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VI. *The Post-Embryonic Development of* Julus terrestris.

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[PLATES 27–30.]

IN a former paper I traced the development of *Julus terrestris* from the ovum within the ovary up to the bursting of the shell and the liberation of the young animal on the twelfth day. In the present paper I propose to take the different organs one by one, and to describe their development. This different way of treating the subject seemed to me to be the best: firstly, on account of the difficulty of describing a long and complicated development like that undergone by *Julus* in its larval life by dividing the history of its growth into periods of time; and, secondly, on account of the nature of the work which has hitherto been done upon this subject.

The two most important works bearing on the subject of my paper are those of NEWPORT (13)* and METSCHNIKOFF (12). The former has observed the general development of *Julus terrestris*, and has given us a most accurate and full description of the external features of the young animals at various stages, from the time of hatching almost up to the adult condition.

METSCHNIKOFF carried on his observations principally on *Strongylosoma Guerinii*, but also investigated the development of other forms, amongst them a species of *Julus*—*Julus Moreletti*—the development of which, he says, agrees almost completely with that of *Strongylosoma*.

NEWPORT'S observations with regard to the external features of the development leave me but little to say; nevertheless, there is one matter which requires a few words. According to NEWPORT, the third body-segment is apodous, as is the case in the adult; while in METSCHNIKOFF'S figure of the young *Strongylosoma* it is the second segment which is without a pair of legs. The question as to which segment is apodous is not so easy to settle as it appears at first sight, and it is very hard to come to a satisfactory conclusion. That there is a great difference between the larval and adult conditions may be seen from figs. 1 and 2 (Plate 27).

Fig. 1 is a drawing of the anterior region of the hexapodous larva, with the ventral

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[*] The numbers within brackets refer to the List of Literature at the end of the paper.

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side uppermost (magnified about 150 diameters). The first pair of legs, *p* 1, seem to belong to the broad neckpiece, 1 *br*, the lateral ends of which do not meet ventrally. The ends of the second ring meet ventrally, forming a complete ring round the body, and it seems as if this segment had no pair of legs. The second pair, *p* 2, seem to belong to the next ring, 3 *br*, and the third pair to the next ring, 4 *br*.

Now, in fig. 2, which is a slightly magnified drawing of the ventral side of the anterior region of an adult *Julus*, the ends of the *third* ring, 3 *br*, meet, and it appears as if this segment, and not the second, as in the larva, had no leg-pair. It might be expected that the nerve cord would afford some help in settling the question as to which segments the pairs of legs belong to, by showing the ganglia from which the leg-pairs are supplied; but in the young animal it is impossible to get a satisfactory longitudinal section showing all the ganglia at once, and in the adult the anterior ganglia are fused into an indistinguishable mass. On the whole, I am inclined, from a consideration of my sections, to think that the first segment of the body is really the apodous one, and that its ganglion fuses early with that in front of it, and that in the course of development the leg-pairs become shifted forward, so as to bring about the difference between the larval and the adult condition which I have shown in figs. 1 and 2.

If this view is correct, it would seem probable that, comparing the appendages with those of Insects, the first body segment (apodous) is equivalent to that which in Insects bears the second pair of maxillæ, while the first pair of legs in *Chilognatha* is equivalent to the first pair of legs in Insects.

The appearance of the ends of the antennæ at an early stage is very peculiar, the antennæ terminating in two long and thick projections, as shown in Plate 27, fig. 4, *pr*. The *Julus* from which the drawing was taken had three pairs of fully-developed legs, but the legs had not yet appeared on the fifth and sixth body segments.

The Cœlom and Generative Organ.

In a paper on the development of the *Chilognatha* (12) METSCHNIKOFF describes the formation of the mesoblastic segments and their protrusion into the legs, and also the separation of the part within the legs from that in the body. He states that in *Strongylosoma* both parts break up into heaps of cells and form muscles.

In *Julus terrestris*, however, this is not the case, and in spite of the difficulties of investigating the final behaviour of the somites in this particular animal, I have succeeded in tracing the alterations they undergo, and have satisfied myself that their development strongly resembles that of the somites in *Peripatus* as regards essentials, though this similarity does not hold in respect of the less important details.

In a former paper (7) I described the arrangement of the greater part of the mesoblast in two longitudinal bands, and the formation of the mesoblastic segments.

Shortly before the young animal is hatched a cavity appears in each mesoblastic segment, as shown in fig. 5, *c.s*, thus forming a kind of vesicle. There are two of these vesicles in each body segment, one on each side, and they are joined by a thin sheet of mesoblast covering the nerve-cord. The mesoblastic cells are easily distinguished from the adjoining epiblast cells by their appearance. They are of a more irregular shape and their protoplasm is clearer, while their nucleus is larger and is very distinct. When the epiblast begins to be thrust out at a certain point to form the first rudiment of an appendage, the vesicle protrudes also, and as the appendage becomes larger, part of the vesicle or somite projects within its cavity. This part is eventually constricted off, as shown in fig. 6, *s.s*, and *cr, s*, so that we have a vesicle-like part of a somite in the appendage and a vesicle-like part of a somite within the body on either side, connected by a thin sheet of mesoblast passing above the nerve-cord to its fellow on the other side of the body.

The cavity within the part of the somite which has remained within the body, and also the cavity in the part within the appendage, constitute, in my opinion, the cœlom, and are equivalent to the similar structures in *Peripatus* and other animals. The part within the body I shall call the somatic part of the cœlom, and that within the legs the crural part of the cœlom.

Leaving for the present the consideration of the fate of the somites of particular segments, I will describe the process which occurs in the greater number of segments in the body. The part of the somite which remains in the appendage loses its cavity, and remains for some time as a mere mass of mesoblast cells within the hollow of the appendage. As the limb grows larger and longer, the mesoblast cells within it lengthen out, change their shape and character, and become the muscles of the leg; this agrees completely with the description of Metschnikoff. The part within the body, however, has a different fate. The vesicles become larger and thinner-walled, and gradually alter their position, moving along the sheet of mesoblast covering the nerve-cord, so as to approach one another. This is shown in fig. 8, *s.s.* As the animal becomes adult they meet above the nerve-cord and fuse with one another, so as to form one continuous tube. A stage where the fusion is almost complete is shown in figs. 9, 10. This tube is the generative organ, which in *Julus* is placed between the nerve-cord and the gut. The structure of the generative tube when just formed is shown in Plates 27, 28, figs. 10, 17, where it consists of a single layer of long cells, with elongated nuclei.

Transverse sections through the generative tube of a female *Julus* of a rather greater age than the one from which fig. 10 was taken, show us the origin of the ova. Figs. 17, 18, 19, 20, 21 show parts of the wall of the generative tube. The cells of which it is composed are much elongated, and have oval nuclei; their protoplasm is very clear, and in all respects they resemble the cells of the cœlomic vesicle. In parts of the generative tube the cells undergo a change. They increase in number, as shown in figs. 18, 19, and some of them attain a larger size. Some of these are destined to become the young ova, while others divide more quickly and form the cells of the follicle which envelop the ova.

A more advanced stage of this process is shown in fig. 20, where some of these cells have increased in size, while others are being divided off from the wall of the ovary. In fig. 21, an ovum has attained a considerable size, while some of the cells have already formed a follicular envelope round it. (F.c.)

In his paper on the generative organs and the egg in the *Annulosa* (11) LUBBOCK pointed out a difference between the ovaries of Myriapods and of Insects; namely, that in Insects like *Coccus* the follicle projected *from* the ovary, while in Myriapods the follicle projects *into* the ovary, the difference being, in his own words: "If, therefore, we consider the ovary as consisting of an outer membrane and an inner epithelial layer, it would appear that while the egg in the Myriapods arises between these two layers, in the Insects it originates on the inner side of both." In the development of the ovary in *Julus*, however, we see that, as in fig. 17, the ovary at the stage when the ova first appear does not consist of two distinct layers between which the ova are formed, but that at certain points the follicle cells, as well as the young ova, are formed from cells budded off from those which compose the single-layered wall of the ovary. Therefore, the distinction pointed out by LUBBOCK, though no doubt valuable as an anatomical character, does not seem to receive much light from embryology.

It will be seen from the foregoing account that the cœlomic spaces have nothing to do with the body-cavity, or vascular system of *Julus*. The body-cavity is a series of spaces contained between the gut and the body-wall. In the earlier stages of development it was represented (see paper 7) by a network formed of mesoblast cells, derived directly from the endoderm and containing the yolk-spherules within its meshes. The yolk-spherules are absorbed in the course of development, and the body-cavity of the adult results from the joining together of the spaces already present in the spongy network. The body-cavity of *Julus* is therefore a pseudocœle, like that of *Peripatus*. I shall deal with the vascular system later on.

I will now consider the behaviour of particular somites. The first pair is that of the antennæ. The part within the appendage gives rise to muscles as happens in other somites. The somatic part breaks up, I believe, and also furnishes muscles, but I have not been able to follow its fate satisfactorily, at any rate it disappears at an early stage. The somites of the mandibles also disappear and are lost; but those of the third pair [the third pair of appendages afterwards becomes the plate beneath the mouth, the deutomalæ of PACKARD (14)] give rise to the salivary glands and thus show a resemblance to *Peripatus*, where the salivary gland arises from the lateral part of the third somite. The details of this process are shown in figs. 11, 12, 13, 14. Fig. 12 is a drawing from a longitudinal section through a young *Julus* just after leaving the shell. The third and fourth segments are shown. The fourth segment shows part of the mass of cells within the rudimentary limb and the somatic part of the somite separated from it. In the third segment there are a few cells representing the crural part of the somite, while the somatic part presents a different appearance to that of the fourth segment. It is much more elongated, and the cells composing it have somewhat altered their character, showing a more regular outline than the cells of the other somites at the same stage. Fig. 13 is a transverse section through the third segment of a young *Julus* of a rather more advanced age. The rudiment of the salivary gland has lengthened since the first stage, and is beginning to curve in the direction of its future course, so that the section has cut it nearly transversely. The cells within the limb are the cells remaining from the crural portion of the somite, and are not yet altered to form muscles. In fig. 14 the salivary gland has a more definite shape, while the mesoblast cells of the crural part have assumed the appearance of muscle-cells, and have already separated into several bundles of muscles which have been cut at different angles. The opening to the exterior is not yet formed. Fig. 11 shows a later stage, where the salivary gland has acquired an opening to the exterior. It is a longitudinal section through the head cut so as to show the three first appendages; the third being the plate resulting from the fusion of the third pair. The salivary gland on each side opens at the base of the labial plate (*deutomalæ*) by an opening formed after the gland has attained a considerable size.

In the posterior region of the body, that is, in the so-called segments, there are as METSCHNIKOFF stated (12) two somites to each body-ring. This is shown in fig. 16, which is a drawing from a section cut longitudinally through a young *Julus*, with three pairs of legs and two double pairs just forming, each double pair being still enveloped in a single sac. The section has cut through the fifth segment through the base of the double pair of appendages rather obliquely, so that one somite, that of the posterior of the double pair, is better shown than that of the more anterior. The crural division of the somite is a mass of cells which has lost its cavity, but is still connected with the somatic part. An earlier stage in the same process is shown in fig. 15—a transverse section through a segment which is just forming—the section has been cut rather obliquely so that the thickness of the epidermis is exaggerated. The double nerve cord is just differentiated from the epidermis, and is cut through so as to divide a ganglion. The thickening of the mesoblast forming the somite, has also been cut through, but as yet there is no cavity in it. The two somites are joined by a thin sheet of mesoblast covering the nerve cord. The only point in which the section shows a difference from sections through the early stages of the formation of the first segments is in the presence of a layer of hypodermic matrix outside the epiblastic layer, from which the nerve-cord is formed. The characteristic appearance of the cells of the different layers is as marked as in the case of the earlier stages of the development.

Comparing the development of the cœlom with that of the cœlom of *Peripatus*, it is clear that while the resemblance of the general plan is very conspicuous, the details differ considerably. In the posterior part of the body of *Julus*, that is behind the third body-segment, we have a part of the somite in the limbs, and a part in the body. The body-part passes towards the top of the nerve-cord, not to the dorsal part of the body as in *Peripatus* (16).

Thus far the resemblance is striking. But the part of the somite within the limbs, which in *Peripatus* forms the nephridium and the vesicle into which the nephridium opens, undergoes a totally different change in *Julus*. The cells alter their character, and furnish the muscles of the limbs. In the development of the salivary gland, too, there is a difference between that in *Julus* and that in *Peripatus*. The body part of the somite in *Peripatus* furnishes the musculature of the pharynx, and the part in the appendage forms the salivary gland and the vesicle into which it opens. In *Julus*, as we have seen, it is the body part of the somite which furnishes the salivary gland, while the limb part provides the muscles which move the plate representing the fused pair of appendages. In describing the formation of the salivary gland I mentioned the changed character of the cells of the somatic part of the somite at a very early stage, and I regard this early change as indicating that the process does not represent the gradual alteration of the somatic part of the somite into a tubular salivary gland, but rather a sudden loss of the character of the somite, and the assumption of the character of a different organ. In other words, the difference from the other somites observed at so early a period, indicates an abbreviation of development, some intermediate stage having dropped out.

One of the most interesting points about the development of the somites is the fact that the so-called double segments have two mesoblastic segments each. As is well known, NEWPORT held that each double segment represented two single segments of an earlier stage in the phylogeny, which had become fused, and retained traces of their original condition. Later on, BALFOUR suggested that the double segments might represent single segments which had developed a second pair of limbs, and had altered the nerve-system and other organs to suit them. He was followed in this suggestion by PACKARD (14), and later by GRASSI (5). It seems to me that this view is contradicted by the facts just mentioned, inasmuch as the segmentation of the mesoblast is one of the most primitive processes in the development, and affords us the best guide to the consideration of the segmentation of the adult.

The presence of two nerve-ganglia to each double segment also favours the belief that each of the latter represents two perfect segments; but I should not be inclined to consider this of itself as sufficiently strong evidence, since the nerve-system undergoes so much modification, in the course of development, that one might easily suppose that a stage where one ganglion to each double segment had existed had dropped out of the development. I cannot, however, suppose this in the case of the mesoblastic segments. The external skeleton of the animal does not exactly coincide with the mesoblastic segmentation, and I hold that the surest guide in considering the segmentation of the adult is the early mesoblastic segmentation.

The Nervous System.

The first appearance of the brain and ventral nerve-cord was described shortly in a former paper (7) and has also been described for *Strongylosoma Guerinii* by Metschnikoff (12). There are, however, one or two points in the later development which deserve notice. The most interesting of these is the appearance of a pair of cerebral grooves resembling those in *Peripatus*. These grooves make their appearance about the time when the young animal leaves the shell. At first they are only shallow depressions, but soon they grow deeper, and eventually have the appearance of two vesicles just within the substance of the brain and communicating with the exterior by narrow openings. In fig. 28 the vesicle appears closed, but a few sections further back in the series the opening was visible. These cerebral grooves do not persist; but a few days later when the three leg-pairs of the larva are complete, they become obliterated and disappear entirely, leaving, as far as I can see, no trace of their former existence. The chief alterations in the shape of the brain in its development are due to the outgrowth of the optic and antennal lobes.

When the ventral nerve-cord is first formed it consists, as is already known, of two cords with ganglionic enlargements on them, and united by a thin median sheet. When the nerve-cord is entirely separated from the epiblast, a species of cavity appears in the ganglia. A ganglion at this stage, with this cavity, is shown in Plate 29, fig. 30, which was drawn from a longitudinal vertical section of a *Julus* which had just left the shell. The section had cut through the middle of the fourth ganglion of the body, and this is the ganglion shown in the figure. The cavity is also shown in fig. 29, *cav. gl.*, where it is gradually becoming obliterated.

The presence of these cavities is not a permanent feature, as they become obliterated when the two cords unite to form a single cord. About the second day after hatching, the nerve-cord—that is, all of it which is as yet developed—undergoes a considerable change, and as new segments are formed their nerve-cord in turn undergoes a like process. The paired ganglia approach one another in the middle line, and join so that the space between them is gradually obliterated; at the same time, the cavities in the ganglia, of which I have spoken, gradually disappear. The effect of all this is to change the shape of the transverse section of the ventral nervous system, from that of two cords united by a thin median sheet, to that of a single stout cord enlarged at the ganglia and showing but a slight trace of its former double character. At the same time the fibrous part of the cord begins to make its appearance. It occurs first at the median dorsal line and increases as the development proceeds till the cord assumes its characteristic appearance, as shown in fig. 23.

Fig. 29 shows the process of the junction of the cords. It is drawn from a transverse section through the third segment of a young *Julus* on the first day after hatching. The cavities in the ganglia are almost obliterated, but are still present, while the only trace of the separation between the cords consists of a small slit-like space in the centre of the ventral nerve-system. The fibrous portion of the cord is distinctly marked off from the surrounding ganglionic part, but is still small. Two nerves are passing off from the ventro-lateral parts of the ganglia.

The cavities which appear in the ganglia have not, in my opinion, anything to do with the cerebral grooves. They differ from the latter in not possessing at any period a connection with the exterior. They exist only for a short time, and disappear completely. I am altogether unable to suggest any explanation of them, and am uncertain whether they have any ancestral meaning or not. Possibly a further study of Myriapod embryology would throw some light upon them. The cerebral grooves, which are not an uncommon feature of arthropod development, have a great resemblance to those in *Peripatus*. It is possible that they may supply the want of aëration to the mass of cerebral tissue, as they appear just after hatching and disappear as soon as the tracheal invaginations begin to be formed.

The Tracheæ.

A pit-like invagination is formed just behind and a little externally to the bases of each pair of appendages. One of these tracheal invaginations is shown in fig. 22, *T.I.* This invagination, the walls of which are thick and are composed of cells like those of the epidermis, gradually becomes deeper and increases in size so as to form a kind of vesicle within the body, close to the nerve-cord (figs. 23, *T.I.*; 8, *T.I.*). This vesicle changes its form, giving off two short thick diverticula, one into the space below the nerve-cord, where it nearly meets its fellow of the opposite side, and the other dorsal-wards, parallel to the body-wall. This is shown in fig. 23. The cells composing these two diverticula break up, alter their arrangement, and form the tracheal tubes. The main part of the vesicle near the leg remains as the tracheal pit, while the diverticulum beneath the nerve-cord breaks up to form the mass of tracheal tubes which occupies that position in the adult. The other diverticulum forms the main tubes, which run dorsal-wards, and give off twigs to the different organs.

In the double segments there are two pairs of these tracheal invaginations; an invagination close to each leg.

The Stink Glands (glardulæ odoriferæ).

In METSCHNIKOFF's paper on the development of the *Chilognatha* (12) he describes the appearance of a paired organ of which he was unable to discover the fate. These organs, which appear at a stage when three pairs of limbs are present, are the first pair of stink glands. They make their appearance as invaginations of the ectoderm in the side of the body in the fifth segment (fig. 24). The invagination increases in size and swells out till it assumes the vesicle-like shape which it attains in the adult. Late in the development a muscular wall is added. The adult structure of these glands has been described by VOGES and other writers, especially WEBER (18). There is a slight peculiarity about the first pair of these glands formed, which is worth mention. They are placed in a slightly different position to those formed later, inasmuch as they are situated rather more dorsally. The difference is slight but perceptible. There is only one pair to each double segment, and they do not occur in any of the single (anterior) segments. Fig. 25 is part of a section through the first pair of these glands at an advanced stage, when the external coat is already added.

