The Development of Echinocardium cordatum.

Part I.—The External Features of the Development.

By

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With Plates 33 and 34.

ANYONE reading through the comprehensive summaries of our knowledge of echinoderm larvæ given by Mortensen (1898, 1901) must be struck on the one hand by the large number of varieties of echinoderm larvæ described therein, and on the other hand, by the paucity of cases in which the parentage of the larva had been accurately determined.

In the summer of 1911, when working at the laboratory of the West of Scotland Marine Biological Association, situated at Millport on the Isle of Cumbrae on the Firth of Clyde, I succeeded in artificially fertilising the eggs of Echinocardium cordatum, and in rearing the resulting larvæ through the whole period of their free-swimming life until they metamorphosed into young urchins. Last summer, (1913) I returned to Millport and repeated my experiments, and again succeeded in rearing the larvæ of this species through their entire development until the completion of metamorphosis. Drawings of the larvæ at every stage of their development were made from living specimens, and these drawings, slightly corrected by comparison with larvæ preserved and mounted whole, have been used to illustrate this paper.

I had originally intended to delay publication until I should have had leisure to work out the internal features of development by means of sections, but the necessary leisure for this seems still to be a long way off, and it seems worth while in the meantime to place on record the external features of the development of a Spatangoid.

Our knowledge of the complete life-history of echinoid larvæ is still extremely scanty; indeed, the only species in which the external features of the development have been completely described are the Clypeastroid, Echinocyamus pusillus, described by Théel (1892), the endocyclic urchins Echinus esculentus and E. miliaris described by myself (1903), and quite recently Strongylocentrotus lividus described by von Übich (1913).

The larva of Echinocardium cordatum was first seen by Johannes Müller (1846). He described the later phases of larval life immediately preceding metamorphosis: he was able to identify the larva as the larva of some echinoid but which echinoid he was quite unable to say. His figures, however, leave no doubt in my mind that he was dealing with the larva of Echinocardium cordatum. The early larva of Spatangus purpureus was described by Krohn (1853), who reared it from artificially fertilised eggs, and his work has been repeated and confirmed by Mortensen (1913), who kept the larvæ alive for three weeks.

The younger stages in the larval development of Echinocardium cordatum were described by Vernon (1898) and more recently by myself (1912). The fully developed larva was described and figured by Mortensen (1901) but the identification of his specimens as the larvæ of Echinocardium cordatum rests on a mere guess because the ground of the identification was the occurrence of the larva in question in the waters of the Lymfiord in Denmark on the sandy bottom of which Echinocardium cordatum was the only Spatangoid which was found.

I have to express my thanks to the Director of the Millport Station, Mr. Richard Elmhirst, for his kindness to me during my stay in Millport and for the assistance which he rendered me in carrying out my experiments.

I am also especially indebted to Dr. Gemmill, Lecturer in Embryology in the University of Glasgow and Vice-President of the West of Scotland Marine Biological Association, for the pure cultures of the diatom Nitschia with which he supplied me both in 1911 and in 1913. To these cultures I ascribe my success in rearing the larvæ through the whole of their development until the completion of metamorphosis.

The methods adopted were exceedingly simple. The laboratory at Millport is situated close to the fairway of the Firth of Clyde, and the water which streams up the firth with every incoming tide is quite uncontaminated and perfectly suitable for rearing the larvæ; the only precaution which it is necessary to observe is to procure the water a few yards from shore and to convey it to the laboratory in an earthenware or glass vessel, since sea-water rapidly contracts contamination from metallic vessels, and for this reason the sea-water which is pumped into the tanks at Millport is unsuitable, since it passes through metallic pipes before reaching the laboratory.

The entire development up to the completion of metamorphosis occupies a period of about four weeks, and is, therefore, very rapid as compared with the development of Echinus esculentus, for in this latter species at least six weeks must elapse before the metamorphosis is completed, and under laboratory conditions a period of two months and more is not infrequently required before the imago condition is attained.

