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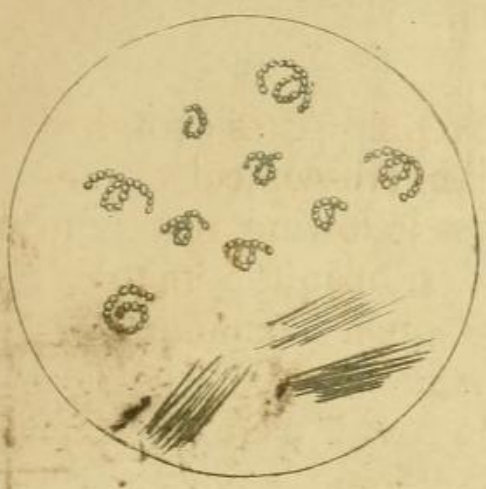

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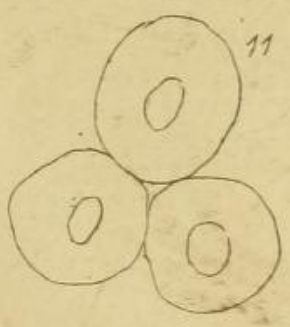

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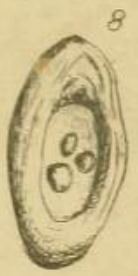

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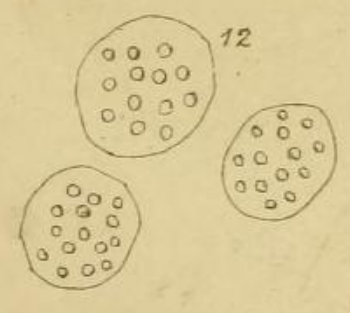

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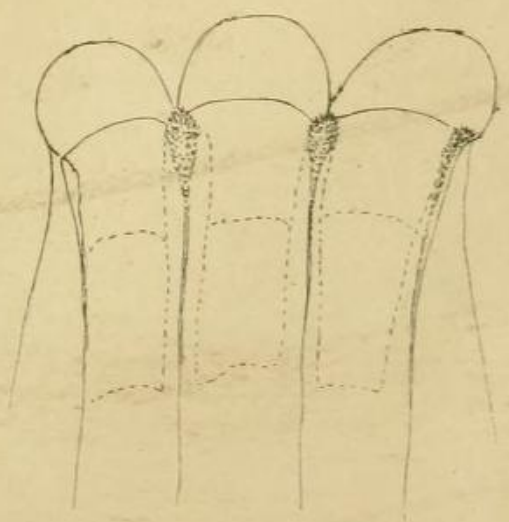

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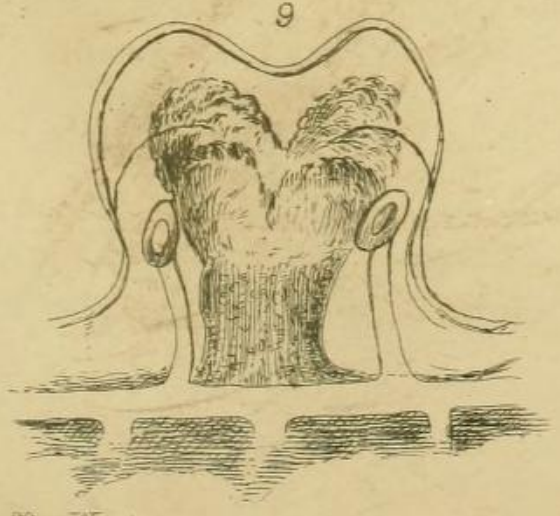


Tuffen West sc.

Objects in Phycocyan.
Structure of the Round Worm.

W. West & Co. imp.

IV.—*The Anatomy of the Round-worm.* (*Ascaris lumbricoides*, Linn.)

By B. T. Lowne, M.R.C.S. Eng.

(*Read before the* Royal Microscopical Society, *Jan.* 11, 1871.)

Plates LXXV. and LXXVI.

The anatomy of the Nematoida still remains in the greatest obscurity, although Cloquet, Otto, Meisner, Schneider, Dr. Bastian, and others, have contributed largely to the literature of the subject. Numerous contradictions are found in their works, and much that is unsatisfactory remains to be cleared up.

About four months ago I was fortunate enough to obtain fifty or sixty large round-worms from a patient, who was the host of nearly two hundred of these parasites. I thought this was a favourable opportunity to endeavour to clear up the more important points in the anatomy of the Nematoid worms. The result of my investigation has been most satisfactory to myself; and although I differ in my conclusions from all previous writers, I have not hesitated to publish the results of my inquiry, as, if I am right, my observations throw an entirely new light upon the anatomy of the Nematoids, and establish their place in the animal kingdom in a most satisfactory manner.

