VI.

CONTRIBUTIONS FROM THE ZOÖLOGICAL LABORATORY OF THE MUSEUM OF COMPARATIVE ZOÖLOGY AT HARVARD COLLEGE.

No. VI.* — ON THE ANATOMY AND HISTOLOGY OF AULOPHORUS VAGUS.†

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Material and Methods.

The material used in the preparation of the following paper was obtained from a ditch by the roadside near Fresh Pond, Cambridge, Mass., in October and November, 1883. In October the surface of the water was so thickly covered by a growth of Lemna as to be almost entirely hidden. Upon gathering the Lemna in a shallow dish, the worms could be easily collected by picking out the tubes which they had constructed from the Lemna leaves. Worms obtained in this way were easily kept all winter in glass jars containing water, in which some additional Lemna had also been placed. They lived and multiplied rapidly, even when not exposed to the sunlight.

For sectioning, the specimens were prepared by the use of either Kleinenberg's picro-sulphuric fluid, osmic acid, or chromic acid, good results being obtained with each. Borax-carmine, or a mixture of borax-carmine and picro-carmine as recommended by Bülow for Lumbriculus, was found to be the best staining fluid. The worms curl in a dorso-ventral plane in the killing fluid, but they may be straightened by placing them on a glass slide between the edges of two square cover-glasses, which are closely applied to the slide and held in position by wetting their under surfaces. The straightening is accomplished by sliding the cover-glasses against the worm, one on each side, care

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being taken not to crush it. This may be done by arranging two pieces of wire, of the diameter of the worm, so that their ends project between the edges of the cover-glasses. The glass slide may be laid for the purpose on a piece of wood, into which the other ends of the wires are fastened. After being straightened in this way, they may be rendered rigid enough for handling by placing on them while still between the cover-glasses a few drops of 70 per cent alcohol, in which they should remain for a minute or two. They are most readily handled by means of a pipette.

General Description and Habits.

Aulophorus vagus was named and described by Leidy in the American Naturalist for June, 1880, as follows: — "Our species I propose to name *Aulophorus vagus.* Body cylindrical, compressed, transparent, with red blood and yellowish-brown intestine. Single individuals of the third of an inch or more in length, composed of from 24 to 35 rings. Head ovoid, extending as a conical upper lip, very mobile and changeable in form, obtuse or sub-acute and minutely hirsute. Eyeless. Caudal ring contracted, and furnished with a pair of long, divergent, digit-like appendages, which are straight or slightly incurved, blunt, and minutely hirsute. Anal aperture surrounded by a rosette of half a dozen prominent, blunt, conical papillæ. The four rings succeeding the head furnished on each side with fascicles of seven to nine podal stylets; the succeeding rings, except the last, with fascicles of 5 to 6 podal stylets, which are shorter than the former. Podal stylets sigmoid with a median shoulder and ending in a furcate hook. The same posterior rings furnished dorso-laterally with fascicles consisting each of usually a single moderately long bristle and a single nearly straight stylet ending in a spade-like expansion. Pharynx capacious, going into the fifth ring, and narrowing into an œsophagus, which ends in the intestine within the ninth ring. Generative organs unobserved. Worm of 3 to 5 lines in length, or more, according to its degree of extension. Living in a tube of its own construction, which it drags about with it. The tube is composed of a transparent cement or basis, incorporated with various materials, such as vegetal particles, sand, dirt, diatoms, spongilla spicules, etc. In creeping about among aquatic plants, Lemna and Wolffia, the worm stretches in such a manner that one third of the body extends from the fore part of the tube, while the forked caudal extremity remains projected from the back end. The worm moves in jerks, alternately extending the fore part of the body and projecting the podal fascicles forward and hooking into the surface on which it is creeping, and then contracting the fore part of the body and dragging along the back part enclosed within the tube. Frequently the motion is aided by eversion of the pharynx, so as to form a disc or sucker which adheres to surfaces like that of a leech. The movements occur in quick succession, so that the worm creeps about quite actively. At times it doubles itself, — thus passing through its tube and reversing its direction. At times, too, it will leave its tube and creep about without one. The papillæ of the anal aperture are clothed with vibratile cils, which produce an active current inwardly as observed in Dero."

The animals are found either single, or composed of 2 to 4 zoöids joined by bud-zones. In March, material kept over winter showed few specimens with bud-zones, and in the great majority of cases the number of segments was 25. The body tapers slightly posteriorly. It ends in an expanded pavilion resembling that described by Perrier for *Dero obtusa.* This pavilion (Pl. I. fig. 1, *pav.*) opens somewhat dorsally, and, when fully expanded, shows no trace of lobes on its dorsal and lateral borders. On its ventral border it presents in all cases two lobes, which are separated by a median notch and project slightly beyond the rest of the border of the pavilion. When the latter contracts, the dorsal and lateral borders become divided into four additional lobes by a median dorsal and two lateral notches. Thus, unless it is examined when fully expanded, the pavilion presents the appearance of "half a dozen prominent, blunt, conical papillæ" surrounding the anus, as described by Leidy. When the animal is in plenty of water, the posterior part of the body is habitually kept bent upward, so that the opening of the pavilion is toward the surface of the water. The digit-like appendages are attached laterally and ventrally, outside the border of the pavilion. Their outer ends are slightly swollen. They project directly backward parallel to one another when the pavilion is contracted; when it is expanded, they diverge. The number of podal stylets in each of the fascicles of the four anterior ventral pairs varies from 8 to 14, but they do not differ from one another at all, except in length, and this, taken in connection with the fact that they are fewer and more uniform in size in immature zoöids, gives no support to the notion advanced by Perrier ('72, p. 68) for *Dero obtusa,* that the fascicles are formed by the fusion of ventral and dorsal fascicles. The stylets in the ventral fascicles differ from those in the dorsal, and one would hardly expect this difference to be obliterated by a fusion of the two. The stylets in these four anterior pairs of ventral fascicles (Pl. I. fig. 2) are longer and straighter than those in the succeeding ventral pairs. The fork on the convex side of the furcate outer end is much longer, sharper, more curved, and more slender than that on the concave side. The number of stylets in the ventral fascicles behind the fourth pair varies from 4 to 7, perhaps according to the age of the animal. They also vary in length. The fork on the convex side of the stylet (Pl. I. fig. 3) is very much smaller and sharper than that on the concave side, but not so long. These stylets are therefore readily distinguished from those in the first four pairs of ventral fascicles. The dorsal fascicles contain from 1 to 3 bristles, and from 1 to 3 spade-shaped stylets. The latter (Pl. I. fig. 4) are not so much curved as the ventral stylets. Their outer ends are flattened and expanded into thin triangular blades, one edge of the expanded portion being nearly straight, and the other concave, and both being strengthened by marginal ribs. A third rib sometimes runs midway between the two marginal ones. The bristles are much longer than the stylets, pointed, and without a median shoulder. The matrix cells of the stylets and bristles may be seen in sections. They have elliptical, granular nuclei, which are closely applied to the stylets and bristles.

In the fall, when the Lemna leaves were plenty, the tubes were formed entirely from them. Specimens kept over winter in glass jars in which there was but little Lemna formed their tubes entirely from Plumatella eggs, as described by Leidy. An isolated specimen in a small dish with some Œdogonium formed its tube entirely from the Œdogonium filaments. The worms were never observed to leave the tube voluntarily, nor were any ever found without a tube. When a single individual becomes divided into two, the two sometimes continue to occupy the same tube, one reversing its direction; or the newly-formed individual may build a new tube by the side of the old one and attached to it. An individual removed from its tube forms a new one in a very short time, frequently in less than ten minutes. The animal is easily driven from its tube by following it up from the posterior end with needles.

