impossible to say; at any rate, for ought we know to the contrary, it may be also formed during the growth of the gonidium of lichens, and it would seem rash at our present state of information to confine it within any limits. Further observations are wanting before we can consider it peculiar to the Confervæ.

The same remark may be applied to the zoospores, the formation of which is also asexual process. We have evidence which shows that the formation of zoospores extends over a wider range than had formerly been believed. There, again, is a fine field here for observation. It is very possible that some of the Volvocinææ may have an origin in some other form of life, especially since Cohn has shown forms of zoospores of *Protococcus pluvialis,* united in such a manner as to partake of many of the features of that tribe. No finer field than the one I have above pointed out is open for the patient observer, who will carefully trace, and as carefully portray, every step of the form in which he is interested.

The Anatomy *of the* Earthworm.

By E. Ray Lankester.

Part I.

Being desirous of publishing a notice of certain new points of structure which I have detected in the earthworm, I thought that it might be well to accompany it with a description of the general anatomy of that Annelid, especially since the later and more accurate observations on this subject have been published as papers in foreign journals, and are scattered about in various French, Belgian, and German periodicals. The appearance too, of a paper in the 'Philosophical Transactions' for 1858, by Dr. Williams, in which the anatomy of the reproductive organs of *Lumbricus* is treated of, has been a further inducement to me to publish my observations on this point. The separate researches of two Continental naturalists, M. Jules d'Udekem and Dr. Ewald Hering, had placed our knowledge of the generative system of the earthworm in a so far satisfactory state that little more remained to be done than to explain a few minor discrepancies between the results arrived at by these authors. Dr. Williams, however, having failed to observe that which is recorded by Dr. Hering and M. d'Udekem, asserts that those authors' observations are "confused and contradictory," and proceeds to give a description of ovaries and testes, which he does not confirm by adequate figures, and which, certainly as far as my observations have gone, do not exist. It is therefore necessary, in justice to these two continental observers, to show, if possible, that their observations are not "confused and contradictory," but that they (more especially Dr. Hering) have given, on the whole, a truthful and accurate account of the reproductive organs of *Lumbricus*; that it is Dr. Williams's observations which are incorrect, and that consequently that author's views as to the modification of the ciliated tubuli into reproductive organs are, at any rate, as far as *Lumbricus* is concerned, untenable.

The frequent use of the microscope, which is necessary in the elucidation of the anatomy of the Annelida, and without which no accurate knowledge of their organization can be arrived at, must be my apology for the publication of a paper of this nature in the pages of a microscopical journal.

From the time of Willis* and Redi† the structure and habits of the earthworm have received much attention from naturalists. Montegre,‡ Sir Everard Home,§ Dufour,|| Dugès,¶ Meckel,** Stein,†† D'Udekem,‡‡ and Hering,§§ are amongst those who have written on the subject, the only author, however, who professes to deal with it as a whole, and who has treated of the entire anatomy of the worm, is Morren,|||| the other writers named having devoted their researches almost exclusively to the reproductive organs. The work of this author was published many years since, but is still remarkable for the amount of labour displayed in it, and the profusion of engravings. The nervous system has formed the subject of papers by M. de Quatrefages and Mr. Lockhart Clarke, to which reference will be made hereafter. I propose to describe the organization of the earthworm under the following heads:—Tegumentary system, Muscular system, Digestive

* 'De Animâ Brutorum.'
† 'De animalibus vivis quæ in corporibus animalium vivorum pariuntur.'
‡ 'Annales du Museum d'Hist. Nat.,' 1825.
§ 'Phil. Trans.,' 1823, p. 11.
|| 'Ann. des Sciences Nat.,' 1825.
¶ Ibid., 1828.
** Müller's 'Archiv,' 1844.
†† Ibid., 1842.
‡‡ 'Memoires de l'Acad. Roy. de Bruxelles,' 1857.
§§ Siebold and Kölliker, 'Zeitschrift,' 1858.
|||| 'De Lumbrici terrestris Historia naturali necnon anatomia tractatus.'

system, Circulatory and Respiratory systems, Nervous system, Secernary system, and Reproductive system. I may here mention that the majority of my observations have been made on the *Lumbricus terrestris,* though I have also dissected many individuals of *L. agricola.*

Tegumentary system.—The tegumentary and muscular systems of the earthworm are so intimately united that it is somewhat difficult to describe the one apart from the other. If a vertical section be made of a portion of the integument of Lumbricus, three distinct strata or layers will be distinguished. The external one is the epidermis, the middle the pigmentary layer, and the internal the muscular layer. If a very thin section of this description be made and placed beneath the microscope, the appearances drawn in Pl. VII, fig. 12, are seen. The epidermis (*e*) appears to be almost structureless and transparent, having, however, a certain finely granular, striated aspect. The pigmentary layer (*a*) contains numerous dark-brown cells, irregularly disposed in a semi-transparent homogeneous matrix, in which also ramify very numerous blood-vessels. The disposition of these capillaries is towards the exterior, the larger branches from which they are derived being situated in and above the muscular layer. The muscular layer (*c*), which varies in size in various parts of the integument, is generally by far the thickest, composed of minute fibres, crossing and intercrossing in various directions, the more superficial ones having a direction parallel with the longitudinal axis of the body, whilst the deep-seated fibres run exactly at right angles to these. Within the muscular layer a small species of nematoid (*b*) may be frequently detected. They are very abundant in all parts of the earthworm, but do not appear to do much harm. I shall have occasion hereafter to refer to this parasite (the *Anguillula Lumbrici* of Dujardin) in speaking of the generative organs, where its existence has given rise to many errors. A delicate layer of cells is perceptible beyond the muscular coat (*a*), which probably belong merely to the corpusculated perivisceral fluid.

The tunic thus formed is constricted into various rings, or annulated, at short intervals throughout the length of the body, which is of a cylindrical tapering form anteriorly, but broad and flat as the posterior region is approached, terminating at length very suddenly by a rapid diminution in the size of the annuli. If a worm be drawn through the hand, from head to tail, no perceptible impediment to its passage is felt; but if the reverse operation is tried and the worm be held by the posterior extremity, a considerable amount of resistance is experienced, in consequence of a roughness of the worm's skin. This roughness is owing to the presence of minute setæ, of which there are four pairs on nearly every ring of the worm's body, those only comprised by the cingulum and the smallest anal segments being free from them. Two pairs of the setæ have a ventral aspect, and a pair on either side are disposed laterally (fig. 8). One of these setæ placed beneath the microscope shows a slightly curved form, is transparent, of a yellow colour and fibrous structure (fig. 7). The broader portion is fixed in the integument, and is softer than the exposed portion.

The setæ are secreted by very minute glands, of which there are four in every segment, each situated in connection with the inserted portions of a pair of setæ. These setigerous glands may be seen in fig. 11, *b*, *d*. In a certain part of the body the setigerous glands often acquire a large size, and their normal function appears to become subservient to some other. Large semi-developed setæ are thus found in them, as also a viscid secretion, the function of which must be discussed in connection with the reproductive system. The setæ are very frequently lost or injured in use by the earthworm, and their place left unsupplied. From this we may conclude that the process of their formation is not rapid, nor adapted to supplying a vacancy immediately on its being required; but, rather, a regular and slow development, which takes place equally, whether injury has been sustained or not, and irrespective of wear. Another feature of the integument which will be noticed by the most casual observer is its enlargement into the "cingulum," extending from the twenty-ninth to the thirty-sixth segment. The cingulum, which, though a tegumentary appendage, is strictly an accessory organ of reproduction, is of a paler colour than the rest of the integument, encloses the dorsal and lateral surfaces of the rings over which it extends, but is not developed from the ventral surface. The structure of this body is glandular, being composed of a great number of minute pyriform papillæ, which secrete a fluid, and also act as adhesive organs during the congress of two individuals. The epidermis covering the papillæ is remarkably thin, and appears to be ruptured when coition occurs. In examining the ventral surface of the worm various minute apertures will be discovered in the anterior segments of the body; but as they are intimately connected with certain of the organs of reproduction, I defer describing them for the present.

Muscular system.—The various modifications of the muscular layer of the integument constitute the principal part of the muscular system in the earthworm. There are but few special developments of muscular tissue in such organisms at all; the various functions which are entailed on special muscles in higher animals being here performed by a simple contractile tunic or membrane. The muscular coat succeeding the pigmentary layer of the integument (the cutis being inseparable, and not easily distinguished from those structures) consist of fibres which run transversely to the longitudinal axis of the body, and by their contractions cause the rings to diminish their diameter; the succeeding layer to this is formed of intercrossing and oblique fibres, whilst the innermost fibres are arranged longitudinally. These last are by far the most numerous, and are largely developed on the ventral surface. They form the straight muscles of Morren. Two lateral muscles, a ventral, and a dorsal, may be distinguished (fig. 11). The setigerous glands occupy a position between the dorsal and lateral and the lateral and ventral muscles on either side. Morren has carefully described an arrangement of minute muscular fibres in connection with the setæ, which he considers as the protractors and retractors of these appendages. Cuvier has also described these.

The object of the muscular attachment appears to be to keep the seta in position rather than to withdraw or extend it, so that the hooklet may yield to pressure from the quarter towards which the worm is progressing, but offer resistance to similar force in the opposite direction. The remaining muscles of the earthworm are the transverse or intraseptal muscles, or modifications of these. Between every segment or ring a very delicate, tenacious, pellucid, muscular membrane exists, loosely connected with the internal viscera, but firmly attached to the walls of the body. These transverse muscles do not entirely close the various rings from each other, but allow the contents of the perivisceral cavity free movement from one end of the body to the other. The fibres of the transverse muscles are very fine, and take a direction from the walls of the splanchnic cavity towards the central viscera. In the first eight or nine rings of the body oblique radiating muscular fibres diverge from the transverse muscles, and become attached to the muscular pharynx to be described hereafter. A somewhat similar arrangement occurs in the terminal rings of the body, where these radiating fibres assist in the expulsion of the fæces from the anal aperture.

Digestive system.—Before proceeding any further in the description of the anatomy of the earthworm, it is necessary to explain the method which has been adopted in dissecting. The best way of killing the worm, which should be of as large a size as can be obtained, is with chloroform, though spirits of wine can be made to answer the same purpose. The advantage of chloroform is that it leaves the subject lax and pliable, whereas in spirits of wine rigidity often occurs, which renders careful dissection impossible. A pin being inserted in the first or labial segment, and the worm pinned firmly in a gutta-percha trough, the dissection may be commenced by a dorsal, lateral, or ventral incision, which should extend from the first to the thirtieth segment. This being done, the cut edges must be separated and pinned out, as much longitudinal tension being used as possible. The organs of the body will then present a very beautiful sight. Many, though, are concealed because of their transparency, and great difficulty will be found in manipulating certain organs on account of their tenuity and the fluid nature of their contents. These difficulties will be entirely obviated by filling the trough with pure spirits of wine.* A most marvellous change then comes over the appearance of the extended annelid; numerous little fibres display themselves, running from the pharynx to the transverse muscles, which also become more evident; the ciliated tubules in each segment make their appearance, and, what is most important, the reproductive organs become so hardened as to admit of careful dissection. I cannot but attribute some of the errors which have been made by the older and certain recent observers to the want of some such method of dissection as this. Fig 5 represents a worm opened by a dorsal incision, and treated in this way.

Mouth.—The mouth in the earthworm is formed by the incomplete structure of the first segment of the body (fig 9). The incomplete ring is a conical or nipple-shaped projection, of a very fleshy, muscular nature, forming what may well be called an upper lip. The mucous membrane of the mouth is reflected inwards, and lines a large oral cavity, considered as the pharynx (fig. 5, *b*, fig. 6). The mouth forms the subject of several figures and a good deal of letter-press in Morren's memoir; but it appears to be a very simply formed orifice,

* Mr. George Busk, who has for many years made the earthworm a favorite study, and who very kindly assisted me when first commencing its dissection, was, I believe, the first to use chloroform and spirits of wine in this way; I regret very much not having had the benefit of his advice in preparing this paper.

the movements of the labial segment, which can be retracted so as to close the oral aperture, being dependent on muscles similar to those existing in each segment of the body, and already described.

The *pharynx* is a broad somewhat flattened and very muscular organ, immediately succeeding the oral aperture; it extends from the second to the seventh ring of the body. The upper surface, exposed when a dorsal incision is made, is very muscular, numerous radiating digital fibres connecting it with the transverse septal muscles; its lateral attachments appear to be the strongest, though numerous radiating fibres may be also detected on the ventral surface of the organ. The outer thick and muscular coat, which thus gives to the pharynx its principal muscular power, is of a yellowish-white colour, and very vascular. If this be opened and carefully examined it will be found to project anteriorly into the hollow cavity which it forms, and gives rise to a sort of disc or sucker by the action of which, no doubt, the earthy food of the worm is drawn into the mouth. A second, much finer muscular coat will also be found underlying this denser one, and intimately connected with the loose folds of mucous membrane which line the pharyngeal cavity. In fig. 3 a small bundle of muscular fibres from the pharynx is drawn; they present the same simple structure and appearance as the muscular tissue from all parts of the body.