The *Ascaris lumbricoides* resembles an earth-worm at first sight. The female varies from ten to sixteen inches, and the male from five to eight inches in length. The extremities are tapered; the anterior extremity being more so. The alimentary canal runs straight through the animal, the mouth and anus being situated at the extremities. There is a distinct space between the body walls and the alimentary canal,—the body cavity,—filled with a pink serum-like fluid, in which the organs of generation lie. This fluid keeps the external walls tense, and escapes with a gush when they are ruptured. The duct of the female generative organs opens on the ventral surface, at the junction of the anterior and middle thirds of the body: that of the male has its orifice very near the posterior extremity. A pair of curved spicules, retracted when at rest, constitute the armature of the male generative aperture, one being placed on either side of the opening.

The body wall consists of the integument and of a thick layer of longitudinal muscles beneath it.

The integument exhibits two diverse layers, an external chitinous and transparent, and an internal cellular portion. The external layer is indistinctly segmented, exhibiting many hundred annuli. This layer is apparently structureless, but may be split up into numerous layers, a fact first pointed out by Czermack. It presents no trace of cellular origin, and I am inclined to look upon it in the

same light as Dr. Cobbold, as being probably an excretion of the inner cellular layer, which consists of small granular-looking cells.

Immediately beneath the integument is a thick layer of longitudinal muscles. The muscular fibres (Plate LXXV., Fig. 3) are about $\frac{1}{300}$th of an inch in diameter, non-striated, nebulous, and occasionally exhibit nuclei at intervals. They are dissolved rapidly by moderately strong acetic acid, and, like all the tissues of the Ascaris, are very elastic.

I have been unable to detect any transverse layer of muscle, although Cloquet has described such a layer, and I suspect with Dr. Cobbold that the annular striation of the integument has given rise to the opinion that such a layer exists.

The mouth is surrounded by three lips, emarginate in front (Fig. 4). The external chitinous layer of the integument is continued into the thick muscular pharynx, which it lines. It is thrown into three ridges which alternate with the lips (Fig. 5), and which are covered with sharp-pointed tubercles, forming three very effective pharyngeal teeth. Fig. 6 represents the rounded anterior extremity of one of these ridges. The exterior of these ridges, which are prolonged to the posterior extremity of the pharynx, gives attachment to the transverse muscular fibres of the pharynx, so that these are divided into three sets.

Several slighter ridges run transversely across the main ridges, and probably give attachment to some of the numerous longitudinal muscular fibres of the pharynx. The fibres of the pharynx are less than half the diameter of those of the body wall, but are, like them, non-striated.

I have been unable to detect any muscle in the alimentary canal below the pharynx, which appears to consist of an external chitinous layer lined with epithelium. In this respect it is precisely like the inner layer of the intestinal canal of an insect. I strongly suspect that the rough surface of the ridges of the pharynx is epithelial, and that the pharynx is elsewhere lined with epithelium similar to that in the remainder of the intestinal canal, but I have been unable to observe this satisfactorily.

I would point out some remarkable affinities with the abranchiate annelida, exemplified in the three pharyngeal teeth and the segmentation of the integument, which is very similar to that in the leech: these seem to indicate a closer affinity than has hitherto been recognized.

One of the first points which attracts the attention of the most casual observer in the external appearance of Ascaris is the presence of four longitudinal white or pinkish lines or bands running the whole length of the animal. These have been incorrectly described by numerous observers as muscles, and Dr. Cobbold has fallen into the singular error of speaking of them as the "only muscles in

Ascaris," although Cloquet has correctly described the longitudinal layer of muscles. Similar bands occur in *Mermis*, *Gordius*,—and indeed, in all probability, in all Nematoids, as well as in Echinorhynchus, &c.

On careful examination it will be at once seen that two of these lines are much broader and more conspicuous than the others: these are lateral in position. The narrower lines are dorsal and ventral, the ventral line in the female deviating from its course and passing on one side of the sexual orifice, not dividing and surrounding it, as is stated by Cloquet.

The alimentary canal behind the pharynx in the anterior portion of the body is stretched across from one of these lateral bands to the other, but in its posterior two-thirds it is merely suspended in the body cavity and surrounded by the convolutions of the ovaries in the female, and of the testis in the male.

