XVII.—*On the Further Anatomy and the Budding Processes of Cephalodiscus dodecalophus (M'Intosh)*. By ARTHUR T. MASTERMAN, B.A., D.Sc., F.R.S.E.; Lecturer and Research Fellow in the University of St Andrews. (With Five Plates.)

(Read 6th June 1898.)

The former paper (5) on the Anatomy of *Cephalodiscus* was incomplete in certain particulars, which I am now in a position to add. These are mainly in regard to the alimentary canal, the nervous system, and the reproductive organs. To the present description of these will be appended an account of the budding processes, which are a very conspicuous feature of the species.

It has been pointed out that the twelve plumes, which are definitely arranged and spread out dorsally in front of the head region, have longitudinal grooves running down their ventral side into the mouth region. "One cannot doubt that in *Cephalodiscus* the cilia of the ventral surface cause currents down the ventral grooves of the plumes, and thence into the mouth, . . . carrying food-particles, entangled in slime, into the alimentary canal, a mode of alimentation analogous to that of *Phoronis*, and indeed of the *Urochorda*" (5). We might add to this, the *Lamellibranchiata*, *Brachiopoda*, and *Amphioxus*. This characteristic method of ingestion by means of ciliary currents must be regarded as a primitive one, and it is interesting to notice the several methods by which the superfluous water current is got rid of, and the food retained. The primary origin of gill-slits has been suggested by both HARMER and BROOKS as connected with this function. The single pair of pharyngeal clefts in *Cephalodiscus* certainly appear to agree with such a theory.

A series of horizontal longitudinal sections through an adult *Cephalodiscus* from before backwards cut the front portion of the pharynx transversely and the hind part longitudinally. Such a series may be seen in figs. 1 to 9.

In fig. 1 it may be noticed that three oral grooves (1, 2, 3) converge from each side of the mouth, passing downwards from the branchial plumes. They are directly continuous with the grooves running down the ventral side of each of the plumes, which unite in pairs to form the oral grooves here seen.

The dorsal wall of the buccal cavity is quite simple, but on the ventral wall appears a slight semi-circular depression. In fig. 2 this depression is observed to have divided into two grooves in the ventral surface of the pharynx, which deepen rapidly. In fig. 3 they present chordoid walls, and as far back as fig. 4, they can be readily

recognised as the two pharyngeal clefts (*p.c.*). In fig. 3 the first pair of oral grooves (3) have bent round so as to lie completely within the pharynx, and in fig. 4 the other two (2, 1) show similar relations. Between the two pharyngeal pouches, in the mid-ventral line, a slight depression can be seen in this figure, and it can be followed into the ventral alimentary portion of the pharynx, which is a conspicuous feature in the remaining figures. In figs. 5 and 6 the oral grooves may be seen to become merged dorsally into a large dorsal hyper-pharyngeal groove, which is at first partially divided into two by a median ridge. Further back (fig. 7) this groove extends across the middle line, and forms the median dorsal portion of the pharynx, which receives the duct of the sub-neural gland, *sn.gl.* (*cf.* plate 24, fig. 13, *loc. cit.*). This gland is seen in figs. 5 and 6. In fig. 7 it has merged into the large dorsal chamber.

In this figure the pharynx presents a symmetrical appearance. Dorsally lies the large dorsal chamber, into which opens, from in front backwards, the duct of the sub-neural gland, *sn.gl.* (in the median line), and (laterally) the two grooves which are formed by the union of the three oral grooves on each side.

The two pharyngeal pouches (*p.c.*) lie laterally and pass towards the ventral surface, whilst mid-ventrally is the large alimentary portion of the pharynx.

A little dorsal to each pharyngeal pouch has appeared a small groove with chordoid walls, which rapidly increases in size (figs. 8 and 9, *n.c.*), and proves to be the commencing pleurochord. In fig. 9 this pleurochord is seen to occupy the dorso-lateral part of the pharynx, the pharyngeal pouch being ventro-lateral. After fig. 9 the latter rapidly decreases in size, as seen in sections, and the pharynx then presents the appearance indicated in plate 25, fig. 17, *loc. cit.*

Other important points may be noticed in a series of transverse sections, such as those shown in figs. 90–99.

Fig. 100 is a semi-diagrammatic reconstruction of the pharynx of *Cephalodiscus*, viewed from the left side. The lines cutting it transversely indicate by their numbers the approximate level at which each of the sections in figs. 90–99 are cut.

Fig. 90 cuts the head (or pre-oral part) of the pharynx, into which falls the sub-neural gland (*sn.gl.*). The lumen of the latter is directly continuous with the four grooves here shown, two dorsal grooves (*d.g.*), and two ventral (*v.g.*).

Figs. 91 and 92 show the two pairs of grooves to become more pronounced. A condition very similar to these sections, especially to fig. 92, is shown in plate 24, fig. 12, of my former paper, though the significance of these grooves had not then been followed out.

Fig. 93 cuts through the mouth-opening and through the front part of the main bulk of the pharynx. Between the dorsal and the ventral grooves, the pleurochordal diverticulum (*n.c.*) and the commencing pharyngeal cleft (*p.c.*) have now become conspicuous features on either side of the section, so that the grooves are widely separated. The dorsal grooves unite more or less in one, and the ventral grooves run down laterally on either side of the mouth (*v.g.*). They were distinctly figured in this

position in a section (plate 25, fig. 16) of the whole animal (5), and they form a very marked peri-pharyngeal band around the buccal chamber. Their position is readily determined, in cross sections, by the fact that they are situated exactly internal to the line of junction of the mesentery between collar- and trunk-cavities, with the gut wall (see fig. 93).

In fig. 94 the pleurochords form the main lateral walls of the pharynx, but the two pairs of grooves are still conspicuous.

Fig. 95 is posterior to the mouth-opening and behind the pharyngeal cleft. Here the two ventral grooves, forming a peri-pharyngeal band, have united behind the mouth in a medium ventral groove, with the middle line slightly raised in a ridge. The two dorsal grooves are still separated by a very characteristic median ridge of thickened cells comparable to a dorsal lamina. In fig. 96 somewhat the same condition holds, though the notochords are becoming reduced in size. This process of reduction goes on very rapidly, till (in fig. 97) the notochordal grooves are of no more importance than the dorsal grooves, and at the same time the ventral groove has become single and median.

In fig. 98 the two dorsal grooves, and the ventral groove alone remain, and in fig. 99 they are reduced to very small calibre and posterior to this they fuse and open into the oesophagus.

