II. *A New Mode of Respiration in the Myriapoda.**

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[Plates 5, 6.]

In the course of some work which I have been doing lately, I have been led to consider the systematic position of the Scutigeridæ or Cermatidæ. C. L. Koch, in his well-known work, "System der Myriapoden," includes this group in an order by itself, dividing the Myriapods into three orders of equal value. These orders are the Chilognatha, the Chilopoda, and the Schizotarsia (the Scutigeridæ). Latzel, on the other hand, and with him most other writers, have included the Scutigeridæ among the Chilopoda, not considering the differences to be of sufficient value to warrant the formation of a new Order.

I came to the conclusion that so little was known of the Scutigeridæ that Latzel was quite right in including them among the Chilopoda; but that a more careful study of their organisation might very likely render it necessary to modify that view, and show that Koch was right in his establishment of a new Order, although, in the absence of published facts, his doing so might be premature.

I began my observations on the anatomy of the group by a careful examination of the respiratory system, being influenced by the circumstance that the existing accounts differ so much that we may say that the respiration of the group is still unknown. Latzel, in his book, 'Die Myriapoden der Oesterreichisch-Ungarischen Monarchie,' gives the following account of the respiration of the Scutigeridæ. "Die Art und Weise, wie diese Thiere athmen, ist noch räthselhaft. Zwar lese ich fast überall, dass sie durch Tracheen athmen, die sich in den Dorsalstomata öffnen sollen, wogegen nach Marcel de Serres ('Mém. du Mus. d'Hist. Nat.,' vol. 4, 1819) unter jedem Rückenschilde zwei Luftsäcke oder Tracheenblasen, welche mit seitlichen und unteren Luftröhren in Verbindung stehen, existiren und Wood (in 'Trans. Amer. Philos. Soc.,' Philad., 1869, p. 145) ausdrücklich sagt: 'The sides have nine pairs of spiracles, opening into the tracheal vessels.'"

Latzel goes on to say that he has examined a great number of Scutigeridæ, and

* The attention of the reader is called to the Postscript on p. 70.

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has never found stigmata or real tracheæ with spiral threads. He examined the dorsal stomata, and found them to consist of two systems of very fine, branched, colourless, closely packed tubes without spiral threads. He thinks that they may be a kind of tracheal lungs differing in construction from those of Scorpions and Spiders, and goes on to say :—

"Dieses Organ mit den Hüftporen der Lithobien oder mit den Pleuralporen der übrigen Chilopoden auf gleiche Stufe stellen zu wollen scheint mir gewagt. Vielmehr ist bei dem Mangel an echten Tracheen in diesem dorsalen Röhrensystem vielleicht doch das Athemorgan, etwa eine Art von Lungentracheen, zu erblicken, die allerdings einen anderen Bau hätten als die entsprechenden Organe bei den Scorpionen und Araneiden" (p. 22).

My material consisted of specimens collected by myself and preserved in different ways some time ago. Though these were excellent for cutting sections, yet I needed the live animal for examination of the tubes, circulation, &c. I therefore tried to get some specimens alive, and, in July, 1891, I received some living *Scutigera* from M. DE LACAZE-DUTHIERS, who collected them for me in the South of France, and packed them so carefully and skilfully that they reached me quite unhurt. I am glad to have this opportunity of thanking him for the kindness which prompted him to take a great deal of trouble (for the animals are never common, and are very rare at this time of the year) to oblige a fellow naturalist.

I shall first describe the organ itself, and then give the reasons which seem to me conclusive evidence that it is a respiratory organ, and then state the bearings which it seems to me to have upon other morphological facts.

The series of organs which, I hope to show, perform the function of respiration in *Scutigera*, are arranged in the middle line at the posterior end of each dorsal scale. They are best seen in a specimen which has been preserved in corrosive sublimate acidulated with hydrochloric acid. Such a mode of preservation bleaches the pigment and renders the heart and the organs very apparent.

Description of Organs.

Each organ is placed in the middle line at the posterior end of a dorsal scale. Each dorsal scale (of which there are eight) is provided with an organ, except the last. The organ consists externally of a slit bounded by two pairs of curved ridges or elevations of the external chitin of the dorsal scale (Plate 1, fig. 2). The pair of ridges nearest the middle line form the lips, so to speak, of the slit and join in front of the slit, forming at their junction a small knob of chitin (fig. 2).

The other pair of ridges are further from the middle line and run nearly parallel to the pair first-mentioned, joining (posteriorly) the rim of chitin round the edge of the dorsal scale, and fading away anteriorly instead of joining like the other pair. These ridges are shown in fig. 2.

The internal parts of each organ consist of an air-sac (figs. 3, 4, 5) into which the slit-like external aperture opens (fig. 3), and a number of tubes (figs. 11, 12, 13) formed of chitin, opening at their thicker ends into the air-sac, branching several times, and each ending in a blunt point of delicate chitin which projects into the pericardial space, to be there bathed in blood. These tubes are arranged in two semicircular masses (figs. 1, 2) which can be plainly seen through the transparent chitin of the body.

General Description of the Parts Surrounding the Organs.

Before entering into a more minute description of the parts of the organ, it will be well to describe shortly the general position of the parts which surround the organs.

The dorsal scales or scutes are eight in number, the fourth being considerably the largest. The scales overlap one another, and the greater part of the organ is contained in the overlapping part. This may be understood from figs. 3, 4, 5, 6, 7, which show a series of transverse sections through the whole body of the animal in the region of the organ. The heart (figs. 10, 3, 4, 5, 6, 7) lies in the dorsal middle line a little beneath the organ, and the pericardial membrane and fat body (figs. 6, 7) enclose the heart and the pericardial space. The ends of the tubes project into the pericardial space and the spaces of the fat body. This fat body is like the fat tissue in other Myriapods (1)* a vascular tissue, through the spaces in which the blood passes on its way back to the heart. In *Scutigera*, the main part of it lies round the heart and pericardium, and the blood passes *directly* from it into the pericardial space.

Descriptions of the Parts of the Organ.

The *air-sac* into which the slit or external opening of the organ leads is an oblong space with thick chitinous walls. (Figs. 3, 4, 5, 10.) The walls are continuous with the exoskeleton of the animal. The greater part of the walls are perforated with the apertures of the tubes which are close together, so that a surface view of the interior of the air-sac looks like the tube ends in the boiler of a steam-engine (fig. 12). The tubes themselves are cylindrical, and are thickest, both as to the diameter of the tube and the chitin of which it is composed, at the end adjoining the air-sac.

At the ends furthest away from the air-sac and nearest to the pericardial space the diameter of the tubes diminishes, and so does the thickness of the walls, till at last the tubes become so thin and membranous that they are exceedingly hard to follow, and can only be made out satisfactorily with the aid of a high-power lens (POWELL and LEALAND, $\frac{1}{12}$ apochromatic; REICHERT, $\frac{1}{15}$ oil imm.). I have succeeded in isolating a single tube, and give a drawing of it. It branches several times, and the branches are pretty uniform in all the tubes as far as I was able to make out. Certainly, the

* The figures in the text refer to the list of literature at the end of the paper.

branch nearest the air-sac occurs in all the tubes. The ultimate branches end blindly in a blunt point (fig. 13).

The point can only be made out clearly in a fresh specimen, as in preserved animals the ends of the tubes are completely clogged with blood corpuscles. The ends of the tubes, as already mentioned, either project into the blood in the pericardium, or penetrate the spaces in the fat body: in either case they are bathed in blood.

The tubes are clothed with cells which resemble those of the hypodermis, and are, in fact, a continuation of the latter. Their appearance is shown in figs. 9, 12, 13. The blood corpuscles can be distinguished from the clothing cells of the tubes by the following characteristics:—Their nuclei are quite round, and stain more deeply than do the nuclei of other cells. The cell-body is quite round and not irregular in shape, as in the case of the clothing cells. An example of the two kinds of cells is shown in fig. 3.

The Fat Tissue.—The peculiar form of tissue known as "fat body" in the Myriapods is of great importance in this class of animals. It packs the organs and enters into a peculiar relation with the heart and pericardium. In all Myriapods with which I am acquainted it pierces the pericardium, and parts of it lie within the latter. In a former paper (1) I traced the origin of this tissue in *Julus terrestris*, and found that it originated from mesoblast cells which remain in the yolk and give rise to the heart, pericardium, and fat body. In *Julus* the circulation is largely carried on by means of this tissue, the blood circulating in its spaces. A specimen of this tissue in *Scutigera* is shown in fig. 9 (Plate 2). It is composed of a network of strands of tissue, with nuclei mostly at the nodes, and smaller or larger oil globules in the spaces close to the strands or strings which compose the network. The spaces are, in many cases, loaded with blood corpuscles. The arteries penetrate the fat bodies and then cease, their walls being no longer distinguishable.

I have not made out the mode of communication, but have found the blood corpuscles in the lacunar spaces. As before mentioned the fat body enters within the pericardium in places, and does so specially, just where the heart is pierced by the ostia, and in such places the lacunæ of the fat body are crowded with blood corpuscles. In fig. 7 (Plate 2) I have shown the corpuscles leaving the fat body, entering the pericardium, and finally clustering round the ostium so as to hide it. SEDGWICK in his monograph of the development of *Peripatus capensis* has shown that a peculiar tissue is present in the pericardium of *Peripatus*. This tissue he calls (9) the pericardial tissue, or reticular tissue of the pericardium. GAFFRON has compared this tissue to the fat bodies of *Tracheates*. The same tissue is also found in the lateral compartment of the body cavity of *Peripatus*, and I think that it may be fairly compared to the highly characteristic fat body of the Myriapods.

Description of a Series of Sections through the Region of the Organ.

Before passing on to the consideration of the reasons for considering the series of organs as respiratory in function, I will complete my description of the individual organ by a short account of a series of sections taken transversely through the whole body in the region of one of the organs. These sections are shown in figs. 3, 4, 5, 6, 7, 8.

Fig. 3 is the most posterior of these sections. It cuts through the animal just where the dorsal shield overlaps the succeeding one, and consequently the section through the overlapping part appears to be completely separate from the rest of the body. In this section we can see the four ridges round the slit-like opening to the exterior. Beneath the slit is the air-sac with some of the tubes leading from it. At the ends of the tubes there is a space in connection with the pericardium, and partly filled with blood corpuscles. Beneath the overlapping part of the dorsal scale, as I have called it, lies the main part of the body, with the heart in the pericardium, and the fat body and the ovary beneath.