This condition of the anterior portion of the alimentary canal is of considerable importance when viewed in relation to the condition of the bands and alimentary canal in Mermis. In Ascaris I have failed to trace any nearer connection between the alimentary canal and the lateral bands than, that the alimentary canal is connected with the body walls at these points by connective tissue of extreme tenuity. I am inclined to the belief that the whole body cavity is lined with an extremely thin membrane which is reflected upon the intestine at these points. It will be necessary hereafter to refer again to this relation of the lateral bands and alimentary canal.

The anus is situated at the posterior extremity of the body, and the alimentary canal is usually filled with dark-coloured chyle.

In these preparations* the whole interior of the body cavity will be seen to be covered with white villi-like processes; these are the appendices nouricières of Cloquet, and when examined with the microscope are seen to be pyriform vesicles, which are filled with a white molecular fluid. They are supported by ducts which form a complicated network over the whole inner surface of the body wall. If a transverse section of the worm be made, this network of tubes may be seen to be connected more closely with the body wall at four points than elsewhere; that is, they are connected with the four longitudinal bands above described.

The dorsal and ventral bands appear to be the main trunks of this system, and to give off lateral branches at short intervals, which support the vesicles themselves. Plate LXXVI., Fig. 2, represents a portion of one of these trunks with its lateral ducts and vesicles. A section of the worm is accurately represented in Schneider's 'Monograph on Nematoids.'

* The preparations here referred to have been presented by the writer to the Museum of the Royal College of Surgeons.

The connection between this system of vessels and the lateral bands is somewhat different. Several longitudinal vessels anastomosing at intervals surround the lateral bands, and represent the dorsal and ventral trunks in this region. These are connected directly with the transverse vessels.

If the anterior extremity of the worm be removed about three-quarters of an inch from the head and slit up with a fine pair of scissors, by passing one of the blades through the pharynx; a preparation may be made like that represented in Fig. 7, by carefully removing the pharynx. The four sets of longitudinal vessels—which, together with the transverse vessels and vesicles, I shall no longer hesitate to call a water vascular system—will be seen to form a plexus by anastomosing with each other, which entirely surrounds the pharynx. This portion of the water vascular system is destitute, or almost destitute, of vesicles. The plexus terminates anteriorly in a well-marked ring. The ring gives off six branches which open externally one on either side of each lip. This ring, and the vessels given off from it in front, are figured by Dr. Bastian,* and described by him as nerves and a nervous ring; in this he has probably been misled by Schneider's† description, although Schneider has clearly described a totally different structure.

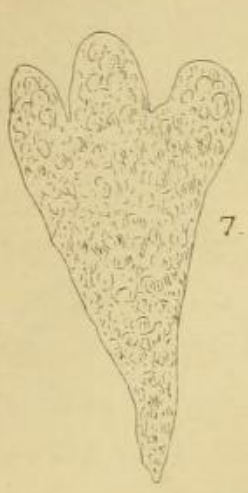
The external openings on the lips (Fig. 4 *aa*) are oval and have a slightly raised margin. The external integument is connected with the walls of the vessels at these points. Just within the margin of each opening there appear to be several perforations, generally two or three; but as far as I can make out they all open into a single duct. These have been described as papillæ, and have always been supposed to be sensory organs. J. H. Flogel‡ has described and figured precisely similar structures on the lips of three different species of Oxyuris, but speaks of them as papillæ over the terminations of nerves. Dr. Bastian§ admits that he has been unable to trace any nerves into the papillæ of Ascaris.

With regard to the transverse ventral slit opening into the water vascular system, which has been described again and again in Nematoid worms, I can find no such opening in Ascaris; there is but one transverse ventral slit, and that is the orifice of the female sexual organs. I have found no such opening in the male.

The transverse opening described in some Nematoids seems, as far as I can judge, to belong to some other system of organs.

If a portion of either the dorsal or ventral main trunk be carefully removed, with its transverse branches and vesicles, it will be found that there are numerous secondary and tertiary vesicles.

