VIII. *On the Structure and Development of the* Cysticercus cellulosæ, *as found in the Muscles of the Pig.* *By* George Rainey, *M.R.C.S., Lecturer on Anatomy and Demonstrator of Practical and Microscopical Anatomy at St. Thomas's Hospital. Communicated by* R. D. Thomson, *M.D., F.R.S.*

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I am aware that this parasite has been found in various other animals besides the Pig, also that it occasionally infests the human subject, but as I have not had the opportunity of examining it in the latter, and as my opportunities of investigating its structure and development in the former have been very abundant, I shall confine my observations to this entozoon as it occurs in the Pig.

The *Cysticercus* in its developed state is found chiefly in the ordinary muscles lodged in the cellular intervals between the fibres, also on the surface of the muscles immediately beneath their fascial investment. These parasites infest the heart in as great abundance as other muscles composed of striped fibres, where they are situated, some in the substance of the walls of the auricles and ventricles, others directly beneath the pericardium between it and the muscular fibres, and others just under the endocardium. They occur also in the muscular coat of the œsophagus, almost as low down as the stomach. But as in the Pig the striped fibres extend nearly to the inferior extremity of this tube, the presence of *Cysticerci* there forms no exception to their usual position in muscles composed of striped fibres. I found but very few in the lower part of this tube, and as yet I have not met with them in the muscular coat of the intestines, in that of the large vessels close to the heart, in any of the glandular organs, nor in any of the structures of the lungs.

However, in one pig, very much infested with them, I found one *Cysticercus* under the mucous membrane of the larynx, also one behind the peritoneum near to the kidney. As these appear to be probably only accidental cases, I am inclined to regard the striped muscles as the true seat of this species of *Cysticercus*.

This *Cysticercus*, when sufficiently developed to be apparent without the aid of the microscope, is seen to consist of an oval cyst, about half an inch in length, having a white globular body in its centre; but if the muscle in which these animalcules are contained has been exposed for a few hours to the air, the white bodies will be the only part very distinctly visible; the cysts in this case having become collapsed from the evaporation of their fluid. If, however, the muscle be put into water for a short time, the cysts will become redistended, and rendered as apparent as before. As often as

* The observations described in this paper were originally communicated to the Royal Society on the 27th of June, 1855. See Proceedings of the Royal Society for December 13, 1855.

these cysts lose their fluid by exposure, they can be redistended by a fresh application of moisture, even after they have been deprived of life, showing that this property of imbibition of fluid is obviously due to physical causes. These entozoa vary very much in size, according to their various stages of development; but the relative dimensions of the white opaque portion and the transparent sac differ most in those individuals which may be considered to have attained the adult state. Wherever they occur they are contained in sacs formed by the condensation of the surrounding tissues, whose strength and completeness vary in proportion to the closeness of the muscular fibres between which the cysts are found; hence in the substance of the muscular walls of the ventricles of the heart, these adventitious sacs are strong and well-defined, whilst they are thin and sometimes indistinct where the muscular fibres are less closely connected together, or when the *Cysticerci* are situated between a muscle and its fascia; however, in all situations they can be easily distinguished by the microscope from the true cyst of the animalcule, their structure being very dissimilar.

If the adult *Cysticercus* be subjected to slight pressure, the opaque globular-looking portion, which was so coiled up within the oval cyst as to form a spiral of about a turn and a half, will be made to protrude, and then the animal will present a form which will admit of an anatomical division into two parts; namely, a ventral portion and a neck, which is the usual mode of dividing this entozoon. See Plate X. fig. 1.

The ventral part is in the form of an oval cyst, about half an inch in its long diameter. It is composed of an extremely thin membrane, rendered uneven on its external surface by minute rounded projections, and its internal presents a granular appearance, as if covered with coarsely-pounded glass. It is furnished with no visible external opening, and is of the same structure everywhere, excepting where it is connected with the neck. Its cavity contains fluid in which there is amorphous granular matter, and some highly refractive particles having an oily aspect, also occasionally minute earthy particles which effervesce in acid.

No fibres of any kind can be distinguished in this membrane, either in its natural state or when acted upon by acetic acid. As this part of the *Cysticercus* is formed first, and exists as a perfect membranous sac some time prior to the addition and development of the neck, there can be but little doubt, this is the part in the perfect animalcule in which the function of nutrition is chiefly performed, and therefore that it is entitled, as well in a physiological as in an anatomical sense, to the appellation of ventral portion.

The neck is a tubular projection from the middle of the ventral portion; its form is somewhat pyramidal, and at its free extremity it presents a quadrilateral enlargement, whose terminal surface is occupied by four circular discs and a ring of hooklets. See Plate X. fig. 1 *b* and fig. 2.

Its length varies very much in different *Cysticerci* according to their age, this part continuing to increase in size after the other parts have acquired certain fixed dimensions. The membranous parietes of the neck are of considerable strength and thickness, and present two orders of fibres, namely, a longitudinal or superficial set, and a transverse or deep one. These are connected by a transparent material which composes the chief thickness of the membrane, which is deeply wrinkled transversely, and thus formed internally into a number of transverse sacculi. The cavity of the neck does not communicate directly by any visible opening with that of the ventral portion. It is almost completely filled with oval laminated particles of earthy matter resembling minute calculi (see Plate X. fig. 3), which effervesce briskly when put into diluted muriatic acid, but which leave a residue of animal matter after all the earthy salt has been dissolved. These bodies begin to be formed as soon as the neck appears, and continue to increase in number as it increases in size.

The probable office of bodies so purely mechanical in their form and simple in their composition, is most likely one which is purely mechanical also. Perhaps by giving a degree of solidity to the neck, they enable the circular and longitudinal fibres entering into its composition, to effect its protrusion from the ventral cavity, and thus serve as an example of a very low type of an internal skeleton.

The terminal surface of the neck is of a quadrangular form, each angle being occupied by a circular disc or sucker, and its centre contains an apparatus of hooklets (see Plate X. fig. 2), and thus the four suckers and hooklets are all situated nearly upon the same plane, a position which would be advantageous for the employment of these organs when the animals are transferred from their deeply-seated and confined position between the muscular fibres to the free surface of a mucous membrane. The suckers are of a circular figure, with a diameter of about $\frac{1}{750}$th of an inch. See Plate X. fig. 4. Each consists of two or three membranous folds, placed at different depths from the surface, of about three-fourths of a circle in extent, so that the passage through a sucker from the external surface to the interior of the neck is rendered rather tortuous, and inclining to a spiral. The external opening of this passage varies very much in different *Cysticerci*, both in size and shape; but it is always smaller than the internal one. It is difficult, if not impossible, to demonstrate by the microscope alone, the existence of a passage through a sucker; however, this fact admits of proof from the circumstance of the carbonic acid, which is evolved in the cavity of the neck during the decomposition of the calcareous bodies, when these animalcules are in acetic acid, being seen under the microscope to pass freely through the openings in the suckers. In the membranous folds of the suckers, both circular and radiating fibres are distinctly visible, resembling in their general characters those in the neck, already mentioned. See Plate X. fig. 4.

