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XXVI.—*Researches on the Development of the Pectinibranchiata.*

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[With two Plates.]

The development of *Buccinum undatum* and *Purpura lapillus* differs so much from anything already known, that we cannot be astonished that the correctness of our former observations has been doubted. To dissipate these doubts, and remedy the imperfections which occur in our first work, we have thought it necessary to recommence our researches; and now, in publishing the results, we can compare them with the investigations of J. Müller†, Vogt‡, Krohn§, Leuckart||, Gegenbaur¶, and Carpenter**, on the marine Mollusca, with which science has recently been enriched.

Buccinum undatum, Linn.

The capsules which enclose the eggs are connected together, and form round or oval groups, which may attain a considerable size. They are often attached to different bodies, for example, to stones, old pieces of wood, oysters, &c.

* Translated by W. S. Dallas, F.L.S., from the 'Fauna littoralis Norvegiæ,' by M. Sars, J. Koren, and D. C. Danielssen; Bergen, 1856.

† Ueber *Synapta digitata*, und über die Erzeugung von Schnecken in Holothurien. Berlin, 1852. Transl. Annals, new series, vol. ix. 1852, pp. 22 & 103. Ueber die Entwickelungsformen einiger niedern Thiere (Berlin Monatsber. 1852, p. 595).

‡ Bilder aus dem Thierleben. Frankfurt, 1852, p. 290.

§ Archiv für Naturgeschichte. Berlin, 1853, p. 223.

|| Zoologische Untersuchungen. Giessen, 1854, 3 Heft, p. 64.

¶ Untersuchungen über Pteropoden und Heteropoden. Leipzig, 1855.

** Quarterly Journal of Microscopical Science, 1855, no. xi. p. 17.

They are frequently very delicate and transparent, especially when they have not long been deposited. It is then very easy to observe the eggs which are enclosed in them. The capsules which have hitherto served for our observations were freshly deposited, so that we were able to follow the development in all its stages.

Each capsule is filled with a viscous humour, as transparent as water, and resembling white of egg; it contains a multitude of eggs (from 600 to 800). The latter vary a little in volume, from 0·257 to 0·264 millim.; and each of them, as we formerly stated*, is furnished with a delicate chorion and with a vitelline membrane closely surrounding the vitellus, which is composed of large or small granules, of a nearly round form, and of the vitelline liquid (*liquor vitelli*). The large granules are clear, of a more oval form, and refract the light strongly; they appear to be of an oily nature. The small granules are all of a dark colour, and round; they are scattered amongst the larger ones. We have found no germinal vesicle, but at the position ordinarily occupied by this, the vitelline mass was still clearer, and in the midst of this [clear] mass we perceived a little clear vesicle.

The first transformation of the eggs was, that the small clear vesicle, of which we have already spoken, approached the periphery of the vitellus, where it could be more easily seen. It extended itself over the vitelline mass, and formed upon it a spherical eminence, which was covered by the vitelline membrane; it had a rounded form, was as clear as water, and contained two or three molecules.

Some days afterwards, we remarked that the eggs had approached each other more closely, that the clear body had advanced still more over the vitellus, and that it had not only pushed the membrane before it, but had at the same time extended the chorion, so that the latter formed an arch. On the eighteenth and nineteenth days, the capsules have usually become a little altered; they are rather clearer at the upper part, the eggs having slipped down to the bottom of the capsule.

