.

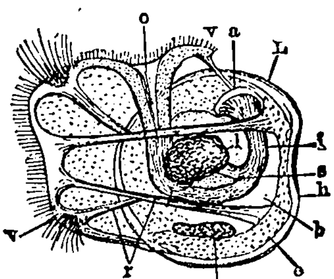

FIG. 3.

Fig. 3 reproduces the interpretation of the structure of the embryo of *Ostrea edulis* as given by the two last-mentioned observers.

The study of the embryos of *O. virginica* and *O. angulata* is attended with much more difficulty than that of *O. edulis*, because the eggs of the latter are twice as large in diameter as those of the two first mentioned, and, as a consequence, their embryos are only about one-eighth as large in volume as those of the last named when they have attained the free-swimming or veliger stage of development. The relatively very small size of the embryo American oyster is therefore unfavorable to its satisfactory study; indeed, it is very reasonable to suppose that its investigation, for this reason, would be vastly much more difficult than that of the young of *O. edulis*.

The following summary of the changes suffered by the young oyster in its metamorphosis into the condition of the spat may be appended:

1. The mouth in the larval oyster is nearly ventral in position, while in the adult it opens more nearly in the direction of the hinge or towards the antero-dorsal region.

2. The retractor muscles of the velum probably atrophy at the end of the larval period; if they are to be regarded as the musculature of the primitive mantle organ, they are replaced in the spat and adult by the radiating and marginal pallial muscles.

3. The intestine of the larva is a simple tubular organ; in the spat it has an internal ridge developed on one side, which finally becomes a pronounced induplicature in the intestine of the adult.

4. The anterior adductor muscle of the larva is replaced by a permanent posterior adductor in the spat and adult. (Huxley.)

5. The heart and gills are wanting in the larva; they are developed as post-larval organs. The gills are at first represented by only two folds, the outer pair are developed later, and apparently from before, backwards, or dorso-ventrally.

6. The connective tissue of the spat and adult, including the organs derived therefrom, seems to be almost entirely developed during post-larval life.

7. The blastocœl is mostly obliterated by the development of the connective tissues.

8. The liver is represented by a pair of diverticula which grow out laterally from the walls of the stomach of the larva; its subsequent development and subdivision into a vast number of follicles is accomplished during post-larval life.

9. Some time after fixation the larval oyster seems to lose the straight hinge border of its valves, which then acquire umbones; the valves retain their symmetry up to the time when the spat shell begins to be formed, and it is probable that most of the larval characters of the animal have disappeared when the formation of the spat shell begins; in other words, the veliger stage is past and is at once replaced by a structural condition of the soft parts which approximates that observed in the adult.