Salivary glands.—Opening into the mouth and pharyngeal cavity are three pairs of glands, which must be considered as salivary organs. Morren appears to have figured these, and Mr. Lockhart Clarke briefly mentions their existence. They are in the form of convoluted tubules, situated near the oral aperture in connection with the dense exterior coat of the pharynx, and require a little examination to be detected.

Passing down the alimentary canal, we come to the *œsophagus*. This commences in the eighth segment of the body, (fig. 5, *c*, fig. 6), and is directly continuous with the muscular pharynx. The latter organ contracts very considerably in the seventh ring, and then is followed by this narrow, delicate, but highly elastic tube. The œsophagus extends to the fifteenth or sixteenth ring; throughout it is composed of a more or less delicate muscular coat and an inner mucous lining. In its passage through the septal muscles it becomes slightly constricted, and the fibres of the one organ appear to become interwoven with those of the other; this is more particularly the case in the eighth, ninth, and tenth rings. The large dorsal vessel which runs all along the alimentary canal attains its greatest development in the region of the œsophagus; it passes directly along the median line of the body, in close connection with the digestive tube, and, with its contractions and dilatations, the œsophagus also performs certain peristaltic movements, the object of which may be connected with the circulatory system. The large lateral vessels, described as hearts, are given off from the dorsal vessel in the region of the œsophagus, and the reproductive organs closely surround it; we have therefore in this region the most vascular and active part of the body. Although the œsophagus itself consists merely of a muscular and a mucous membrane, possessing no special secernary powers, yet the dorsal blood-vessel, throughout its connection with the œsophagus, is more or less invested with a yellowish-brown mass of cellular matter, which sometimes extends to the lateral vessels and hides the true walls of the blood-vessels from view. If a portion of this yellow mass be placed under the microscope with a high power, it will be found to consist of minute cells, the contents of which are still finer granular particles (fig. 13). They exactly resemble the cells which, in connection with the blood-vessels, invest the whole of the intestine, yet to be described, and which have always been considered as performing a secernary function similar to that of the liver. This yellow mass may therefore be regarded as an organ of secretion in connection with the œsophagus, of similar nature to the hepatic membrane of the intestine.

Œsophageal glands.—Situated in the twelfth and thirteenth rings, and nearly or entirely concealed by the testicular masses, are three pairs of very remarkable glands, which have never yet been described. In fig. 5 the reproductive organs have been turned back, so as to expose these (*h*). The dorsal blood-vessel is in close connection with them, and two of the great lateral vessels lie in contact with their surfaces. Morren, indeed, in pl. xxxi of his memoir, gives a rough figure of two of these glands, but does not add any accurate description of them. Dr. Williams, in his paper in the 'Philosophical Transactions,' describes a figure in his pl. vi as the reproductive organs of the earthworm, and denominates a certain mulberry-like mass "calciferous glands." No description of these glands is given in his memoir, and the figure is so utterly unlike *anything* existing in the earthworm that I cannot say whether the œsophageal glands are meant, although no other calciferous bodies are to be met with in *Lumbricus*. In fig. 4 the three pairs of œsophageal glands and part of the œsophagus are seen removed from the attached blood-vessels and septal muscles, considerably enlarged. The most anterior pair, which exists in the twelfth ring, are somewhat round and full, pale in colour, and with an immensely vascular surface, the vessels running parallel to one another, and frequently so numerous as to give the organs a bright-red colour. They are firmly attached to the walls of the œsophagus, but do not appear to have any communication with its interior. When opened they are found to contain either a single hard crystalline mass or numerous smaller bodies of a similar appearance, when placed under the microscope, to that drawn in fig. 10. The wall of the pair of pouches is thin, and the presence of the hard bodies beneath can be detected by simply pressing the glands. When a portion of the crystalline substance is treated with acetic acid, it dissolves with great effervescence. It is therefore probable that the substance is carbonate of lime. These glands do not always contain crystalline bodies, and occasionally a worm is found in which all three pairs of œsophageal appendages have lost their vascularity and size. I am not able to give any clue as to the function of this first pair of glands; it may be connected with the formation of the egg-capsule, which is said to contain carbonate of lime; on the other hand, it may be a provision for disposing of any superabundance of mineral matter in the blood. I have frequently found the crystalline bodies passed into the œsophagus and lodged in the capacious crop. The second and third pairs of œsophageal glands are situated in the thirteenth ring, and have a form and appearance differing from the first. They are a little smaller, and their walls are much thicker, but no less vascular, than the first pair. They contain a milky fluid, which, when examined with the microscope, is found to consist of very minute granules, somewhat similar to those of the hepatic membrane of the intestine. A very thin section, made vertically through one of these glands, shows the structure drawn in fig. 2, an inner epithelial coat, a vascular region in which the blood-vessels are arranged in loops as seen in the figure, and an outer more delicate membrane, forming the sheath of the organ on which the externally visible vessels extend; these, as in the anterior pair of glands, are very numerous, and run parallel to one another.

The arrangement of the vessels interiorly in loops is very remarkable, and may be easily observed when the vessels are naturally injected. All three pairs of glands present this structure. The use of the milky secretion contained in the second and third pairs may be in the process of digestion;

indeed, this appears most probable, but the properties of the secretion cannot be determined. That these three pairs of glands are of very vast importance in the economy of the worm cannot be doubted, when their proximity to, and connection with, the great vessels of the body is considered, and it is somewhat surprising that they should have escaped the notice of previous observers.

Crop or stomach.—Leaving the œsophageal glands, we may follow the course of the alimentary canal, closely adhered to by the dorsal vessel and its surrounding granular mass, to the sixteenth or seventeenth ring. Here the œsophagus terminates, and the digestive tube expands into a voluminous heart-shaped sac, which may be regarded as a species of stomach. Sometimes this organ commences in the fifteenth ring of the body, and at other times it occupies only the sixteenth segment; this appears to be a matter of indifference, depending merely on the growth of the septal muscles. The muscular wall is here well developed, and the continual contractions, which it performs even after the worm is pinned out for observation, show that one of the principal functions it performs is the propelling of food on its course through the alimentary canal. Very numerous blood-vessels are distributed to its surface, whilst the interior is lined by a loose, largely developed mucous membrane.

Gizzard.—The eighteenth and nineteenth rings of the body are occupied by a hard cartilaginous-looking ring, which is attached to the muscular sac just described. Its walls are very thick, and composed of fibrous tissue much resembling the muscular fibre, but they do not appear to be contractile. The blood-vessels, which are very freely distributed to the surface, are disposed in a transverse direction, and are very minute. This organ has been called the gizzard by previous writers, though whether its functions are those of a gizzard does not appear at all certain.

Intestine.—Immediately attached to the remarkable fibrous ring just described is the intestine, which passes throughout the rest of the body with very little change in its structure. It is a loosely and much plicated tube, with very delicate elastic walls, which are so disposed as to occupy a small space whilst possessing a large amount of surface. The wall is composed of three distinct coats, of which the interior one is mucous membrane, with a finely ciliated epithelium; the middle, delicate muscular tissue; and the exterior, a mass of yellow cells, forming an olive-brown-coloured investment for the whole intestine, which is of the most tender nature, and very easily ruptured. The cells, possessing granular contents, are exactly similar to those found in the yellow tissue surrounding the dorsal blood-vessel by the œsophagus, and they appear to perform the same offices. It is almost universally admitted that this yellow tunic of the intestine should be considered as discharging the functions which are distributed to various organs in the higher animals, viz., those of the gall-bladder, the pancreas, and the gastric glands. And it may therefore be conveniently called the hepatic membrane.

The very numerous blood-vessels which ramify in this portion of the digestive tube, and around which the development of the hepatic cells is greatest, is connected, of course, with the elimination of nutriment from the contents, and it is probably in this part of the viscera that the chief amount of absorption takes place.

The muscular coat of the intestine is very delicate, but exercises considerable force in the propulsion of food. The transverse septal muscles, which are intimately connected with the folds of the intestine, also assist in causing those movements of the digestive cavity by which the passage of aliment is effected.

Anus.—After passing through three hundred and fifty rings in a well-grown worm, or less, the alimentary canal terminates in the last segment of the body. The modifications of the septal muscles, which by Morren were described as peculiar muscles of the anus, and the contractility of the muscular membranes of the intestine and of the integument, effect the discharge of the fæces. The ciliated epithelium of the mucous membrane may be best observed near the anal aperture, where it appears to have its greatest development.

Recapitulation.—The digestive organs of the earthworm consist of a mouth, situated in the first anterior segment of the body; of an oval muscular pharynx, extending to the eighth segment; of a narrow contractile œsophagus, expanding in the fifteenth or sixteenth ring into a muscular crop, followed by a hard fibrous ring occupying the seventeenth and eighteenth segments. The rest of the body is traversed by the intestine, a plicated, delicate, elastic tube, invested in a membrane of granular cells, and terminating in the last ring of the body. Connected with the pharynx are three convoluted bodies, considered as salivary organs, and attached to the œsophagus are three pairs of glands in the twelfth and thirteenth segments, the two posterior pairs of which secrete a milky fluid, probably to assist in digestion.

The food of the worm is such vegetable matter as is contained in the rich loamy soils which it selects for habitation.

(*To be continued.*)

DESCRIPTION OF PLATE VII,

Illustrating Mr. Lankester's paper on the Earthworm.

Fig.

1.—Pharynx, with radiating muscular fibres, opened so as to show the loose interior fold or pouch.

2.—Structure of œsophageal glands.

3.—Muscular fibre from pharynx.

4.—The three pairs of œsophageal glands.

5.—Earthworm opened by a dorsal incision, the transverse muscles partially removed.

a. Cephalic ganglia.
b. Muscular pharynx, with attaching fibres.
c. Ciliated tubules (segment-organs).
d. Enlarged lateral blood-vessels.
e. Œsophagus.
f, g, i. Male organs of reproduction.
h. Œsophageal glands.
k. Crop.
l. Fibrous stomach or gizzard.
m. Intestine.

6.—Alimentary canal, removed from the other viscera.

7.—Setæ, natural size $\frac{1}{20}$th of an inch.

8.—Seven segments from the lower part of the body, showing the setæ natural size $\frac{1}{3}$rd of an inch.

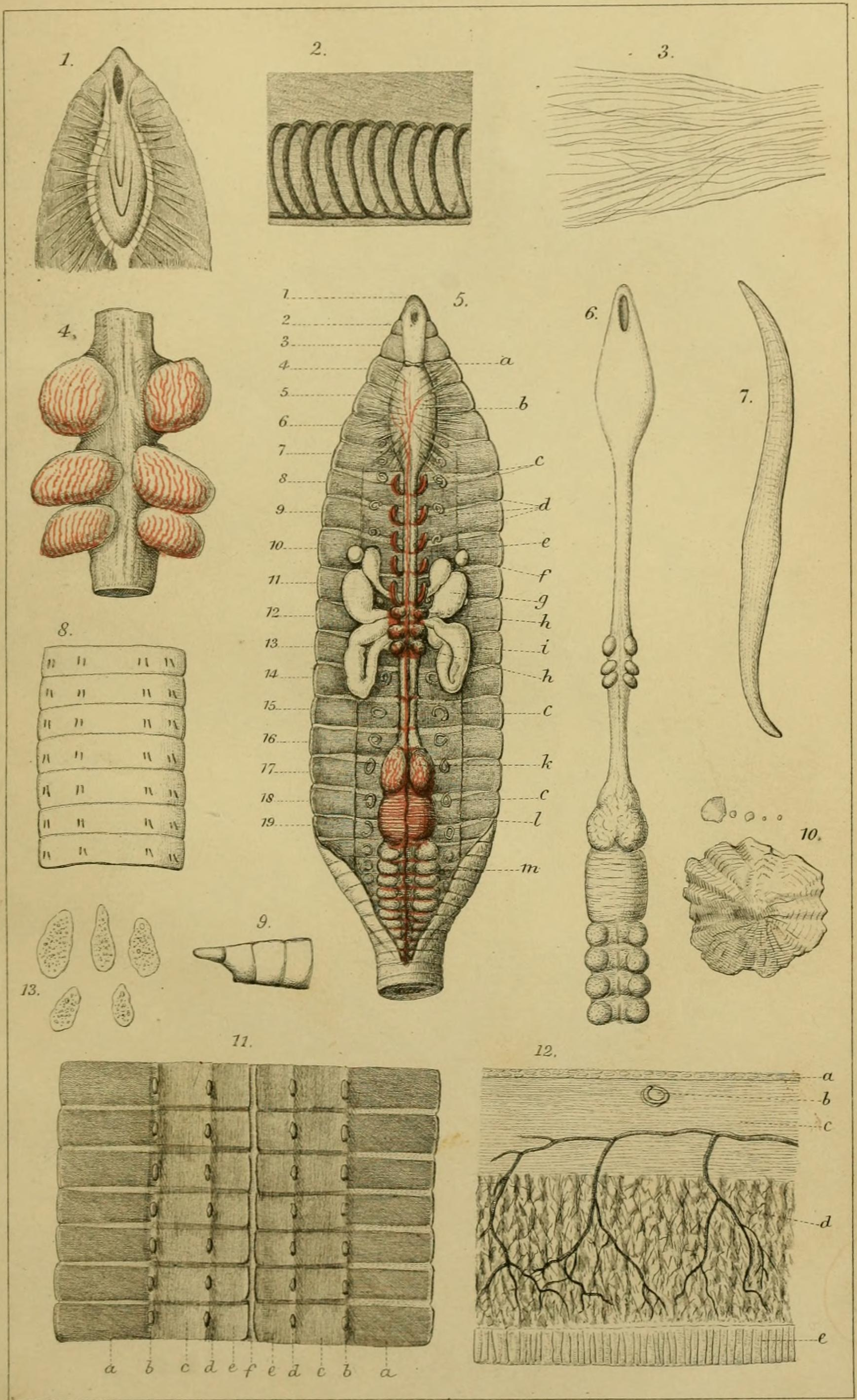
9.—First, second, third, and fourth segments.