We thus see that the pharynx of *Cephalodiscus* has a pair of dorsal grooves separated by a dorsal lamina, and a ventral hypo-pharyngeal groove, joined at the front end by a peri-pharyngeal groove. At the point where the dorsal grooves join the peri-pharyngeal groove, the sub-neural gland opens. The relation of the peri-pharyngeal grooves to the ventral alimentary portion of the gut in *Cephalodiscus* seems to corroborate the suggestion that the endostyle and thyroid are homologous with this part of the pharynx in *Balanoglossus*. These grooves are all too small for water-currents and their arrangement prompts an irresistible comparison with the mucus-grooves in the pharynx of *Urochorda*, and although one can only cautiously apply close homologies yet the already tentative comparison of the sub-neural gland (5 and 6) to that of the *Urochorda*, is considerably strengthened by its similar relationship to the dorsal and peri-pharyngeal grooves.

In fig. 100 is seen a lateral view of the whole pharynx. The funnel-shaped mouth (*m*) shows the three oral grooves (*o.g.*) on each side converging into the opening of the pharynx. Round this opening is the peri-pharyngeal groove, running down from the sub-neural gland (*sn.gl.*), from which also proceeds the dorsal groove.

Down the dorso-lateral region runs the large paired pleurochordal ridge, which, rising gradually from behind, bends over in front, and opens by the pharyngeal cleft (*p.c.*) downwards and outwards to the exterior.

From this description of the pharynx and its connected structures, it is not difficult to understand to a great extent the functions performed by each part.

The twelve branchial plumes with their pinnæ are spread out from behind the buccal shield, and currents of water and food-particles pass down the ciliated ventral

grooves of these which join in pairs to form the three oral grooves on each side. The current of water and food-particles then passes through the peri-pharyngeal ring, into the main body of the pharynx. It is difficult to conjecture whether the mucoid stream passes forwards ventrally up this ring, and backwards dorsally, or whether the mucus, emerging from the sub-neural gland, passes backwards both dorsally and ventrally, but in either case, the food-particles become entangled in the mucus and are eventually carried backwards through the narrow œsophageal opening into the stomach whilst the water, flowing up to this opening, in the centre of the pharynx, will return as a back-flow along the notochordal grooves.

In *Phoronis*, as has been indicated in a preliminary note (7), the water-current is got rid of by means of the epistome, but in *Cephalodiscus* a large quantity of water must be carried into the pharynx, and the pharyngeal slits are admirably situated for its removal. Their chordoid walls must serve to keep the clefts permanently open. In addition to this, it appears probable that the dorso-lateral grooves which I have termed pleurochords will also serve to carry off the superfluous water outwards and forwards. The pharynx contracts to a small œsophageal opening at the hind end, and the whole structure suggests that, whilst the mucoid strands, laden with food, pass on to the stomach, a back current of water passes forwards along the cavities of the pleurochords and out by the pharyngeal clefts (fig. 100). If this be so, then the chordoid structure, both of the pharyngeal clefts and of the pleurochords may be due to the necessity for rigid channels to allow of the escape of cloacal water. Whether as paired pleurochords or as a median notochord, this function would persist in the early *Chordata* till pharyngeal clefts were formed at the posterior end of the pharynx, or as in *Phoronis* an extra-stomial means of separating the water from food were evolved. The notochord would then persist only in those forms in which it had secondarily acquired a supporting function (*Euchorda*).

Thus the loss of pleurochords in *Phoronis* may be traced to the peculiar adaptation of the epistome and the preclusion of a saving secondary function owing to the sedentary habitat, whilst the loss of the notochord in the *Urochorda* is primarily due to the removal of the necessity for the secondary supporting function, involved in a like manner in the adoption of a sedentary habit.

Thus one is led to suggest that the notochord of the Chordata primarily owed its origin to the necessity for a rigid channel in the endodermal walls of the pharynx, intimately connected with the primitive process of ciliary ingestion of food. The function of the notochord as an elastic primary axis to the body would thus be a secondary modification.

This assumption appears to be justified by the fact that the pleurochord of *Cephalodiscus*, permanently in the condition found in the embryonic *Euchorda* alone, i.e., as an endodermic longitudinal groove, most probably fulfils this function.

All the *Chordata* except the *Vertebrata* (or *Holochorda*) carry on their ingestive processes by ciliary action, with the consequent necessity for a separation of the water

and food-currents, hence it is certain that the chordate pharynx and allied organs have arisen, and have reached a complexity as high as that of *Amphioxus*, under these conditions. In this category may be included the notochord (or pleurochords), pharyngeal clefts, endostyle, sub-neural gland and the hyper-pharyngeal groove of *Amphioxus*, which are intimately connected with the vertebral column, gill-slits, and visceral arches, thyroid gland, hypophysis and sub-notochordal rod respectively, in the true *Vertebrata*.

Assuming that the pharynx of the earliest archi-chordate was homogeneous, and that the return water-current from the oesophagus took a dorsal course along grooves formed by the continuity of the current, then the epithelial cells lining these grooves would lose their secretory power, and might easily undergo a chordoid degeneration, which, serving as an efficient means for keeping open the cloacal grooves, would become permanent, and the pleurochords would become established. The paired condition may be primitive or secondarily acquired in the *Diplochorda*.

The Gonads.

Both Professor M'INTOSH (4) and Dr HARMER (1) have figured and alluded to the ovaries and oviducts of *Cephalodiscus* and to their descriptions. I have little to add. I have been equally unsuccessful with them in the search for male elements. In one preparation of part of the coenœcium there appears a dense cloud of minute, darkly-staining oval bodies, which might possibly be interpreted as free spermatozoa; but it is fairly certain that the colony obtained by the *Challenger* is "female" throughout. In a series of sections in the horizontal longitudinal plane, the oviducts and ovaries are cut nearly transversely, though at an angle.

In fig. 10, the left side shows the opening of the oviduct to the exterior, as a slight cup-shaped invagination of the ectodermal cells. On the right side, the oviduct (*g.d.*) is cut rather further back, and the cells are here seen to be longer, with their nuclei more irregularly arranged than is the case with the ectoderm. The oviduct is covered on the inner side by the wall of the coelome, which is here rather thicker than elsewhere. In fig. 11 the dorsal mesentery is observed to give out a lateral mesentery on each side to the base of the oviduct. On the right hand of this figure the oviduct is free from the ectoderm, and is seen to be supported by the lateral mesentery. Here the oviduct has a fine lumen, with indications of cilia. The epithelial cells show masses of black pigment, chiefly at their inner ends.