The enclosed liquid was not so viscous as before, and the clear body, in many eggs, had traversed the chorion and become dispersed in the liquid; whilst, in others, it was still united with the vitellus by a slight pedicle, formed by the vitelline membrane. In these the chorion was much enlarged, and ruptured at the highest point. In the pedicle there were no

* Here, as in many other places, we must refer the reader to our previous investigation of the history of the development of the Pectinibranchiata.

traces of vitelline molecules. The little body of which we are speaking was first observed by M. Carus, and subsequently by MM. Dumortier, Pouchet, Van Beneden, Bischoff, F. Müller, Nordmann, Vogt, Rathke, Kölliker, Reichert, Leydig, Lovén, and many others. Some of these authors take it for the projected germinal vesicle, others for the germinal spot, and others again for a drop of exuded vitelline liquid. Like M. Lovén, we formerly regarded it as the germinal spot, but new observations have caused us to change our opinion, so that we now agree with Rathke, Leydig, and Leuckart. Another question, which has greatly attracted the attention of naturalists, is to ascertain whether this body has anything to do with segmentation. There is much difference of opinion upon this point amongst authors. Rathke, Pouchet, Reichert and Leydig entirely deny any such connexion. F. Müller, Nordmann, and Lovén believe that this body shows the direction in which the segmentation takes place. As most of the eggs of *Buccinum undatum* do not undergo segmentation, and in the small number which pass through the stages of this process this body is pushed out of the egg before segmentation commences, it is clear that we cannot speak of any relation between the latter and the body pushed out. Soon after this little body has escaped from the eggs, we see that the latter begin to agglomerate. The humour, which was previously thick and viscous, then becomes more liquid, so that there is no longer any difficulty in getting out the contents of the capsules. The chorion has already begun to detach itself in most of the eggs, forming a mass in the humour.

Some days afterwards, the act of conglomeration is completed; the eggs appear to be agglomerated at the bottom of the capsule. The viscous humour has become perfectly fluid, like water, and round the agglomerated eggs we see a greyish, finely granular, semitransparent mass, which assists in joining the eggs together (Pl. XVI. fig. 1 *a*). The chorion is redissolved in most of the eggs. In a little while we observe a group in the conglomerate formed by the whole of the eggs,—a larger or smaller number of eggs appearing to be wrapped up in a transparent veil formed by a viscous and finely granular humour exuded from the eggs. This humour contracts by degrees, and forms a very delicate membrane, which separates the group more and more from what surrounds it. A group of this kind, when recently formed, has much resemblance to a heap of balls placed one upon the other (fig. 1 *b*). The exudation of the finely granular humour continues, which enlarges the membrane, principally at the upper part, the narrowest part of the group. We also perceive slight contractions in the membranous envelope, which cause the eggs to press against each other still more (fig. 1). We cannot as yet find any trace of the formation of organs; the exuded mass is homogeneous and semitransparent, but usually becomes more and more abundant above, until at last it exhibits on the upper part of the membrane some extremely fine cilia. Soon after the formation of these, we see some cirrhi, and it is only then that the movements of the embryo commence. As the cirrhi become more numerous and larger, the movements become more and more lively; and shortly afterwards the embryo detaches itself from the common mass. This separation sometimes takes several hours, and often carries away with it a portion of the eggs, which, being still separated from the embryo, die. The above-mentioned exudation, to which we have paid attention in our first memoir, differs in its quantity; for sometimes it happens that it only makes its appearance as a border or clear line within the membrane, and in other cases it may be very considerable before the embryo has detached itself. The number of eggs which take part in the conglomeration to form the embryo varies as much as the quantity of embryos in the different capsules. The ordinary number of eggs which collect to form one embryo is from thirty to sixty, but we have very frequently found that it was composed of 130 eggs. It is to be observed, that the fewer the individuals [embryos] in a capsule, the greater the number of eggs of which they consist, and consequently the individuals are always larger. The form of the embryos also undergoes some variations, but they are ordinarily oval or reniform. The number of individuals also varies greatly; thus sometimes we have found five or six, sometimes eighteen to twenty-four, and even thirty-six. Gray says that a capsule contains more than 100 eggs, and that only four or five young are excluded from it. Howse shows us twenty-four; he also describes egg-capsules, which, he says, belong to *Fusus Norwegicus* and *Turtoni*, and of which those of the former only contain two or three embryos, and those of the latter six.