* Dr. Bastian "On Nematoid Worms," 'Phil. Trans.,' vol. clvi., p. 54.
† Schneider, 'Monographie der Nematoiden,' and 'Mull. Archiv.' 1863. P. 1.
‡ 'Köll. Zeitschrift für Zoologie,' band xix., p. 234.
§ *Loc. cit.*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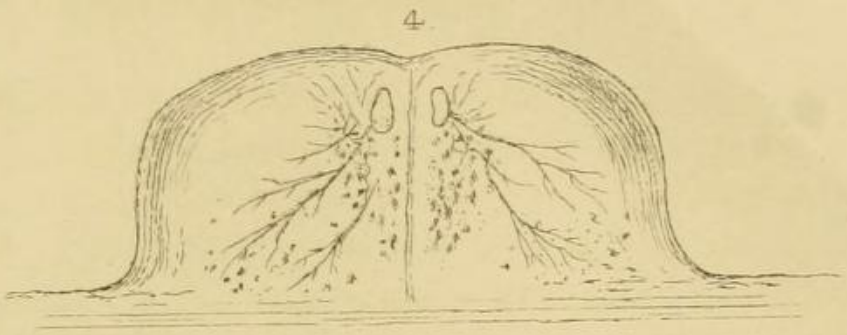
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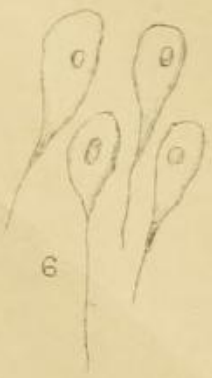
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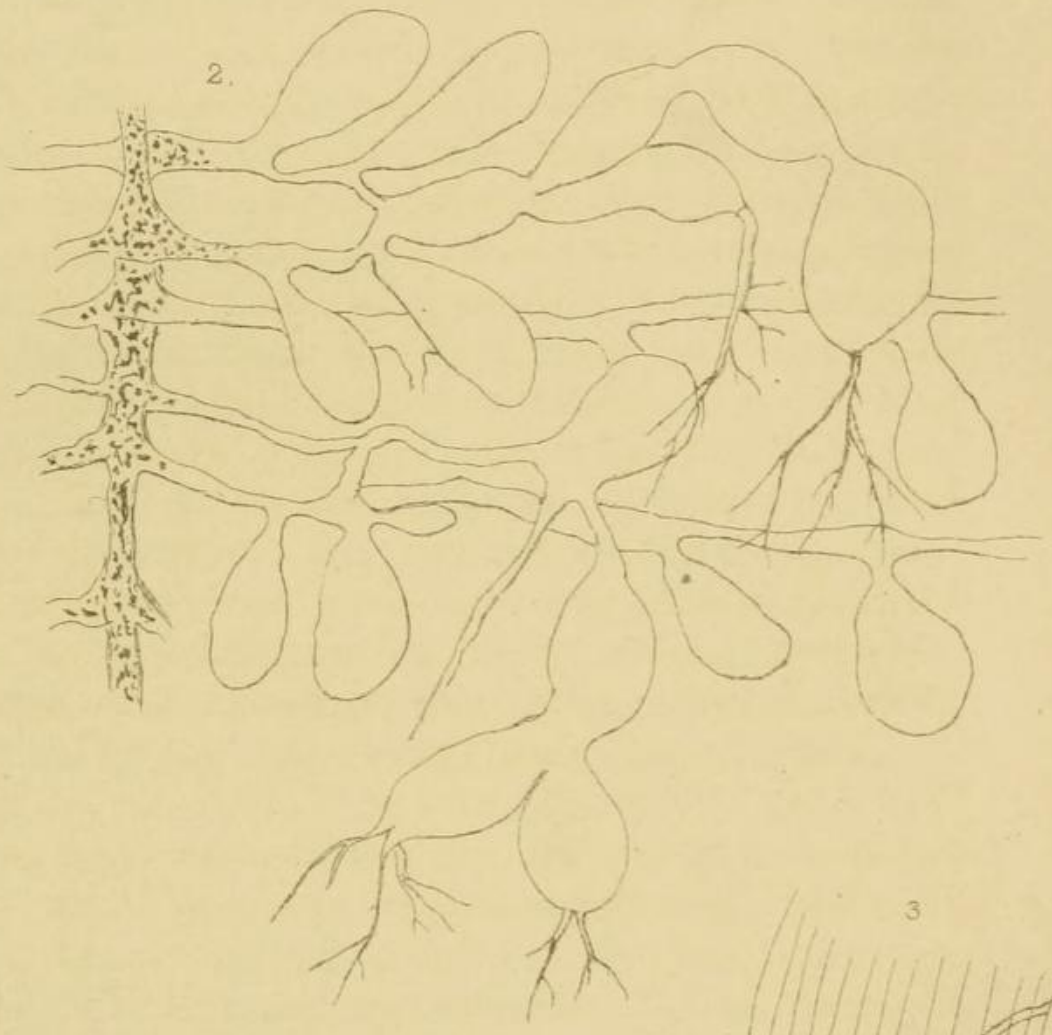
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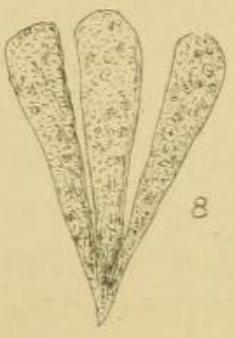
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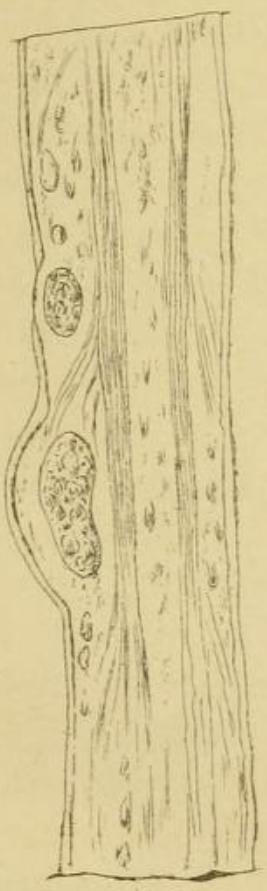
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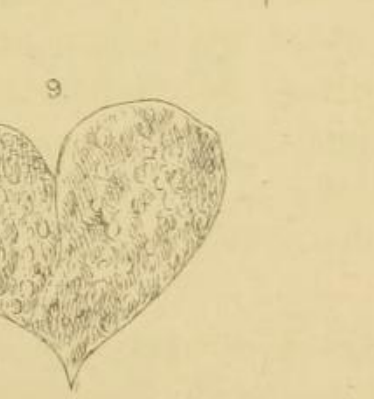