The Heart and Fat-body.

The mesoblast cells remaining in the yolk, and described in a former paper (7), as derived from the hypoblast, give rise to the heart and fat-body. Soon after the young animal leaves the shell a number of mesoblast cells are collected in the dorsal region of the animal near the future position of the heart. These cells are of irregular amœba-like form, and their processes anastomize so as to form a network, as shown in figs. 31, 32, 33. The tube of the heart is formed by the coming together of the meshes of this network, as shown in fig. 33, while other processes of the cells give rise to the various muscles of the heart. The ostia are spaces left open in the formation of the tube and are not subsequent perforations. In each double segment there are two constrictions formed, as shown in fig. 35, *os* : these are the lips of the ostia in course of formation, and are not, as supposed by NEWPORT, a junction of two separate chambers. The blood corpuscles are also formed by these mesoblast cells.

The fat-bodies are formed by the same mesoblastic cells, which when the yolk is completely absorbed are present as a sort of network occupying the position of the future fat-bodies (fig. 34, *F.b.*). Later in the development there is a copious secretion of oil globules in the cells composing the network, and they finally assume the character of the fat-body cells, as shown in figs. 36, 37, *F.b.* I believe that all the cells of the fat-body have this character, and I have not observed two different kinds of cells in the adult fat-body, the only difference being in the amount of oil globules secreted, some cells being almost free from them.

As the heart of the adult *Julus* has never been fully described, it is necessary to give a somewhat more detailed account of its structure than I have done for most of the adult organs.

The heart in the adult is situated dorsally between the hypodermic matrix and the digestive tube. There are two pairs of ostia in each segment, situated nearly dorsally (fig. 36, *os*). These ostia are originally spaces left in the tube during development. The shape of each ostium is shown in fig. 38, and it will be seen that the ostia resemble the second modification described by GRABER in his paper on the Insect heart (3). The lips of the ostia which project into the tube of the heart are formed by four peculiarly-shaped muscle-cells, shown in Plate 30, fig. 40, which evidently control the operations of the ostium. The arteries (fig. 37) are situated more ventrally than the ostia, and there are two pairs to each segment. They are placed nearer the centre of the segment than are the ostia. NEWPORT describes them as given off close to the ostia. These arteries lead directly into the spaces of the fat-body. The tube of the adult heart consists of three coats (fig. 39), corresponding to the "Intima," "Muskelschicht," and "Adventitia," of GRABER (3). Of these coats the internal ("Intima") is not nucleated, being secreted by the cells of the middle coat ("Muskelschicht") early in development. The middle of the three coats ("Muskelschicht") is a well-developed muscular structure. The striæ are well marked and the nuclei easily seen. The arrangement of the muscles is worth notice. The fibres are circular and are disposed in bands; a narrow band alternating with a broad one. This coat, which is derived directly from the cells of which the heart was first composed, is the principal structure of the circulatory apparatus. The external coat ("Adventitia") is formed of connective tissue, and is continued over the arteries. It does not appear till late in the development. It is shown in figs. 37, 39.

It will be seen that this account of the heart of *Julus* agrees rather with GRABER'S and LANDOIS' description of the Insect heart than with that of WEISMANN (19). NEWPORT describes the heart of Myriapods generally as consisting of three coats, but gives no account of the heart of *Julus* in particular.

The heart is suspended by thin muscle fibres, which are attached to the hypodermic matrix layer. There are also muscle fibres which are attached to the fat-body and probably correspond to the aliform muscles of the Insect heart. The cavity in which the adult heart of *Julus* is enclosed is partially cut off from the rest of the body-cavity by a pericardial membrane, formed from the same network of cells which gives rise to the heart and which is continuous with the fat-bodies. This is shown in figs. 36, 39.

The Eye.

The formation of the eye begins on the fourth day of larval life as described by NEWPORT, and continues until the animal is adult. A single ocellus appears first, and the rest are added one by one till the full number is reached. The process of development is the same in the case of each eye-spot. A deposition of pigment granules of a dark red-brown colour takes place within a thickened mass, which has been formed by a multiplication of the cells of the hypodermis, and this secretion of pigment is accompanied by a separation from one another of certain cells within the mass. The result of this process is the formation of a vesicle bounded by a mass of dark pigment. The cells composing the external wall of this vesicle, *i.e.*, the part of the vesicle nearest the surface of the body, give rise to the lens which fuses with the chitin of the exoskeleton, and the same cells continually add layers to the lens till it assumes its full size. They are then, as far as I have been able to follow their fate, absorbed, their nuclei disappearing altogether, and their substance furnishing the last layer of chitin to the lens.

It is possible that these cells may still exist in the adult eye, but I have been unable to see them. The difficulties of decolorising and preserving render it very hard to say definitely that such cells are not present. The nuclei, which are very distinct in the earlier stages, become fainter and fainter as the later stages are reached till, in the adult, they fade away altogether.

Figs. 44, A, B, C, show the earliest stage I have been able to obtain. They are taken from transverse sections through the head of a young *Julus* about four days after hatching; and owing to the small amount of pigment present at this stage, it was unnecessary to decolorise. They show three consecutive sections through the eye at the time of the beginning of the first ocellus. The hypodermis is thickened, and forms a mass round the first pigment spot. The pigment is disposed round the small hollow space which I have called the vesicle. The nuclei are rather large and stain deeply.

Figs. 45, 46, show a later stage in the development of the same eye-spot. The eye, when viewed from the exterior, had the appearance shown in fig. 50, the spot *oc*, 2, being a new eye-spot just forming. Soon after the stage shown in these figures a capsular membrane is formed round the ocellus by the mesoblast cells in the body. The appearance of this capsule will be best understood by a reference to fig. 53, which is a section rather obliquely through a fairly-developed eye-spot. The section has cut so far to one side of the middle line that it has missed the lens altogether, and instead of cutting the cavity of the vesicle, has cut along the side of its wall.

Figs. 49, 51, show that the front wall of the vesicle has become thinner, and is composed of a single layer of cells, which, as I have before mentioned, will secrete the lens. Fig. 52 shows a further stage. The cells forming the back and sides of the vesicle have become longer and are beginning to assume their final shape; while the cells of the front wall have become very thin and are adapted to the shape of the increasing lens to which they make additions. In the course of the further development to the perfect eye-spot, the principal changes are connected with the increasing size of the lens, which becomes so large as almost completely to fill the space which was originally the hollow of the vesicle. The cells of the back and sides of the vesicle lengthen and assume their final shape. The thin front-wall cells lose their nuclei, as I have already mentioned; the back and sides of the vesicle remaining continuous with the hypodermis.

Before the period at which the eye begins to be formed, the hypodermis consists of a layer of cells one cell thick. The cells themselves are oblong, and are arranged so that their long axes lie parallel to the surface. The chitinous exoskeleton is secreted at the outer edge of these cells. Just before the first eye-spot makes its appearance the hypodermic cells alter their shape and become larger and of a more round form. They then begin to divide and multiply, so as to form the mass in which the first formation of the eye begins.

The cells forming the walls of the vesicle are all of a roundish, but somewhat irregular, shape. As soon as the vesicle is formed, while it is as yet quite small, the cells forming the back and sides begin to elongate, and at the same time a junction takes place between them and the ganglionic cells of the brain. Fig. 55 shows two ganglion cells and two cells of the back wall of the vesicle joined together. I have not made out the exact period when this connection takes place, but just before the appearance of the vesicle there is no such connection—the separation of the brain from the epidermis being complete.

The cells forming the back and side walls of the vesicle elongate as the latter increases in size, and pigment is deposited at the surface of the upper (*i.e.*, the part nearest the interior of the vesicle) two-thirds of each cell. This is shown in fig. 57, which is a drawing of a single cell from the back wall of an ocellus. The pigment is all confined to the external two-thirds of the cell, the part round the nucleus being clear. The end pointing towards the surface forms the rod ("Stäbchen" of GRENACHER) which is therefore terminal, not axial, thus agreeing with PATTEN's expectations (15). I have been unable to make out the fringed ends of the rods described by GRENACHER (6). I find, in a transverse section cutting an adult ocellus in a plane parallel to the surface, that I get the same appearance as GRENACHER described; in fact, his figure would serve for an exact representation of my section, but I believe this appearance, which I do not get in similar sections through earlier stages, is due to the action of reagents. At no stage of the development could I see anything like an axial fibre in the retinal cells of the ocelli.

The cells of the exterior wall become flat rather than round, and their nuclei become very faint during the latter part of their development.

The capsule forming the covering of the ocelli is a cellular membrane formed by the mesoblast cells of the body-cavity which have been mentioned before. They begin to form the capsule at a very early period of the vesicle stage.

Just before the formation of the capsule a number of small irregular amœba-like cells make their appearance within the eye mass, and among the cells forming the lateral and internal walls of the vesicle (figs. 45, 46, 47, 48, *pg.c.*, *mes.c*). These eventually develop into cells like those called pigment cells by GRENACHER. I believe them to be descended from the irregular amœba-like mesoblast cells, present within the body-cavity, for the following reasons:—No such cells are present within the eye mass before the period just mentioned as that at which they make their appearance. Just before they make their appearance, the mesoblast cells are present in considerable numbers close to the ocelli, and some of them are in the act of dividing rapidly, the division resulting in the presence of very small irregular-shaped cells resembling those afterwards found within the walls of the vesicle. All sizes are found, from the parent mesoblast cells to the small cells just mentioned (fig. 47). Now, the only other cells from which the pigment cells could have originated are those of the walls of the vesicle, and if this were the case, I should expect to find some traces of division, and some intermediate-sized cells between the long-shaped large cells of the vesicle, and the very small irregularly-shaped cells which I have called the pigment cells. If I am justified in my belief, that these small cells which appear in the walls of the ocelli are descendants of the mesoblast cells of the body-cavity which have wandered into the ocellus, they are evidently intrusive pigment cells, like those described by KINGSLEY in his development of the eye of *Crangon* (8), and by LANKESTER and BOURNE for the eye of *Scorpio* (9).

In fig. 46 the continuations of the cells of the internal wall of the vesicle have collected so as to form a nerve which joins the brain (fig. 46, *n*, *oc*). This nerve pierces the capsule as described by GRENACHER. I do not think this the place for a detailed account of the adult eye, a subject which I hope to take up at a future time.

The formation of the simple eye-spots of *Julus* as just described exhibits a curious type of development, and one which, so far as I know, is unlike anything which has yet been investigated. It is clear that the mass of the ommateum is of exclusively hypodermic origin, while the capsule is mesoblastic, and, if I am right in the view expressed some lines further back, the pigment cells are also mesoblastic. The cells forming the front wall of the vesicle and furnishing the lens must be regarded, in my opinion, as having kept in a great measure their hypodermic function, the clear lens being in its structure and mode of formation exactly similar to the ordinary chitinous exoskeleton which covers the rest of the body at this stage. I do not, therefore, regard the front wall of the vesicle as representing the vitreous body cells, but as ordinary hypodermic matrix. The internal and lateral walls of the vesicle are cells which have become changed and have lost their hypodermic function, while they have acquired or retained the epidermic function of retinal cells. The mode of development seems to me to indicate that the eye-spot of *Julus* is not the most primitive type of eye, but that it has been evolved from a more primitive form of eye, the traces of which have been retained. The distinct vesicle formed as the first starting point seems to me to be such a primitive feature. If my views as to the pigment cells are correct, the first formation of pigment by the cells of the vesicle and the later intrusion of the pigment cells from the mesoblast indicates that the present exochromic eye of *Julus* was derived from an earlier autochromic eye. The ordinary hypodermic cells of the matrix layer are themselves capable of forming pigment, as is shown in fig. 58, which is a section through the hypodermis of a young though adult *Julus*. The pigment is here formed round the surface of the cells exactly as in the earlier stages of the vesicle. From this I conclude that the pigment cells of the ocellus in *Julus* have a function beyond the mere production of pigment. They probably serve to pack the other cells of the vesicle, like the intra-neural cells of the Scorpion eye, as described by LANKESTER (9).

The development of the eye-spots of *Julus* from a vesicle agrees with PATTEN'S belief that the simple eye of Myriapods has been developed from a vesicle invaginated from the ectoderm, as shown in his diagram [fig. 143 of his paper (15)].

The front wall of the vesicle, however, which should according to him be the vitreous layer, is clearly the corneal hypodermis. The original hypodermis present before the formation of the eye (according to PATTEN the external of the three layers), is represented by the external chitin of the exoskeleton formed by it, and now fused with the external wall of the vesicle which now represents the corneal hypodermis.

General Conclusions.

The previous part of this paper contains the chief facts of the development which I have succeeded in obtaining, and I will now consider whether they have any bearing on the more general questions of the phylogeny of the Myriapoda. One of the most important of these questions in view of the recent researches on *Peripatus* is whether the development of *Julus terrestris* offers any points of resemblance to that of this animal. That it does so, I think, is hardly to be denied. The formation of the mesoblastic somites and the origin of the generative tube are strikingly similar. The behaviour of the crural part of the somite is, however, different; the difference being apparently due to the disappearance of the segmental organs. The formation of the salivary gland, while it resembles that of *Peripatus* in being derived from the somite, yet differs completely in the fact that it is formed from the somatic part of the somite.

The formation of the nerve-cord does not in my opinion show any very striking resemblance to that of *Peripatus*. The points in which it agrees are only general resemblances, such as might occur in almost any Tracheate. The development of the eye does afford some ground for believing it to be derived from an eye like that of *Peripatus*, inasmuch as it is formed from a vesicle, but this resemblance is only a general one, and the retinal elements are not, as in *Peripatus*, derived directly from the brain. The heart and pericardium show a striking similarity to those of *Peripatus* in their development as spaces in the mesoderm separate from the cœlomic spaces of the somites. This also is probably a feature common to many Arthropods. The presence of the cerebral grooves is another *Peripatus*-like feature of the development which is also a general point and common to other Tracheates. Thus we see that while there are many similar features in the two developments they are for the most part of a general character, and are at the same time essential features which would be likely to occur in many Tracheata, assuming that the latter are descended from a *Peripatus*-like ancestor.

One part of the development of *Julus terrestris* seems to me to have an interest when considered in its relation to the recent investigations of Mr. SCUDDER on the Carboniferous Myriapods (17). In a former paper (7) I drew attention to the early form of the nervous system, and showed that the two cords which formed its principal part were widely separated; and in the present paper I have shown that in the further course of development the cords came together, and fused, so as to form a single cord. A reference to figs. 1 and 23 of this paper, and to fig. 34 of my former paper (7), will show that this tendency to concentration is shared by the limbs, and also by the whole ventral surface of the body. Now, in SCUDDER's paper on the structure and affinities of the Carboniferous Myriapods of the genus *Euphoberia* (17) he points out features which correspond exactly with this embryonic condition of *Julus*. He describes the ventral plates of *Euphoberia* as occupying the whole ventral surface of the body, and the legs of each pair as placed at some distance from one another, so as to have a clear space between them. It must be remembered that the approximation of the legs and the reduction of the ventral region is a distinguishing character of the existing Diplopoda.

A most interesting question relating to the phylogenetic history of the Myriapods is the matter of the so-called double segments. Were they originally two distinct segments, or were they single segments which have acquired a second pair of limbs? NEWPORT supported the first view; while subsequent writers, especially BALFOUR (though he only suggested it, not considering the evidence sufficient to come to a definite conclusion) and PACKARD, advocated the second. The latter writer puts the evidence in favour of this view very clearly, so I will quote his words (14):—"The phenomenon of two pairs of limbs to a segment, so unique in Tracheata, may be explained by reference to the Phyllopoda among the Branchiata. The parallel is quite exact. The larvæ in both groups have but a single pair of appendages to a segment; the acquisition of a second pair in the Diplopods is clearly enough a secondary character, and perhaps necessary in locomotion in a cylindrical body with no sterna." He adds in a note:—"It is plain that, as BALFOUR suggests ('Comparative Embryology,' p. 324), the double segments have not originated from a fusion of two primitively distinct segments. There is, however, a misconception as to the nature of the 'double segments.' They are not so, in fact. The scutes are single, undivided, but the ventral region is alone imperfectly double, bearing two pairs of appendages, just as single segments of Apodidæ may bear from two to six appendages; the differentiation is confined to the ventral limb-bearing region and limbs alone; the dorsal part of the segment does not share in the process."

The results of the present paper, however, show that the double character of the segments is a much more essential one than is assumed by the acceptance of the above view. The circulatory system, the tracheal system, the nerve cord, and above all the mesoblastic segmentation, all show this duplication; and the only parts of the double segments which are single are the broad plate covering the dorsal and lateral parts of the body, and the stink glands, which, as I have shown, are invaginated in the dorsal plates during development. Looking at the palæontology of the subject, we see that even the dorsal part of the body-ring ("scute" of PACKARD) shows distinct traces of a division in the most ancient classes of fossil Myriapods. The Archipolypoda, an order including the families of Archiclesmidæ, Euphoberidæ, and Archijulidæ, show this peculiarity (ZITTEL's 'Handbuch der Palæontologie').

NEWPORT (13) spoke of the double segments as resulting from the fusion of two originally distinct segments, but it seems to me that it is more correct to consider each part of the so-called double segments as a segment complete in itself but joined to its fellow by the fusion of two dorsal plates, a circumstance probably due to the process of concentration which we see has taken place in the ventral region of the body, with the result that relations which were originally *Euphoberia* are changed to those obtaining in the adult *Julus*.

I fully recognise the difficulty of drawing any definite conclusions as to the phylogeny of a class from the embryology of a single form; at the same time the results of my investigations seem to me to indicate that the Chilopods and Diplopods branched off from some common ancestor at some period not very long before the appearance of the Archipolypoda, and that both are remotely descended from some *Peripatus*-like stock.

My investigations, the results of which are included in this paper, were begun in 1882, and have been entirely carried on in the Morphological Laboratory at Cambridge.

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DESCRIPTION OF PLATES 27–30.*

Lettering used throughout the figures.

Al.	Aliform muscle.
An.	Antenna.
Art.	Artery.
b.r.	Body ring.
brn.	Brain.
C.	Cavity.
Cap.	Capsule.
Cer.gr.	Cerebral groove.
Ch.	Chitinous exoskeleton.
Cor.	Cornea.
Cr.s.	Crural part of somite.
Deut.m.	Deutomalæ.
Ep.	Epidermis.
Ex.	Chitinous covering and hypodermis.
Ex.c.	External coat.
F.b.	Fat-body.
F.w.	Front wall.
F.c.	Follicle cells.
G.	Gut.
Gl.	Ganglion.
H.	Heart.
Hyp.m.	Hypodermic matrix.
In.	Invagination.
Int.	Internal coat.
L.	Leg.
Ln.	Lens.
M.	Mesoblast.
Mes.c.	Mesoblast cells.
Musc.	Muscle.
M.w.	Muscular wall.
Malp.T.	Malpighian tube.
N.cl.	Nerve cell.
N.S.	Nerve system.
N.	Nucleus.
N.wk.	Network.
O.	Ovum.
Oc.	Ocellus.

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* The first four figures were drawn for me, under the microscope, by Mr. H. CHAPMAN, and I am indebted to him for the great care and patience with which he fulfilled his difficult task. The remaining figures were drawn by myself, under ZEISS' camera lucida, and are, unless stated to the contrary in the description of the figure, actual representations of my sections.