The hooklets, as before observed, are situated in a circle around the centre of the square space before described. See Plate X. figs. 2 and 5. They are generally twenty-six in number, thirteen long and as many short, arranged alternately, a long and a short one. Occasionally, but very rarely, there are more: I have seen as many as twenty-nine. The longer hooklets are about $\frac{1}{150}$th of an inch in length, the shorter ones are a little less. Each consists of a curved part resembling a bird's claw, and a straight part or handle; and at the junction of these two parts there are rounded processes or tubercles, two in the short hooklets, and only one in the long ones, an anatomical mark by which the two kinds can be easily distinguished. See Plate X. figs. 6 *b* and 6 *c*. They are composed of a very highly refractive, dense, and perfectly homogeneous substance possessed of a slight degree of elasticity, and not acted upon by acetic acid. In the curved portion there is a cavity filled with a fibrous material, the other parts are perfectly solid. They are placed (see Plate X. fig. 5), like the radii of a circle, with the extremities of their handles turned towards its centre, which corresponds to the centre of the quadrangular area on which they are situated, and their handles not meeting at this point circumscribe a small circular space, which, if perforated, would correspond to the mouth of the animalcule; but at this part there is no opening. The membrane is simply depressed, so as to present a conical hollow. By pressure upon the neck, this part can be made to protrude in the form of a tongue-like process. The handles of the hooklets are connected with this process, so that when it moves they must move with it. See Plate X. fig. 7 *a*.

Besides the radiating fibres which connect the handles of the hooklets to the membrane just described, there are other fibres which occupy the spaces between their curved portions. These have an arched form with their concavity turned towards the hooklets, into which they seem to be inserted. See Plate X. fig. 5 *e*. There are also two zones of circular fibres; one is placed over the curved portion of the hooklets, and the other over their handles. Between these zones there is a circular interval which contains the tubercles of the hooklets. See Plate X. figs. 5 *b* and 5 *c*. These fibres lie close to the hooklets, but in what manner they are attached to them, or whether they are inserted into them or not, I am unable to determine. Although these fibres are sufficiently distinct in the well-developed *Cysticercus* to leave no doubt of their presence, yet their morphological characters are not sufficiently defined to indicate their precise nature. However, their connexion with organs which are obviously intended to perform a mechanical office, and which would be useless unless they admitted of a certain amount of motion, furnishes a high degree of physiological evidence, that if all these fibres are not muscular, at least a part of them is.

The Development of the Cysticercus cellulosæ.

The earliest indication of this species of *Cysticercus*, which admits of certain recognition as a form of cystic entozoon, is the presence of a collection of reniform corpuscles of about $\frac{1}{2666}$th of an inch in length and $\frac{1}{8000}$th in breadth, mixed with very minute, highly refractive molecules of different sizes in the substance of a primary fasciculus of a muscular fibre, or between its sarcolemma and the sarcous elements. See Plate X. fig. 11.

Though such a collection of corpuscles has a moderately definite shape, being somewhat fusiform, yet it has not a complete investment. It soon, however, acquires a very distinct membranous covering, which is first apparent about its middle, and afterwards at its extremities. Its dimensions in this stage of its formation may be about $\frac{1}{150}$th of an inch in length and $\frac{1}{1500}$th in breadth, but these are by no means regular. The external investment at first appears only as a bright line of homogeneous substance, best defined on the side next the sarcous matter. It soon, however, increases in thickness, and afterwards becomes converted into short fibres, which increase in size and distinctness as the animalcule grows larger. These fibres are peculiar; there is nothing that I am acquainted with analogous to them. They have not the sharp and well-defined outline of true cilia, nor are they pointed like setæ, or curled like cirri. They have somewhat the nature of white fibrous tissue, their distinctness being impaired by acetic acid. They are of different lengths in the same entozoon, and generally longer, though not thicker, in the large than in the small ones. Their length averages about $\frac{1}{2100}$th of an inch.

The most remarkable circumstance connected with them is the great uniformity of their arrangement in different *Cysticerci*. See Plate X. figs. 12 and 13. They cover the whole of the outer surface of the investing membrane, and on opposite sides of the same entozoon, their form, size, and direction are similar, so that the two halves taken longitudinally are in this respect symmetrical. If the direction of these fibres be examined about midway between the two extremities of one of these animalcules, they will be seen to project from the surface at right angles with the axis of its body; but if traced each way from this point they will be observed gradually to incline to this axis at an angle which keeps diminishing as they approach the two extremities, so that the fibres nearest to the two ends almost coincide in their direction with that of the axis, and thus correspond in their situation to the barbs situated on each side of the extremity of an ordinary feather. See Plate X. figs. 12 and 13.

As the first position of these animals is in the very substance of a primary muscular fasciculus (see Plate X. fig. 14), it is obvious that the mechanical action of this apparatus will be to aid their longitudinal development whilst new cells are in progress of formation in their interior. For it is scarcely possible that the muscular fibrillæ by which they are surrounded, can, when in action, fail by their friction to urge the two extremities onwards in opposite directions, whilst at the same time the fibres by which these entozoa are covered are in consequence of their direction preventing the separated ends from regaining their former position, and thus the two ends being always carried in opposite directions without the possibility of a counter movement, a general elongation must ensue. This apparatus also, by splitting up the primary fasciculi, will serve a locomotive purpose, and thus enable these animals to reach the cellular intervals between the muscular fibres, where their further development will be completed. That such is the effect of the fibres in question is evident on a careful inspection of some of the fasciculi in which these animalcules are contained, in which a separation of the fibrillæ can be seen to have been produced by the pointed ends of the entozoon; these fibrillæ having been obviously turned out of their original course, and some directed to one side and some to the other. This explanation receives confirmation from the fact of those *Cysticerci* which are developed in the muscular parietes of the heart being of a different shape from those formed elsewhere, although their structure in all other respects is precisely the same. These *Cysticerci*, in the first or vermicular stage of their development, are very short and thick, and of an oval shape. Their locomotive fibres, though perfectly demonstrable, are very short, and in many instances imperfect. See Plate X. fig. 15.

