V. *On the Structure and Nature of the* Dracunculus, *or Guineaworm.*

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(Plates XXI. & XXII.)

Read February 19th, 1863.

AMONG the numerous parasites which infest the human frame, the Guineaworm (*Filaria medinensis*, Gmel.) is one of those which has been known from the most ancient times,—the first undoubted reference to it being made by Agatharchidas*, the philosopher and historian of Cnidus, who lived about 140 B.C., in the time of Ptolemy Alexander. Küchenmeister†, however, discusses the question whether Moses was not the first writer who mentioned the worm, and whether the "fiery serpents" referred to in the Book of Numbers were not in reality *Dracunculi*.

Owing to the tedious and very painful nature of the consequences entailed by the presence of this worm in the human body, more perhaps has been written concerning this parasite than upon any other single Entozoon. The statements regarding its nature have, however, been most conflicting, as may be seen by reference to the works of Küchenmeister, Bremser‡, and Moquin-Tandon§. Up to within comparatively recent times its very animality has been denied, and that too by the distinguished French surgeon Larrey, who might well have acquired a more exact knowledge of its real nature during his residence in Egypt. He held that it was nothing more than a portion of "dead cellular tissue;" Richerand, that it was a "fibrinous concretion;" whilst Ambroise Paré declares that the effects produced by the presence of the worm are due only to a kind of tumour or abscess proceeding from "acidity of the blood." For other views equally novel, as well as for a history of the effects produced by the worm whilst lodged in the subcutaneous tissue of the body, and the medical treatment of the disease, also called *Dracunculus*, I would refer especially to the works before mentioned, as well as to other papers, to which reference will be made, in the Indian journals, as in the present communication I shall confine myself to the natural-history aspect of the question.

Gmelin‖ was the first to assign the Guineaworm its place amongst the true Helminthes, in the order Nematoidea; but a more thorough investigation of its anatomy will, I think, lead us to doubt the propriety of considering it a species of the genus *Filaria*.

It is endemic in the tropical parts of Asia and Africa, in the island of Grenada, with the small neighbouring Grenadine group, and doubtfully so in the island of Curaçoa; but it has not been met with anywhere in the tropical regions of the continent of America.

* Δρακόντια μικρὰ, Agatharchidas apud Plutarchum, Quæst. conviv. lib. viii. quæst. 9, Op. moral., ed. Düben, Paris, 1841, i. 894.

† Küchenmeister's 'Manual of Parasites,' translated by Dr. Lankester for Syden. Soc., vol. i. p. 390.

‡ Sur les Vers Intestinaux, French edition, by Grundler, p. 198.

§ Eléments de Zoologie Médicale, 1859, p. 333.

‖ Systema Nat., p. 3039.

It is not, however, universally distributed over the countries in which it is endemic, but is confined to certain limited areas, and is much more abundant at some times than at others—both which facts will be seen further on to have their special significance.

In the regions where it is prevalent, this parasite is met with principally in the subcutaneous tissue of persons who have exposed themselves to certain conditions known to be favourable to the production of the disease*. In about four-fifths or more of the whole number of recorded cases, these worms have been situated in the lower extremities, below the knees; and taking into consideration the fact that the people so affected mostly go about with bare legs and feet, and other evidence of a similar nature which will subsequently be alluded to, it is generally admitted at the present day that the worms are contained in some imperfectly known condition in the waters and damp places of these regions, and that they also in some unascertained manner make their way through the integuments of the body, and then acquire extraordinary dimensions in the subcutaneous or intermuscular cellular tissue.

Having once located itself within the body, the worm grows rapidly, without producing any signs of irritation, or attracting much notice, for a period varying from eight to twelve or fourteen months. This has been aptly termed by Mr. Busk the "latent period" of its existence. After a time, however, the head begins to make its way to the surface, and then commences the long category of troubles peculiar to the disease, till the parasite has been completely extracted.

The worms are usually stated to vary in length from six inches to ten or twelve feet, and to be about $\frac{2}{3}$rds of a line in thickness. When fresh, they are of a milk-white colour, and nearly cylindrical. All that have hitherto been examined have been found to be undoubtedly female and viviparous, with the exception of three specimens, to which allusion will again be made further on.

Having had six of these worms placed at my disposal for examination through the liberality and kindness of Professor Harley, of University College, I have availed myself of the opportunity of making a most careful investigation of their structure. But before stating the results of my own observations, I think it will be well to give a brief account of our previous knowledge on the subject. It is really surprising to find the ignorance which prevailed concerning the anatomy of this worm anterior to the writings of Busk and Carter, though this may be accounted for to a great extent by the comparative rarity with which these parasites are met with in Europe, and from many of the observers having had but one, and that an imperfect specimen for examination.

Rudolphi, in his earlier work†, has little to say concerning the anatomy of the Guinea-worm; indeed he confesses, "totius vermis anatome desideratur." The only positive characters he gives are, "Margine oris tumido, caudæ acumine inflexo," whilst in his later work‡ he speaks of the numerous young contained within the parent worm in the following terms:—"Filariæ nostræ prole quasi farctæ sunt, quod si harum longitudinem, illius vero minutiem spectas, fœtuum multa millium millia singulis tribuit. Oviductuum

* The Guineaworm has also been met with in dogs and horses.

† Entozoorum historia naturalis, Amstelodami, 1809, vol. ii. pars 1. p. 55.

‡ Entozoorum Synopsis, Berolini, 1818, p. 205.

indoles quoad particulas tantum examinari potuit, sed ab illa aliarum specierum eo recedere visa, quod tunicæ leves neque fœtuum velamenta fere ulla sisterentur, sed passim tantummodo inter innumeros fœtus grumosi quid adesset." In the body of this work, also, Rudolphi speaks of certain peculiarities in the shape of the anterior and posterior extremities of the worm as characterizing the two sexes, though, in an appendix, he retracts this statement, on finding, after more careful observation, that all the worms examined were female and proliferous.

Dr. Chapotin* gives the following account of the anterior extremity of *Filaria medinensis*:—"Examinée à la loupe, l'extrémité antérieure, légèrement renflée, m'a paru offrir, dans le centre un suçoir, sur les côtés duquel se voient deux petites protubérances arrondies," whilst the posterior extremity, he says, is constantly "terminée assez brusquement par un petit crochet contractile, et dont j'ai vu les mouvements."

M. Jacobson, in a letter to M. de Blainville†, narrates that, in the extraction of one of these worms, he accidentally wounded it with the point of the lancet, and from the opening thus made, he says, "découloit une matière blanche; mais ce que m'étonna le plus, c'est que le ver se vida, et que les parois de son corps s'affaissèrent." On submitting this white matter to microscopical examination, he found, not eggs as he expected, but that it consisted almost entirely of small actively moving worms. He says, "ce qui est presque inconcevable, c'est la quantité innombrable de vermicules dont le corps du dragonneau est rempli, sans que j'ai trouvé aucune trace de viscère qui les renfermeroit. . . . . . Sont-ce bien les petits du dragonneau? . . . . . ou bien, je n'ose presque pas faire cette question, le dragonneau ne seroit-il qu'un tube ou un fourreau rempli de vermicules?" He seems to have made no further observations upon the structure of the parent worm, though he gives figures of seven or eight of its countless progeny, to which I shall have again to refer.

Leblond examined a small fragment of a Guineaworm, one inch and a half in length—being one of the separate portions of the only specimen of the worm contained in the Musée d'Histoire Naturelle at Paris—and seems to have been the first and only observer, before Mr. Carter, who recognized the existence of both a genital and an alimentary tube. He says ‡, "Je l'ai fendu longitudinalement, et j'ai trouvé, au sein de l'enveloppe musculo-cutanée, un tube fibrineux gorgé de matière verdâtre, qui était évidemment une portion du canal intestinal; puis un autre tube également fibrineux éraillé, qui renfermait un nombre immense de jeunes filaires. J'ai dû regarder ce tube comme une portion des cavités génitales."

Professor Owen remarks§, "In a recent specimen of small size we have observed that the orbicular mouth was surrounded by three slightly raised swellings, which were continued a little way along the body and gradually lost. . . . . . The caudal extremity of the male is obtuse, and emits a single spiculum; in the female it is acute and suddenly inflected." He also notices two longitudinal muscular bands, and an external elastic

* Bulletin des Sciences Médicales, Mai 1810.

† Nouvelles Annales du Muséum, tom. iii. p. 80, 1834.

‡ Quelques Matériaux pour servir à l'histoire des Filaires et des Strongyles. Précis analyt. des travaux de l'Acad. Roy. de Rouen, 1835, p. 150.

§ Cyclopæd. of Anat. and Physiol., Art. "Entozoa," 1837, pp. 122, 143.

integument, but, after careful examination of three specimens, was quite unable to discover any trace of either generative or digestive organs. After briefly describing the external characters of the minute contained worms, he adds, "What is most remarkable is, that these embryos are not, as in *Strongylus* and the Nematoid genera above mentioned, enveloped in an egg-covering, nor are they included in a special generative tube, but float freely along with a granular substance in the common muscular envelope of the cavity of the body,"—an observation already made, as above cited, by Rudolphi.

In his more recent work*, Professor Owen is altogether silent as to the existence or non-existence of either generative or alimentary organs; but, speaking of the integument of the Nematoid worms, he says, "In the Nematoid parasites of the human subject and in almost all the order, it is more or less smooth: it consists of a thin, compact epidermis, and of a fibrous corium firmly attached to the outer transverse muscular fibres. The corium consists of decussating fibres." It will be seen hereafter that nearly all these statements are at variance with subsequent observations, and that Leblond's description was probably perfectly correct, though Professor Owen doubts its accuracy.

Rudolph Wagner partially examined two specimens of the Guineaworm, and has given a description of them with figures†, as an introduction to a commentary by Birkmeyer‡. He describes the head, with its four papillæ, and the hooked tail, but does not mention any difference in the size of the separate papillæ. He speaks also of an anal aperture at the inner curvature of the tail, serving at the same time as an outlet for the genital organs, and marks its situation in a figure. Seeing a white tube running through the whole extent of the body, he says, "Hoc intestinum pro ovario habui; nam ex incisionibus quas in variis corporis locis institui, fila tenuissima (fig. 5 *a*, *b*, *c*) extrahere potui, quæ quominus pro prole habeamus, nihil obstare videtur." The specimens were not further dissected, as they were destined for the Zoological Museum of Erlangen.

Dujardin§ gives no particulars concerning the anatomy of the Guineaworm, save that the mouth is simple and round, the tail a little acute and recurved, and that all specimens hitherto found have been female and viviparous.

Mr. Busk‖ gives a much fuller and more accurate account of the anatomy of the Guineaworm than any we have yet met with, and is indeed the first writer who has furnished us with anything like a detailed description of this interesting Entozoon. Owing to the great rarity of meeting, in this country, with a worm having its anterior extremity uninjured, he is not very certain about the anatomy of the head, but agrees with other observers as to the acutely inflected tail, and gives figures of different varieties.

He considers the integuments to be composed of two tubes, between which are contained the two longitudinal muscles. The external tube is a transparent, striated, elastic structure, whilst the internal is composed of a soft pulpy substance covered with a deli-

* Lect. on Comp. Anat. and Phys. of Invert., London, 1855.

† Wagner's is the only correct figure of the whole Guineaworm I have met with; but the anterior extremity is more blunt and abrupt, and the lateral papillæ larger, than in the specimens I have examined.

‡ Birkmeyer, De Filar. Medinensi Comment., Onoldi, 1838.

§ Hist. Naturelle des Helminthes, 1845, p. 44.

‖ Transactions of the Microscopical Society, vol. ii. p. 80, 1846.

cate membrane. This pulpy substance forms rounded lobular projections into the cavity of the body, and are considered by Mr. Busk as analogous to somewhat similar processes observed in *Strongylus* and *Ascaris*—the "*appendices nourriciers*" of Cloquet. After speaking of the longitudinal muscles, he says, "On each side of these muscular bands is a thin tract of a peculiar substance, and in the middle of each of these tracts is a more or less transparent line. The substance composing the tracts is minutely granular, and presents no other aspect under the highest power I have been able to employ. The transparent line appears to be a canal excavated in the granular substance, and is without visible walls." These granular tracts and canals I have been unable to discover in the worms examined by myself, and I shall further on have to suggest a possible cause of the difference.

Mr. Busk also describes a straight narrow intestinal canal of uniform calibre, extending from the mouth to near the posterior part of the body, where it has an obscure cæcal ending. He could discover no trace of an anal aperture. Around this narrow alimentary canal, between it and the rounded processes of the inner tube, he states that the *general cavity* of the body is filled with innumerable small worms, all of the same size, with more or less granular matter. He did not detect that these young worms were contained in a genital tube.

Mr. Carter has written three papers* of great interest on the anatomy of the *Dracunculus* and the "microscopic Filaridæ" of the island of Bombay; but it is to his last and longest communication, embodying the results of his most recent investigations, that I shall have principally to refer. The great care which Mr. Carter has taken, and the numerous observations he has made with a view to throw some light upon the early history of the Guineaworm, are most valuable contributions towards a scientific elucidation of this very difficult question; and if followed up by equally zealous attempts by others enjoying the same advantages, the enigma would doubtless soon receive a final solution.