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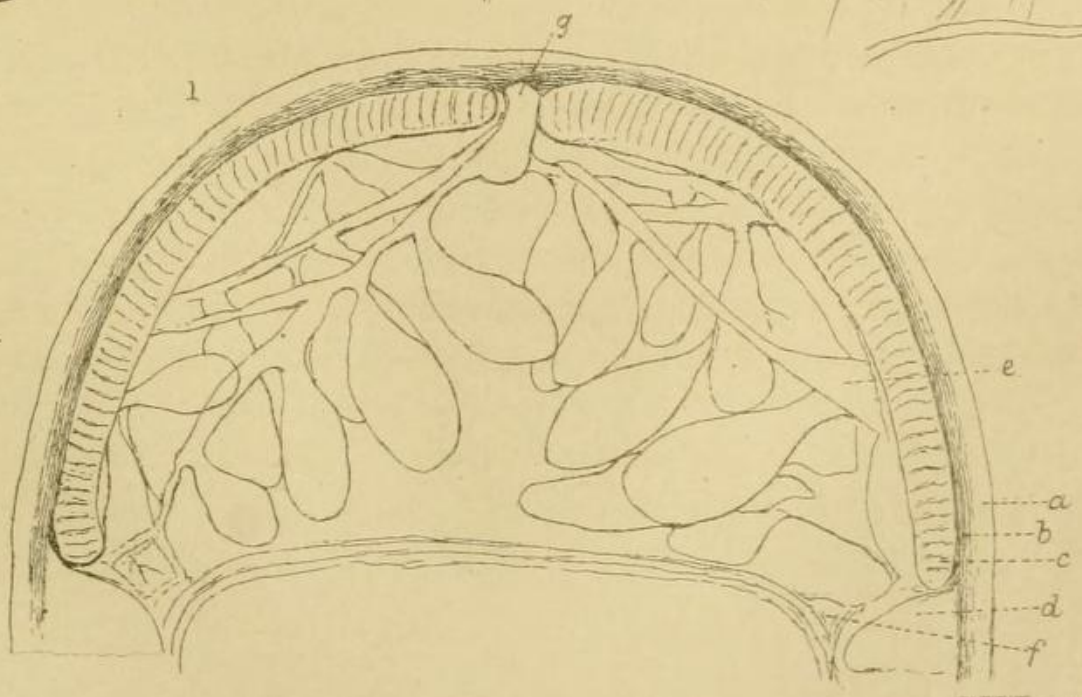

Tuffen West sc.

W. West & Co. imp.

Structure of the Round Worm.

These differ from the primary vesicles in opening into each other, and into the primary vesicles, just as the latter open into the transverse vesicles.

These secondary and tertiary vesicles give off minute dichotomously dividing vessels, which dip into the muscular layer, and ramify in and over all the organs of the body, forming a true pseudo-hæmal system. The main trunks, lateral branches, and vesicles of the water vascular system have an external coat of fine muscular fibres, an inner membranous coat, and an epithelial lining. The pseudo-hæmal vessels seem to consist of membrane only.