Os.	Ostium.
P.	Pair of legs.
Pr.	Projection.
Pg.	Pigment.
Pg.c.	Pigment cells.
Pro.m.	Protomalæ.
Percd.	Pericardium.
S.	Somite.
SS.	Somatic part of somite.
Sal.gl.	Salivary gland.
Sec.c.	Secreting cells.
Seg.	Division of segment.
St.gl.	Stink glands.
Sus.m.	Suspensory muscle.
T.I.	Tracheal invagination.
Up.L.	Upper lip.
Ves.	Vesicle.
V.bl.s.	Ventral blood space.
V.N.C.	Ventral nerve cord.
W.ov.	Wall of ovary.
Y.S.	Yolk spheres.

PLATE 27.

Fig. 1. Drawing of a young *Julus*, late in the stage where three pairs of legs are present. Slightly magnified. *An.* Antenna. *Oc.* Ocelli. 1 *br.* First body ring. 2 *br.* Second body ring. 3 *br.* Third body ring. 4 *br.* Fourth body ring. *P.* 1, 2, 3. First, second, and third pairs of limbs.

Fig. 2. Drawing of an adult *Julus*, showing the first three pairs of legs. *An.* Antenna. 1 *br.* 2 *br.* 3 *br.* 4 *br.* First, second, third, and fourth body rings.

Fig. 3. Drawing of the ventral side of the head of a just-hatched *Julus*, showing the relative position of the mouth parts. Magnified about 150 times. *An.* Antennæ. *Pro.m.* The mandibles or protomalæ of PACKARD. *Deut.m.* The maxillæ or deutomalæ of PACKARD (afterwards form a broad plate).

Fig. 4. Drawing of the antenna of a young *Julus*, in the same stage as Fig. 1. *pr.* The projecting spikes at end of antenna.

Fig. 5. (ZEISS F. *Oc.* 2). Drawn from a longitudinal vertical section of the 10th day *Julus*. The section cuts the 3rd segment. The mesoblastic segment has a cavity within it: The cœlom. *Ep.* Epiblast. *S.* The mesoblastic somite. *C.S.* The cavity within the somite or cœlom.

Fig. 6. (REICHERT, $\frac{1}{15}$ *homog. Oc.* 1). A slightly later stage. The somite has divided into two parts. *SS.* Somatic part of somite. *Cr.s.* Crural part of somite. *SS.* Somatic part of somite. *Ep.* Epiblast. *YS.* Yolk spherules.

Fig. 7. (ZEISS F. *Oc.* 2). A slightly older stage. The crural part of the somite has lost its cavity. The somatic part is slightly pushed out of place by the invagination of the tracheal sac. *M.* The thin sheet of mesoblast uniting the two somites. *N.C.* Nerve cord. *SS.* Somatic part of somite. *Ep.* Epiblast. *C.S.* Crural part. *T.I.* Tracheal invagination.

Fig. 8. Magnified 450 diameters. A later stage than the foregoing. The somatic part of the cœlom is passing upwards towards the top of the nerve cord. *T.I.* Tracheal invagination. *SS.* Somatic part of somite. *M.* Mesoblast uniting somites across the nerve cord. *F.N.S.* Fibrous part of nerve cord. *G.N.S.* Ganglionic part of nerve cord.

Fig. 9. The two somatic parts have met above the nerve cord to form the generative tube. A section through the whole animal, magnified about 250 diameters. *H.* Heart. *F.b.* Fat-body. *N.C.* Nerve cord. *G.* Gut. *SS.* Somites.

Fig. 10. Part of the same section as the last. Magnified 450 diameters. *C.SS.* Cavity of somite. *F.N.S.* Fibrous part of nerve cord. *G.N.S.* Ganglionic part of nerve cord.

Fig. 11. ($\frac{2}{3}$-in. BECK. *Oc.* 5 ZEISS). A longitudinal section through the head of a young animal, late in the stage where three pairs of legs are present, to show the salivary gland. *Up.L.* Upper lip. *brn.* Brain. *Sal.gl.* Salivary gland. *Pro.m.* Protomalæ. *Deut.m.* Deutomalæ. *P.* 1. First pair of legs.

Fig. 12. 450 diameters. Longitudinal vertical through the 3rd and 4th segments, showing the first development of the salivary gland. *SS.* 4. Somatic part of somite of 4th segment. *Cr.s* Crural part of somite. *SS.* 3. Somatic part of 3rd somite.

Fig. 13. Magnified 250 diameters. Part of a transverse section cutting the somite of the 3rd pair of appendages (later the deutomalæ). *Sal.gl.* Salivary gland. *Cr.s.* Crural part of the somite. *Ep.* Epidermis.

Fig. 14. 450 diameters. Part of a longitudinal section cutting the same segment. *Sal.gl.* Salivary gland. *Musc.* Muscles of limb. *Deut.m.* One of the deutomalæ.

PLATE 28.

Fig. 15. 500 diameters. Ventral half of a transverse section through a freshly developing segment (double segment). This section was cut rather obliquely, so that the epidermis seems rather thicker than it would otherwise. *Ep.* Epidermis. *Hyp.m.* Hypodermic matrix. *M.S.* Mesoblastic somite. *Gl.N.C.* Ganglion of nerve-cord. *M.* Thin layer of mesoblast uniting ganglia.

Fig. 16. Part of a longitudinal section through a young animal late in the three-legged stage, cutting the bases of the 4th and 5th pairs of legs (the legs of the first double segment). *L.* 4. One of the 4th pair of legs. *L.* 5. One of the 5th pair. *SS.L.* 5. Somatic part of the somites of the 4th and 5th pair. *Cr.s.* 4. Crural part of somite of 4th pair.

Fig. 17. Magnified 250 diameters. Part of a transverse section through a young *Julus* with perfect ovary. *N.C.* Nerve-cord. *V.bl.sin.* Part of the ventral blood sinus. *W.ov.* Wall of ovary. *Ov.* Young ovum. *F.c.* Follicle cells.

Fig. 18. Part of the wall of the ovary of the same *Julus*, magnified 450 diameters. *W.ov.* Wall of the ovary. *C.ov.* Cells divided off from the cells of the cell-wall.

Fig. 19. 450 diameters. Another part of same ovary; cells divided off from wall of ovary rather bigger. *W.ov.* Wall of ovary. *Ov.* Young ovum. *C.ov.* Cells divided off from wall of ovary.

Fig. 20. Another part of same ovary. Same magnification. Letters as before.

Fig. 21. Another part of same ovary. Same magnification. One cell has reached a considerable size, and will become a young ovum; others have surrounded it, and will form the follicle.

Fig. 22. Magnified 450 diameters. Part of a transverse section through a *Julus* with three pairs of legs, to show the first invagination of tracheæ. *SS.* Somatic part of somite. *T.I.* Tracheal invagination. *L.* Limb. *N.C.* Nerve-cord.

Fig. 23. Half of a transverse section through a late hexapodous stage. *G.* Gut. *Malp.T.* Malpighian tube. *SS.* Somatic part of somite. *Tr.I.* Tracheal invagination. *L.* Leg. *Y.S.* Yolk spherule.

Fig. 24. First invagination of stink gland. The section is a longitudinal one through part of the 7th segment when first formed. *St.gl.in.* Invagination of epidermis to form stink gland. *Musc.* Muscles.

Fig. 25. Part of a longitudinal section showing a later stage in the formation of the stink gland. Magnified 250 times. *Hyp.m.* Hypodermic matrix. *M.St.gl.* Mouth of stink gland. *St.gl.* Stink gland. *Ext.c.st.gl.* External coat of stink gland.

Fig. 26. Part of a transverse section through a later stink gland, to show structure. Magnified 450 times. *Ext.c.st.gl.* External coat of stink gland. *Sec.c.* Secreting cells.

Fig. 27. Part of a longitudinal section through the head region of a just-hatched *Julus*, to show brain. 250 diameters. *Cer.gr.* Cerebral groove. *brn.* Brain. *Hyp.m.* Hypodermic matrix. *Gl.* Ganglia. *G.* Gut. *V.N.C.* Ventral nerve-cord.

Fig. 28. Transverse section through head of *Julus* of same age as the last, to show brain. 250 diameters. *Hyp.m.* Hypodermic matrix. *Cer.gr.* Cerebral groove. *G.* Gut. *F.br.* Fibrous part of the brain.

PLATE 29.

Fig. 29. Transverse section through animal a little later than fig. 28. 250 diameters. *G.* Gut. *M.* Mesoblastic covering of gut. *Sp.* Small cavity remaining after the two ganglia have approached and fused. *Cav.gl.* Cavity in ganglion. *Y.S.* Yolk spheres. *Cr.s.* Crural part of somite still remaining. *tr.i.* Tracheal invagination.

Fig. 30. Section through 3rd ganglion of ventral cord, soon after first formation. *Cav.gl.* Cavity in ganglion. *M.* Mesoblastic covering of ganglion.

Fig. 31. (ZEISS F. *Oc.* 2.) Dorsal part of a transverse section through a young *Julus* shortly after hatching, showing the network of mesoblastic cells from which both the heart and the fat-body are formed. *Ch.* Chitinous exoskeleton. *Hyp.m.* Hypodermic matrix. *N.wk.* Network of mesoblast cells.

Fig. 32. A highly magnified (ZEISS L. water immersion, *Oc.* 2) part of the network. *Y.S.* Yolk spherules. *C.* Cells. *N.* Nucleus.

Fig. 33. (ZEISS D. *Oc.* 2.) A more advanced stage than fig. 31. *Ch.* Chitinous exoskeleton. *Hyp.m.* Hypodermic matrix. *Susp.m.* Fibre forming suspensory muscle of heart. *N.wk.* Cells forming network. *C.ht.* Cavity of heart.

Fig. 34. Later stage. The chitinous exoskeleton has been rather torn away from the hypodermic layer in the act of cutting. *Y.S.* Yolk spheres. *C.ht.* Cavity of heart. *Percd.* Pericardium. *Musc.* Muscles. *F.b.* Part of the forming network.

Fig. 35. ($\frac{1}{15}$ *hom. im.* REICHERT.) Part of a longitudinal section through a forming segment in posterior region of heart. *Ch.* Chitinous exoskeleton. *Ht.* Heart. *Os.* Ostium forming. *Wg.* Wall of gut. *Ex.* Exoskeleton of segment.

Fig. 36. (ZEISS D. *Oc.* 2). Adult *Julus.* Part of a longitudinal section to show heart. *Ch.* Exoskeleton. *Hyp.m.* Hypodermic matrix. *Seg.* Division between segments. *F.b.* Fat-bodies. *Ht.* Heart. *Percd.* Pericardium. *Os.* Ostium.

Fig. 37. (ZEISS D. *Oc.* 2.) Part of a longitudinal horizontal section through an adult *Julus* to show artery. The external coat of the heart is continued over the artery. *F.b.* Fat-body. *O.gl.* Oil globule. *Art.* Artery. *Ext.c.* External coat of heart.

Fig. 38. Longitudinal section through a heart nearly formed, in a *Julus* with seven pairs of legs. *Ht.* Cavity of heart. *Os.* Ostium.

Fig. 39. Transverse section through nearly formed heart. *Ext.c.* Forming external coat. *M.w.* Muscular wall of heart. *Int.* Intima. *Percd.* Pericardium. *Al.mus.* Fibre which represents aliform muscle in Insect heart.

PLATE 30.

Fig. 40. ($\frac{1}{15}$ REICHERT *Oc.* 2.) Transverse section through adult heart, showing ostium. *Os.* Ostium. *Mus.* Muscles of ostium.

Fig. 41. ($\frac{1}{15}$ REICHERT *Oc.* 2.) Part of a section through a forming heart, to show the formation of the external coat and suspensory muscle.

Fig. 42. ($\frac{1}{15}$ REICHERT *Oc.* 2.) Part of a longitudinal section through an adult heart, to show the arrangement of muscles in alternate broad and narrow bands. *Int.* Internal coat. *B.mus.* Bands of muscles. *Sus.m.* Attachment of a suspensory muscle.

Fig. 43. (REICHERT $\frac{1}{15}$ *Oc.* 2.) Structure of external coat of adult heart; from a longitudinal section.

Fig. 44. A, B, C. Three consecutive sections through the beginning of the first eye-spot. The hypodermis is slightly thickened round the beginning ocellus. *Pg.* Pigment. *Oc.* Beginning of ocellus.

Fig. 45. Section through further advanced ocellus. *Mes.c.* Mesoblast cell in body cavity. *Cap.c.* Cell of forming connective tissue capsule. *Pg.c.* Pigment cells. *Ves.* Vesicle.

Fig. 46. About same age as last. *P.c.* Pigment cells. *No.c.* Nerve from ocellus. *Ves.* Vesicle.

Fig. 47. Further advanced ocellus. *Ves.* Vesicle. *F.w.ves.* Front of vesicle. *Oc.* Ocellus.

Fig. 48. Section through advanced ocellus, and cutting a more complete ocellus obliquely. *Oc.* Advanced ocellus, cut obliquely. *F.w.ves.* Front wall of vesicle. *Ves.* Vesicle. *Hyp.* Hypodermis. *P.g.* Pigment cells.

Fig. 49. Further advanced ocellus. *Ch.* Exoskeleton. *Hyp.m.* Hypodermis. *Ves.* Vesicle. *Pg.c.* Pigment cell.

Fig. 50. 150 diameters. Head of young *Julus*. *Oc.* 1. Advanced ocellus. *Oc.* 2. Beginning ocellus.

Fig. 51. *Cor.* Thickened chitin, the beginning of the cornea. *F.w.v.* Front wall of vesicle from which the corneal lens is increased. *B.w.v.* Back wall of vesicle. *Cap.* Capsule.

Fig. 52. (REICHERT $\frac{1}{15}$ *homogen.* *Oc.* 1.) The lens is beginning to be formed. *B.w.v.* Back wall of vesicle. *Cap.* Capsular membrane. *Hyp.* Hypodermis. *Ln.* Lens.

Fig. 53. Section through advanced ocellus. The section is taken through the side of the ocellus, and not through the middle line. *Ch.* Chitinous exoskeleton. *F.w.v.* Front wall of vesicle. *Cap.* Capsule. *B.w.v.* Back wall of vesicle.

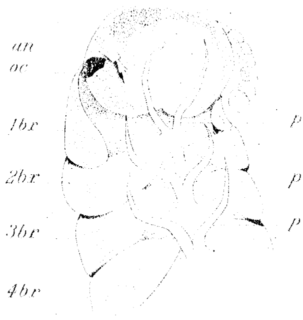
Fig. 54. Pigment cell inside ocellus, to show size relative to surrounding cells. About 700 diameters.

Fig. 55. (Reichert $\frac{1}{15}$ *homogen. Oc.* 1.) Early stage of ocellus, to show junction between the cells of the vesicle and the nerve-cells. *Hyp.* Hypodermis. *Ves.* Vesicle. *Con.p.* Process connecting the nerve-cell and the vesicle cell. *N.C.* Nerve-cord.

Fig. 56. Single cell from nearly adult ocellus.

Fig. 57. Cells from retina of nearly adult ocellus.

Fig. 58. Part of transverse section through adult exoskeleton and hypodermis. *Ch.* Exoskeleton. *Hyp.m.* Hypodermic matrix. *Pg.* Pigmented part of hypodermic matrix cells.



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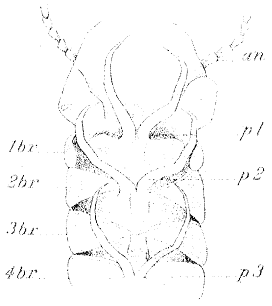

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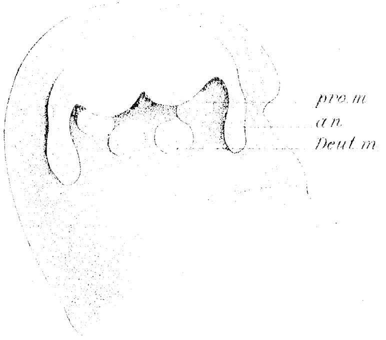

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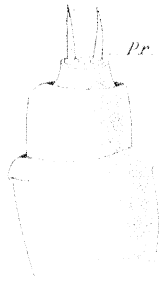

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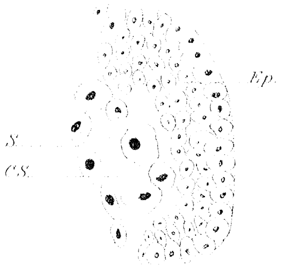

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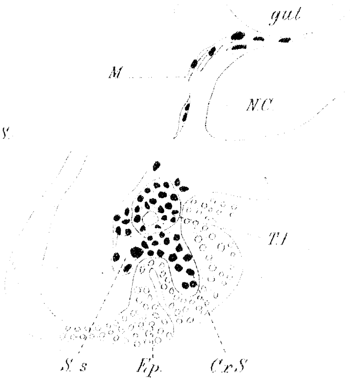

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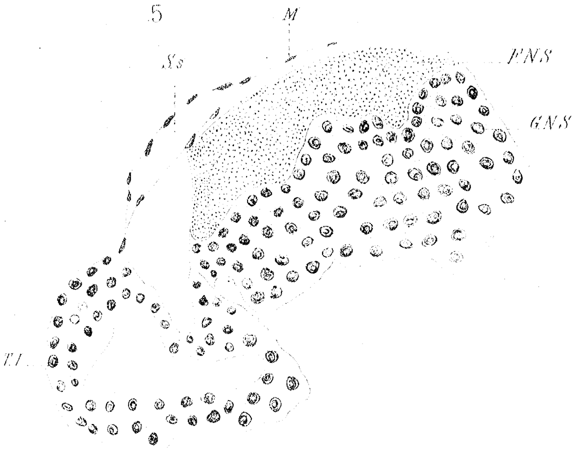

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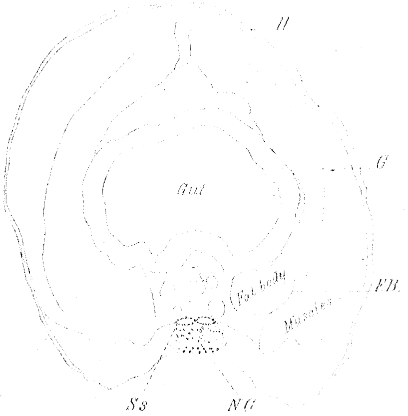

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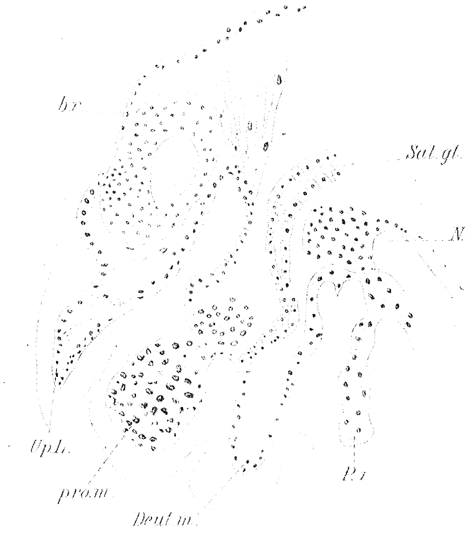