Now that we have seen how the eggs are grouped together, and how the exudation takes place, as well as how the commencement of the embryo is formed, we may follow their development. When the cilia and the cirrhi make their appearance in sufficient quantity upon the upper part of the membrane, the differentiation of the organs commences in this exuded and homogeneous mass, for we begin to see slight outlines of the rotatory organs, which then very rapidly acquire their peculiar forms. But almost at the moment of their appearance we observe the foot as a dense and almost square mass, which is still adherent to the rotatory organs. As soon as these increase in size, the foot acquires a more and more rounded form, detaches itself from them, becomes thicker, and acquires a yellowish tint and a cellular structure. Cells are also formed in the rotatory organs, but these are neither so compact nor arranged so much upon one another as in the foot. On the margins and on the surface of the latter we observe very fine cilia.

The rotatory organs are extremely clear and transparent. Vogt* has best described their form, and, as our observations agree with his, we shall not speak of them. We shall only remark, that the cirrhi are shorter in *Buccinum undatum* than in *Actæon.* The foot advances considerably in front, and we soon observe the two auditory organs at its base (fig. 2 *g*). These consist of two round, clear vesicles, which are filled with a fluid as limpid as water, and exhibit double outlines; each vesicle is furnished with a single otolithe. When the embryo is compressed with a little force, the otolithes almost always break into four regular fragments. The tremulous movement which most authors have observed in the otolithes has not been remarked by us in *Buccinum undatum*; and, although we have employed pretty high magnifying powers, we have been unable to discover the cilia on the inner wall of the vesicle.

Whilst the rotatory organs and the foot are being developed above, the membrane surrounding the lower part of the embryo grows thicker, its outlines become strongly defined superiorly by a distinct margin, and it thus forms the mantle (fig. 1 *d, d, d*). This increases by a permanent exudation from the vitellus, and cells are successively formed in the mass. On the bottom of the mantle, a round, transparent, and membranous shell is then formed (fig. 2 *a*). At the same time we observe, at the two sides of the base of the foot, the two salivary glands, which are pyriform (fig. 1), and in which round cells are formed by degrees. Their lowest portion, which is the largest, is filled in the centre with a multitude of pigment grains, very strongly coloured. Almost at the same time, we perceive the place of the mouth and pharynx, and traces of the heart. The buccal orifice forms a pretty large cleft, which is furnished with cilia; it occurs at the point where the two rotatory organs meet in front. It is continued into the pharynx, which has the form of a funnel, broad above and narrow beneath; all its inner portion is covered with cilia. Grant† was the first who observed the heart in *Buccinum undatum*, and called attention to its strong pulsation. He also pointed out that the embryos of *Purpura, Trochus, Nerita, Doris,* and *Æolis*, had at the sides of the head two round organs covered with twisting cirrhi, by which movement was effected. He did

* Annales des Sciences Naturelles, 3 série, vi. p. 44.

† Edinburgh Philosophical Journal, vii. p. 121. Unfortunately we only know this Journal from the extracts given by other authors.

not, like Forskäl, observe the shell; but Sars was the first to confirm Forskäl's observations regarding the shell.