He gives a full description of the anterior extremity, describing the mouth as terminal, punctiform, and surrounded by a smooth-bordered quadrangular space, and four papillæ—two large and two small. Tail presenting the usual hooked appearance, but no anal aperture. The body consists of a firm, cylindrical integument, lined with a coating of muscular fibres, within which again, loosely suspended by delicate filaments of cellular tissue, in the peritoneal cavity, are the alimentary canal and generative organs. The muscular coat, he says, is composed of delicate circular fibres, adhering to the external integument, between it and the two large longitudinal muscles. He also mentions "sarcoid" processes in about the last inch and a half of the anterior and posterior extremities, projecting from the integuments into the cavity of the body. Alimentary canal divided into œsophagus, intestine, and rectum, the two former being contained within a common peritoneal sheath, having a constriction at their point of junction, and of which that surrounding the œsophagus is the wider. The œsophagus, which is about two inches in length, and very narrow, has also a muscular sheath within the peritoneal. The diameter of the intestine itself is about three times as great as that of the œsophagus, with which it is continuous at the constriction in the peritoneal sheath. It is uniform in calibre,

* Trans. of Med. and Phys. Soc. of Bombay, 1853, p. 45; Annals of Nat. Hist., 3rd ser., vol. i. 1858, p. 410; Ibid. vol. iv. 1859, pp. 28, 98.

and the space between it and its containing sheath is occupied by dark-coloured oil-globules, supposed to be hepatic. The rectum is only about one-eighth of an inch long, very narrow, without any sheath, and attached to the ventral muscular band at the inner curvature of the tail. The organs of generation are described as consisting of a large cylindrical ovisac, extending through the body, of uniform calibre to within an inch and a half of either extremity, where it terminates abruptly at each end in a narrow blind tube; but no external communication or vulva could be discovered. The contents of this ovisac were innumerable vermicules, all of the same size, and some granules, which Mr. Carter considers as the remains of ovarian envelopes, though he has never been able to detect anything like a distinct membrane. He has never seen a male worm.

Mr. Carter considers that the structure of the contained young and also of the "microscopic Filaridæ" of the island of Bombay, as observed by him, agrees in all essential particulars (size, of course, excepted) with the account above given, save that the young of the Guineaworm have never any trace of generative organs. Full particulars of their anatomy will be found in the 'Annals of Natural History' for 1859.

I have examined six specimens of *Filaria medinensis*, all of which were taken from the lower extremities of a well-known surgeon of Bombay, by whom they were given to Dr. Harley. The specimens were all of the same age, though of different sizes—four being about thirty inches long, one only eighteen inches, and the other three feet long. All were female and viviparous, and perfect specimens, with the exception of one, in which the head was wanting; and their good preservation was probably owing to the method of their extraction by a native of Bombay, who, after making a minute aperture in the integuments, as nearly as possible opposite the middle of the worm, passed under its exposed body a small hook, and then by gentle traction, at the same time that the skin around was kneaded, each worm was extracted at a single sitting of perhaps an hour or less, instead of by the tedious process of rolling it daily round a small piece of wood.

As the manner in which this gentleman became affected with these parasites is pretty definite, both as to their mode of entrance and their age, I shall quote his account from a Report read to the Pathological Society of London by Dr. Harley.

After stating that he had been many years in Bombay, and never affected with Guineaworm, though accustomed often to be out shooting and drink freely of the water of wells, without being very particular as to quality, he says:—"At last, however, I one day discovered that I had what at first appeared to me to be varicose veins, but which in a day or two I found to be Guineaworms in my legs. At first I was at a loss to account for the presence of a Guineaworm in my body, till I remembered that one day, whilst out shooting, one of my boots burst, and being too impatient to wait till another pair was brought, I took off both boots and stockings and went on shooting barefooted over a piece of swampy stubble; and I believe that the worms entered my feet on this occasion; for after an interval of six or eight months the first worm appeared, and that is about the time generally allowed* for the worms to come to maturity in the human body."

I will now proceed to give the results of my own observations.

* As a rule, the period is certainly longer than this.

External Characters.—Worms varying in length (Pl. XXI. fig. 1) from eighteen inches to three feet, and from $\frac{1}{10}$th to $\frac{1}{15}$th of an inch in diameter, of a milk-white colour (or light straw when kept in spirits), mostly quite smooth, but sometimes slightly annulated by rugose contractions; cylindrical, or more or less flattened laterally, and tapering gradually towards both extremities. About $\frac{1}{20}$th of an inch from the posterior extremity the body becomes more abruptly narrowed, and terminates usually in a sharply curved tail or point. In some cases, however, the tail is straight, and in others, as pointed out by Carter, it is more acutely bent upon itself, and seems connected to the adjacent portion of the body by a delicate membrane (Pl. XXI. figs. 4, 5, 6, 7). On opposite sides of the body are seen, extending along its whole length, two opaque bands, corresponding with the great dorsal and ventral muscles, and two more translucent intermuscular spaces. For a short distance from the anterior extremity, two narrow, white lines may also be seen running along the body, each being midway between the lateral spaces. No vulva discoverable; anal aperture doubtful—if present, situated in the concavity of the tail.

The integuments are so elastic, that the worm may be stretched to nearly twice its natural length.

Examined with a low power of the microscope, the head presents the following characters:—Mouth punctiform, about $\frac{1}{2000}$th of an inch in diameter, situated in the centre of a somewhat flattened terminal disk, and surrounded by a circular eminence or lip* (Pl. XXI. fig. 2) $\frac{1}{270}$th of an inch in diameter. Around the mouth are four papillæ, two of which (much larger than the others, and also nearer the oral aperture) are continuous with the narrow white lines before mentioned, and are therefore situated vertically; whilst the two lateral, more remote from the mouth, not prominent, and scarcely more than opaque spots are situated at the commencement of the gradually widening, lateral, intermuscular spaces. The upper and lower papillæ are prominent, and well seen in outline (Pl. XXI. fig. 3), being about $\frac{1}{1000}$th of an inch in height, $\frac{1}{500}$th of an inch in breadth at the base, and $\frac{1}{200}$th of an inch apart, whilst the small lateral papillæ are $\frac{1}{125}$th of an inch apart. The mouth and papillæ are situated in the midst of an opaque, whitish, quadrangular space, about $\frac{1}{100}$th of an inch from side to side, the papillæ being situated towards the angles, from which also proceed the two opaque-white, gradually widening, lateral spaces and two narrow dorsal and ventral lines, which are only about $\frac{1}{2000}$th of an inch wide†. Between the white lines surrounding the head may be seen longitudinal muscular fibres—the origins of the four longitudinal muscles.

Integuments.—The integuments of the worm are composed of a transparent, almost structureless, chitinous substance, arranged in a number of concentric lamellæ, presenting peculiar linear markings. Altogether it forms a very tough and highly elastic cylindrical investment.

Analogy would point also to a deep cellular layer of integument; and though I have

* The circular rugæ of Carter.

† It will be seen afterwards that this opaque quadrangular space and four converging lines correspond to the quadrangular commencement of the sheath of the alimentary canal and its crucial mesenteric process going (Pl. XXI. fig. 13) to the intermuscular spaces.

not been able to discover any trace of it, this may be due to the fact that the worms examined were not recent specimens, but had been preserved in spirits of wine.

The integuments of the Nematoid worms have been described by Von Siebold, Dujardin, Owen, and other writers, as composed of a structureless epidermis, and a corium made up of layers of longitudinal and oblique decussating fibres; but, after a most careful examination, I have been unable to discover that any such distinction can be drawn between the different portions of the integument of the Guineaworm—the whole thickness being almost identical in structure, and apparently composed of successive excreted * epidermic layers. I think it will be possible to show also that what appear to be layers of decussating fibres, in the Guineaworm and some other Nematoids that I have examined, are not such in reality. A true corium or enderon, as before stated, I have failed to recognise.

The average thickness of the integuments is $\frac{1}{400}$th of an inch, though it is considerably thinner towards either extremity of the body. It may be divided into two principal parts—an external portion with transverse markings, constituting about one-half of the whole thickness, not divisible into lamellæ; and an internal portion, made up of about thirty very delicate lamellæ, having longitudinal or oblique markings.

The *external* portion of the integument is composed of a thick, chitinous layer, tough, elastic, transparent, and perfectly structureless, save that it presents transverse markings at intervals. These lines (Pl. XXI. fig. 8) have an average distance of $\frac{1}{1400}$th of an inch from one another, though near either extremity of the worm they are as little as $\frac{1}{6000}$th of an inch apart, the distance between the lines gradually diminishing up to this point. They are about $\frac{1}{7000}$th of an inch in breadth, and easily recognisable when most of the lamellæ covering them internally have been stripped off. They vary slightly in their distance from one another, are wavy, but do not preserve any parallelism between themselves; and moreover they frequently join one another or bifurcate, so that they by no means form perfect circles round the body.

The external surface of the integument seems perfectly smooth, there being no appreciable depressions corresponding to the annulose markings such as may be seen to a slight extent in *Ascaris lumbricoides* and *A. mystax*; but there is some considerable alteration in the refractive power of the membrane in these situations, as when seen a little beyond the proper focal distance these markings become most distinct, appearing as bright white lines.

The *internal* portion is composed of three different sets of very delicate lamellæ, each being transparent, glass-like, and structureless with the exception of certain faint rectilinear markings at regular intervals, which correspond in breadth to those between the transverse lines of the outer portion of the integument, viz. about $\frac{1}{1400}$th of an inch. These lines also seem due to some variation in structure producing an alteration in the refractive power of the lamellæ.

Each set appears to be composed of about ten superimposed lamellæ, the markings of the external being longitudinal, whilst those of the inner two sets are oblique, in opposite directions. When seen superimposed, the markings of the middle set of lamellæ are found to intersect those of the internal set at an angle of about 85°, or nearly at a

* Huxley, Art. "Tegumentary Organs," Cyclop. of Nat. & Phys. pt. xlvii. 1855, p. 484.

right angle, leaving diamond-shaped spaces between the points of intersection, and constituting a system of spirals in opposite directions round the body of the worm (Pl. XXI. fig. 10).

These linear markings preserve a nearly uniform distance from one another, and pursue a straight course, without dividing or communicating in any way, similar to those of the external portion. And there is this in common with the three sets, that the lines, whether longitudinal or oblique, of the several superimposed lamellæ do not correspond in position; so that when those of the most superficial lamellæ are in focus, there may be seen generally about nine fainter lines of deeper lamellæ shining through, and closely filling, what would otherwise be each clear interlinear space (Pl. XXI. fig. 9).

This appearance is very deceptive, and gives *each set of lamellæ* the aspect of a *single striated or fibrous membrane*, as I, for some time, believed them to be, until on examining one of these supposed membranes with a high power, I discovered that a portion of a very delicate lamella had been torn off from those subjacent, leaving a toothed edge. The linear markings of this superficial lamella could be traced distinctly up to the torn edge; and in this situation also the lines of the uncovered portion of the subjacent layer were plainly visible, corresponding with a portion of the interval between the lines of the lamella above (Pl. XXI. figs. 11, 12). This I have frequently seen since; and the observation evidently affords the key to the arrangement of these markings generally: and the fact is most important, as showing that this anomalous appearance of fibrous membranes in the integuments of these worms is a mere optical delusion, and that the membranes have no real existence, but that instead there exists a series of delicate and successively excreted chitinous lamellæ, having linear markings in definite directions—an arrangement fully in harmony with what we know of other analogous structures.

The two internal sets of lamellæ may be readily isolated by tearing a small piece of integument to pieces with needles; but the external set with the longitudinal markings is very difficult to separate from the outer portion of the integument, to which it is intimately adherent. These longitudinal lines are not so rectilinear as the oblique, and they are all rather difficult of detection, requiring a high power to distinguish those of the superficial lamellæ plainly from those of the lamellæ beneath. In this respect they are very different from the transverse markings of the outer half of the integument,—the greater distinctness of these being apparently due to the fact that the alteration in texture, on which the markings depend, extends through the whole thickness of this outer portion, whereas the lines which have a similar direction in each of the three sets of lamellæ do not correspond in position, and, being produced by an alteration in the texture of one delicate lamella only, are necessarily very faint.

There seems to be some slight difference, too, between the texture of this thick outer portion and the internal lamellæ, since its torn edge is generally even, whilst that of the lamellæ is always sharply jagged and toothed.

The structure of the integuments of *Ascaris lumbricoides* and of *A. mystax* corresponds, in its general nature, with that of the Guineaworm just described, though it differs in several minor and unimportant details. The markings of all the layers are much more rectilinear and distinct in both these worms. They possess an external coat with circular or transverse lines, the same as in *Filaria medinensis*, but, unlike it, they have no series of lamellæ with longitudinal markings, intervening between this outer coat and the lamellæ with oblique markings. When seen superimposed, the oblique lines of these lamellæ are found to intersect each other and the transverse lines of the outer coat at a very acute angle. Internal to this, in *Ascaris lumbricoides*, there is also what appears to be a single delicate lamella, with very faint and close longitudinal markings; but I have not been able to discover anything similar in *A. mystax*. The lamellæ with the oblique markings do not seem so numerous in either of these species as in the Guineaworm, and the external portion constitutes about three-fourths, instead of one-half, of the whole thickness of the integument. The integuments of these worms also are not so favourable for examination as that of the Guineaworm, on account of the extreme difficulty in isolating their component parts.