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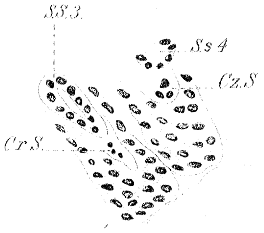

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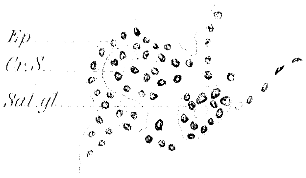

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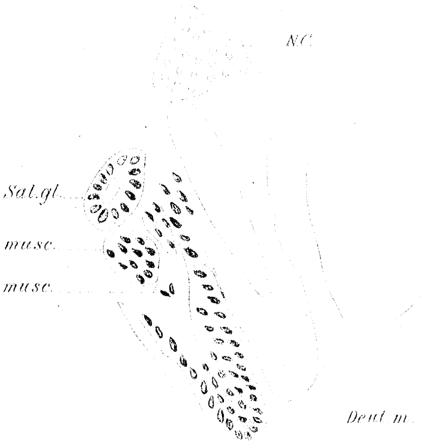

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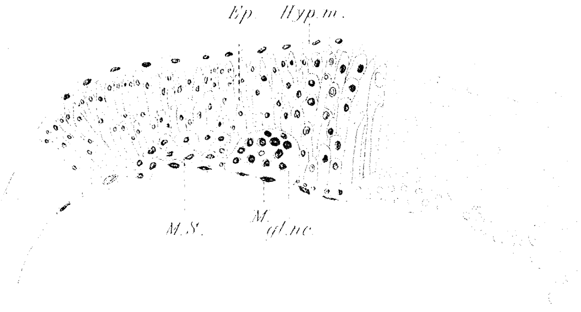

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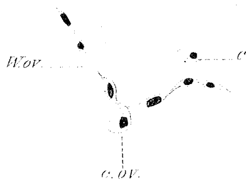

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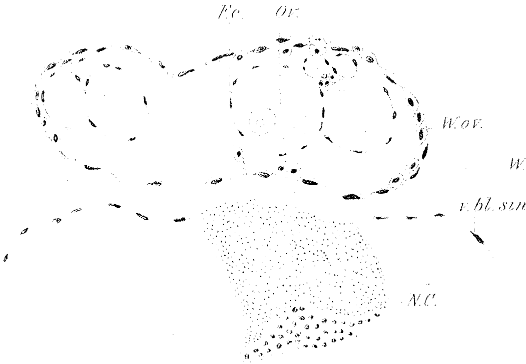

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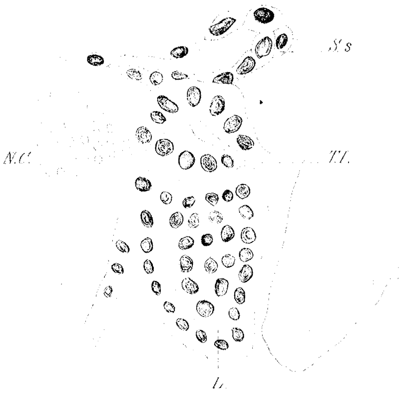

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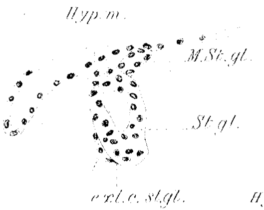

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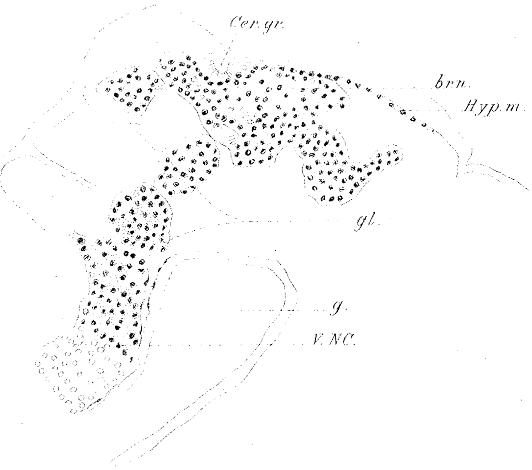

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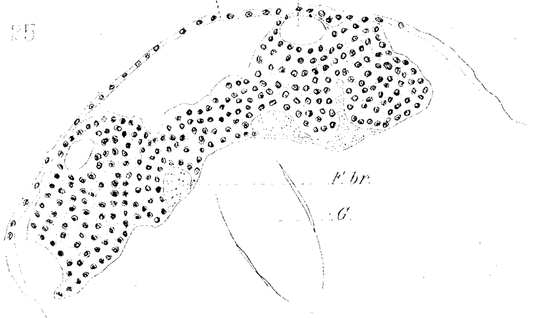

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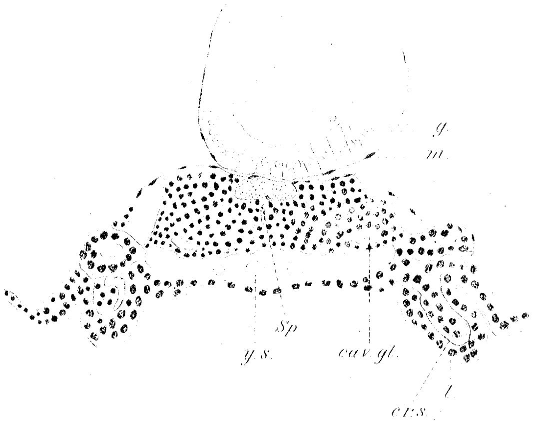

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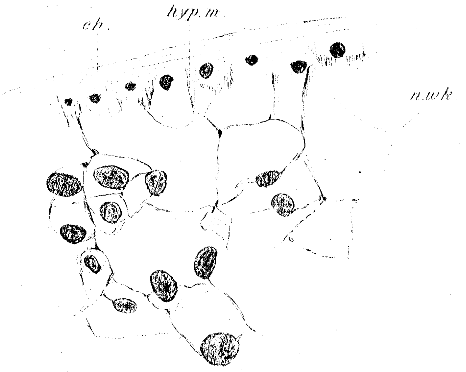

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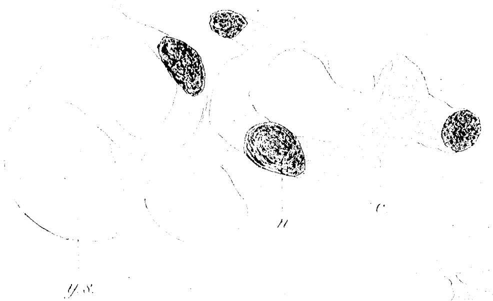

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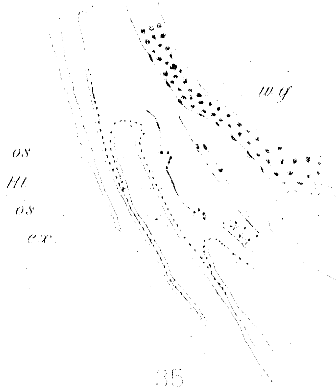

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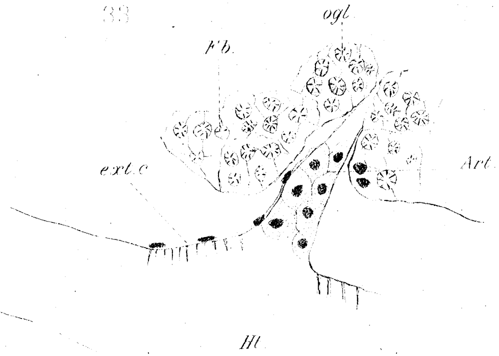

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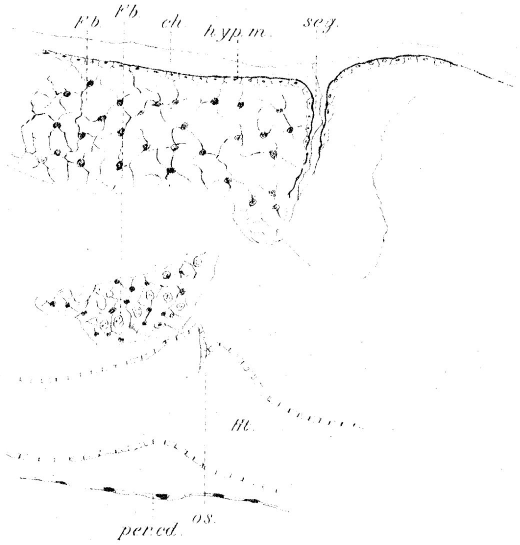

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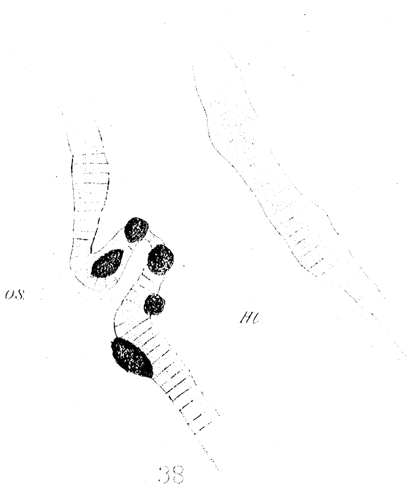

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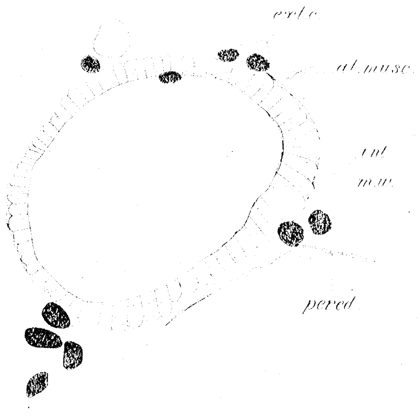

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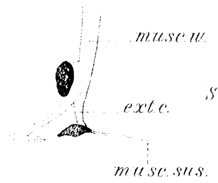

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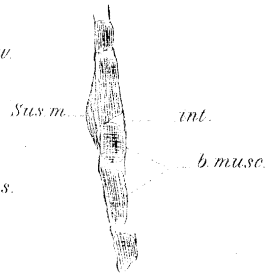

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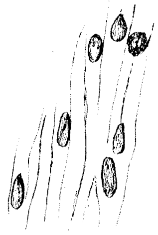

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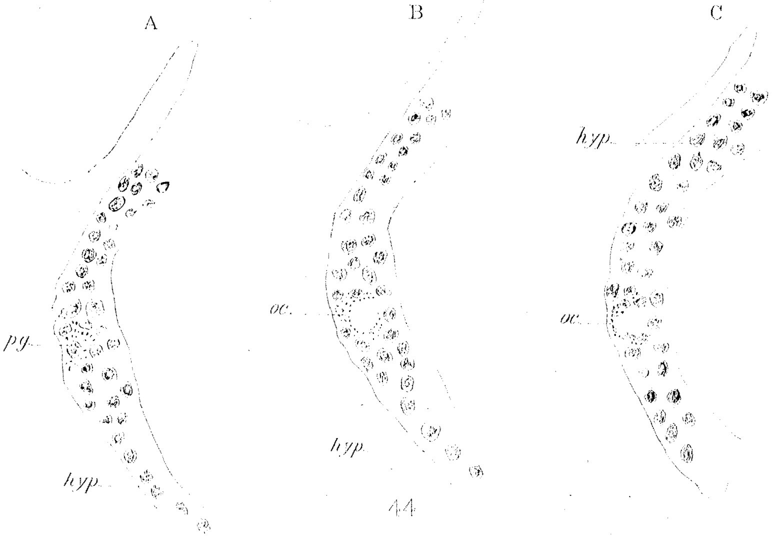

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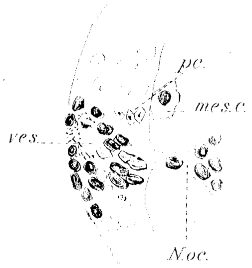

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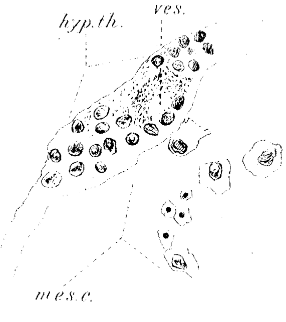

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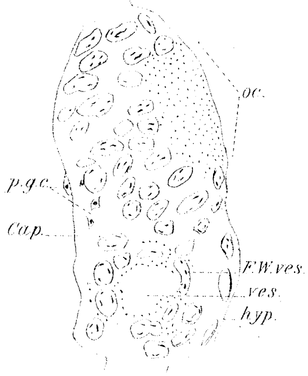

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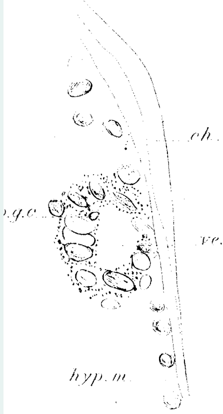

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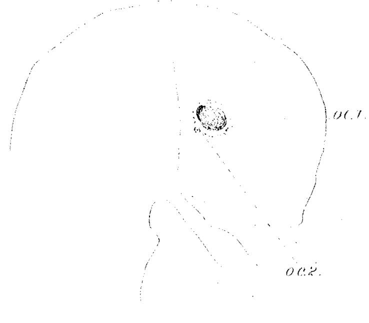

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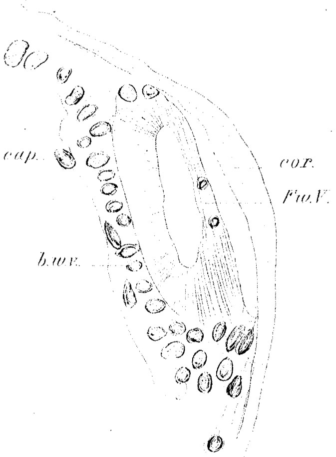

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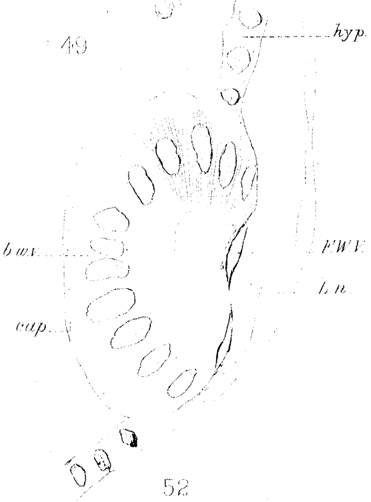

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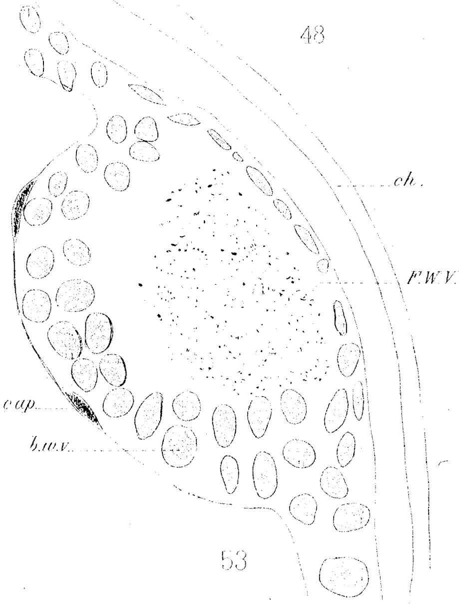

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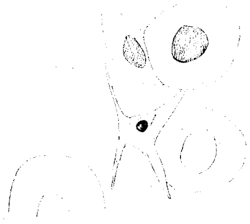

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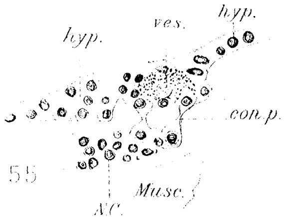

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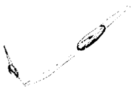

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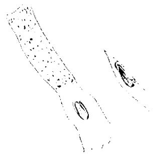

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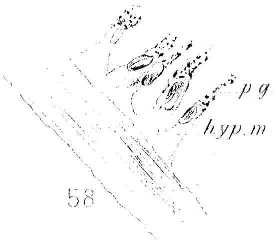

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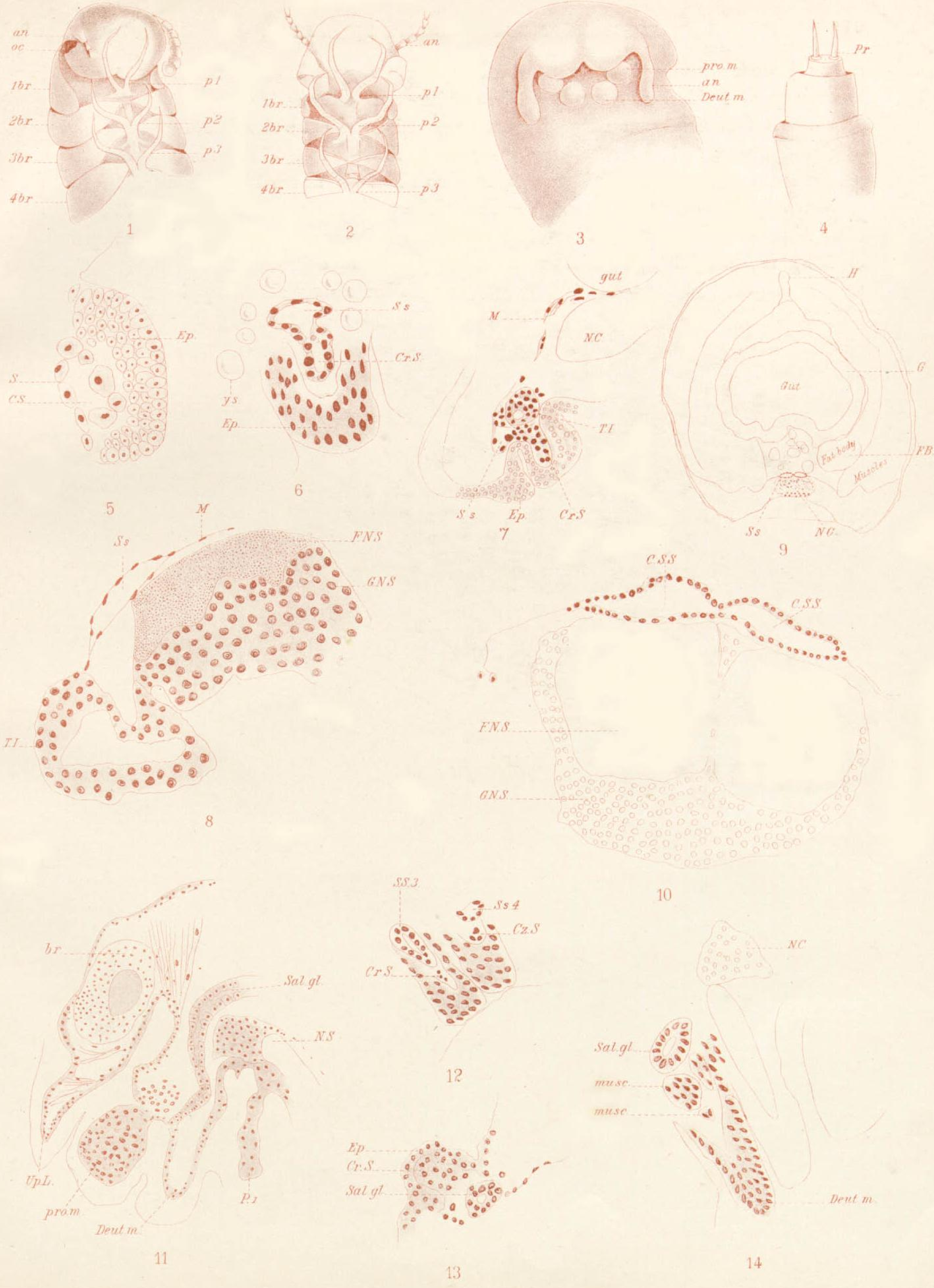


PLATE 27.