At the point where the heart makes its appearance, we see first of all a transparent, greyish, and finely granular mass, of a nearly round form, and placed close to the common membrane, which has assisted in forming the rotatory organs and the foot above, and the mantle below. Some contractions soon show themselves in the membrane, exactly at the spot where the greyish exuded mass just mentioned occurs. We then perceive some small and extremely fine muscular tubes, which indicate the direction of the contractions. These become stronger and stronger, and as no limitation has yet taken place, we see the contractions extend over the mantle, the foot, and the rotatory organs. During the contractions, the membrane at the spot where the heart shows itself gradually acquires the form of a vesicle, the outlines of which become more and more distinct, and in the walls of which we discover several muscular tubes. By thus becoming limited, the membrane forms the heart, which then detaches itself from the rotatory organs, from the foot and the mantle, and is situated to the right on the back (fig. 2 *d*). The heart takes a very oblique position, and is quite naked externally. Subsequently its walls become stronger, and enlarge; the muscular tubes are multiplied, transverse tubes are formed, and it becomes filled with a fluid as limpid as water (fig. 3 *f*). We have often counted the pulsations, and found that they vary in rapidity; we may usually count forty to fifty pulsations in a minute; but these strokes are not always regular, for after some feeble beats, we may observe that the pulsation is stronger. It also frequently happens that the heart suddenly ceases beating, and is, as it were, in a state of repose for some time. After a rest of this kind, the pulsation is much stronger. The primary tubes of the heart are cylindrical and dilated in some places; their walls are excessively delicate and shining, and they refract light quite differently from the rest of the mass. We have not observed any fluid in these tubes, nor have we remarked any cellular structure. In the rotatory organs we observed similar muscular tubes, but here several are seen to approach each other, and in many places it may also be remarked that they ramify. This ramification becomes more and more abundant as it approaches the periphery of the rotatory organs; and as the finest branches cross each other, there appears a muscular network which serves to move the organs, of which we have just spoken, in all directions. Amongst these muscular ramifications there are some small calcareous granules, scattered in the mass, which strongly refract light.

In our former memoir we stated that the eyes were formed at the same time as the auditory organs; but, according to the investigations which have since been made, this is not the case, for the eyes can only be perceived a little while after the formation of the auditory organs. Leydig has pointed out that at first the eye is a vesicle occurring at the base of the tentacles. We have had the opportunity of confirming his remarks, but we have also found that the inner wall of this vesicle is furnished with cilia. This vesicle is filled with a liquid, in which there is a multitude of strongly-coloured, yellowish pigment-grains, which are surrounded by an extremely delicate pellicle. When the cilia acted upon the pigment-grains, the latter acquired a rolling motion. We were unable to observe the lens; it does not appear until a later period of development. In observing the eyes, we also saw the two conical tentacles.

As we have already stated, the *pharynx* is one of the first organs to make its appearance; some time afterwards, the proboscis, the stomach, and the œsophagus show themselves. The latter makes its appearance as a cylindrical cavity surrounded by the proboscis, and in its excessively delicate walls we perceive several very clear lines, which are the earliest-formed muscular fibres. As soon as the œsophagus issues from the proboscis, it bends a little backwards and upwards, follows the lower part of the proboscis for some time, then again describes a curve by bending a little to the left, and enters the stomach. It is very difficult to follow the œsophagus during its development, as it is not only surrounded by the proboscis, the walls of which are thicker and less transparent, but it is also completely covered by it. This is the reason of our being unable to decide whether the whole length of the œsophagus is formed at once, or whether it becomes elongated by descending towards the stomach. The latter appears at first almost in the form of a ball, and seems to be formed by a single vitellus secreting a greyish, semi-transparent mass, which solidifies and forms a delicate membrane, which is first of all produced upwards and unites with the œsophagus, and afterwards downwards to form the rudiments of the intestines, which curve to the right, there form a curvature, pass to the opposite side, and lastly terminate by an anus in the branchial cavity (fig. 3 *t*). The stomach is always filled with a crowd of vitelline granules, which are continually rolling: this movement is caused by cilia, with which the whole of its inner surface is covered. It is not only the inner wall of the stomach that is clothed with cilia, but also that of the œsophagus and the whole intestinal canal.

It is only now that we observe the first traces of the nervous system, which are recognizable by two oval, yellow, and compact bodies (cerebral ganglia) surrounding the œsophagus. At the same time that we observe these, we see the traces of the two pedal ganglia, which are placed side by side, more or less oblong, and of a deep yellow colour.