Muscular System.—This is composed of four powerful longitudinal muscles firmly attached to the inner integumental layer, two of which occupy the dorsal and two the ventral region. They are made up of non-striated muscular tissue. As the longitudinal fibres run along the convexity and the concavity of the tail respectively, and the intestinal tube will afterwards be seen to terminate in the midst of the fibres occupying the concavity, as first pointed out by Mr. Carter, we must look upon these as ventral, and those along the convexity as dorsal, whilst the curve of the tail is thus ascertained to be in the median longitudinal vertical plane of the body, having a direction from above downwards.

Only two longitudinal muscles have been described by other observers; but I think a more careful examination, particularly of the anterior extremity of the worm, will show that there are in reality four of these muscles, as in many other of the Nematoidea, two being dorsal and two ventral. The origins of the four muscles completely surround the head with a thin layer of fibres, the boundaries of each being marked off by the four crucial lines (Pl. XXI. fig. 13). The two dorsal, running close together for two or three inches, one on each side of the middle line, then become fused as it were into one great muscle—though a trace of the original division continues apparent throughout the whole length of the worm, and becomes again rather plainer towards the tail. The two ventral muscles are arranged in just the same manner; so that a broad, lateral, intermuscular interval is left on each side between the dorsal and ventral group, equal in breadth to one-sixth of the circumference of the body. The four muscles are all of nearly the same size, each being of just the same breadth as one of the lateral spaces (Pl. XXI. fig. 19). Each is composed of fasciculi of very fine fibres, about $\frac{1}{40000}$th of an inch in diameter, whilst the breadth of the fasciculi themselves is about $\frac{1}{500}$th of an inch (Pl. XXI. fig. 24). Frequent interchange of fibres takes place between contiguous fasciculi (Pl. XXI. fig. 23).

The arrangement of the muscles and their fasciculi may be well seen in the series of transverse sections shown in Pl. XXI. figs. 13–21.

The four muscles, after leaving the head, soon acquire a perceptible thickness; and it may be seen that the adjacent borders of the two dorsal and two ventral muscles respectively are very thin, whilst each gradually increases in thickness towards its free border bounding the lateral spaces. The irregularity of the inner surface of the muscular bands, owing to the arrangement of the fibres into prominent fasciculi, is very evident for about the first two inches from the head. Further on the fasciculi are less prominent, and, the muscles acquiring a more uniform thickness, each pair becomes fused, apparently, into one great muscle, occupying the dorsal and ventral regions respectively. Where much compressed by the distended ovisac, the muscles seem to undergo partial absorption * (Pl. XXI. fig. 20).

Many contradictory statements have been made both as to the presence and arrangement of transverse muscular fibres in the Nematoid worms; and though Mr. Carter states that they occur in the Guineaworm, I have failed, after most careful search, to discover any trace of them. The transverse markings of the integument, dimly shining through the peritoneal membrane, present a very deceptive appearance.

Nervous System.—The only traces of a nervous system that I have been able to discover are two delicate ganglionated cords, extending the whole length of the worm, one occupying the centre of each lateral intermuscular space. They are situated, with a minute vessel to be afterwards described, in the midst of a pulpy substance, between the peritoneum and inner layer of integument, on which they lie. Some slight change, too, is produced in the texture of the integuments at this place, by which its refractive power is increased; for when quite bared on the inner side, and seen a little beyond the proper focal distance, a bright line is observed, of the same position and breadth as the nervous cord which had lain over it.

I have traced these cords close up to both extremities of the worm, but have not been able to discover any connecting central ganglion anteriorly, or distinct termination posteriorly. The two cords pursue a slightly wavy course, and seem to give off no branches in any part of their length. Each is about $\frac{1}{1400}$th of an inch in diameter, and marked with distinct, elongated swellings, or ganglia, at intervals of about $\frac{1}{13}$th of an inch (Pl. XXI. figs. 22, 25, *c*, *c*, 26). The average breadth of the ganglia, at the widest part, is $\frac{1}{400}$th of an inch, each having an irregularly crenated margin †. The intervals between the swellings are not perfectly equal, neither do the ganglia on opposite sides of the body correspond in longitudinal position.

* The powers of locomotion possessed by this worm whilst still in the body seem considerable; they may sometimes be felt quite superficially beneath the skin, and in a few days have disappeared entirely from their former situation, having either penetrated deeply between the intermuscular planes of cellular tissue or else moved considerably in the subcutaneous tissue, as in the following case related by Dr. Smyttan in the 'Transactions of the Medical and Physical Society of Calcutta,' vol. i. p. 182. He says, in the case of a Lieut. F——, "The worm could be distinctly traced under the skin at the top of the left shoulder. By-and-by it found its way to the elbow, where it was as distinct, and in the course of a few weeks made its way by gradual progress to the wrist, from which place it was extracted." This power of locomotion accounts perhaps most feasibly for the very exceptional case quoted in the same paper, in which two Guineaworms were found alive in the cavity of the abdomen—one attached to the peritoneum, on the surface of the liver, and the other to that of the kidney, but otherwise floating freely amongst the coils of intestine. This is the only recorded case I have met with of these worms being found within any of the great cavities of the body.

† A bright, highly refracting body, about $\frac{1}{2000}$th of an inch in diameter, is seen in the centre of nearly all the ganglia; but careful examination shows that the dot is in no way connected with the ganglion, but belongs to a faintly outlined gland-cell, to be afterwards described, lying on its surface.

Much doubt and uncertainty prevails amongst anatomists concerning the nervous system of the Nematoid worms; so that little or nothing definite can be said with regard to its arrangement in the order generally.

Walter's* elaborate and precise observations on the anatomy of *Oxyuris ornata* seem to show that this animal possesses a most complex and highly organized nervous system, consisting of cerebral and caudal ganglia, from which, and from the cords connecting them, numerous branches are supplied to all parts of the body. But it would be desirable that such observations should be confirmed by other anatomists, since in another species of the same genus, a common human parasite, *Oxyuris vermicularis*, no nervous system has as yet been discovered.

Blanchard†, following Cloquet‡, in his description of *Ascaris lumbricoides* considers it to possess a dorsal and a ventral, median, longitudinal, nervous trunk, and, moreover, considers this to be the typical arrangement of the nervous system in the Nematoidea. This opinion is shared by many other anatomists; but, when speaking of the circulatory system of the Guineaworm, I shall presently point out why it appears to be untenable.

What I have just described as existing in *Filaria medinensis* agrees with the distribution of the principal nervous trunks in the Nemertidæ and some of the Trematode worms; and a careful examination of recent specimens of the Guineaworm may perhaps hereafter show some central connecting ganglia anteriorly, and thus render the resemblance more complete.

Organs of Circulation.—The representatives of this system met with in the Guineaworm belong, doubtless, as in its allies the Tæniadæ and the Trematoda, rather to the "water-vascular system" and the function of respiration than to the propulsion of true blood; yet still, in the present imperfect state of our knowledge, I have thought it better to describe them under the above head.

Four equidistant longitudinal vessels extend through the whole length of the body, situated, like the nervous cords, in the midst of a pulpy substance beneath the peritoneal membrane. The two which occupy the median line of the dorsal and ventral regions respectively are much larger than the two lateral vessels. All four extend from one extremity of the body to the other; but how they terminate in either direction I have been unable to determine, neither have I succeeded in finding any external aperture with which they communicate, such as is generally met with in connexion with the water-vascular system of the Annuloidea.

The dorsal and ventral vessels are in all respects similar, occupying the median intermuscular interval in each situation (Pl. XXI. fig. 22, *e*, *f*). They have an opake-white colour when seen with a powerful lens; but when examined under the microscope by transmitted light, they are found to be very delicate thin-walled tubes (Pl. XXI. fig. 28). They pursue a very undulating course, and are by no means of one uniform calibre, being frequently bulged at intervals. Throughout the greater part of their extent they are

* Zeitsch. für wissen. Zoologie, vol. viii. 1857, p. 163.

† Ann. des Sciences Naturelles, 3ième série, tom. xi. 1849, p. 138.

‡ Anatomie des Vers intestinaux, Paris, 1824, p. 38.

about $\frac{1}{666}$th of an inch in diameter, but anteriorly and posteriorly are reduced to $\frac{1}{1000}$th of an inch.

The lateral vessels are very much smaller, being only about $\frac{1}{6000}$th of an inch in diameter, and near the extremities of the body not more than $\frac{1}{10000}$th of an inch. They are situated outside the nervous cords, and may be seen through their substance pursuing a gently undulating course and having a uniform double contour (Pl. XXI. fig. 26). These vessels may sometimes be seen lying on the integuments after the nerve has been stripped off, and on one occasion I saw the broken extremity of a vessel distinctly projecting alone from the membrane on which it was lying.

In the specimens of Guineaworm examined by Mr. Busk, he did not discover any vessels in the situations I have described, but alludes to what appear to be four lacunar canals, one on each side of the dorsal and ventral muscular bands, in the middle of peculiar tracts of granular substance. I have met with nothing corresponding to this in the specimens examined by myself.

What I have described as dorsal and ventral vessels in the Guineaworm, correspond in position and general appearance with the dorsal and ventral nerves of Blanchard, Cloquet, and other anatomists, in *Ascaris lumbricoides*; but when portions of these structures are submitted to the microscope and examined by transmitted light, they are found to present important differences.

In *Ascaris* we find a tube with irregular swellings at varying intervals, composed of a delicate investing membrane, closely packed with small, roundish, highly refracting, fatty-looking particles. The well-known lateral cords in the same worm are three or four times as thick as those just described, and present a distinct channel or lacunar passage running through their centre, but in other respects are precisely similar, being made up, like them, of the same bright fatty-looking particles contained within a homogeneous membrane. I think, however, after the most careful examination, that there are also indistinct traces of a lacunar passage in the dorsal and ventral cords.

I have found four bodies essentially similar to these in *Ascaris mystax*; and, according to Blanchard, they are to be met with in most Nematoids*.

Professor Huxley† has described, in an *Oxyuris* of the Plaice, two contractile vessels communicating with the exterior and lodged in lateral cellular bands, which are doubtless homologous structures with those just mentioned as existing in *Ascaris*.

There can be little doubt, then, that these lateral cords are in some way connected with the development of a water-vascular system; and considering that the dorsal and ventral cords have exactly the same histological characters, I see no reason why these latter should be held to belong to the nervous system, even had we not the further evidence before us which the Guineaworm presents. But here, in the precise situation of these

* Walter (*loc. cit.*) describes four such bodies in *Oxyuris ornata*, and terms them "fat-canals" (Fettschläuche). He thinks they are in some way connected with the development of the animal, as these structures are most distinct and densely crowded with fatty particles when the animal is young, but that the latter gradually disappear with advancing age and maturity.

† Lect. on Gen. Nat. Hist., Med. Times and Gaz. 1856, vol. ii. p. 384.

so-called nervous cords, we meet with vessels that do not contain a trace of the characteristic fatty particles met with in *Ascaris**.

Filaria medinensis would seem to present us with a higher type of development, in which lacunar channels in the axis of peculiar "fat-canals" are replaced by distinct walled vessels.

Glandular System.—Lining the whole interior of the body is a bed of pulpy granular matter, containing numerous interspersed gland-cells. This system is most highly developed dorsally and ventrally, especially in the anterior part of the body, where it is situated on the corresponding muscles, and forms distinct circumscribed projections; but in the lateral regions, where it lies on the inner layer of integument, no regular projections can be seen. In both situations its inner boundary, or investing membrane, seems formed by the peritoneum lining the general cavity of the body.

For about two inches from the anterior extremity, over the dorsal and ventral muscles, well-marked glandular processes (Pl. XXII. fig. 29) are met with, projecting into the cavity of the body. They vary much in shape as well as size, being either flask-like, ovoidal, oblong, or quite irregular in form; and whilst those situated in the middle line, next the dorsal and ventral vessels, are very small, they gradually enlarge outwards towards the free borders of the muscles.

To the naked eye and by reflected light these processes are of an opaque milk-white colour; but when examined under the microscope by transmitted light, each is seen to be composed of a very delicate limiting membrane containing fine granular matter and a distinct spherical cell varying from $\frac{1}{1000}$th to $\frac{1}{350}$th of an inch in diameter, more densely crowded with the granular material, and having a central dot or nucleus about $\frac{1}{2000}$th of an inch in diameter (Pl. XXII. fig. 30). These projections are apparently connected at their base with an areolar arrangement of filamentous tissue, lying on the surface of the muscles—the areolæ corresponding in size with the processes with which they are connected.

Sometimes near the posterior extremity distinct projections are also met with; but throughout the greater portion of the body the muscles are lined with a comparatively smooth layer of more equal-sized glands, having a beautiful mosaic-like arrangement (Pl. XXI. fig. 27). Where much pressed upon by the distended genital tube, this layer wholly disappears (Pl. XXI. fig. 20).

Opposite the lateral spaces I have not been able to trace any arrangement into separate glands, the highly granular nucleated cells in that situation seeming to be dispersed, at intervals, through a thin stratum of the pulpy substance†, though, from a figure given by Carter in the Transactions of the Bombay Medical Society, I imagine the tessellated

* There is just a possibility that these dorsal and ventral vessels of the Guineaworm may be collapsed canals from which all the fatty particles have been absorbed, as is stated to occur late in life in *Oxyuris ornata*; but all I can say is, that such absorption does not take place in *Ascaris lumbricoides*, as I have never seen any difference in the quantity of these fatty particles in many specimens that I have examined; neither can they have been dissolved out by spirit, as they may be found as numerous as ever in specimens of *Ascaris* which have been three times as long in spirits of wine as the Guineaworms examined.