They stay most of the time at the surface of the water, and, when in a dish, usually at the side. There they lengthen their bodies, head downward, and seize the side of the dish by using the everted pharynx as a sucker. Then, by alternately shortening and lengthening the body, they continually move the tube up and down. The alimentary canal of the worms found at the surface of the water frequently contains a great many large air-bubbles, but such bubbles have never been seen in animals taken from the bottom of the jar. The bubbles are especially noticeable in specimens whose tubes are formed of heavy material, and not of Lemna leaves nor Plumatella eggs. It would seem, then, that when its tube is heavy the animal has the habit of swallowing air-bubbles to keep it afloat. When driven from its tube, it swims about like a water-snake, but immediately seeks cover. Its food consists of diatoms and other unicellular Algæ and small water animals of every kind.

The only method of reproduction that I have observed is that by budding. No attempt has been made to determine the existence of a numerical law governing the budding process. The phenomena do not seem to differ from those described for related forms. In the sixth and seventh segments rounded cell-masses have been seen, which are probably the rudiments of the testes and ovaries, but they were never sufficiently developed to allow a satisfactory study of them.

Anatomy.

The Body Wall.

The body wall consists of four layers, in the following order, from without inward: a cuticula, the matrix of the cuticula or dermis, an annular muscular layer, and a longitudinal muscular layer.

The *cuticula* is a thin structureless membrane covering the entire surface of the body. It is easily seen in all sections, and may be demonstrated by leaving the animal for half an hour in a very weak chromic acid solution, or by using a very weak solution of potassium hydrate. Frequently, when the animal dies in water, the cuticula becomes raised up into vesicular swellings and is thus rendered plainly visible; when some part of the animal, as a digitiform appendage, is crushed, it then also shows plainly. The cuticula presents no markings under a power of six hundred diameters.

The matrix of the cuticula, the *dermis*, consists in most regions of a single layer of prismatic cells. The latter are, however, several layers deep on the frontal lobe. This layer is thicker at the head and tail ends, and in the region of the head and tail it is also thicker on the ventral than on the dorsal side. The dermal cells have large granular nuclei, the walls of which are frequently more distinct than those of the cells themselves. Each nucleus contains one or several nucleoli. The cells and their nuclei are longer in the head and tail regions than elsewhere.

Many unicellular dermal glands (Pl. II. figs. 11, 13, *drm. gl.*) are found in the region of the head, especially on the frontal lobe, and a few in the region of the pavilion. These glands vary in shape. Frequently a tubular neck is seen leading to the surface, and a minute opening is sometimes visible. In sections the glands are seen to contain pale nuclei, usually near the bottom or on one side, and their contents appear granular and not stainable. They are very conspicuous on the frontal lobe in the living animal, and appear as sacs, sometimes slightly lobed, and always filled with rounded granules. When the animal is strongly compressed under a cover-glass, the contents of these glands are occasionally forced out through the neck. The nuclei have not been seen in the glands in the living animal.

The appendages of the dermis are the podal stylets, bristles, hairs, and cilia. The hairs are found over the whole body, but they are more numerous on the frontal lobe and on the digitiform appendages of the pavilion than elsewhere. They may possibly serve as sense organs. Cilia are found over the whole border and interior surface of the pavilion, and on the extreme front end of the pre-oral lobe.

The *muscular system* consists of a layer of annular fibres immediately beneath the dermis, and, still deeper, a layer of longitudinal fibres. There are also special muscles for moving the bristles, the pharynx, and the supra-œsophageal ganglion. Muscular fibres also help to form the partial partitions between the segments, and in the interseptal regions run from the body wall to the alimentary canal, suspending the latter. The fibres in the annular layer (Pl. II. figs. 11, 16, 17) are not so large as those in the longitudinal layer, and are seen with difficulty, but they show plainly in specimens that have been mounted for some time in balsam. The layer of longitudinal fibres is divided by the four rows of bristle sacs into four longitudinal bands, a dorsal, a ventral, and two lateral. These bands, as is easily seen in specimens mounted entire in balsam, are sharply marked off from one another by spaces that contain no longitudinal muscular fibres. Each band is divided into two secondary bands by spaces that contain no muscular fibres, or much fewer and narrower ones than are found elsewhere. This division into secondary bands is not always visible in specimens mounted entire, but is usually evident in such specimens near the posterior end of the body. In cross sections, however, this division becomes plain. The spaces between the halves of the lateral bands are occupied by the nervous lateral lines (Pl. II. fig. 17, *l. ln.*). The space dividing the ventral band lies immediately beneath the ventral nervous cord, and is the plainest of the four. This arrangement of longitudinal muscular bands agrees with that found by Perrier ('72, p. 72) in *Dero obtusa*.

The special muscular fibres for moving the pharynx and brain are described in connection with those organs. The muscles for extruding the bristles do not differ from those described for related forms. Instances have been found, both in the living animal and in sections, of fibres running from a dorsal to a ventral bristle sac on the same side, and serving, doubtless, to retract the bristles.

The muscular fibres of both the annular and longitudinal layers are spindle-shaped and flattened. A few of them contain median swellings with large, granular central nuclei and nucleoli, while others have a small nucleus on the free edge, and therefore approach the muscular fibres of Nematodes in form. The cells of the bristle sacs, partitions, and all the special muscles, consist of a large central part containing a granular nucleus with its nucleolus, and of two or more processes arising from the central part.

The peculiar muscular cells found inside the digitiform appendages of the pavilion are described in connection with that organ.

Connective-Tissue Cells.

Connective-tissue cells (Pl. II. figs. 11, 16, 17, *cl'*.) are found in great abundance everywhere in the body cavity. They are of various sizes, being sometimes very large, and have deeply stainable, granular contents and nuclei with nucleoli. They vary in shape, but always have one or more long processes which are attached to surrounding parts. They are found in the greatest number above the pharynx, where they form an almost continuous mass, which connects the pharynx to the body walls above, thus helping to support it. These cells also line the body walls internally, and take part in the formation of the partitions. Many of them connect the alimentary canal and the nervous system to the body walls and to each other; and, in fact, they bind together all the internal organs. They form the external covering (neurilemma) of the nervous system, and also pass in between the ganglionic cells and the fibrous portion of the nervous substance, thus separating them. Whether or not they form the tissue that separates the nerve fibres from one another I have been unable to determine.

The Alimentary Canal.

The alimentary canal is a simple tube running through the axis of the body cavity, and held in place by numerous muscular fibres and connective-tissue cells from surrounding parts, in addition to the dissepiments. Its walls are composed of three layers: an internal cuticula, a layer of ciliated epithelial cells, and a membrana propria. To these may be added a very imperfect layer of annular muscular fibres, and an equally imperfect layer of longitudinal fibres. The intestinal tract is divided into four distinct parts: a mouth cavity, a pharynx, an œsophagus, and an intestine.

When closed, the *mouth opening* (Pl. I. figs. 1, 6), which is situated on the ventral face of the first segment, has the shape of a brace (⏞) with its cusp directed forward. Numerous superficial grooves radiate from it, the largest of them passing forward from the centre of the opening, the cusp, in some cases extending almost to the anterior end of the pre-oral lobe.

The *mouth cavity* (Pl. II. fig. 11) extends from the mouth opening vertically upward to a point just beneath the supra-œsophageal ganglion, where it joins the pharynx. Sometimes it is slightly convex forward. Its walls consist of the internal cuticula, the layer of epithelial cells, and the membrana propria. So far as observed, its epithelial cells are not ciliate.