10.—Crystalline body from the anterior pair of œsophageal pouches.

11.—Integument of earthworm, all viscera being removed. *a a.* Dorsal muscle. *c c.* Lateral muscles. *e e.* Ventral muscle. *f.* Neural canal. *b b.* Lateral setigerous glands. *d d.* Ventral setigerous glands.

12.—Transverse section of integument. *a.* Internal epithelial layer. *b.* Parasitic nematoid. *c.* Muscular layer. *d.* Pigmentary vascular layer. *e.* Epidermis.

13.—Cells from the hepatic membrane of the intestines.



E. Ray Lankester, del. ad nat.

Tuffen West sc. W. West, imp.

line are the largest on the plate, that at the outer or convex border being the larger. Indications of six other apertures exist, external and towards the convex outline of the shield. The three apertures in the articular end distinguish it from the eye-like slit of *S. digitata*. The shorter form of the anchor and the arrangement of the apertures distinguish this from all the other species of Synapta described.

In conclusion, the author refers to his generalisation in his paper on the pedicellariæ of the Echinodermata, that the anchor plates in the genus Synapta are the analogues of the pentagonal plates of the shell of Echini proper and the anchors are spicula; but the analogues of the spines of Echinidæ and Prasteridæ organs for locomotion as well as defence, hookless to enable them to crawl out of their burrows. (See Plate I.)

He also presents his kindest thanks to Professor Thomson, of Belfast, and M. J. P. Gallienne, of Guernsey, who have so generously placed these specimens at his disposal, and would propose *S. Thomsonii* for the Carrickfergus specimen, if not previously described by any other naturalist.

The ANATOMY *of the* EARTHWORM.

By E. RAY LANKESTER.

PART II.

IN the last number of this Journal the tegumentary, muscular, and digestive organs of the earthworm were briefly described, the form and structure of certain œsophageal appendages being more particularly noticed. The following pages will be devoted to the consideration of the Reproductive system, and of such secreting organs as are not of necessity connected either with it or the digestive system.

Segmental organs.—This name was proposed by Dr. Williams,* of Swansea, for certain organs which had long been known and appeared to exist in Annelides disposed in pairs in each segment of the body. These organs in the earthworm and the Oligocheta generally are in the form of tortuous ciliated canals, attached to the diaphragmatic muscles, communicating by one extremity with the exterior, and terminating at the other in a free, open expansion, on to which the cilia of the interior of the tube are continued. In the Limicolæ, the walls of the

* 'Phil. Trans.,' 1858.

canal are somewhat thick, transparent, and show a cellular structure; the cilia are large and vigorous, and the tube is long and frequently closely bent on itself, so as to give the appearance of a double tube. Gegenbaur* has described a more complicated arrangement in the earthworm, which I have not been able fully to confirm, the great difficulty of placing one of these tubes under examination in the microscope, without tearing or twisting it into every variety of form, being one of the chief causes, no doubt, of this discrepancy.

According to Gegenbaur, the segmental organ or ciliated canal of the earthworm is folded and refolded on itself in such a manner as to produce four canals of different dimensions running parallel to one another, the diameter of that which belongs to the end of the canal nearest to its external aperture being much greater than that of the others. The whole of the canal thus bent and complicated is held together by a membrane, on the surface of which ramify very numerous blood-vessels, derived from the abundant capillaries of the diaphragm-muscle. In fig. 4 is drawn a ciliated canal from one of the terminal posterior segments of a large earthworm. The canal appeared to be folded on itself once, and to increase much in size towards its external termination, the walls increasing in thickness rather than the calibre of the canal becoming enlarged, whilst towards its interior termination the tube was very much smaller, and its walls remarkably thin, the interior being freely ciliated. The expanded termination, for which no name is at present in use in this country, possesses a structure of conspicuous hexagonal cells, with distinct nuclei, the surface being densely fringed with cilia, M. D'Udekem has proposed the name "entonnoir vibratile" for the homologue of this expanded portion of the tube, and perhaps the name "ciliated inductor" may be found a convenient though free translation of this term. The network of vessels with which the ciliated canals are connected is described by Gegenbaur, as also by Dr. Williams, who has figured the anastomosing capillaries and their sacculi. If a small portion of one of the ciliated tubes be examined with a power of 200 diameters, the various arrangements of its parts shown in Pl. I, fig. 2, will be seen. The greater part of the wall appears to be composed of the thick, granular tissue (*a*), which is bounded externally by a delicate structureless membrane, and internally by an equally structureless layer produced at intervals into coarse cilia (*b*). On the surface of the tube, the blood-vessel (*c*) is disposed, giving

* 'Köll. and Siebold's Zeitschrift,' 1852.

off few branches and enlarging at intervals into very remarkable sacculi, closely connected with the tissue of the ciliated canal. The fluid contained in the blood-vessels is of a pale red colour, and in the sacculi appears to contain granular matter. The cilia of the canal retain their vibratile movement for a considerable period of time after their removal from the worm, and a careful examination shows that they are urging a liquid containing minute cells, granules, &c., towards the external aperture, which, it should be stated, is so minute as to escape detection on the surface of the worm's body.

It can hardly be doubted that the function of these tubes is excretory, and not respiratory, as sometimes supposed; and, indeed, this appears now to be conceded by many distinguished anatomists. The glandular walls connected with the sacculi of capillary vessels present all the essential parts of a kidney, and it is as such that they must be considered. The "ciliated inductor" undoubtedly removes a certain quantity of the perivisceral fluid from the body, but by so doing it assuredly does not assist the oxygenation of the red fluid, which may be called the blood. For the views which have been entertained on this subject, I must refer the reader elsewhere, to such papers as that of Gegenbaur, of Williams, and the researches of D'Udekem and Claparéde. Drawing a conclusion merely from structural grounds, the ciliated canals of the Oligocheta, and hence of all Annelida, can only be considered as primarily excretory organs or kidneys; the facts which will be hereafter detailed with regard to the differentiation of these canals, adding also a certain amount of weight to the structural argument. The ciliated canals, therefore, of the earthworm, may be considered as *inversions of the integument*, similar in function and essential points of structure to the kidneys of higher animals. In the Lumbricus, a pair of canals of similar structure exists in every segment of the body but the first. In the Naiidæ, the beautiful and elaborate researches of D'Udekem and Claparéde have shown that in the generative segments of the body they are modified so as to form "vasa deferentia" and "Fallopian tubes." Whether this arrangement obtains in any manner in Lumbricus remains to be considered.

Mucous pores.—In the cuticle of the earthworm a system of very minute canals exists, which was briefly referred to in treating of the tegumentary system, and which might either be described in connection with the respiratory mechanism, or here, if we regard these ducts as excretory pores. Fig. 8, Pl. II, shows a vertical section of the integument of *Lumbricus*, taken from the posterior part of the body, where the colouring matter is deficient. The thin structureless epidermis (*a*) is seen to be underlaid by a somewhat fibrous, but more or less homogeneous tissue, in which are excavated a series of canals of great minuteness, but sufficient to form a most extensive communication between the perivisceral fluid and the exterior. These canals branch much in the same way as the interstitial canals of dentinal tissue, and indeed, present a very marked resemblance in arrangement and form to the tubules of the teeth. Whether the communication of their contents with the surface is direct by orifices in the epidermis, or whether it takes place by a process of osmosis, appears to be uncertain. It is undoubtedly through these minute canals which exist throughout the integument of the earthworm, that water passes to the perivisceral cavity, and a denser fluid passes out, though it appears that the setigerous glands briefly noticed in my last paper, also secrete a fluid of considerable density, which is stated by Dr. Williams to have a remarkable power of absorbing oxygen from the atmosphere. This is no doubt a valuable and convenient property in the mucous secretion, but I have not been able to test it in any way, and cannot, therefore, confirm Dr. Williams's statement. The consideration of the respiratory, vascular, and nervous systems of the earthworm must be deferred for the present, and the much-disputed organs of reproduction noticed.

Organs of Reproduction.—It is impossible here to review the various errors most pardonably made by some of the earlier writers on this subject; Home, Morren, Dugés, and others, were misled by the presence of parasites, and by the absence of any conspicuous true ovary, into all kinds of mistakes. The papers of M. D'Udekem and Dr. Hering, whose truth and accuracy is denied by Dr. Williams, whilst seeking to support an untenable theory, have, however, made the field clear, and the discovery of the true ovaries due to M. D'Udekem, has rendered the appreciation of the rest of the "genitalia" a comparatively easy task.

Testes and Seminal Vesicle.—The testes have been described with considerable accuracy by Dr. Ewald Hering;* but, by some means, that author has been led to regard them as seminal vesicles; whilst he calls certain very minute bodies, which they contain, the true testes. D'Udekem, on the contrary, regarded the seminal vesicles of Hering, as I also am disposed to do, as the male glandular organs. They consist of two pairs (Pl. I, figs. 1, 3), the anterior of which is bilobed, placed in the eleventh and twelfth seg-

* 'Köll. and Siebold's Zeitschrift,' 1857.

ments. In structure each is a membranous bag of very considerable vascularity, composed of a delicate fibrous tissue, and an internal secreting surface, the whole being distended with its contents, which are zoosperms in all stages of development. The fibrous tunic of each pair of testes, which appears to be slightly elastic, is continued across the median line, forming in each case a sac, which *may* be considered as a "seminal vesicle," the lobulated glandular bodies, in each case, being somewhat apart; the fibrous sheath connecting the two, and forming the delicate sac or bag, envelopes the expanded termination of two efferent tubes. This bag is extremely delicate, and easily ruptured; though no very large accumulation of spermatozoa ever takes place in it, yet, in position, it is a seminal vesicle; the connection between it and the lobulated testicle on either side is considerably constricted. The testes, then, in the earthworm, consist of a double pair in the eleventh segment, connected by their fibrous sheath with one another, and with the expanded termination of the vasa deferentia, and of a single larger pair in the twelfth segment similarly connected.

The contents of the testes are very remarkable, and were the cause of numerous errors as to the true nature of those bodies. Cysts of Gregarinidæ (*Monocystis Lumbrici*), and free individuals of the same parasite, as also of the *Anguillula Lumbrici*, abound. The development of the zoosperms is very apparent; they can be traced from the form of a minute cell, up to the aggregations of ciliated vesicles, which eventually disperse (figs. 7—11, Pl. I). With regard to the testes or appendages of the seminal vesicles, as Dr. Hering considers them, it appears to me that that author has described a more general communication between them and the sac enveloping the termination of the vas deferens than exists, since a constriction shuts off what I believe to be the testicle from the seminal vesicle or sac. M. D'Udekem appears unfortunately to have overlooked the presence of the seminal vesicle altogether.

Vasa deferentia.—These were discovered by M. D'Udekem.* They consist of a pair of ciliated tubes communicating with the exterior in the fifteenth ring, and bifurcating in the twelfth, so that each of them has a pair of anterior terminations. These are expansions of the tube, excessively fragile and delicate, as also are the tubes, thickly ciliated, very vascular, and enveloped in the sacs or seminal vesicles, formed by the fibrous sheath of the testicles, a *pair* in each sac (figs. 1, 3, Pl. I; fig. 1, Pl. II). The expanded

* 'Mem. de l'Acad. Roy. de Bruxelles,' 1856.

termination and the ciliated tube bring forcibly to mind the ciliated tubes devoted to excretory purposes; but as these also exist in the same segments as the vasa deferentia, we are apparently prevented from considering the latter as modifications of the former, though we have no such difficulty in the case of the Limicolæ. The structure of the expanded "ciliated inductors" of the vasa deferentia is merely a pavement of polygonal cells, excessively delicate, and most easily ruptured and destroyed. The continuation of this epithelial membrane into the duct, and the continuity of the fibrous sheath of the seminal vesicle, and the structureless membrane forming the external envelope of the duct, are seen in fig. 12, Pl. II. Their presence, as that of the vasa deferentia themselves, appears to have escaped all observers previous to M. D'Udekem, and also one since, Dr. Williams.