A brief résumé of the times (reckoned from the moment of fertilisation of the egg) required for the attainment of well-marked stages in the developmental history of Echinocardium cordatum is given below:

Free-swimming blastula	10 hours
Formation of primary mesenchyme and incipient gastrulation	15 ,,
Gastrulation completed	30 ,,
Formation of cœlom and first trace of stomodæum, the post-oral (anal) arms of the larva formed	2 days

Formation of antero-lateral arms and of aboral process	3 days
First trace of postero-dorsal arms . .	4 „
Postero-dorsal arms fully developed; first trace of "Echinus rudiment" and of præ-oral arms	9 „
Hydrocoele with incipient lobes; first trace of postero-lateral arms .	10–12 „
Formation of antero-dorsal arms; tube-feet protruding with amniotic cavity	14–16 „
Formation of adult spines; absorption of aboral process	18–22 „
Metamorphosis complete	24–30 „

The egg is not a sphere but an ellipsoid, and its shape corresponds to that of the blastula which is developed from it (fig. 1). The egg of Echinus is spherical and gives rise to a spherical blastula; it follows that the shape of the blastula, since it is conditioned by the shape of the egg, is always a maternal character. At the aboral pole of the blastula of Echinocardium there is a patch of thickened epithelium consisting of long, narrow, filamentous cells bearing long cilia (*ap.*, fig. 1); this patch, like the apical plate of the annelid larva, must be regarded as a sensory organ, the purpose of which is to direct the tiny larva in its course through the water. No such organ can be detected in the blastula of Echinus which progresses by a rolling motion, but in the gastrula of Echinus, in which the rolling motion gives place to motion along a definite line, a very similar organ can be detected.

As in other Echinoid larvæ mesenchyme cells (*p. mes.*, fig. 1) are given off from the pole of the blastula opposite the one at which the sensory organ is situated, before any sign of the invagination which is to form the archenteron can be detected. The main purpose of this mesenchyme—which is termed the primary mesenchyme, is to form the basis in which the rods of the larval skeleton are secreted. By the close of the second day not only is the archenteron completely formed, but the first rudiments of the larval skeleton have appeared (*calc.*, fig. 2). They are in the form of two calcareous "stars" situated to the right and left of the middle line. In each "star" one arm grows outwards and impinges on the ectoderm and so causes the formation of one of the first pair of arms of the larva. In Echinocardium this outwardly directed rod is accompanied by another rod parallel to it, which arises as a branch from another arm of the star. These parallel rods are connected at intervals by cross-bars, and are conveniently regarded as one compound latticed rod which receives the name of post-oral rod (*p. o. r.*, fig. 3), and which forms the skeleton of the post-oral arm. The post-oral arms which are thus the first of the larval arms to be formed are often termed anal arms by German writers on Echinoid development (*p. o. a.*, fig. 3). From the apex of the archenteron mesenchyme cells continue to be given off. These cells, which are termed secondary mesenchyme (*s. mes.*, fig. 2), form the wandering cells which traverse the blastocele or primary body-cavity of the larva and also form the delicate and sparse connective tissue which is found in this cavity later. We have seen that the post-oral rods arise, each from an outwardly-directed branch of one of the calcareous stars. The other branches of the calcareous stars grow in length, and one which extends downwards towards the lower pole of the larva is termed the body-rod; another which extends horizontally inwards towards the middle line along the posterior surface of the larva is termed the horizontal rod. A third branch of each star which extends upwards towards the upper pole of the larva is termed the antero-lateral rod. At the lower pole of the larva there is to be seen a mass of mesenchyme cells wedged in between the lower ends of the two body-rods. In this mass there can be detected a minute calcareous star (*ab. calc.*, fig. 4) which is the rudiment of the skeleton of the aboral spike.

In the meantime a bilobed outgrowth appears at the apex of the archenteron; this is the rudiment of the cœlom. It soon becomes cut off and divided into right and left sacs (*cœ.*, fig. 4), whilst the rest of the archenteron which forms the GUT, becomes marked out by constrictions into œsophagus, stomach and intestine. Between the rudiments of the post-oral arms and the part of the body into which the nascent antero-lateral rods project there appears a concavity. This concavity causes the part of the body supported by the antero-lateral rods to stand out prominently and we shall call it the oral lobe (*o. l.*, figs. 3, 4, and 5). The cilia which clothed the whole surface of the gastrula become now confined to a thickened band of epithelium which runs along the edge of the oral lobe and over the tips of the post-oral arms. This is the longitudinal ciliated band, the order of locomotion in the larva (*l. cil.*, fig. 3).