Fig. 1. Drawing of a young *Julus*, late in the stage where three pairs of legs are present. Slightly magnified. *An.* Antenna. *Oc.* Ocelli. 1 *br.* First body ring. 2 *br.* Second body ring. 3 *br.* Third body ring. 4 *br.* Fourth body ring. *P.* 1, 2, 3. First, second, and third pairs of limbs.

Fig. 2. Drawing of an adult *Julus*, showing the first three pairs of legs. *An.* Antenna. 1 *br.* 2 *br.* 3 *br.* 4 *br.* First, second, third, and fourth body rings.

Fig. 3. Drawing of the ventral side of the head of a just-hatched *Julus*, showing the relative position of the mouth parts. Magnified about 150 times. *An.* Antennæ. *Pro.m.* The mandibles or protomalæ of PACKARD. *Deut.m.* The maxillæ or deutomalæ of PACKARD (afterwards form a broad plate).

Fig. 4. Drawing of the antenna of a young *Julus*, in the same stage as Fig. 1. *pr.* The projecting spikes at end of antenna.

Fig. 5. (ZEISS F. *Oc.* 2). Drawn from a longitudinal vertical section of the 10th day *Julus*. The section cuts the 3rd segment. The mesoblastic segment has a cavity within it: The cœlom. *Ep.* Epiblast. *S.* The mesoblastic somite. *C.S.* The cavity within the somite or cœlom.

Fig. 6. (REICHERT, $\frac{1}{15}$ *homog. Oc.* 1). A slightly later stage. The somite has divided into two parts. *SS.* Somatic part of somite. *Cr.s.* Crural part of somite. *SS.* Somatic part of somite. *Ep.* Epiblast. *YS.* Yolk spherules.

Fig. 7. (ZEISS F. *Oc.* 2). A slightly older stage. The crural part of the somite has lost its cavity. The somatic part is slightly pushed out of place by the invagination of the tracheal sac. *M.* The thin sheet of mesoblast uniting the two somites. *N.C.* Nerve cord. *SS.* Somatic part of somite. *Ep.* Epiblast. *C.S.* Crural part. *T.I.* Tracheal invagination.

Fig. 8. Magnified 450 diameters. A later stage than the foregoing. The somatic part of the cœlom is passing upwards towards the top of the nerve cord. *T.I.* Tracheal invagination. *SS.* Somatic part of somite. *M.* Mesoblast uniting somites across the nerve cord. *F.N.S.* Fibrous part of nerve cord. *G.N.S.* Ganglionic part of nerve cord.

Fig. 9. The two somatic parts have met above the nerve cord to form the generative tube. A section through the whole animal, magnified about 250 diameters. *H.* Heart. *F.b.* Fat-body. *N.C.* Nerve cord. *G.* Gut. *SS.* Somites.

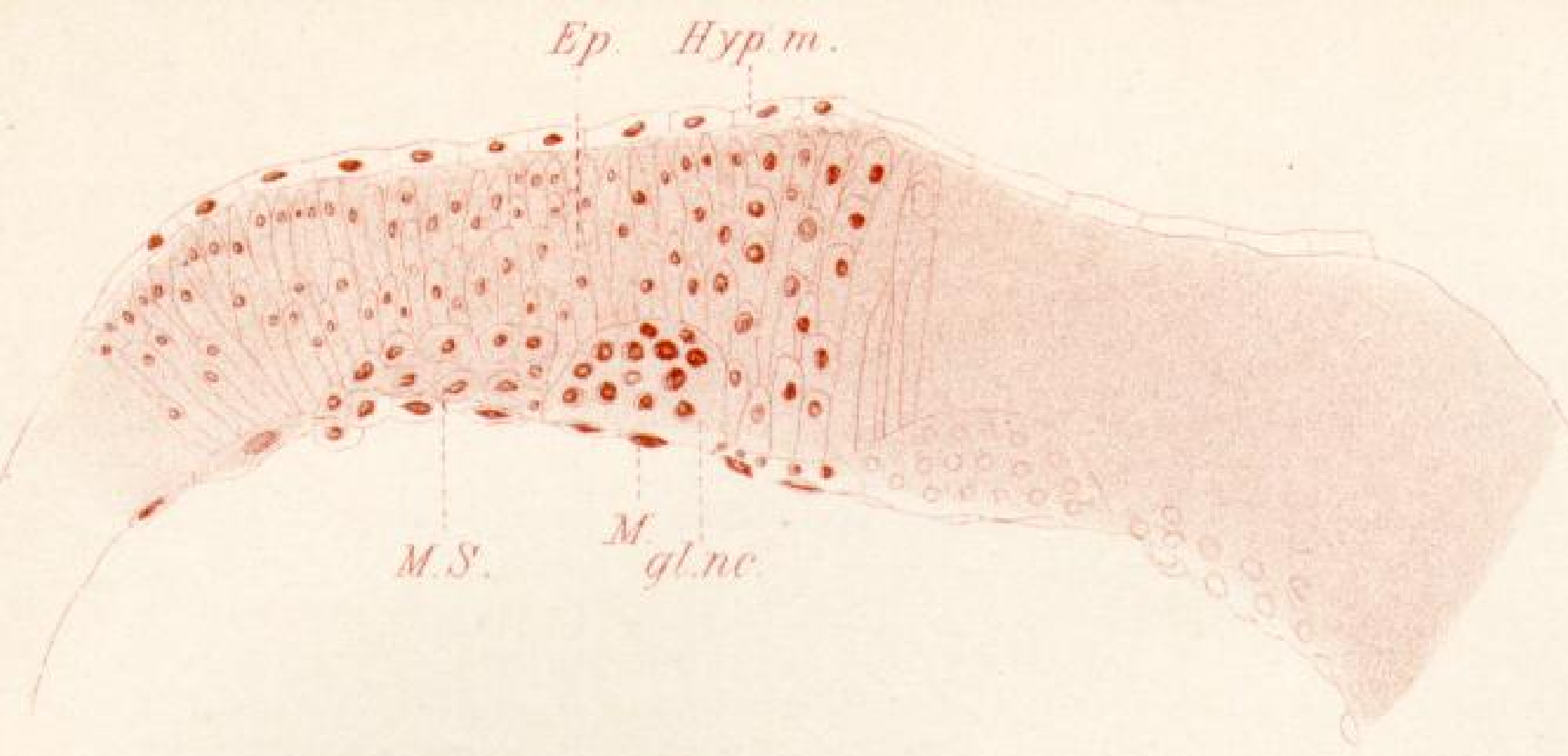
Fig. 10. Part of the same section as the last. Magnified 450 diameters. *C.SS.* Cavity of somite. *F.N.S.* Fibrous part of nerve cord. *G.N.S.* Ganglionic part of nerve cord.

Fig. 11. ($\frac{2}{3}$-in. BECK. *Oc.* 5 ZEISS). A longitudinal section through the head of a young animal, late in the stage where three pairs of legs are present, to show the salivary gland. *Up.L.* Upper lip. *brn.* Brain. *Sal.gl.* Salivary gland. *Pro.m.* Protomalæ. *Deut.m.* Deutomalæ. *P.* 1. First pair of legs.

Fig. 12. 450 diameters. Longitudinal vertical through the 3rd and 4th segments, showing the first development of the salivary gland. *SS.* 4. Somatic part of somite of 4th segment. *Cr.s* Crural part of somite. *SS.* 3. Somatic part of 3rd somite.

Fig. 13. Magnified 250 diameters. Part of a transverse section cutting the somite of the 3rd pair of appendages (later the deutomalæ). *Sal.gl.* Salivary gland. *Cr.s.* Crural part of the somite. *Ep.* Epidermis.

Fig. 14. 450 diameters. Part of a longitudinal section cutting the same segment. *Sal.gl.* Salivary gland. *Musc.* Muscles of limb. *Deut.m.* One of the deutomalæ.



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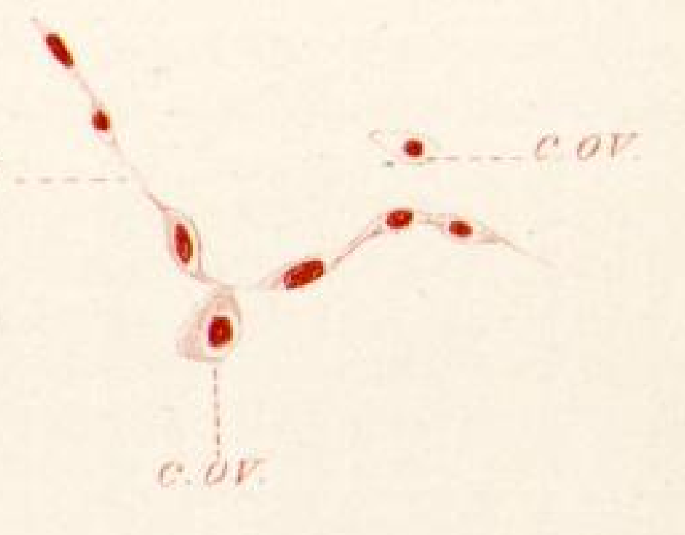

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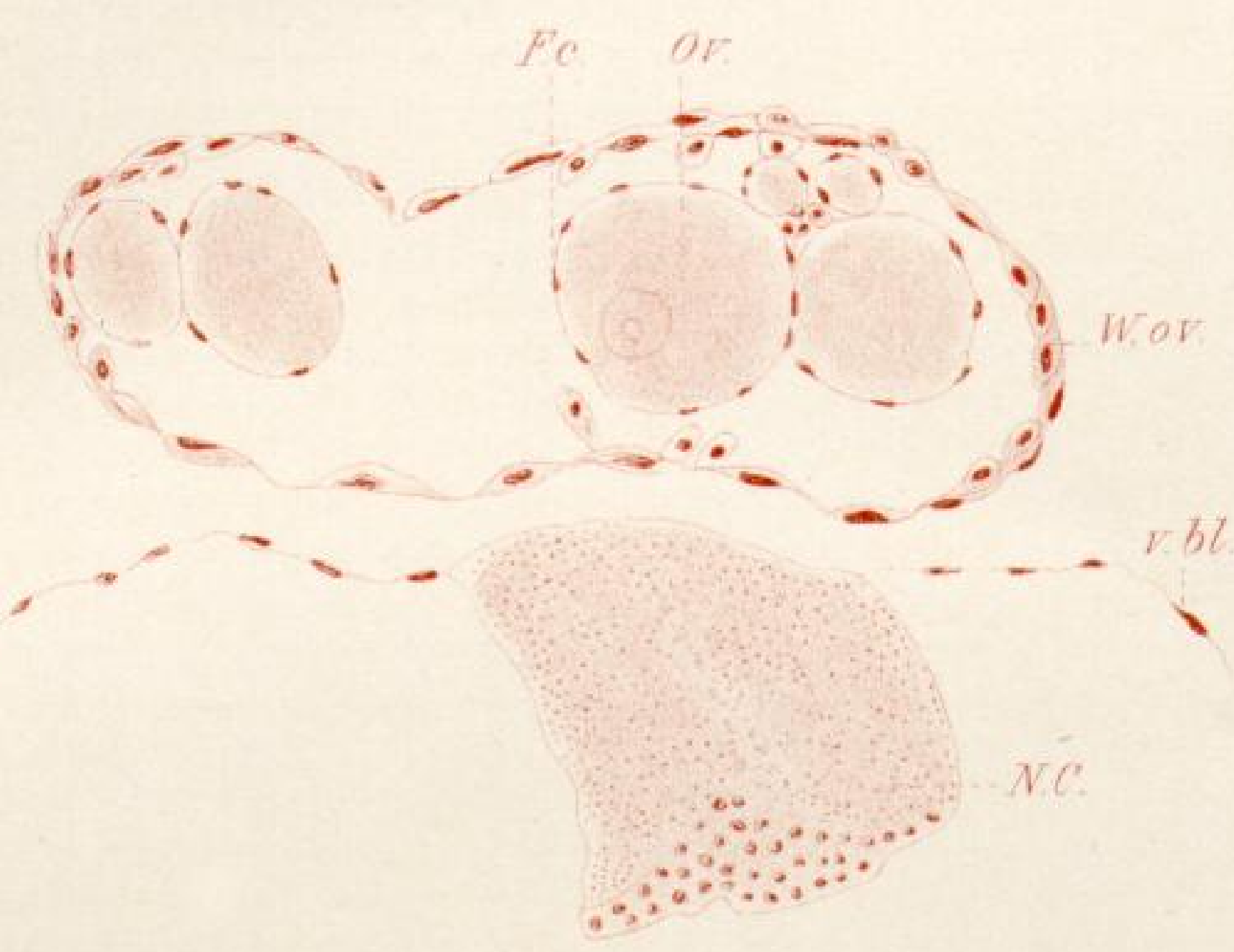

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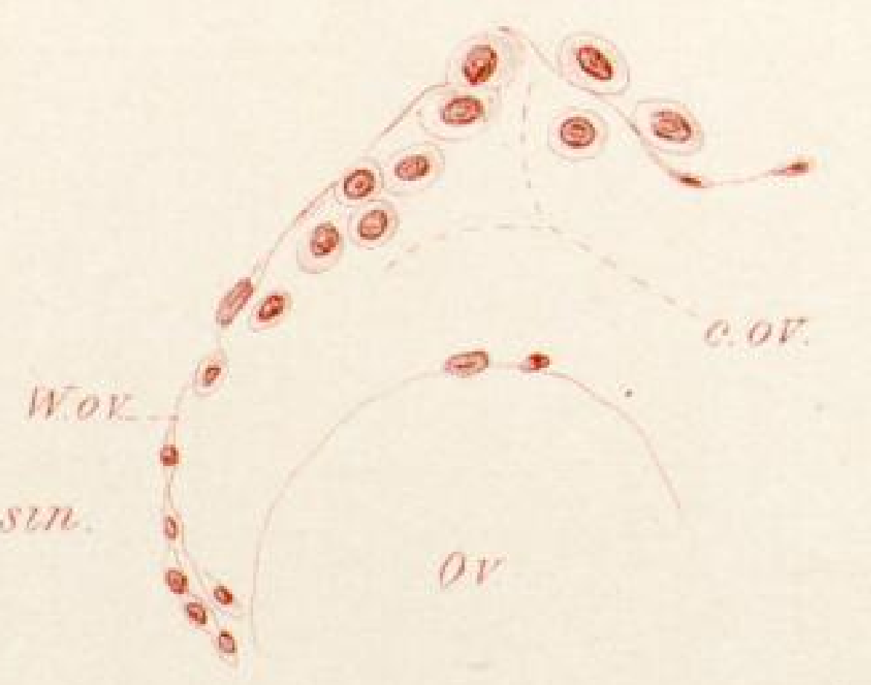

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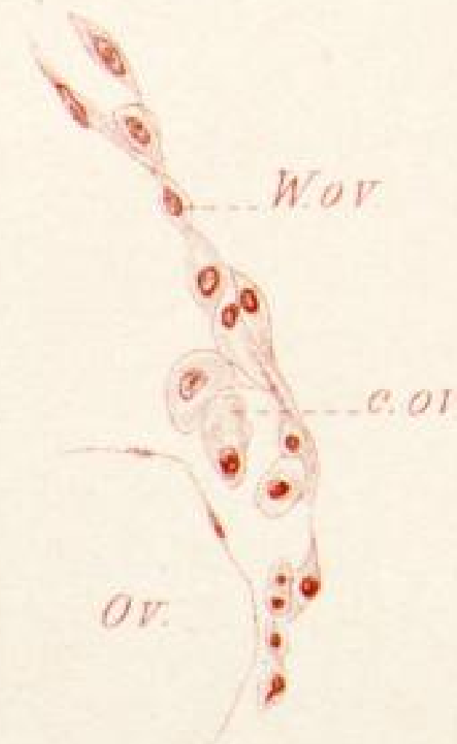

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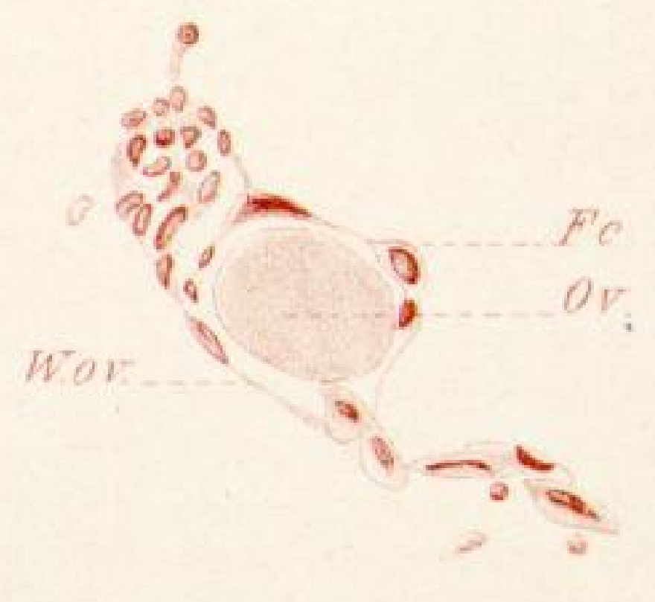