The next figure (fig. 4) is a section taken a little anteriorly to fig. 3. The ridges are no longer present, but the air-sac is larger. The spaces at the ends of the tubes are filled with blood corpuscles and a portion of the fat body (*bl.c. fat body*).

Fig. 5 is a little anterior to the section shown in fig. 4. In this part of the segment the dorsal scale no longer overlaps the one behind it, and consequently this part of the organ is within the main part of the body. The fat body still envelopes the tube ends, and we now see the pericardial membrane joining it, thus making the spaces at the ends of the tubes (seen in the preceding sections) a part of the pericardial space. In other words, the spaces separated off from the rest of the body-cavity by the pericardial membrane are, (1) in the greater part of the segment, a triangular space enclosing the heart, and (2) in the region of the organ, the same space and all the spaces in the overlapping part of the dorsal shield round the organ. All these spaces are in communication with one another and are separate from the rest of the body-cavity.

The next figure (fig. 6) shows a section anterior to the last. The tissues of the organ have quite disappeared, and in their place is a space occupied on each side by the two masses of fat body, which were shown in the last figure, and which are now enclosed by the pericardial membrane. The space marked *ext. sp.*, shows that the overlapping part of the dorsal scale is almost past. It is, in fact, the remnant of the space that in the posterior sections divided the overlapping portion of the dorsal scale from the rest of the body.

In fig. 7 the main part of the segment is reached and the organ is no longer present. The fat bodies are within the pericardium and the blood corpuscles are passing from them to the ostium of the heart round which they are clustered so as to hide it. The

last figure (fig. 8) shows the position the heart and pericardium in the middle of a segment.

I will now give my reasons for believing these organs to be respiratory.

Reasons for regarding the Organs as Respiratory in Function.

In the first place we have a Myriapod in which alone among Myriapods there is no known mode of respiration. As LATZEL sums up the matter, "Die Art und Weise wie diese Thiere athmen, ist noch räthselhaft." That they do not breathe by means of stigmata and tracheæ is, I think, undeniable. I have myself carefully examined them during life, and in the preserved specimen by means of the simple and compound microscope, and I have been unable to find any traces of ordinary tracheæ and stigmata which in all other Myriapods are easily seen. We know from the habits of the animal that it exhibits an amount of activity and quick motion which is remarkable in its class, and the details of its anatomy agreeing with this characteristic—ST. RÉMY has shown lately that alone among Myriapods, *Scutigera* has its nervous system permeated by bloodvessels (10)—indicate an unusual need for perfect aëration of the blood. Now, if I can show that an examination of the organ in question affords good ground for regarding it as respiratory, it seems to me that the absence of any other organ that can possibly be supposed to be respiratory affords a strong presumption in favour of my views.

Next, we have the structure of the tubes themselves. They are of chitin, and are of considerable length. The chitin grows thin and membranous towards the end, affording a good opportunity for the interchange of gases.

Then there is the fact that the tubes are full of air. I satisfied myself on this point by killing the living animal by a drop of chloroform, immediately cutting out the organ, and teasing out the tubes in a drop of glycerine. When the tubes so treated are placed beneath the microscope they have the peculiar shining appearance which tracheal tubes usually have when placed in fluid beneath the microscope.

Next, we may consider the position of the tube ends with regard to the pericardium. I have shown that the tube ends are actually within the pericardium, and as has been pointed out by LANKESTER, in Arthropods the pericardium is filled with blood, therefore the tube ends are in such a position that they are continually bathed by blood. I was able by carefully cutting out the organ and surrounding tissues from an animal which had just been killed, and placing them in salt solution beneath the microscope, to watch the blood coagulating and corpuscles collecting round the tube ends.

Then there is the position of the organ itself. The organ is so placed that the connection between the tube ends and the blood takes place just before the return of the blood into the heart through the ostia. If, then, the organ is respiratory the aëration of the blood takes place just where it is needed. The impure blood after

circulation is aërated before passing into the heart for redistribution through the body.

There is, finally, another point which I put forward with some hesitation, inasmuch as it rests on the correctness of my own theoretical views as to the development of the Myriapods. In a former paper (1) I came to the conclusion that the chief differences in the form of the body of Myriapods were connected with an unequal development of the dorsal and ventral regions of the body, the ventral region of the body in the adult retaining more of the primitive characters than the dorsal. Now, in *Scutigera*, the dorsal scutes do not agree with the ventral segmentation of the body, so that an organ sunk in the dorsal plate must represent a late development in the history of the species. To put it in another way, we have in Myriapods, as shown in my paper on the post-embryonic development of *Julus terrestris*, a true segmentation or mesoblastic segmentation which is primitive, and an apparent segmentation which can only be regarded as a segmentation on superficial inspection. This apparent segmentation is not a primitive character, but a late modification of the organism. The respiratory organs of *Scutigera* are arranged in accordance with the apparent segmentation, not with the true segmentation; and are, therefore, organs which have appeared late in the history of the group.

Now this organ in *Scutigera* differs so much from all other organs of respiration known in the Myriapoda, and is confined to such a small class (for *Scutigera* is neither common nor widely distributed) that we are, I think, justified in saying that it is a newly developed mode of respiration, and, as such, is situated in the very part of the body where we should expect such an organ to arise.

Such are the reasons which lead me, as I think, justly, to believe that these organs are respiratory; and for the rest of my paper I shall assume this point proved, as in my opinion it is.

The mode of respiration in *Scutigera* differs from that in other Myriapods in the following particulars :—

1. The tracheal tubes are collected into one definite organ in each dorsal shield instead of being distributed about the body.
2. The tubes have no spiral thread.
3. The organs act on the blood in the pericardium, and this blood is distributed by the heart as aërated blood. In other Myriapods the tracheæ act on the blood in the different organs of the body.

These are the points in which the respiratory organs of *Scutigera differ* from ordinary tracheæ. They *resemble* them in the following particulars :—

1. The tubes open into an air chamber which may be compared to a tracheal vesicle.
2. The tubes are cylindrical and are composed of chitin.
3. The tubes branch.

Now, comparing the organs in question with the tracheal lungs of Spiders, we find that they resemble the latter in these points :—

1. The tubes open into a large air-chamber, considerably larger than a tracheal vesicle.

2. The number of tubes is very great.

3. In both cases there is an arrangement for bathing the tubes in a blood sinus.

4. In both cases there is a supply of aërated blood to the heart.

The differences between the organs of *Scutigera* and the tracheal lungs of Spiders are—

1. The form of the tubes, which are cylindrical in *Scutigera*.

2. The absence of the membrane which in Spiders surrounds the organ, and which, in *Scutigera*, is possibly replaced by the clothing cells.

4. The branched form of the tubes in *Scutigera*.

We see from the foregoing comparison that the respiratory organ in *Scutigera* holds a position intermediate between the Spider's lung-book on the one hand and the tracheæ found in other Myriapods on the other. The three kinds of respiratory organs—the tracheæ, the respiratory organ of *Scutigera*, and the tracheal lungs of Spiders—form a series advancing from simple to complex in such a way that it is almost impossible to doubt that they are related together. Now this question arises: Are the tracheæ derived from the organ of *Scutigera*, or *vice versâ?* It is just possible that the respiratory organ of *Scutigera* may have been developed separately, and that there may be no connection between them; but this is a view for which I see no evidence, and, when speculating on a point like this, we must go by evidence, and leave bare possibilities until something arises to render them probable. The question, then, is whether the tracheæ are the starting-point in our series, or the Spider's tracheal lung; that is, in my opinion, whether the simpler form has developed from the more complex, or the more complex from the simpler?

The view that tracheæ have developed into the lungs of Spiders was advocated by LEUCKART in 1849 (7), and this view held ground for some time. Lately, however, the work of RAY LANKESTER on *Limulus* has given rise to new views on the subject, and his theory has been supported from an embryological point of view by J. S. KINGSLEY and others. KINGSLEY's views are thus stated in his paper (2):—"Having derived the lungs of the Scorpion in this manner (*i.e.*, from the gills of *Limulus*), but little remains to be said concerning the origin of the tracheæ in the Spiders. Many years ago LEUCKART showed that the so-called lungs of the Arachnids were but modifications of the peculiar tracheæ of the same group. This conclusion holds good to-day, and I would accept it in an inverted condition. The tracheæ of the Arachnids are but modifications of the pulmonary organs existing in some of the group."

LANKESTER's views are stated in his paper (4). He imagines a common ancestor of *Limulus* and *Scorpio*, with six pairs of mesosomatic appendages, and says that the last four of these have been transformed into the Scorpion's lung-book, by being

invaginated into the Scorpion's body so as to project into the blood sinus, thus transforming an aquatic form of respiration into a terrestrial.

Now, first of all, let us take KINGSLEY's views and consider what bearing the present investigations have on them. If the tracheæ are derived from the lungs of Spiders, we are driven to the conclusion that in the respiration, at any rate—an important function affecting the whole organisation—the Scutigeridæ alone of the class of Myriapods have retained a primitive mode of respiration and that, as far as the respiration is concerned, the Chilopods, Chilognaths, and *Peripatus* have lost this primitive condition, and have developed tracheæ. Now, this does not at all agree with what we know of their anatomy and development. In my paper (1) I gave my views as to the relationships of Myriapods, and I have not altered my opinion. I now consider that the occurrence of an organ of respiration intermediate between the tracheæ of Myriapods and the lungs of Spiders, in an undoubted Myriapod, quite disposes of the view that the tracheæ of some Spiders are but modifications of the pulmonary organs found in others of the group, unless we are prepared to admit that the highly specialised Myriapod *Scutigera* is of a more primitive type than Chilognatha, the other Chilopoda, and *Peripatus*. My own opinion is, that we have a series from the simple tracheæ found in *Peripatus* up to the complete lungs of Spiders, which is incapable of explanation in the present state of our knowledge, except as representing the stages of development of tracheæ into the pulmonary organ of Spiders. I consider that the results I have obtained confirm LEUCKART's views (8) as to the way in which the development took place.

Let us now consider what bearing the facts recorded in this paper have on LANKESTER's views. His theory, as already stated, is that the appendages of a common ancestor of *Limulus* and *Scorpio* have developed into the gills of *Limulus* on the one hand, and the lungs of *Scorpio* on the other. Of course it is possible that the Scorpion's lung may have a different origin from that of the Spiders. If this is the case, however, it seems to me that the differences between Spiders and Scorpions must be much more essential than is at present supposed by most naturalists; more so than is, in my opinion, warranted by what is known of their anatomy and embryology. If the lungs of Scorpions are derived from those of Spiders, and those of Spiders from tracheæ, then an important argument in LANKESTER's "*Limulus* an Arachnid" falls through.

