ON THE STRUCTURE OF *BIMASTOS PALUSTRIS*, A NEW OLIGOCHAETE.

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THE earthworm of which this paper treats is not uncommon in the vicinity of Philadelphia, where it was first discovered in Fairmount Park, in February, 1893.

Since then it has been found in a number of places in Pennsylvania and New Jersey, within thirty miles of its original locality, and it will probably be found to extend, at least, throughout the valley of the Delaware River system.

It frequents the damp, soft soil on the banks of springs and streams, but has not been found in the bottom mud. It has been taken in common with *Allurus tetraedrus*, *Sperganophilus tamesis*, and several species of *Lumbricus* and *Allolobophora*. I have not found its cocoons, and the only fact that I have learned, relating to its breeding habits, is that individuals bearing spermatophores are found from the latter part of February until the first of December, when this is written.

The anatomy has been studied by means of dissections, supplemented with continuous series of longitudinal and transverse sections.

External appearance. — This worm may reach a length of three inches when fully extended, the number of somites varying from eighty to one hundred. The anterior somites are somewhat longer than those behind the clitellum, but the disparity is not so marked as in many other terrestrial Oligochaeta.

The prostomium is large and not distinctly dovetailed into the peristomial somite, being continued upon the latter by a pair of grooves which traverse about one-half of its length, and are not connected posteriorly by a transverse groove, as in *Allolobophora* and species of *Lumbricus*.

The anus is terminal, the anal somite being a little longer than the somites immediately preceding.

In the anterior region the cross-section is nearly circular, but behind the clitellum the body is more rectangular, in the living worm being almost square, with setae borne upon the angles. The setae are in four couples upon every somite, except the first, where they are wanting. They are *f*-shaped, and are nowhere modified, except to become less curved in the clitellum. The two setae of the dorsal couple are closer together than those of the ventral couple. They are arranged according to the formulae $1-1 > 2-3 = 4-4$ and $1-2 < 3-4$. Posteriorly, the distance between couples is more nearly equal. The nephridiopores open near the ventral couple of setae, and commence in somite IV. Dorsal pores are present, the first lying in furrow 5-6 and opening, internally, into the somite behind. There are, usually, several evident in the clitellum, and often the full number corresponding to the six somites of that region may be demonstrated.

In sexually mature individuals the body is much swollen in somites XIV, XV, and XVI, each ventro-lateral region bearing a somewhat nipple-shaped protuberance, whitish in color. These protuberances are due, partially, to the development of hypodermal clitellar tissue in this region, but principally to the great development of the prostates. The external orifices of these glands, the male genital-pores, are situated latero-ventrally upon the posterior portion of somite XV, close to furrow 15-16. The aperture is slit-like, and is surrounded by a lustreless area, which makes its position very conspicuous.

The regularity of the segmentation is somewhat interrupted and disarranged in this region, the intersegmental furrow 15-16 being evident only dorsally, and in the middle region ventrally; in the ventro-lateral region it is almost obliterated, but may still be demonstrated in sections. Furrow 14-15 is curved forwards, and 16-17 backwards around the base of the prostatic prominence. Upon somite XIV, at the summit of another, but much smaller papilla, is the oviducal pore, an oblique, slit-like aperture near furrow 14-15, and internal to

the male pore. Both pairs of orifices lie between the two couples of setae, but closer to the ventral couple.

The somites behind the genital protuberances narrow and upon XXIII to XXVIII, inclusive, is a well-marked clitellum, which is complete ventrally, although thinner, and usually showing the intersegmental furrows quite distinctly.

Anteriorly, *B. palustris* is of a deep pink color, owing to the vascularity of its body-walls. The color becomes lighter ventrally, whilst posteriorly the walls are thin and pale, almost transparent, the blood-vessels and intestine being readily seen through them.

The clitellum is clay-colored.

The posterior region of this worm is readily broken, and partially regenerated worms are frequently met with.

Body-walls. — The body is covered by a cuticle of the usual character, except in the regions immediately surrounding the male pores, where it is either wanting entirely, or else is extremely attenuated and much interrupted.

The hypodermis is as in *Lumbricus* and other terrestrial Oligochaeta.

The clitellum, as above stated, occupies somites XXIII to XXVIII, inclusive. It is well marked, both in color and texture, and is continuous, though but two-thirds as deep, ventrally. The hypodermal layer is developed at the expense of the muscular portion; both the circular and longitudinal musculatures are much reduced in this region, the former, in places, being almost obsolete in some specimens.

In the clitellar tissue proper, the same cellular elements are found as in the corresponding region of *Lumbricus*, the unmodified hypodermal cells, however, being less numerous. The outer third of its thickness is occupied mainly by somewhat flask or club-shaped cells, containing coarse, refractive granules, which closely fill nearly the entire cell. The lower portion of each cell is a nucleated and nucleolated protoplasmic mass prolonged into a tail-like process, the ultimate fate of which I could not determine.