On the inner aspect of the oral lobe the stomodæum (*stom.*, fig. 4) appears as a shallow depression; this soon becomes connected with the endodermal œsophagus and the alimentary canal is thus completed; the blastopore of course persists as the anus. All the changes are completed by the end of the second day.

Along the sides of the compound œsophagus a band of thickened epithelium makes its appearance. This is the rudiment of the adoral ciliated band (*ad. cil.*, fig. 6). During the third day the new centre of calcification mentioned above develops rapidly. From one of its arms there is developed a latticed rod consisting of three parallel rods bound together by cross bars, which projects backwards and pushes out a corresponding club-shaped protrusion of the body-wall which is the well-known aboral spike of the spatangoid larva. The latticed rod is known as the aboral rod (*ab. r.*, fig. 5). The antero-lateral rods also develop rapidly and push out a pair of protrusions of the ciliated band which are the rudiments of the antero-lateral arms (*a. la.*, fig. 5). From each antero-lateral rod there is given off a posterior branch which runs back towards the lower pole of the larva parallel to the body rod. This branch is termed the recurrent rod (*r. r.*, figs. 4 and 5). In order to support the heavy aboral rod connections are formed between the recurrent and body rods on each side and the lateral branches of the aboral rod (fig. 5), but the lower extremities of the body rods rest against the sides of the aboral rod without fusing with it (figs. 8, 9).

The little four-armed larva can now feed, and if placed under suitable conditions rapidly grows in size. Already by the end of the fourth day two additional calcareous centres appear, situated one on each side of the larva in the concavity between oral lobe and post-oral arms. Each of these centres has three rays—one directed outwards, one upwards and one downwards. From the outwardly directed ray there is developed a latticed rod consisting of two parallel bars connected by cross-bars. This rod is the postero-dorsal rod; and as it grows it pushes out a corresponding protrusion of the ciliated band which is the postero-dorsal arm (*p. d. a.*, fig. 6). By the eighth or ninth day this arm has grown to two thirds the length of the corresponding post-oral arm and another calcareous centre has appeared. This latest centre is a median unpaired crescent situated on the dorsal side of the œsophagus at the base of the oral lobe. It is termed the dorsal arch (*d. a.*, fig. 6) and in succeeding days it furnished by the growth of its two ends, two rods termed the præ-oral rods which form the skeleton of the two præ-oral arms. These last-named arms are situated in front of the mouth just beneath the antero-lateral arms and slightly nearer the middle line (*pr. o. a.*, fig. 6), and it is a noteworthy circumstance that whereas the other arms only appear when the corresponding rods of the larval skeleton impinge on the ectoderm, the rudiments of the præ-oral arms appear before the branches of the dorsal arch reach them. The formation of the arm is certainly not due to a mechanical stretching of the ectoderm by the growing rod beneath it, for in unhealthy larvæ the ectoderm can become contracted and the rod projects from the apex of the arm as a bare spine; we must rather picture the growth of the ectoderm which forms the arm as the response to a chemical stimulus emitted by the calcareous rod, and in the case of the præ-oral arms we must admit that their first beginnings are entirely independent of the origin of the skeleton.

Important internal changes have meanwhile taken place. The cœlomic sac on each side has become divided into anterior and posterior portions, the anterior situated at the side of the larval œsophagus, the posterior at the side of the larval stomach. On the left side the anterior division has given origin to a posterior thick-walled outgrowth; this is the hydrocoele (*hy.*, fig. 6), the rudiment of the adult water-vascular system. This lies just beneath the ectoderm on the left side in the concavity between postero-dorsal and post-oral arms. An invagination of the ectoderm, which will form the amniotic cavity, appears just over the spot where the hydrocele is situated and becomes closely applied to it. The two adpressed structures form a compound rudiment which I have termed the Echinus-rudiment (1903), and by the growth of this rudiment the oral disc of the adult is formed in the manner described by me (1903). The larval œsophagus is surrounded by a band of circular muscles by the aid of which the peristaltic movements involved in swallowing are carried on. These muscles (*musc. circ.*, Pl. 34, fig. 15) are developed from the walls of the anterior divisions of the cœlom. The larva has now attained a stage in development which in exceptional cases may be attained by a larva of Echinus esculentus in the same time, but which more frequently requires sixteen or seventeen days for its accomplishment in the latter species.