The whole water vascular system is filled with a viscid molecular fluid, and is most conveniently seen by staining the tissues with an alkaline solution of carmine, or by treating a portion of the worm with dilute acetic acid. Specimens so treated and mounted in glycerine jelly are exhibited under the microscopes.

I will recapitulate the main points, in order to avoid any chance of being misinterpreted. The water vascular system consists, according to my observations, of a ring round the pharynx, connected with pores in the outer sides of the lips, and giving off a plexus of vessels posteriorly. From this plexus two large trunks, one dorsal and the other ventral, pass to the posterior extremity of the body, and two lateral sets of smaller longitudinal vessels accompany the lateral bands.

Both lateral, dorsal, and ventral vessels give off transverse vessels, which form a plexus, and bear numerous vesicles. The vesicles open into other, and these into other vesicles, the latter giving off fine vessels, which I have called pseudo-hæmal. The pseudo-hæmal vessels ramify in and upon all the other tissues.

The similarity of the whole water vascular system of Ascaris to the ambulacral system of the Echinodermata can hardly escape notice. If the Ascaris possessed ambulacral processes in connection with the vesicles above described, the two sets of organs would be nearly identical.

The water vascular system of Ascaris seems also to afford a strong indication that Professor Huxley's hypothesis concerning the nature of the so-called pseudo-hæmal system of Echinoderms and Annelida is correct, that they really belong to the same system of tubes with the ambulacral and water vascular systems.

I further suspect very strongly that in Ascaris we see a transitional form, in which the water vascular system is immediately concerned with the function of nutrition, with a somewhat rudimentary condition of the alimentary canal, seen in the absence of a muscular coat beyond the pharynx, which is connected closely with the condition of things met with in the anenterhelminths, or worms without any intestinal canal, where, as in Tenia, the function of nutrition undoubtedly devolves upon a system of tubes homologous with a

water vascular system. The remarkably anomalous condition of the alimentary canal of Mermis seems to stand between the condition seen in Ascaris, and that in Tenia, Echinorhynchus, &c.

The lateral bands present histological elements precisely similar to those described by Claparède * in the ventral cord (*Bauchstrang*) of the earth-worm, about the nervous nature of which there can, I think, be no doubt whatever. These are accurately figured by Schneider.†

Each lateral band is divided into two, longitudinally, by a well-marked raphé of fibrous tissue, and a central canal may be seen on either side of the raphé. This may be clearly observed in a transverse section. The greater part of the band consists of fine fibrous tissue, minute oil-globules, and small corpuscles, called by Claparède, in the earth-worm, connective tissue nuclei. Besides these, there are numerous larger scattered ganglion corpuscles, just as there are in the ventral cord of the earth-worm. I have distinctly traced the connection between these and the nerve filaments. The whole band is invested by a delicate layer of epithelium, exactly as that of the earth-worm is.

In the earth-worm the ventral cord terminates in a ganglionic ring round the pharynx;‡ in Ascaris the lateral bands terminate in a similar ganglionic ring.

The pharyngeal ring gives off a thick band of similar structure to each of the lips, which terminates in four large lobes. Posteriorly the ring gives off several short tapering bands, identical in structure with the lateral bands. These are soon lost in the tissues. Occasionally one or both lateral bands split before joining the ring. Nerves are given off at intervals from either side of the lateral bands, which may be traced running transversely to the muscular layer, and ramifying in the integument.

Schneider§ has clearly seen and described this nervous ring in *Ascaris megacephala*, and has figured the lateral nerves given off from the lateral bands;‖ but he has failed to trace the connection between the lateral bands and the ring, and describes the nerves as coming from a nerve-trunk in the interior of the lateral bands. I suspect this has arisen from his method of treating his preparations with acetic acid, and from the fact, that the longitudinal nerve-fibres, which form chiefly the nerves, are situated in the centre of each half of the lateral bands; whilst the commissural fibres and ganglion cells are scattered over their periphery.

With regard to the nature of the axial canals in the lateral bands, I confess I am ignorant. I have a strong suspicion that

* E. Claparède, 'Zeitschrift für Zoologie,' band xix., p. 563.
† 'Monographie der Nematoiden.' ‡ Claparède, *loc. cit.*
§ 'Monographie der Nematoiden,' and in 'Mull. Archiv.' 1856. P. 1.
‖ 'Monographie der Nematoiden.'

they are pseudo-hæmal sinuses, from the large number of minute pseudo-hæmal vessels which appear to ramify from them. These are very apparent when a transverse section of the band is stained with carmine fluid. The disposition of the parts of the bands are represented in Figs. 4 and 5, Plate LXXVI.