The deeper portions of the clitellum consist of long-necked, club-shaped cells containing a clear or very finely granular

material. The protoplasmic basal portions of these gland cells are prolonged into fine filaments, which join one another to form the partitions between the columns of cells, and finally ramify in the circular muscle-layer. Each of these cells, at its base, contains a nucleus and nucleolus.

The deficiency in the depth of the ventral portion of the clitellum is in the deeper layers of cells; otherwise, this portion is similar to the dorsal. The cells described are similar to those figured for *Lumbricus* by Cerfontaine (6), except that in the present species the cells of the deeper layer are more robust, and the arrangement more irregular.

This is the only region in which my preparations show the blood capillaries passing directly into the hypodermal layer.

In the first two somites the longitudinal muscles are deflected from the body-wall, and are attached to the buccal chamber in such a manner as to serve as retractors of that portion of the alimentary canal.

The longitudinal layer of muscles is thicker ventrally than dorsally, and is somewhat interrupted in the line of insertion of the setae. It has the usual bipinnate arrangement, blood-vessels and nerves running in the "rachis." The circular muscle-layer is of uniform thickness on all aspects of the body. Many of the fibres in both layers are tubular, or solid with a clear axial portion, and lie imbedded in a large quantity of connective tissue.

The dorsal and ventral pairs of setae are usually connected by muscular slips passing, on each side, internal to the longitudinal muscle-layer, and just beneath the coelomic lining.

There are also oblique fibres subtending a portion of the ventro-lateral region, between somite XVI and the clitellum. When these contract they flatten the ventral surface and produce a well-marked ventro-lateral ridge, extending from the genital region to the clitellum. These oblique fibres run between the fibres of the longitudinal system, and are similar to the "arciform" muscles which Cerfontaine (6) has figured in *Lumbricus*.

None of the setae in the region of the genital apertures are modified, but in connection with certain of the follicles, or

setigerous glands, we find some remarkable structures, which resemble the glandular masses found upon the ventral faces of certain somites in species of *Lumbricus*, *Allolobophora*, and *Allurus*.

Behind each seta of the ventral pairs, on somites XIII and XVI, we find sac-like invaginations of the hypodermis, the outlets of which lie just within the mouths of the setigerous glands. The relations of these invaginated pouches to the setae remind one of the sebaceous glands of a hair follicle. The cuticle extends a short distance into the mouths of these pouches, thins out, and disappears. The ordinary hypodermal cells wall the outer two-thirds of the pouch, which about equals in depth the thickness of the circular muscle-layer. Into the deeper third open the numerous mouths of unicellular glands, flask-shaped cells with very long and slender necks.

These gland-cells lie on the inner face of the body-wall, the cell aggregate projecting into the body cavity, and being covered internally by the coelomic lining only. They are filled with a granular material, and in the head may be distinguished a nucleus and nucleolus, somewhat clearer than the surrounding protoplasm.

The long necks of these cells, which are the more granular portions, pass, parallel to one another, in a fasciculus through the longitudinal muscle-layer, and empty, as aforesaid, into the deeper portions of the invaginated sac. The latter, in my specimens, was filled with an apparently mucoid material, which may be of utility in causing adhesion of the worms during copulation.

These glands are advantageously situated to pour out their secretion along the setae. They do not occur in the somites bearing the genital openings, nor were they met with elsewhere. They must be regarded as a simple form of multicellular hypodermal gland. The long-necked flask-cells are manifestly hypodermal in origin. That they are not of coelomic origin is probable from the continuity of the coelomic membrane over their inner surface. They appear to be similar to certain cells forming a portion of the prostate.

The hypodermis is otherwise modified in the region of the

genital openings. Running from somite XIII to XVI, or XVII, we find a strip of clitellar tissue lying between the dorsal and ventral couples of setae. The coarsely granular cells of the clitellum are not represented in this region, which, moreover, is quite detached from the clitellum proper, the hypodermis of somites XVIII to XXII being unmodified. Not a little of the swelling in the genital region is due to this increased hypodermal thickness.

Alimentary canal. — The alimentary canal is quite highly specialized and differentiated into well-marked regions.

The buccal chamber lies in the first two somites. Its lining epithelium is columnar, with oval nuclei near the free end of the cells; it is connected with the body-wall of the first two or three somites by irregular, radiating muscle-bands, derived from the longitudinal muscle-layer of the body-wall. Other than this the musculature is slight, the circular layer of enteric muscles consisting of but a few scattered fibres.

Succeeding the buccal chamber is a well-marked pharynx occupying about two somites, but appearing to be much more extensive, owing to the great displacement of the septa. Owing to inequalities in the depth of the cells of the epithelial lining, the latter in its ventral and lateral regions is thrown into ridges and papillae. Upon the dorsal wall, or roof, of the pharyngeal sac, the epithelium is of quite different appearance. The cells are of uniform depth, more slender and with a more elongate nucleus; moreover, they are furnished with cilia, whilst the other cells of the pharyngeal region are non-ciliated.