From this point the development of Echinocardium and Echinus begin to diverge more and more. For whereas in the larvæ of the latter genus horizontal crescentic bands bearing very strong cilia begin to be differentiated from the longitudinal ciliated band, and the aboral ends of all the rods of the larval skeleton begin to be absorbed, in larvæ of Echinocardium neither of these changes take place, but on the contrary by the ninth or tenth day a new pair of larval arms, unrepresented in the Echinus larva, begin to make their appearance. These are the postero-lateral arms (*p.l.a.*, fig. 8), which arise from near the base of the aboral spike and which extend horizontally outwards. Each is supported by a postero-lateral rod (*p.l.r.*, fig. 7), which is in reality only one of the lateral branches of the aboral calcareous star which has grown outwards. At the apex of the aboral spike there is a crest of ciliated epithelium (*ab. cil.*, fig. 8) which is entirely independent of the principal longitudinal ciliated band. By this time the hydrocoele has become marked out into incipient lobes which are the rudiments of the radial water-vascular canals and of the primary tube-feet of the adult (*hy. l.*, fig. 8), and the amniotic invagination has become converted into a closed amniotic cavity (*am.*, fig. 8).

By the end of the second week a sixth and last pair of arms have made their appearance. These are the antero-dorsal arms; they spring from the dorsal surface of the oral lobe near its base and each is supported by an antero-dorsal rod which arises as a branch from the corresponding præ-oral rod. The larva has now attained its full complement of arms, viz. twelve, or if we count the aboral spike as an arm, thirteen, and for this reason Johannes Müller termed it the "Pluteus with thirteen arms." To judge from Mortensen's (1913) figure it differs from the larva of Spatangus of corresponding age in the fact that in the latter larva the aboral spike is as long as the rest of the body including the præ-oral arms, whereas in the larva of Echinocardium, as fig. 9 shows, the aboral spike is only one fourth as long as body including præ-oral arms. The living larva at this stage is a marvellously beautiful object. All the thirteen arms are dotted over with patches of bright red pigment which is especially massed near their tips, and interspersed with the patches of this pigment are patches of a light yellowish-green pigment, and the two pigments combine to give the larva a wonderfully gay appearance.

The fully developed larva of Echinocardium has thus four larval arms not possessed by the larva of Echinus and in addition the aboral spike. Nevertheless it only possesses one more centre of calcification than is present in the larva of

Echinus and that is the centre for the aboral spike. This furnishes not only the aboral rod but also the postero-lateral rods, whilst the dorsal arch, as we have seen, supplies the skeleton for the antero-dorsal as well as for the præoral arms.

During the third week the aboral spike begins to be absorbed. This absorption takes place at the tip; the ciliated crest is lost and the aboral rod becomes shorter. The absorption seems to be carried out by the agency of the cells carrying the red pigment, for these are seen thickly massed about the free end of the spike. The other arms grow longer so that the tips of the præ-oral, antero-lateral, postero-dorsal and post-oral arms extend to about the same distance from the body taking the web of skin connecting the post-oral arms as the base-line. Two large vacuities (*vac.*, fig. 11) appear in this web one on each side. The other arms, viz. the antero-dorsal and postero-lateral, grow much longer but do not attain the length of the rest. The rods supporting all these arms become much attenuated so that they actually become flexible. The Echinus-rudiment grows in size and the lobes of the hydrocœle begin to appear as tentacles projecting into the amniotic cavity (*ten.*, fig. 10). From the floor of the amniotic cavity there grow up other protrusions; these are the rudiments of the spines of the adult (*ad. sp.*). Outside the amniotic cavity there begin to appear alternating circles of calcareous stars. These are the rudiments of adult plates belonging to the aboral region of the adult (*ab. p.*, figs. 12 and 13).