I must now say a few words on SEDGWICK's "Origin of Metameric Segmentation" (8). His views on tracheæ are stated thus, "The tracheæ were at first simple pits of ectoderm in a diploblastic animal, and they gradually became more complicated, and branched as the other organs became more complicated and folded. The development of tracheæ fits in perfectly well with this view. The tracheal respiration is then a primitive method of respiration, which has persisted in but few of the triploblastica . . . a special localisation of tracheæ is found in the pulmonary sacs of the Scorpions."

It seems to me that my observations confirm this view strongly. In my opinion

the organ of *Scutigera* is intermediate between the simple tracheæ and the lungs of Spiders, and fills up a gap which has hitherto been wanting, so that the series now goes, simple tracheæ, organ of *Scutigera*, lungs of Spiders, lungs of Scorpions.

My investigations were carried out partly in the Morphological Laboratory at Cambridge, and partly in my private laboratory.

Postscript.

(Added May 10, 1892.)

After sending in the foregoing paper to the Royal Society my attention was drawn, on March 6, to a paper published in A. Schneider's 'Zool. Beiträge,' 1885—"Das Respirationssystem der Symphylen und Chilopoden," by Dr. E. von Haase.

This paper anticipates my own in the following particulars :—

In the description of the air-sac.

In the description of the branching of the tubes and the way in which the tubes end.

In the fact that the blood is arterial in the heart.

In the statement that blood does not circulate between the individual tracheæ.

In the fact that each respiratory arrangement may be considered as a single organ, and that this organ is intermediate between the tracheal lungs of Spiders and the true tracheæ of Spiders.

My paper is untouched in the important point of the arrangement for the supply of blood to the end of every tube, which renders the organ sufficient for the whole function of respiration, whereas Dr. von Haase, on p. 75 of his paper, doubts whether the respiration is carried on by the organ alone, or whether there is not some supplementary means of breathing.

List of Literature referred to.

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2. Kingsley, J. S. "Notes on the Embryology of *Limulus*." 'Quart. Journ. Micro. Sci.,' vol. 25, 1885, p. 521.
3. Koch, C. L. "System der Myriapoden," Regensburg, 1847.
4. Lankester, E. Ray. "A New Hypothesis as to the Relationship of the Lung-book of *Scorpio* to the Gill-book of *Limulus*," 'Quart. Journ. Micro. Sci.,' vol. 25, 1885, p. 339.
5. Lankester, E. Ray. "*Limulus* an Arachnid," 'Quart. Journ. Micro. Sci.,' vol. 21, p. 504.

6. LATZEL, R. "Die Myriapoden der Oesterreichish-Ungarischen Monarchie," Wien, 1880.

7. LEUCKART, A. "Ueber den Bau und die Bedeutung der sog. Lungen bei den Arachniden," 'Zeitschr. Wiss. Zool.,' vol. 1, 1849, p. 246.

8. SEDGWICK, A. "On the Origin of Metameric Segmentation and some other Morphological Questions," 'Quart. Journ. Micro. Sci.,' vol. 24, p. 43.

9. SEDGWICK, A. "A Monograph of the Development of *Peripatus capensis.*" 'Studies from the Morphological Laboratory in Cambridge,' vol. 4; 'Quart. Journ. Micro. Sci.,' vol. 28, p. 383.

10. ST. RÉMY, G. DE. "Thèse présentée à la Faculté des Sciences de Paris." Poitiers, 1890.

DESCRIPTION OF PLATES 5 AND 6.

PLATE 5.

Fig. 1. A preserved specimen magnified $3\frac{1}{2}$ times and seen from the dorsal surface. This figure was drawn for me, under the microscope, by Mrs. SINCLAIR. All the other figures are by myself.

Fig. 2. The over-lapping part of the dorsal scale, torn off and drawn under the microscope with a D ZEISS objective.

Fig. 3. The series of sections from 3 to 8 are slightly diagrammatic, that is, they are representations of many sections and are not drawn from single sections. Fig. 3 is a section cut transversely through the whole body just at the posterior end of the over-lapping part of a dorsal scale.

Fig. 4. Section transversely through the body slightly anterior to fig. 3.

Fig. 5. Transverse section through the body slightly anterior to fig. 3. The pericardial membrane is shown joining the fat body.

Fig. 6. Transverse section a little anterior to the preceding.

PLATE 6.

Fig. 7. Transverse section a little further anterior. The heart is cut in the region of an ostium.

Fig. 8. Transverse section still further anterior, about the middle of a segment. An artery is shown leaving the heart.

Fig. 9. A portion of the fat body highly magnified.

Fig. 10. Diagram of a longitudinal section through the region of the organ, to show the mutual relations of the heart, the pericardial membrane, and the organ.

Fig. 11. A single tube isolated, showing the branches, drawn from the fresh specimen.

Fig. 12. A small part of the wall of the air sac with the tubes going off from it. Highly magnified.

Fig. 13. End of a tube with one of the clothing cells and two blood corpuscles which have clung to it. From the fresh specimen.

Letters used in all the Figures.

Bl. c. Blood corpuscle.
Ch. Chitin.
Ext. r. External ridge.
Ext. sp. Space dividing the over-lapping part of the dorsal scale from the rest of the body.
H. Heart.
hyp. Hypodermis.
hyp. cell. Hypodermic cell.
Int. r. Internal ridge.
Nucl. Nucleus.
Ost. Ostium.
Percd. memb. Pericardial membrane.
Percd. Pericardium.

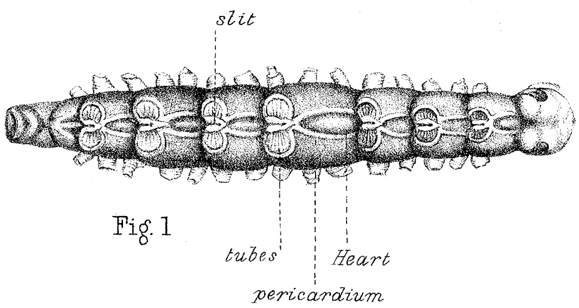


Fig. 1

A. C. Sinclair del.

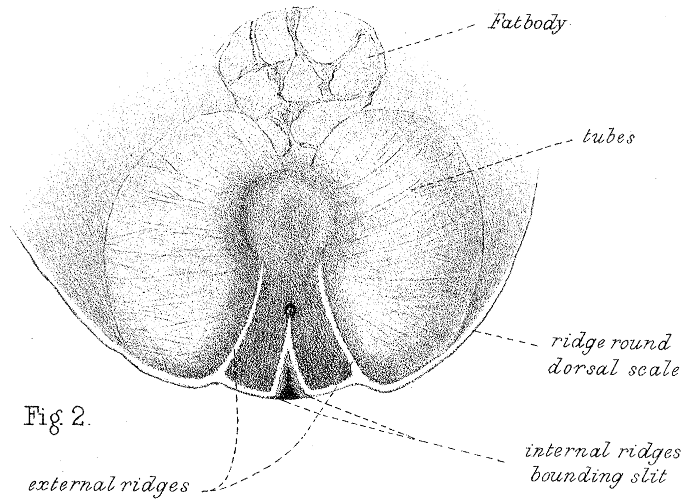


Fig. 2.

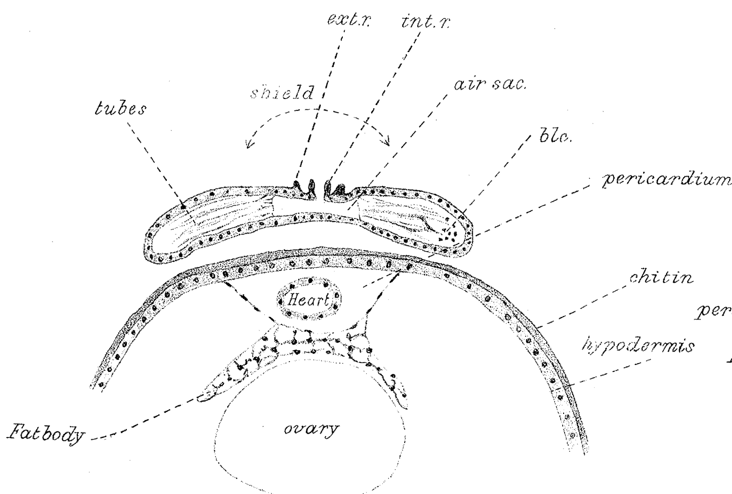


Fig. 3.

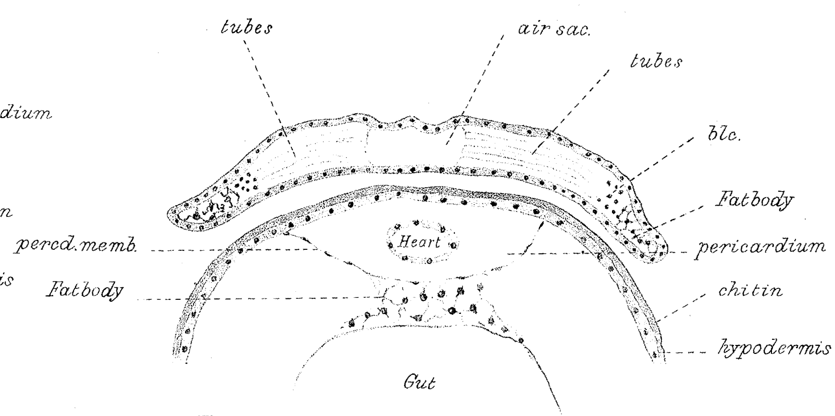
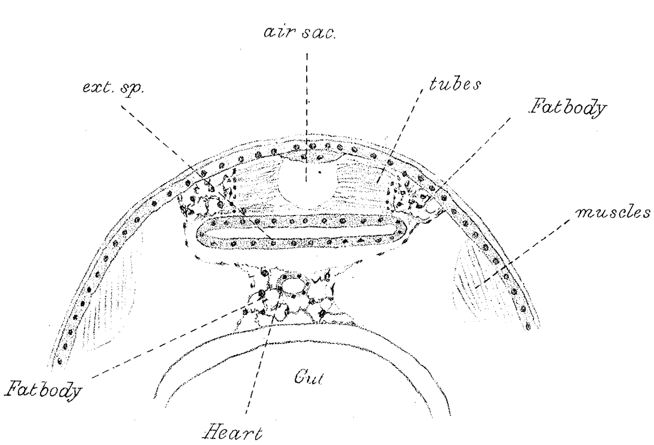


Fig. 4.