The *pharynx* (Pl. I. fig. 1; Pl. II. figs. 11, 14, 15, 16) extends horizontally backward from beneath the brain in the first segment to the partition between the fifth and sixth segments, where it passes into the œsophagus. Its greatest internal diameter occurs at about the middle of the second (first post-oral) segment, where, measured vertically, it is about three times that of the preceding and succeeding parts of the alimentary canal. From this point it tapers in both directions, but more rapidly forward. When seen in median longitudinal section (Pl. II. fig. 11) the cavity of the pharynx therefore appears to be somewhat spindle-shaped, though that is far from being its true form. This cavity is divided by two longitudinal folds, one projecting from each lateral wall, into an upper and an under chamber (Pl. II. figs. 14, 15, 16), as described by Bülow ('83, p. 71) for Lumbriculus. When the pharynx is in its natural position a cross section (Pl. II. figs. 14, 15) shows that the upper chamber is triangular, with the vertex of the triangle uppermost; while the lower one is elliptical or crescent-shaped with its long axis horizontal, and, when crescent-shaped, the concavity of the crescent uppermost. Sometimes a peculiarity of the lateral folds, attributable to the state of muscular contraction, causes the apical part of the triangular upper space to project on each side, and the whole upper chamber thus becomes T- or Y-shaped. The walls of the upper space are composed of the internal cuticula, the membrana propria, and a layer of much lengthened epithelial cells (Pl. II. figs. 11, 16, *e t'*.), the long axes of which are perpendicular to the surface of the pharynx. These cells have elliptical granular nuclei, situated at their deep ends, while their granular cell protoplasm is concentrated at their free inner ends, which bear many short, thick, very active cilia. In sections the cilia are seen to be matted together into columnar masses, the real nature of which may be learned by a comparison of a large number of specimens. Among these cells are found a few (Pl. II. figs. 11, 16, *mc. gl.*) that are larger and have less granular and less stainable contents, and a smaller nucleus more centrally located. They are similar to the cells found by Nasse ('82, p. 15) in the same position in Tubifex. They were believed by him to be mucous glands (Schleimdrüsen).

The walls of the lower chamber have the cuticula and membrana propria, and a layer of much flattened epithelial cells. The latter are especially flattened in the anterior half of the pharynx, where the floor of the lower chamber is therefore very thin. No cilia have been observed on the walls of the lower chamber. Both longitudinal and circular muscular fibres are better developed on the pharynx than in any other region of the alimentary canal, as is plainly to be seen in sections. They do not by any means, however, form a continuous layer.

Muscular fibres (Pl. II. fig. 11, *mu.*) also arise from the extreme anterior wall of the first (head) segment, and are inserted into the pharynx just beneath the middle of the supra-œsophageal ganglion. These, with other fibres running obliquely downward from the walls of the mouth cavity to the body walls, both anteriorly and posteriorly, serve as protractors of the pharynx.

Covering and closely applied to the walls of the upper chamber of the pharynx are found a large number of peculiar, more or less rounded masses of cells (Pl. II. figs. 11, 16, *gl'.*). These masses, or clusters, are several cells deep, and lie in groups, the size of which is determined by the frequency and position of the muscular fibres and the processes from the connective-tissue cells above the pharynx. The cells composing these masses have granular contents, and their nuclei contain each only a single nucleolus. They are ellipsoidal in shape, and their inner ends are frequently prolonged into processes reaching toward the pharynx. Similar cells have been described by Nasse ('82, p. 15) in Tubifex. On account of their position, and of their being divided into groups, they are regarded by him as digestive glands. He saw no opening, however, leading from them into the alimentary canal. In two instances I have been able to trace a process from one of these cells passing through the layer of epithelial cells to the pharyngeal cavity. Hence it seems probable that all these cells open into the cavity of the pharynx; but whether they have a digestive function is still open to question.

The largest of the connective-tissue cells are found above the pharynx. They are very deeply stainable, have many processes, and almost completely fill the space between the pharyngeal glands and the dorsal wall of the body.

Thus the pharynx forms a highly specialized organ. It is, moreover, in almost constant use for purposes of prehension. It is used both in seizing the food and in locomotion. When it is extruded, the mouth opening is rounded and the pharynx has a cylindrical form. The protrusion is initiated by the action of the protractor muscles already described, and completed by the pressure communicated through the fluids of the body to the walls of the partly extruded pharynx, when the body walls are forcibly contracted. When it is extruded, the strong vibratile cilia of its walls are easily seen. They must help to render the extruded pharynx of use as a sucking disc, a purpose to which the mucous glands are doubtless also subservient. When applied to any object, the extruded portion may be rendered concave on its outer surface by the action of the muscular fibres in its walls, and those which pass from it to the body walls above; thus it becomes an effective sucking-disc.

The *œsophagus* begins at the septum between the fifth and sixth segments, and ends at that between the eleventh and twelfth. A slight but sudden increase in the size of the tube separates it from that part of the pharynx which immediately precedes it. The presence of liver cells also marks its beginning. It is of uniform diameter until it reaches the ninth segment, although it may be somewhat convoluted. In the eighth, ninth, and tenth segments it is much swollen, while in the eleventh it is of the same diameter as in those preceding the enlargement.

It is marked off from the intestine following it by (1.) a sudden large increase in the size of the tube near the partition between the eleventh and twelfth segments; by (2.) a difference in the length of the cilia in the two parts; by (3.) a difference in the brown drops in the liver-cells of the two regions; by (4.) a difference between the epithelial cells, as may be seen in sections; and by (5.) the absence, in most cases, of epithelial glands in the œsophagus, and their presence in the intestine.

While the cilia of the œsophagus are so long as to almost fill its lumen, those in that part of the intestine immediately following it are very short, or perhaps in some cases entirely absent.

In a portion of the œsophagus, viz. in the enlargement of the ninth and tenth segments, the lining epithelium presents a peculiar appearance (Pl. II. fig. 17, *en'*.). It no longer exists in the form of a simple layer; but, while the greater portion of the cells remain destitute of cilia, and form a more or less continuous layer next to the membrana propria, there are other, less numerous cells, which project far into the lumen of the canal and are richly ciliate at their free ends. They are of various shapes, the basal ends being often produced into two or more diverging processes, which thus give the ciliate cells the appearance of spanning one or more of the cells of the non-ciliate layer. Although in many instances they appear to arise from the free surfaces of the latter, it is only a deceptive appearance, since their processes really extend to the membrana propria. They are to be regarded as the effect of a differentiation which results in an increase in the amount of surface exposed to the aliment, and at the same time relegates to a few cells the function of propelling the food along the canal. This peculiarity serves as a ready means of distinction between œsophagus and intestine, and is most apparent in cross sections. Similar, but not identical cells have been observed by Timm ('83, p. 148) in *Nais elinguis*.

A few epithelial glands have been seen in the œsophagus in the ninth, tenth, and eleventh segments, but as a rule they are absent from the œsophagus, while abundant in the intestine.

The *intestine* extends from near the partition between the eleventh and twelfth segments to the anus. It is distinguished from the œsophagus by the characters mentioned above. The tube grows suddenly larger in the twelfth segment, and then gradually tapers to the anus, being slightly constricted at each partition in the fore part of its course. The part of it following the œsophagus has either very short cilia or none at all. Farther back the cilia become longer, and near the anus they almost fill the canal.

Many endodermal glands (Pl. III. fig. 28, *en. gl.*) are found scattered throughout the epithelium of the intestine. They are unicellular and jug-shaped, usually somewhat larger than the neighboring endodermic cells of the same region. Sometimes they appear empty, but usually they are filled with a granular non-stainable material, or contain a nodule of such substance near the centre. Each opens into the interior of the intestine by a narrow canal, which is frequently visible in sections.