This difference might have been anticipated, considering the close texture of the muscular fibres of the heart, the absence of any well-formed sarcolemma, and the shortness of the fibres occasioned by their frequent interlacement, all which circumstances would materially tend to diminish the effect of, as well as the necessity for, the fibres which cover the surface of the entozoa, and therefore be unfavourable to their longitudinal development. After these *Cysticerci* have reached the spaces between the muscular fibres, their subsequent development is the same as in other situations, and the perfect animals formed in the heart cannot be distinguished from those formed in other muscles. I may also add, that, while in the vermicular stage, the *Cysticerci* developed in the short muscular fibres of the tongue, are of a shape resembling very much those of the heart.

The investing membrane which has just been described as covered with cilia, is entirely filled with corpuscles, all of one kind, remarkably characteristic, and differing only according to their states of development. The perfect cells are best seen in the middle of an entozoon, but their mode of formation, and the subsequent changes which they undergo, must be examined in those parts which are increasing most rapidly, as in the growing ends of an animalcule.

The first appearance indicative of an increase in the length of an animalcule is a thinning of the investing membrane, and a separation or partial detachment of the cilia-like fibres at the growing end. Next, a clear space, of the form of the part which is about to be added, is perceptible a little in advance of this extremity, apparently the result of a very fine membranous protrusion. This contains numerous dark molecules of different forms and sizes mixed with granules more or less perfectly spherical: the most perfect of these globular bodies are those which are nearest to the perfectly formed part of the animalcule. These corpuscles, when completely formed, have a bright oily-looking aspect, and a diameter of about $\frac{1}{5000}$th of an inch. See Plate X. fig. 8.

These corpuscles have the appearance of being formed by the coalescence of molecules which had existed in the clear space before any corpuscles were apparent, by which they are afterwards replaced. After a growing end has become thus filled with these globular bodies, the terminal membrane becomes more and more distinct, and the cilia-like fibres are afterwards added, which are generally neither so regularly disposed, nor so distinct as on other parts of an entozoon. Next, these corpuscles lose their spherical form and become flattened, and lastly, they assume their characteristic elliptical or reniform figure before mentioned (see Plate X. fig. 10), which they retain as long as the entozoon remains in its primary muscular fasciculus. This shape, however, is not essential to these corpuscles, but merely results from the rounded form of the masses into which they are grouped together, each corpuscle, by its convexity, forming a segment of the circular outline of its respective group. These corpuscles contain very fine dark granules, so variously disposed in different ones, as to present a variety of appearances, such as circular or oval spaces, which might be taken for nuclei or nucleoli. These collections of corpuscles make up nearly the whole of an animalcule, and they frequently give to it a lobulated and sometimes an obscurely annulose appearance. See Plate XI. fig. 2.

The entozoa, as long as they remain in the primary fasciculi, retain all those characters which have so far been described, but these characters gradually disappear after they have broken away from the cavity of the sarcolemma, and gained access to the spaces between the muscular fibres.

In this new situation they gradually lose their former membranous clothing studded with cilia-like fibres, which can occasionally be seen partially deprived of its corpuscular contents, though sufficiently perfect to admit of demonstration. See Plate X. fig. 16. The reniform corpuscles before aggregated together in circular groups now gradually lose their distinctness of outline, and imperfectly coalesce into confused ill-defined masses, having an oily aspect, so that, if in this state one of these vermicules be crushed under the microscope, amorphous oily and granular matter will be seen to have escaped from it, similar to that contained in the ventral part of the adult animal. Here, too, the restraint to the lateral growth of these entozoa being very much diminished, their breadth increases rapidly, and they present globular projections extending out very irregularly from their sides, giving them an irregular figure. See Plate XI. fig. 2. These projections gradually take on the form of those which were described on the ventral part of the perfect entozoon. The largest of the entozoa which I have seen in this stage is about $\frac{1}{12}$th of an inch in length, and $\frac{1}{40}$th in breadth.

The next facts requiring especial notice, are those connected with that stage of development which takes place after the animalcule has become surrounded by an adventitious cyst.

The first indication of the formation of such a cyst is, the turgescency of the capillaries, or some of the smaller vessels in the vicinity of one or more entozoa. Granular bodies, exudation corpuscles, and fibres of different shapes next make their appearance. These at first only partially obscure the entozoon, but afterwards completely conceal it. When the cyst is first formed, the animalcule can, by a good light and careful examination, be obscurely seen within it, and by dissection under the microscope it can be dislodged. See Plate XI. fig. 1, which is an accurate representation of one of these animals folded up in its cyst. Thus folded up, it measures $\frac{1}{16}$th of an inch in length.

Plate XI. fig. 7 shows a *Cysticercus* removed from its adventitious cyst. It has still somewhat of the folded character of the preceding specimen. This is $\frac{1}{7}$th of an inch in length, and $\frac{1}{28}$th in breadth. The interior of a cyst being smaller than the animalcule contained therein, it naturally follows that during its growth one portion must be folded over another. By this means it is adapted to the confined locality in which it is lodged during the period of its development. Hence the ventral portions of all *Cysticerci* are, when first taken from their cysts, very much plicated; but these plicæ disappear after the ventral sac has become distended with the fluid brought into contact with its surface.

Up to this point of the development of the *Cysticercus*, it is a simple cyst growing by the assimilation of fluid imbibed equally by every part of its surface, no one part differing sensibly in its structure from another. No portion of this surface presents any indication of incipient hooklets or suckers. There is nothing either on its surface or in its interior analogous to the structure of an ovum. Nor is there any other anatomical character which would raise its organization above that of a simple acephalocyst. However, this so exactly resembles in its structure that of the ventral portion of a perfect *Cysticercus*, that it is impossible to doubt their identity of character. Its size, too, is not much beneath that stage where the suckers and hooklets first begin to present obscure indications of the part they are about to occupy. I may observe, moreover, that this form, and all the preceding ones, together with perfect *Cysticerci* provided with the regular number of hooklets and suckers, can, in many specimens of diseased muscle, all be found intermixed together in a space not exceeding a square line.

The dimensions of that form of *Cysticercus* in which there are obscure, though sufficiently certain, indications of the site about to be occupied by the neck and suckers, are about $\frac{1}{10}$th of an inch in length, and $\frac{1}{19}$th in breadth. See Plate XI. fig. 8.