On the dorsal surface of the oral lobe an epithelial thickening can now be seen. This is almost certainly homologous with the organ which I have described (1903) as the larval brain in the larva of Echinus esculentus. The corresponding organ in Echinocardium cordatum shows two outgrowths which pass towards the halves of the longitudinal ciliated band—a fact which indicates that the probable function of the organ is to co-ordinate the activities of the two halves of the ciliated band (*l. b.*, fig. 12)

Towards the end of the third week the Echinus-rudiment has grown in size so much that it not only takes up the entire left side of the larva, but extends round on to the dorsal surface and also on to the ventral surface of the larva, displacing the anus (*a.*, fig. 15) to the right side. It becomes thickly studded with conical adult spines, which fit so closely together that the whole presents the aspect of a tesselated pavement (fig. 11). In two points the larva differs conspicuously from the larva of Echinus esculentus at the corresponding stage. (1) The larva of Echinus develops a series of plates on its right side which bear small four-sided clavate spines and three pedicellariæ, whereas the larva of Echinocardium shows no trace of these extra-amniotic spines and pedicellariæ. (2) The echinus-rudiment in the larva of Echinus grows in size but is confined to the left side and it develops only four adult spines in each interradius, whereas in the larva of Echinocardium the Echinus-rudiment develops many spines and extends far over both on to the dorsal and ventral surfaces of the larva (figs. 14 and 15).

At some time during the fourth week the critical epoch in the development of Echinocardium cordatum is reached and the metamorphosis of the larva into the imago takes place with startling rapidity. I have often watched a larva with all its processes except the aboral spike fully developed, change into an urchin inside half an hour. The roof of the amniotic cavity, which we may term the amniotic veil, becomes torn, and the tentacles and spines of the Echinus-rudiment emerge. The epithelial skin of the larval arms flows back into the body leaving the supporting rods to project as bare spines. I use the word "flow" advisedly for this is the appearance which is presented: the epithelial covering often becomes massed into drops, and it is at once evident that the separation of its component cells one from another is a mere temporary and superficial phenomenon, and that the epithelium as a whole behaves like a film of fluid. The projecting spines soon become broken off and the little urchin becomes launched on its career. The adult mouth appears to be open from the beginning, whereas in Echinus it is covered with an epineural veil which is only perforated some days later. The outline of the urchin is ellipsoidal, not circular as in the imago of Echinus, and whereas in Echinus the oral surface is flat and the five primary tube-feet are the principal organs of locomotion, in Echinocardium on the contrary the young urchin moves about by the aid of its spines and the oral surface is rounded. A curious consequence of this difference in mode of locomotion is seen in the condition of the water-vascular system in the late larvæ and young imagines of the two genera. In Echinus this system is gorged with fluid for the tentacles are very extensible. In Echinocardium the lumina of the water-vascular ring and tentacles are very narrow since the tentacles are only extensible to a slight extent.

There is another great difference between the young imagines in the case of the two genera. In Echinocardium the five primitive tube-feet, which, it must be remembered, represent the apical terminations of the radial canals, arise from near the mouth, and all the spines are situated further from the mouth, and apparently must belong to the apical region of the fully developed adult. In Echinus, on the contrary, the tube-feet arise from the edge of the oral surface of the young imago, and the pointed spines are situated as near or nearer to the mouth, and hence belong to the region of the corona in the fully developed adult. Only the square-topped spines which arise outside the amniotic area belong to the apical region of the fully developed adult. Hence the conclusion inevitably follows that the floor of the amniotic cavity does not represent the same region in the two genera, and the speculation is awakened that perhaps in the far-off common ancestor of Echinus and Echinocardium no amnion was developed at all, but the spines and tube-feet of the adult were developed in an exposed condition on the side of the larva, as is the case in Asteroidea.

Most of the spines of the imago of Echinocardium are conical, but there occur at one end of the ellipsoidal imago a short crescent of shorter flattened club-shape spines (*cl. sp.*, fig. 16). These I regard as the first prophecy of the flattened spines of the adult. Surrounding the mouth and alternating with the tube-feet are five short inwardly directed spines. These I regard as the homologues of the teeth of regular Echinoids (*dent.*, figs. 16 and 17). Whilst reserving an account of the internal anatomy of the larva for another paper, I may say here that sections show that these "teeth," unlike the other spines, have roots which project inwards into dental pockets, as do the teeth of regular Echinoids. All the spines have thick collars round their bases. These collars consist of nervous epithelium, underneath which are the muscles connecting the spines to the plates of the skeleton.