† Near the tail and in other parts of some of the specimens examined, the only trace of these cells was a faint oval or circular outline, with one or more bright, highly refracting bodies enclosed.

arrangement into distinct glands must, in recent specimens, prevail in the lateral spaces as well as over the muscles.

These processes are doubtless, as suggested by Busk, analogous to the "appendices nourriciers" of Cloquet, described by him in *Ascaris lumbricoides* and also existing in *Strongylus gigas*. In the Guineaworm, as in *Ascaris*, they are more especially developed over the surface of the muscles, though those of *Ascaris* differ in the fact that they are much more regular in form, and also that the largest processes are situated in the median line of the dorsal and ventral regions, whilst the reverse obtains in *Filaria medinensis*. In intimate structure, too, the processes in *Ascaris* are not so firm and solid, and contain distinct areolæ as well as granules in their interior, whilst neither in the fresh nor preserved specimens examined have I been able to detect the central nucleated cell, which is constant in the Guineaworm.

This extensive glandular system, existing in the simplest and most elementary form, is perhaps concerned with the absorption and elaboration of the nutritive fluid or blood contained in the general cavity of the body, and with which it is brought into contact throughout its whole extent.

Besides this system of glands, I may perhaps mention in this place the collection of fat-cells to be presently described as surrounding the alimentary canal. These, Mr. Carter believes, have an hepatic function; and if so, they would also be subsidiary to the absorption and elaboration of fluids contained in the intestine, and thus be intimately connected in function with the extensive glandular system just described.

Organs of Digestion.—The alimentary canal consists of a very narrow œsophagus and a wider intestine presenting no distinct stomachal dilatation, and throughout its whole extent enclosed in a loose peritoneal sheath, on which distinctly flattened epithelial cells can be recognized. The œsophageal portion is also lined with a distinct layer of muscular tissue. In its course through the body the intestine is for the most part unattached to the parietes, and winds several times round the genital tube before terminating, about $\frac{1}{60}$th of an inch from the posterior extremity, in the concavity of the tail.

The œsophagus is from one and a half to two inches in length, and very narrow, having an average diameter of about $\frac{1}{500}$th of an inch, though it varies somewhat in different parts of its course. Its walls are comparatively very thick, and appear to be muscular—the central canal being only $\frac{1}{2000}$th of an inch wide, though very likely this is narrowed by the action of the spirits of wine.

This narrow œsophagus is contained in a much broader musculo-peritoneal sheath (Pl. XXII. figs. 31 & 33 ı), together with a consistent mass of white granular matter*. For about one-sixth of an inch behind the oral aperture the sheath is attached to the parietes of the body by four strong, crucial, mesenteric processes going to the inter-muscular spaces, from the angles of the sheath, which in this situation is quadrilateral (Pl. XXI. fig. 13 *b. d, d, d, d*) instead of being more or less rounded as in the remaining

* This fine granular matter is precisely similar in appearance to that met with in the general cavity of the body; so that I am disposed to regard it merely as the remains of a fluid containing a large quantity of organic matter in solution.

part of its course. A similar arrangement of mesenteric processes is said to be met with in *Strongylus gigas*. For about the first inch the peritoneal sheath is maintained in the centre of the body by means of the glandular processes with which it is in contact on all sides. It varies much in size in different parts of its course, though the average breadth is about $\frac{1}{70}$th of an inch. It is less than this just behind the mouth, and for the last half-inch also tapers to about $\frac{1}{117}$th of an inch in diameter, which is the same size as that surrounding the commencement of the intestine. At the termination of the œsophagus there is a distinct constriction of the sheath (Pl. XXII. fig. 33 $_2$); and although this undergoes no change in size, the contained tube does.

The whole of this œsophageal sheath is lined with a layer of muscular tissue composed of longitudinal intercommunicating fasciculi, the separate fibres of which are about $\frac{1}{15000}$th of an inch in breadth.

The intestine at its commencement is twice or three times as broad as the œsophagus, being $\frac{1}{166}$th of an inch in diameter (Pl. XXII. fig. 33 $_2$); it has much thinner walls, and, as well as its containing sheath, continues of a nearly uniform size throughout its whole extent, only tapering somewhat towards the posterior extremity, where the intestinal tube is $\frac{1}{222}$nd, and its sheath $\frac{1}{188}$th of an inch in diameter.

The whole intestinal canal is surrounded, between it and its sheath, by a collection of various-sized, highly refracting fat-cells, which have been before alluded to, and which may be considered to have an hepatic function*. These cells commence at the constriction between the œsophagus and intestine, and are continued, together with the peritoneal sheath, quite to the termination of the intestine (Pl. XXII. fig. 33 $_4$), though Mr. Carter supposed that both were absent from the terminal portion, judging from what he had seen of the structure of the "microscopic Filaridæ."

I quite agree with Carter, that the intestine terminates in the concavity of the tail, where it is attached to the middle of the ventral muscle (or rather in the median line between the *two* ventral muscles); and though neither of us has succeeded in satisfactorily recognizing an anal aperture in this situation, yet I think there can be little doubt that such a minute aperture does exist, more especially after the independent observation of Wagner†, who, not knowing where the intestinal canal terminated, observed a minute opening precisely in this situation, as shown by his figure.

Organs of Generation.—The genital apparatus consists of a large, highly organized sac or uterus, distended with young *Filariæ* and a little fine granular matter. It occupied the whole of the peritoneal cavity in the specimens examined, except from one to two and a half inches from the anterior extremity and about a quarter of an inch or less from the tail. Both anteriorly and posteriorly, this large sac terminates abruptly in a small tube twisted several times round the intestine (Pl. XXII. figs. 34, 35), or forming a knotted glandular-looking mass. Each tube is about one inch in length, and the two are in every

* May they not also be homologous with the peculiar "*corpus adiposum*" described by Meissner (Zeitsch. für wissen. Zoologie, Bd. v. 1854) in connexion with the alimentary sheath of *Mermis albicans*?

In the portions of the alimentary canal of the specimens examined which had been compressed by the genital tube, only an indistinct trace of these cells could be detected (Pl. XXII. fig. 33 $_3$).

† *Loc. cit.*

way alike. In common with other observers, I have been unable to discover any vulva or vagina; but the symmetrical formation of the two extremities of the genital tube leads me to believe that the genital aperture, if it does exist, must be situated a short distance behind the middle of the body—regarding the two terminal tubes as ovaries, and the large sac as a double oviduct or uterus, which by its enormous development appears to form one great tube, and which has obliterated the vagina*. This point could only be satisfactorily cleared up by the examination of very young specimens, before the genital apparatus had assumed such an unusual development.

Mr. Carter appears, however, to have examined worms of different ages, and is positive that there is no proper outlet to the generative organs. His observations go to prove that the distended genital tube in the mature worm is protruded through a rupture of the integuments near the mouth. If this be the usual case, the specimens I have examined cannot have been full-grown, as in them the termination of the genital tube was at least one inch, and in one specimen $2\frac{1}{2}$ inches, from the anterior extremity.

This process of giving exit to the young or the ova by rupture of the integuments and genital tubes, seems by no means an unusual occurrence in the Nematoid worms, judging from the statement of Rudolphi†, who, speaking of *Cucullanus*, says:—"Ovula, verme quieto, per intervalla ex volva pullulent, quin eodem disrupto, quod sæpe accidit, ovula vel embryones ex ovariis prolapsis pariterque ruptis vi quâdam et undatim protrudantur."

In the specimens I have examined, throughout the greater part of the length of the worm the uterus was distended to such an extent as to have become closely adherent to the parietes of the body, the alimentary canal being pressed flat between the two. This adhesion between the coats of the uterus and the parietes of the body is, throughout nearly its whole extent, so intimate that they cannot be readily separated till after maceration in water for a day or two; and even then the genital membranes can only be scratched off piecemeal by needles after the body of the worm has been slit open. For about one or two inches, however, from either blunt extremity of this large sac it is not adherent to the peritoneum, but is separated by some fine granular matter, and can be removed entire.

Such being the condition of the genital tube, if any portion of the worm not bordering upon either extremity be examined, the observer is liable to entertain most erroneous opinions concerning its anatomy, as, on slitting open the integuments, the adherent uterus is also cut (Pl. XXI. fig. 20), and a consistent cylinder of opaque white matter only is met with, which, on being broken up and submitted to the microscope, is found to consist wholly of young *Filariæ* and a little fine granular matter—not a vestige apparently of a containing tube or alimentary canal being visible. This, I have little doubt, is the explanation of Professor Owen's and M. Jacobson's statement that the worm consisted of a mere sac with contained young, but without any trace of either genital or intestinal

* One cannot but be struck with the extremely abortive condition of the ovarian tubes proper of the Guineaworm, as compared with the development of the uteri or ovarian ducts; and this is the more remarkable when we consider that these are precisely the parts of the female generative organs which are most developed in the Nematoids generally. In *Ascaris lumbricoides* each ovary measures, according to Cloquet, about *four feet*, instead of *one inch*, as in *Filaria medinensis*.

† Entozoor. Hist. Nat. i. p. 310; *vide* also *ib.* ii. pt. 1, p. 105.

tubes. Mr. Busk, too, did not recognize the genital tube, and hence his assumption (most probable in such a case) that the Guineaworm was one of the intermediate or "nursing" forms of a worm, similar to the parent of *Cercariæ* amongst the Trematoda. I was also much deceived at first by this peculiar arrangement, and unable to recognize any genital or intestinal tube, owing to the usual situation of the latter alongside one of the longitudinal muscles (Pl. XXI. fig. 22 *d*), where it for some time escaped observation, appearing only as a faint band of granular matter; and it was not till on one occasion I observed this tube twisted on itself, and crossing one of the lateral spaces, that I saw what it really was, and obtained an insight into the correct anatomy of the worm. I have nowhere met with any reference to this great development of the genital tube, and its close adherence to the parietes of the body.

I will now describe the structure of the uterus and ovarian tubes.

The uterus is a powerful and highly organized sac, made up of four distinct coats—an external or peritoneal investment, a transverse or circular layer of elastic tissue, a layer of longitudinal muscular fibres, and a simple internal membrane. The peritoneal coat is a delicate membrane, having roundish or oval, nucleated, flattened epithelial cells scattered over its surface, varying from $\frac{1}{3000}$th to $\frac{1}{600}$th of an inch in diameter (Pl. XXII. fig. 36). The next coat is composed of a beautiful fibrous reticulated network of elastic tissue, as perfect as that met with in the middle coat of an artery, the fibres of which vary from $\frac{1}{2000}$th to $\frac{1}{1000}$th of an inch in diameter (Pl. XXII. fig. 37). The fibres have a circular arrangement, and form a continuous investment of the whole uterine sac, stopping short abruptly at the ovarian tubes. This coat is not easy to isolate, as the fibres mostly break off in the same line as the membranes on either side of it; occasionally, however, a portion may be seen projecting alone beyond the membranes. The network can be seen indistinctly through the external or internal coats. The third layer is an investment of very delicate longitudinal muscular fibres, lying close together, the individual fibres not being more than about $\frac{1}{30000}$th of an inch in diameter (Pl. XXII. fig. 38). The internal coat is a delicate, homogeneous structure, serving the purpose of a mucous membrane.

The small terminal ovarian tubes are rather less than an inch in length, and about $\frac{1}{90}$th of an inch in diameter. They are pretty constant in size throughout their extent, tapering only slightly towards either extremity (Pl. XXII. figs. 34, 35). The free extremity is blunt and rounded or imperfectly lobed. Their structure is totally different from that of the large uterine sac, and seems closely to resemble that of the intestine, with which it agrees also in general aspect. There seems to be an inner homogeneous membrane, which is closely invested by a peritoneal covering prolonged from the uterus, but no intervening muscular or elastic coats. Amongst the granular contents of these tubes may be detected multitudes of nuclei and cell-germs, and in one or two instances I have seen one or even two of the full-sized young contained within them, but they are never distended in the same way as the large uterine sac is.

This structure of the genital organs seems to agree closely with what Meissner * has described in *Mermis albicans*, if we omit the absence of a recognized vulva and vagina in *Filaria medinensis*.

* *Loc. cit.*

Young Filariæ.—The whole uterus is distended with a dense mass of young of pretty nearly the same size, whilst intermingled with them in every part are crowds of germs, or "pseudova"*, and all intermediate grades between these and the most perfect form of the young worm met with within the body of the parent. Mixed up with these young, in the various stages of their development, are the remnants of the membranes which at first enveloped them, and some fine granular matter.

The pseudova are doubtless formed in part in the small terminal ovarian tubes; but, from the totally irregular manner in which they are distributed amongst the more mature young, there can be little doubt that they are, during the whole period of the growth of the parasite, produced with great activity everywhere throughout the length and breadth of the uterus†. At Mr. Busk's suggestion, I employed some of the Magenta-solution in the examination of the uterine contents, and, from the fact of its colouring all the youngest tissues most vividly, it brings into sight at once crowds of young in all stages of development, which, without its aid, are liable to escape observation. Different-sized masses of germs, of a blood-red colour, may then be seen everywhere intermixed with the more mature and lightly coloured young; but, owing to their having been in spirits so long, they were not in so favourable a condition as could have been desired for examination.