The first indication of the addition of the neck with the suckers and hooklets to the ventral part of a *Cysticercus*, is the appearance about its centre of a slightly raised body, depressed in the middle, with longitudinal folds proceeding from each side of it towards the poles of the ventral cyst, appearing as if at this part the parietes of the latter had been drawn inwards. See Plate XI. fig. 8. On two sides of this hollow there are dark transverse lines, rather more distinct on one side than on the other, indicating the commencement of the transverse rugæ of the neck, mentioned in the description of this part in the perfect animal, in which the laminated earthy bodies are contained. About the central part of the cervical projection there is an ill-defined oval space, having a granular appearance, and containing some minute spherical particles of a dark colour, consisting apparently of a highly refractive material. See Plate XI. fig. 8. In this condition of the entozoon there is nothing in this space which has the slightest resemblance to the parts which are there about to be developed, namely, the hooklets, suckers, and earthy concretions; and it is only by the comparison of these obscure appearances with the other specimens in which the development of the hooklets is a little more advanced, that their true signification can be learned. See Plate XI. figs. 10 and 12.

Of these parts I will first describe the development of the hooklets, these being the most remarkable and characteristic organs of a *Cysticercus*.

By comparing the preceding specimens with one in which some of the hooklets are in progress of development, and sufficiently advanced in their formation to leave no doubt of their real nature, it will be seen that the highly refractive globular particles seen in Plate XI. fig. 8 are portions of the material of which the hooklets are composed. The entire number of these organs is not in progress of formation at the same time, but only about six are being developed at once, and when these are nearly completed, others make their appearance. The primary condition of one of these organs is very remarkable, consisting merely of a confused and irregular group of very bright particles of a pale straw-colour, which are of various shapes, but still all have a contour more or less curvilinear, and the smaller ones are of a spherical figure. Their size varies from about that of the third part of a handle of a perfect hooklet, to a particle so minute as scarcely to be appreciable by the highest powers of the microscope. There are all the intermediate sizes between these extremes. Notwithstanding, however, these extremes of size and form, all these particles possess the same optical and physical properties, so as to be perfectly recognizable, both when apart and when joined together in the perfect hooklet. See Plate XI. figs. 10 and 12, in which they present no appreciable change in their general appearance.

At a period of the development a little more advanced, some parts of a hooklet can be recognized among these various forms, especially the curved portion, as being most characteristic; also some parts of a handle can be distinguished; lastly, the larger pieces, formed obviously by the coalescence of smaller ones, can be seen fused, as it were, together, more or less completely in a newly-formed hooklet, in which frequently the joining is so incomplete as to amount to little more than mere apposition of the coalescing particles. See Plate XI. figs. 12 and 14.

The part first formed is the hook: this has at first its internal cavity rather larger than that in the older ones, and there is an irregularity of its outline, indicating a want of complete union of its component particles. The handle is formed next: this is more remarkable for its want of symmetry than the curved part, some pieces of it appearing to be merely applied to each other. See Plate XI. figs. 10 and 14. Lastly, the tubercles are added. Neither the whole nor the parts of a hooklet undergo any increase in size after being once formed, but, on the contrary, rather suffer a slight diminution. The hooklets of the old *Cysticercus* are frequently smaller than those of the young ones. But these organs vary a little in different animalcules, being rather smaller in some than in others, but those belonging to the same individual are remarkably regular in this respect.

From the facts that have just been mentioned, the hooklets of the animalcule in question do not appear to be formed by cell-development. For by the most careful examination of these organs, both recent, and after the application of acids, I have not been able to distinguish anything which can be looked upon as a cell or cell-nucleus, calculated to give the idea of their being developed from previously existing cells, or in dependence of cells; but, on the contrary, all the various forms and characters which they present during the process of their formation simply indicate the coalescence of very minute spherules of an homogeneous material, exceeding the number of a complete set of hooklets, into small globular masses, and these again into larger pieces, and so on successively, until recognizable portions of hooklets come into view, which, coalescing, build up, as it were, an entire organ.

It is worthy of remark, that if these structures had been produced directly from the metamorphosis of previously existing cells, the circumstances connected with their formation would have been the most favourable for observing both the original cells and the changes which they passed through; indeed, so much so, that it is almost impossible that they could have escaped notice. First, because these parts are of such a size and degree of transparency as to admit of examination with the highest powers of the microscope without the necessity of disarranging them, or disturbing their position by manipulation. Secondly, because the material of which they are composed is so dissimilar in appearance to that forming the adjacent tissue, and so characteristic, that it cannot be confounded with the structures in their immediate vicinity. Thirdly, because at one view, in a favourable specimen, hooklets can be seen in every stage of their formation, from the first grouping together of the masses of formative particles to the blending of them into perfect organs; and lastly, because it is not as if a mere thread of tissue were formed amongst other threads, slightly differing in appearance, as fibres of elastic tissue, for instance, in a mass of connective tissue, but the objects referred to are perfect organs, which possess an arrangement of parts connected together with order and remarkable regularity. So that, under such circumstances, if these organs had been preceded by nucleated cells, and the cells had been transformed into hooklets, neither these cells in their primitive state, nor in their several stages of transformation, could have escaped detection.

The parts next to be noticed are the suckers. Indications of these are visible as soon as the hooklets. They appear as four circular spaces, presenting a granular aspect, about the size of perfectly-formed suckers. The two sets of fibres next make their appearance, the radiating and circular, which have not at first the sharp outline which they afterwards acquire, but still appear obscurely granular. As the tissue of these organs possesses nothing characteristic like that of the parts just described, the progressive changes which they undergo during the different periods of their formation can be but imperfectly distinguished; and hence no further description of them will be necessary.

It has been observed in respect to the two sets of organs above described, that their size does not increase materially after once formed; exactly the reverse is the case in reference to the part called the neck, and the quantity, though not the size, of the laminated bodies, which increase in number as the cavity of the latter increases in size. These bodies appear as soon as the hooklets and suckers, and they are as large when first formed as afterwards, but there are indications of the transverse wrinkles of the neck before either hooklets or suckers can be distinguished. See Plate XI. fig. 8. The neck afterwards continues to grow, so that its relative length in respect to the ventral portion is some indication of the age of a *Cysticercus*.

It is probable that this part does not arrive at its full size until after it has been protruded, which I have never seen to be the case in any animalcules occurring in or between the muscular fibres, and which perhaps is not effected until the entozoa quit their confined locality between the muscular fibres, and gain access to the free surface of a mucous membrane, there, as physiologists generally believe, to be further developed into a higher form of entozoon.