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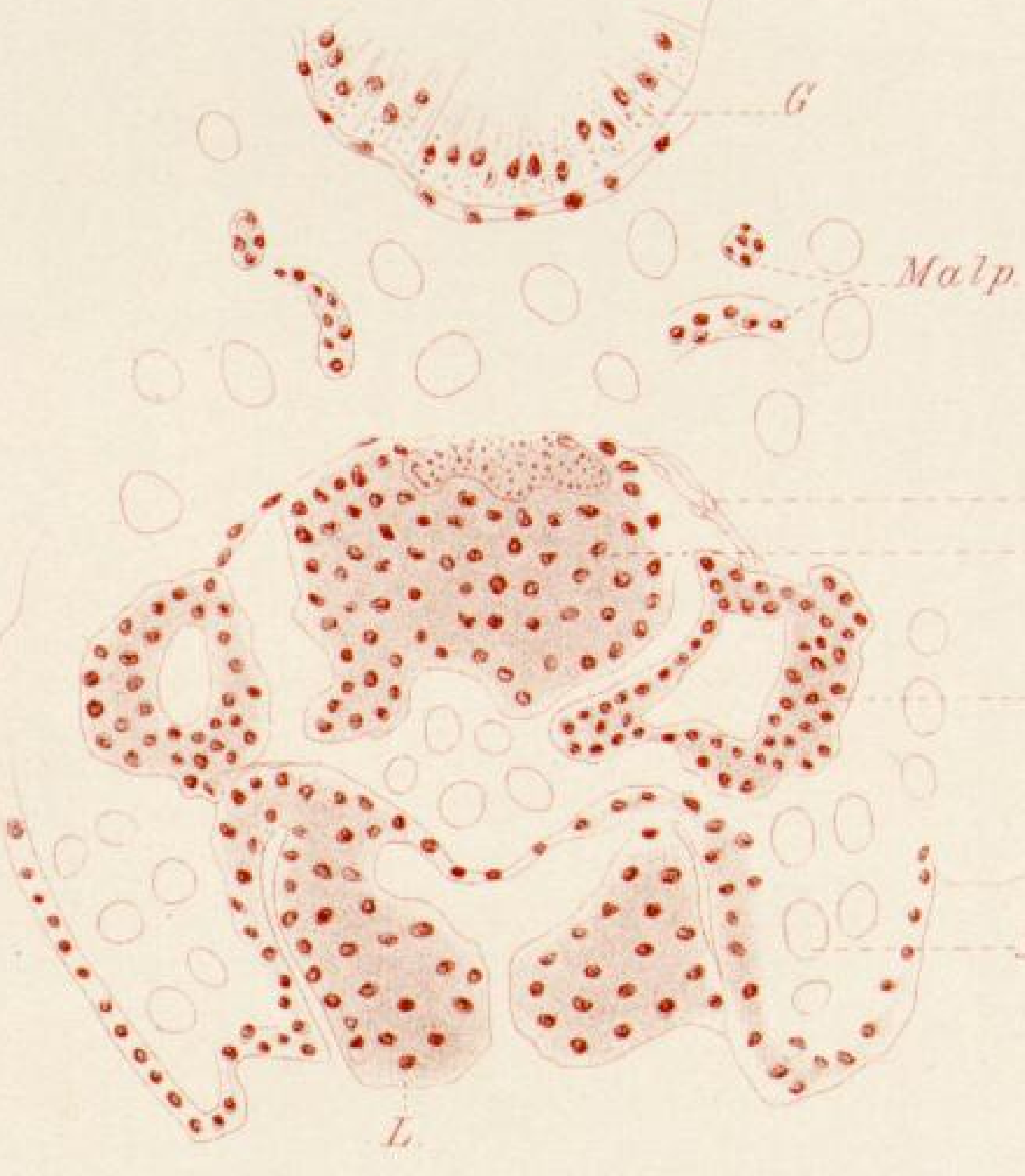

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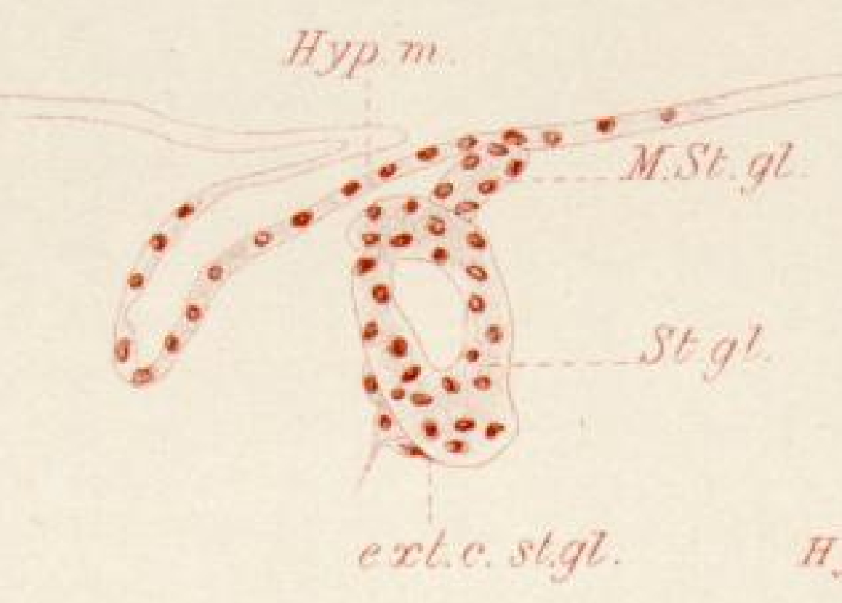

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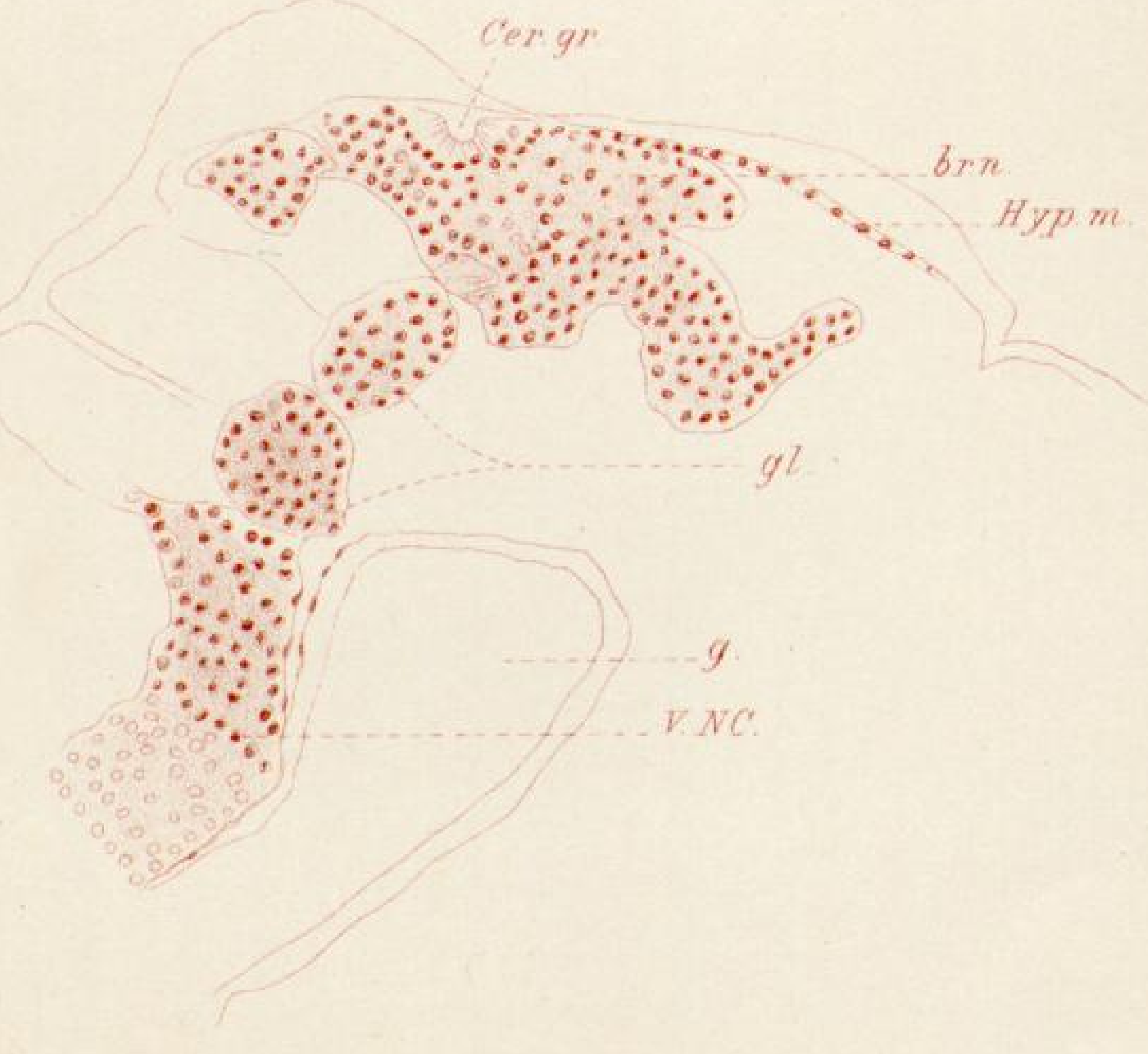

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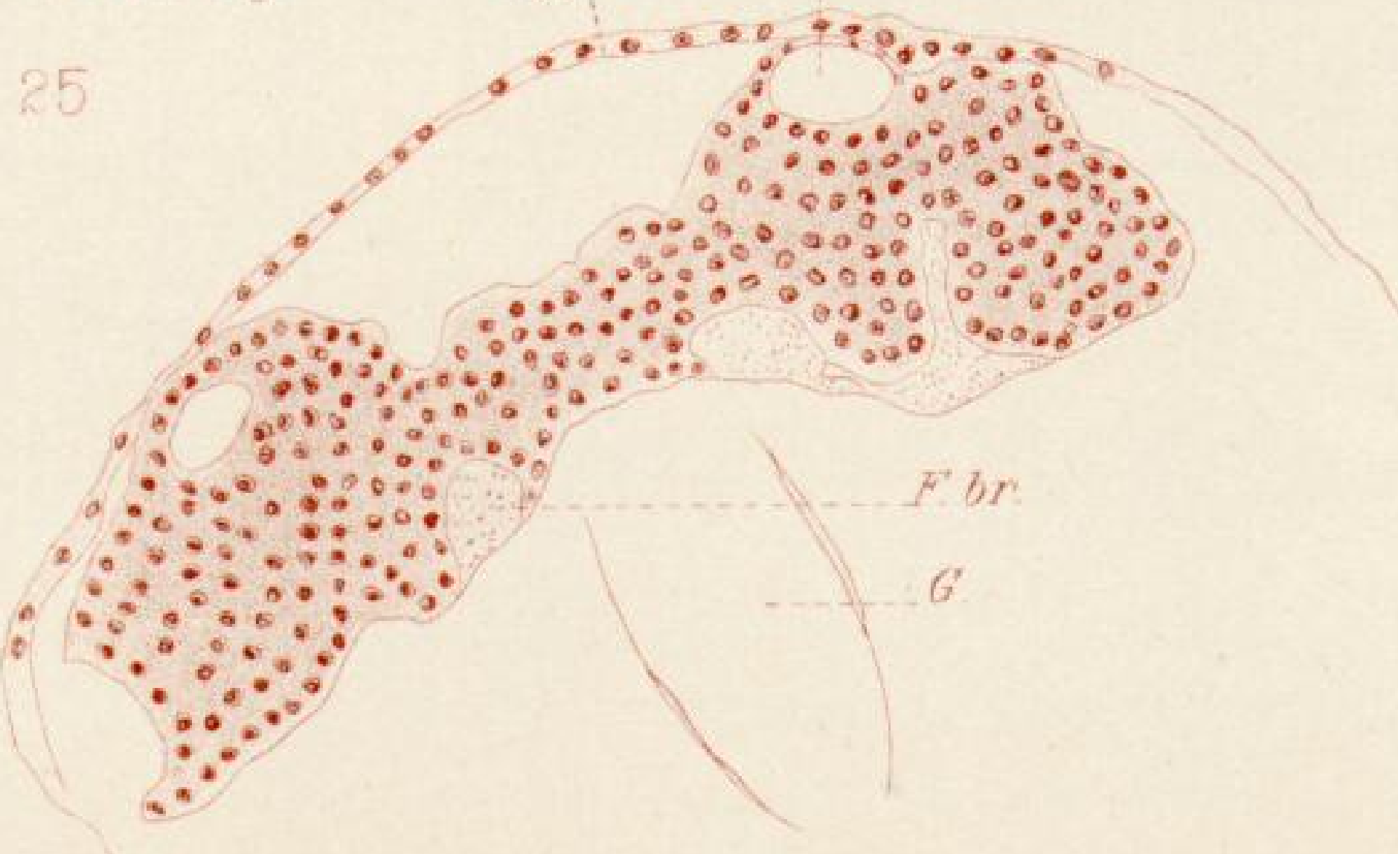

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PLATE 28.

Fig. 15. 500 diameters. Ventral half of a transverse section through a freshly developing segment (double segment). This section was cut rather obliquely, so that the epidermis seems rather thicker than it would otherwise. *Ep.* Epidermis. *Hyp.m.* Hypodermic matrix. *M.S.* Mesoblastic somite. *Gl.N.C.* Ganglion of nerve-cord. *M.* Thin layer of mesoblast uniting ganglia.

Fig. 16. Part of a longitudinal section through a young animal late in the three-legged stage, cutting the bases of the 4th and 5th pairs of legs (the legs of the first double segment). *L.* 4. One of the 4th pair of legs. *L.* 5. One of the 5th pair. *SS.L.* 5. Somatic part of the somites of the 4th and 5th pair. *Cr.s.* 4. Crural part of somite of 4th pair.

Fig. 17. Magnified 250 diameters. Part of a transverse section through a young *Julus* with perfect ovary. *N.C.* Nerve-cord. *V.bl.sin.* Part of the ventral blood sinus. *W.ov.* Wall of ovary. *Ov.* Young ovum. *F.c.* Follicle cells.

Fig. 18. Part of the wall of the ovary of the same *Julus*, magnified 450 diameters. *W.ov.* Wall of the ovary. *C.ov.* Cells divided off from the cells of the cell-wall.

Fig. 19. 450 diameters. Another part of same ovary; cells divided off from wall of ovary rather bigger. *W.ov.* Wall of ovary. *Ov.* Young ovum. *C.ov.* Cells divided off from wall of ovary.

Fig. 20. Another part of same ovary. Same magnification. Letters as before.

Fig. 21. Another part of same ovary. Same magnification. One cell has reached a considerable size, and will become a young ovum; others have surrounded it, and will form the follicle.

Fig. 22. Magnified 450 diameters. Part of a transverse section through a *Julus* with three pairs of legs, to show the first invagination of tracheæ. *SS.* Somatic part of somite. *T.I.* Tracheal invagination. *L.* Limb. *N.C.* Nerve-cord.

Fig. 23. Half of a transverse section through a late hexapodous stage. *G.* Gut. *Malp.T.* Malpighian tube. *SS.* Somatic part of somite. *Tr.I.* Tracheal invagination. *L.* Leg. *Y.S.* Yolk spherule.

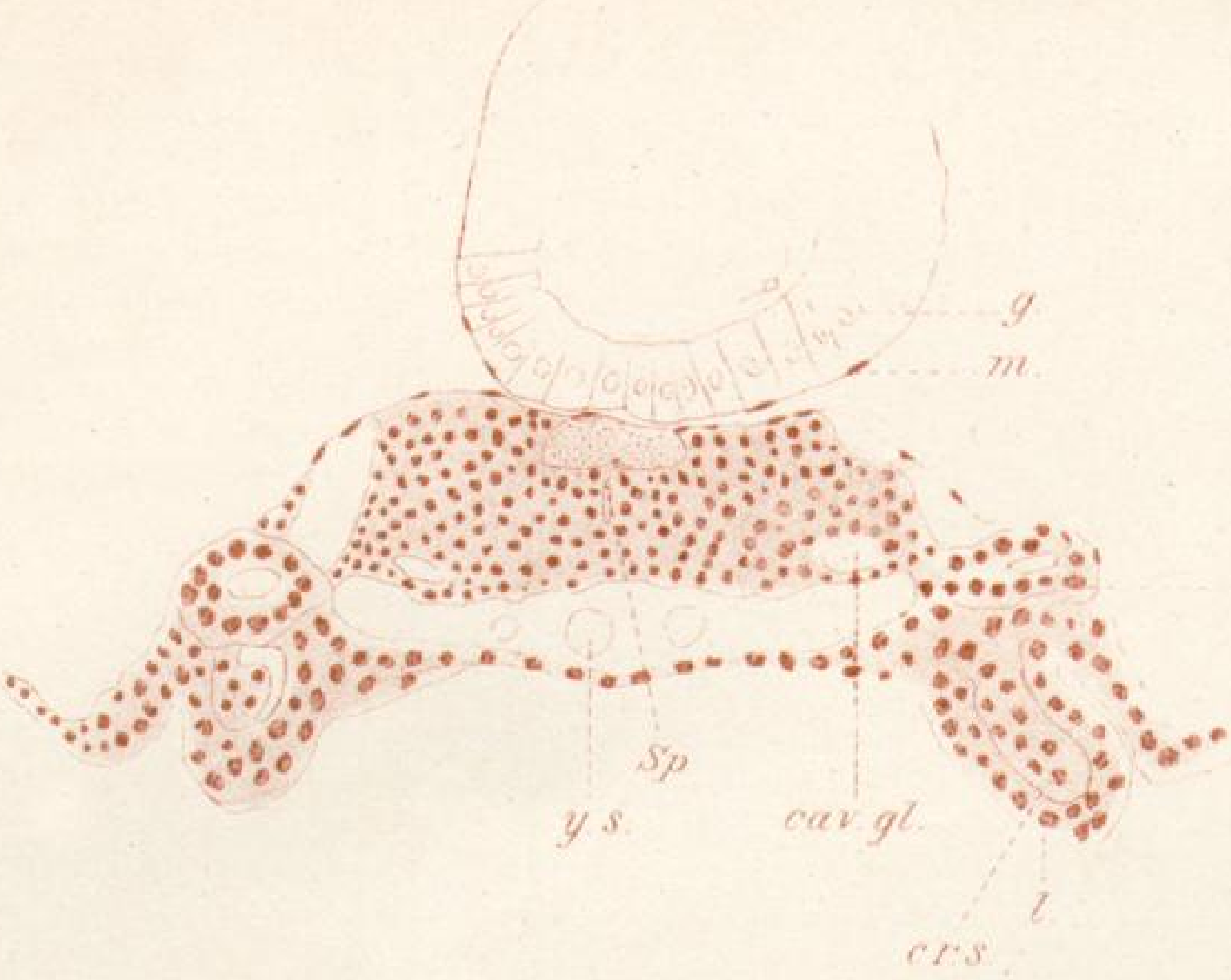
Fig. 24. First invagination of stink gland. The section is a longitudinal one through part of the 7th segment when first formed. *St.gl.in.* Invagination of epidermis to form stink gland. *Musc.* Muscles.

Fig. 25. Part of a longitudinal section showing a later stage in the formation of the stink gland. Magnified 250 times. *Hyp.m.* Hypodermic matrix. *M.St.gl.* Mouth of stink gland. *St.gl.* Stink gland. *Ext.c.st.gl.* External coat of stink gland.

Fig. 26. Part of a transverse section through a later stink gland, to show structure. Magnified 450 times. *Ext.c.st.gl.* External coat of stink gland. *Sec.c.* Secreting cells.

Fig. 27. Part of a longitudinal section through the head region of a just-hatched *Julus*, to show brain. 250 diameters. *Cer.gr.* Cerebral groove. *brn.* Brain. *Hyp.m.* Hypodermic matrix. *Gl.* Ganglia. *G.* Gut. *V.N.C.* Ventral nerve-cord.

Fig. 28. Transverse section through head of *Julus* of same age as the last, to show brain. 250 diameters. *Hyp.m.* Hypodermic matrix. *Cer.gr.* Cerebral groove. *G.* Gut. *F.br.* Fibrous part of the brain.