For a short time there persists a trace of the oral lobe of the larva with short stumps representing the remnants of the antero-lateral and præ-oral arms and a shallow pit representing the last trace of the larval stomodæum, which has become disconnected from the œsophagus (*ol.*, fig. 16). Soon, however, this also disappears. Some of the young urchins lived for a week and grew in size. In one of these (shown in figs. 17 and 18) the five first sphæridia have appeared (*sph.*, fig. 17). These are situated outside the teeth in an adradial position, each sphæridium lying beside a tube-foot. These sphæridia, therefore, cannot correspond to the five inter-radial sphæridia of the adult; the post larval history of Echinocardium is quite unknown and a study of it would throw light on many important problems.

In reviewing the life-history which has just been described it is evident that we are dealing with a type of development much more modified than that of Echinus, and one in which the features of the adult appear at a still earlier stage than is the case with that genus.

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EXPLANATION OF PLATES 33 AND 34,

Illustrating Prof. E. W. MacBride's paper on "The Development of Echinocardium cordatum.

LIST OF ABBREVIATIONS EMPLOYED.

a. Larval anus. *ab. calc.* Calcareous centre for formation of aboral rod. *ab. cil.* Aboral crest of cilia. *ab. mes.* Aboral mass of mesenchyme. *ab. pl.* Rudiment of plate belonging to the aboral surface of the adult. *ab. r.* Aboral rod. *a. d. a.* Antero-dorsal arm. *ad. cil.* Adoral band of cilia. *ad. sp.* Adult spines. *a. l. a.* Antero-lateral arm. *a. l. r.* Antero-lateral rod. *am.* Amniotic cavity. *a. m.* Adult mouth. *a.p.* Apical plate of the early larva. *b. r.* Body-rod. *calc.*

Calcareous centre for the formation of the larval skeleton. *cl. sp.* Clavate spine of the adult. *cœ.* Cœlom sac. *d. a.* Dorsal arch. *dent.* Spine possibly homologous with the tooth of a regular Echinoid. *h. r.* Horizontal rod. *hy.* Hydrocœle. *hy. l.* Lobe of hydrocœle. *int.* Intestine. *l. a.* Vestiges of larval arms. *l. a. c.* Left anterior cœlom. *l. b.* Larval brain. *l. p. c.* Left posterior cœlom. *œs.* Œsophagus. *o. l.* Oral lobe of the larva. *p. d. a.* Postero-dorsal arm. *p. d. r.* Postero-dorsal rod. *p. l. a.* Postero-lateral arm. *p. l. r.* Postero-lateral rod. *p. mes.* Primitive mesenchyme. *p. o. a.* Post-oral arm. *p. o. r.* Post-oral rod. *pr. o. a.* Præ-oral arm. *r. a. c.* Right anterior cœlom. *r. p. c.* Right posterior cœlom. *r. r.* Recurrent rod. *s. mes.* Secondary mesenchyme. *sph.* Sphæridium. *st.* Stomach. *stom.* Stomodæum. *ten.* Primary tentacle of the water-vascular system. *vac.* Vacuity in the web connecting the two post-oral arms.

Fig. 1.—Blastula 15 hours old. × 200. *ap.* Apical plate carrying specially long cilia. *p. mes.* Primitive mesenchyme.

Fig. 2.—Gastrula about 32 hours old. × 200. *calc.* Centre of calcification for the larval skeleton. *s. mes.* Secondary mesenchyme.

Fig. 3.—Larva 2 days old viewed from the ventral surface. × 200. *a.* Larval arms. *ab. mes.* Mass of mesenchyme in which the skeleton of the aboral spike is formed. *b. r.* Body-rod of skeleton. *cœ.* Unpaired rudiment of the cœlom. *h. r.* Horizontal rod of skeleton. *p. o. a.* Rudimentary post-oral arm. *p. o. r.* Post-oral rod.

Fig. 4.—Larva of same age as last, but more advanced in development, viewed from the dorsal surface. × 125. *ab. calc.* Calcareous centre for the formation of the aboral rod. *a. l. r.* Antero-lateral rod. *cœ.* Cœlomic sac. *r. r.* Recurrent rod. *stom.* Stomodæum.

Fig. 5.—Larva 3 days old viewed from the dorsal surface. × 125. *ab. r.* Aboral rod. *a. la.* Antero-lateral arm. *œs.* Œsophagus. *st.* Stomach.