I have repeatedly observed certain oval cellular bodies, of greater transparency than the bands themselves, at intervals bulging out, and apparently compressing the normal structure of the bands. They are very irregular in their occurrence, and I have been unable to make out their import. They are very like the cellular bodies which Meisner described as so abundant in the lateral bands of Mermis. Meisner thought the lateral bands of Mermis were connected with the alimentary canal, and called them corpora adiposa. The connection between the alimentary canal of Ascaris and the lateral bands is by connective tissue only, as has been already stated; and the same is even more marked in Gordius.* The specimens in which I observed the cellular bodies had been preserved in spirit too long, but I have no doubt they are collections of ganglion corpuscles, so that they may be looked upon as true ganglia. The lateral bands contain a large quantity of oily matter, and unless examined in a tolerably recent condition it is impossible to make out their true nature.

Cuvier seems to have rightly interpreted the nature of the lateral bands. Meisner has described certain nervous cords in Mermis, but I suspect he fell into the same error as Cloquet and Otto, who described the dorsal and ventral bands in Ascaris as nerve-trunks. Perhaps Meisner has described a portion of the water vascular system as a nerve-trunk; I do not know, as I have not examined Mermis; but I cannot help believing that the bands, or some of them, for there are three, are homologous to those in Ascaris. In Gordius there is a single ventral cord, which undoubtedly represents the lateral bands in Ascaris; in this I think I agree with Schneider. It is on the ventral aspect of this cord in Gordius that Meisner described his ventral nerve-cord, but Grenacher† has failed to detect it. The last-named author thinks that the ventral cord in Gordius as well as the lateral bands in Ascaris are mere folds of the cellular layer of the integument. In this I cannot agree with him; and his beautiful drawings of Gordius, in the paper already referred to, are far from giving me the idea, that the ventral cord is so simple a structure as he is inclined to consider it. The epithelial layer covering the lateral bands may, however, be a portion of the inner layer of the integument, and this leads me to say a few words on a point of very considerable interest.

* Dr. H. Grenacher, 'Zur Anatomie der Gattung Gordius.' 'Köll. Zeitschrift für Zoologie,' band xviii., p. 322.

† *Loc. cit.*

I am beginning to suspect that the nervous system of the invertebrata is developed, like that of the vertebrata, externally to the serous layer of the blastodermic membrane. I expect soon to be able to throw some light upon this subject; let it suffice at present to say that it is possible that the cellular layer of the integument of Nematoids may represent the serous layer of the blastodermic membrane, and this is apparently folded so as to invest the lateral bands. The ento-thoracic growths of the integument in insects point to the same conclusion. But this is mere theory with our present knowledge.

From my observations I conclude that the nervous system in the Scolecida is not formed on so variable a type as imperfect observations have hitherto led us to believe; but that it is entirely transitional between that of the Annelida and Echinodermata.

In the Echinodermata we find a ganglionic ring around the pharynx giving off nervous cords in a radiate manner, the cords, like those in Ascaris, being ganglionic. In Ascaris, if I am right, we have a ganglionic ring giving off several short and two long ganglionic nerve-bands. In the earth-worm, according to Claparède, we have a single ventral nerve-cord connected with a ganglionic ring. A step leads us to the condition seen in many Annelida—a single ventral nerve-cord with ganglionic enlargements, and the transition is easy to the whole series of Homogangliata.

If we compare the nervous system of Tetrastema, one of the Nemertids, with that of Ascaris, as I have described it, we shall be struck with their close similarity. In Tetrastema we have the lateral disposition of the main nerve-trunks, as in Ascaris; but they are no longer ganglionic bands. We have the œsophageal ring, but we have a pair of cephalic ganglionic enlargements added.

From all that I have said it will be apparent that the Nematoid worms stand in a clearly intermediate position between the Echinodermata and Annelida. The water vascular system with its vesicles remind one strongly of an Echinoderm; the pharynx, pharyngeal teeth, and segmented integument are clearly those of an Annelid, whilst the nervous system is more nearly like that of the earth-worm than that of an Echinoderm. In Gordius I think there can be no doubt of this, where there is but a single ventral cord. I cannot agree with Dr. Bastian's view that the Nematoid worms are more nearly allied to Echinoderms than to Scolecida, although I must think much credit is due to him for having first pointed out strong affinities with the Echinodermata,—not stronger affinities, however, than those known to exist between Nemertids and Echinoderms.