The smallest germ discoverable is about $\frac{1}{5000}$th of an inch in diameter, but the most common size is about $\frac{1}{3334}$th of an inch. From the frequency with which two or four of these bodies are met with closely in contact, I am induced to think that they multiply also by fissiparous division, though this may be merely an accidental collocation. The size of the germs met with gradually increases; and when they are about $\frac{1}{1500}$th of an inch in diameter, they appear to be made up of a spherical mass of pretty large cells enclosed within a delicate envelope. This mass soon begins to increase in one direction more than another, becoming elongated and more or less irregularly twisted; and about this time its investing membrane becomes ruptured (Pl. XXII. fig. 44), and the almost shapeless germ is thus early found to possess a distinct tail. From this stage onwards the young worm, often twisted like a corkscrew, becomes narrower and longer, assumes a more regular outline, and a fine granular instead of a cellular appearance (Pl. XXII. figs. 51–58). At last rugæ begin to form on its body; and by degrees an alimentary canal becomes visible, and distinct parietes to the body bounding an abdominal cavity. The anterior part of the alimentary canal is the most distinct and the first to be differentiated.

The young seem to go on growing until they attain a size of about $\frac{1}{42}$nd of an inch long by $\frac{1}{1428}$th broad ‡, and then development, rather than growth, seems to become the

* The term proposed by Prof. Huxley for ova which have been produced by a process of "parthenogenesis," which will be shown hereafter to be the most probable mode of production of young in the Guineaworm.

† The size and rapidity of growth of these worms seem to depend, principally, upon the formative energy of their generative organs, and the rapidity with which fresh pseudova are continually being produced, as much as to the growth of those already formed, since this appears soon to reach a limit; and accordingly in the smallest of the specimens that I examined, measuring only 18 inches, there were not nearly as many developing germs as in those (of the same age) which measured from 30 to 36 inches.

‡ This is pretty nearly the size given by all observers who have measured the young, with the exception of

more active process; and this would account for the great majority of the young being so nearly of the same size.

In five of the specimens of Guineaworm examined the young were more or less coiled, usually two or three times, with the tail either projecting as a tangent or curved also; but in the remaining specimen nearly all the young were straight * (Pl. XXII. fig. 56).

The full-sized young are unequally spindle-shaped, tapering slightly towards the anterior extremity, which is rounded, presenting no trace of papillæ, but a small central depression leading to the mouth, whilst at the commencement of the posterior two-fifths of its length the body begins to taper, and for the last fifth of its extent is narrow and linear, measuring only about $\frac{1}{20000}$th of an inch in diameter †. Its body is marked with circular rugæ, at intervals of $\frac{1}{10000}$th of an inch, which are not visible, however, on the narrow tail. The young worm being translucent, an intestinal canal can be most distinctly recognized in some specimens, running in part through the central cavity of the body, which also contains a number of bright, highly refracting particles. At the junction of the anterior three-fifths with the posterior two-fifths of the length of the worm, where the body begins to diminish in size, two different appearances are presented by different individuals, which will be presently described and explained. No trace of distinct muscular tissue can be recognized.

The intestinal tube is about $\frac{1}{87}$th of an inch in length, and appears to consist of a simple ‡ canal of varying calibre, pursuing a nearly straight course, and terminating cæcally at about the middle in length of the worm (Pl. XXII. figs. 57, 58). It does not fill the cavity of the body, but leaves a distinct space on either side of it, and, from the observations of Robin and Moquin-Tandon § on the living young, appears moveable and unattached to the parietes. The œsophagus, just behind the mouth, is $\frac{1}{10000}$th of an inch in diameter, and gradually widens to $\frac{1}{3300}$th of an inch, of which size it continues for nearly the whole of the latter half of its course—till, in fact, it becomes narrowed again to $\frac{1}{5000}$th of an inch at its junction with the stomach. The œsophagus forms nearly one-half of the whole intestinal canal. The commencement of the stomach is the widest part of the tube, measuring $\frac{1}{2000}$th of an inch in diameter. It is about $\frac{1}{450}$th of an inch in length, and either forms one dilated cavity or is divided by slight constrictions into two or three smaller ones. Its junction with the intestine, from the gradual nar-

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Mr. Carter, who says their usual length is $\frac{1}{33}$rd of an inch long by $\frac{1}{633}$rd of an inch broad; but as this would make their breadth rather more than twice as much as those ordinarily met with, I think it probable there may have been some mistake about these measurements.

* Duncan (in Trans. of Med. & Phys. Soc. of Calcutta, vol. vii. 1855) says, from observations made on the young of the Guineaworm, that the straight or coiled condition depends upon the manner of death. They are straight when this has been slow and gradual, and more or less coiled when they have died more suddenly.

† Duncan (*loc. cit.*) speaks of a form of young which seems rather incredible: he says, "Out of, I think, two Nharoos (the Bombay name for Guineaworm) the young ones had *double tails*, which they separated and reunited with great rapidity; in the latter state it appeared exactly as one: these were rather thicker in the body than the others."

‡ I have not been able to detect in the young worm, as Mr. Carter has described it, the intestinal tube proper and its peritoneal sheath, but possibly this may be due to my not having examined living or recent specimens,—though I also differ from him as to the termination of the canal, which certainly cannot depend upon the cause just stated.

§ Zoologie Médicale, Paris, 1859, p. 135.

rowing, is frequently imperceptible. This latter portion of the tube is about $\frac{1}{285}$th of an inch in length by $\frac{1}{5000}$th broad, and continues of much the same size till it terminates in a blunt cæcal extremity. In a few specimens I have observed the terminal portion of the intestine reflected on itself (Pl. XXII. fig. 58).

Behind the extremity of the intestinal canal, for some little distance, the abdominal cavity seems occupied only by bright particles, of irregular size and shape; but then we come to the bodies which present a different appearance in different specimens, as before mentioned.

In the form by far the most frequently met with, at the point where the young animal begins to decrease in size, a central rounded body may be observed, about $\frac{1}{2200}$th of an inch in diameter, with a dark or light spot in the centre, according to the varying focal distance, and which seems to represent a central aperture (Pl. XXII. fig. 57 *e*). Sometimes above this traces of two or three large cells may be recognized, whilst behind nothing definite can be made out, save that the cavity of the body is visible for about $\frac{1}{400}$th of an inch.

In other specimens of the young worm the central body and spot are wanting, but in its stead two lateral sacculi are met with (Pl. XXII. fig. 59 *e*, *e*), about $\frac{1}{3300}$th of an inch in diameter, that communicate with the exterior by a minute channel through the integuments, which can sometimes be distinctly recognized. At other times the channel is obscured by a protrusion, which appears to have taken place through it, of a minute bilobed papilla, projecting $\frac{1}{10000}$th of an inch from the side of the body. When the projections are seen, the sacculi are indistinct (Pl. XXII. fig. 60). The parts above and below are just the same as in the other variety.

From the extreme rarity with which worms were met with presenting the two lateral sacculi, as compared with the multitudes presenting the single central body, I was at first disposed to regard the difference as in some way characteristic of different sexes, till convinced by Mr. Busk that the difference was due only to the position in which the young worms were looked at—the central body being one of the lateral sacculi, and the central dot its aperture, the former appearing larger in this position than when seen laterally. When convinced that this was the correct interpretation, I was at once enabled to explain the reason why the double sacculi were so rarely seen; for out of the five specimens of the Guineaworm in which the young were more or less coiled, it was the rarest thing possible to meet with this form, whilst in the sixth specimen, in which the young were nearly all straight, it occurred very frequently. All this is explicable by the supposition that the sacculi are situated on the sides of the body, and that the young are constantly coiled in one definite direction in the median vertical longitudinal plane of the body, so that when lying flat they would present one or other side uppermost, showing a single central body in the situation mentioned; whilst those which were straight, being at the same time cylindrical, would lie indifferently on any part of their circumference, and thus sometimes appear with one sacculus only, sometimes with two; and all intermediate positions can be recognized, if carefully sought for.

What the nature of these sacculi may be is not very clear. Mr. Busk suggests that they may be the rudiments of the water-vascular system; but the protrusions from them are difficult to reconcile with this view. At all events, they appear hitherto to have escaped observation, as the only writer who has noticed anything different from the ordinary kind of worm with the single central body is M. Jacobson*, who mentions and figures young with "deux petits mamelons" in this situation, and, curiously enough, alludes to no other form†, and apparently did not recognize the internal sacculi at all.

The young, in this stage of their development, are asexual, though the rudiments of some organ appear to exist just above the sacculi, which may ultimately develope into a genital apparatus (Pl. XXII. figs. 57, 58, 59, 60, *f*).

The description I have given of the mode of termination of the alimentary canal does not agree either with that of Mr. Carter‡ or of M. Charles Robin§; but I have noticed the cæcal termination so plainly, and in such a large number of specimens, that I have the less hesitation in advancing anything in opposition to such skilful observers. According to Carter, the central body at the root of the tail is a gland, and the very narrow termination of the intestinal tube opens near it. Robin, on the contrary, says the intestinal canal terminates at the central spot of the cellular body, which he regards as a prominent anus.

The accounts given by different writers of the vitality of the young worms are rather contradictory: Carter regards them as very delicate, and but slightly tenacious of life, whereas the positive observations of Busk, Robin, Deville, and others go to prove that they may remain in a torpid state, when *not perfectly* dry, for even twelve or more hours, and then be restored to their usual life and activity by the addition of a little fresh water. They seldom live more than five or six days in pure fresh water; but then, as has been very reasonably suggested, it is scarcely to be expected that they should, seeing that *pure* water is not the natural habitat of the microscopic Filaridæ, which they so closely resemble. Forbes|| has found that they lived longest (about twenty days) in fine impalpable clay but slightly covered with water and exposed to the sun's rays.

General Observations on the Nature and History of the Guineaworm.

Having investigated the anatomy of *Filaria medinensis*, several interesting questions have to be considered as to the real nature of the parasite, its early history, and the mode of production and ultimate fate of its young; and on these several points I will now make a few brief observations.

Several years ago, before so much was known of its anatomy, Mr. Busk, in the very interesting paper before alluded to, suggested that the Guineaworm was an *intermediate stage* in the development of a nematoid worm, and analogous to one of the so-called "nurses" of *Cercariæ*, described by Steenstrup and other anatomists as a transition form in the development of the Trematoda. This opinion he based upon the facts, that no well-authenticated case of a male parasitic Guineaworm existed—all that had hitherto

* *Loc. cit.*

† In the figures which he gives, the young are also represented as being straight.

‡ Ann. of Nat. Hist. 1859, vol. iv. p. 32.

§ Gaz. Méd. de Paris, 1855, p. 363.

|| Madras Quart. Journ. of Med. Science, 1837.

been carefully examined having proved to be female and viviparous—and that there was no trace of distinct genital organs, the young being apparently produced in the general cavity of the body. The existence of a blind intestinal canal, as demonstrated by Mr. Busk, was not incompatible with this theory, as it has been shown by M. Filippi* that some of the "nurses" (*rediæ*) are characterized by the possession of a rudimentary alimentary canal, whilst others (*sporocystes*) are simple sacs containing young, without viscera of any kind. But the discovery in the Guineaworm of distinct genital organs, with a vascular and nervous apparatus, fairly entitles us, I think, to look upon this worm as a *fully developed specimen* of one of the highest types of the order Nematoidea, and more particularly so as the remaining special grounds which induced Mr. Busk to advance his hypothesis can be explained in other ways.

The common opinion prevailing in India amongst the natives is, that the ova or young of some aquatic worm enter the body with the water that is drunk, and in some unexplained way get to the subcutaneous tissue, and there become developed into Guineaworms. But the opinion of most naturalists and scientific men is opposed to this, and more in accordance with the general nature of the evidence bearing on the question. They agree so far with the popular belief, that in the early stage this parasite is a microscopic animalcule, having its habitat in water and damp places, but that it makes its entrance into the human body by being brought into direct contact with the naked integuments, which it perforates in some unascertained manner. I should not have thought it necessary to bring forward evidence in support of this latter view, had it not been that the former hypothesis has been maintained by many medical men in India, and even as late as 1856 has been again strongly advocated by Dr. Greenhow†.

Granting that the ova or young are capable of resisting the action of the gastric juice‡, the former view altogether fails to account for the overwhelming frequency with which the parasite is found in the lower extremities rather than equally diffused throughout the cellular tissue of the body generally, in the same way as we find *Trichina spiralis* universally distributed through all the muscles of the body.

But in support of the opinion that the Guineaworm enters directly from without, we have the positive evidence that the parasites are met with most frequently in just those parts of the body that are oftenest brought in contact with water or damp marshy places. From some statistics collected from the Indian journals by Professor Aitken, and kindly placed at my disposal, I find that, out of 930 recorded cases of *Dracunculus*, 98·85 per cent. occurred in some part of the lower extremities, and the great majority of them about the feet and ankles. A similar distribution is observed

* "Mémoire pour servir à l'histoire génétique des Trématodes," Ann. des Sciences Naturelles, 1854.

† Indian Annals of Medical Science, vol. iii., 1856.

‡ I do not lay any stress upon the experiments of Forbes (Trans. of Med. & Phys. Soc. of Calcutta, vol. i.), who tested the action of the gastric juice upon the young of the Guineaworm, by giving some, suspended in water, fresh from a Sepoy's leg, to two young puppy dogs, one of which was killed four hours and the other twenty-four hours afterwards, and in both cases all the young worms were found "dead in the mucus of the stomach and duodenum," because it is not fair to draw inferences from the effects of experiments upon the young of the parasitic Guineaworm which have been produced and reared in such an unusual situation, and then apply them to the young of an aquatic animalcule subject to such totally different conditions.

where a plurality of worms has occurred in the same subject, as may be seen in a case related by Lorrimer*, where thirteen† of these parasites were thus disposed:—

4	in left	foot,	2	in right	foot,
2	„	leg,	1	„	leg,
1	„	thigh,	3	„	forearm.