The Ovaries.—The discovery of the ovaries of the earthworm is also due to M. D'Udekem; they have since been described by Hering, and may be found, by a careful examination of the thirteenth segment of the worm, situated on the inner ventral surface, close to the nervous chord (fig. 1, Pl. I, fig. 3, Pl. II). This, however, becomes almost an impossibility without the use of spirits of wine, by which these otherwise transparent and very minute bodies are coagulated, and rendered visible. There is no difficulty, when their nature is considered, in understanding how the presence of these organs has been overlooked, and others mistaken for them. The ovaries of Lumbricus are never more than $\frac{1}{16}$th of an inch in length, and consist of a very fine structureless membrane in the form of a conical tapering sac, provided with minute blood-vessels and enclosing ova in all stages of development, those situated in the narrow part being the most advanced. By one extremity the ovary is attached to the diaphragm between the twelfth and thirteenth compartments, the other is free and tapering, being sometimes terminated by minute papillæ (fig. 3, Pl. II), the function of which is indeterminable. The relative size of the ovaries in *Lumbricus* is a remarkable fact, when we consider the size which these bodies attain in *Tubifex, Euaxes,* and other *Limicolæ.* Dr. Williams denies the existence of these bodies, and asserts that both Hering and D'Udekem have described what they did not see. It is hardly necessary for me again most emphatically to confirm those authors' statements, and to deny the truth of Dr. Williams's allegations.

The Oviducts.—These were discovered by Dr. Hering, and form a most valuable addition to our knowledge of the anatomy of the earthworm, inasmuch as they throw great light on the homologies of its reproductive organs. They are attached, one on either side of the nervous chord, to the walls of the body, in the fourteenth segment, having each an orifice, in close proximity to the pores of the setæ of the inner series. At their insertion they are fine, delicate tubes, but gradually expand, and terminate in very widely opened ciliated receptacles, attached to the diaphragm-muscle, separating the thirteenth from the fourteenth segment, in which there is an orifice on either side formed by these ducts (fig. 1, Pl. I, fig. 2, Pl. II). They frequently contain ova in an advancing state of development. In the structure of these smaller ducts, about $\frac{1}{8}$th of an inch in length, we are again reminded of the ciliated segment organs, a pair of which, however, with all their normal attributes, exist in the 13th and 14th rings of the body, as in all others. The ova from the ovary drop into the oviduct without any direct communication between the two, the ciliary movements being sufficient to impel the ova, as also the ciliary movements of the ciliated inductors of the spermatic ducts are sufficient to urge the spermatozoa from the sac formed by the extension of the fibrous sheath of the testicle.

Spermatic Reservoirs or Spermathecæ.—Situated on either side in the line of the exterior setigerous glands, in the 10th and also the 11th ring, is a pair of small globular sacs, having a somewhat dense though very vascular wall, and a pedunculated base, the peduncle being a hollow canal communicating with the exterior by very obvious apertures, between the 9th and 10th, and 10th and 11th rings. The contents of the sacs are fully developed spermatozoa, and their function is to retain the seminal fluid received in copulation, and to emit it again, upon the ova when those bodies are deposited in the egg-capsule (Pl. I, fig. 10, Pl. II, fig. 1). In colour they are much brighter and whiter than the testes, which are discoloured by the numerous impurities they contain. Dr. Williams ignores also the existence of these organs, which have been known for many years, and were fully described by both D'Udekem and Hering.*

External Organs.—Having thus reviewed the essential organs of reproduction, the ovary and testis, and their ducts,

* The accuracy of D'Udekem's and Hering's observations is confirmed by Mr. Busk, who, M. Claparéde states, informed him, as he also has told me, that he had independently ascertained the same facts as they had. A very interesting and valuable criticism of the papers of MM. D'Udekem, Hering, Carter, and Williams, is to be found in one of the chapters of M. Claparéde's 'Recherches sur les Annelides, Turbellaries, &c.' Geneva, 1861.

and the spermatic reservoirs, the apertures of the ducts may be described. An excellent drawing of these is given by Hering, from a specimen of the epidermis of the worm, which he obtained by maceration (Pl. II, fig. 6). The observations may readily be repeated, if spirit be used first to harden the cuticle. Two series of double apertures are then seen on either of the median line belonging to the setæ. Between the 9th and 10th ring, and 10th and 11th, the apertures of the spermatic reservoirs are observed. In the 14th segment between the two series, on either side, is the aperture of the oviduct, and in the fifteenth segment, in connection with a large, well-marked development of the integument on either side, is the aperture of the vas deferens. No apertures to the ciliated canals can be detected, which, however, exist nearer the median line than any of the pores drawn. It will be observed with regard to the apertures of the seminal reservoirs, vasa deferentia, and oviducts, that they all exist in a line between the exterior and interior, or lateral and ventral series of setæ, whilst, as before stated, the apertures of the ciliated canals are between the two ventral series of setæ.

In addition to the pores just mentioned, an exterior organ of generation is found in the cingulum, a glandular mass surrounding the segments from the 29th to the 36th inclusive. Its structure has been before alluded to in connection with the tegumentary system; a portion is figured, highly magnified (Pl. II, fig. 4), showing the papillæ; and the whole organ is shown in Pl. II, fig. 7.

Capsulo-genous Glands.—Besides the regular glands developed on the parietes of the body, the earthworm exhibits numerous glands, destined in all probability to form the egg-capsule, in which both zoosperms from the spermatic reservoirs and ova are deposited. These glands were first detected by M. D'Udekem, who figures them in his beautiful and elaborate paper. They are merely an excessive development of the setigerous glands of the ventral or inner series, occurring in the 9th, 10th, 11th, 12th, and 13th rings of the body. The white colour and thick fleshy look which is sometimes observed about the exterior of these segments is due to the development of the capsulo-genous glands. Whether the capsulo-genous glands have everything or anything to do with the formation of the egg-capsule is very difficult to determine; but the supposition of M. D'Udekem is so plausible, and comes from so good an authority, that it cannot but be received until absolutely disproved. The secretion of the capsulo-genous glands is a thick glairy liquid, containing minute granules. It has been suggested that the crystalline body contained in the anterior œsophageal pouch, described in the last number of this Journal, supplies a certain amount of lime to assist in the formation of the egg-capsule; but this view has not the least foundation in facts—as there does not appear to be any communication between the œsophageal pouches and the exterior, excepting possibly through the intestinal canal. The capsuli-genous glands (*e*), the ciliated tubes (*a*), the efferent male ducts (*c*), the oviduct (*d*), and the spermatic reservoirs (*b*), are seen in Pl. II, fig. 1.

Coition and Parturition.—Almost as little is known, as far as regards the earthworm, of the former of these processes as of the latter. An exchange of zoosperms is effected by the mutual juxtaposition of the pores of the spermatic reservoirs and those of the efferent ducts. How the passage of the seminal fluid takes place is not exactly understood. Portions of the cuticle everted in the form of a temporary copulatory organ have been found attached to the apertures of the vasa deferentia in large worms; but these are by no means persistent. Again, with regard to the manner of the formation of the egg-capsule, we are in total ignorance, though, judging from analogy, we may conceive it to be formed on the exterior surface of the worm, its body serving as a mould. Whilst gradually drawing itself through the so-formed sac, ova and zoosperms are deposited, and the capsule is in some way closed. The subject, however, is one which requires much investigation, attended as it is with so many and almost insurmountable difficulties.

Homologies of the Reproductive Organs.—I wish now briefly to consider the homological relations of the earthworm, representing the *Oligochæta Terricola*, and the *Oligochæta Limicola*, whose structure and anatomy have been so ably and charmingly investigated by Claparéde,* and D'Udekem. In the genera *Tubifex*, *Euaxes*, *Stylodrilus*, *Pachydrilus*, &c., these authors have found that the ciliated canals, of which (as in the earthworm) a pair exists in each segment, are deficient in certain rings of the body apparently, and these segments are those which contain the spermatic reservoirs, the vasa deferentia, and the oviducts, and generally the first five or six anterior segments. The following table, taken from M. Claparéde's 'Récherches Anatomiques sur les Oligochètes,' p. 62, illustrates this: *s* means ordinary segment organ, *r* sperm reservoirs, *o* oviducts, and *c* efferent canals.

* 'Récherches sur les Oligochetes,' 1862. Geneva.
' „ „ Annelides, &c.,' 1861. Geneva.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	
Tubifex Bonneti, *Clap.*	...	...	...	...	...	..	S	S	...	R	C	...	S	&c.
Limnodrilus Udekemianus, *Clap.*	...	...	...	...	..	...	S	S	...	R	C	...	S	&c.
„ Hoffmeisteri, *Clap.*	...	...	...	...	...	...	S	S	...	R	C	...	S	&c.
Lumbriculus variegatus, *Grube*...	...	...	...	...	...	...	S	...	R	C	C	O	S	&c.
Stylodrilus Heringianus, *Clap.* ...	...	...	...	...	...	...	S	...	R	C	C	O	S	&c.
Trichodrilus Allobrogum, *Clap*...	...	...	...	...	...	...	S	S	(O?)	C	cR	R	S	
Enchytraus vermiculus, *Hoffm.*	...	...	...	...	R	...	S	S	S	S	S	C(o)	S	&c.

Gegenbaur, describing the ciliated canals of Lumbricus and Sœnuris, stated that M. D'Udekem, in considering that the segment organs were wanting in the generative segments of Tubifex, was wrong, and that the efferent canals which he described were only enlarged segment organs. Dr. Williams, of Swansea, soon after this, made known his views, which are embodied in a paper in the 'Philosophical Transactions' for 1858. He certainly has the credit of having appreciated the fact *that the segment organs in the Limicolæ are in certain segments developed into efferent canals of the reproductive system;* but in attempting to go beyond this that author has been led into many errors and inaccuracies, and his paper has been well-styled by Claparéde "un échafaudage audacieux et peu solid." He attempted to show that not only were the efferent canals modifications of the segment organs, but that the essential glands, the ovary and testis, were developed from them—a proposition which jars against all homologies of the reproductive organs, from the protozoa upwards. To further his view, Dr. Williams published a most remarkable account of the genitalia of the earthworm, and depreciated the accurate observations of Hering and D'Udekem; alternating testes and ovaries of large size were discovered with conspicuous apertures externally, whilst the real ovaries, the oviducts, spermatic reservoirs, and efferent canals, were *entirely* ignored, and their existence denied. I should not have thus emphatically exposed Dr. Williams's inaccuracies had not his statements and views been largely quoted and approved in a book of extensive circulation, viz., 'Rymer Jones' Animal Kingdom,' a work which is much read and consulted by students of comparative anatomy.

Seeing, then, that the segment organs are deficient in the segments containing the oviduct, sperm reservoirs, and efferent canals, amongst the Limicolæ, and considering that in structure they are all very similar in this group, it is concluded that the oviducts, sperm-reservoirs, and efferent canals, are the modifications of the segment organs; the essential organs, of course, having nothing to do with the modification. This is the view advanced by M. Claparéde, and universally received, with regard to the *Limiculous oligochetes*. What may be the relations between the segment organs of the Terricolæ and their efferent ducts, is the question which now occurs. M. Claparéde, at the conclusion of his 'Recherches,' briefly refers to this question, merely to mention its difficulty, and to promise a future attempt to answer it.