The *liver cells* are lens-shaped, with a large nucleus containing a single nucleolus. They are closely applied by one of their broader surfaces to the wall of the alimentary canal, just outside the layer of blood-vessels with which the latter is immediately invested, and which can be well seen only in certain longitudinal sections. Over a part of the intestine these cells are arranged in longitudinal bands, as if they covered the intestinal network of blood-vessels. They contain numerous golden-brown drops. In the posterior part of the intestine these drops are still present in the liver cells, but they are colorless. Over the anterior part of the intestine a few of these brown drops are to be found, which are much larger than those met with over the rest of the alimentary canal. They are here seen to have a distinct limiting envelope, which is frequently broken, so that the contents of the drop have escaped. In such cases it appears to be the envelope that gives color to the drop. No such marked distinction of parts is visible in the drops occupying the cells upon the rest of the intestine. Over the whole of the œsophagus, however, the drops are larger than elsewhere, and most of them show a limiting membrane; this is especially noticeable in the anterior part of the œsophagus. The transition in the size of the drops is gradual, and does not sharply mark off the œsophagus from the intestine.

Floating in the body cavity are found globular cells, which contain very numerous brown drops that are frequently large, and have a limiting membrane. These cells often become compacted together into large masses. Clear, globular "lymp-cells" are also found floating in the body cavity.

The Vascular System.

The vascular system consists of a dorsal and a ventral vessel, united by a plexus in the head and one in the region of the pavilion, and by numerous vessels surrounding the alimentary canal. The dorsal vessel is covered, except in the pharyngeal and part of the œsophageal region, by the liver cells, and is contractile, whereas the ventral vessel is free from liver cells, and is not contractile. In the eighth, ninth, and tenth segments these two vessels are united by lateral branches, which float freely in the body cavity, one on each side in each segment. Like the dorsal vessel, they are contractile. There are often found traces of a vascular network lying beneath the liver-cells of the intestine and also uniting the dorsal and ventral vessels; but owing to its being hidden by the liver-cells, I have been unable to trace it out satisfactorily.

The plexus uniting the two vessels in the head has been figured and minutely described by Perrier ('72, p. 79) for *Dero obtusa*. In mounted specimens the blood-vessels are rarely to be seen, and are never visible throughout their entire course, while in the living animal their observation is difficult, because they are invisible except when distended with blood. Only at considerable intervals of time does the plexus in the head become entirely filled, and usually then for only a fraction of a second; so that it is difficult to map out the entire plexus in any one animal, especially as those animals that have the most vigorous circulation are also the ones that move most rapidly. But, from an examination of a large number of specimens, I am certain that the arrangement in the head region is as follows: the *dorsal vessel* passes forward to above the brain (Pl. I. fig. 6) and there bifurcates. The branches resulting from its bifurcation pass downward at the sides of the brain, and, bending backward, finally unite at a considerable distance behind the mouth to form the ventral vessel. Before bifurcating, however, it gives off three pairs of lateral branches. Of these three pairs, the most anterior is given off just behind the mouth (the position of which is indicated in the figure as though seen through the tissues of the head). Each one of this pair, after passing outward to near the margin of the head, bifurcates, one of its branches passing forward and the other backward, and both joining the recurrent branch of the same side which results from the bifurcation of the dorsal vessel. The other two pairs of branches given off by the dorsal vessel pass out laterally, and probably also join the recurrent branches just mentioned. Some specimens show many other smaller vessels, and there is always a more or less complicated anastomosis of vessels around the pharynx, joining the dorsal and ventral vessels. It is possible that all these vessels present individual variations of branching and arrangement.

In the posterior region (Pl. II. fig. 5) the ventral vessel passes backward to near the notch between the two lobes on the ventral border of the pavilion. There it bifurcates, one branch running to the right and the other to the left along the border of the pavilion. These two branches become united on the dorsal border of the pavilion, and thus form a complete ring around its margin. Each half of this marginal ring gives rise to two branches. Each of the smaller pair arises close to the ventral bifurcation, and, passing along the median edge of the small lobe on the ventral border of the pavilion, makes a curve outward in that lobe, and then passes forward to unite with the larger branch lying on the same side. The larger branches arise at nearly opposite points in the lateral portion of the marginal ring, and, quickly converging as they pass forward, unite in the median dorsal line to form the dorsal vessel. This form of plexus differs from that found in *Dero obtusa* only to the extent of the modification rendered necessary by the difference in the form of the pavilion.

The contractile branches uniting the dorsal and ventral vessels in the eighth, ninth, and tenth segments present the most favorable opportunity for studying the contraction of the blood-vessels. When one of these vessels is distended, its walls are seen to contain large, prominent nuclei, evidently belonging to muscular elements (Pl. I. fig. 7). When contracted the muscular elements are seen to be much shortened and thickened. The walls of the vessels also show longitudinal and transverse striæ. The vessels contract rapidly and are distended much more slowly. Their contractions take place at different rates in different individuals, and under different conditions. The observed limits are 11 and 24 contractions per minute. Although the ventral vessel does not contract, its walls contain the muscular elements mentioned above, but in less number.

No trace of blood corpuscles is seen in the living animals, but in sections the blood-vessels are frequently found filled with a granular mass apparently containing many corpuscles. This appearance may be due, however, to the action of reagents on the blood.

The Respiratory Organs.

The function of respiration is performed, in great part at least, by the pavilion. This and the distribution of blood-vessels to it have been already described. It is thickly covered with cilia, which produce an inward current of water. It contains numerous branched muscular elements, so arranged as to cause it to contract and close. The digitiform appendages are hollow, their cavities being continuous with the general body cavity. Their walls (Pl. III. figs. 29, 30) are composed cf a single layer of dermal cells covered by the cuticula, which is beset with hairs (not shown in the figure). The cavity of each appendage contains many branched muscular cells, the processes of which are attached to the walls of the appendage.

Respiration is doubtless also carried on through the richly-ciliated walls of the intestine, which are covered by a network of blood-vessels and bathed by a steady stream of water.

The Nervous System.

The nervous system consists, as in related forms, of (1.) a supra-œsophageal ganglion and (2.) two commissures joining this to (3.) the ventral cord. The first two parts make up the circum-œsophageal ring.

The supra-œsophageal ganglion, or *brain*, (Pl. II. figs. 11, 19, 20; Pl. III. figs. 21, 25–27,) is situated immediately above, and in front of, the point where the mouth cavity joins the pharynx, and is divided by a median superior and anterior fissure into lateral halves, each of which is rudely spherical in shape. A bundle of muscle fibres (Pl. II. fig. 11, *b. mu.*) passes from its posterior face upward and backward to the body wall. This bundle, together with a few fibres passing from its anterior face upward and forward, serves to support the ganglion in place, and perhaps to move it slightly. The ganglion is composed of a central fibrous part, surrounded on all sides except the lower by a layer of nerve-cells from one to four cells deep. On the lower surface the fibrous part of the ganglion is exposed.

Bülow ('83, p. 75) has described six pairs of nerves arising from the corresponding ganglion and commissure in *Lumbriculus variegatus.* In Aulophorus I have found only four pairs, three from the ganglion, and one from the commissure. The first pair (Pl. II. fig. 19; Pl. III. fig. 26, n^1.) corresponds to the sense nerve of Bülow. Each arises from about the middle of the anterior face of its half of the ganglion, and passes to the extreme anterior end of the segment. It is there distributed to the body walls. In Lumbriculus, Bülow ('83, p. 75) describes a group of cells in the anterior end of the first segment. These cells constitute a so-called sense organ, and to them this nerve is distributed, and is therefore called by him a sense nerve. Cross sections of Aulophorus show apparently similar large cells in the same position, but longitudinal sections (compare Pl. II. fig. 11) show these to be nothing more than sections of the swollen parts of the muscular cells whose processes pass to the walls of the pharynx.

The second and third nerves from the supra-œsophageal ganglion (Pl. III. fig. 25, n^2, n^3) arise together, lower and farther from the median plane than the first nerve. A short distance from their origin they separate, one passing to the anterior walls of the segment, and the other to the upper lip and adjacent parts.