Accidental circumstances also lend support to this theory, as borne out by a statement of Ninian Bruce‡, who says:—"It has been observed that Bheesties, or water-carriers, in India, who carry the water in a "mushuk," or leathern bag, suspended from their shoulders, over the back and side, are most subject to the Guineaworm in those parts which come in contact with the mushuk." Mr. Busk, too, says it is not even necessary for a person to land or drink any of the water in places where the Guineaworm is endemic, as sailors have become infected merely by the contact of their naked skin with water contained in the boats of the natives that come off to a vessel from infected places.

Dr. Chisholm§, in a long and interesting paper on the Guineaworm as met with in the island of Grenada, brings forward what at first sight appear most incontrovertible arguments to prove that the source of infection is in the water drunk by the negroes from certain wells dug near the sea in a brackish volcanic soil; but Scott‖ has no doubt suggested the real explanation of the facts related by Dr. Chisholm, when he says that the negroes who frequented these wells were really infected by contact with the wet marshy soil of the low situations in which the wells were dug, and that their freedom from this troublesome parasite after they ceased to frequent the wells, and used tank or cistern water instead, was really due to these reservoirs being situated near the habitations on a dry and elevated soil.

Taking all these facts into consideration, as well as the account before given of the manner in which the worms I have examined seemed to have entered the body, and some special observations by Mr. Carter to be presently noticed, we have, in favour of the second hypothesis, an amount of evidence which, if not perfectly satisfactory, it would at least be almost impossible to explain in any other way.

In the papers to which I have made such frequent reference, Mr. Carter has done much to show that a very intimate relationship exists between the Guineaworm and certain "microscopic *Filaridæ*," to which he has given the name of *Tank-worms*, abounding in the gelatinous Algæ of the tanks, ponds, and damp places generally in the neighbourhood of Bombay. His arguments are based upon two principal series of observations:—In the first place, the marked prevalence of *Dracunculus* in those regions where the various species of Tank-worms are common, and where the subjects of the disease have been known to have exposed themselves to the circumstances favourable to

* Madras Quarterly Journal of Medical Science, 1837.

† Poupée Desportes has seen a case where fifty worms were taken from the same patient. *Vide* Kunsemüller, 'Sur les Maladies de Saint-Dominique.'

‡ Edin. Med. and Surg. Journal, vol. ii. (1806) p. 145.

§ *Ib.* vol. xi., 1815.

‖ *Ib.* vol. xvii., 1821.

contagion, as contrasted with the great scarcity of the disease in other situations, where careful observation has failed to discover these microscopic Filaridæ. As an instance of this, he states that, "out of a school of fifty boys bathing and dabbling throughout the day in a small pond in their enclosure, whose muddy sediment swarmed with the so-called 'Tank-worm,' not less than twenty-one in one year had *Dracunculus* in more or less plurality; while such was not only not the case in any of the other schools of the island, but in the school of which I have had medical charge for more than ten years, with an average number of 346 children present, only two or three cases have occurred* during that time; and microscopic Filaridæ do not exist, so far as I have been able to ascertain, in the sedimentary deposit of the tank in their inclosure, from which the children of this school are solely supplied with bathing-water." Secondly, he dwells upon the close similarity he has observed in the anatomy of the parasitic Guineaworm, its young, and of these microscopic Filaridæ, especially one species to which he has given the provisional name of *Urolabes palustris*. But, for these anatomical details and the plates, I must refer to the author's own paper. He has discovered and given descriptions of several distinct species whose young have all the same kind of long, linear tail as that described in the young Guineaworm, by the extremity of which they have a great tendency to attach themselves to external objects, and then by a kind of wriggling motion are enabled to imbed themselves in any soft substance. He thinks that in this way, soon after they have escaped from the ovum, when imperfectly developed and not broader than a human blood-corpuscle, they may insinuate themselves into the ducts of the sudatory glands†, whose average size is nearly three times as broad, viz. about $\frac{1}{1200}$th of an inch‡. From this situation, or perhaps directly, without the intermediation of a perspiratory duct, they may bore their way into the subcutaneous tissue by means of a very small, rigid, exsertile œsophagus which was capable of being protruded in all the species examined.

This supposition of a boring-power possessed by these small animals is fully in harmony with recognized facts long known with regard to species of the order Trematoda. The young and immature forms of many of these species are known to penetrate from

* And these could mostly be accounted for by visits the children had made to other localities.

† In a more recent paper (Trans. of Med. & Phys. Soc. of Bombay, 1861, App. p. 1) Mr. Carter says, "No case, however, has yet occurred where a young *Filaria* of the free species has been found entering or in one of the sudorific ducts; so this is still an assumption; but having met with an instance in which young Filaridæ were found entering a fungus by analogous apertures on the surface, even smaller than those of the sudorific ducts, it seems desirable that the facts should be recorded to show that at least in the vegetable kingdom this kind of entrance takes place."

On examining a large fungus of the genus *Xylaria* growing on the decayed trunk of a tamarind-tree, he says, "Some delicate, glistering, thread-like bodies were seen to project from the summit of the conceptacles," these being "little globe-shaped sacs imbedded in and scattered over the surface of the fungus, upon which they open by minute mouths or ostioles respectively, which, when measured, were found not to exceed the $\frac{1}{1880}$th of an inch in diameter, so that they are smaller than the orifices of the sudorific ducts of the human body; and from each of these ostioles was projecting a single *Filaria*—the head in the conceptacle."

He adds that the specimens were too immature to discover their species, and that he has lately found similar worms in the greatest abundance in all the larger species of fungus in the neighbourhood of Bombay.

‡ The full adult size of *Urolabes palustris* is $\frac{1}{6}$th of an inch long by $\frac{1}{370}$th broad, though some of the other species are much smaller.

without through the skin of fishes and of frogs, into the bodies of snails, and in large numbers into the eyes of freshwater fishes, as discovered by Nordmann*.

Should this supposition of Mr. Carter prove correct, as the very close correspondence between the anatomy of these microscopic Filaridæ and of the Guineaworm renders highly probable, several very interesting questions arise for solution. Did the young worm seek its new habitat before or after impregnation? Why are females only discovered in the body? And is there one species of *Dracunculus* only, or many, corresponding with different species of microscopic Filaridæ?

Mr. Carter thinks it probable that these worms enter the body whilst very young, and when they are not more than $\frac{1}{3200}$th of an inch in diameter, and at this early period of their existence they have only the rudiments of genital organs; so that he thinks they must be unimpregnated when they penetrate the integuments. And seeing that a full-sized Guineaworm measuring eight or ten feet in length is, as it were, a continuous sac fully distended with the very minute young, it must contain a progeny numbering at least two or three millions, and I think it would be difficult to understand how a young worm, containing this number of ova, could be so minute as entirely to escape observation whilst penetrating the skin; it would also be very difficult to conceive how the female of so minute an animal could receive a sufficient quantity of the male fluid to fertilize such an enormous quantity of ova.

It does not seem at all probable, either, that in its new situation beneath the integuments the female could be brought into contact with a male; and therefore when Mr. Carter suggests that the young may have been produced from "buds"† instead of fertilized ova, I think he has suggested the real explanation of their genesis, and that I shall be able to support this position by several pretty conclusive arguments.

Much light has of late been thrown upon this process of "parthenogenesis" by the able investigations of Mr. Lubbock‡ and Professor Huxley§; and we need have the less hesitation to call in the aid of so exceptional a process to explain the history of the Guineaworm, seeing that this method of reproduction has been recognized in so many animals much higher in the scale of organization, as may be seen from the following valuable *résumé*, by Professor Huxley, of the classes and orders in which it has been met with. He says, "Among the Annulosa, the Rotifera and Turbellaria possibly possess it to a small extent; the Nematoidea‖ do not possess it at all. Many Trematoda possess it; others, such as *Aspidogaster*, have nothing of the kind. The Acanthocephala are not known to possess it; the Echinodermata are regarded by Professor Owen as possessing it, but their different families show every gradation from simple metamorphosis to something like agamogenesis. A few Annelida possess this power in a marked degree; in many, nothing of the kind is known. The *Nais* has it; the Earthworm and the Leech have it not. Of the Crustacea, some, such as many Branchiopoda, exhibit it in the highest perfection;

* Steenstrup's 'Alternation of Generations,' Ray Soc. edition, translated by Busk, p. 98.

† Ann. of Nat. Hist., 1859, vol. iv. p. 109.

‡ "On Two Methods of Reproduction in *Daphnia*," Phil. Trans., 1857 and 1859.

§ "On the Agamic Reproduction and Morphology of Aphis," Trans. Linn. Soc., 1858, vol. xxii.

‖ Of course, if subsequent investigation confirms the opinion here adopted, this statement would require alteration.

but no trace of it has yet been found in Copepoda, Cirripedia, Pœcilopoda, Edriophthalmia, or Podophthalmia. In the Myriapoda and Arachnida the process is not known; but we find it in the highest Articulata—the Insecta—and this not, so far as we know at present, in Aptera or Orthoptera, but in a few Hemiptera, Hymenoptera, and Lepidoptera; and there is every reason to believe that it only occurs in isolated, though perhaps in many, genera of these orders. Take the Mollusca again: agamogenesis occurs in the Polyzoa and Ascidioida, not in the Brachiopoda. It is not known to occur in any of the Lamellibranchiata; and among the higher Mollusca, the nearest approach to it is presented by the animal (whatever it is) which gives rise to the 'Synapta-Schnecken' (high Gasteropods) and by the Hectocotyligenous Cephalopoda."

The fact that neither vulva nor vagina is discoverable in the Guineaworm would, if their absence were absolutely proved, throw us back upon this process of agamogenesis, in which the young are produced from pseudova without the influence of a male, as the *only* possible explanation. Such a defective development of the female generative organs in *Dracunculus*, as compared with their observed condition in the microscopic Filaridæ, can be met also by a similar suppression of parts, though to a minor extent, in the viviparous females of the *Aphis*, in which the spermatheca and two colleterial glands have been shown to be wanting, though found in connexion with the vagina of the oviparous female*.

In support of this opinion also we have the probability that, throughout the *whole parasitic stage of the life of this Entozoon*, germs are being actively produced in every part of the genital tube, seeing that in six specimens of the worm, taken from the human body after a residence in it of eight or nine months, this formative process was actually going on up to the very time of their extraction—as proved by the uniform dissemination of crowds of pseudova and young, in the very earliest stages of development. How, unless we resort to the phenomena of agamogenesis, can we account for this amazing fecundity at a time so remote from the only period when union with a male was possible? For even were the worm possessed of the most capacious spermatheca, it must long since have been obliterated by the distention of the genital tube, considering that this has become closely adherent to the parietes of the body; yet, nevertheless, up to the very last does this wholesale production and development of germs continue. What, then, are we to consider as the stimuli so efficacious in the production of pseudova and young in the virgin Guineaworm? Doubtless the two very conditions which have been proved to be so necessary for the continuance of agamic reproduction in the *Aphis*, concerning which Professor Huxley remarks, "The number of successive broods has no certain limit," till "on the setting in of cold weather, or in some cases on the failure of nourishment, the weather being still warm, males and oviparous females are produced." But, located as it is in the body of a warm-blooded animal, the Guineaworm is subjected in the highest degree to the influence of these two very conditions—being constantly maintained at a high and uniform temperature, and supplied by imbibition with nutritive and highly organized fluids.

* Is there any possible connexion between the special direction of the arrested development which has led to the non-formation of the *outlets* of the genital organs only in the Guineaworm, and the fact before stated, that the young or ova of Nematoid worms are frequently discharged by a simultaneous rupture of the integuments and some portion of the containing tube?

The obscurity of this process and our inability to explain its nature should of course be no barrier to our acceptance of it as a fact, if this be in accordance with all the evidence that can be brought to bear upon the subject. And, in reality, what clearer insight do we gain into the essential nature of the process by which new organic beings are generated, by supposing the germ-cells of the female to be subjected to the influence of certain cell-products of the male? By long habit and association, indeed, we are apt to think, when this occurs, we have all that is necessary for the explanation of the process, whereas in truth it is but the throwing in of another unknown term into the problem—an attempt to resolve "*ignotum per ignotius*." Nor can we expect to be able to solve all the difficult phenomena of reproduction, when other common organic processes of growth, development, and secretion are in themselves so obscure. Professor Huxley aptly remarks on this subject, "When we know why, in a mass of tissue of identical structure throughout, one part becomes a brain, another a heart, and a third a liver—when we can answer these every-day questions of the Sphinx, we may attempt her more difficult riddles without running too great a risk of being devoured."