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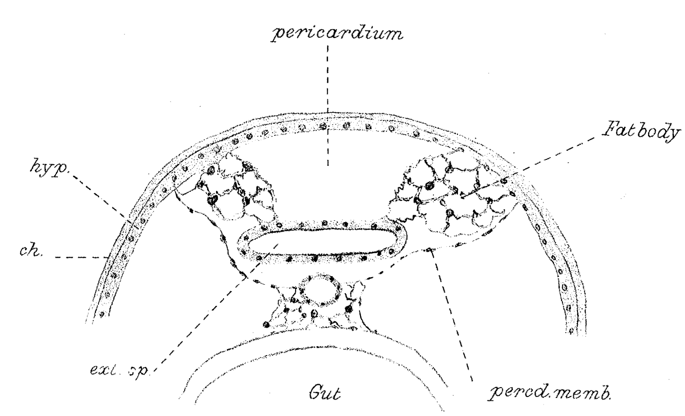
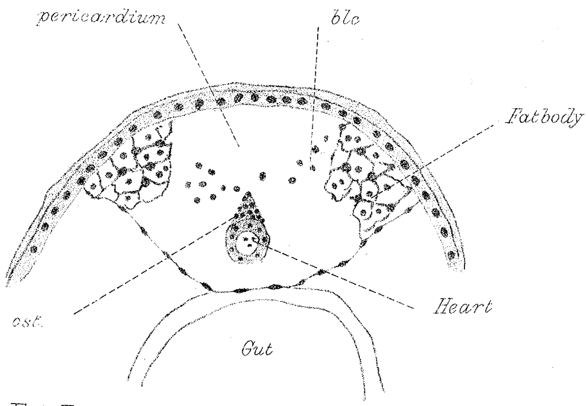


Fig. 6

F. G. Sinclair del.

Cambridge Engraving Company. lith. et. imp.



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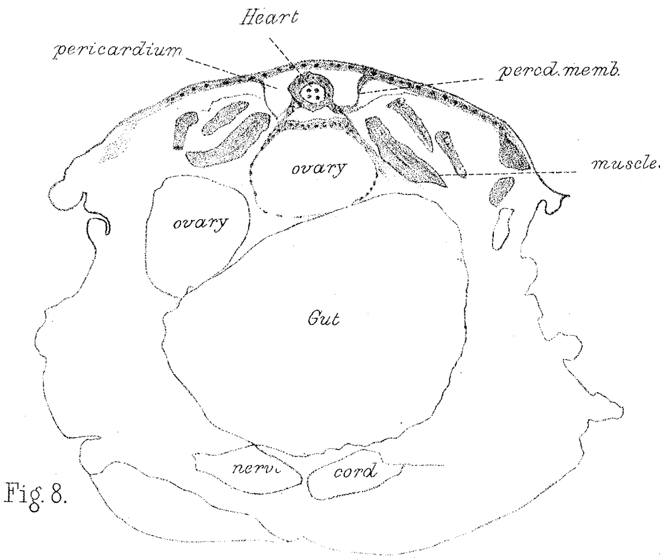

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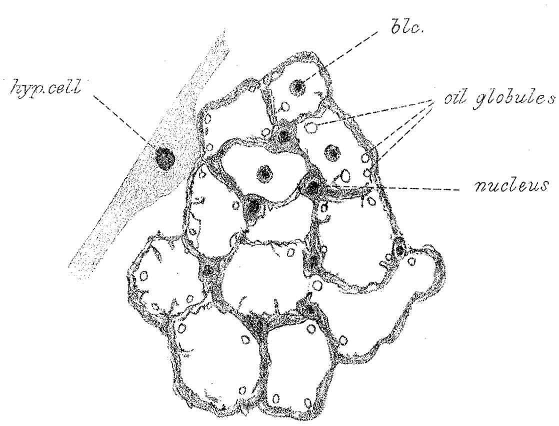

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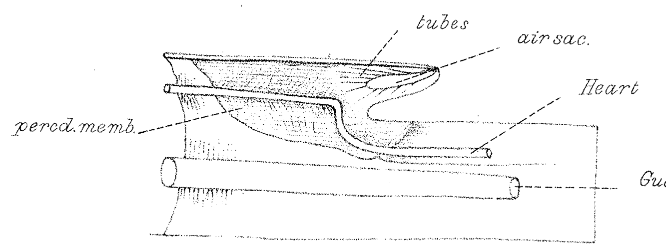

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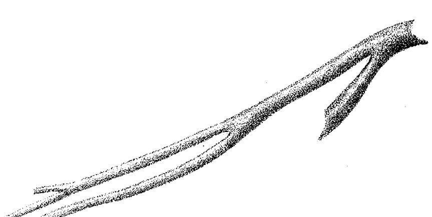

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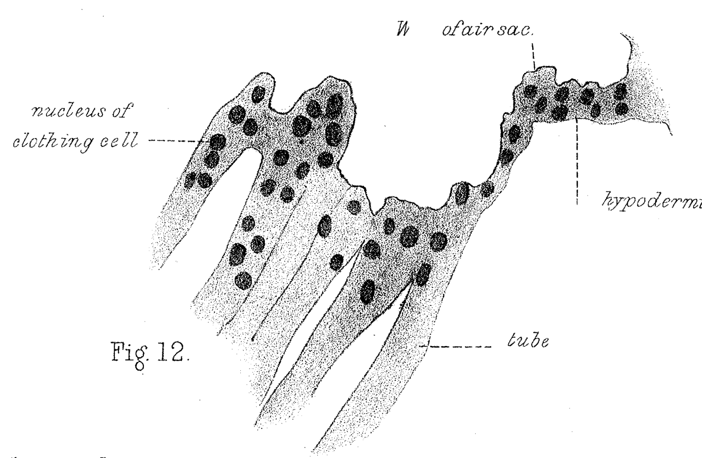

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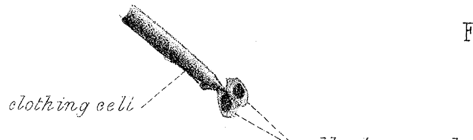

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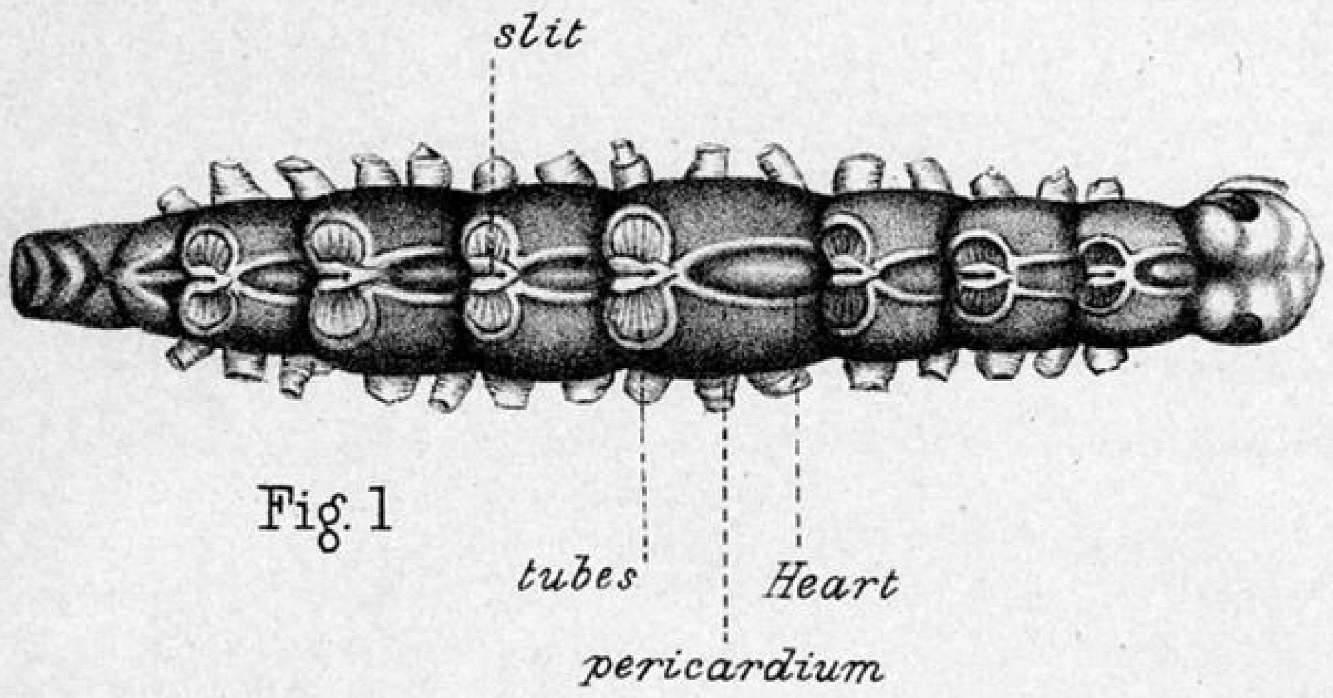
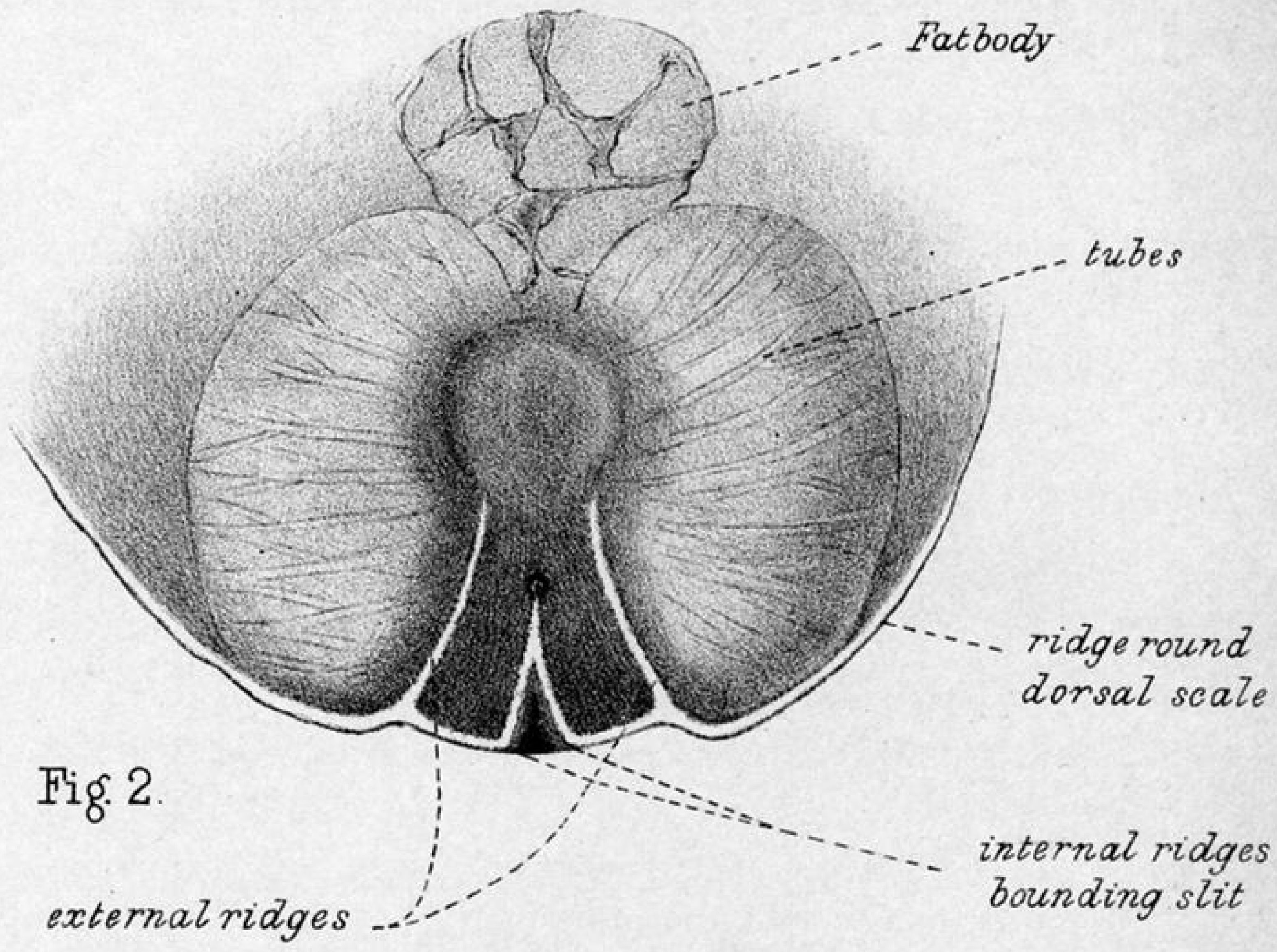