The dorsal and lateral walls of the pharynx are covered in by a dense mass of muscle, blood-vessels, and glandular appearing cells. The latter are especially abundant in somites IV, V, and VI, where they are aggregated into paired masses. In somites IV and V the respective pairs are united in the middle line, but in somite VI the masses are much smaller and are confined to the sides of the oesophagus. I have been unable to find any communication between these cells and the lumen of the canal. Similar masses of tissue surround the pharynx in other genera of earthworms.

Behind the pharynx the oesophagus gradually increases in diameter, and changes from a flattened to a circular cross-section, forming a long tubular pouch extending for five or six somites. The papilliform arrangement of the epithelium, seen in the ventral portion of the pharynx, becomes more pronounced. When viewed *en face*, the flat-topped papillae are seen to be closely packed and polygonal in shape; under a low power the interior of this region of the enteric canal has a velvety appearance. As shown in Fig. 7, which is a longitudinal section, the epithelial layer alone is concerned in this condition. The increase in surface is enormous.

Following the region just described is a structure, resembling in its general characters, the calciferous glands of *Lumbricus*. Externally, this portion of the alimentary canal is of uniform diameter, and there are no pouches such as are conspicuous in the corresponding region of *Lumbricus*, and when the walls are ruptured there is no exudation of milky fluid. Longitudinal blood-vessels, seen through the outer wall, produce a striate appearance externally. Figs. 4, 5, 8, 9, and 10, show the structure of this region.

In somite XI the oesophageal epithelium becomes erected into longitudinal ridges, shown in cross-section in Fig. 8, *a*. In the lateral regions these rugae increase rapidly in height, as may be seen in Fig. 8, *b*, which is three sections behind 8, *a*. At the same time the several ridges begin to fuse, and the epithelium, which has become ciliated, encroaches upon the lumen of the canal, and a few sections further back the latter is reduced to a mere ciliated slit, with its long diameter dorso-ventral. A transverse section in this region shows slender struts radiating in all directions from the ciliated epithelium, and connected at their outer ends with the musculo-peritoneal layer. In other words the epithelial and muscular layers, instead of adjoining one another, or being separated only by a blood sinus, have become arranged into two tubes, a laterally compressed epithelial, and a nearly circular muscular one. The two tubes are connected by longitudinal laminae, which cut up the space between into wedge-shaped cavities.

Each lamina contains a great blood sinus, expanded both externally and internally, as shown in Fig. 9. These blood-vessels have walls of their own, apparently structureless membranes with very small, flat nuclei scattered sparsely on the surface.

These lamellar vessels are supplied by circular trunks in the neighborhood of the septa, as shown in Fig. 10, which is a tangential section. The circular trunks are given off from the dorsal vessel, and may, at times, break up into a network instead of remaining single; this vascular reticulum, however, appears to be always confined to the immediate neighborhood of the septum.

The spaces lying between the laminae are lined, throughout, by a granular layer containing numerous nuclei, each with a nucleolus. The nuclei are especially abundant in contiguity with the muscular and epithelial layers.

The lining epithelium of this region consists of ciliated columnar cells, the outlines of which are distinct in their free moieties only; their bases become lost in the nucleated protoplasmic mass just mentioned.

In somite XIV the epithelium loses its cilia and becomes thrown into great ridges, shown in Fig. 8, *c*, which a little further back abruptly terminate in backwardly-directed, valve-like folds (Fig. 5, *V*).

Claparede (7) has investigated the histology of the calciferous glands of *Lumbricus terrestris*, and my observations upon *Bimastos*, whilst agreeing with his in the main, differ in certain particulars. In reference to the blood supply of these glands, and of the adjoining portion of the oesophagus, he states, briefly, that longitudinal vessels run parallel to one another and to the axis of the body, just beneath the epithelium, and that they are connected, at intervals, by radiating vessels, with a vascular net-work beneath the muscular layer.

In the present species, as stated above, each longitudinal vessel, and its connecting radiating vessels, are fused into a vascular plate, extending from the epithelium to the muscular layer, and extending the whole length of the septum between the two adjacent follicles. In places, this vascular space may

become very thin, but appears to never become entirely interrupted.

Claparede states that in *Lumbricus terrestris* the follicles are lined with glandular *cells*; in *Bimastos palustris*, as I have shown (Figs. 9 and 10), this lining consists of a finely granular, evidently protoplasmic layer, *not* divided into cells, and containing numerous nuclei, many of them lying on the surface.

I have not found the rifts, or communications, between the follicles and the oesophageal lumen, which Claparede observed in *Lumbricus*.

Claparede's figures do not satisfactorily represent the histology of this organ.

Behind these oesophageal "pouches" the oesophagus rapidly dilates to form the thin-walled, highly vascular crop. This is lined by a non-ciliated nucleated epithelium of columnar cells; the outlines of the deeper portions of these cells are indistinct and free(?) nuclei are seen beneath their bases. Scattered here and there are flask-shaped cells, containing a granular secretion (Fig. 11, *g*). The epithelial cells are of irregular height, and great moniliform blood-vessels still further add to the irregularity of the inner surface.