Should future investigation confirm the opinion that the Guineaworm enters its host at a very early stage of its existence, and before the development of its sexual organs, its remaining in this situation till young are produced and ready to be brought forth, is a phenomenon different from what usually occurs, and also from what is met with in the nearly allied *Gordius* and *Mermis*, with reference to which Von Siebold has established that the immature worms penetrate the bodies of insect larvæ, and after remaining there some time, emerge from the bodies of their hosts, and then only, in the free stage of their existence, develope organs of reproduction, ova, and young. Siebold says*, "Ainsi à raison des faits que je viens d'exposer, on ne rencontre jamais certaines Helminthes hors du corps de leurs hôtes naturels à moins que leur croissance ne soit achevée; et certaines espèces aussi ne se voient dans l'intérieur du corps des animaux dont elles doivent être les parasites que lorsqu'elles sont déjà parvenues à une taille déterminée." This difference in the two groups of Entozoa mentioned depends upon the necessity of the conjunction of the two sexes for the fertilization of ova; but there is a third class, comprehending the *Tæniæ* and other hermaphrodite worms, which, from the absence of such a necessity, are enabled to pass through the whole cycle of their development in one or more different animals; and in a subdivision of this class we must assign a place for the Guineaworm, since, having a power of producing young by an agamic process, it remains in the condition of a parasite through nearly the whole period of its existence.

As before stated, all the specimens of Guineaworm hitherto carefully examined have been found to be female and viviparous; and the only writers who mention male worms (so far as I have been able to discover) are Professor Owen, M. Leblond, and Dr. M'Clelland; but in each case the observations are, as will be seen, incomplete, and scarcely definite enough to turn the overwhelming balance of evidence on the other side.

Professor Owen† gives a figure of what he considered a male Guineaworm, and says, "The caudal extremity of the male is obtuse, and emits a single spiculum; in the female

* "Sur la Production des Helminthes," Ann. des Sciences Nat. tom. v., 1855.

† Art. *Entozoa*, Cycloped. of Anat. & Physiol. part x. (1837) p. 122.

it is acute and suddenly inflected." This is the only observation he makes concerning it; and as not a word is said about its internal anatomy, we may presume that it was assigned to the male sex from its external characters alone. But a comparison of the figure Professor Owen has given with Pl. XXI. fig. 7, will, I think, warrant us in believing, till some more definite statement is made, that his so-called male worm was similar to the one figured by myself, whose rather unusual form appeared due to the circumstance of its being more than ordinarily distended with young up to within a short distance from the extremity of the tail.

M. Leblond* having examined one of the portions of the only specimen of Guineaworm contained in the Musée d'Histoire Naturelle at Paris, and found it to be part of a female worm, containing young, then *squeezed* another portion and expressed some white matter, which, when broken up by the aid of needles, and submitted to a high power of the microscope, he says, "m'a paru constituée de corpuscules irréguliers diversiformes. Peut-être ces corpuscules étaient-ils spermatiques. Dans cette hypothèse le fragment indiqué êut fait partie d'un autre individu." But can we admit this hypothesis? To say the least, it is very improbable; and then M. Leblond could not have been certain even that the matter examined came from the genital tube rather than the intestinal canal or general cavity of the body.

Dr. M'Clelland† gives a plate of two or three different forms of the caudal extremity, one of which, pl. 10. fig. 1, he *suspects* only may be characteristic of a male worm, though Küchenmeister‡ alludes to it, on the authority of Diesing, as the actual representation of such a worm§.

I think, then, we are fairly entitled to consider that no satisfactory evidence has yet been brought forward of the detection of a male parasitic Guineaworm; and such being the case, the reason why females only are met with is a very interesting question.

This may be explained, it appears to me, in one of two ways: either both male and female representatives of the species, of which the Guineaworm is an after-development, make their way through the integuments of persons exposing themselves to the conditions favourable for their penetration, but that the males in their new situation never attain any great size, and consequently, producing no inconvenience, do not attract attention, whilst the females, by the enormous development of their genital organs and contents, under the stimulus of high temperature and abundance of nutriment, soon attain such a size as to be palpable in superficial situations. It seems very probable that the male, if it penetrated, would never attain any considerable magnitude; and that it might remain in its new habitat without producing irritation is rendered very likely, seeing

* "Quelques Matériaux pour servir à l'histoire des Filaires et des Strongyles," Précis Analyt. des Travaux de l'Acad. Roy. de Rouen, 1835, p. 150.

† Calcutta Journal of Nat. History, vol. i. p. 359.

‡ *Loc. cit.* p. 390.

§ The only other reference to a male worm that I have met with seems too improbable to require further notice. It occurs in a paper by Dr. Greenhow, before alluded to, in which he says:—"I have not been fortunate enough to meet with a male worm; but the before-named native doctor tells me that he has seen several. He describes them as twice as long and four times as thick as the female, that is, about four feet long and *nearly half an inch in diameter*."

that during the whole period of the growth of the female*, till the maturity of its young, it does not cause any inconvenience, and but rarely attracts attention; and this has in consequence been termed by Mr. Busk the "latent period" of its existence.

Or it may be that females only penetrate the integuments, impelled, as is frequently the case with the females of other animals, by a sort of instinct to seek a new habitat for the production of their young. But if, as we have supposed, the young worms penetrate before the genital organs are completely formed, this latter explanation would be rather improbable, as the sexual instincts could not then be reasonably supposed to come into operation.

But however this may be, whether both males and females penetrate, or females only, I think there can be little doubt that this occurrence (at all events as far as warm-blooded animals are concerned) must be regarded as an exceptional rather than an invariable event in the history and development of these microscopic worms, when we consider the vast number in which these creatures, low in the scale of organization, are found in situations favourable to their existence†. So that these worms may be considered to have an *ordinary* existence in the waters and damp places which they naturally frequent, having then their sexual organs fully developed and capable of producing true ova in the usual manner, as well as an exceptional or *extraordinary* existence as parasites of certain warm-blooded creatures, in which condition females only have been met with, that seem to have the outlets of their sexual organs undeveloped, and to contain young which have been formed from internal buds or pseudova by a process of zooid development.

Whether or not the young so produced are capable of existing externally, in their natural medium, there does not seem at present sufficient evidence to enable us to decide. But there are no real grounds for the belief, on the other hand, that the disease is contagious, as it has been sometimes stated to be. There is, indeed, no evidence to show that the young can or do continue their existence beneath the integuments, where they have been reared, although they are frequently liberated in this situation by the rupture of the parent worm. In these cases the young die and are discharged with the pus and other inflammatory products which are the invariable sequence of such an accident.

We now come to the consideration of the last question to which I shall allude, viz. as to whether there be one species of *Dracunculus* only in the various countries in which the Guineaworm is endemic, or several different species corresponding to one or more genera of worms. This question was mooted long ago by Dr. M'Clelland‡, but does not seem to have received much attention since. He says, "It appears to us probable, however, that we have many kinds of *Dracunculus* even in India; should this be the case, some may

* This must be very rapid: it has been calculated by Mr. Busk that the rate of increase is frequently about an inch per week.

† Of course it is highly probable that these aquatic worms may inhabit ponds and places wholly unfrequented by man, and rarely so by quadrupeds; so that it does not seem at all likely that more than the smallest fraction of their whole number would ever have an opportunity of becoming parasites, if such a state were a necessary stage in their existence.

‡ Calcutta Journ. of Nat. History, vol. i., 1841.

be endemic in the hot season in dry arid tracts, some during the rains in low moist situations, and some peculiar to the cold or winter months. We have hardly a reason for concluding, as appears to have been taken for granted by Dr. Chisholm and all subsequent writers, that the disease of Grenada, which appears there during the winter, is the same as that which appears in the East Indies during the rains, however the general form of the animals that occasion the disease in both cases may correspond." We have, unfortunately, but little evidence bearing upon this opinion*, but what little we have seems to lend it support. How else can we account for the great difference in size usually attained by mature individuals in different countries? Thus, the average length of specimens of *Dracunculus* in Bombay and India generally, seems to be from twenty-six to thirty inches, or even less. Mr. Carter, who has had so much experience, says he has never measured one exceeding thirty-two inches in length. In Egypt, according to Clot Bey, they vary from six inches up to four feet in length, whilst, as far as I have been able to ascertain, all the very long worms, from eight to twelve feet, have been African†.

In all probability, the specimens of Guineaworm examined by Mr. Busk were African, since he says, "In every instance that has come under my notice I have found that the length of the worm has nearly reached, and in some instances has exceeded, six feet." Should this be the case, it may perhaps account for the difference before alluded to in the anatomy of the worms he has described from what I have met with in specimens from Bombay.

Then, again, are the Guineaworms that have been met with in Horses‡ and Dogs§ of the same species as those which infest the human subject?

In conclusion, I would refer to the great difference observed, in various countries, and in different parts of India, in the times of the annual epidemic prevalence of the disease

* I think perhaps it may be well to record here the three statements of difference in the external characters of worms that I have met with in different writers; for although no great stress can be laid upon them, they might, by drawing attention to already observed peculiarities, assist in the determination of this question.

"Respecting the structure of a worm which M. d'Obsonville extracted from his own leg, Bingley quotes that author. The body was not thicker than a strong thread; but when the animal was extracted, it was found to be of the length of two or three ells. Its head was of a chestnut colour, and to the naked eye it appeared to terminate in a small black point. On examining it with a common magnifying-glass, it appeared to be formed of a series of small rings, united to each other by an exceedingly fine membrane; and a single intestine extended through the body."—*Trans. of Calc. Med. & Phys. Soc.*, vol. i. (1825) p. 157.

"The worm was of equal volume till within the last inch, when it became a very *little larger*, was *spirally indented*, and ended in a small hooked point."—*W. Scott, Edin. Med. & Surg. Journ.*, vol. xvii. p. 96.

"The tail is attenuated to a very sharp point, and bent like the point of a cobbler's awl. It is also *armed with a few rough points*. . . . Some, however, are without these points, having the tail smooth."—*M'Clelland, loc. cit.*

† The most trustworthy account I have met with of this great size attained by the Guineaworm is in a "Dissertatio de Dracunculo," by Gallandat (Nova Acta Acad. Nat. Curios., vol. v. (1773) Append. p. 103), who, after stating that he had himself been to the coast of Guinea and seen what he describes, says:—"Hoc animal, quod plerumque octo, novem, decemve, un- et duodecim pedum longitudinem æquat, extrahitur prudentissime volviturque circum laminam ligneam ut facilius exeat."

‡ Forbes, Madras Quart. Journ. of Medical Science, 1839.

§ Dr. Smyttan, Trans. of Med. & Phys. Soc. of Calcutta, vol. i., 1825.

as perhaps having also some slight bearing upon this question*. Thus, at Bombay the disease is most prevalent during the rainy months of June, July, August, and September; whilst, according to the missionary Dubois†, its annual epidemic recurrence in the Carnatic villages is in December, January, and February, "during which time more than half the inhabitants suffer;" and during the same months, as before stated, the disease was found to be most frequent by Dr. Chisholm in Grenada and the small Grenadine group of the West Indian Islands.

I must now bring this long communication to a close, hoping that the subject may be taken up by skilful and patient investigators in the countries where this parasite is endemic, by whom alone can the missing links in the chain of its history be supplied.

EXPLANATION OF THE PLATES.

Plate XXI.

Fig. 1. Average-sized Bombay Guineaworm, measuring 30 inches in length by $\frac{1}{15}$th of an inch in breadth.

Fig. 2. Head of Guineaworm, magnified about 100 diameters: (*a*) orbicular mouth surrounded by a slight prominent lip; (*b*) one of large papillæ; (*c*) one small lateral papilla; (*d*) lateral intermuscular space; (*e*) dorsal intermuscular space; (*f*) quadrangular or nearly circular opaque space corresponding to sheath of œsophagus.

Fig. 3. Anterior extremity seen in profile: (*a*) upper and lower papillæ; (*b*) one of dorsal muscles; (*c*) lateral intermuscular space; (*d*) one of ventral muscles.

Figs. 4, 5, 6, 7. Different forms of caudal extremity: letters as in fig. 3.

Fig. 8. Irregular transverse markings of the external portion of integument.

Fig. 9. Set of superimposed lamellæ with longitudinal markings: (*a*) the lines of superficial lamellæ; (*b*) lines of lamellæ, seen beneath.

Fig. 10. Two sets of superimposed lamellæ with lines in opposite directions: letters as before.

Fig. 11. A portion of a single glass-like lamella, with its linear markings and jagged torn edges.

(The figures 8–11 are magnified about 600 diameters.)

Fig. 12. Three portions of lamella of unequal length, showing that the markings of the under layers correspond with some portion of the intervals between the lines of the layer above.

Fig. 13. Transverse section of the worm just behind the head: (*a*) section of small thick-walled œsophagus; (*b*) quadrangular œsophageal sheath; (*c*) granular matter within sheath, with œsophagus; (*d, d, d, d*) four strong mesenteric processes; (*e*) thin origin of one of the four longitudinal muscles; (*f*) one of the glandular processes; (*g*) integument.

Figs. 14, 15, 16, 17, 18. Transverse sections at gradually increasing distances from head up to $1\frac{1}{2}$ inch, showing the speedy disappearance of mesenteric processes, the disposition of the four longitudinal muscles and their fasciculi, the varying dimensions of the peritoneal sheath of the

* This difference would appear to depend more upon variations in the breeding-season of the parent aquatic worms than upon differences in the times of incubation or latency of the worm as a parasite.

† Edin. Med. & Surg. Journ. vol. ii., 1806.

œsophagus, the diminution in thickness of the glandular layer, and, in figs. 17 and 18, the sudden encroachment of the blunt end of the dilated oviduct or uterus distended with young upon the peritoneal cavity.