The margin of the mantle extending upon the dorsal surface of the animal forms a cavity clothed with cilia, in which the heart and the branchiæ are placed. The first traces of the branchiæ were two scarcely visible cords, which, originating from the margin of the mantle, met below, and formed an interlacement. When the development was further advanced, we saw that these cords were tubes which formed several loops, and that by this means they had some resemblance to a corkscrew. The loops were smaller above and below, whilst in the middle they were broader and closer together. A brisk movement, produced by cilia, was soon observed on their inner margins. In his memoir Lovén* has stated, that as regards the development there exists a great resemblance between the Gasteropoda and the Acephala. In the latter he has shown how the branchiæ are formed, and we have had the opportunity of observing that this formation takes place in the same way in *Buccinum undatum* and *Purpura lapillus*.

Nearly at the same time that the formation of the branchiæ takes place, there appears at the bottom of the branchial cavity a vesicle which is formed by the secretion of a greyish and semi-transparent mass. Muscular fibres soon make their appearance in this mass. The vesicle is oval and nearly pyriform, and terminates below in a pretty long canal, which follows the course of the intestine, but loses itself in the dark vitelline mass. We could not observe any communication between the canal and the heart, as was observed by Gegenbaur in the Pteropoda. When the development is further advanced, the latter divides into two chambers, of which one is smaller than the other. Between these chambers there is a valve, which is always in motion. The walls of the vesicle are delicate, semitransparent, and furnished with a multitude of muscular and varicose tubes, which run in all directions, longitudinally and transversely. These tubes are smaller than those in the heart; for this reason a higher power is necessary to observe them well. The contractions of the vesicle coincide with the dilatations of the heart (and *vice versâ*), although it is impossible to perceive any communication between these organs. It is filled with a clear fluid, in which a great many dark molecules are found. We think that this organ is a commencement of the kidney.

Some time now passes without the appearance of other organs, and everything seems to cooperate in completing all that has

* Bidrag till Kännedomen om Utvecklingen af Mollusca Acephala Lamellibranchiata, p. 96.

been commenced. The head and back become more and more visible, and covered with fine cilia; we also perceive cilia on the tentacles, which have become longer. The eyes have acquired a more conical form, and we see the lens in them distinctly. The proboscis and the tongue are completely developed, and on the latter we see the armature as described by Lebert and Lovén. The salivary glands are now large enough to enable us perfectly to trace their excretory duct, which follows the œsophagus upwards. The siphon, furnished with cilia, is then clearly perceptible. The foot has changed its form, and become longer; from its upper part two rounded lobes arise. As regards the structure of the foot, it is composed of a multitude of primary, cylindrical, muscular tubes, which are also varicose, and cross each other in all directions, without, however, forming a mass. In the interior of the tubes we observed neither nucleus nor cells.

In this period of development the nervous system becomes tolerably visible. We observe the two large cerebral ganglia (Pl. XVII. fig. 1 *a, a*), which are of an oval form, and between them two smaller ganglia (*b, b*). From the lower part of each large ganglion a short and thick nerve arises (*h*), which joins the branchial ganglion (*d*), and from the upper part a more delicate and rather longer branch, which runs to the eye (*l, l*). The small cerebral ganglia are round, and about half the size of the large ones. Each of them gives off a slender branch (*k, k*) to the auditory organs, and another, a little stouter (*g, g*), to the two pedal ganglia (*c, c*). The latter are of an oblong form, and it is in their broadest part, which is turned towards the cerebral ganglia, that the two nerves just mentioned lose themselves; these two nerves start from the smaller cerebral ganglia. From the broadest part of each [pedal] ganglion starts a pretty strong nervous branch (*i, i*), which meets on the left with the branch which the large cerebral ganglion sends off to the branchial ganglion; to the right this same branch meets with the branchial ganglion, but without joining it. Nearly at the middle of each pedal ganglion a nerve (*m, m*) originates, which runs to the lobate foot, and at this point forms a small ganglion (*f, f*), from which three branches (*o*) arise. The narrowest part [of the pedal ganglia], on the other hand, gives off several branches (*n, n*) to the part of the foot which is furnished with an operculum. The branchial ganglion is of an oblong form; its largest part turns upwards, and it is in this that the three branches, to which we have referred above, lose themselves, so that this ganglion is in communication with the two large cerebral ganglia, and with the pedal ganglia. From its narrower part, which goes downwards, originates a thick nervous trunk (*p*), which terminates in a ganglion (*e*). From the same part arises a more delicate branch, which runs to the heart (*q*). From the ganglion (*e*) issue two branches (*r r*), which pass to the intestines. When the animal is perfectly developed, the ganglia unite, and form a single cerebral mass.