In every segment of the earthworm but the first we have a normal segment organ opening near the median ventral line, and in the 10th, 11th, 14th, and 15th rings we have the apertures placed more laterally (always beyond the first series of setæ) of the sperm reservoirs, the efferent canals, and the oviducts,—organs presenting marked and decisive points of similarity in structure to the normal segment organs, and also to the corresponding modified segment organs in the Limicolæ. Are not, then, the efferent ducts and sperm reservoirs of the earthworm modified segment organs? It is hardly possible to deny the probability of this, in the face of the similarities of structure and general homologies existing between the Limicolæ and Terricolæ, which would be totally upset were we to conceive that the reproductive ducts of each are constructed upon entirely different plans. Assuming, then, that the efferent ducts of Lumbricus and its spermatic reservoirs are modified segment organs, and the actual homologues of the segment organs are ducts of the Limicolæ, we can only account for the presence of two segment organs in a single segment—a normal and a modified one—by conceiving the typical number of segment organs in the oligochetæ generally to be four in each segment, a pair on either side, one or both of which may be suppressed or modified (see Pl. II, fig. 5); as also we have four setigerous glands, of which one pair may be suppressed. In the Limicolæ *both* pairs of segment organs are suppressed in the first six segments, and a *single* pair throughout the rest of the body. In the Terricolæ, on the contrary, *both* pairs are absent *only* in the first anterior segment, whilst *one* pair is suppressed throughout all the other segments excepting those very vascular and well-nourished segments containing the "genitalia," with which the second pair of segment organs here unsuppressed, is connected. This view of the case is further borne out by the presence of a double pair of what may be considered as modified segment organs, in each segment of the leech and perhaps some other Annelids. Seeing that the ovary or the testis, from the protozoon, with its nucleus and nucleolus, up to man himself, are homologous structures in each group o the animal kingdom, being specialised developments, and not modifications of existing structures, the homologies of the reproductive organs of the earthworm may be considered as satisfactorily ascertained, the testes and ovaries being the homologues of testis and ovary in all other animals, and the efferent canals and sperm reservoirs the homologues of the system of ciliated canals or segment organs common to most Annelida, and remarkable in the group of oligochetes as being developed into auxiliary organs of reproduction.*

In Pl. II, fig. 3, an ideal typical segment of an oligochæte is drawn. Suppress the pair of canals attached nearest the ventral surface, and the type of the Limicolous group is obtained. Conceive the exterior pair converted each into a blind sac, and the type of the segment containing the sperm reservoirs in Lumbricus is seen. Imagine three such tubes as the exterior, blended; and the bifurcated ciliated vas deferens of Lumbricus results, whilst both are suppressed altogether, to form the anterior segments of the Limicolæ, or left almost without modification to form the fourteenth segment of the earthworm, with its oviducts and segment organs.

Recapitulation.—The generative organs of the earthworm consist of two pairs of testes, situated in the eleventh and twelfth segments, connected with two seminal vesicles; a pair of bifurcated ciliated vasa deferentia, connected with each testis by means of a ciliated receptacle enveloped in the fibrous sheath of the testis, and opening in the fifteenth segment; a pair of minute transparent ovaries situated in the thirteenth segment, opposite the orifices of two oviducts placed in the fourteenth; a pair of spermatic reservoirs in the tenth and eleventh segments: five pairs of capsulo-genous glands, and the cingulum. The sperm reservoirs, the oviducts, and vasa deferentia, are homologous with the same organs of the Limicolæ (Naiidæ), and are the modifications of a series of segment organs suppressed in other annuli. The normal segment organs exist in all segments but the first two, and form an inner series which is suppressed in the Limicolæ, whose segment organs are the representatives of the exterior series suppressed in all but six segments of the Terricolæ. All the segment organs, however, should be considered as homologous.

(*To be continued.*)

* In the Limicolæ it appears to be the interior series of segment organs, or those which form the normal ciliated tubes in the Terricolæ, which are suppressed.

ORIGINAL COMMUNICATIONS.

The Anatomy *of the* Earthworm.
By E. Ray Lankester.

Part III.

In the present number of the Journal the hæmal and nervous systems of the earthworm remain to be described. No special respiratory organs can be indicated. The processes, therefore, of the oxygenation of the blood and tissues will be considered in connection with the hæmal system.

Hæmal System.—In the earthworm, as in other Annelidæ, there are two fluids, each of which has claims to rank as "blood." One of these fluids is red and free from corpuscles, and contained in a very extensive series of vessels; the other is colourless and transparent, abounding in nucleated cells and corpuscles, and occupies the general or perivisceral cavity—the space intervening between the digestive tube and the muscular parietes of the body or integument. It is obvious that the latter corresponds to the fluid contained in and circulated by the heart of the Insecta and Crustacea, as has been shown by the researches of De Quatrefages. It is no less evident, as Professor Huxley has suggested, that the red vascular fluid is homologous with the water-vascular system of the Turbellaria, Trematode worms, and other Scolecida, which again appears in the Echinodermata as the ambulacral system, communicating with the exterior in the Echinidea and Asteridea, but definitely closed in the Ophiuridea, Crinoidea, and Holothuridea. The two fluids of the Annelid are represented still lower down in the scale of creation by one, as that contained in the somatic cavity and canals of the Clenophorous Actinozoa, which gives evidence of its homologies with the ambulacral system of Echinoderms by its relation to the tentacular processes, and with a nutrient system, such as that of the Asteropods by its intimate connection with the contents of the stomach. Thus, then, we gain a very definite view of the probable homologies of the two fluids in the earthworm, but it is not yet apparent which of the two should be called "blood," and recognised as the homologue of that fluid in the vertebrata—whether that which represents the sanguineous system of Insects, or the red fluid, homologous with the water-vascular system of Scolecida.

The following view, which tends to explain the matter and place it in a clear light, is put forward by my friend Professor Busk. In vertebrata the blood can be separated into two parts—the red corpuscles and the clear white plasma with the white corpuscles. The function of the red corpuscles, it is generally admitted, is to carry oxygen—in fact, is respiratory. The function of the plasma, on the other hand, with its white corpuscles, is simply nutrient. Assuming that this is a correct view of the case, since it is supported by many and conclusive facts, and, indeed, is very generally conceded, let us turn to the Annelida. We find a red fluid, undoubtedly devoted to respiratory purposes in many genera, and a colourless plasma with white corpuscles, bathing all the organs of the body. The conclusion is, obviously enough, that the red vascular fluid represents simply the corpuscles, whilst the colourless corpusculated fluid is homologous with the white plasma of vertebrate animals. It would be unsafe to draw any conclusions as to the respective functions of the fluids from this comparison. The functions of the two fluids in the Annelida have yet to be much studied, all that zoologists at present appear to be agreed upon being that the red vascular fluid is the chief medium through which respiration is effected; how far this function is shared by the corpusculated fluid, or how far nutrition is also a part function of the red fluid, are questions to which no decisive reply has yet been offered, though the considerations above adduced would tend (perhaps erroneously) to the conclusion that respiration belongs to the one and nutrition to the other exclusively.* In speaking, then, of these two fluids, I prefer

* M. Milne Edwards, in the remarkably exhaustive and valuable work, which he is now completing, commenced in 1857, and entitled 'Leçons sur la Physiologie,' adopts, to a great extent, the view advanced first by De Quatrefages, and used aftewards, more or less, by Dr. Williams, that in the Annelida, as a rule, the perivisceral fluid becomes oxygenated and transfers its oxygen to the vascular fluid, which, however, in other cases may become directly oxygenated by the direct contact of its containing vessels with external fluids. He also considers the vascular fluid as having a nutrient function (vol. ii, p. 95; vol. iii, p. 239).

Professor Huxley, on the other hand, is inclined to regard the system of vessels in which this usually red fluid is contained as an extreme modification of the water-vascular system of Trematoda and Cestoidea, which is by M. Milne Edwards considered as an excretory apparatus, by others as adopting such names as "red" and "colourless," or "vascular" and "perivisceral," fluids, to using the terms "pseudo-hæmal" or "chylaqueous system."

Colourless or Perigastric Fluid.—On opening an earthworm by a longitudinal incision the various chambers of the body formed by the interseptal muscles will be found to contain a certain amount of a free fluid, having a more or less milky appearance, but generally very nearly clear. This is the "colourless" or "perigastric fluid;" it varies very considerably in amount in different specimens, but is always most abundant towards the posterior end of the body. Though the interseptal muscles or diaphragms divide the perivisceral cavity of the earthworm into various chambers, it must not be supposed that each of these is hermetically sealed. In addition to the general osmosis by which the fluids of two contingent chambers can be exchanged, there are openings in the diaphragms, imperfect attachments to the intestinal wall and ganglionic cord, by means of which a communication is established freely from one end of the body to the other. Thus it is that in the last segments of the body we find by far the largest amount of perigastric fluid, containing also a variety of conspicuous foreign bodies, in the form of small white cysts, detached setæ, &c; the fluid itself also has a decidedly milky appearance. It was this congregation of foreign bodies at the posterior portion of the worm which led Sir Everard Home to regard the earthworm as self-impregnating and viviparous; it is, no doubt, owing to the continual pressure in an antero-posterior direction, to which the movements of the worm subject its body, that this accumulation takes place; but it of course depends also on the fact that there is a free communication between the various cavities, and that the fluid has no definite course of circulation to follow. In most cases, when a worm is opened, the anterior segments of the body will be simply moist, whilst the fluid increases in quantity as the posterior annuli are approached.

Communications with the exterior.—The perigastric fluid has two direct and apparently special series of communications with the exterior, by means of which it can escape from the worm's body; and another equally special series of communications, by which it appears that fluids can pass *from* the exterior, and become part of its substance. The most important of the two series of exits is that furnished by the "segmental organs," described in my last paper, which, by

respiratory, and by others as nutrient; the truth being, probably, that its function combines, more or less, the offices of all three, or of the first two at least.

means of their ciliated inductors and interiors, establish a continuous current, setting from their internal to their external apertures, which, of course, carries off daily a certain amount of the perivisceral fluid, since the trumpet-like inductors of the ciliated canals float freely in this liquid. Placed along the dorsal aspect of the worm's body, my friend Professor Busk has pointed out to me a series of openings or pores of considerable size, which form a second means of exit for the perivisceral fluid. They are situated nearly in the median line, and number three or four in each segment. All do not seem directly to perforate the integument and subcutaneous muscular layers; but they vary in this respect, as also in their relative position, which is not subject to any regularity. One of these orifices, situated in the median dorsal line of the segment, appears always to be larger than the others, and penetrates directly to the perivisceral cavity (fig. 9). That these openings form a very ready and frequent means of escape to the "colourless fluid" may be ascertained by handling a large earthworm, when some considerable quantity of colourless fluid is nearly invariably found to escape from its dorsal surface.*

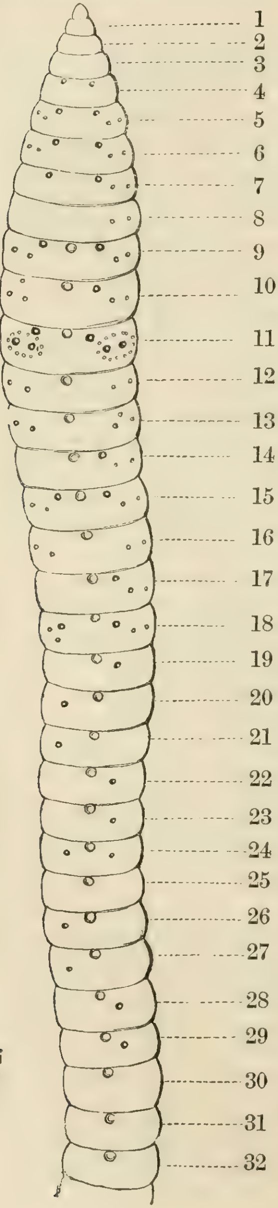


Fig. I.

* The following are Prof. Busk's notes on the subject, which, with Fig. 1, he has kindly given me to make use of.

Lumbricus terrestris.

Large specimen, with clitellus, &c., apparently well developed. Killed with chloroform, and the cuticle stripped off.

Surface presented pores as shown in figure No. 1.

The range of median dorsal pores commenced in the interspace between the 8th

The means whereby the aqueous constituent of the perivisceral fluid appears to me to be chiefly replenished is to be found in the remarkable minute tegumentary canals, described and figured in my last paper, and resembling somewhat in their appearance "dentinal tubules." These minute canals

and 9th rings, and was thence continued, apparently without interruption, to the caudal extremity.

The fluid expressed from these pores was of a dirty grayish colour, thin and opaque. Examined under the microscope it contained numerous spherical particles and pyriform granular bodies, besides irregular organic particles. The only other openings observable on the dorsal aspect, as far as to the 32nd ring, where the clitellus commenced, were minute rounded pores of smaller size than the median dorsal, and situated, not in the intervals between the rings, but on the sides of the rings themselves, at a greater or less distance from the dorsal median line; they occurred in the following rings, viz. (see Fig. 1, p. 102).

There being none on the 1st, 2nd, 3rd, 8th, 12th, 16th, 25th, 30th.

From these puncta could be expressed a clear fluid, containing only minute nucleolar particles, and it was probably derived from the subcutaneous *glandular* tissue, constituting the lubricating fluid of the surface.

In a second specimen, prepared in the same way, and at the same time, and apparently in the same condition as to development, the arrangement of the pores and puncta was as follows.

No. 2.—Median dorsal pores commenced between 8th and 9th rings, and they afforded a fluid precisely like that of the former case. The puncta were situated in the following rings:

There being none perceptible on the 1st, 2nd, 3rd, 4th, 16th, and they were not looked for beyond the 22nd. The fluid expressed from them was the same as in the former case.

In other cases, again, the median dorsal pore did not exist anterior to the 11th segment, and the lateral puncta appeared very variable.

Besides these pores and puncta, in a worm which had been immersed in water, a general sweating or oozing from very minute pores, was observable all over the surface, especially on the dorsal aspect.