In the region of septum 15-16 a large valvular transverse fold arises from the dorsal and lateral walls, and projects into the enteric cavity. This fold is thick and vascular, and the circular layer of muscle being strongly developed, it forms an efficient valve between crop and gizzard. In Fig. 5, which purports to be a dorso-ventral, longitudinal section, this valve is wrongly represented. The intestine was somewhat twisted here, and the section has passed through the two lateral walls, instead of the dorsal and ventral. The valvular fold does not occur on the ventral wall.

The crop occupies about one somite, XV, but a short thin walled region exists in a portion of the following somite. This is succeeded by a muscular gizzard, occupying somites XVII and XVIII, and sometimes a portion of XVI. In structure, it is similar to the organ in *Lumbricus*, Fig. 12.

The sacculated intestine immediately follows the gizzard, and in somite XXI the typhlosole first becomes apparent.

Male organs. — There are two pairs of sperm sacs, one pair lying in each of somites XI and XII. They are whitish in color, and are the most conspicuous organs when the worm is opened. They are attached to the anterior septa of the somites in which they lie, and do not enclose the testes or funnels. Owing to their large size, the septa are much displaced and the sperm sacs appear to occupy more than one somite; in longitudinal sections, however, this appearance is readily seen to be illusive. Septum 12-13 is thrust so far backwards by the posterior pair of sacs, that the cavity of XIII is almost obliterated. The interiors of the sperm sacs are much cut up and subdivided by trabeculae of muscle and connective tissue, with contained blood-vessels. As is common in terrestrial Oligochaeta, a pair of testes lies in each of somites X and XI. They are digitate in shape and are attached to the anterior septa of their somites, into which they freely depend.

The ciliated rosettes are large, of the usual form, and are attached to the anterior face of the posterior septa of the somites which contain the testes. From each of the four a ciliated duct passes back and unites in somite XIII, with its fellow of the same side, to form a common sperm duct.

The ducts usually, in Oligochaeta, unite in the somite behind the posterior funnel; the longer independent course in this worm is noteworthy, and was noticed both in dissections and in longitudinal and transverse sections. The ducts are not convoluted after perforating the septa, to which their respective funnels are attached, and unless gorged with spermatozoa, are not obvious when the worm is opened, being imbedded in the tissues of the body-wall, particularly posteriorly to their place of union.

In somite XV the sperm-duct ascends the anterior face of the large prostate, and being imbedded in the tissue of that organ it is rarely that this portion of its course can be demonstrated by dissection.

Upon reaching the summit of the prostate it plunges into its walls, loses its cilia, its epithelial cells gradually elongate and merge into the columnar cells lining the cavity of the gland, and its lumen becomes continuous with the latter.

The prostate is very well developed and to its large size is due, in a great measure, the conspicuous swelling noticeable in the region of the genital pores. It occupies somites XV and XVI, being strongly constricted into two lobes by the intervening septum. The portion lying in somite XV is by far the larger, and almost fills that somite on each side of the alimentary canal.

The lobe in somite XVI is shorter and less robust, being confined to the anterior portion of the somite.

The lumen of the prostate lies entirely within the lobe occupying somite XV; dorsally, where it receives the sperm-duct, it is quite narrow, but in its ventral two-thirds it rapidly enlarges and extends laterally to the external pore already described. In section the cavity is somewhat triangular in shape, as may be seen in Figs. 13 and 14. Fig. 13 is a longitudinal section near the entrance of the sperm-duct, and Fig. 14 is taken from a section, external to this, through the male external pore. It is lined by non-ciliated columnar cells, interspersed with the necks of other cells which may be distinctly recognized as glandular. In some regions the columnar cells form a true lining epithelium, but in most places they are numerically of secondary importance. Where they are most abundant their outlines are quite distinct, and each is seen to contain an oval nucleus and a nucleolus.

Externally to the columnar cells is a thick wall of club-shaped unicellular glands, differing in appearance in different regions. The prostate is well supplied with blood-vessels; the muscular portion is poorly developed, and instead of forming a distinct layer, as in *Moniligaster*, the fibres are irregularly distributed amongst the gland cells.

Upon its coelomic surface it is covered by a delicate coelomic membrane, continuous with that lining the coelom generally, and dipping down between the imperfect lobules into which the gland-cells tend to arrange themselves.

In the upper two-thirds of the prostate, these glandular cells have clear, almost transparent, oval heads with central nucleus and nucleolus, and long duct-like necks which run in a mass towards the central lumen. The swollen nucleated portions

are arranged at different depths, and the duct-like prolongations are consequently of various lengths. I was unable, except in one or two doubtful cases, to follow the individual cells to their openings into the atrial cavity, but many could be traced for about half of the distance, when they became lost in the multitude; others could be followed from their orifices outwards to about the same region, and as there was no difference in appearance it is but reasonable to assume that these glandular cells open by their long necks into the cavity of the prostate. I have in many cases all but absolutely demonstrated the continuity.