The shell, which, at the commencement of the formation of the embryo, was very delicate and membranous, and which was at first of an oval or reniform shape, subsequently acquires the form of a Nautilus, but becomes more oblong by degrees. The calcareous matters then begin to be deposited in great quantity, so that a layer of transverse and longitudinal striæ is distinctly formed, causing the shell to be less transparent than before. However, the internal organs may still be seen. Both the heart and the vesicle have become divided into two chambers, of which the superior is the smaller. We also observe a strong muscle which starts from the inner face of the shell, and passes to the foot (Pl. XVI. fig. 3 *r*). Finally, we observe a small dark body, consisting of cells containing a yellow pigment; almost immediately afterwards, a similar body makes its appearance quite close to this, and this is followed by a third. These three bodies become blended together, and form the liver, which is somewhat oblong (fig. 3 *u*). On the inner wall of the mantle we perceive a series of folds, in which a mass of mucous glands is situated (mucous laminæ). In proportion as the young animals grow, still more calcareous matter appears in the shell, the mantle becomes thicker, and it is almost impossible then to distinguish the internal organs. The two rotatory organs have completely disappeared, and behind the tentacles we see a raised line, which shows the position in which they were situated. The shell has acquired a yellowish colour, and become hard, brittle, and only semitransparent. When the young animals abandon their capsules, they begin to creep, with the tentacles, the foot, and the siphon extended. They differ from the adult animal only in the shell, which has not, as yet, more than one or two turns of the spire. At the end of five months, the shell is completely developed, and if we examine a young animal in this stage, we do not yet find any traces of the organs of generation, and the grouped eggs still fill the hinder part of the shell.

This is the way in which the development of *Buccinum undatum* usually takes place. Thus only by an assemblage of well-organized eggs coming together to form the embryo, can it, in its ulterior growth, attain such a perfection as to be in a condition to continue an independent existence. But, by the side of this extraordinary development, comes a series of phænomena, which, on the one hand, follow the ordinary law of the development of animals of the lower classes, and consequently differ greatly from the rule which we have given for the development of *Buccinum undatum*; and, on the other hand, prove that a single egg cannot furnish sufficient materials for the future perfection of the animal.

We have observed that in each egg-capsule there were one or more eggs which, not being included in the act of conglomeration, passed into a separate development. Even before the mass of eggs is perfectly conglomerated, we see some which undergo a segmentation, which, however, is subjected to many changes. Thus the vitellus divides into 2 equal and opake spheres, each of which again divides into 2 other equal spheres, so that we then distinguish 4 equal spheres; each of these divides in the same way into 2 equal spheres, and this division continues until the vitellus resembles a mulberry. But it is not rare for the process of segmentation to stop at the formation of the first 2 spheres of segmentation, which begin to exude a clear humour, and this, almost at the moment of exudation, changes into a delicate membrane (Pl. XVII. fig. 6). As the exudation increases, the membrane enlarges, and by degrees its upper surface is covered with cilia, and soon with cirrhi. The embryo thus formed begins to turn upon itself even in the fluid (fig. 7). This, however, is not the usual way in which the formation of embryos takes place in isolated eggs, for it very often happens that the exudation and the development of the embryo do not commence until the segmentation is well advanced, and after the formation of 4, 8, or even 16 spheres of segmentation (figs. 8–12).