Fig. 1

A. C. Sinclair del.



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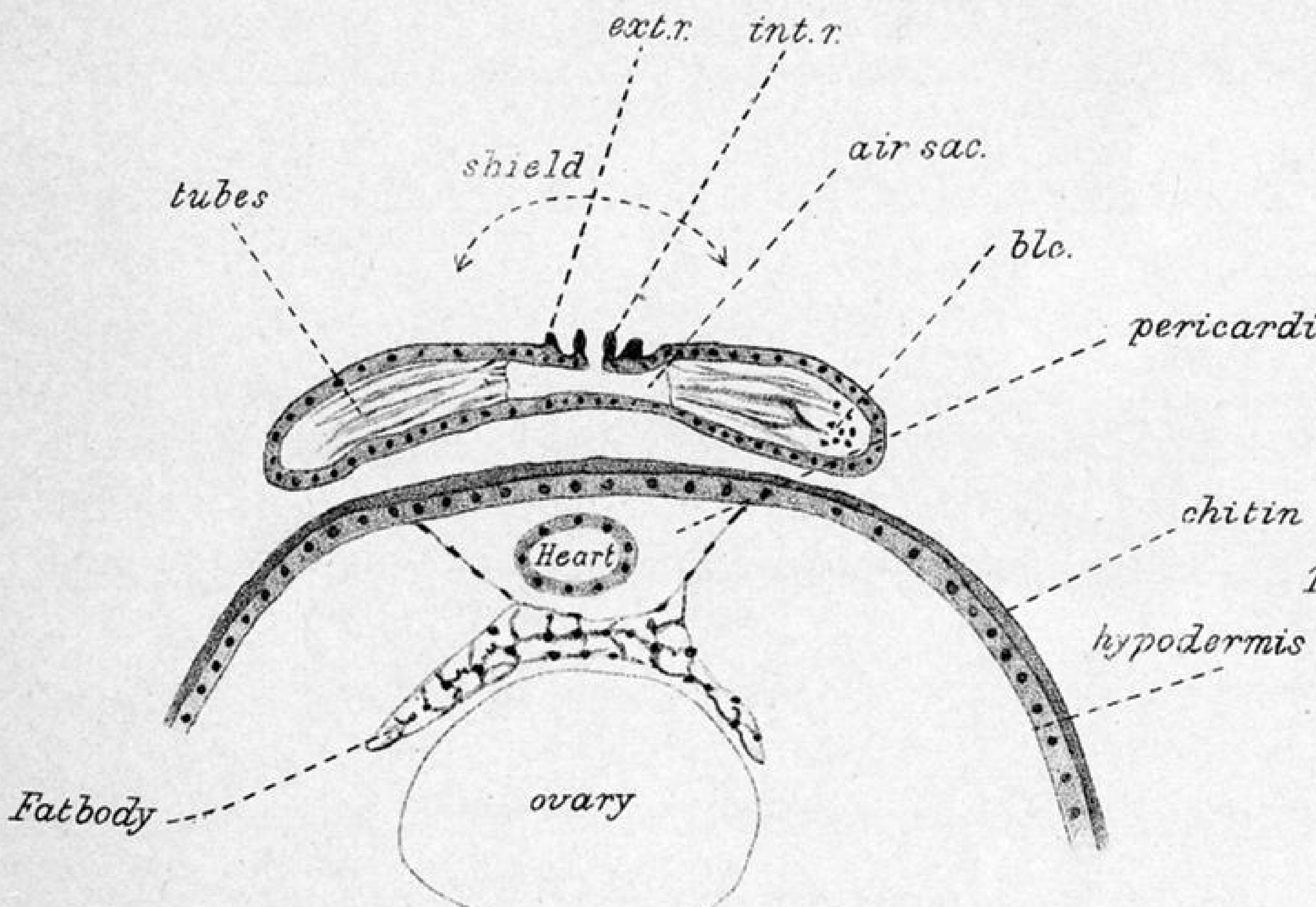

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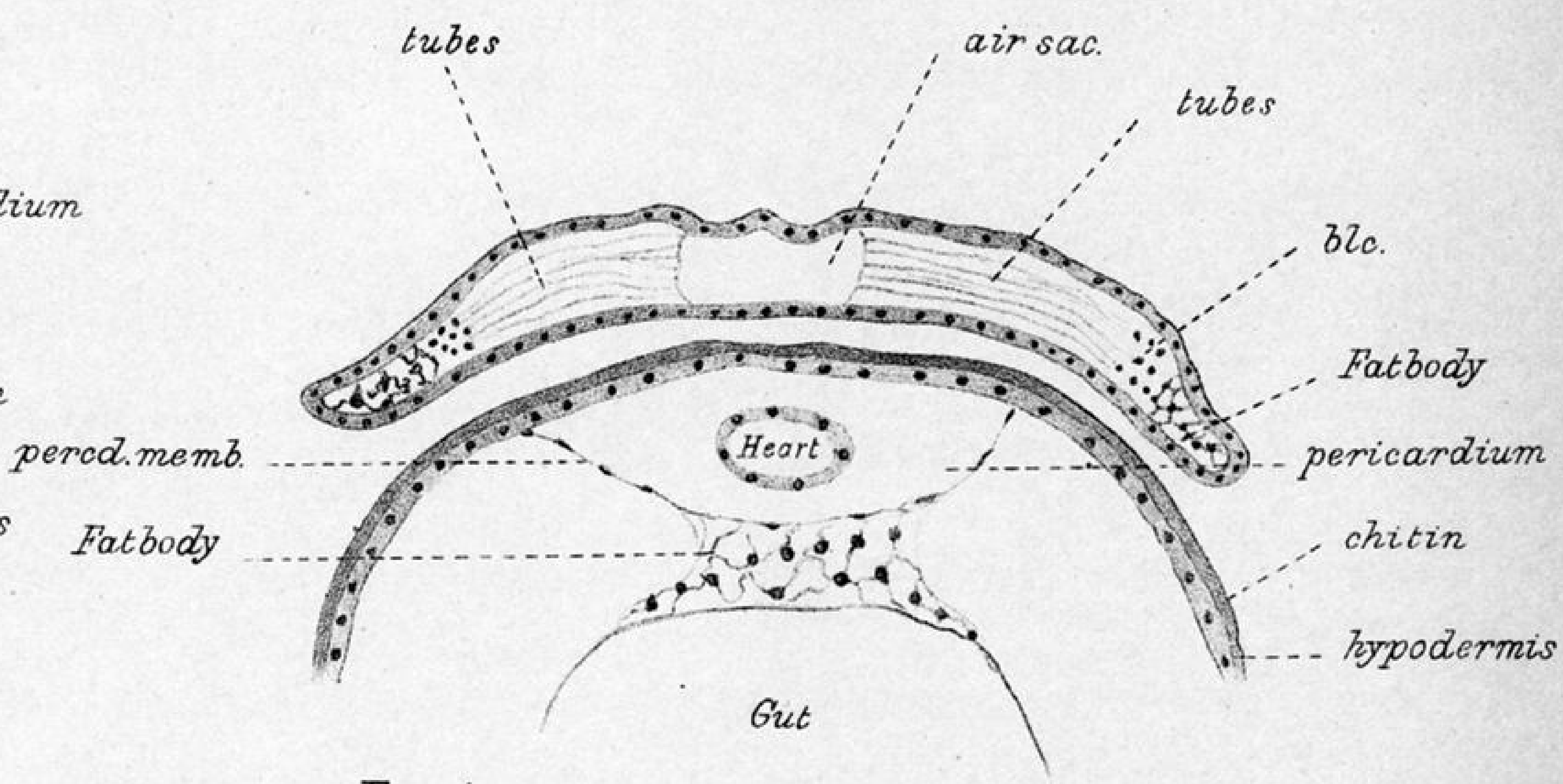