Fig. 12 gives two views of the junction of the oviduct (*g.d.*) with the ovary (*ov.*). On the left side the cells of the oviduct, with their abundant pigment, can be observed almost encircling the lumen of the ovary, whilst, especially on the inner side, the wall of the ovary can be recognised. On the right the oviduct is represented by a mere segment, whilst the greater part of the section is occupied by the reticular tissue of the ovary.

In this section the dorsal blood-vessel gives off an ovarian vessel running in the lateral mesentery to the ovary. It appears to terminate in contact with the ovary (*l.b.s.*), but in reality it surrounds the whole ovary, as can be easily determined in other specimens.

In fig. 13, both ovaries are seen in section at their upper ends. The ovary appears to consist of a mass of typically mesodermic tissue, consisting of a fine protoplasmic meshwork with nuclei scattered throughout it. Here and there are seen large egg nuclei, with a deeply-staining nucleolus. With progression backwards these nuclei become fewer and more prominent, whilst masses of protoplasm become aggregated around them. They then (fig. 14) tend to arrange themselves in three rows, and are of so large a size that they constrict the central space into a triangular lumen, which in fig. 15 is reduced to a mere slit.

In specimens with nearly ripe ova, the ovaries press outwards upon the rectum and other surrounding parts, and as Professor M'INTOSH (4) has remarked, they appear as large rounded protuberances in the body of the individual.

In the mesodermic covering of the ovary is a thin chondroid skeletal layer, which becomes greatly thickened at the posterior end.

The peculiar structure and appearance of the oviducts led them to be at first mistaken, in an external view, for eyes; and later, when their true structure was known, Dr MARCUS GUNN and Professor M'INTOSH (4) suggested that they were of the nature of phosphorescent organs. Considering the habitat of the animal, this appears to be by no means improbable, the light forming a possible attraction to the male element. It seems also likely that these so-called "oviducts" function solely for the introduction of the spermatozoa into the lumen of the ovary, in which fertilisation may be effected, the egg being afterwards set free, possibly by the death of the parent. This is rendered probable by the following considerations:—

Firstly, the eggs ripen from the mouth of the ovary backwards, so that the most advanced are found at the posterior end, furthest from the oviduct.*

Secondly, the ripe eggs formed in the coenecium are enormous in comparison with the size of the parent, and it is difficult to conceive of their extrusion through the oviducts or elsewhere without extensive rupture of the tissues.

Thirdly, the very active asexual reproduction would justify the low sexual fecundity implied in this suggestion.

In comparing these organs with those of *Phoronis*, we may note that the oviducts lie in a pair of lateral mesenteries, occupying a similar position to those of *Phoronis*, in which are situated the nephridia. The ovaries are evidently proliferations of the coelomic wall in each case, and the main distinction appears to consist in the "closed" condition of the oviducts in *Cephalodiscus* as compared with the "open" nephridia of *Phoronis*, a difference very closely paralleled by that existing between the urogenital systems of the *Teleostei* and the *Elasmobranchii* (compare figures 16 and 17).

* Cf. Remarks upon ovaries of *Cribrella oculata*, by Professor M. SÆRS. *Fauna litt. Norvegiæ*, Christiania, 1846.

On the other hand, the similarity of the gonads of *Cephalodiscus* to those of *Balanoglossus* is patent. They differ mainly in the fact that, as in the case of the pharyngeal clefts, there is only a single pair.

Nervous System and Pedicle. (Ventral Sucker.)

In a former paper already referred to, the nervous system was described as consisting of a dorsal ganglion over the sub-neural sinus, a pre-oral ring, a post-oral ring, and a pair of lateral nerves down the trunk. In addition, there are nerves to each of the plumes.

Fig. 85 is a diagram giving the distribution of the main nervous tracts, though the more or less general nervous plexus is not indicated. In the mid-ventral line of the trunk, from the trunk backwards, there passes a broad nervous tract which can be traced directly into the pedicle. The lateral nerves can be followed into the same organ.

Fig. 18 shows a transverse section of the pedicle. In the mid-ventral line may be seen the ventral nerve (*v.n.*) cut in section and forming a long ridge, with the chondroid layer between it and the coelome. On each side is a lateral nerve (*v.l.n.*) similar in appearance but not so prominent. In all these nerves there can be discerned a fine lumen which is more or less continuous throughout the pedicle. The three nerves gradually approach towards each other till at the tips they become indistinguishable.

Immediately inside the ectoderm is a fairly thick layer of chondroid tissue, and internal to it, is a well-defined layer of longitudinal muscles (*l.m.*). The coelomic space in the middle is directly continuous with the trunk-cavities, and the dorsal and ventral blood-vessels are direct continuations of the similar vessels in the trunk.

The main difference between the structure of the pedicle and that of the trunk is the absence of endodermic elements (intestine) in the former. The acknowledged secondary character of a reduplicated gut leads one to conclude that the pedicle is morphologically the hind end of the body, and that the actual posterior sacculated part of the animal is a secondary dorsal protuberance. A basal fixative portion of the body in *Phoronis* can be shown on similar grounds to be the true hind end of the body, and therefore homologous with the pedicle of *Cephalodiscus*. It will be seen later that this interpretation of the pedicle agrees with its relationships as seen in the buds.

Sexual Reproduction.

In going over a series of specimens mounted by the late Professor BUSK, and now in the possession of Professor M'INTOSH, I was struck by the appearance of an adult, which I have figured here (fig. 86).

It will be noticed that in the cloacal region there is a group of cyst-like structures closely pressed together and having a resemblance to a number of larvæ enveloped in their egg-capsules.

After drawing the specimen, it was removed from its mounting and sectioned, but its state of preservation has prevented even the determination of the exact position of these structures, whether in the rectum or the ovary, though they are more probably in the latter.

The examination of another specimen in the same collection furnished a series of eggs free in the cœnœcium, which were at different developmental phases, and from these I have been enabled to figure at least three stages.

Fig. 87 shows the egg contained in its capsule with a stalk of attachment, very much as described by Professor M'INTOSH (4), but of a more elongated outline. Fig. 88 shows a later stage in which the elongation is more pronounced and the egg has assumed a pear-shaped outline.

In fig. 89 a larval stage is seen, which is of some interest. A constriction has appeared slightly forward of the equator and divides the body into two segments. The resemblance of this larva to the early larval stage of *Balanoglossus*, as figured by Bateson, prior to the external differentiation of the collar-segment, is very striking.* The presence of these larvæ indicates that at any rate a certain amount of the development takes place in the cœnœcium, and that it may be possible to obtain a series of eggs and larvæ in which the early stages may be successfully followed out.