In the preceding observations on the development of the *Cysticercus cellulosæ*, I have confined myself entirely to such facts as are so obvious and easy of verification, as to leave no doubt of their general accuracy, also to such explanations of their meaning as appear to be almost self-evident; and here I might have concluded this paper had there not remained some considerations entirely of a theoretical nature too important to be omitted.

It will be asked, how the *Cysticercus*, in its earliest condition, such as I have described it, finds access to the interior of a primary fasciculus. Before attempting to answer this question, I must observe that my description commences from a condition of this entozoon so complete, that no one, on examining it with the microscope, and comparing it with those forms in which the development is more advanced, would doubt their identity. But this form, though so low, is very far from being the earliest indication of an abnormal state of the muscular fibres in all those animals which are infested with immature *Cysticerci*. These conditions of the muscular fibres can at once be seen to be abnormal, but still they are altogether of an ambiguous character, and therefore I have deferred till now the consideration of them only from a wish to keep that which is certain and distinct from that which is only probable.

Besides the cells and molecules already described as accumulated in sufficient quantity to present the undoubted form of a *Cysticercus* (see Plate X. fig. 11), numerous minute irregularly-shapen particles are also found in the same specimens of diseased muscle.

These occur either singly or grouped together in clusters of different shapes and sizes. Some lie immediately beneath the sarcolemma, others are deeply seated in the substance of the primary fasciculi. See Plate XI. figs. 3 and 4.

They exist both in fasciculi containing imperfect entozoa, and in those of the same specimen in which entozoa are not yet formed.

These particles do not resemble in the least the scattered nuclei normally existing in muscular fibres, nor are they like the spherules of oil into which muscular fibres are sometimes converted. Occasionally, however, there is a state of fatty degeneration of the muscular fibres, coexisting with this disease, which is known by the regularly spherical form of the particles of oil, and their general arrangement in lines; also by their more equal refraction of light. The particles peculiar to the cystic disease very often occur where there is no fatty degeneration whatever; in no instance do they look like the globules of oil seen in fatty muscle and formed at the expense of the sarcous matter, but they exist independently of oil-globules, and appear to be lodged between the smallest fibrillæ, tending to separate them longitudinally.

Now, as these particles always exist in conjunction with the earliest forms of *Cysticerci*, and in such cases only, and as it is almost impossible that such a collection of corpuscles and molecules as the one I have described to be the earliest *unmistakeable* form of this entozoon could have at once come into existence in so characteristic a form as that delineated in Plate X. fig. 11, I believe that these particles are antecedent ambiguous forms of *Cysticerci*, and that this is the first stage of the disease as it exists in muscle. And it is further worthy of remark, that in some specimens of muscle very much infested with *Cysticerci*, I have found some of the capillaries and small blood-vessels containing molecules of an organic character; some were so completely filled with such particles as to be entirely deprived of blood-corpuscles, and to be recognizable as blood-vessels only by their mode of ramification. Their tunics had become so attenuated as not to be visible under the microscope, and the mass of molecules within them presented the appearance of casts of their interior. In some of these vessels the coat appeared to have been destroyed, and the molecular matter to have become extravasated among the muscular fibres. See Plate XI. fig. 5, which is the representation of a blood-vessel $\frac{1}{333}$rd of an inch in diameter, filled with organic molecules, from the heart of a pig very much infested with *Cysticerci*. Although, in the instance above mentioned, the quantity of organic molecules in the blood-vessels was so abundant as to be easily detected, yet I may observe that in most cases of *Cysticerci* I have not been able to find these molecules in the capillaries, especially when they contained blood-corpuscles, so that I am not enabled to state that the presence of molecules in these vessels in sufficient quantity to admit of detection by the microscope is invariably demonstrable. However, in all cases the smaller blood-vessels and capillaries are in an abnormal condition, but whether this is wholly attributable to the irritation of the incipient entozoa, or to some other cause, is a point which I have not yet been able to ascertain.

Their calibre is very irregular. Some are much distended with blood-corpuscles, and others have their coats so attenuated as not to be distinctly visible. This condition of the vessels is best seen in muscles so small as to allow of microscopic examination without the necessity of mechanically separating their fibres, as in the muscles moving the eye-ball, especially near the part where the muscular fibres are connected with the tendon. Although the presence of these abnormal particles of an ambiguous character in the interior of the primary fasciculi, and that of minute molecules in the blood-vessels and their capillaries, with the attenuation of their coats, may not fully answer the question proposed as to the precise manner in which the first forms of *Cysticerci* find their way into the muscular fibres, still I think these facts render it highly probable that such forms of the entozoa as are represented in Plate X. fig. 11, existed at first as those minute particles which I have described in the muscular fibres, and that these had found their way to the muscular fibres through the medium of the blood.

Without urging any opinion as to the source whence these entozoa are derived, I may here state, that from certain data which I have collected, and which I will now briefly mention, I believe it possible to institute a course of experiments which might throw some light upon this question.

Through the kindness of Mr. Fisher, Inspector of Newgate Market, and some other persons employed there as salesmen, I have been enabled to examine specimens of measly pork taken from at least fifty different pigs. In one class of these specimens I found scarcely any but adult *Cysticerci*, after examining, perhaps, fifty different pieces; I might, however, find one or two of the immature ones, but these were always in the last stage of the vermicular form. In others, a second class, I could find only the earliest stages of the *Cysticerci*, and none of the perfectly-formed ones. And in the third class of specimens, I found them in every possible stage of development, even in the same field of the microscope. I think the last class of specimens was the largest.

Now the inference I deduce from these facts is, first, that the animals from which the first set of specimens were taken had some time prior to their being slaughtered been placed under circumstances favourable for the production of *Cysticerci* (most probably the food had contained the germs of these animalcules), but had for a certain period been withdrawn from them, so that all the younger animalcules—those constituting the vermicular stage—had been, as it were, used up to produce the adult ones; secondly, that those from which the second set had been taken had only been recently placed under such circumstances, and had remained so circumstanced up to the time that they had been slaughtered; and thirdly, that those from which the third set of specimens had been taken, had, both some time previously, and immediately before they were slaughtered, been placed under circumstances favourable for the production and development of *Cysticerci*. Now, as to the determination and discovery of what these favourable circumstances are, it would be necessary that the history of infected animals, giving similar microscopic indications, should be *most* minutely inquired into, especially in relation to those different periods of the disease, and that the investigation of all these circumstances should be tested by a series of careful experiments upon living animals and by examinations of their food, and all the circumstances under which they are placed, both during the period these animalcules are being developed in the muscles and afterwards; so that negative as well as positive evidence might be obtained on the subject.