The fourth nerve (Pl. III. fig. 25, n^4) arises from the commissure and passes to the lower lip. No nerve has been found passing from the supra-œsophageal ganglion to the lateral line, nor has more than one been found to arise from the commissure.

The œsophageal commissures pass obliquely backward from the brain to the ventral cord in the anterior part of the first bristle-bearing segment. They are composed principally of fibrous nerve substance, but there are a few ganglionic cells on their surfaces, except for a short distance in the middle part of their course, where the nerve cells are entirely wanting.

The *ventral cord* passes backward from the point of union of the two commissures to the region of the pavilion, where it gradually merges into the terminal germ-zone (Pl. III. fig. 31). In cross section it is roughly elliptical, or bluntly crescent-shaped, with the concavity up (Pl. II. figs. 16, 17; Pl. III. figs. 22–24). Its central part is fibrous, and has a median superior and a median inferior groove. Lying in the floor of the superior groove are the three "primitive nerve fibres" of Ratzel ("Röhrenfasern") which are claimed by Bülow ('83, p. 92) to be of mesodermic origin, and therefore not to be compared to the chorda dorsalis of vertebrates. A single "fibre" begins in the third segment, while farther back two smaller ones are added to it, one on each side. The three, continuing side by side without branching, remain of nearly uniform calibre until just before the posterior end of the ventral cord is reached, when they disappear. Through most of their course they appear to be simple empty tubes, but the middle and larger "fibre" shows slightly stainable contents in its extreme anterior and posterior ends. The inferior groove is filled throughout its course with ganglionic nerve cells, and this is the only part of the cord where the layer of nerve cells is unbroken. The fibrous central part of the cord swells slightly and gradually in the middle of each segment (Pl. I. fig. 10). Its upper surface is free from nerve cells throughout its entire length, whereas the rest of its surface is covered by a layer of them which varies from one to four cells in depth, and forms a series of ganglionic swellings. This ganglionic layer is thickest at the centre of the segment, where the fibrous part itself attains its greatest diameter. There is a very short space in the region of the partitions, where the ganglionic cells, except in the ventral groove, are wanting. Muscular fibres pass from the centre of each ganglion to the body walls on each side and to the alimentary canal above. The ganglionic matter of the first four bristle-bearing segments is fused together into one mass, with only a slight increase in size in the middle of each segment.

The ganglionic nerve cells are apolar, unipolar, or rarely bipolar, and polygonal in form. Their nuclei are very large, leaving only a narrow zone of cell protoplasm around them. In each nucleus there may be one or several nucleoli, which appear as bright granules. The processes of these cells are sometimes traceable for a long distance, and pass into the fibrous nerve substance.

The nervous system is invested by a neurilemma formed of connective-tissue cells, which also pass in between the ganglionic and fibrous elements, and separate them from one another. This separation is, however, not complete, nor is it always evident, though, for the sake of uniformity, it has been so represented in the figures.

The fibrous part of the nervous system is composed of fibres, each of which is surrounded by a sheath, most likely of connective tissue. A similar structure was seen by Nasse ('82, p. 13) in Tubifex, and is known to exist in other worms and among the Gastropoda.

The *lateral lines* (Pl. II. fig. 17) consist of a few cells, occupying the longitudinal space at the middle of the side walls of the body, between the dorsal and ventral halves of the lateral band of longitudinal muscles. They are considered by Bülow ('83, p. 75) to be nervous in function, and their connection with the œsophageal commissures has been traced by Semper in the case of Nais, but in Aulophorus I have been unable to trace them as far forward as the region of the commissures.

Segmental Organs.

The segmental organs (Pl. I. fig. 8) correspond closely to the description given by Perrier for those of *Dero obtusa.* Each somite after the sixth or seventh contains a single pair, which begin in the preceding segment and open out through the ventral wall of their own somite. Each organ is a thick-walled tube whose interior is lined by short, fine, vibratile cilia. Its first portion, lying in the anterior of the two segments concerned, is an expanded funnel, the opening of which bears cilia which are much longer than those found elsewhere in the tube. After passing the dissepiment, to which it is attached, there is an elbow-shaped, glandular expansion of the tube. From this expansion the tube turns toward the opposite side of the body, and, rising vertically, makes many convolutions, at the same time becoming covered with an irregular granular concretion. Nuclei may be seen in parts of this granular matter, and at times whole cells are visible, so that it is really composed of rounded cells closely applied to the tube and covered with granular matter. Following this cell-covered portion of the tube is a convoluted portion like that following the glandular swelling. The tube finally ends in an expansion which opens to the outer world a little in front of the ventral fascicle of podal stylets.

Throughout its course the walls of the tube show transverse striæ. The cells covering a part of it possibly secrete the glutinous material that forms the basis of the tubes in which the animals live; but the presence of similar cells in related forms that do not build a tube is opposed to this view.

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EXPLANATION OF FIGURES.

The signification of the abbreviations used is as follows: —

ann. mu.	Annular muscle fibres.
an. o.	Anal orifice.
b.	Brain.
b. mu.	Muscles attached to *b.*
cil.	Columnar mass of cilia.
cl'.	Connective-tissue cells.
cta.	Cuticula.
dg. app.	Digitiform appendages.
drm.	Dermis.
drm. gl.	Dermal glands.
d. va.	Dorsal blood-vessel.
en'.	Peculiar entodermic cells.
en. cta.	Endodermic cuticula.
en. gl.	Endodermic glands.
e t'.	Epithelial cells of the walls of the upper pharyngeal chamber.
ex. of.	External orifice of segmental organ.
fbr. n.	Fibrous (?) nervous matter.
g. cl.	Mass of indifferent germ cells.
gl'.	Digestive (?) glands.
gn. n.	Ganglionic nervous matter.
hp.	Liver cells.
in.	Intestine.
i. of.	Internal orifice of segmental organ.
lg. mu.	Longitudinal muscles.
l. ln.	Lateral line.
mb. pa.	Membrana propria.
mc. gl.	Mucous glands.
mtx.	Matrix cells of the podal stylets.
mu.	Muscular fibre.
mu'.	Branched muscle cells.
n.	Nervous substance.
$n^1.–n^4.$	First to fourth pairs of nerves from the brain and circum-œsophageal commissure.
œ.	Œsophagus.
or.	Mouth.
pav.	Pavilion.
phx.	Pharynx.
pr. n.	"Primitive nerve fibres."
sg. o.	Segmental organ.
stl.	Podal stylets.
val.	Body wall.
v. stl.	Ventral podal stylets.
v. va.	Ventral blood-vessel.

Plate I.

Fig. 1 *Aulophorus vagus*, dorsal view. The actual length is indicated by the straight line at one side of the figure.

Fig. 2. Podal stylets, such as form the first four pairs of ventral fascicles.

Fig. 3. Podal stylets, such as occur in the ventral fascicles after the fourth pair.

Fig. 4. Fascicle of dorsal stylets and bristles.

Fig. 5. Diagram of the circulation in the pavilion, dorsal view.

Fig. 6. Diagram of circulation in the head, dorsal view.

Fig. 7. Blood-vessel: α, expanded; β, contracted.

Fig. 8. Segmental organ.

Fig. 9. Frontal section through the ventral part of the anterior end of body, showing the commissures and part of the ventral nervous cord.

Fig. 10. Frontal section through the ventral nervous cord.

Plate II.

Fig. 11. Sagittal section through the head and pharynx. *mu.*, muscle fibres used to protract the pharynx.

Fig. 12. Cells of the walls of the upper space of the pharynx.

Fig. 13. Dermal glands in the living animal.

Figs. 14, 15. Outlines of cross sections of the pharynx.