Asexual Reproduction.

Professor M'INTOSH (4) has already given a general description of the budding processes in *Cephalodiscus*, but a re-investigation of the subject, with plenty of good material, has enabled me to work out further details.

The buds are borne upon the pedicle, at the extreme distal extremity and upon the ventral surface. The distal extremity of the pedicle is modified into a sucker, and it is on the ventral border of this sucker that a pair of buds are produced. Occasionally three may occur, but, at least in some cases, the presence of a third is accounted for by the fact that the pedicle of a bud has commenced to bud in its turn, so that no less than three generations may be in organic continuity with each other.

Apart from this phenomenon we may say that two buds, on either side of the mid-ventral line, are the rule. This arrangement is comparable to that found in the creeping stolon (gymnocaulus) of *Rhabdopleura*, as already pointed out by Professor LANKESTER (3).

The pair of buds are rarely at the same stage of development; one is often at the stage with three pairs of plumes, whilst the other is a mere knob.

The bud first appears as a small rounded protuberance of the ventral body-wall, to one side of the mid-ventral line. It consists of a single layer of ectoderm and of mesoderm surrounding a space which is part of the pedicular cœlome.

* Cf. also the larval *Phoronis*, as figured by CALDWELL. *Quart. Journal Micros. Science*, pl. ii. fig. 3.

This protuberance becomes constricted at the base and then appears as a small knob (fig. 19) which presents no external differentiation.

The internal structure of this bud can be understood from the sections shown in figs. 29-32, selected from a series cut transversely to the long axis.

At the distal extremity (fig. 29) a thick layer of ectoderm, containing a mass of nuclei and ill-defined cell-walls, is lined on the inside by a thin layer of mesoderm, in which are scattered a few nuclei. Protoplasmic threads of mesoderm interlace across the central coelomic lumen.

In fig. 30 the coelome is shown to be divided in the middle by a mesentery, running as is seen later, dorso-ventrally. Within this mesentery (fig. 31) is formed a blood-sinus (*m.s.*), which may be followed through the pedicle (fig. 32) into the ventral blood-vessel and mesentery of the pedicle (see fig. 18). At the level of fig. 30, the median blood-sinus has moved dorsalwards and merged into a large dorsal sinus (*sn.s.*) underlying the ectoderm which proves to be the rudiment of the sub-neural sinus.

A sagittal longitudinal section through a similar bud is seen in fig. 36. If it had been exactly median, it would have shown the median sinus (*m.s.*) continuous with the sub-neural sinus.

Further development proceeds by a rapid growth of the apical portion of the bud resulting in the formation of the pre-oral lobe (protomere or buccal shield), one portion of which protrudes dorsally immediately in front of the sub-neural sinus, and grows out ventrally to such an extent that the bud assumes the appearance of being bent upon itself (fig. 19, left-hand bud).

A transverse section through the pre-oral lobe (fig. 33) shows a thickened ventral wall and a coelomic cavity in continuity with that of the rest of the bud.

A section at the base of the pre-oral lobe (fig. 34) shows the sub-neural sinus and the median mesentery as in fig. 30, but, in addition, the ectoderm is invaginating, forming a diverticulum (*g.*) pushing into the median sinus and gradually downwards between the two walls of the mesentery (fig. 35). Below the level of fig. 35 a cross-section presents the same character as fig. 32.

The commencing invagination of ectoderm shown in figure 34 gives rise, as may be easily demonstrated in later stages, to the whole of the alimentary canal of the adult, the orifice of invagination persisting as the mouth, and the anus being a new formation. The endodermal layer of the parent plays no part whatever in the formation of the bud, the whole future endoderm being derived from the ectoderm of the bud.

It is important to notice that the first invagination takes place opposite the sub-neural sinus and immediately behind the buccal shield, which is therefore pre-oral in position from the outset.

In the next stage the buccal shield has grown out laterally as well as in the dorsal and ventral line (fig. 20), so that the body now appears to consist of three parts, the buccal shield, the body in which is contained the future trunk and collar and the long cylindrical pedicle, which has commenced to elongate.

A median sagittal section through this bud (fig. 37) shows but little advance in differentiation upon the last stage. The endodermic pouch has become larger and reaches further backwards than in earlier stages. At the dorsal lip of the mouth is seen a slight depression, which is the first trace of the sub-neural gland (*sn.gl.*, HARMER's notochord). In such a case as this, where the whole endoderm is derived from the ectoderm, it is impossible to locate the origin of the sub-neural gland in any special embryonic layer, but it may be noted that its first appearance is much further outside the pharynx and away from the sub-neural sinus than later.

Subsequent growth results in a clearer definition of the three areas already referred to, and in the appearance of two dorsal rounded knobs immediately behind the buccal shield (figs. 21 and 22). Sections indicate some important changes in the internal structure. In a horizontal longitudinal section (fig. 38) it is seen that the ectoderm has become drawn in behind the buccal shield, and where the pedicle meets the body. The rapidly enlarging endodermic sac touches it at these two parts forming two circular lines of contact. In this way the single coelomic space is nipped off into a single pre-oral cavity (protocoel), a pair of collar-cavities (mesocoel) still separated by the persistent median mesentery and a pair of trunk-cavities (metacoel) which are still continuous through the pedicle with the coelome of the parent.

A stage very like this was figured by Dr HARMER (1) and led him to compare the bud of *Cephalodiscus* at this stage with the young *Balanoglossus*.

The cavities of the two knobs, which are the first pair of plumes, are in direct continuity with the two collar-cavities. Fig. 39 is a median sagittal section through the bud shown at fig. 22. We may here note that the endodermic sac has increased in size and the sub-neural gland has moved backwards towards the sub-neural sinus. The dorsal posterior lip of the hind-gut has commenced to move forwards along the mid-dorsal line. Between this stage and that shown in fig. 37, the hind apex of the endodermic sac touches the dorsal ectodermic wall, and then from this point the intestine grows forwards as seen in fig. 39, till it eventually opens to the exterior, a little way behind the sub-neural sinus.

In this manner the dorsal reduplication of the gut is brought about, and it seems reasonable to suppose that the spot where the endodermic sac first touches the ectoderm represents the primitive posterior position of the anus, the later forward growth of the intestine indicating a phyletic forward movement of the anus (*cf.* Segmental duct of *Vertebrata*). The endodermic sac never comes in contact with the wall of the bud between the mouth and the pedicle, so that the pedicle could not be regarded as a dorsal process.