In concluding this paper, the author thinks it right to append a brief reference to the views at present entertained as to the nature and relations of the Cystic entozoa, in order that the bearing of his own researches may be more clearly apprehended.

A similarity in the form and armature of the head in the *Cysticercus* and Tape-worm, had led the earlier ento-zoologists to suspect that there was some latent affinity between the Cystic and the Cestoid entozoa, and this surmise has, through recent investigations, grown into a consistent doctrine, according to which it is held that the *Cysticercus* and *Tænia* are but different conditions of the same animal. It is accordingly now generally understood that the ovum, or rather embryo, of a tape-worm, being introduced into the body of some higher animal, penetrates through the tissues, probably by aid of the three pairs of hooklets with which it is armed, and on arriving at a suitable resting-place is developed into a *Cysticercus*,—in some cases undergoing intermediate changes in its progress thither; that the *Cysticercus* is destitute of reproductive organs, but that when the flesh of the animal which has afforded it a temporary abode is devoured by a second animal, the parasite, thus introduced into the alimentary canal of a new host, meets with a fitting nidus for further development, and, losing its caudal vesicle, lengthens out, acquires transverse articulation, and assumes the form of a jointed tape-worm. The term *scolex* is applied to the cystic, and *strobila* to the tænioid form of the entozoon; and, as each articulation of the *Tænia* is furnished with a perfect sexual apparatus, and, when charged with fertile ova or embryos, may separate in due time from its neighbours, a single segment has been looked on as constituting a distinct being, and is named a *proglottis*.

The evidence of the conversion of cystic into cestoid entozoa is ample. A particular form of *Cysticercus* grows into a particular species of *Tænia*, of which it is the *scolex*; at least this definite specific relation is probable; and it has now been shown, by numerous and varied experiments, that when *Cysticerci* are given to an animal with its food, they gradually pass into *Tæniæ*, provided the *Cysticercus* made use of is the true scolex of a species of *Tænia* capable of being harboured by the animal subjected to experiment. The *Tæniæ* thus produced agree in number with the *Cysticerci* swallowed, at least never exceed them; they may be traced in progress of development, and when given successively at suitable intervals, the resulting *Tæniæ* present corresponding differences of advancement.

The *Cysticercus cellulosæ* is believed to be the scolex of the *Tænia solium*, which infests the human alimentary canal; and in an experiment made on a condemned criminal, these cystic parasites put into the food a short time before execution were afterwards found in the intestine converted into incipient *Tæniæ*, recognizable as the *Tænia solium*.

The *Tænia* being thus developed from the *Cysticercus*, it should naturally follow that the *Cysticercus* is, in its turn, derived from the *Tænia*; and the fact is established by experiments which may be regarded as complementary of the former. Mature segments of tape-worm, full of embryos, have been given to different animals with their food, and the tissues of these animals have become infested with *Cysticerci*. In this way the *Tænia cœnurus*, given to sheep, has been followed by the production of *Cœnurus cerebralis* in the brain of these quadrupeds; *Cysticercus fasciolaris* has been produced in mice from the *Tænia crassicollis* of the Cat; *Cysticercus pisiformis* has been generated in rabbits from embryos of the *Tænia serrata* of the Dog; and, not to mention other cases, pigs have become infested with the *Cysticercus cellulosæ*, after receiving with their food ripe segments of the *Tænia solium* of the human subject. Moreover, Stein found in the alimentary canal of the larvæ of *Tenebrio molitor*, the usual six-hooked embryos of an undetermined species of *Tænia*, and on the outer or peritoneal surface of the stomach of the same larvæ, numerous encysted *Cysticerci*, on nearly all of which the six hooklets shed by the embryo could be perceived adhering to the cyst and thus clearly showing the connexion of the two. In like manner Meissner found cysts containing *Cysticerci* in the body of the Slug; and although he did not discover *Tænia*-embryos, he found what were unmistakeably their six hooklets attached to the body of the *Cysticercus*.

While, however, the proof of the derivation of the *Cysticercus* from a *Tænia*-embryo thus seems complete, the process of conversion of the one into the other has not hitherto been followed completely in its different steps. The observations of Leuckart on this head are perhaps most to our present purpose. He found, that on giving the ova of *Tænia serrata* to rabbits, a numerous brood of *Cysticercus pisiformis* appeared in the liver, which situation he conceives they might have reached by the route of the vena portæ. At first they were very small white bodies having none of the marks of *Cysticerci*; they afterwards enlarged, assumed an oblong shape, and, piercing through the substance of the liver, escaped into the peritoneal cavity; then, in a thickening which appeared at the fore-part of the very simple vermiform body, was developed the characteristic head of the *Cysticercus* with its suctorial disks and circlet of hooks. No trace of the six *embryo-hooks* could be detected in connexion with the *Cysticerci*. These observations of LEUCKART were published in 1855, and were not known to the author when he first communicated his researches to the Royal Society in the summer of that year. Allowing for differences not unlikely to modify the process in different cases, the facts observed by LEUCKART are in no way irreconcileable with the conclusions arrived at in this paper; and after due consideration of the present state of knowledge concerning the relations subsisting between the Tape-worm and *Cysticercus*, the author sees no reason to distrust the evidence on which he has represented the *Cysticercus cellulosæ* as immediately developed from a peculiar vermiform animal, whatever be the mode in which the latter may be derived from a *Tænia*-embryo.

Finally, the facts made known in this communication may perhaps serve to throw light on the nature of certain bodies of an ambiguous description observed by VON HESSLING* to be occasionally present in the muscular tissue of the heart of the Ox, Sheep, and Roe Deer. These objects appear under the form of oval aggregations of granules of a peculiar kind, enclosed in an outer capsule and parted into several smaller masses somewhat like the segments of a yelk in the process of division. Without hazarding an opinion as to their destination, VON HESSLING compares these bodies to the elongated tubular capsules filled with similar spore-like granules, which were discovered in the abdominal muscles of mice by MIESCHER, and subsequently in rats by BISCHOFF and SIEBOLD. These singular formations are described by the last-named observers as being lodged within the sarcolemma of the muscular fibre. SIEBOLD is inclined to regard them as vegetable parasites; but they offer many points of resemblance to the early condition of the *Cysticercus* as described in the foregoing pages.

DESCRIPTION OF THE PLATES.

PLATE X.

Fig. 1. A *Cysticercus* with its neck protruded.
a. The ventral part.
b. The neck.