Chitinous spicules, or fibres, project from the mouths of these cells into the cavity of the prostate, or as is more accurate, into the atrial cavity, Benham having shown that this cavity is atrial whilst the term prostate should, in strictness, be applied to the glandular cells only. The chitinous filaments may, in many cases, be followed some distance into the necks of the cells, which latter I shall designate as chitinogenous glands. They are the most abundant cells of the prostate, and in the region in which they open the columnar atrial cells are comparatively few in number. Fig. 18 shows a portion of this region with the chitin spicules projecting from the mouths of the cells. Fig. 15 shows a section through the prostate from central cavity to circumference.

The second form of gland cells, although constituting a large portion of the walls of the organ which I have here called prostate, are perhaps not to be accounted homologous with the prostates of other worms.

These cells are also club-shaped, and their swollen inner ends are somewhat larger than the corresponding portion of the chitinogenous cells, and also appear to be rather more distorted through mutual pressure. They are arranged in bunches, or lobes, between which the coelomic membrane passes for a short distance. The ducts, or necks, of these cells (Fig. 16) are longer than those of the chitinogenous cells, and are arranged in a manner more strictly parallel to one another. The entire cell is filled with a granular material which stains deeply, and the nucleus is noticed as a more homogeneous

body lying in the swollen end of the cell and containing a more deeply stained nucleolus. The mouths of these cells open around and just within the male genital pore. In this region the ordinary hypodermal cells appear to be absent, in consequence of which the cuticle appears to be lacking also. The entire surface appears to be occupied by the apertures of the unicellular glands, thus giving the lustreless appearance noticed in the description of the external characters.

These granular cells are in appearance and arrangement quite like those of the post-setal glands, and it is probable that they are morphologically equivalent.

In a portion of the lower third of the prostate forming a zone between the orifices of the granular cells and of the chitinogenous cells, respectively, there is a continuous lining of columnar cells with well defined boundaries and containing oval nuclei and nucleoli (Fig. 17). Just without this lining lies the mass of granular cells forming the thickness of the organ, but their ducts, instead of passing directly to the atrial cavity, pass ventralwards parallel to the lining epithelial layer, to open, as above stated, in the neighborhood of the external pore (Fig. 14).

The cells which I have designated chitinogenous glands are without much doubt derived from the general columnar cells lining the atrium. They are certainly not hypertrophied cells of the coelomic layer, for, as has been pointed out, this exists as a distinct though delicate membrane covering the glandular mass upon its coelomic surface.

The lobe of the "prostate" lying in somite XVI appears to contain the granular gland cells only.

The glandular mass surrounding the terminus of the sperm canal differs, then, in several respects from the similar organ which has been described in other earthworms. In the first place, two distinct forms of gland cells are found, lying in different regions and secreting diverse products.

I believe that the chitin-producing upper portion of the mass corresponds with the prostates of *Moniligaster*, *Acanthodrilus* (2 and 5), *etc.*, and that the granular cells opening in the neighborhood of the genital pore are to be considered in connection

with the post-setal glands in the neighboring somites, and are, perhaps, homologous with the capsulogenous glands of *Perichaeta* and other genera (3).

In *Bimastos* the muscular coat of the prostate is much weaker than in *Moniligaster*, and is scattered irregularly through the glandular mass, instead of forming a zone just without the columnar lining cells, as in *M. Barwelli* (2), or deeper in the walls, as in *M. indicus* (5).

The gland cells are also less distinctly arranged in bundles than in the forms mentioned, and in this respect are more like those in the glandular portion of the prostate of *Deinodrilus* and its allies. The swollen heads of the cells, however, show a tendency towards bunching.

Benham has furnished us with a reasonable explanation of the much-discussed relations existing between the parts just described and the atria and prostates of *Tubifex*. According to his view, the columnar epithelium and the scattered muscle fibres are the much-reduced remains of the atrial wall, whilst the gland cells are referrible to the cement glands.

As I shall show, the cement glands of *Tubifex* and the chitin-producing cells of *Bimastos* perform the same function in the economy of reproduction.

From the shape of the atrial cavity and the character of the cell products I was early led to credit this organ with the fabrication of the spermatophores, and it was with considerable satisfaction that I afterwards found spermatophores in the course of manufacture within the cavity. In many instances it was possible, in sections, to follow the chitin filaments from the mouths of the cells, or even from some distance within the cells, to the walls of the spermatophore. From their position in the atrium it would appear that the spermatophores are extruded "head" first.

Lankester (8) and others have long ago shown that the spermatophores, or sperm ropes, of *Tubifex* are formed by the secretion of the cement glands poured into the atrium as a matrix. It is generally claimed, as stated by Vejdovsky (11), that in the *Lumbricidae*, which have no atria, the spermatophores are secreted by the spermathecae, that is, by the female

apparatus *after* copulation. In *Bimastos*, and we must believe the same of *Criodrilus* (4 and 10), the secretion must precede copulation, and the latter consist of the transfer of charged spermatophores from the male organs to the body wall of a second individual, there to await final disposition. The whole question of the mechanism and methods of copulation in earth-worms is in an exceedingly hazy condition.