The next important external change is the separation of the collar-area from that of the trunk (fig. 23), caused by a bulging outwards of the former. At this stage the trunk is also more clearly separated from the pedicle and their line of junction is now on the under-side. The two plumes have elongated and their distal extremities have swollen out to form the compound eyes.

A series of transverse sections of this stage is shown in figs. 40 to 48.

In fig. 40 is seen the cross-section of the buccal shield. Its ventral wall is greatly thickened, and in the deeper part of the dorsal wall can be discovered a differentiation of nervous tissue. On the left of the middle line is shown a proboscis-pore (*p.p.*) in process of development as an invagination of ectoderm. In fig. 41 it opens into the pre-oral coelome. Above the buccal shield is seen a cross-section of the plumes. At an earlier stage they are circular, but the surface nearest the buccal shield is here depressed to form a longitudinal groove. In the mid-dorsal line the mesodermal lining of the coelome is thickened by an accumulation of nuclei with protoplasmic processes; these are situated at the anterior end of the sub-neural sinus. In section 41 the pre-oral coelome is still cut ventrally, but dorsally the sub-neural sinus (*sn.s.*) is seen, covered by the central nervous mass, and containing the sub-neural gland (*sn.gl.*). The cross-section of this gland is here closely similar to that already described in the adult. In fig. 43, the plumes can be traced into the collar region, and on the right-hand side a second plume is indicated. The collar-cavities lie on either side dorsally, and between them is seen the dorsal blood sinus (*d.s.*), the direct continuation of the sub-neural sinus in fig. 41.

In this series the dorsal sinus can be followed as far as the mouth (fig. 44), but in many specimens is seen in the dorsal mesentery shown in figs. 45 and 46.

From the study of a number of specimens, it is quite clear that the blood system, as in fig. 36, consisting of a median mesenteric sinus and a terminal sub-neural sinus, is invaded by the endodermic sac from the ventral side in such a way that the median sinus is separated by the post-oral part of the sac into a dorsal and ventral blood-sinus, and the pre-oral part (sub-neural gland) effects a similar separation at its base, but at its distal extremity it rests in the sub-neural sinus.

These relationships are easy to follow in such a stage as shown in figures 40 to 48, and although matters are complicated in the adult by further differentiations, there can, to my mind, be no possible interpretation of the parts other than that given here.

I emphasise this because my interpretation of the sub-neural sinus and gland was called in question recently by Dr HARMER (2). He would consider the sub-neural sinus as a structure closed on all sides by mesoderm. If such were the case, his suggested homology with the "proboscis-vesicle" of *Balanoglossus* would have some facts to recommend it, but the structure of the sinus, as depicted as accurately as may be in figures 40 to 44, and later in figures 78 to 84, seems to me to indicate that at these stages (*a*) there is no trace of a closer mesodermic vesicle; (*b*) the sub-neural gland, arising far out, eventually rests freely in the dorsal sinus and its direct continuation, the sub-neural sinus, the dorsal wall of both these sinuses being formed by ectoderm alone. I have not been able in any later stage to detect any structure developed in this region at all comparable to the "proboscis-vesicle."

So far, therefore, as the study of the buds is concerned, their structure appears to corroborate my former interpretation of the parts as re-stated in answer to Dr HARMER's criticism (6).

Returning to figure 43, we see here only the collar-cavities (*c.c.*) and the dorsal sinus, whilst the base of the sub-neural gland is shown to open to the exterior in the mouth region. On the right-hand side the oral groove is recognisable. In fig. 44 both oral grooves are seen, and in fig. 45 the mouth is freely open ventrally. The collar-cavities are divided by a pair of trunk-cavities which lie on either side of the median dorsal mesentery. On the right hand appears an oviduct (*g.d.*) arising as an invagination of the ectoderm. The cross-section of the pharynx here shows a pair of lateral grooves which are the first trace of the pleurochords.

In fig. 46 we can note the paired ectodermal oviducts (*g.d.*) and below them the trunk-cavities. Laterally are the collar-cavities, and ventrally are the two collar-pores (*c.p.*) arising in a precisely similar manner to the proboscis-pores and the "oviducts" as pair ectodermal tubes.

In fig. 47 the stomach (*st.*) presses against the dorsal wall, and the trunk-cavities and ventral mesentery complete the section. In the mid-ventral line can be discerned a commencing nervous differentiation.

Fig. 48 is cut at the commencement of the pedicle, and shows the intestine in contact with the dorsal wall.

In this feature the bud is at an earlier stage than that which is shown in fig. 39, where the intestine has commenced its forward migration.

The mesentery is now incomplete, and the ventral sinus runs down to meet the ventral sinus of the parental pedicle. The mesoderm is partially differentiated in the ventral area into muscular tissue, which will later become the longitudinal muscles. In the ectoderm outside this the ventral nerve-tracts are clearly distinguishable. They are continuous with those of the adult.

On either side of the pedicle is a lateral groove (*l.g.*) which is of constant occurrence, and gives the pedicle at this stage a characteristic cross-section. The basal-fixing extremity of *Phoronis* presents a similar pair of lateral grooves most clearly defined immediately after metamorphosis. In the buds of *Cephalodiscus* they disappear early (see fig. 59), and their meaning is doubtful.

From this series and the above description can be obtained an idea of the structure of a typical bud of *Cephalodiscus*, with one pair of plumes.

The simple archimeric segmentation into five archicoeles, the simple and non-reduplicated gut, and the primitive blood-system of sinuses should be emphasised, whilst the identity in structure and origin at this stage of the proboscis-pores, the collar-pores and the "oviducts," is very striking. The proboscis-pores alone appear to open into the coelome.

Fig. 24 is a dorsal view of a bud intermediate in external character between the bud with one pair of plumes, just described, and that with two pairs, shown in figs. 25 and 26.

The second pair of plumes are seen to arise near the base of the first, as simple horn-like protuberances, whilst the first pair have developed a number of pinnæ from

the apex downwards. The further development of the tentacles will be referred to later, though it may be here stated that the stage to which development of the plumes has reached is only a rough criterion of the amount of internal differentiation. Thus the sections of fig. 24 to be described are of as advanced a stage as those cut through figs. 25 and 26, and seem to represent, as far as is possible, the stage indicated externally by the presence of two pairs of plumes.

Figs. 49 to 59 represent this stage in sections.