Fig. 16. Cross section of the pharynx.

Fig. 17. Cross section of the œsophagus at the 9th ring.

Fig. 18. Dermal cells.

Fig. 19. Frontal section through a lateral half of the brain.

Fig. 20. Cross section through a lateral half of the brain. *cl'.*, connective tissue forming the neurilemma.

Plate III.

Fig. 21. Isolated nerve cells from the brain.

Fig. 22. Cross section through the region of the bristle sacs.

Fig. 23. Cross section near a partition.

Fig. 24. Cross section near the region of the bristle sacs.

Fig. 25. Sagittal section through the brain and one commissure.

Fig. 26. Sagittal section through a lateral half of the brain.

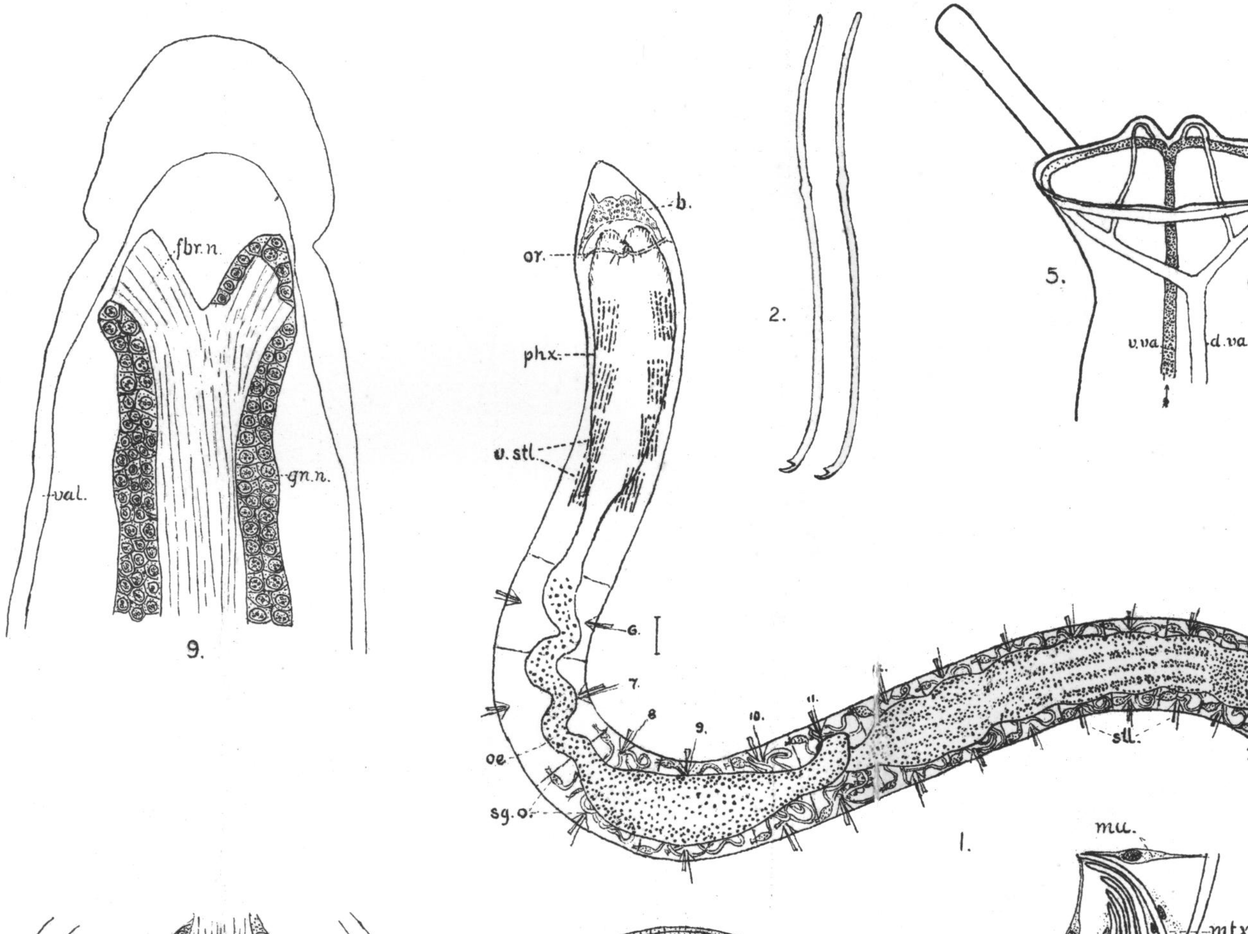
Fig. 27. Frontal section through the brain.

Fig. 28. Cross section of the intestine.

Fig. 29. Section cut obliquely through the region of the pavilion.

Fig. 30. Cross section of one of the digitiform appendages. *mu'.*, branched muscle cells.

Fig. 31. Sagittal section through the region of the pavilion, cut somewhat obliquely.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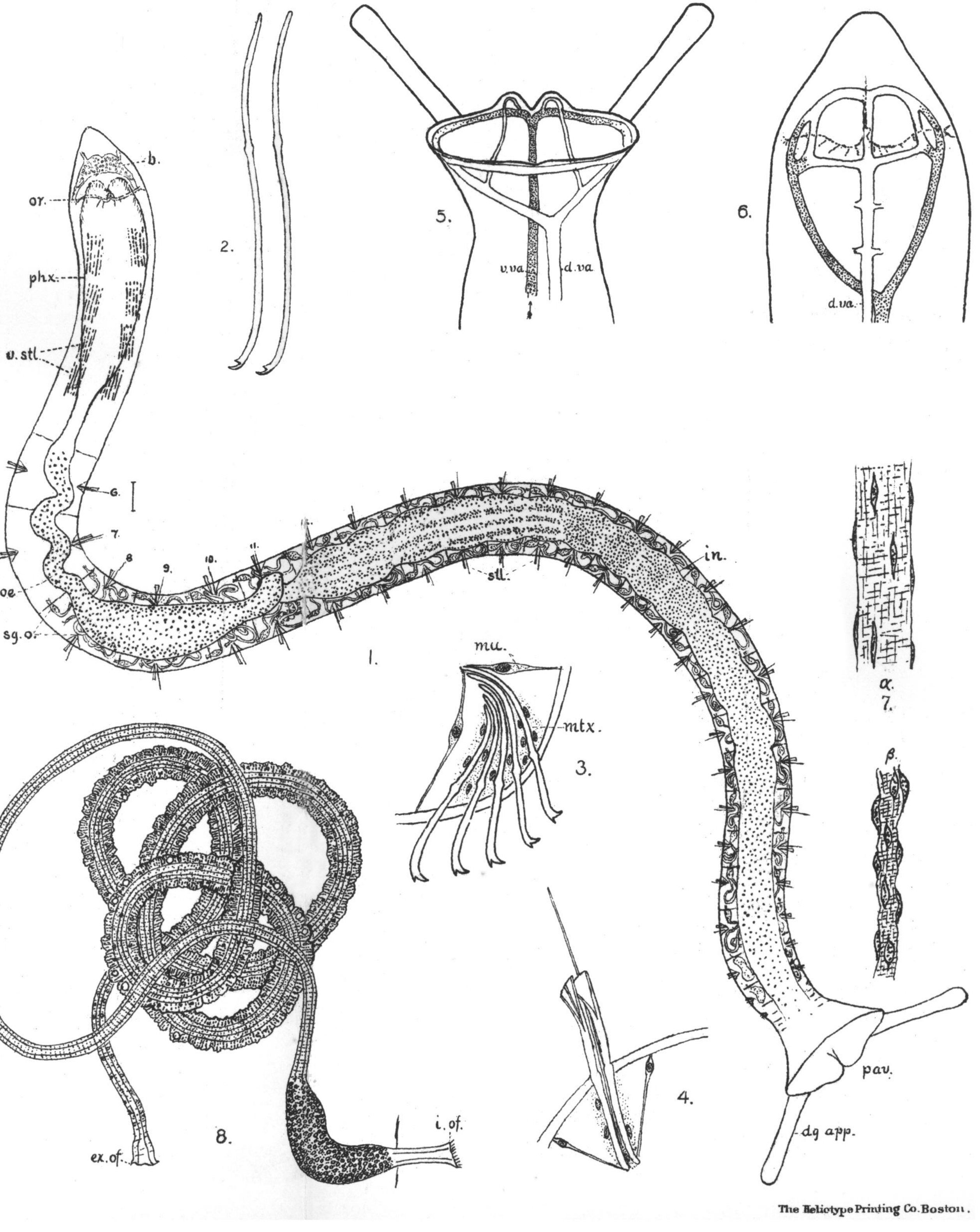