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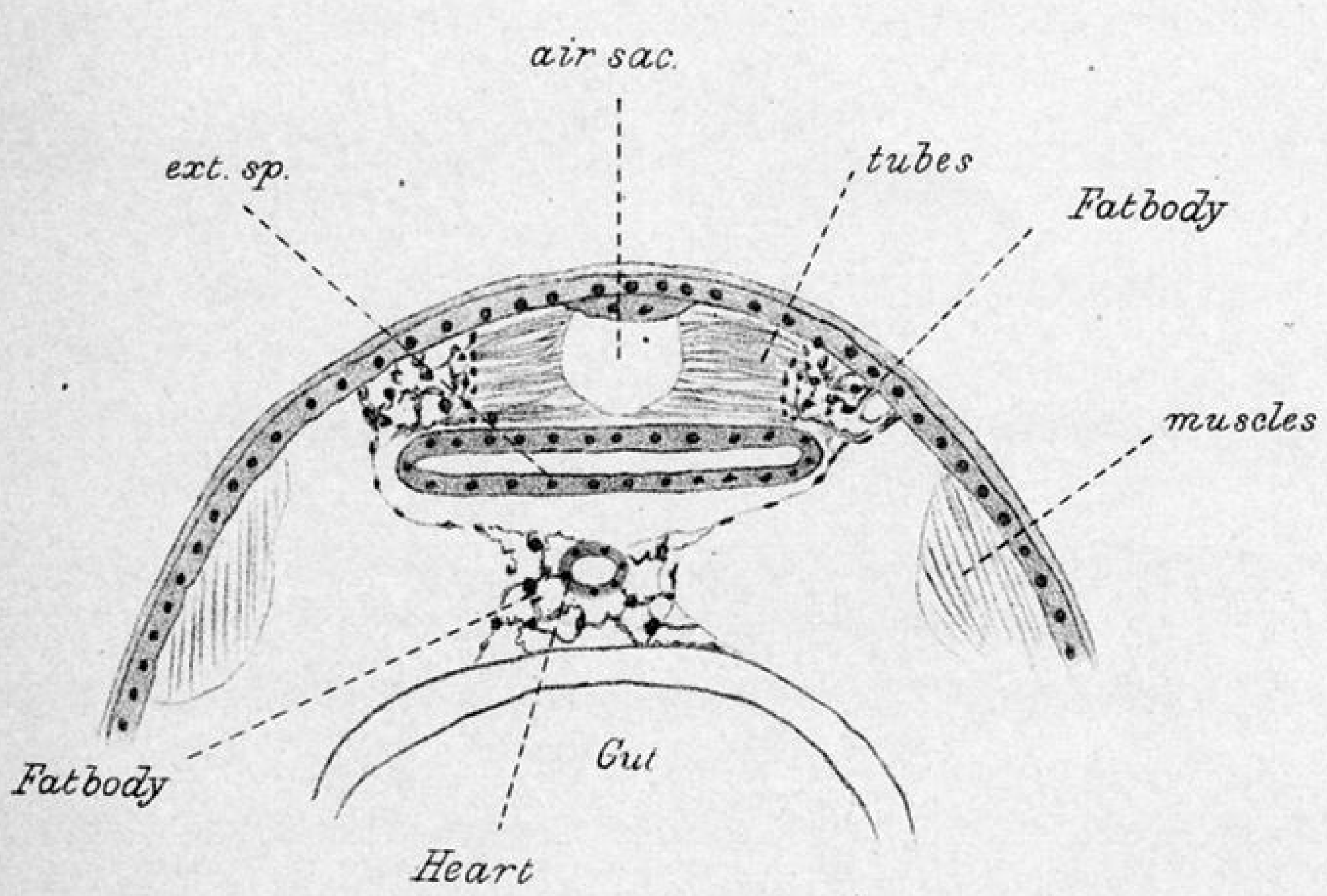

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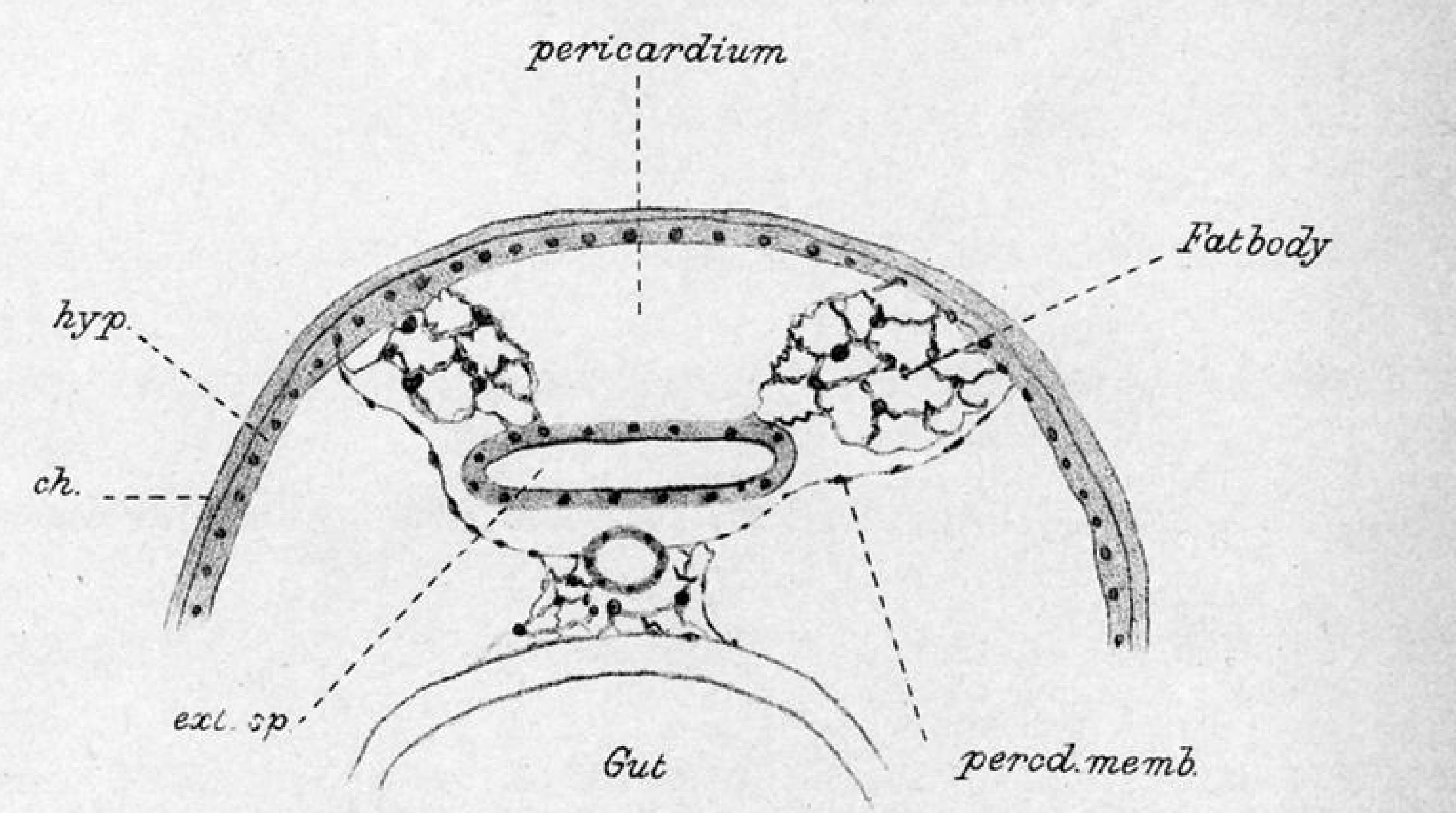


Fig. 6

PLATE 5.

Fig. 1. A preserved specimen magnified $3\frac{1}{2}$ times and seen from the dorsal surface. This figure was drawn for me, under the microscope, by Mrs. SINCLAIR. All the other figures are by myself.

Fig. 2. The over-lapping part of the dorsal scale, torn off and drawn under the microscope with a D ZEISS objective.

Fig. 3. The series of sections from 3 to 8 are slightly diagrammatic, that is, they are representations of many sections and are not drawn from single sections. Fig. 3 is a section cut transversely through the whole body just at the posterior end of the over-lapping part of a dorsal scale.

Fig. 4. Section transversely through the body slightly anterior to fig. 3.

Fig. 5. Transverse section through the body slightly anterior to fig. 3. The pericardial membrane is shown joining the fat body.

Fig. 6. Transverse section a little anterior to the preceding.