In fig. 49 there is shown a considerable advance over fig. 40. The nervous layer is well developed, both dorsally and ventrally, in the buccal shield and in the dorsal ectoderm of the plumes. The sub-neural sinus has thickened mesodermic walls, probably contractile.

Fig. 50 shows the sub-neural gland in cross-section, now of much less proportionate size than in fig. 41.

In fig. 51 the post-oral lamella and collar-cavities are evident, and a cross-section of the pharynx has a very characteristic outline. The median dorsal and median ventral grooves are continuous with the aperture of the sub-neural gland. The paired dorso-lateral grooves are the commencing pleurochords, and the ventro-lateral grooves are the paired oral grooves. These latter run in fig. 52 to the exterior.

The rectum, bounded by the trunk-cavities laterally and the oviducts (*g.d.*) running in lateral mesenteries, are also seen in this figure.

In figs. 53 and 54 the ovaries (*ov.*) developing from the coelomic wall, and the post-oral lamella should be noted, whilst the latter figure shows, on the left side of the pharynx a pharyngeal pouch, not yet opening to the exterior (*p.c.*). Its formation from an evagination of the pharyngeal wall is in accordance with its structure in the adult.

The pharynx (*ph.*) stomach (*st.*) and rectum (*in.*) are all cut in fig. 55 behind the gut (fig. 58), the dorsal and ventral sinuses merge into one, to again separate in the pedicle, in which the mesentery is interrupted (fig. 59). The longitudinal muscles, traces of which may be found at the extreme front-end of the pharynx (fig. 53), become very prominent, and are of an advanced histological structure posteriorly (fig. 57). They extend round the whole coelome in the pedicle (fig. 59). The single ventral nerve-tract in this region spreads out further forwards (fig. 56) and can be traced upwards as a pair of lateral cords (fig. 55) and (fig. 54) into the post-oral ring.

The external appearance of the four-plumed stage is indicated in figs. 25 and 26. The buccal shield is of enormous size, greater in proportion than in the adult, and the median curved line of pigment is distinct. In front view (fig. 26) it is saddle-shaped, and in side view (fig. 25) it shows a thickened rim.

This figure shows that the pedicle, at first terminal, and in the direct axis of the body, becomes apparently ventral by the dorsal protrusion of the trunk and its contained structures. Thus the pedicle becomes shifted till it appears, in figs. 27 and 28, and still more in the adult, to be an appendage of the ventral body-wall.

A nearly median longitudinal section through the bud (fig. 26) is illustrated in fig. 60. The buccal shield attains at this stage its greatest proportionate size, and within it we may notice some important differentiations. The sub-neural gland (*sn.gl.*) has moved backwards to reach the dorsal wall, and has now come at its distal end into close relationship with the sub-neural sinus (*sn.s.*). The postero-ventral wall of the latter has become slightly pushed in (at least in the preserved specimen) and the mesodermic wall of the invaginated part becomes thickened by a grouping of mesodermic nuclei and protoplasmic strands. Certain of these cells protrude into the cavity of the sub-neural sinus in a symmetrical radiate manner, the first traces of which may be sometimes recognised in the earlier buds with two plumes (*pr.s.*). The anus now opens as a wide aperture to the exterior, in the same dorsal position as in the adult.

The stage with three pairs of plumes develops from the preceding in quite a regular manner by the formation of a third pair, at first in the same straight line as the other two, and in the ordinary course the bud becomes detached from its parent at this stage. This is effected by a simple constriction of the end of the pedicle where it is fused with the parental pedicle. The connecting tissue becomes narrower and narrower, the ectoderm presses in on all sides upon the coelomic channel, whilst at the same time sections through a late stage of the process indicate a certain amount of histolysis especially in the longitudinal muscles. Specimens can be obtained in which the junction is so narrow that a gentle shake serves to detach the bud from its attachment, and sections of the bud show that the coelome is closed and that the ectoderm although thin is continuous over the tip of the pedicle. In these cases one might fairly assume that the bud remains in contact with the parent only by virtue of the adhesive power of the pedicle. The free buds at this stage are roughly about $\frac{1}{4}$ the bulk of the adult. No reference up till now has been made to the size of the buds which have been described. The reason for this omission is that the size of the buds corresponding to any particular degree of differentiation varies within wide limits, so that no fast rule can be stated.

The size of the early buds in fig. 19 can be gauged by comparison with the pedicle to which they are attached, and the same applies to the four-plumed stage in fig. 25.

On the other hand the rest of the figures except fig. 28 are drawn to nearly the same scale as fig. 25. Fig. 27 illustrates the appearance of the bud soon after detachment. In this instance the buccal shield and post-oral lamella have been removed to show the arrangement of the plumes, which will be alluded to later. Fig. 28 gives the entire bud in side view, at about the same stage. The buccal shield is still of enormous size and partially over-laps the short contracted pedicle. Sections through such a stage show that except for the plumes and gonads the bud may be regarded as a small-sized adult.

Fig. 61 shows that the pharyngeal clefts are now open to the exterior, and that their walls are assuming a chordoid character, and fig. 62 indicates very clearly the

three ventral nerve-tracts which are still very prominent. In the adult they are greatly reduced. In some respects they remind one of the large ventral nerve-mass in young *Sagitta*.

The muscles are now quite distinct, and in fig. 63, which is through the base of the pedicle, they are seen to extend round dorsally.

Development of the Plumes and Pinnæ.

The plumes arise throughout in pairs. They first make their appearance as a papilla, which elongates to a finger-shaped process (fig. 69), the distal extremity of which becomes slightly swollen (fig. 70), and then bulbous (fig. 71). The epithelium of this bulbous extremity then becomes modified to form the eyes. The cuticle of certain of the epithelial cells becomes thickened (fig. 75), and soon the thickening protrudes into the cavity of the cell as a lens-like body (figs. 76 and 77). Later it is detached from the cuticle and lies freely in the protoplasm. Here it becomes rounded off to form the lens.

Immediately below the eye a pair of small processes arise laterally (fig. 72), and grow rapidly to form the paired pinnæ. The other pinnæ arise as a double row in succession downwards (figs. 73 and 74).

Each plume is at first circular in outline, but at an early stage the ectoderm of one side is pushed in to form a groove (fig. 40), so that the outline in section is horseshoe-shaped.

The order of development of the plumes is peculiar. The first pair arise close to the middle line, with their groove facing towards the dorsal surface of the buccal shield (figs. 40 and 64). The second pair arise outside these (figs. 49 and 65), and are at first in the same relation to the buccal shield.