The spermatophores of *Bimastos* are usually borne in pairs upon the lateral regions of the body in front of the genital openings, usually on somites XII or XIII. One worm may bear as many as six. They bear some resemblance to the spermatophores of *Criodrilus*, but are somewhat more complex than is indicated by descriptions of that form. They are chitinous club-shaped bodies, perfectly transparent, except the head, which is white with contained spermatozoa. The upper portion is curved and the base expanded into a disc for attachment, as shown in the figure. The upper swollen portion contains a cavity divided by curving transverse partitions into a number of narrow chambers, or pockets, each gorged towards its blind end with spermatozoa.

The partitions do not extend quite across the cavity of the spermatophore, so that there is a channel across the mouths of the pockets by which they are in communication with the exterior at the free end of the spermatophore, which is irregular and ragged, and often shows a raveling out of the chitinous filaments of which it is composed. The spermatophores are very firmly attached to the cuticle, by what means I cannot say, unless the granular cells of the prostate, whose function is unaccounted for, may secrete a cement for this purpose. The position of their orifices would suggest some such utility, or perhaps the secretion of albumen for the cocoon.

When the spermatophore is subjected to pressure, as under a cover-glass, the spermatozoa float freely out, and therefore appear to be unfixed in a cement substance such as is found in the sperm-rope of *Tubifex*. In sections of the spermatophore this point is obscure.

Female organs. — The ovary is attached to the ventral portion of the hinder surface of septum 12–13, and lies, as usual,

entirely within somite XIII. It consists of a circular disc-shaped mass, prolonged at its free end into a short tail containing the most mature ova. The septum to which it is attached has been thrust backwards by the enormous development of the sperm sacs, until it roofs over the entire length of the ovary, and the cavity of somite XIII is very much reduced.

The oviduct opens internally upon the anterior face of septum 13-14, being there expanded into a ciliated disc closely adhering to the septum. Near its upper mediad border this disc is invaginated into somite XIV, carrying with it the muscular septum. There is thus formed a small globular sac opening into somite XIII, but apparently lying in the succeeding somite. It is lined with cubical ciliated cells continuous with the cells of the ciliated disc, and is covered by top-shaped cells derived from the coelomic membrane. Between these two layers lie muscle fibres in two layers at right angles to one another.

This sac is probably an ovisac, but is similar to none of the published descriptions of that organ in other worms, and it is, moreover, so small that it could not accommodate more than two or three ova at a time. Its interior is undivided by partitions or trabeculae, and the muscular layer is well supplied with blood vessels. The oviduct passes through septum 13-14, from the lateral ventral border of the ciliated disc, that is, from the portion farthest removed from the ovisac. It is ciliated for its entire length, and has an outer irregular, but mostly circular, layer of muscle and connective tissue fibres continuous with the same tissues in the septum and body walls. Blood capillaries lie imbedded in this musculo-connective tissue tunic or between it and the lining layer of columnar ciliated cells.

For a short distance, after passing through the septum, the walls are thrown into internal longitudinal ridges, principally due to irregularities in the length of the ciliated cells; at its distal portion, however, it is oval or circular in cross section. Some of the sections showed ova at about the middle of their journey to the exterior. Spermathecae are not present. Although the sections were carefully examined, I was unable to

find even such rudimentary organs as Beddard (1) has described in *Allurus*.

Vascular system.—The vascular system has not been investigated, except in a very general way. There are three longitudinal trunks running from end to end, or nearly so; these are dorsal, sub-intestinal, and sub-neural.

The dorsal trunk is single throughout, and in the anterior region gives off five pairs of somewhat moniliform contractile vessels in somites VII, VIII, IX, X, and XI. The first four of these always flow directly into the sub-intestinal trunk; the fifth pair sometimes first pass into the intestinal wall, from which they emerge laterally and thence flow into the sub-intestinal trunk. In the latter case the free portion of the vessel is only about one-third as long, and is much weaker than its fellows. In front of these lateral arches the dorsal vessel ramifies in the buccal and pharyngeal mass.

A pair of oesophageal vessels arise from the sub-intestinal trunk in somite X and pass laterally forward to supply the tissue surrounding the anterior portion of the alimentary canal.

The sub-neural vessel lies within the neural sheath, and gives off branches, along with the nerves, to supply the body walls.

A vessel in frequent communication with the dorsal trunk traverses the typhlasole.

Central nervous system.—The main features of the nervous system are as usual in *Oligochaeta*. The supra-oesophageal ganglia lie in the third somite; the first pair of the ventral ganglionic chain, in the fourth. Several large nerves are given off from the supra-oesophageal ganglia and the oesophageal ring, and go to supply the buccal muscles as well as the prostomium and the body walls of the first two somites. The first pair of ventral ganglia send large nerves forward to the ventral wall of the second and third somites. The ventral nerve cord contains the usual tubular fibres, and is surrounded by a muscular sheath containing a copious blood supply derived from the sub-neural trunk. Nerves are given off laterally to the body walls in each somite; they penetrate the longitudinal

muscle layer about in line with the ventral couple of setae, and then follow the course of the circular muscles, giving off branches to the hypodermis and longitudinal muscle bundles.