Fig. 2. The free quadrilateral surface at the extremity of the neck, showing the four suctorial disks at its angles, and the ring of hooklets at its centre.

Fig. 3. The two sets of fibres, longitudinal and transverse, visible in the membrane of the neck of the *Cysticercus*, also the laminated calcareous particles.

* Zeitschrift für Wissenschaftliche Zoologie, vol. v. p. 196.

Fig. 4. A suctorial disk sufficiently magnified to show the circular and radiating fibres.

Fig. 5. The entire number of hooklets *in situ*:—(*a*) the circular area circumscribed by the handles of the hooklets; (*b*) the external zone of circular fibres; (*c*) the internal zone; (*e*) the radiating fibres placed between the hooklets, and connecting them together; (*f*) fibres connecting the hooklets to the central membrane.

Fig. 6. Three hooklets:—(*a*) one as seen in profile, showing the curved portion and the handle, and at their union a tubercle; (*b*) one of the larger hooklets with only one tubercle; (*c*) a smaller hooklet with two tubercles.

Fig. 7. The circular depressed part circumscribed by the inner extremities of the handles of the hooklets, as shown in fig. 5 (*a*), has been here made to project: (*a*) the fibre connecting it with a hooklet.

Fig. 8. The growing extremity of an entozoon, showing the extreme end filled with minute molecules and globular corpuscles in various states of development.

Fig. 9. The end of an entozoon covered with cilia-like fibres, and containing molecular matter; also a transverse section of the body or middle part covered with cilia-like fibres placed upon an investing membrane, and filled with reniform corpuscles.

Fig. 10. Reniform corpuscles removed from the interior of an entozoon by pressure.

Fig. 11. The earliest recognizable form of the vermicular state of the *Cysticercus cellulosæ* contained in the interior of a primary muscular fibre.

Fig. 12. A *Cysticercus* of the vermicular form removed from the interior of a muscular fibre, showing the direction and the arrangement of its cilia-like fibres.

Fig. 13. A *Cysticercus* similar to the above, showing the exceedingly thin investing membrane at one of the extremities, devoid of cilia, this part being only of very recent formation.

Fig. 14. A *Cysticercus* in the substance of a primary muscular fibre; the cilia-like fibres are only faintly visible, being pressed by the surrounding muscular substance closely to the animalcule.

Fig. 15. A *Cysticercus* in its vermicular state taken from the muscular parietes of the heart, showing its general form and its cilia-like fibres. The latter are much less distinct than in vermicular *Cysticerci* taken from other striped muscles.

Fig. 16. The ciliated investment of a portion of a *Cysticercus* of the vermicular form, from which the reniform corpuscles have been removed.

PLATE XI.

Fig. 1. Shows a *Cysticercus* of the vermicular form folded upon itself in an adventitious cyst, a portion of which is seen upon one of the ends of the animalcule. This *Cysticercus*, as thus folded up, measures $\frac{1}{16}$th of an inch in length.

Fig. 2. A *Cysticercus* which has left the interior of a muscular fibre, and become situated in a cellular space between the muscular fibres, among the fat-vesicles always occurring in greater or less abundance in such situations. The crenate border and obscurely annulose appearance are here shown.

Fig. 3. A portion of a primary muscular fasciculus, in which irregular particles, of different shapes and sizes, are mixed with the muscular fibrillæ.

Fig. 4. Another portion of a primary fasciculus, in which the same kind of particles as those shown in fig. 3 are grouped together.

Fig. 5. A blood-vessel $\frac{1}{333}$rd of an inch in diameter filled with organic molecules, taken from the heart of a pig very much infested with *Cysticerci*.

Fig. 6. A portion of the same blood-vessel, magnified 400 diameters, showing the microscopic appearance of its molecular contents.

Fig. 7. A *Cysticercus* removed from its adventitious cyst, whose length is $\frac{1}{7}$th of an inch, and breadth $\frac{1}{28}$th. This is the highest stage of the vermicular form, and it combines the characters of that represented in fig. 2 and that in fig. 1 of this Plate, also those of the next figure.

Fig. 8. Shows that stage of the development of the *Cysticercus* in which is seen the earliest indication of the future neck with its hooklets and suckers. The whole of the animalcule is here shown as magnified 15 diameters. (*a*) the part to be occupied by the neck, where traces of its plicated form, also suckers and hooklets, are beginning to appear.

Fig. 9. Shows the part marked (*a*) in the preceding figure, magnified 100 diameters, these parts being faintly indicated.

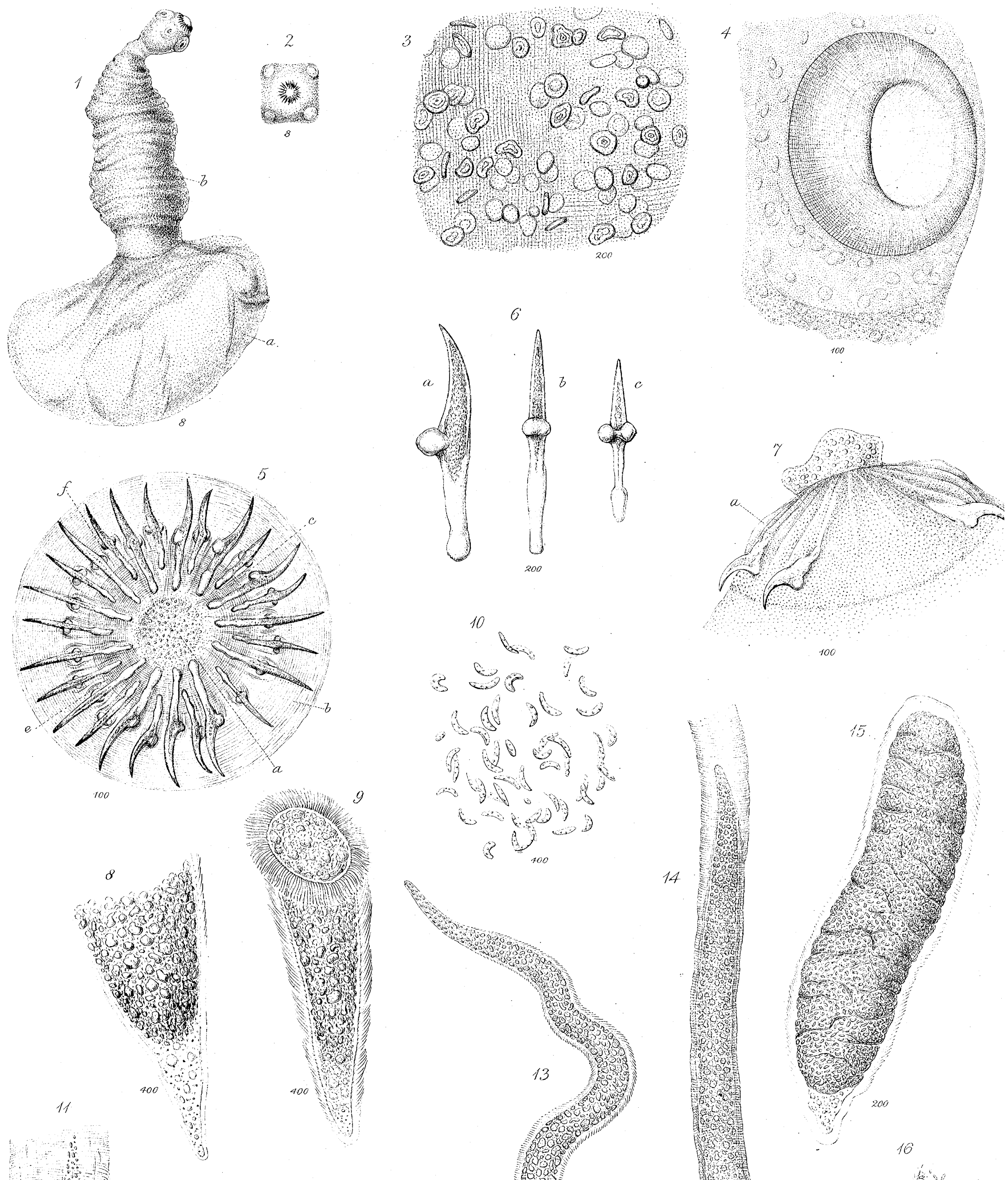
Fig. 10. Shows a stage in which the hooklets are in progress of development; the neck is but little more advanced than in fig. 9. The entire entozoon is here shown as magnified 10 diameters.