In the course of development, however, both pairs commence to rotate upon their own axis, and also to move in a posterior direction away from the buccal shield.

Thus, in fig. 49, the plumes have rotated about 90°, or a little more in the case of the first pair. The grooves are not evident at this level, but the nerve tracts are always at the opposite side to the grooves. The third pair of plumes arise outside, and at the base of the second pair, and they behave subsequently in a similar manner to these. Thus the three pairs of plumes come to lie a little way back from the buccal shield, and with their grooves and pinnæ facing away from this organ. Fig. 27 shows this arrangement, and also the rudiment on the left side, of one of the fourth pair.

The three last pairs of plumes are later in development, and differ slightly in their growth from the three first pairs. The fourth arise almost parallel to and nearer the buccal shield than the third, whilst the fifth appear first between the second and the buccal shield, and lastly, the sixth arise just in front of the first pair. These points are illustrated in figs. 66, 67, and 68. These three pairs develop grooves facing the buccal shield, as in the case of the others, but they do not rotate.

Such is the very peculiar way in which the arrangement described in the adult is obtained, and the meaning of their method of origin formed an interesting puzzle. A comparison with the mode of origin of the tentacles in *Actinotrocha* has given a solution which has satisfied me, and may, I hope, appear plausible to others.

In *Actinotrocha* the tentacles, when stretched above the head as in the adult, are arranged, viewed from above, as in fig. 68A. The thick epithelium corresponding to that of the oral grooves is on the inside of each tentacle. They arise in succession on each side on the dorsal surface of the collar region, immediately behind the pre-oral hood. A stage with only six pairs is figured for simplicity. In comparing the arrangement with that of *Cephalodiscus*, we note that whereas, in the former case, the tentacles move round ventrally to surround the mouth and epistome, in the latter this is impossible, because the buccal shield (homologous with the pre-oral hood or epistome) is used as a sucker. In this case, therefore, the plumes, after travelling part of the way towards the ventral surface (fig. 68B), turn backwards and move up again. To put the process more correctly, the actinotrochan-like ancestor of *Cephalodiscus* adopted an adhesive function for the pre-oral hood, immediately upon the assumption of a partially sedentary existence. A general morphological rule for sedentary animals with tentacles is that these organs become directed forwards in front of the head, so that in this case the three last pairs, unable to move forwards in the ventral line, moved forward and dorsally upward to take up the position found in *Cephalodiscus*.

If the ontogeny of the plumes recapitulated the whole of phylogeny, the first three pairs of plumes should migrate in procession from the point of origin of the first (which corresponds exactly with that of the tentacles of *Actinotrocha*) down to nearly the mid-ventral line, and then upwards and backwards (*ab.* fig. 68B). Such an apparently useless migration would not be likely to occur, and we do not find that these plumes migrate even as far as (*cd.* fig. 68B). The migration would be gradually shortened till the present condition is arrived at, in which each plume moves directly from its point of origin to its later position. At the same time, it is evident that the rotation through 180° of each plume results in the three plumes having their oral grooves facing away from the buccal shield, just as would occur in the phyletic migration. On the other hand, the last three pairs, occupying a position corresponding with that of the last three pairs in *Actinotrocha*, arise in an equally direct and simple way, as in this larva, and undergo no rotation.

The Development of the Sub-Neural Gland and the surrounding Organs.

In the early buds, as already stated, the sub-neural gland by a movement inwards comes to lie with its distal end in the sub-neural sinus, but as development proceeds, the coelomic wall immediately ventral to the tip of the gland becomes thickened and tucked in, invading the sub-neural sinus as a short diverticulum of the pre-oral coelome.

Such a condition is found in the stage with one pair of plumes, and the series of sections here (figs. 78 to 84) described, lie between figs. 40 and 43. They are drawn by camera under a Zeiss microscope with obj. F. In fig. 78 the mesodermic cells forming a thickening of the anterior wall of the sinus are cut through, whilst the next section (79) passes through the sub-neural sinus itself. In fig. 80 a few mesodermic cells are cut through, apparently loose in the blood-sinus, but in reality they are of the same nature as the cells seen in the next section, but cut obliquely. In fig. 81 is seen the pre-oral sac invaginated from the pre-oral coelome, and it still opens freely into the latter. It appears to be filled internally with a homogeneous darkly-staining material, which, in later development, thins out to form a uniform layer around the walls of the pre-oral sac as in the adult, and then is indistinguishable from the chondroid tissue.

Attached to the mesodermic wall of the sac are a number of cells (*t.c.*) which have a characteristic form, being somewhat fusiform with the nucleus near the centre, one end free and the other attached. They radiate in all directions except posteriorly, where the head of the sub-neural gland lies. A few can be seen in fig. 82 attached to the posterior edge of the pre-oral sac, which lies slightly over the sub-neural gland. In fig. 81 the dorsal wall of the sinus is seen to consist of ectoderm alone, and the sub-neural sinus can be traced without break into the dorsal sinus in figs. 83 and 84. In fig. 82 it is seen to be limited on the left by the pre-oral coelomic wall, and, owing to a slight obliquity, on the right by the wall of the collar-coelome; in the following sections the collar-coelome is alone seen. In the latter figure may be noticed the sub-neural gland, free in the blood-sinus, which surrounds it on all sides. In the sinus are a few cells, either free blood-corpuscles or cells detached from the radiate cells. Such is the peculiar morphology of these parts, and their functions are not easy to conjecture.

A stage differing little from this is found in fig. 60, in nearly median longitudinal section.

Subsequent development consists in an expansion of the pre-oral sac, which becomes of somewhat irregular outline, in a loss of regular arrangement by the radiate cells, and in a partial closure of the aperture of the pre-oral sac. The posterior wall of the sub-neural sinus grows backwards across the aperture, and comes in contact with the pre-oral coelome immediately covering the head of the sub-neural gland. Thus, in the adult, a median longitudinal section through this region gives one the impression that the pre-oral sac is closed ventrally and has no communication with the pre-oral coelome, thus seeming to bear out the statement of Dr HARMER (2). The aperture, however, secondarily closed on the middle line, is still open on each side. Thus, in the adult, the pre-oral sac still communicates with the pre-oral coelome by a pair of short channels, which are easily demonstrable by longitudinal sections a little to either side of the median plane.

On the other hand, I have entirely failed to find any trace of a communication between the pre-oral sac and the dorsal blood-sinus, such as should exist if Dr HARMER'S

interpretation of this organ as the heart were accepted, and I have every reason to believe that such cannot be demonstrated.