No other kinds of permanent openings exist in any part of the body except the mouth and anus. The sexual openings in the 16th segment appear to be formed only at the time they are wanted, and of these, as well as of the smaller lobes on either side, no vestige whatever is perceptibie, even in very large worms, when not sexually mature. The same may be said of the clitellus, of which no indication whatever is often perceptible; one, also, of the two adherent discs (?) in the 27th segment, which appear to be formed solely for the purpose of sexual congress. They are developed on the situation, and, in fact, by a thickening of the integument immediately around the inner pair of setæ in that segment. This swelling is very porous, and a mucous fluid can be freely expressed from the pores. Another change in the external aspect of the worm, connected with the period of sexual activity, consists in the thickening and opacity of the subcutaneous tissue, in the ventral halves of the segments, extending from 8th or 9th to 14th or 15th (?), and which is more observable in the inside. And in the 11th segment, at this time, an elevation and porosity of the skin is set up around the inner pair of setæ, which, in some cases, are themselves altered in shape from the rest, and when pulled out they draw out with them a long stringy appendage, not apparently of cætera descent.

undoubtedly have the power of absorbing liquid by capillary attraction from the external surface, as may be demonstrated by immersing the caudal extremity of a worm in a solution of carmine and ammonia, when the capillary tubes will be found containing carmine if viewed under the miscroscope. *Composition.*—The composition of the perivisceral fluid which is thus situated in the worm's body now remains to be considered. Chemically, it appears to resemble dilute serum, and to have much the same constitution as the blood of higher animals, being, however, poorer, or containing a larger amount of water. Portions of it coagulate, and it becomes turbid when submitted to the action of strong spirits of wine; it has, moreover, a slightly saline taste, and an alkaline reaction with turmeric paper. When examined with the microscope it is seen to consist of a plasma and corpuscles, the latter varying in number, size and form. The general form of the corpuscles is a flattened transparent cell, containing granules and a nucleus, and about the $\frac{1}{1000}$th of an inch in diameter; sometimes they exhibit amœboid movements, but generally are inert. A great variety of particles of other forms are to be found in this perivisceral fluid, particularly at the posterior portion of the body. Among these are young forms of the *Monocystis Lumbrici*, one of the Gregarinidæ,* encysted individuals of this species, its pseudo-navicula, parasitic nematodes, and their eggs (fig 6). The colourless fluid presents, therefore, a marked contrast to the vascular fluid with regard to its intimate structure; its function may be briefly considered when the disposition and nature of the vascular fluid has been described.

Vascular, Non-corpusculated, or Coloured Fluid.—The vascular fluid of the earthworm is contained in a very extensive series of vessels, which have three principal trunks and various ramifications. The vascular system in Annelida is divided, by M. Milne Edwards,† into two parts—the cutaneous and the visceral. In the ideal representative, Annelida, the *cutaneous system* is considered as being composed of two longitudinal lateral trunks, which communicate with one another by their cutaneous and terminal capillaries, and also (as in the higher forms of Annelida) by direct transverse vessels, called by M. Milne Edwards the "inferior commissural vessels." This forms the cutaneous system; the two lateral trunks may be united into one and form a single *ventral* vessel, when, of course, there are no inferior commis-

* See the author's paper in this Journal, April, 1863.
† Loc. cit., vol. iii, p. 252.

sural vessels. In order to understand well the *visceral system* it is necessary to consider it as being composed again of two dorsal and two sub-intestinal trunks, each pair having a tendency, in the various modifications met with in the class, to coalesce and form a single vessel. The two dorsal vessels, when they are developed, are connected by transverse vessels, called "superior commissural vessels;" the two sub-intestinal vessels, or the one which they form, also communicate with the dorsal vessel by lateral branches, called "deep commissural vessels;" and, again, the capillaries of the cutaneous system communicate with the dorsal vessel, or it with them, by the "latero-dorsal" vessels, thus establishing a general communication.

Having thus seen what is the general arrangement in the Annelida, let us turn to the earthworm. If killed with chloroform, the worm presents on the dorsal surface of its alimentary canal, when opened, a rhythmically moving dark-coloured vessel, generally containing a considerable amount of the red fluid. This is the dorsal vessel of the visceral system, and extends from the eighth segment throughout the body (Part I, Pl. VII, fig. 5, and Pl. II, figs. 1, 2, 3, *a*). Beneath the intestine, but not closely attached to it as is the dorsal trunk, is the single sub-intestinal vessel (Pl. VI, figs. 1, 2, 3, *b*), also with highly contractile walls, but generally not to be observed in movement, inasmuch as the dissection required before it is reached destroys the lingering vitality of the worm. The sub-intestinal vessel extends throughout the whole length of the body excepting the first four or five anterior segments, where it is broken up into capillaries. The dorsal and sub-intestinal vessels are connected by the lateral "deep commissural vessels" (Pl. VI, figs. 1, 2, 3, *l*), thus completing the visceral system of M. Milne Edwards. Of the deep commissural vessels there are two in each segment posterior to the sixteenth, embracing the alimentary canal; those from the sixteenth to the nineteenth, in connection with the stomach and gizzard, dividing into a wonderfully fine capillary plexus, the vessels of which in the fibrous gizzard have a horizontal parallel disposition. From the nineteenth ring backwards the deep commissural vessels consist merely of a pair in each segment, closely attached to the wall of the intestine, and imbedded in or covered up by the yellow granular substance which is spread over its surface and is supposed to have a biliary function. Anteriorly to the sixteenth ring the deep commissural vessels are single; in fact, the two are fused into one, and, until the seventh segment is reached (when they cease to exist or become as the dorsal vessel itself, broken up into a capillary network investing the pharynx), they assume a more or less doubly conical form, and have been called by authors on the subject "hearts" (see Part I, Pl. VII, fig. 1).*

When the nervous cord extending along the ventral interior surface is dissected away from its attaching branches, and its inferior surface is examined, a delicate vessel, capable, however, of much expansion, is seen closely attached to it, sending out branches with the nerve-branches, and, in fact, following the ganglionic cord and its branches throughout the worm (figs. 1, 2, 3, *b*). It forms a capillary plexus at the cephalic and at the caudal extremities, thereby communicating with the dorsal and sub-intestinal trunks; this is, then, the main trunk of the *cutaneous system*, the single ventral vessel representing the two longitudinal lateral vessels met with in some other Annelida. The rest of the cutaneous system (figs. 1, 2, 3, *e*) of vessels is seen in the innumerable ramifications and delicate networks visible on the inner surface of the perivisceral cavity, which form one of the main objects of beauty attracting the eye when an earthworm is opened for dissection. There is no special superficial cutaneous circulation, that is to say, disposed near the external surface; a few vessels penetrate the muscular layers of the integument and give off numerous delicate branches, which are occasionally seen in the pigmentary layer; but there is no great cutaneous plexus, as, in fact, may be partly seen by the completely colourless aspect of the posterior three fourths of any worm's body; in fact, the integument of the earthworm has a *remarkably small* true cutaneous circulation, being, such as it is, merely adapted to perform the general offices of a vascular fluid. It is upon the interior superficies of the integuments that a plexus exists, belonging to the *cutaneous system* of M. Milne Edwards, which, perhaps, it were better to call *peripheral*. This plexus is supplied in each segment by a branch on either side from the ventral or sub-ganglionic vessel; it is also connected in each segment (the seven cephalic segments are exceptional) with the sub-intestinal vessel by a special branch on either side, and with the dorsal vessel by large vessels, given off on either side, closely connected with the diaphragmatic muscle, and sending branches elsewhere also. These latter vessels, or their representatives in other Annelids, are what M. Milne Edwards calls the *latero-dorsal* vessels. Thus, then, we see a general connection

* A somewhat serious error has been unaccountably made in the figure referred to. There should, of course, be but *one* pair of "hearts" in each segment.

established between the three longitudinal trunks—between the great dorsal and the sub-intestinal by the deep commissural vessels, between the ventral and the dorsal and sub-intestinal by the internal superficial tegumentary plexus, and, again, between all three by the capillaries into which they break up at either extremity of the worm.

There is, however, another distribution of the branches of the great trunks by which they become connected, and it is in the diaphragmatic muscles and the segment-organs. A branch is given off on either side in each segment from the sub-intestinal vessel near the anterior septum, from the ventral vessel near the posterior, and these on either side entering the diaphragmatic muscle are distributed to the segmental organs in the manner described in my last paper, forming small lacunæ and networks most intricately and intimately ramified; and thus we have in connection with each segment-organ a special *afferent* and *efferent* branch. The latero-dorsal vessels send ramifications through the diaphragmatic muscles with which they are closely connected, as also do the branches from the ventral vessel, which, though not so constant and regular in their disposition as the pair of vessels in each segment given off from the dorsal trunk, may nevertheless be conveniently spoken of as the *latero-ventral* branches. Neither the latero-dorsal nor the latero-ventral vessels send any branches whatever to the segmental organs, which are supplied solely by the special branches from the sub-intestinal and ventral vessels; these branches may therefore be called the afferent and efferent excretorial vessels.

A modification of the visceral circulation takes place in the seven segments posterior to the seventh. It is in these segments that the organs of generation are situated, as also the three pairs of œsophageal glands, organs which are all most profusely supplied with the vascular fluid, and for the purpose of feeding which it would be supposed that the arrangements of an ordinary segment would be found inadequate. Accordingly, parallel to the sub-intestinal vessel are found two others, one on either side, with which the enlarged, deep, commissural vessels, or hearts, communicate (fig. 2, *p*). Branches are given off from all three of these longitudinal vessels to the various organs; the central sub-intestinal vessel supplying, especially, the testes and ciliated inductors of the vasa deferentia, whilst the parallel additional vessels seem more closely connected with the œsophageal glands.

We have, then, in the various segments of the worm's body four principal modifications of the circulation, the simplest of which is that extending from the 19th segment to the penultimate one, and represented diagrammatically in figs. 1 and 3. The seven cephalic segments, and the one caudal, in which the circulation is merely capillary, all the great trunks being broken up, form a second modification, whilst the third is that described above in the generative segments, and represented diagrammatically in fig. 2; whilst a fourth modification occurs in the 15th, 16th, 17th, 18th and 19th segments, where the deep commissural vessels are large and *single*, but there are no additional parallel vessels.

Structure of the Vessels.—The vessels, thus disposed for the purpose of circulating the red fluid, may be considered as possessing an internal structureless amorphous tunic, without epithelium, and an external tunic of more or less modified connective tissue; between these two are longitudinal and transverse muscular fibres in some of the smaller as well as in the large vessels.* In most of the vessels the transverse fibres are radiated from a point and placed in bundles at intervals (fig. 7). The result is that when the transverse fibres contract they produce an uneven moniliform appearance in the blood-vessels, but are the more effective in propelling the fluid. The alternating points of contraction and expansion in the dorsal vessel and so-called hearts are well seen when a worm is freshly opened.

Structure of the Vascular Fluid.—The vascular fluid is completely devoid of corpuscles, and is entirely structureless. It is more easily coagulated than the perivisceral fluid, but otherwise appears to have the same composition. The nature of its colouring matter is not known.

Functions and homologies of the Vascular and Perivisceral Fluids.—It has been already pointed out that De Quatrefages has established the existence of undeniable homological relations between the perivisceral fluid of the Annelida and the fluid occupying sinuses and lacunæ among the Crustacea, Arachnida, and Insects,† and circulated by a heart with valves, and considered as true blood. The researches of Professor Huxley‡ tend to establish the conclusion that in the vascular system we have a closed representative of the water-vascular system of Scolecida. The function of the two fluids does not in any way necessarily affect the question of their homologies, and in considering the part which they play in the animal economy we must not be hampered by the

* See Leydig's 'Lehrbuch der Histologie.'

† 'Annales des Sciences Nat.,' 1843—1854.

‡ 'Brit. Ass. Reports,' 1854.

hypothesis sometimes hazarded as to the function of the water-vascular system of Scolecida or the blood-sinuses of Arthropods. There can be no doubt that the vascular system of the earthworm, as in other Annelids, is adapted for exposing its fluid to the action of oxygen. How does it do this, and has it any other functions? In no Annelid can it be satisfactorily shown that the vascular fluid has a definite circulation; the fluid is made to move, to oscillate, and pass more or less from one series of vessels to another by the contractions of the vessels, but, as M. Milne Edwards observes, there is no definite circle of movement. In certain Annelids M. De Quatrefages has shown that the perivisceral fluid absorbs oxygen; this he has demonstrated chemically, and it appears that, as a rule, the perivisceral fluid absorbs oxygen, to which the vessels of the vascular system afterwards become submitted. In the earthworm, then, it is probable that the perivisceral fluid absorbs oxygen or water containing oxygen through the capillary canals forming a characteristic structure of the integuments. To the action of this the fluid contained by the vascular plexuses and the great vessels is everywhere more or less exposed by osmotic action. It would appear also that this process takes place to a very large extent in the vessels distributed to the numerous diaphragmatic muscles, which are necessarily very largely subject to the action of the perivisceral fluid.

Another vastly important function of the vascular fluid, and one for which it seems specially adapted, is *excretion*. This takes place through the segment-organs, and is also shared in a minor degree by the perivisceral fluid which is continually passing through them.