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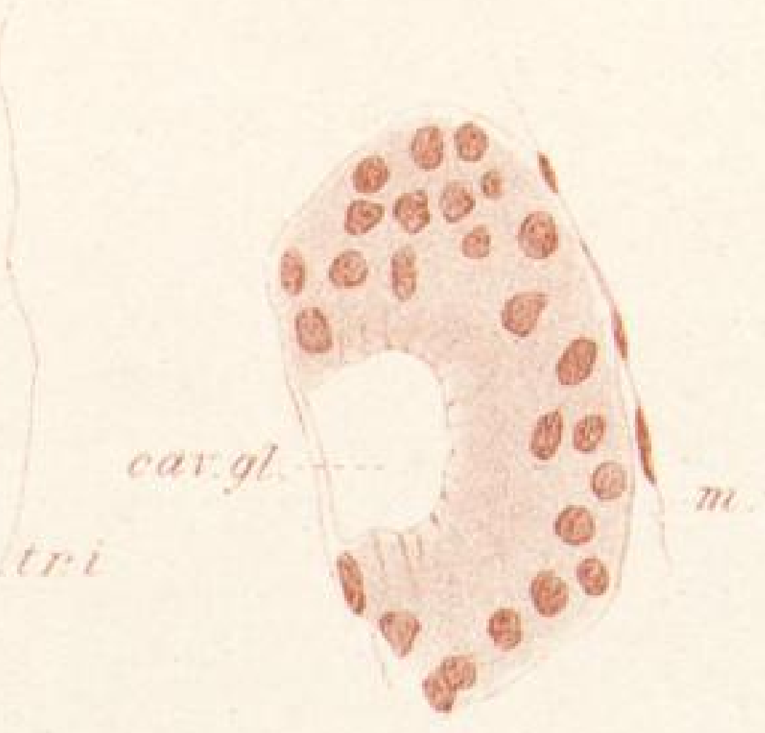

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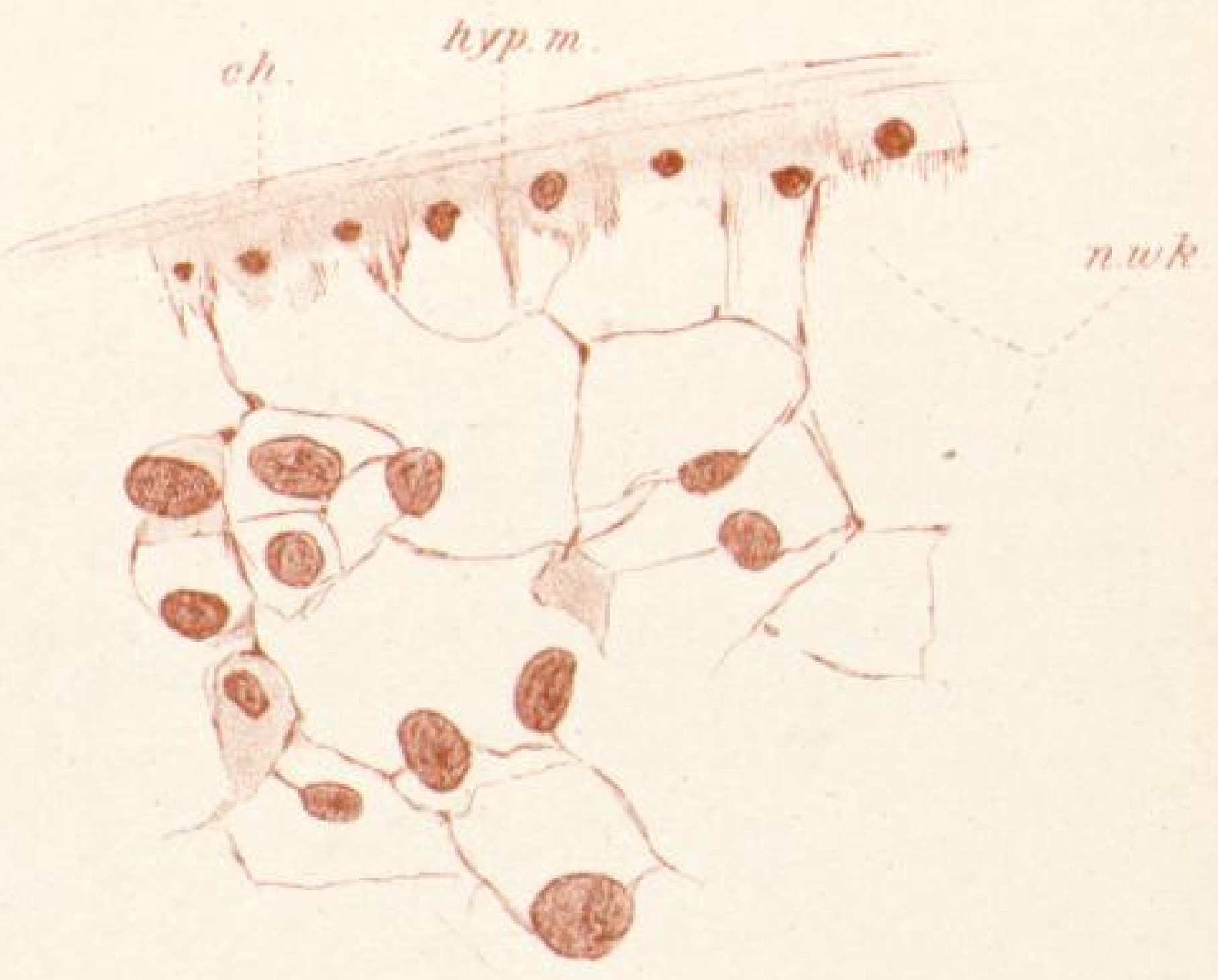

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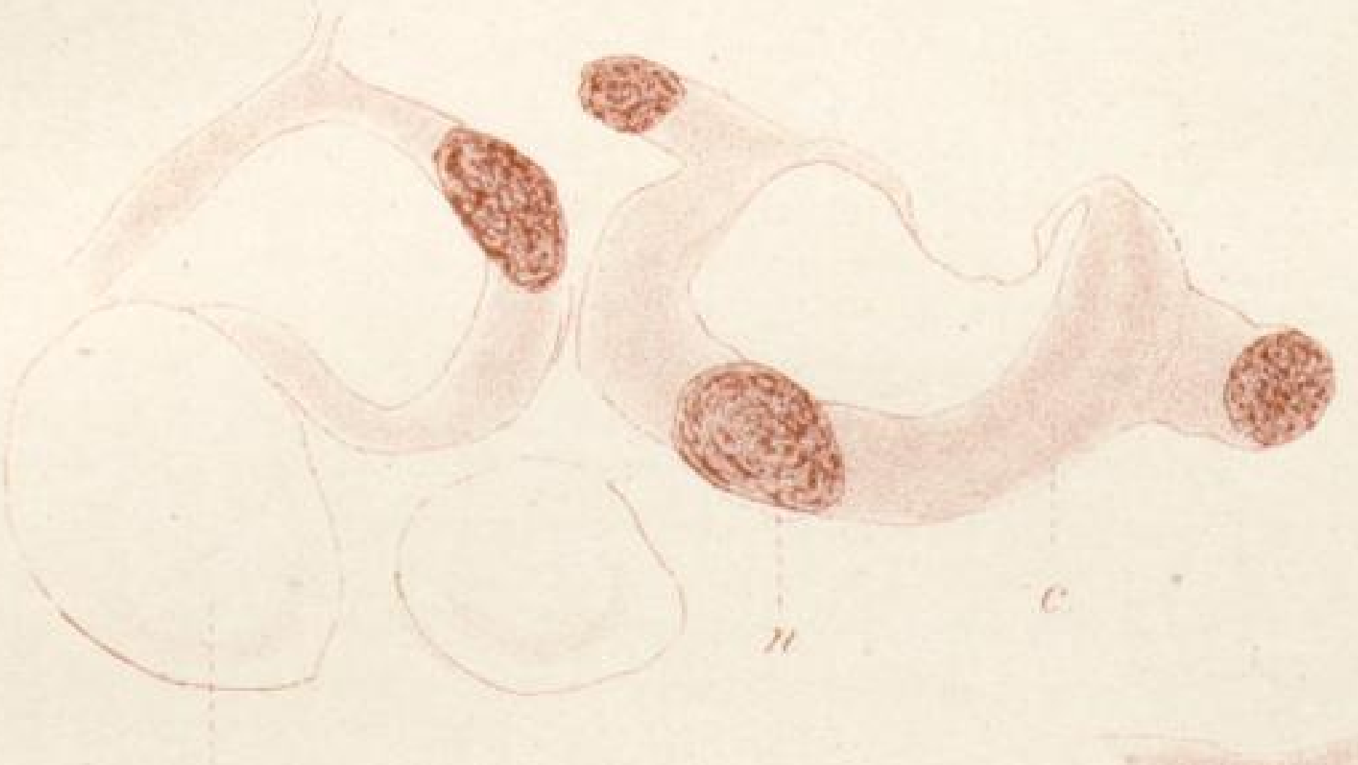

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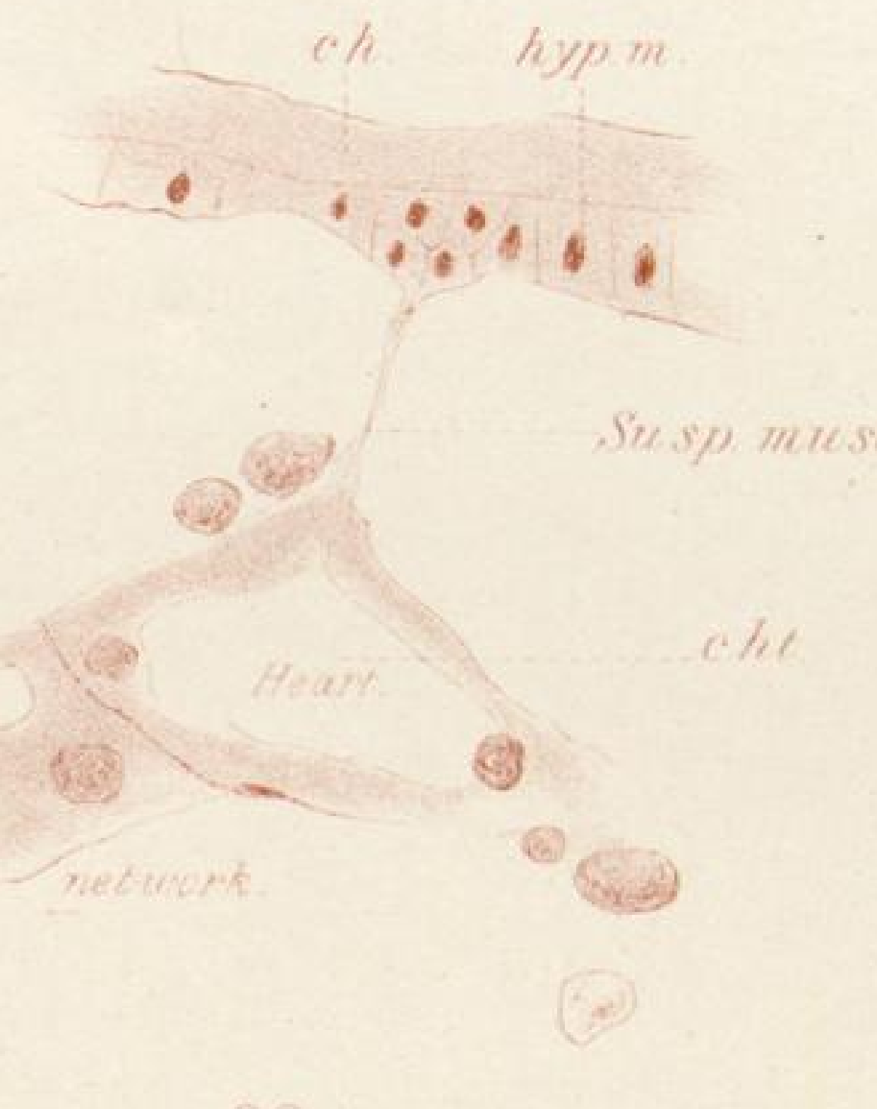

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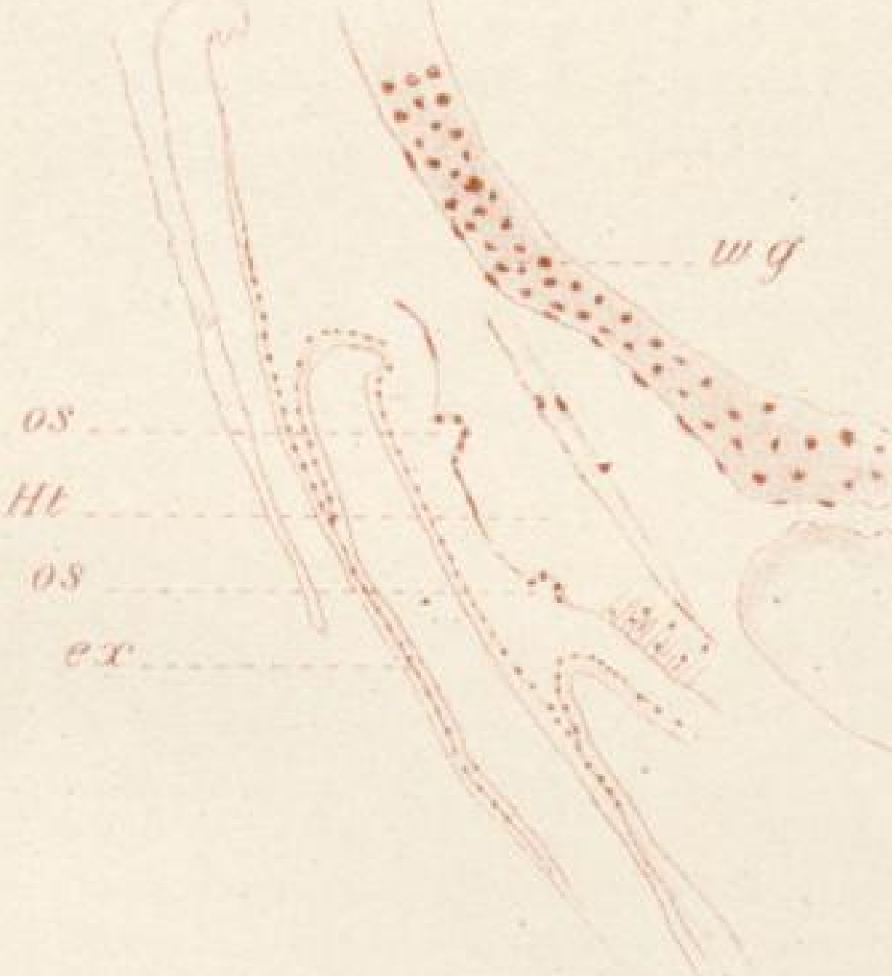

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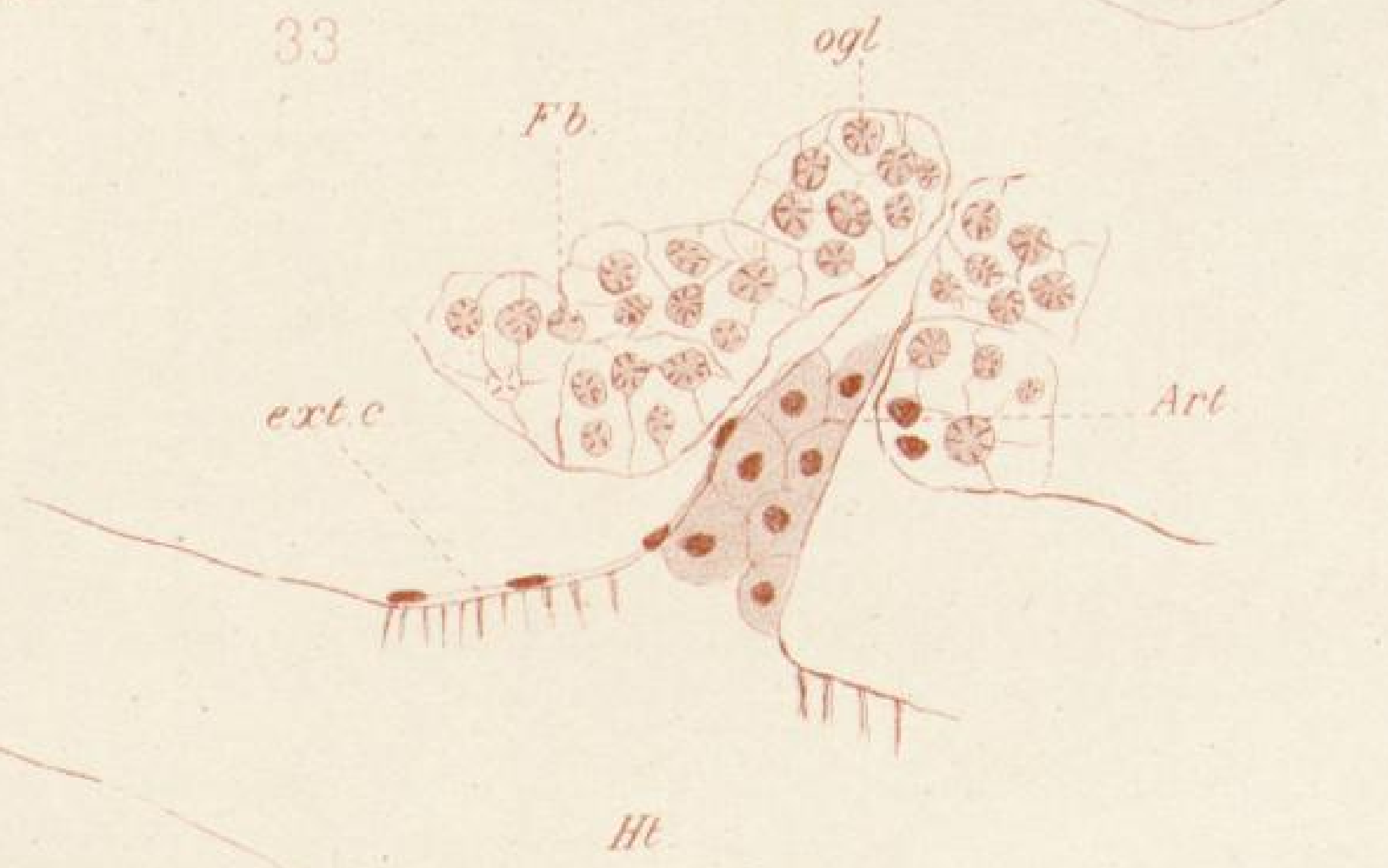