Whether the segmentation goes through all its stages, or stops at the first, it is certain that when the above-mentioned exudation has commenced, the segmentation ceases, and the formation of the organs begins. Before entangling ourselves more deeply with the development of these embryos, we must compare our observations on those eggs of *Buccinum undatum* which undergo segmentation, with those of other naturalists upon the process of segmentation in different Mollusca.

C. Vogt has observed, that when the first 4 spheres of segmentation are formed, there are produced between them 4 other small spheres, which set themselves in action and form the rudiment of the peripheric organs, whilst the central spheres remain longer without alteration. He thinks that these 4 small spheres of segmentation may be formed by exudation from the larger spheres. Leuckart has made the same observations upon the development of the Heteropoda. J. Müller has observed that the germinal vesicle in *Entoconcha mirabilis* does not disappear, but divides, and forms the clear bodies in the spheres of segmentation. At first 2, and then 4 large spheres of segmentation are formed; they are opake, and each of them is furnished with a small, clear nucleus. After the formation of these, we distinguish 4 smaller spheres, which are clear and furnished with a similar clear nucleus. These latter spheres have a cellular appearance. J. Müller found it impossible to explain how these little spheres issue from the large spheres of segmentation. These 4 clear spheres multiply rapidly, however; their number may reach 8, 16, or even more, whilst the 4 large opake spheres remain inactive. Even after the cilia have made their appearance round the cellular peripheric layer, the 4 large spheres of segmentation have undergone no change.

Gegenbaur has also observed that in the Pteropoda the germinal vesicle divides, and that it forms first 2 and then 4 large spheres of segmentation, of which one of the latter again divides into two. He thinks that the peripheric layer is formed by one of the 4 spheres of segmentation which has become changed into a layer of clear cells. The 3 central spheres also remain inactive at first. In *Hyalea tridentata* one of the 2 spheres of segmentation divides into 2 smaller ones, and these into 2 others, until a mass of clear cells is formed surrounding the inactive sphere of segmentation. It sometimes happens also that this divides into 2 equal spheres.

Another modification observed in regard to the process of segmentation in *Hyalea* is, that the vitellus divides into 2 unequal spheres of segmentation, the largest of which again divides into 2, producing 3 equal spheres. One of these also divides into several smaller spheres, and forms a peripheric layer which surrounds the 2 inactive spheres.

Thus we see that, even in the same species, the segmentation may undergo considerable alterations. We have already seen that in *Buccinum undatum* the germinal vesicle disappears, and that there is no clear body in the spheres of segmentation. We have also remarked, that although the greyish, transparent mass already mentioned is exuded in various stages of segmentation, this nevertheless occurs most frequently when the vitellus is divided into 4 or 8 segments. This exuded mass must be regarded as the peripheric layer already mentioned, for we soon observe in it a cellular structure which forms the rudiments of some external organs,—the rotatory organs and the foot,—whilst the central part and the true spheres of segmentation appear to remain long without alteration (Pl. XVII. figs. 5–12).

In describing the ordinary development of *Buccinum undatum*, we have endeavoured to explain clearly the way in which the organs are developed; and as the embryos which issue from a single egg do not appear to present any modification of development, it would only give rise to a repetition if we were to describe the formation of the organs here.