Absortion of alimentary matters may equally be the function of both fluids; certain matters passing by osmose through the very delicate walls of the intestine into the perivisceral cavity, and others possibly, though not very probably, being absorbed by the delicate networks formed by the visceral branches of the vascular system. It has been hinted by Claparède* that the greenish-yellow mass of granules enveloping the intestine and the dorsal vessel and its branches, even at its anterior extension, may have some connection with the formation of the corpuscles of the perivisceral fluid, and assist materially in other respects in the functions of that liquid. It appears very certain that in the earthworm the perivisceral fluid absorbs aliment through the intestinal walls, and nourishes all the organs which it bathes, and also it brings oxygen to the vascular

* 'Recherches sur les Oligochetes.'

fluid, whilst this latter removes waste matters from and oxidizes the tissues, and performs all the offices of excretion and secretion.

Nervous System.—The nervous system of the earthworm consists of a sub-intestinal and supra-intestinal chain of ganglia, with their branches. I have little or nothing here to add to the very elaborate, accurate, and detailed description given by Mr. Lockhart Clarke, in his paper published in the 'Proceedings of the Royal Society' for 1857, but will give a brief description of the subject of his researches, in which I shall make extensive use of his essay.

In the centre of the third ring of the worm, overlying the pharynx, are two closely united pyriform ganglia, or a single bilobed ganglion, of which the lobes are united by their broad ends in the mesial line. This is the *supra-œsophageal ganglion.* The small end of each of its lobes divides into two nerve-trunks, of which one forms the root of its cephalic nerves (fig. 6), and the other the *pharyngeal crus,* which curves round the sides of the pharynx, to join the first subventral ganglion.

From each crus, or from either side of the collar thus formed (see fig. 6), there spring eight or nine nervous branches. The first four or five arise from the under part of its anterior half, and immediately enter the upper surface of a minute and delicate cord-like chain of ganglia, the chain which was above designated the *supra-intestinal portion* of the nervous system. This very interesting structure was, to all intents and purposes, discovered by Mr. Clarke, since Brandt and others had only spoken of it as a simple dorsal twig, given off from the bilobed cephalic ganglion. The chain lies on the side of the pharynx, concealed by the crus. The breadth of its first ganglionic enlargement is the $\frac{1}{200}$th of an inch in a good-sized worm. Each border of the chain gives off several trunks of considerable size, which unite to form a continuous plexus, supplying with its inner part the muscular and mucous coats of the pharynx, with its outer the muscular bands and salivary tubules. From the pharynx the plexus descends along the side of the œsophagus, lying on the abdominal vessels, and communicates with minute filaments from the nerves of the subventral ganglia.

The four or five nerves which are given off on either side from the posterior part of the crus communicate with each other by loops before they leave it. The first and largest sends some filaments to the muscular bands of the mouth, upon which they communicate by evident but slight dilatations with the plexus of the pharyngeal chain, and, after supplying the muscles of the anterior segments, are lost in the integument of the lower lip. The rest take nearly the same course. But what is extremely interesting is that the roots of the nerves of this the posterior set are continuous across the crus with those of the anterior set belonging to the supra-intestinal chain.

The *subventral chain* of ganglia forms with its nerves the sub-intestinal portion of the nervous system. It is a double cord, gangliated at short intervals by the addition of vesicular substance and extending from the third ring throughout the body. Anteriorly the cords are divergent and form the two pharyngeal crura, posteriorly they become closely cemented along the middle line. The ganglionic enlargements vary in shape, size, and approximation, at different parts. Each gives off from its sides two pairs of nerves, which, after sending some filaments to the diaphragmatic muscles and bands, supply the longitudinal circular and oblique muscles of the rings midway between the ganglia; the intervening cords give off a single pair, which are distributed to the deep muscles on each side (see fig. 6).

The *cephalic nerves*, which take their origin in one of the trunks on either side, into which the bilobed supra-pharyngeal ganglion divides, are distributed to the lower surface of the first segment, forming a very delicate organ of touch; another portion of the nerves forms a curious plexus in the pigmentary layer, and is connected with the large clear cells there met with. Mr. Clarke suggests the possibility of these forming a mechanism adapted to the perception of diffused light, though not of distinct vision. That the first segment of the worm, with its nervous plexuses, does form a very important organ of perception, there can be no doubt.

Structure of the Nerves and Ganglia.—In fig. 8 nerve-cells and a portion of a nerve-fibre from the sub-ventral chain are drawn. In fig. 7 a portion of the cord, less highly magnified, is represented. The structure of the various parts of the nervous system of the earthworm, as studied by Mr. Clarke, has yielded most interesting and important results. Each lobe of the cephalic or supra-pharyngeal ganglion is a pyriform sac, which is very thick and convex posteriorly, where it is partially separated from its fellow by a deep notch. This convex portion is opaque white, and filled with a mass of semifluid granular substance, and oval, round, and pyriform cells of various sizes, but often very large. The anterior half, by which the lobes are joined, is merely lined by a lamina of cells, and only at its upper part, its under side having a cell here and there. The interior of this portion is entirely fibrous, and consists of a broad, transverse, commissural band, derived from the pharyngeal collar, and of fibres from the roots of the cephalic nerves. Each crus of the collar enters its lobe on the under side. Some of its fibres curve backwards to the convex vesicular mass; others ascend to, perhaps partly terminate in, the cells near the roots of the cephalic nerves, and the rest cross transversely, as the broad band, to be continuous in front of the notch with that of the opposite ganglion.

The supra-intestinal chain of ganglia, when placed under a $\frac{1}{8}$th objective, displays a remarkable structure. The under surface of the entire chain—cords as well as ganglia—is covered with a lamina of round, oval, and pyriform cells, and on its upper surface a row of cells of the same kind is found along each border. At every point of communication between the branches which form the plexus a minute ganglionic enlargement is seen, from which new branches proceed to form other enlargements of the same kind. As the plexus extends from the chain the ganglionic points diminish in size, while the smaller branches given off from the trunks increase in number, and communicate like a capillary network. The ganglia of the subventral chain have their vesicular substance on the under surface, and consist of about two strata of cells continuous in a lamina across both cords. Along their borders, however, the cells form a thicker layer or column, which extends for some distance along the intervening cords. In form and general appearance the cells are similar to those of the pharyngeal chain, but many of them are larger. Within the ganglia the roots of the nerves diverge in three different ways—1, longitudinally; 2, transversely; and 3, to the gray or vesicular substance. The first, or longitudinal, form a large portion of the nerves, and run in equal numbers in both directions, backwards and forwards, along the whole length of the corresponding cord. In their course some of them near the border separate in succession from the rest and enter the lateral column of cells; others proceed as far as the next nerve, with the roots of which they form loops, and pass out, while the rest continue onwards and, perhaps, in succession form similar loops with distant nerves. Mr. Lockhart Clarke has shown that the same kind of arrangement exists in man and the mammalia as well as here. The second order of fibres are less numerous and, in general, less distinct than the rest. They proceed from the middle of each opposite root, and cross the cords directly. The third order of fibres are those distributed to the vesicular substance. Mr. Clarke was not able, after repeated examinations with the microscope, to trace an undoubted continuity between the cells and nerve-fibres in more than one or two instances, although there is good reason to believe that such a connection exists. Dr. Rorie, in a paper published in this Journal two years since, which cannot certainly bear comparison with Mr. Clarke's,* figures multipolar nerve-cells from the ganglia of the earthworm. His observations are, in all probability, erroneous, as my own entirely confirm those of Mr. Clarke, whose accuracy, care, and acuteness, are, moreover, too well known to be doubted.

Functions and Homologies.—The supra-intestinal portion of the nervous system evidently presides over the operations of the viscera, whilst the sub-intestinal portion is more closely connected with the locomotive function. The supra-intestinal chain is, however, as we have seen, connected by its branches with the sub-intestinal ramifications, and its roots also are closely associated with those of the other nerves arising from the pharyngeal crura. Mr. Clarke considers that it combines the office of a sympathetic with certain other functions which in many invertebrata are entrusted to separate and special centres; such as the labial, pharyngeal, and visceral ganglia in cephalophorous mollusca. By experiments I have satisfactorily demonstrated to myself that the pharyngeal chain is independent of the other nervous centres, although, at the same time, subject to their influence, and can control the suctorial movements of the mouth and pharynx, and is a centre of reflex action. Mr. Clarke has also established this fact by experiment.

Two parts of the human brain are compared by Mr. Clarke to the transverse cephalic band of *Lumbricus*. One is the arched and commissural band of fibres prolonged through the corpora quadrigemina, from the upper and inner part of the fillet on each side. The other part, which is analogous or homologous with the cephalic band, is the corpus callosum. Dr. Rorie, in the paper quoted above, advances the opinion—stating, at the same time, that he reserves his reasons—that the supra-œsophageal ganglia are analogous to the cerebrum of man and the higher mammalia, and to the spinal cord, whilst the ventral chain he regards as belonging to the sympathetic system, and the pharyngeal crura he considers to be the homologue of the vagus. I need hardly say that, as Dr. Rorie brings forward no facts to support this view, and as Mr. Clarke very ably and carefully gives details of structure and anatomy to support his, the opinion of most intelligent persons will coincide with that of the latter observer.

RECAPITULATION.—*The hæmal system* of the earthworm

* 'Quart. Journ. Micro. Science,' April, 1864.

consists of a corpusculated colourless fluid, contained in the somatic cavity, and provided with exits and a series of capillary canals for the entrance of liquid, and of a red-coloured, non-corpusculated fluid contained in three longitudinal trunks and their ramifications. Both are albuminous; the former is homologous with the blood of Insects and Crustacea, and probably performs a nutritive function; the latter is homologous with the water-vascular system of Scolecida, and has an excretory or urinary function through the segmental organs, and a respiratory function, in connection with the oxygen absorbed by the perivisceral fluid.

The nervous system consists of a supra- and a sub-intestinal portion, both of which present the usual components of fibres and cells. The principal centre is the cephalic bilobed ganglion, homologous with the corpus callosum and the commissure prolonged through the corpora quadrigemina. From this in one direction pass the cephalic nerves, in the other the phargyngeal crura, uniting beneath the pharynx to form the subventral cord and ganglia. From the pharyngeal crus four branches on either side unite to form the supra-intestinal chain or plexus discovered by Lockhart Clarke, and homologous with the sympathetic and visceral ganglia of mollusca. Four other twigs on either side are distributed to the pharynx. The muscles of the segments are presided over by the subventral cord. There are no special organs of sense, unless the labial segment should be so considered.

BIBLIOGRAPHY.

Boeck.—Om 7 Artsformer of *Lumbricus terrestris* iagttague i Norge; in 'Forhandlgr. skand. Naturforsk,' 2 Möde 1840, p. 273.

Charrin.—Le Lombric terrestre, vulgairement appelé ver de terre. Sujet tiré au sort. Paris, impr. d'Apperl, 1852.

Clarke, John Lockhart.—On the Nervous System of *Lumbricus terrestris*; in 'Proc. Roy. Soc. London,' vol. viii, 1856, p. 343—352.

D'Udekem, Ful.—Developpement du Lombric terrestre; in 'Mém. Cour. et Mém. d. Sav. etrang. de l'Acad. de Belg.,' tom. xxvii, 1856. *Beneden* P. T. van.—Rapport sur le Mémoire de M. Jul. D'Udekem; in 'Bull. de l'Acad. de Belg.,' tom. xx, 3, 1853, p. 357. *Schwann*, Th.—Rapport sur le même Mém.; ibid., pp. 397, 398. *Cautraine*. The same, in 'L'Institut,' xxii, No. 1063, 1854, pp. 107—172.

Dufour, Léon.—Notice sur les cocons ou les œufs du *Lum-*

bricus terrestris; in 'Ann. Sci. natur.,' tom. v., 1825, pp. 17—21. Nouvelle notice, accompagnée de figures; in 'Ann. Sci. nat.,' tom. xiv, 1828, p. 216. Also 'Tsis von Oken,' 1834, pp. 1024, 1025.

FITZINGER, L. J.—Ueber die Lumbrici; in 'Isis,' 1833, pp. 549—553.

GEGENBAUR, C.—Ueber die sogenannten Respirationsorgane des Regenwurm; in 'Zeitschrift f. wiss. Zool.,' Bd. viii, 1856, pp. 400—424.

GRASS, Ern. Sig.—*Lumbricorum terrestrium* regeneratio; in 'Ephem. Acad. Nat. Cur.,' dec. 2, ann. 8, 1689, pp. 202, 203.

HERING, Ewald.—Zur Anatomie und Physiologie der Generationsorgane des Regenwurms; in 'Zeitschrift f. wiss. Zool.,' Bd. viii, 1856, pp. 400—424.

HOME, Everard.—Lumbrici in Copulation; in 'Home Lect. on Comp. Anat.,' vol. iv, 1823. See also 'Phil. Trans.,' 1828.