Nephridia.—The nephridia are paired in each somite, beginning in IV, where they are smaller than in the somites succeeding. The external opening is near the ventral couple of setae. These organs appear to present no differences from those of *Lumbricus*.

The principal facts treated in the foregoing paper are as follows :

1. Behind each seta of the ventral couples in somites XIII and XVI are sac-like invaginations of the setigerous follicles receiving the secretion from long-necked granular cells, the swollen inner ends of which lie within the body cavity.

2. Around the atrial cavity are thick walls of club-shaped unicellular glands of two kinds. The clear cells of the upper portion secrete chitin for the manufacture of the spermatophore, the latter being fabricated in the atrial cavity. The granular cells which form the basal portion of the anterior lobe and all of the posterior lobe of the prostate, open around the male genital pore, and resemble the secreting cells of the post-setal glands.

3. The coelomic end of the oviduct forms a ciliated disc which is directly invaginated into somite XIV to form the ovisac. The oviduct is covered by a tunic containing muscle fibres.

4. The sperm ducts on each side join far back in somite XIII.

5. A structure similar to the calciferous glands of *Lumbricus* is described and compared with Claparede's description of *Lumbricus terrestris*.

Following is a definition of the genus:

GENUS BIMASTOS, H. F. M. (9).

1. Prostomium continued on peristomium by grooves.
2. Clitellum on XXIII to XXVIII, complete.
3. Setae in four couples.

4. Certain somites in genital region with hypodermal glandular structures in relation with the setae.
5. Male pores paired on XV on papillae; female pores paired, XIV.
6. Sperm sacs, two pairs, in XI and XII.
7. Funnels and testes, two pairs, in X and XI; free.
8. Prostates, one pair, in XV and XVI; bilobed.
9. Spermathecae, none.
10. Nephridia paired.
11. Alimentary canal, complex. Ciliated oesophageal structure (calciferous gland), in several somites between XI and XV. Crop. Gizzard, one, in somites XVII and XVIII. Not constricted by septum. 1 species *B. palustris*, n. sp. Eastern Pennsylvania and New Jersey.

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EXPLANATION OF PLATE XXVI.

FIG. 1. Ventral view of anterior region. $\times 3$. ♂, male pore. ♀, female pore. *Cl.*, clitellum. 1 *a*, posterior five somites.

FIG. 2. Side view of anterior region. $\times 3$. Letters as in Fig. 1.

FIG. 3. Dorsal view of same. Letters as before. *D.*, dorsal pores.

FIG. 4. Worm opened in dorsal median line. $\times 8$. *B.*, buccal chamber. *S.G.*, supra-oesophageal ganglia. *Gl.*, glandular masses attached to oesophagus and pharynx. *C.v.*, contractile lateral trunks. *C.oe.*, ciliated region of oesophagus (calciferous? gland). *Cr.*, crop. *G.*, gizzard. *I.*, intestine. *Cl.*, clitellum. *D.*, dorsal trunk. *P.*, prostate. *S.d.*, sperm duct. *F.*, ciliated rosettes. *T.*, testes. The sperm sacs have been removed to show the structures beneath.

FIG. 5. Longitudinal median section. $\times 15$. *B.m.*, radiating buccal muscles (retractors). *S.c.*, supra-oesophageal commissure. *Ph.*, pharyngeal sac. *Gl.*, glandular masses. *S.*, sperm sacs; the two pairs overlap, and consequently both are cut in each somite. *V.c.*, ventral nerve cord. *Oe.*, papilliform portion of oesophagus. *C.oe.*, ciliated region of oesophagus (calciferous gland?). *V.*, valvular folds terminating this portion of oesophagus. *Cr.*, crop. *Va.*, valvular fold depending from dorsal and lateral walls. (The intestine in section shown was somewhat twisted, and was cut in the lateral portion of the fold below. There is no fold in the ventral region.) *G.*, gizzard.

FIG. 6. Longitudinal section through setigerous gland and post-setal gland of somite XIII. $\times 250$. *Coe.*, coelomic membrane. *G.*, gland cells. *S.m.*, muscles of seta. *L.m.*, longitudinal muscle layer. *C.m.*, circular muscle layer. *G.n.*, necks of gland cells. *C.*, cuticle. *S.*, seta. *S.g.*, invagination of hypodermis to form setigerous glands. *M.*, mass of secreted material in cavity of post-setal gland.

FIG. 7. Longitudinal section of anterior region of oesophagus. $\times 400$. *L.m.*, longitudinal muscle layer. *C.m.*, circular ditto. *E.*, papillae of columnar epithelium.