As soon as the rotatory organs and the foot are formed, we see the otolithes, the salivary glands, and the nascent shell; the spheres of segmentation then become less dark, the embryo enlarges, the foot becomes thicker, and in the interior we perceive a movement of rotation, which indicates the nascent stomach, from which a tube, the pharynx, is soon produced upwards, rounded in the form of a funnel. But whilst this takes place, the vitelline mass has greatly diminished, at the same time that the spheres of segmentation, which were previously compact and opake, appear to be less compact and more transparent. A tube is produced downwards from the stomach, which, however, soon stops, and in which we see a rolling movement (the rudimentary intestine). The rotatory organs increase greatly in size, giving the embryo a very brisk motion. The foot becomes thicker and the pharynx firmer, and whilst all this is taking place, the vitelline mass diminishes to such an extent, that at last we can only distinguish a few traces of it. The embryo is, properly speaking, perfectly transparent, and thus acquires an airy appearance, which, coupled with its very brisk movements, renders observations very difficult. Some time then elapses without any fresh changes being observed, no new organ makes its appearance, and the last traces of the vitelline mass disappear entirely. But from this time we observe a retrograde tendency; the embryo becomes smaller and the foot thicker, whilst the rotatory organs shrink, and the part where the shell is situated becomes round, so that the whole acquires the form of a balloon. As the organs disappear, the vital force gradually diminishes, and at last we have before us a little shrivelled monster, which exhibits a slight ciliary movement, but which otherwise remains quiet at the bottom of the vessel until it dies. This is the case with all the embryos which are developed from a single egg; they have but a short existence, during which only a few organs are formed.

There is not much difference in the development of those which are evolved from two eggs. Thus we have observed that where two eggs unite, the vitelli undergo no segmentation, but a rapid exudation of a greyish and semitransparent mass takes place. This mass becomes firm, and converted into a membrane, on which cilia are formed. The embryo is then formed in the same way as that which is developed from a single egg, except that it is larger and stronger. When the foot, the rotatory organs, the salivary glands, the stomach, the œsophagus, and the intestines are formed, we see that a portion of the vitelline mass is used up, and we then perceive a slight contractile movement in the direction of the rotatory organs, which indicates the future heart. This takes more and more the form of a clear vesicle, in which we detect some muscular tubes. The contractions are not very strong. The embryo has then increased in size, both the intestines and the œsophagus have become longer and thicker, whilst the greater part of the vitelline mass has disappeared. We can discover no more new organs after this period; the remainder of the vitellus entirely disappears, and the embryo shrivels greatly, becomes deformed, and dies. Thus when 2 eggs united, a new organ, the heart, made its appearance, although without developing itself perfectly. We have also seen 3 eggs cooperate: the same phænomena were presented, the only difference being that the organs were more strongly developed, so that the heart became more muscular, and the intestines longer; but as the vitelline mass was exhausted before any other organs made their appearance, the embryo began to shrivel, and died. (See Pl. XVII. figs. 13–17.)

[To be continued.]

XXVII.—*A Revision of the Genera of some of the Families of Conchifera or Bivalve Shells.* Part III. Arcadæ. By John Edward Gray, Ph.D., F.R.S., F.L.S. &c.

[Continued from vol. xiii. p. 418.]

Fam. Arcadæ, Gray, Ann. & Mag. N. H. xiii. 417.

Tribe 1. Arcaina.

The hinge of the more typical form of this family consists of two oblong or linear teeth in each valve, one placed on each side of the line directly under the umbo of the shell. These teeth are divided transversely into cross-ridges, alternating and interlocking with the cross-ridges of the teeth of the opposite valve.

The teeth may be compared to the lateral teeth of *Spisula* in *Mactradæ* and *Meretrix* in *Veneridæ*, and more especially to the teeth of the genus *Trigonia*; only in this family, instead of the teeth being grooved on the sides, the grooves are sufficiently deep to divide the teeth into transverse interlocking plates.

The separation of what has been usually regarded as a continuous series of teeth into groups, each forming a distinct tooth, like the teeth of *Trigonia*, has been overlooked by conchologists, though it was noticed by me in the 'Synopsis of the British Museum,' in 1840, p. 143, thus: "The hinges of the valve consist of a number of transverse interlocking teeth, which appear to be formed by the subdivision of two elongated lateral teeth."

The space which separates these two teeth or groups of plates