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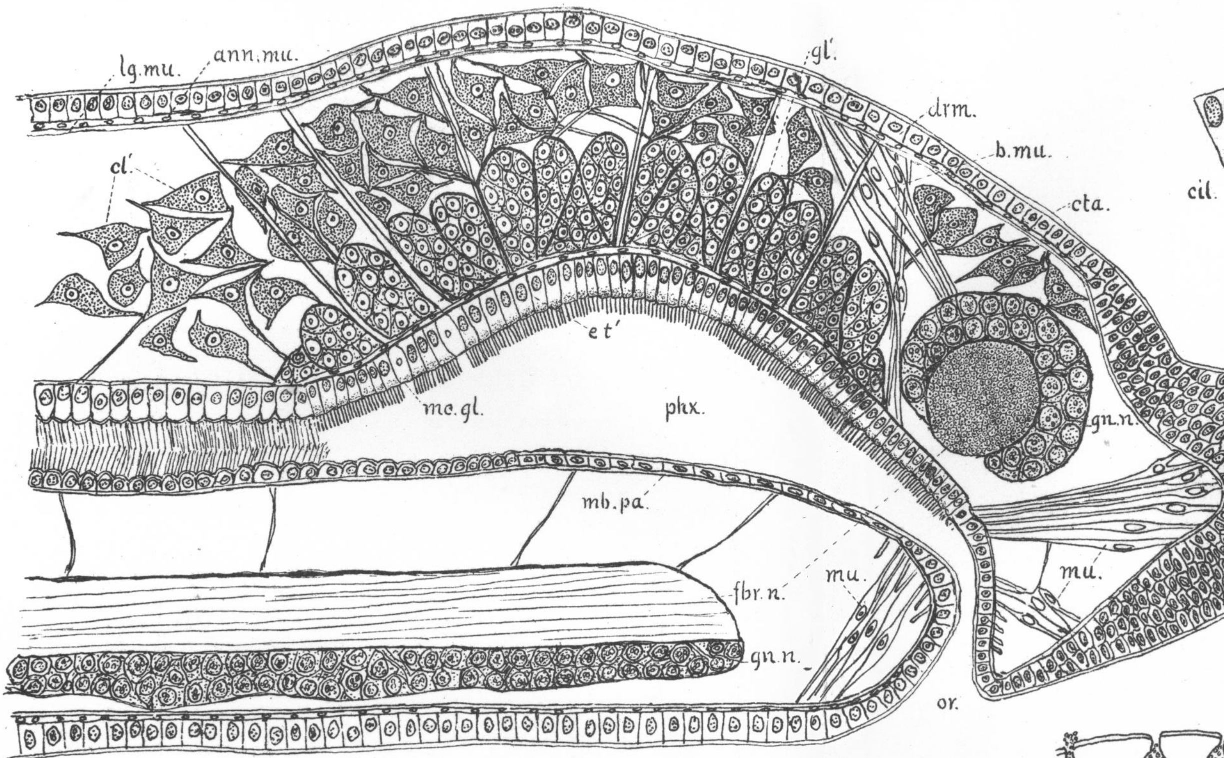

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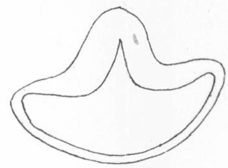

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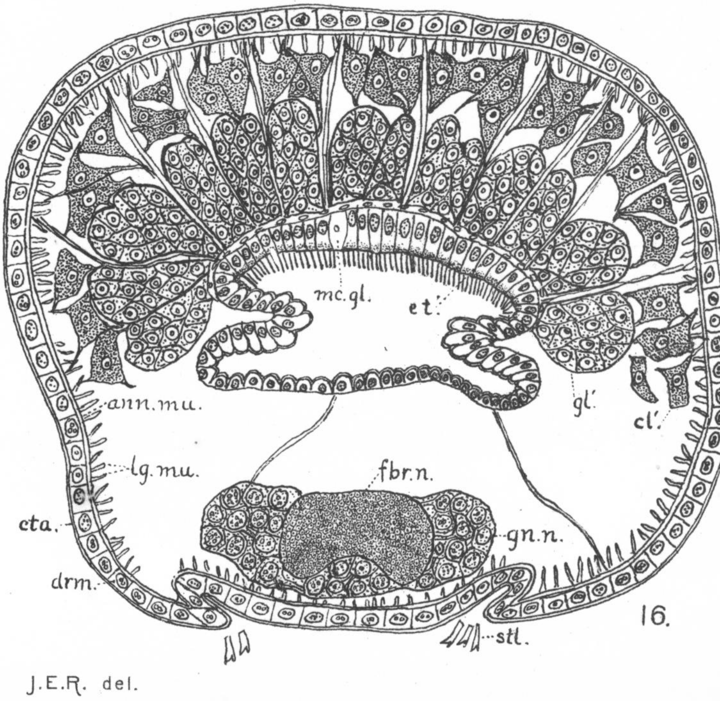

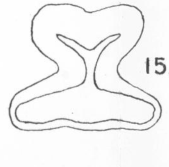

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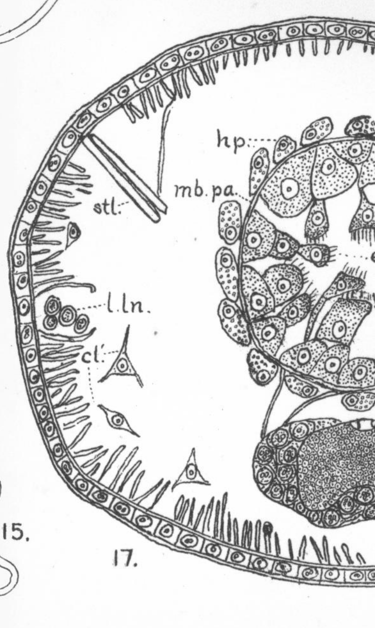

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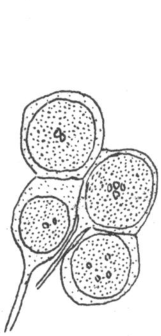

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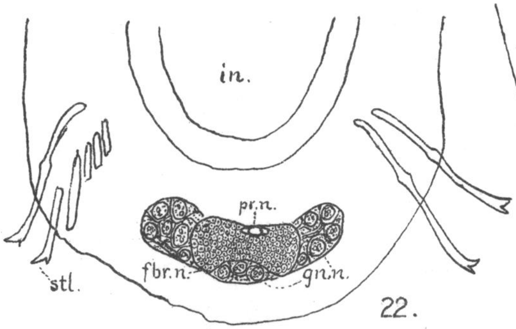