In the discussion upon these points between this author and myself, we have been blamed for complicating the points at issue by each using a different nomenclature, so I may be excused for giving the following table illustrating the two views :—

1. "Sub-neural gland,"	=	Harmer's "notochord."
2. "Sub-neural sinus,"	=	„ "proboscis-vesicle."
3. "Pre-oral sac,"*	=	„ "heart."

HARMER accepts the presence of my "dorsal blood-sinus," and believes that it will be proved to communicate with (3) and not with (2); and, on the other hand, he denies the communication of (3) with the pre-oral coelome.

Whilst denying my interpretation of the "paired notochords," HARMER corroborates my description of them, and, apparently, of the other leading anatomical points in my work not mentioned above.

It appears to me that the disputed points will have to be settled by a renewed investigation of the development of *Balanoglossus*. Should the proboscis-vesicle of *Balanoglossus* be indubitably proved to arise from mesenchyme or from the proboscis-coelome, then it is possible that *the pre-oral sac above described may represent, in Cephalodiscus, the more primitive condition of the homologous structure*, whereas, should the proboscis-vesicle prove to be developed from ectoderm, it would probably have, as formerly suggested (6), to be regarded as the distal extremity of the sub-neural gland.

In any case, a rhythmically pulsating organ with an internal cavity, completely closed, is so anomalous a structure that more knowledge of its structure and development is very essential. It seems possible that the proboscis-vesicle of *Balanoglossus* may yet be proved to communicate with the pre-oral coelome by minute lateral apertures in a similar manner to the pre-oral sac in *Cephalodiscus*. The radiating cells above described would then represent the proboscis gland (*cf.* larval nephridia of *Annelida*), and the resemblance of proboscis-vesicle and pre-oral sac would be very close, both functioning as contractile vesicles for the expulsion of excretory fluids into the pre-oral coelome.

Summary.

The following is a brief summary of the chief features dealt with in the foregoing :—

- (1) The pharynx has special adaptations for the separation of food and water-currents, amongst which may be reckoned hyper- and hypo-pharyngeal

* Prior to this, the organ here referred to has been unnamed; the above name may be suggested for adoption in that it is descriptive without in any way implying a special homology.

grooves, the peri-pharyngeal groove, sub-neural gland, the pharyngeal clefts, and the pleurochords.

- (2) The notochord of the *Chordata* may be primarily derived from this source as a channel for cloacal water from the point of separation to the points of exhalation, *i.e.*, pharyngeal clefts.
- (3) The gonads are suspended in lateral mesenteries, and surrounded by a blood-sinus, communicating with the dorsal sinus.
- (4) The pedicle or ventral sucker has a ventral nerve cord and two ventro-lateral cords, a dorsal and a ventral blood-sinus, and complete inner layer of longitudinal muscles.
- (5) The buds arise usually in pairs ventrally. The ectoderm and mesoderm of the bud are formed directly from those of the pedicle. The endoderm is formed by invagination of the ectoderm.
- (6) The pharyngeal clefts arise as endodermal diverticula which break through the ectoderm to the exterior. From their structure and relationships to the pleurochords in the adult, they would seem to be simply the oral termination of the latter. The two primitive chordate characters of notochord and pharyngeal cleft would thus appear to have arisen from a common rudiment resembling the pleurochord of *Cephalodiscus*. The anal end of the intestine is at first in contact with the ectoderm posteriorly and just above the pedicle, but later moves up to the oral end and then opens to the exterior.
- (7) The blood system arises as a system of sinuses between the coelomic cavities and the ectoderm, continuous from the first with those of the adult.
- (8) The sub-neural gland arises far out and moves secondarily into connection with the sub-neural sinus.
- (9) The first three pairs of plumes arise near their final position, into which they move gradually with a rotation through 180°, the last three, forming the inner row of the adult, arise *in situ*.
- (10) The oviducts, proboscis-pores, and collar-pores all arise in a similar manner, as paired ectodermal tubes.
- (11) The gonads arise as proliferations of the mesoderm lining the trunk-coelome.
- (12) The adult characters are assumed when three to four pairs of plumes are present; and separation from the parent is then effected by constriction.
- (13) The lens of the branchial eyes is formed by cuticular hypertrophy and later detachment.
- (14) Sexual development commences in the egg-capsule whilst attached to the inner wall of the coenœcium, and results in the formation of a larva segmented into two parts by an annular constriction.
- (15) The pre-oral sac arises as a diverticular invagination of the posterior wall of the pre-oral coelome, and its bounding cells become modified into spindle-shaped excretory cells free in the sub-neural sinus.

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LIST OF ABBREVIATIONS.

1.2.3. (in Plates I. and V.)=oral grooves.	<i>p.c.</i> =pharyngeal cleft.
1.2.3. (in Plate IV.)=plumes in order of development.	<i>ph.</i> =pharynx.
<i>c.c.</i> =collar-cavities.	<i>p.l.l.</i> =post-oral lamella.
<i>c.p.</i> =collar-pores.	<i>pn.</i> =pinna.
<i>d.g.</i> =dorsal groove.	<i>p.p.</i> =proboscis pore.
<i>d.s.</i> =dorsal sinus.	<i>pr.cœ.</i> =pre-oral cœlome.
<i>g.</i> =gut diverticulum.	<i>pr.s.</i> =pre-oral sac.
<i>gd.</i> =gonaduct.	<i>r.</i> =rectum.
<i>in.</i> =intestine.	<i>sn.gl.</i> =sub-neural gland.
<i>l.b.s.</i> =lateral blood-sinus.	<i>sn.s.</i> =sub-neural sinus.
<i>l.g.</i> =lateral grooves.	<i>st.</i> =stomach.
<i>l.m.</i> =longitudinal muscles.	<i>t.c.</i> =trunk-cavity.
<i>m.s.</i> =median sinus.	<i>v.g.</i> =ventral groove.
<i>m.</i> =mouth.	<i>v.n.</i> =ventral nerve.
<i>nc.</i> =notochord (pleurochord).	<i>v.l.n.</i> =ventro-lateral nerve.
<i>ov.</i> =ovary.	<i>v.s.</i> =ventral sinus.

DR A. T. MASTERMAN ON CEPHALODISCUS DODECALOPHUS. Pl. I.—PLATE I.

D^r A. T. MASTERMAN ON CEPHALODISCUS DODECALOPHUS. M^cI.—PLATE II