Fig. 6.—Larva 8 days old viewed from the dorsal surface. × 125. *ad. cil.* Adoral ciliated band. *d. a.* Dorsal arch. *hy.* Hydrocœle. *p. d. a.* Postero-dorsal arm. *p. d. r.* Postero-dorsal rod. *pr. o. a.* Præ-oral arm.

Fig. 7.—Larva 9 days old viewed from the ventral surface. × 125. *p. l. r.* Postero-lateral rod.

Fig. 8.—Larva 9 days old a little more advanced in development than that represented in fig. 7 viewed from the dorsal surface. × 125. *ab. cil.* Aboral crest of cilia. *am.* Amniotic cavity. *hy. l.* Lobes of the hydrocœle. *p. l. a.* Postero-lateral arm.

Fig. 9.—Larva 16 days old viewed from the dorsal surface. × 100. *a. d. a.* Antero-dorsal arm.

Fig. 10.—Larva 18 days old viewed from the dorsal surface. × 75. *ten.* Primary tentacles of the water-vascular system.

Fig. 11.—Larva 22 days old just about to metamorphose viewed from the ventral surface. × 75. *ad. sp.* Spines of adult. *vac.* Vacuity in the web of skin connecting the post-oral arms.

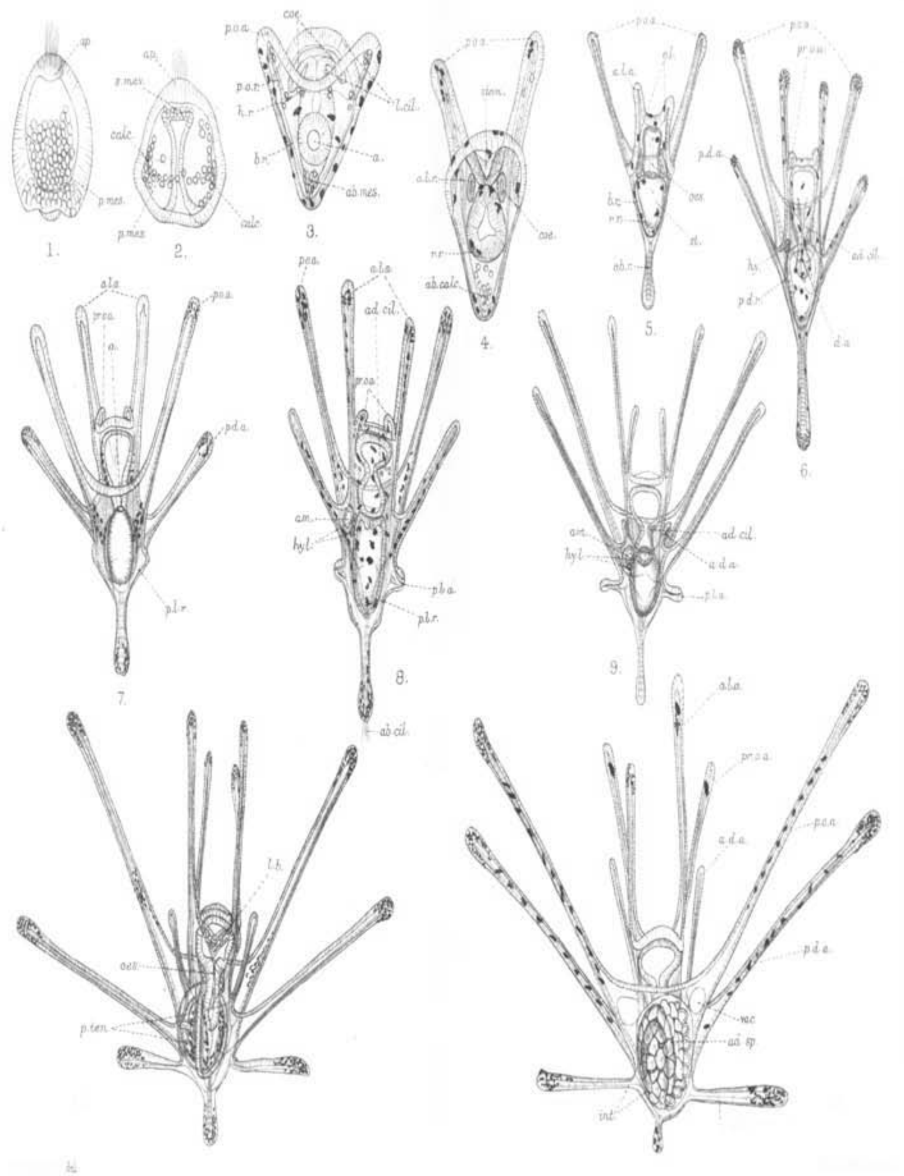
Fig. 12.—Central portion of a larva 20 days viewed from the dorsal surface. × 125. *ab. p.* Rudiments of plates belonging to the aboral surface of the adult. *l. a. c.* Left anterior cœlom. *l. b.* Larval brain. *l. p. c.* Left posterior cœlom. *r. a. c.* Right anterior cœlom. *r. p. c.* Right posterior cœlom.