Fig. 19. Section about two inches from the head, showing the great thickness of the longitudinal muscles, of which the two dorsal and two ventral have come so closely in contact as apparently to form a single muscle only in each situation; (*g*) dilated uterus, occupying nearly the whole of the cavity of the body, and compressing the intestine (*a*) enclosed in its sheath (*b*).

Fig. 20. Appearance of transverse sections through nearly the whole extent of the body of a mature worm, showing great distention of the uterus, whose walls have become adherent to the parietes of the body; the glandular layer lining the body has been obliterated and absorbed by the pressure, and the muscles diminished in thickness: (*a, b*) intestine enclosed within its sheath, compressed into a flat band along the thin edge of one of the longitudinal muscles.

Fig. 21. Transverse section through the worm, about one inch from the tail; showing the uterus, near its termination, not so much distended, and the reappearance of the glandular layer lining the peritoneal cavity. (The figures 13–21 are all magnified about 100 diam.)

Fig. 22. Integument slit open through the right lateral intermuscular space, showing, (*a*) two ventral muscles; (*c*) ganglionated nervous cord in centre of lateral space; (*d*) intestinal canal lying parallel and in contact with the edge of one of the longitudinal muscles; (*e*) median ventral vessel; (*f*) median dorsal vessel. (× 5 diam.)

Fig. 23. Communications of the muscular fasciculi with one another. (× 100 diam.)

Fig. 24. Portion of one of the muscular fasciculi made up of exceedingly slender fibrillæ. (× 500 diam.)

Fig. 25. Portion of the parietes slit open through the left longitudinal dorsal muscle: (*a*) two ventral muscles; (*b*) two dorsal muscles; (*c*) ganglionated nervous cord; (*e, e*) median, dorsal, and ventral vessels; (*f*) tessellated arrangement of glands on surface of muscles, each including a nucleated gland-cell; (*g*) one of similar gland-cells situated in a pulpy stratum over lateral space; (*h*) appearance of gland-cells when much altered from some cause, as noticed in some specimens.

Fig. 26. A nerve-ganglion and adjacent portion of nervous cord, highly magnified, with appearance of the lateral vessel as seen through it: (*a*) irregular crenated margin of the ganglion; (*b*) lateral vessel. (× about 600 diam.)

Fig. 27. Mosaic-like collection of glands with longitudinal vessel, scraped from the surface of the two dorsal muscles: (*a, a*) included spherical, light, granular, nucleated gland-cells; (*b*) median vessel.

Fig. 28. Portion of median dorsal vessel, highly magnified, showing its sinuous course and irregular calibre.

Plate XXII.

Fig. 29. Glandular projections on the surface of one of the muscles near the head, as seen by reflected light: (*a, a*) large processes near the lateral borders of the muscles; (*b, b*) very small processes over contiguous median borders; (*c*) median vessel running through this pulpy matter. (× about 100 diam.)

Fig. 30. Three of the projections as they appear by transmitted light: (*a*) enclosed spherical gland-cell; (*b*) dot or nucleus.

Fig. 31. Anterior part of worm (twice the natural size) slit open through mid-dorsal region: (*a*) œsophageal sheath; (*b*) unction of œsophagus with intestine; (*c*) anterior ovarian tube; (*d*) anterior portion of uterus.

Fig. 32. Posterior extremity of worm (twice the natural size): (*a*) intestinal canal; (*b*) posterior portion of uterus; (*c*) posterior ovarian tube; (*d*) termination of intestine in concavity of tail, mid-ventral region.

Fig. 33. Different portions of alimentary canal and its peritoneal sheath.

1. Small portion of sheath of œsophagus: (*b*) showing epithelial cells on its surface; and (*a*) the small included œsophagus.
2. (*b*) constriction in peritoneal sheath at junction of œsophagus with intestine; (*d*) fat-cells surrounding intestine.
3. Portion of middle part of intestine, which has been compressed by the distended uterus, showing obliteration of the fatty liver(?)-cells, and presence of epithelial cells on the peritoneal sheath.
4. Terminal portion of intestine, with sheath and liver-cells surrounding it up to the extremity. (× about 150 diam.)

Fig. 34. Anterior termination of uterus, with ovarian tube attached: (*a*) abrupt termination of uterus; (*b*) ovary; (*c*, *c*) young accidentally found in ovary.

Fig. 35. Precisely similar posterior termination of uterus, with ovarian tube attached. (× about 80 diam.)

Fig. 36. Portion of peritoneal covering of genital tubes, with scattered various-sized epithelium-cells on its surface.

Fig. 37. Reticulated fibrous network of elastic tissue from the second coat of the uterus.

Fig. 38. Very fine longitudinal muscular fibres, composing the third coat of the uterus. (Figs. 36, 37 & 38 × about 400 diam.)

Figs. 39–55. Showing various stages in the development of the young, from the smallest pseudovum recognizable to nearly the full size attained by the young, in which, however, only the rudiments of the anterior part of the alimentary canal can be detected.

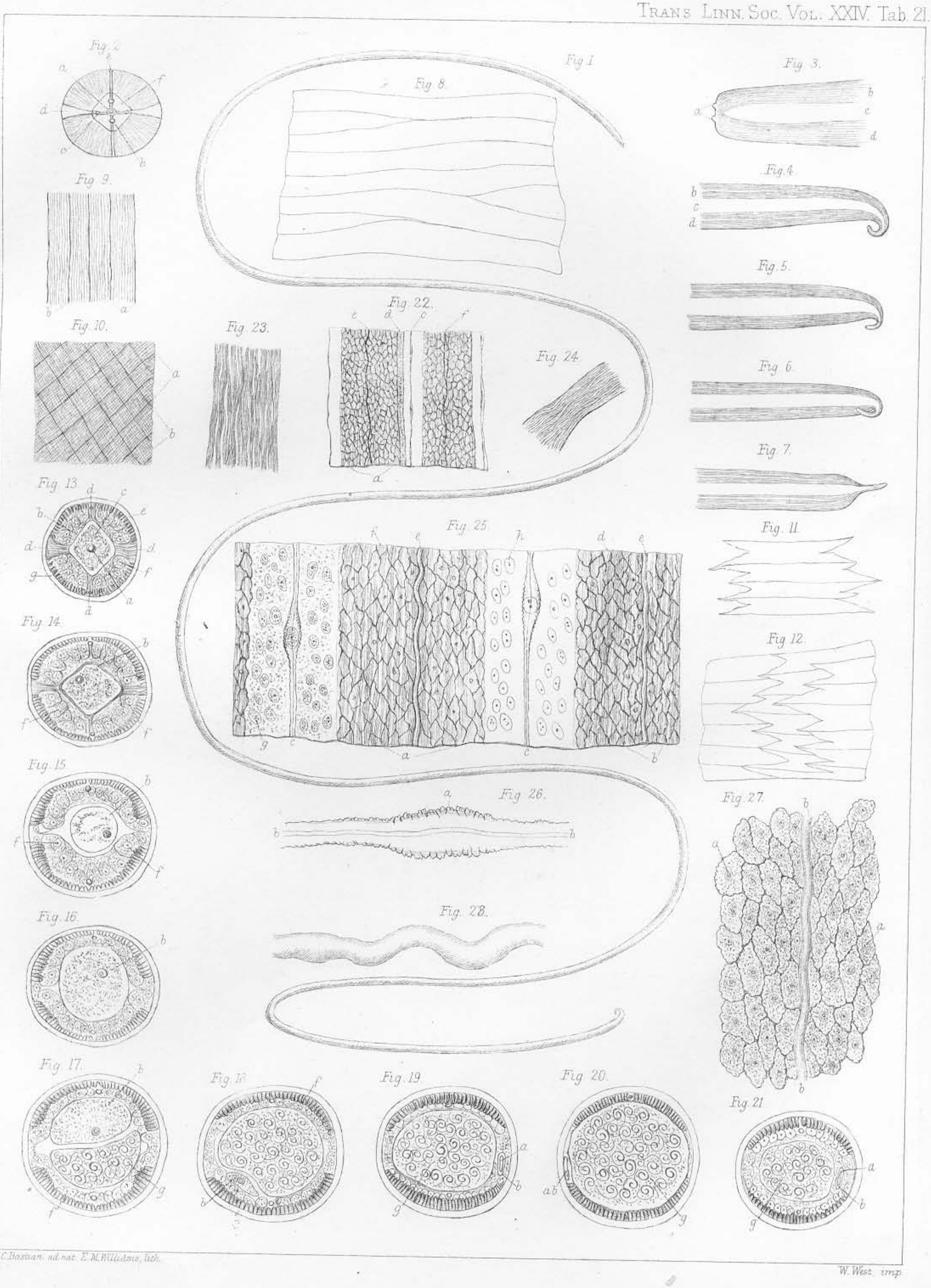
Fig. 56. The various forms of young worms, magnified about 100 diam.: (*a*) granular débris mixed with young; (*b*) peculiar and regular corrugations produced in some of the young, perhaps by the action of the spirit in which they were preserved.

Fig. 57. One of young, seen sideways, showing, (*a*) circular rugæ; (*b*) œsophagus; (*c*) stomach; (*d*) cæcal termination of intestine; (*e*) single sacculus, with central aperture; (*f*) rudiments of some organ, perhaps genital? (*g*) termination of abdominal cavity and circular rugæ; (*h*) linear tail.

Fig. 58. Worm seen in same position, showing reflection of terminal portion of intestine.

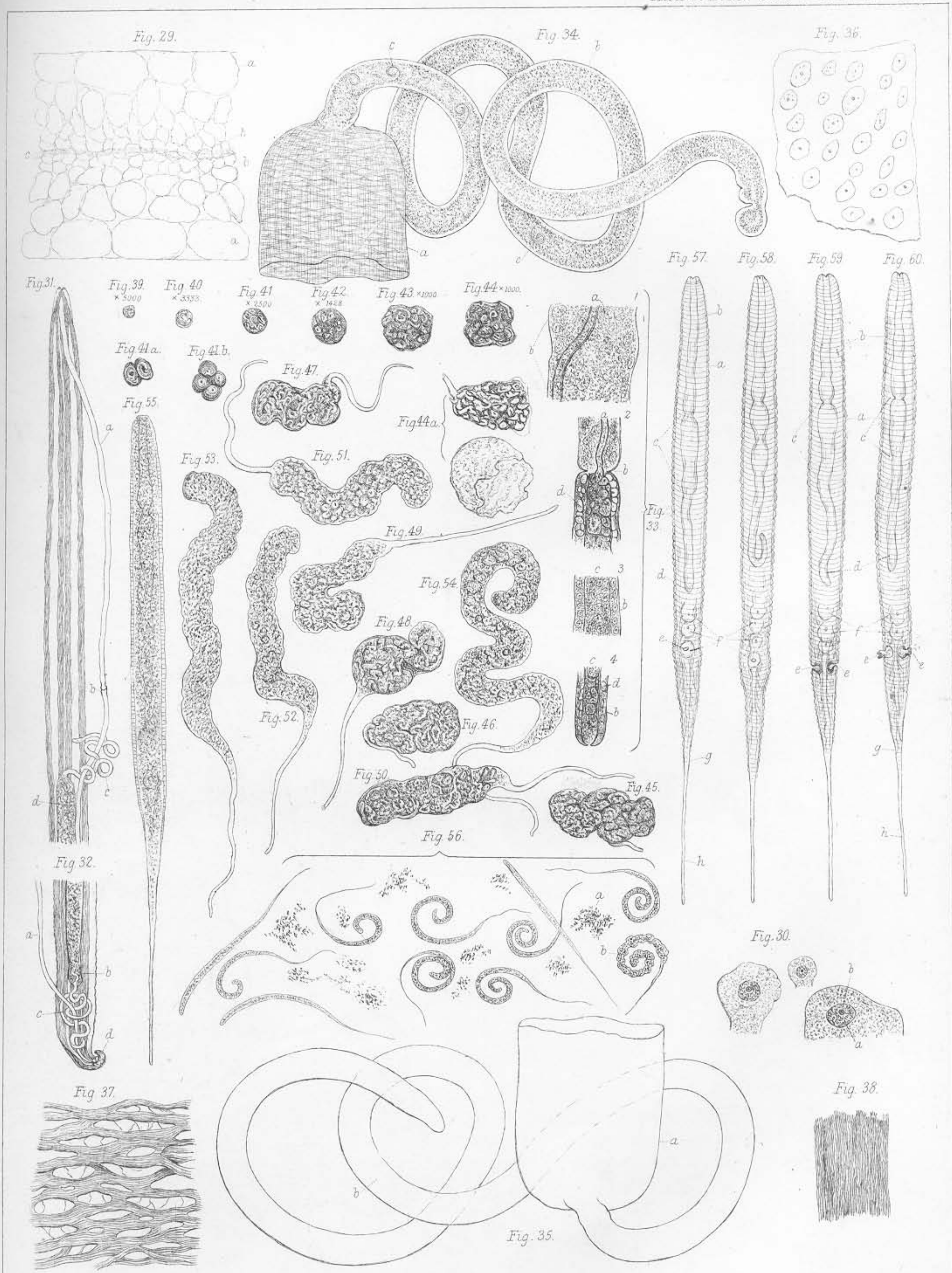
Fig. 59. Worm showing both lateral sacculi.

Fig. 60. Worm in same position as last, showing minute bilobed projections from the lateral sacculi. (Last four figures all × 500 diam.)



H.C. Bastian. ad nat. E.M. Williams, lith.

W. West imp.



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