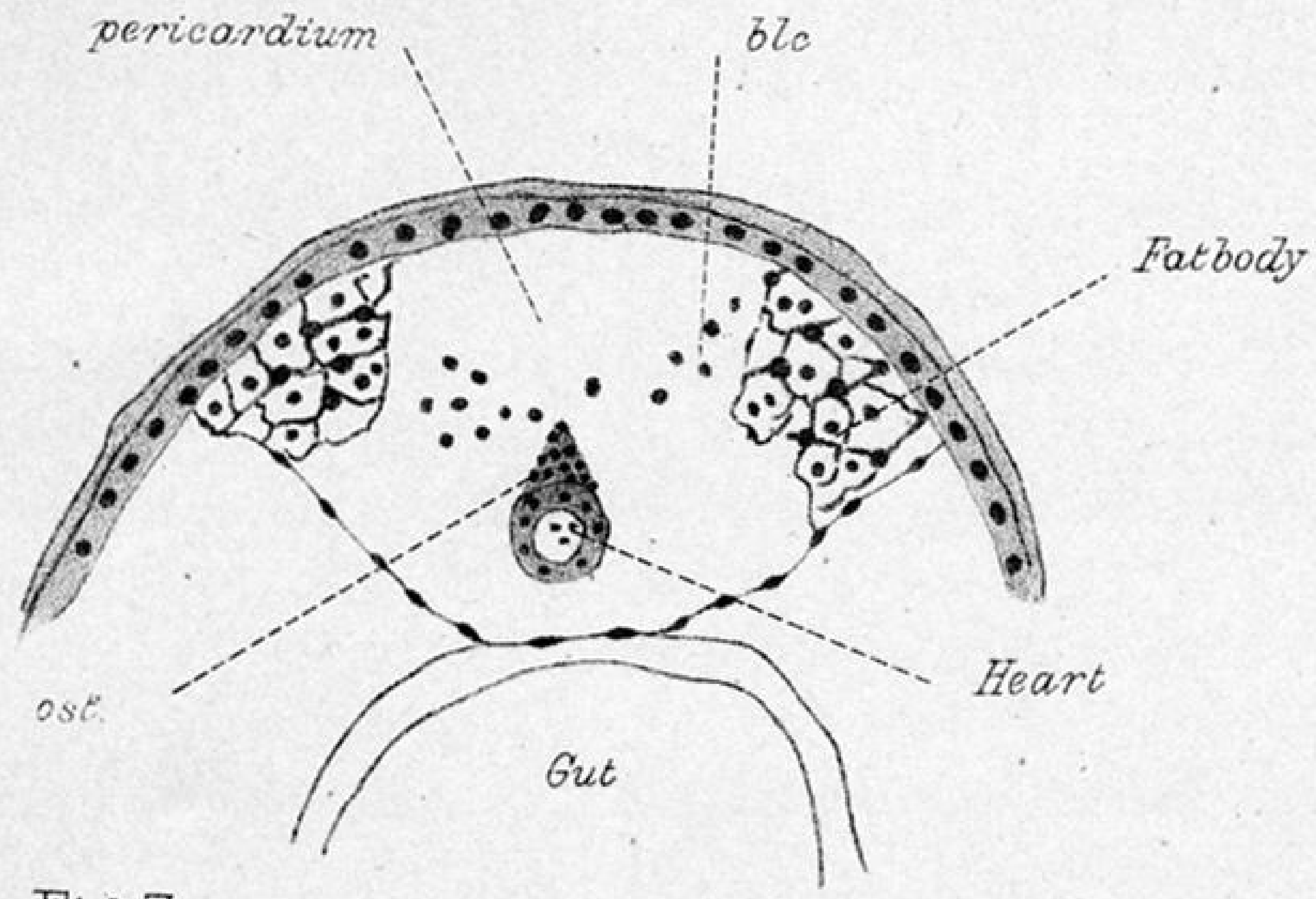


Fig. 7.

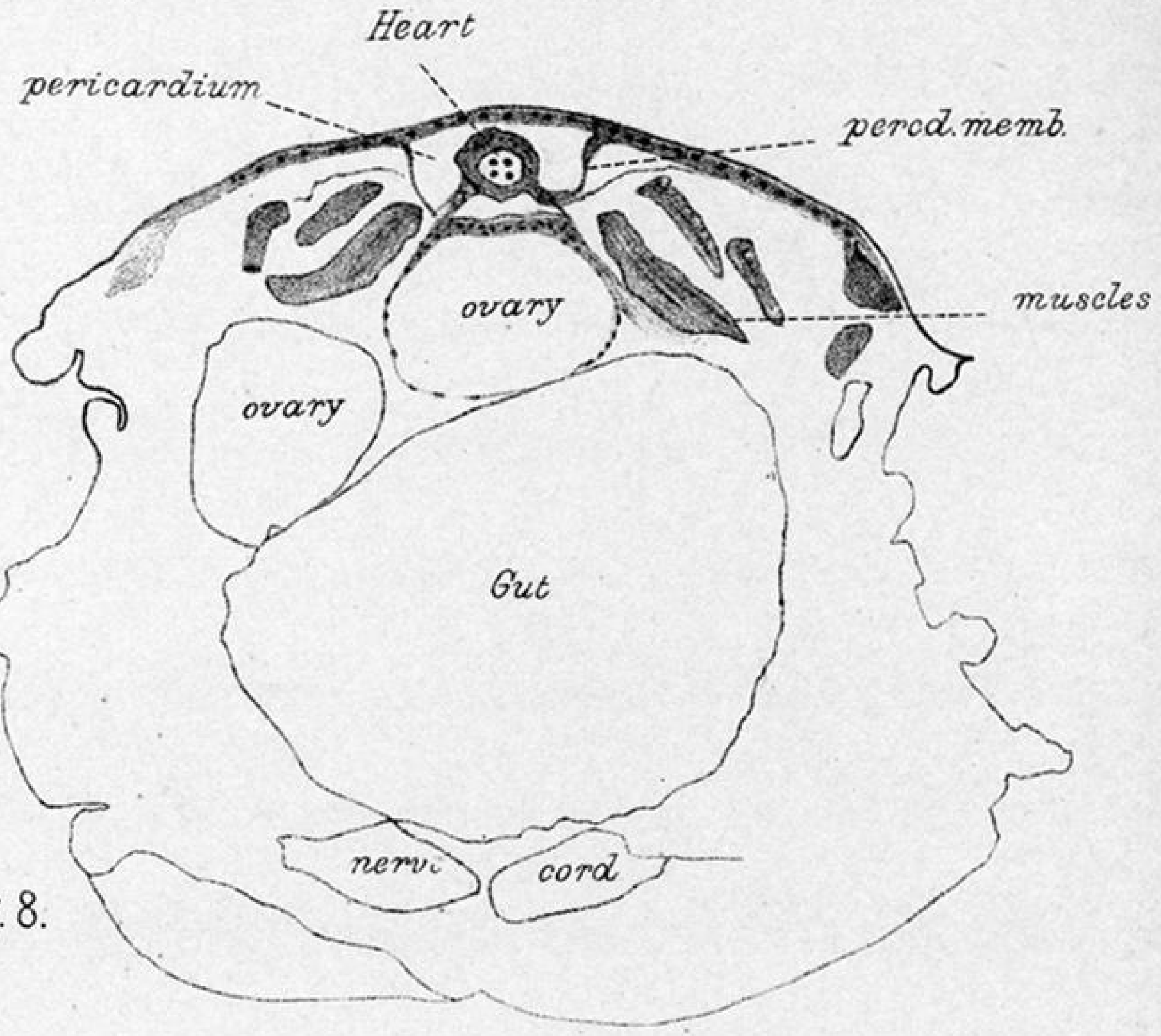


Fig. 8.

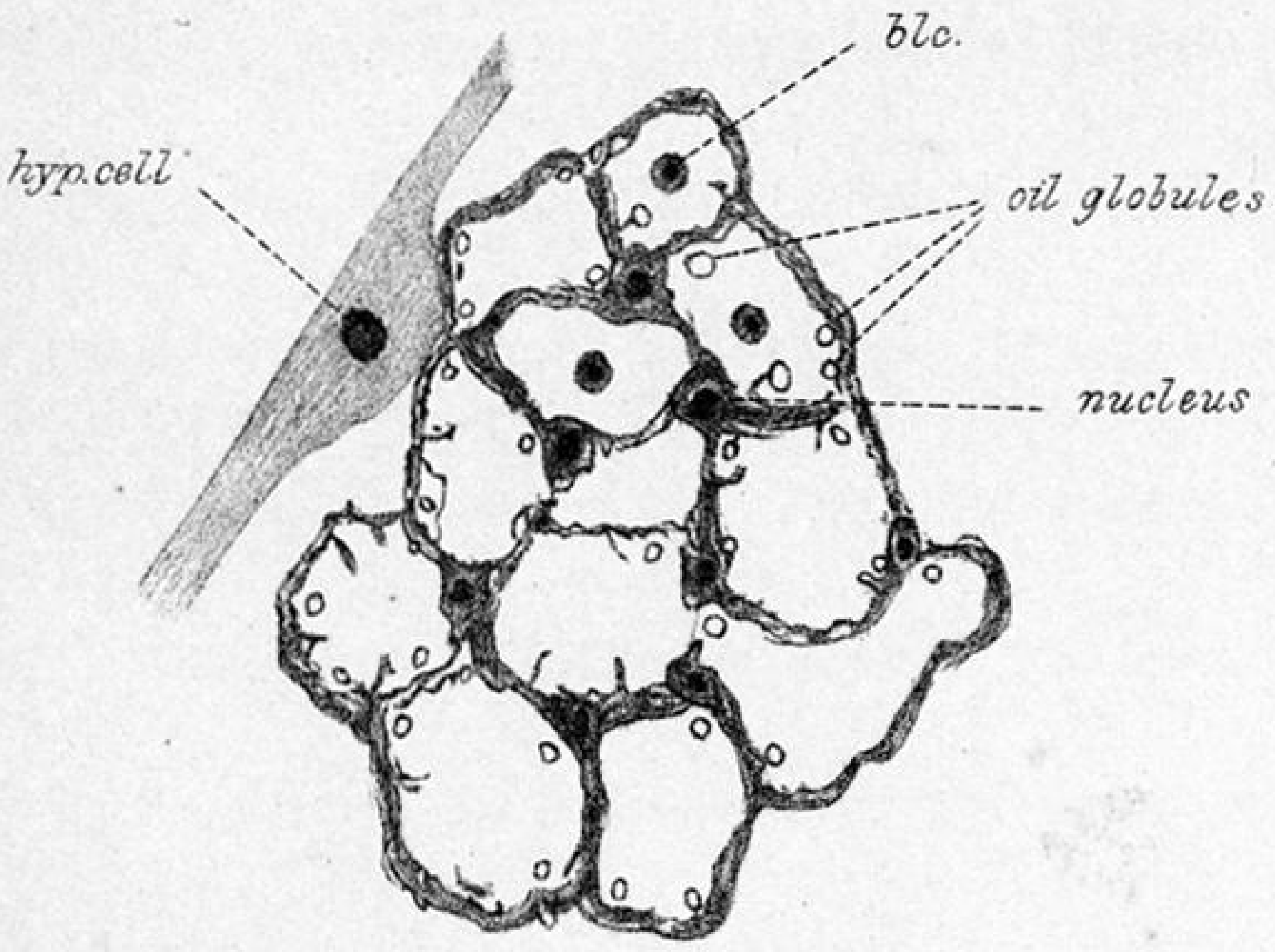
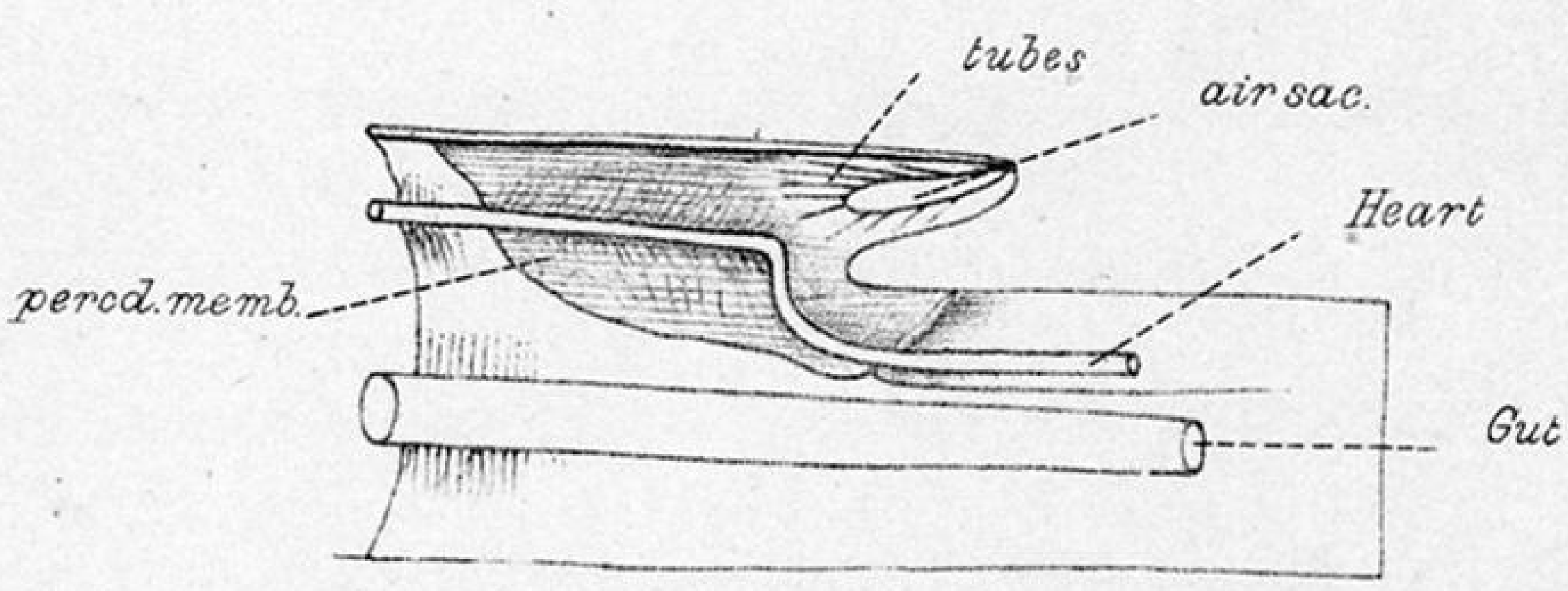