The transition from the form seen in Ascaris to that of the anenterhelminths, especially Echinorhynchus, which has the lateral

bands of Ascaris, seems to me to be indicated in the want of muscularity in the intestinal canal of Ascaris: and its remarkably modified form in Mermis, where it is entirely deficient, except in the anterior part of the body. Again, it is difficult to doubt the affinity between the Nemertida and the Nematoida.

I have little to say further on the anatomy of Ascaris, the reproductive organs have been so carefully described by Cloquet, Dr. Cobbold, and others. I will only add to their descriptions that the walls of the ovaries uteri and vagina, as well as of the testis and its duct, have a distinct muscular coat, upon which nerves and pseudo-hæmal vessels may be traced.

I have also a few facts to add concerning the development of the sexual elements.

The ova in the upper part of the ovaries somewhat resemble conical epithelial cells, and fill the whole ovarian tube, meeting in its centre or axis. They are white and very granular, and exhibit no distinct cell wall. I am doubtful about the nucleus, but believe I have detected it in several instances. These conical ova are more loosely packed in the lower six or eight inches of the ovarian tube, and begin to exhibit traces of division at their base. Lower still they have formed distinct buds, which become detached and form the yelks of the eggs. Meisner has observed a similar process of multiplication of ova in Gordius, and in some Lamellibranchiata. In the larger part of the genital tract, the so-called uteri, the ova become invested first in a strong yelk-capsule, and later in a beautiful sculptured chorion. The ova are deposited in strings, like those of Mermis, adhering by the chorions.

It has been stated that several months elapse, during which period the ova need to be submerged in water, before development proceeds in them to yelk segmentation; but I have specimens of eggs taken from a worm, which was placed in spirit as soon as it was voided, which exhibit several distinct stages of yelk segmentation.

The male sexual element exists in the upper part of the tubular testis in the form of minute distinctly nucleated caudate cells, attached to each other in a manner precisely similar to the budding ovarian cells; they do not exceed the $\frac{1}{2000}$th of an inch in their long diameter. Lower down in the testis they are polygonal from pressure, and have increased to $\frac{1}{1500}$th of an inch in diameter, still with conspicuously bright nuclei. The nuclei are replaced in a more advanced part of the testis by bright nuclear particles, of which there are from twenty to thirty in each cell. The remainder of the male sexual canal, which is very capacious in proportion to the testis, was entirely filled with similar cells, so that I am ignorant of any further changes which they may undergo.

The development of the ova as far as it is at present known has

been described by Dr. Cobbold, I have, therefore, no more to add upon this head.

This concludes what I have to say on the structure of Ascaris. I have endeavoured as far as possible to avoid errors, and trust I have done somewhat to put the anatomy of the Scolecida on a more secure footing than it has hitherto possessed.

DESCRIPTION OF PLATES.

Plate LXXV.

Details of the Anatomy of Ascaris lumbricoides, &c.

Fig. 3.—A fibre of muscle from the body wall × 120.
„ 4.—The mouth seen in front. *a*, *a*, openings of water vessels × 30.
„ 5.—The pharynx laid open, showing the ridges in the interior, × 10.
„ 6.—Anterior extremity of one of the pharyngeal ridges × 40.
„ 7.—Anterior extremity of the worm laid open, showing, *b*, *b*, the water vascular, and *d*, *d*, the nervous bands, with their ramifications and connections, × 15.
„ 8.—The external opening of one of the water vessels × 120.
„ 9.—One of the lips × 30.
„ 10.—Cells from the upper portion of the testis × 750.
„ 11.—Cells from the middle portion of the testis × 500.
„ 12.—Cells from the duct of the testis × 500.

Plate LXXVI.

Details of Anatomy of Ascaris lumbricoides.

Fig. 1.—Half a transverse section, made about two inches from the head, × 20, showing, *a*, external layer of integument; *b*, cellular layer; *c*, muscular layer; *d*, lateral nerve-band; *e*, transverse water-vessels bearing vesicles (*appendices nouricières*); *f*, alimentary canal; *g*, dorsal water vascular trunk × 20.
„ 2.—A portion of the dorsal trunk, with transverse vessels, vesicles, and pseudo-hæmal vessels, detached from the other structures, × 25.
„ 3.—A portion of the testis, with pseudo-hæmal vessels ramifying upon it, × 60.
„ 4.—A transverse section of one of the lateral bands × 40.
„ 5.—A portion of one of the lateral bands, × 25.
„ 6.—Ganglion corpuscles from the same × 500.
„ 7.—A budding yelk from the lower part of the ovary × 200.
„ 8.—Three yelks from the upper part of the ovary × 200.
„ 9.—A budding yelk, from the lower extremity of the ovary, dividing into two, × 200.