Fig. 11. The hooklets of the preceding specimen, magnified 100 diameters. Six of them are sufficiently advanced to be recognizable: (*a*) particles of the material of which others are about to be formed, grouped together, but not yet coalesced sufficiently to form any recognizable portion of a hooklet.

Fig. 12. A form a little more advanced, showing the entire entozoon, magnified 10 diameters.

Fig. 13. The hooklets of the same specimen, magnified 100 diameters, exhibiting the same appearances, indicative of coalescence, as in fig. 11; here there are, however, portions of hooklets sufficiently formed to be recognizable, mixed with particles of the same material not having yet received a recognizable figure.

Fig. 14. Portions of hooklets from different specimens, magnified 200 diameters.



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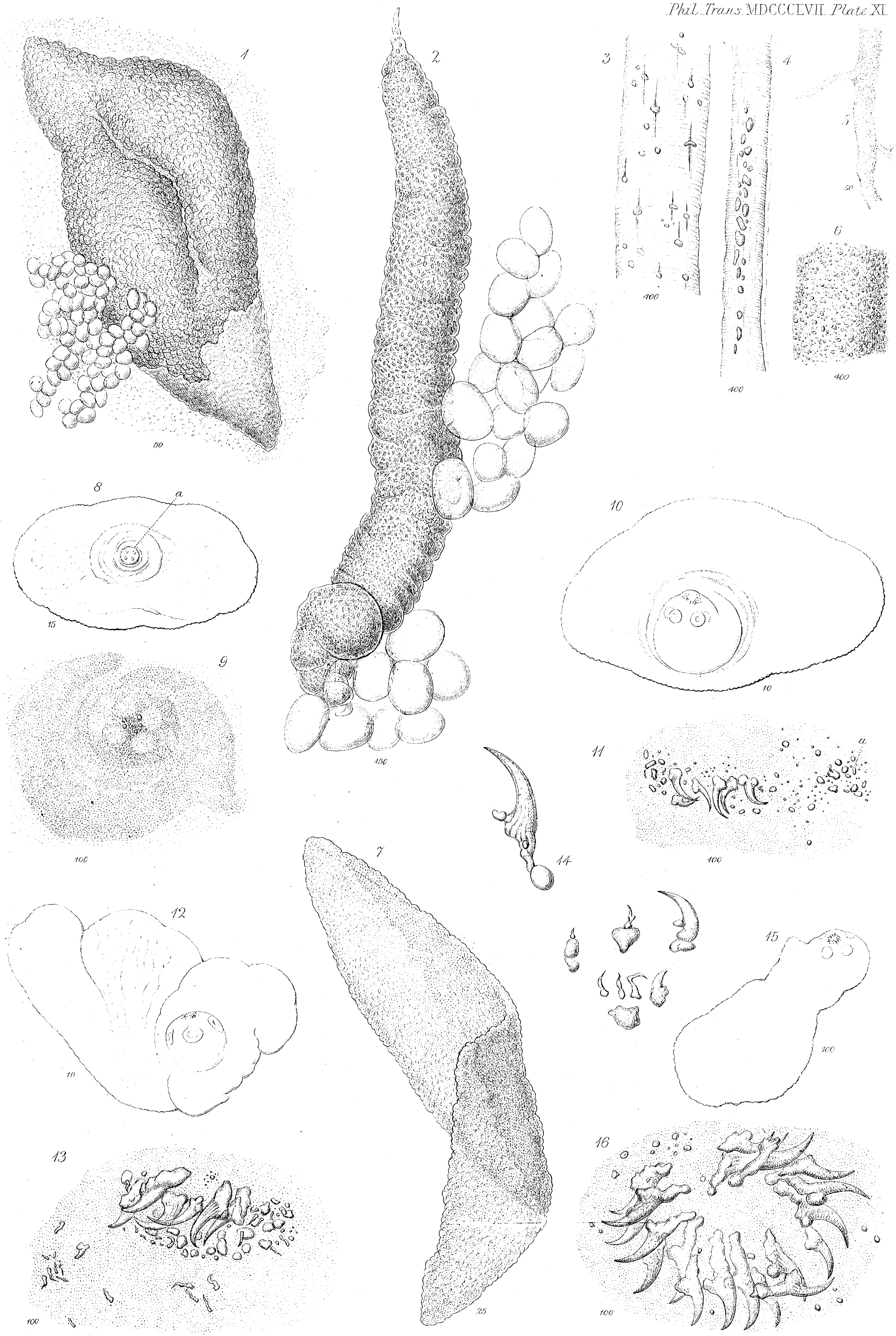

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