FIG. 8. 8 *a*, transverse section just in front of ciliated region of oesophagus. 8 *b*, three sections back of *a*. Ciliation commencing and lacunae, *Ca.*, appearing in walls. 8 *c*, a transverse section about six sections posterior to 8 *b*. 8 *d*, a transverse section in the hinder region of ciliated tract. *P.m.*, musculo-peritoneal layer. *E.*, ciliated epithelial layer. *Ca.*, lacunae between vascular lamellae. 8 *e*, section through region of valvular folds (*V.* in Fig. 5) terminating the ciliated tract. All $\times 50$.

FIG. 9. Cross section of portion of ciliated tract (calciferous glands?) to show histology. $\times 400$. *C.m.*, circular muscle layer. *L.m.*, longitudinal ditto. *B.v.*, radiating longitudinal blood vessels. *N.*, nuclei lying in protoplasmic mass on walls of blood canals. *C.*, masses of these nuclei contiguous with epithelial and with muscular layers. *E.*, ciliated lining epithelium of oesophageal tract.

FIG. 10. Tangential section through one of the circular trunks of ciliated region of oesophagus. $\times 400$. *C.v.*, circular trunk. *B.v.*, longitudinal vessels given off from *C.v.* *N.*, nucleated protoplasmic mass on walls of blood vessels. A section through this region in a plane parallel to that of Fig. 9 would show the radiating vessels connected by a great annular trunk at their outer ends.

EXPLANATION OF PLATE XXVII.

FIG. 11. Longitudinal section through valvular fold *Va.* in Fig. 4. $\times 400$. *B.v.*, blood vessels. *E.*, columnar lining cells of crop. *G.*, gland cells. *N.*, free (?) nuclei lying at bases of epithelial cells. *M.*, muscle fibres derived from circular layer of alimentary canal.

FIG. 12. Longitudinal section of gizzard. $\times 400$. *C.*, thickened cuticular lining. *E.*, epithelial layer secreting *C.* *B.v.*, longitudinal blood vessel. *C.v.*, circular vessels between the bundles of the greatly hypertrophied circular muscle layer *C.m.* *L.m.*, longitudinal layer of muscle.

FIG. 13. Longitudinal vertical section of prostate. $\times 70$. 14-16 and 15-16 septa. *P.*, layer of chitin-producing cells surrounding atrial cavity *A.* *L.m.*, longitudinal and *C.m.*, circular, muscle layers of body wall. *Hy.*, hypodermal layer. A few sections external to this, the upper end of atrial chamber receives the sperm duct.

FIG. 14. Longitudinal vertical section of prostate, more lateral than Fig. 13, and passing through external male pore. $\times 70$. *A.*, atrial cavity. δ , male pore (atriapore). *P.*, layer of chitin-producing cells. *G.*, layer of granular gland cells. The approximate distribution and the region in which these cells open is shown by the cross-hatched area. *S.d.*, sperm duct passing up the anterior wall of prostate. 14-15, 15-16, 16-17 septa, *L.m.*, longitudinal, and *C.m.*, circular muscle layers of body wall. *Hy.*, hypodermis.

FIG. 15. Section of prostate in the region *P.* of Fig. 13. $\times 210$. *Co.*, coelomic membrane. *P.*, chitinogenous glands. *N.*, necks of same, with chitinous spicules, *Ch.*, protruding from their mouths into atrial cavity. *Mm.*, muscle fibres. *E.*, layer in which lie scattered columnar cells with oval nuclei.

FIG. 16. Section of prostate through one of the regions *G.* in Fig. 14. $\times 210$. *Co.*, coelomic membrane. *G.*, granular gland cells prolonged into slender necks, *N.*, parallel to one another.

FIG. 17. Columnar cells lining atrial cavity in the narrow zone between the orifices of cells of regions *P.* and *G.*, Fig. 14. $\times 750$.

FIG. 18. Enlarged section of region *E.* in Fig. 15. $\times 750$. *Ch.*, chitinous filaments, which in some cases may be traced into the necks, *N.*, of the chitinogenous gland cells. *E.*, nuclei of the columnar cells lying amongst *N.*

FIG. 19. Entire ovary. $\times 125$.

FIG. 20. Longitudinal section of ovary in outline. $\times 125$.

FIG. 21. Two well-developed eggs in ovary. $\times 325$. *F.*, follicle. *F.c.*, Aggregation of follicular cells. *V.*, vitelline membrane, which is the only covering of the eggs when discharged into the body cavity.

FIG. 22. Transverse section of oviduct. $\times 350$. *M.p.*, musculo-connective tissue tunic covering the oviduct; continuous with *S.* of Fig. 23. *E.*, ciliated columnar cells continuous with *E.* of Fig. 23.

FIG. 23. Ciliated disc (funnel) of oviduct. $\times 170$. The Roman numerals indicate the somites. *E.*, ciliated cells becoming lower in ovisac (?). *O.*, peritoneal top-shaped cells covering *O.* in somite XIV. *S.*, septum. *L.m.*, longitudinal muscle layer of body wall.

FIG. 24. Spermatophore. $\times 70$. *B.*, flattened and expanded base for attachment. *P.*, pockets separated by curved partitions and all opening into chamber *C.*, which is in communication with exterior at free end of spermatophore.