LEO, Jul.—Ueber die Fortpflanzung der Regenwürmer; in 'Isis,' 1820, lit. auz., 386—387. De structura *Lumbrici terrestris*; in 'Isis,' 1822, pp. 492—496.

MECKEL, Fr.—Ueber die Zeugung der Regenwürmer; in 'Meckel's Deutsche Arch. f. Physiol.,' Bd. i, 1815, pp. 467, 468.

MONTEGRE, De.—Observations sur les Lombrics ou vers de terre; in 'Mém. du Muséum,' tom. i, 1815, pp. 242—252.

MORREN, Carol. F. A.—Quæritur descriptio structuræ anatomicæ et expositio historiæ naturalis *Lumbrici vulgaris*, sive *terrestris* (with 31 plates); in 'Ann. Acad. Gandav.,' 1825, p. 6 (280 pages).

MURRAY, John Andr.—Observationes, &c., Lumbricorum setis; in 'Dessen. Opusc.,' tom. ii, 1786, pp. 401—412.

NEWPORT, Geo.—On the reproduction of lost parts in Earthworms; in 'Proc. Linn. Soc.,' vol. ii, No. 54, 1853, p. 256.

PONTALLIÉ.—Observations sur le Lombric terrestre; in 'Ann. Sciences natur.,' 3 sér., "Zool.," tom. xix, 1853, pp. 18—24.

QUATREFAGES, A de.—Sur l'anatomie des Sangsues et des Lombrics; in 'Soc. Philom. Extr. Proc.' verb 1847, pp. 85, 86; 'Ann. Sciences natur.,' 3 sér., "Zool.," tom. viii, 1847, p. 36.

RORIE, J.—On the Nervous System of *L. terrestris*; 'Quart. Journ. Micr. Science,' April, 1863.

SANGIOVANNI.—Ueber die Reproduction des Regenwurms; in 'Fror. Not.,' No. 147, 1824, pp. 230, 231.

SURIRAY.—Notices sur quelques parasites et produits organiques du Lombric terrestre; in 'Ann. Sciences natur.,' 2 sér., "Zool.," tom. vi, 1836, pp. 353—358.

TREVIRANUS, G. B.—Ueber die Zengung des Erdregenwurms; in 'Tiedemann u. Treviranus' Zeitschr. f. Physiol., Band. Heft 2, 1835, pp. 154—166.

WICHMANN, Joh. Ern.—Vom Gürtel des Regenwurms; in 'Berlin. Beschäftgen,' Bd. iii, 1777, pp. 231—240.

RECORD *of the occurrence, new to* IRELAND, *with* NOTE, *of a Peculiar Condition of the* VOLVOCINACEOUS ALGA, STEPHANOSPHÆRA PLUVIALIS (Cohn), *and Observations thereon.* By WILLIAM ARCHER.*

THE discovery in Ireland of the very interesting and very beautiful and apparently very rare organism, *Stephanosphæra pluvialis* (Cohn), would in itself alone be worthy of a record in the 'Proceedings' of this society. But inasmuch as, whilst I had a supply of this "Volvocine" in my possession, a remarkable phase or condition in its history—so far as I am aware, not before observed in this form, though not without parallels elsewhere—presented itself to my notice, the value of that record becomes thereby in so far enhanced.

Spending an evening in the month of June last at Bray, I took a walk upon the "Head," promising myself, indeed, not much of interest (save the beautiful view), from its dry and rocky summit. The weather had lately been showery, and during the day a considerable quantity of rain had fallen. This had left behind small deposits of rain-water in a few little hollows amongst the rocks. In one of these tiny pools I perceived the water tinged with a beautiful light-green colour. A few moments' inspection, even without a lens, was sufficient to indicate that this green hue was due to the presence of myriads of some "volvocinaceous" plant; and with a lens I soon perceived, by the annular and band-like green portions of the organisms, as they appeared under so low an amplification, alternately brought to view, that I had had the good fortune to encounter that seemingly rare organism, *Stephanosphæra pluvialis* (Cohn), which Professor Cohn journed from Breslau to Hirschberg to see, and for the occur-

* Read before the Natural History Society of Dublin, May 6, 1863.

DESCRIPTION OF PLATES II & III,

Illustrating Mr. E. Ray Lankester's paper on the Earthworm.

PLATE II.

Fig.

1.—Genitalia of *Lumbricus terrestris,* much enlarged.

2.—Portion of ciliated canal or segment organ of Lumbricus.
a. Granular tissue. *b.* Cilia. *c.* Capillary.

3.—Testes, seminal vesicles, and vasa deferentia, of the right side, seen posteriorly.

4.—Ciliated canal or segment organ from posterior of body.

5.—Fibrous tissue of testis.

6.—Nucleated epithelium of ciliated receptacle.

7—11.—Development of zoosperms.

12.—Commencement of the seminal duct, or vas deferens.

PLATE III.

1.—Segment organs, and their modifications, in the 8—15 segments of Lumbricus.
a. Normal canal.
b. Sperm-reservoir.
c. Vas deferens.
d. Oviduct.
(*a*–*d*: Segment organs?)
e. Capsulogenous gland.

2.—Oviduct, magnified.

3.—Ovary, more highly magnified.

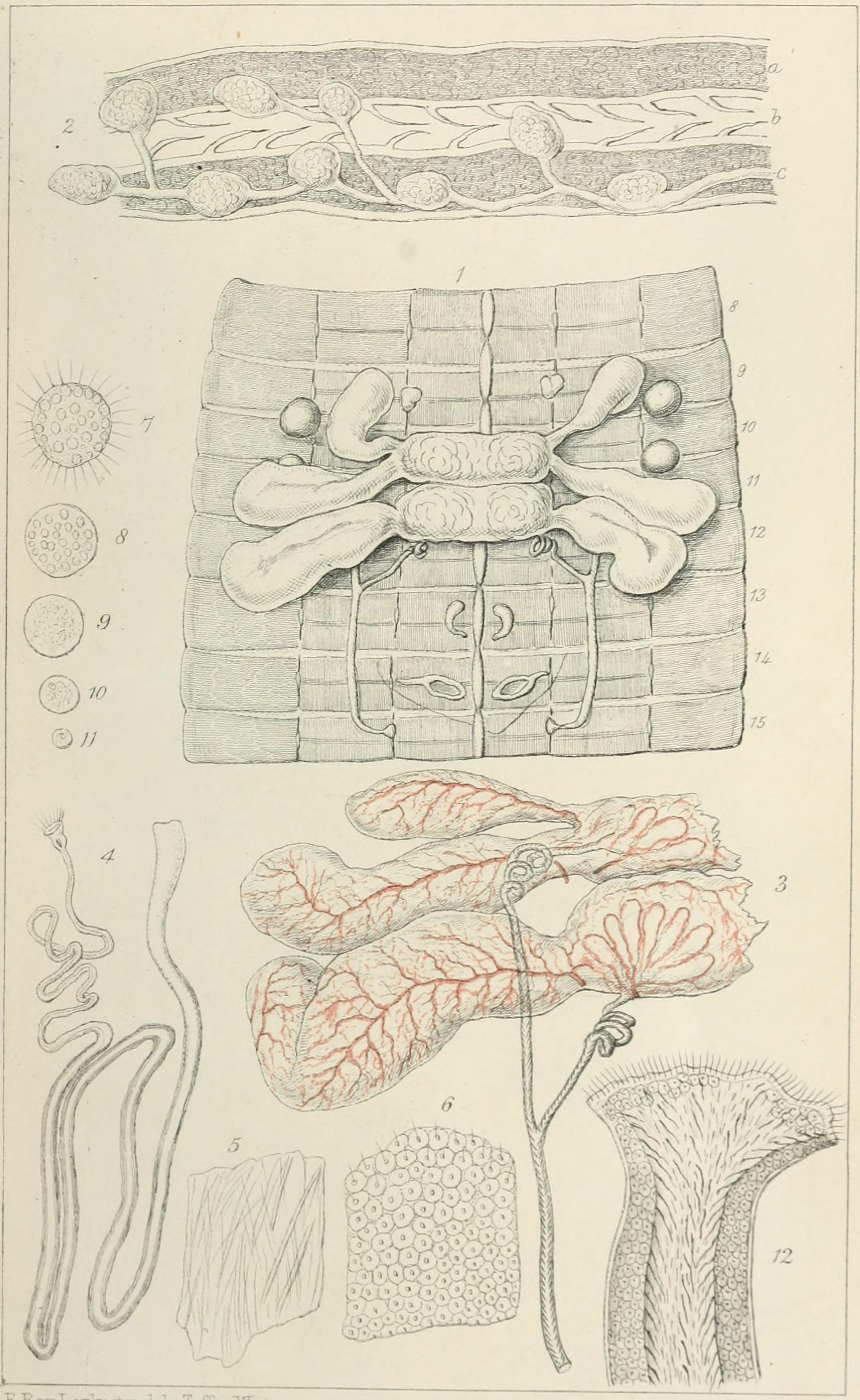
4.—Papillæ of cingulum.

5.—Typical segment of an Oligochete.

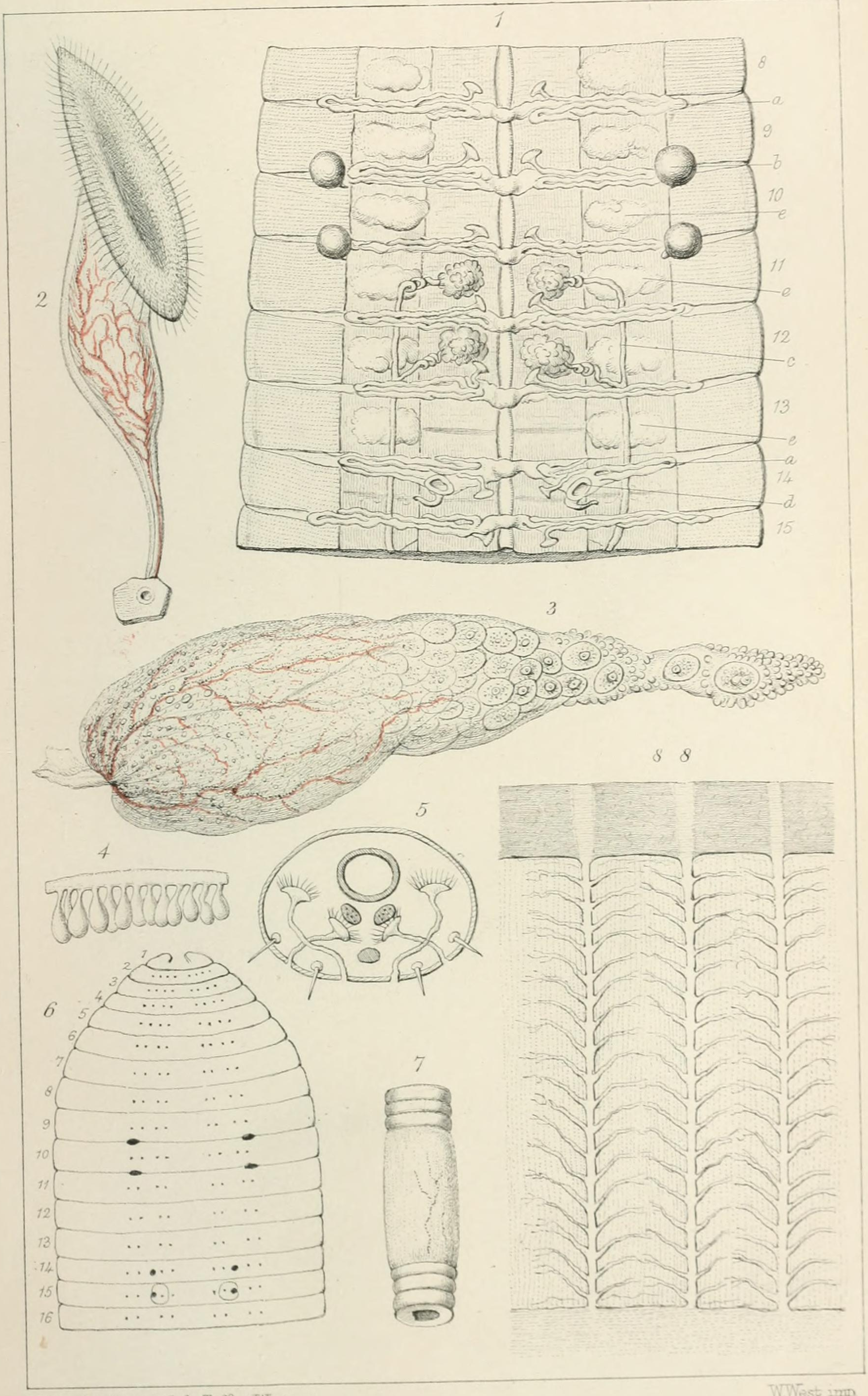
6.—Pores of the first sixteen segments.

7.—Cingulum.

8.—Dermal canals.



E. Ray Lankester del. Tuffen West sc. W. West imp.



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