Fig. 13.—Central portion of a larva 20 days old viewed from the ventral surface. × 125. *int.* Larval intestine. *vac.* Vacuity in the web of skin connecting the post-oral arms.

Fig. 14.—Dorsal view }
Fig. 15.—Ventral view } of the central portion of a larva of 23 days about to metamorphose. × 125. *ad. sp.* Spines of the adult.

Fig. 16.—Oral view of a just metamorphosed imago. × 125. *a. m.* Adult mouth. *cl. sp.* Clavate spines. *dent.* Tooth. *l. a.* Stumps of larval arms. *o. l.* Remnant of oral lobe of larva.

Fig. 17.—Oral view }
Fig. 18.—Aboral view } of imago which has lived for some days after the metamorphosis. × 125. *sph.* Sphæridum.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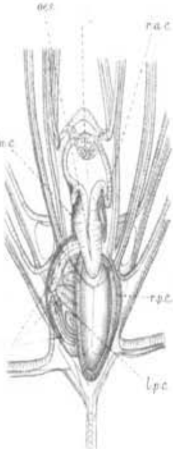

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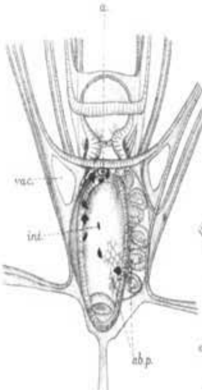

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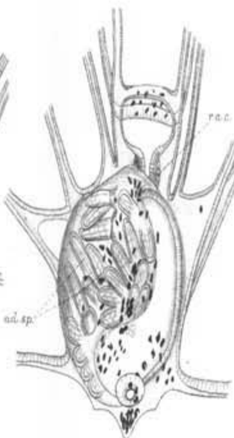

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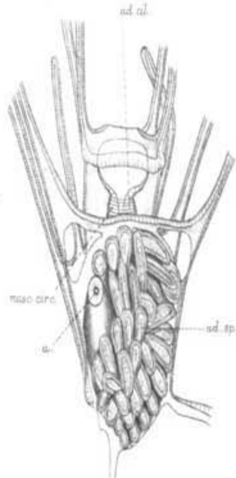

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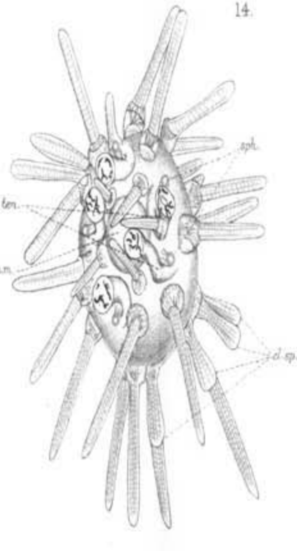

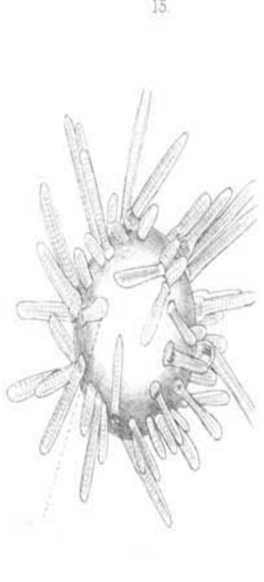

E.W. MacBride del.

cLsp.