Fig. 9.



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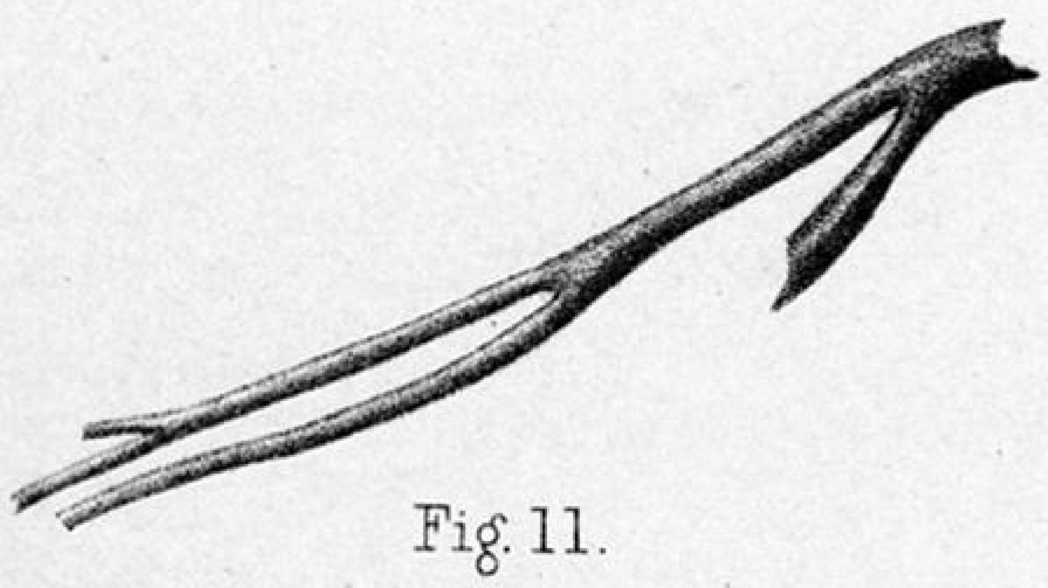

Fig. 11.

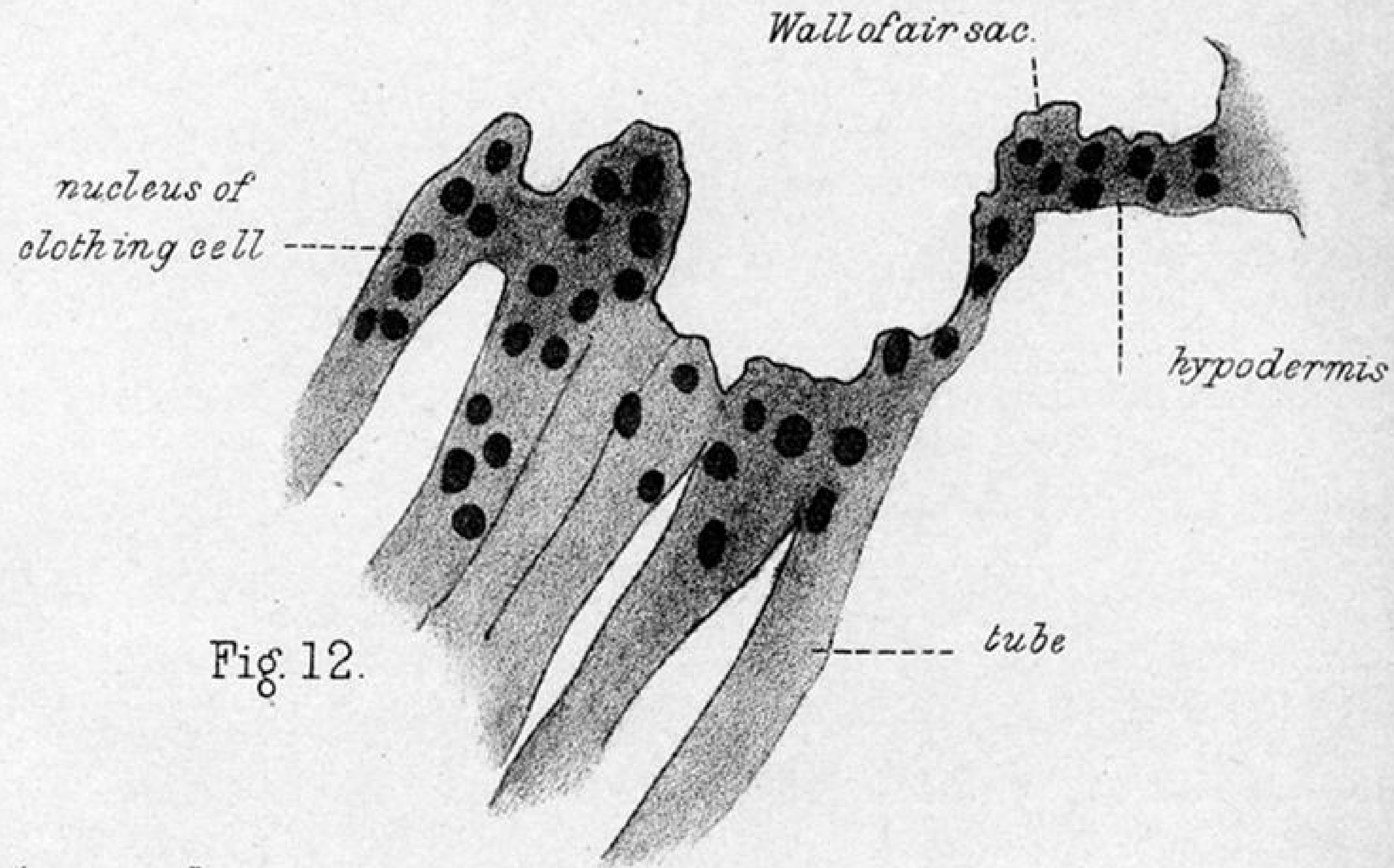

Fig. 12.

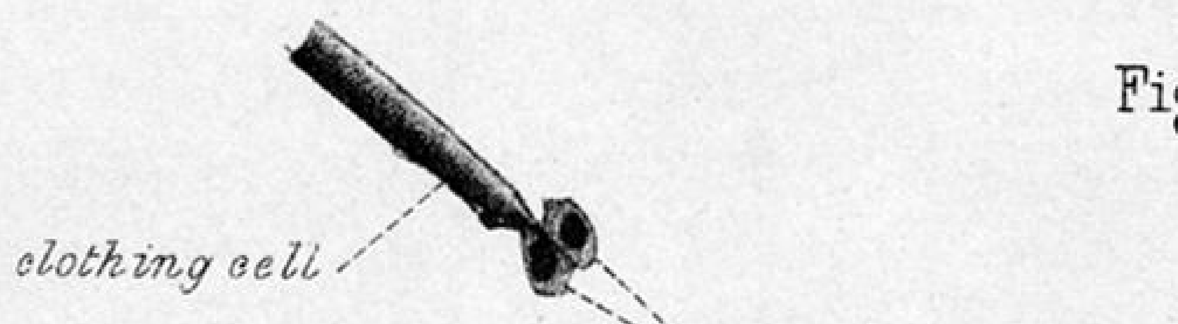

Fig. 13.

PLATE 6.

Fig. 7. Transverse section a little further anterior. The heart is cut in the region of an ostium.

Fig. 8. Transverse section still further anterior, about the middle of a segment. An artery is shown leaving the heart.

Fig. 9. A portion of the fat body highly magnified.

Fig. 10. Diagram of a longitudinal section through the region of the organ, to show the mutual relations of the heart, the pericardial membrane, and the organ.

Fig. 11. A single tube isolated, showing the branches, drawn from the fresh specimen.

Fig. 12. A small part of the wall of the air sac with the tubes going off from it. Highly magnified.

Fig. 13. End of a tube with one of the clothing cells and two blood corpuscles which have clung to it. From the fresh specimen.