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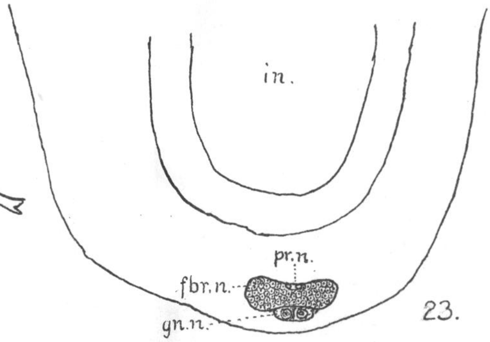

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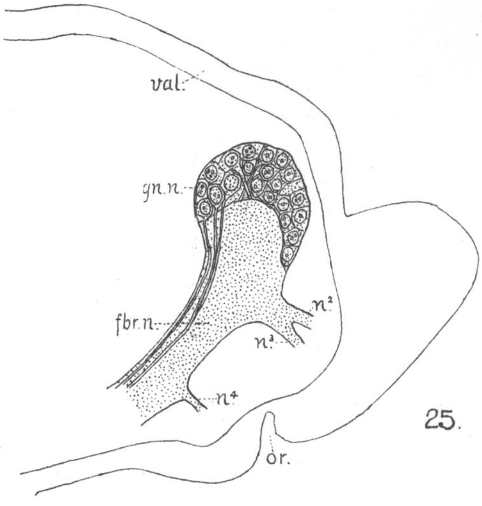

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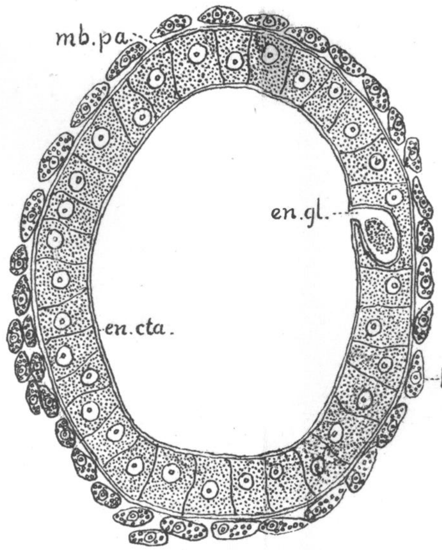

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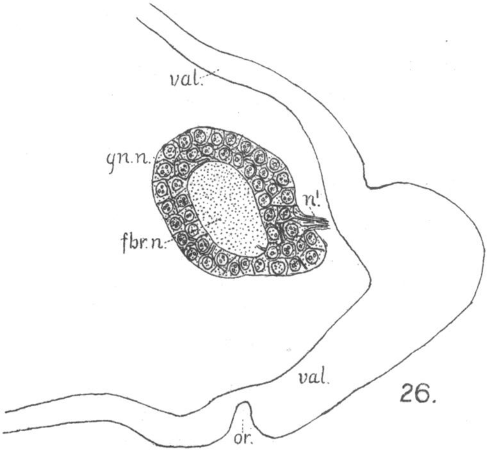

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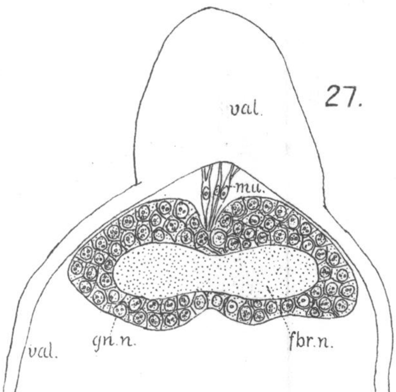

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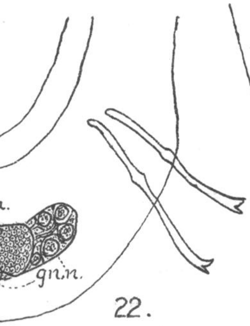

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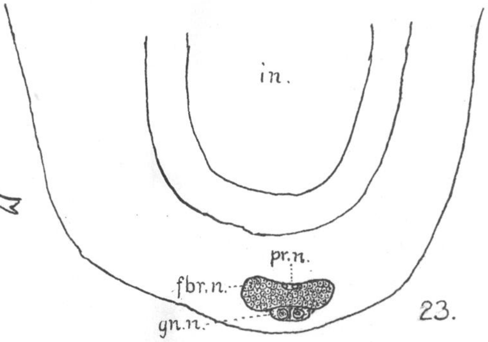

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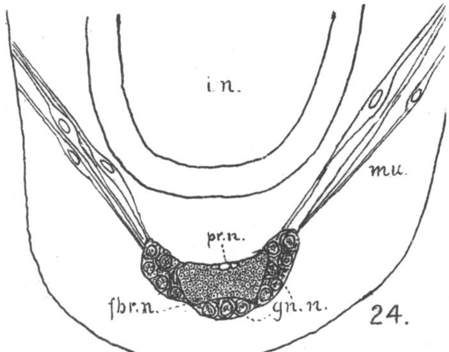

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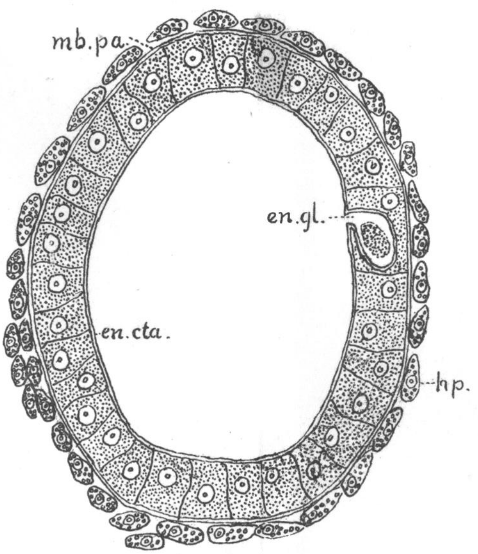

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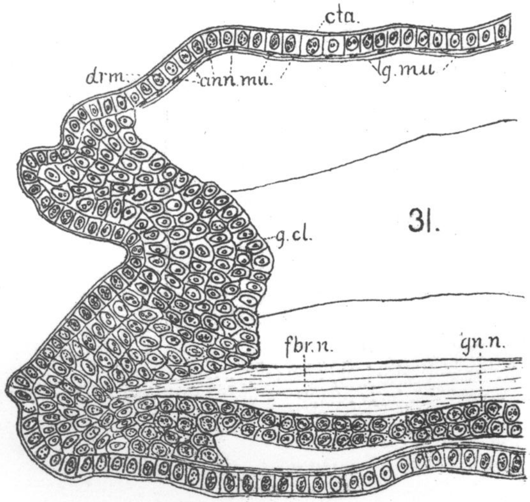

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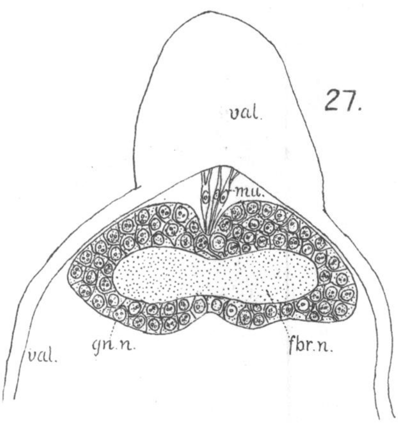

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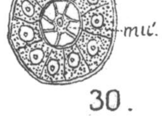

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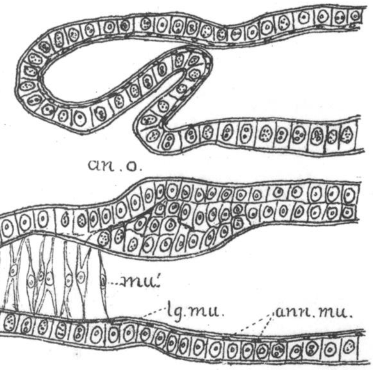

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