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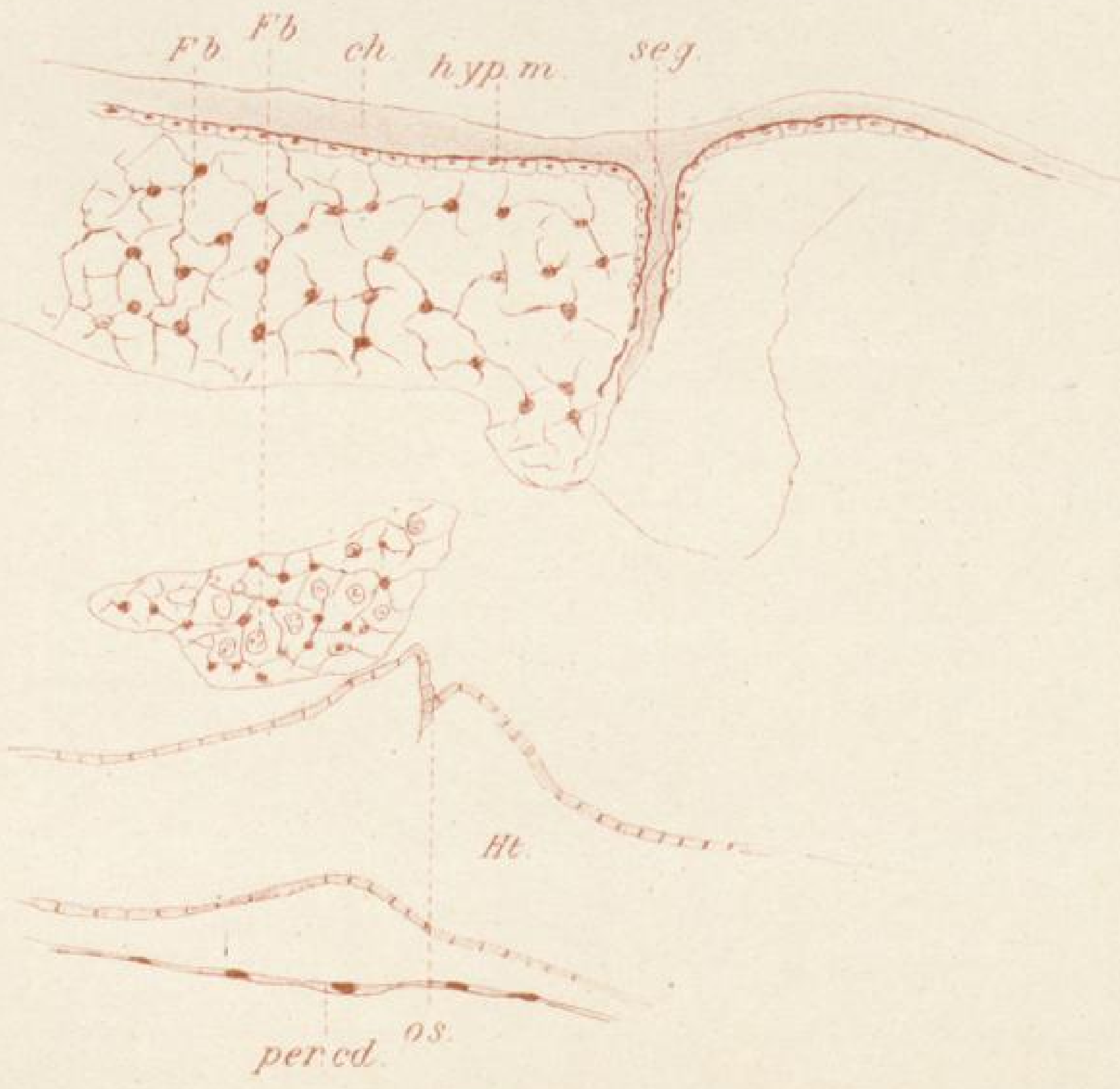

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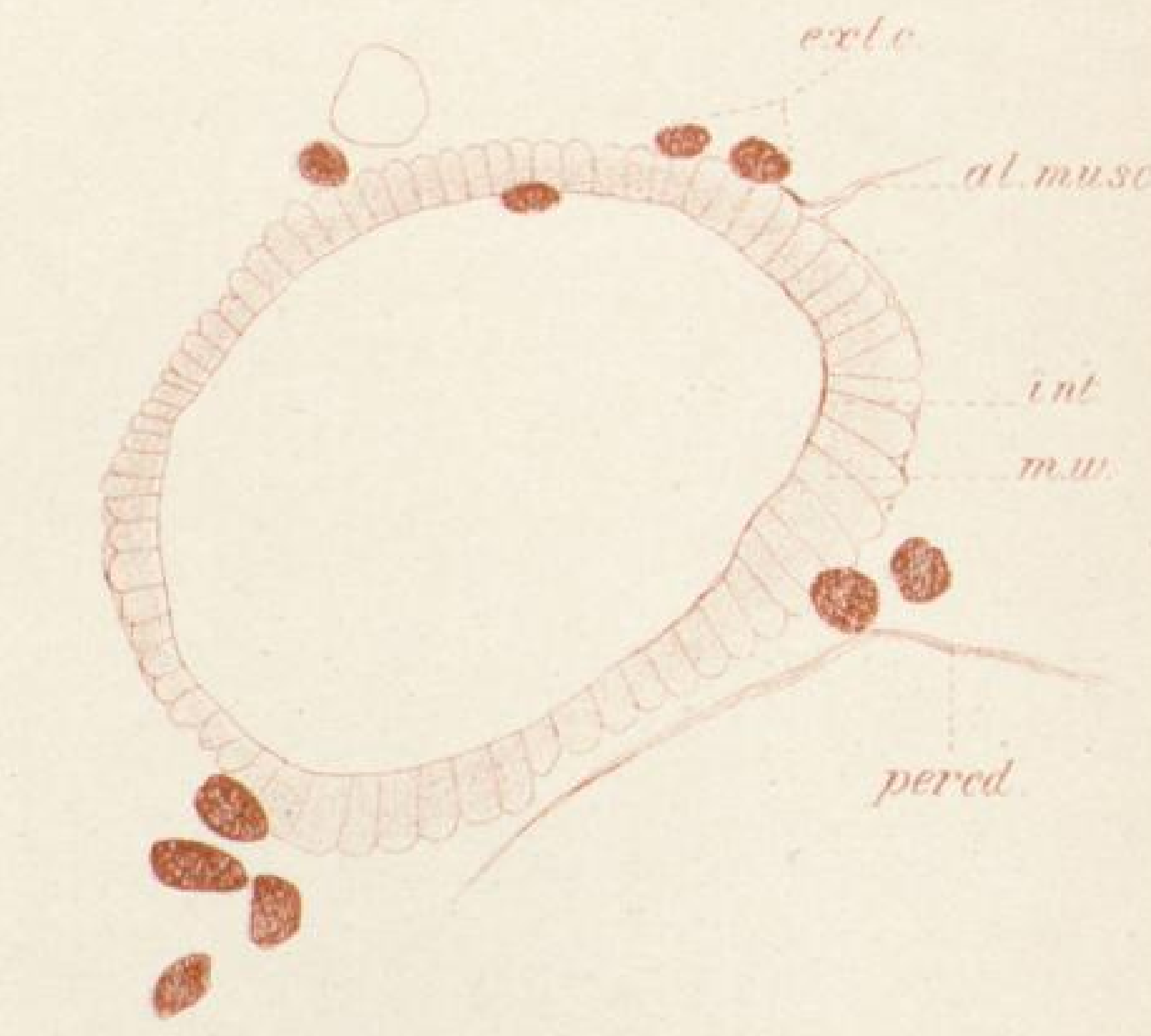

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PLATE 29.

Fig. 29. Transverse section through animal a little later than fig. 28. 250 diameters. *G.* Gut. *M.* Mesoblastic covering of gut. *Sp.* Small cavity remaining after the two ganglia have approached and fused. *Cav.gl.* Cavity in ganglion. *Y.S.* Yolk spheres. *Cr.s.* Crural part of somite still remaining. *tr.i.* Tracheal invagination.

Fig. 30. Section through 3rd ganglion of ventral cord, soon after first formation. *Cav.gl.* Cavity in ganglion. *M.* Mesoblastic covering of ganglion.

Fig. 31. (Zeiss F. *Oc.* 2.) Dorsal part of a transverse section through a young *Julus* shortly after hatching, showing the network of mesoblastic cells from which both the heart and the fat-body are formed. *Ch.* Chitinous exoskeleton. *Hyp.m.* Hypodermic matrix. *N.wk.* Network of mesoblast cells.

Fig. 32. A highly magnified (Zeiss L. water immersion, *Oc.* 2) part of the network. *Y.S.* Yolk spherules. *C.* Cells. *N.* Nucleus.

Fig. 33. (Zeiss D. *Oc.* 2.) A more advanced stage than fig. 31. *Ch.* Chitinous exoskeleton. *Hyp.m.* Hypodermic matrix. *Susp.m.* Fibre forming suspensory muscle of heart. *N.wk.* Cells forming network. *C.ht.* Cavity of heart.

Fig. 34. Later stage. The chitinous exoskeleton has been rather torn away from the hypodermic layer in the act of cutting. *Y.S.* Yolk spheres. *C.ht.* Cavity of heart. *Percd.* Pericardium. *Musc.* Muscles. *F.b.* Part of the forming network.

Fig. 35. ($\frac{1}{15}$ *hom. im.* Reichert.) Part of a longitudinal section through a forming segment in posterior region of heart. *Ch.* Chitinous exoskeleton. *Ht.* Heart. *Os.* Ostium forming. *Wg.* Wall of gut. *Ex.* Exoskeleton of segment.

Fig. 36. (Zeiss D. *Oc.* 2). Adult *Julus.* Part of a longitudinal section to show heart. *Ch.* Exoskeleton. *Hyp.m.* Hypodermic matrix. *Seg.* Division between segments. *F.b.* Fat-bodies. *Ht.* Heart. *Percd.* Pericardium. *Os.* Ostium.

Fig. 37. (Zeiss D. *Oc.* 2.) Part of a longitudinal horizontal section through an adult *Julus* to show artery. The external coat of the heart is continued over the artery. *F.b.* Fat-body. *O.gl.* Oil globule. *Art.* Artery. *Ext.c.* External coat of heart.

Fig. 38. Longitudinal section through a heart nearly formed, in a *Julus* with seven pairs of legs. *Ht.* Cavity of heart. *Os.* Ostium.

Fig. 39. Transverse section through nearly formed heart. *Ext.c.* Forming external coat. *M.w.* Muscular wall of heart. *Int.* Intima. *Percd.* Pericardium. *Al.mus.* Fibre which represents aliform muscle in Insect heart.

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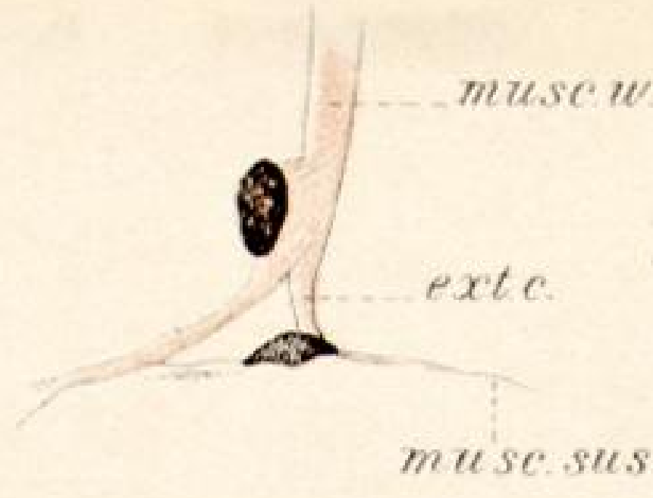

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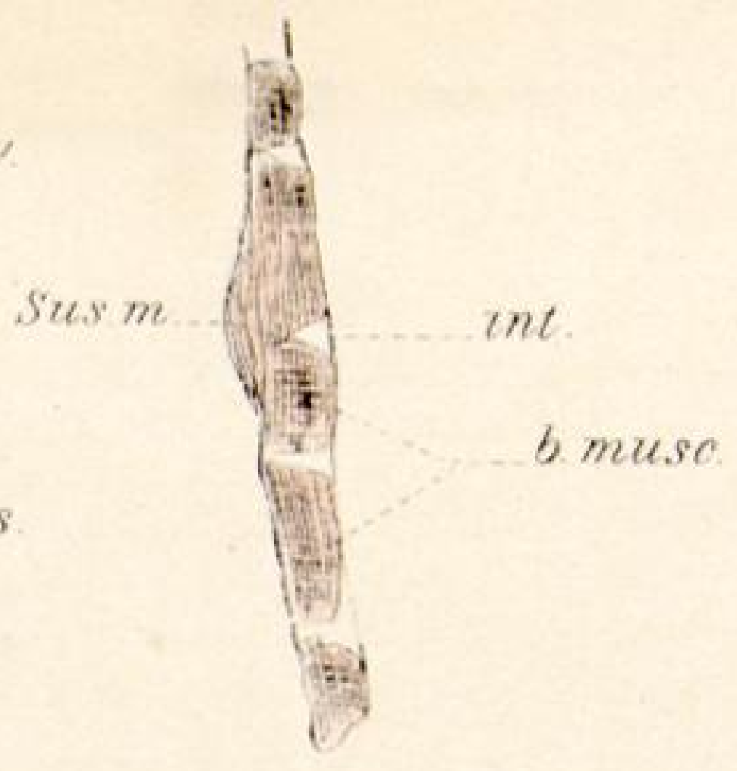

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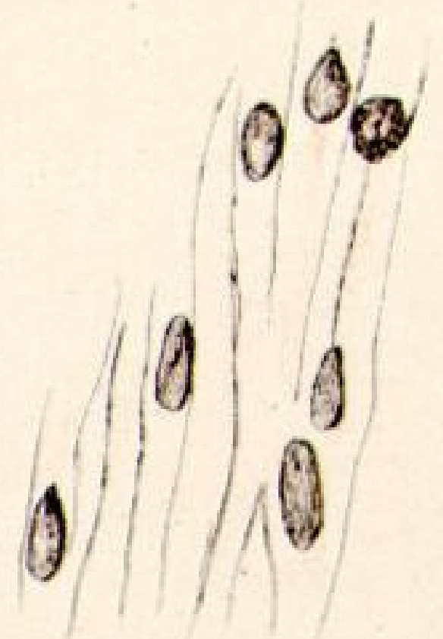

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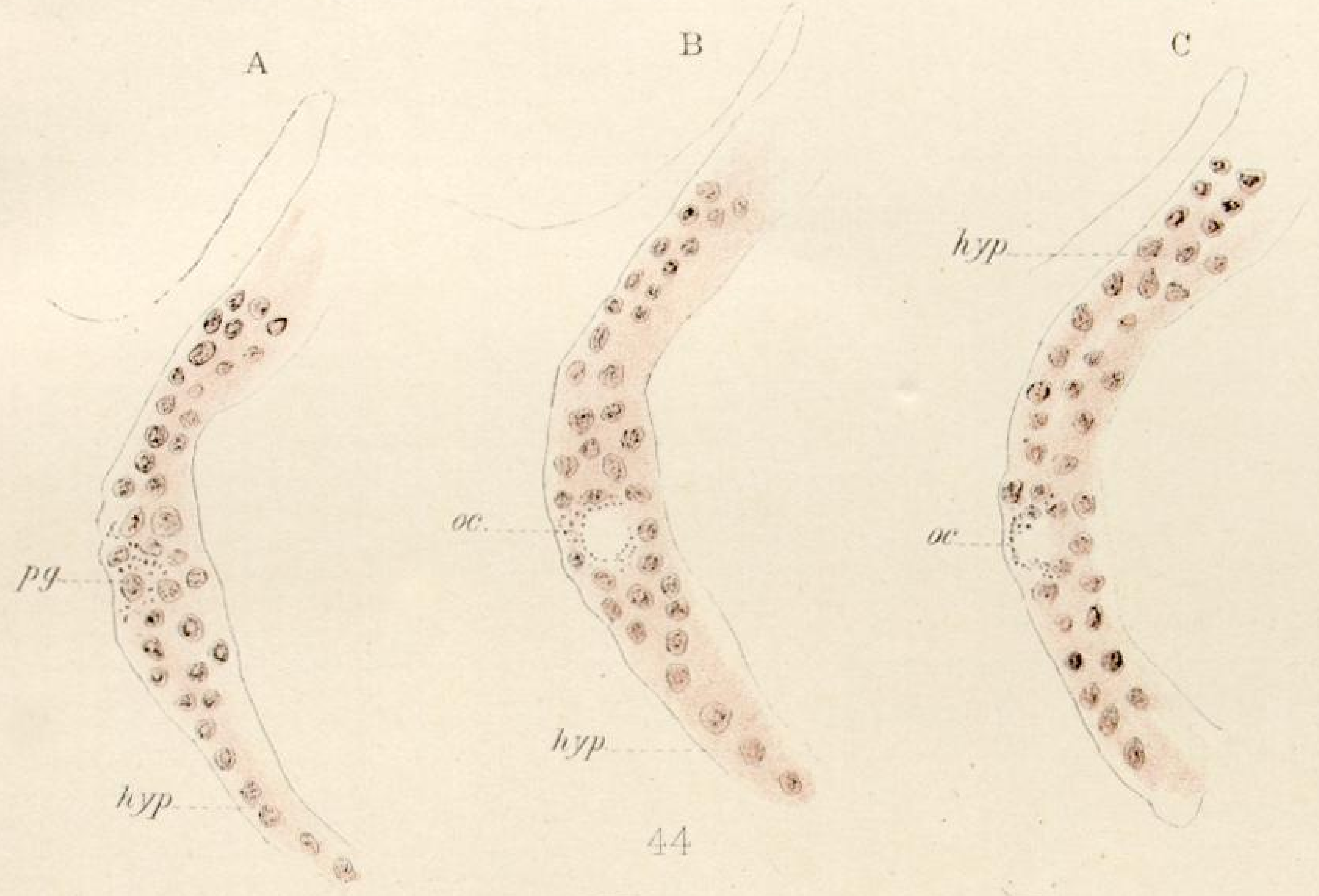

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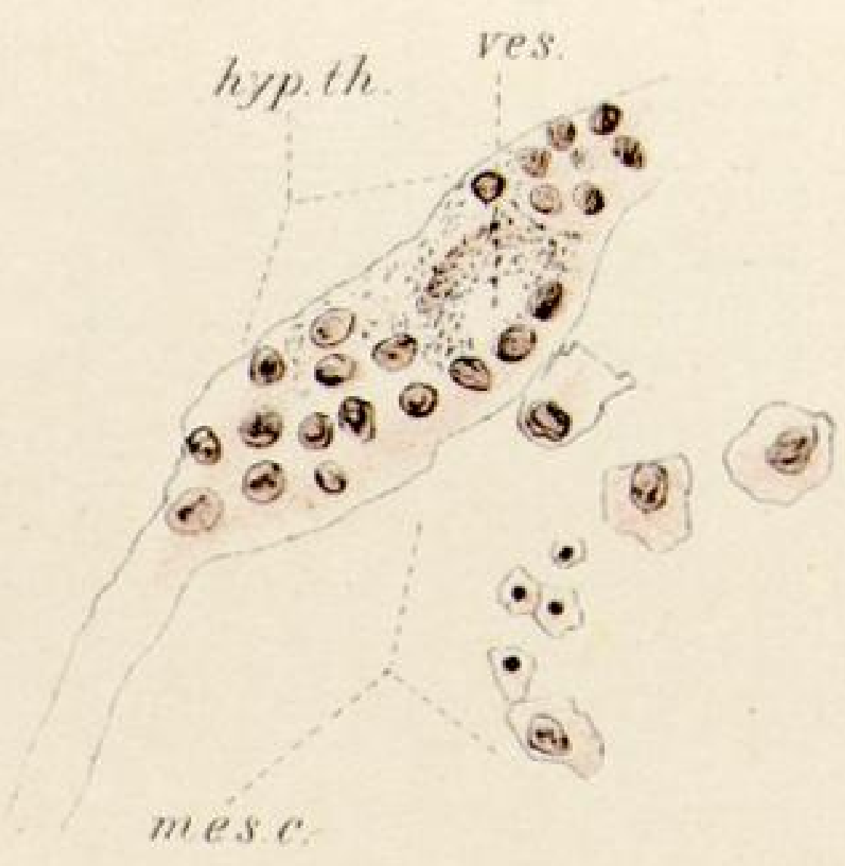

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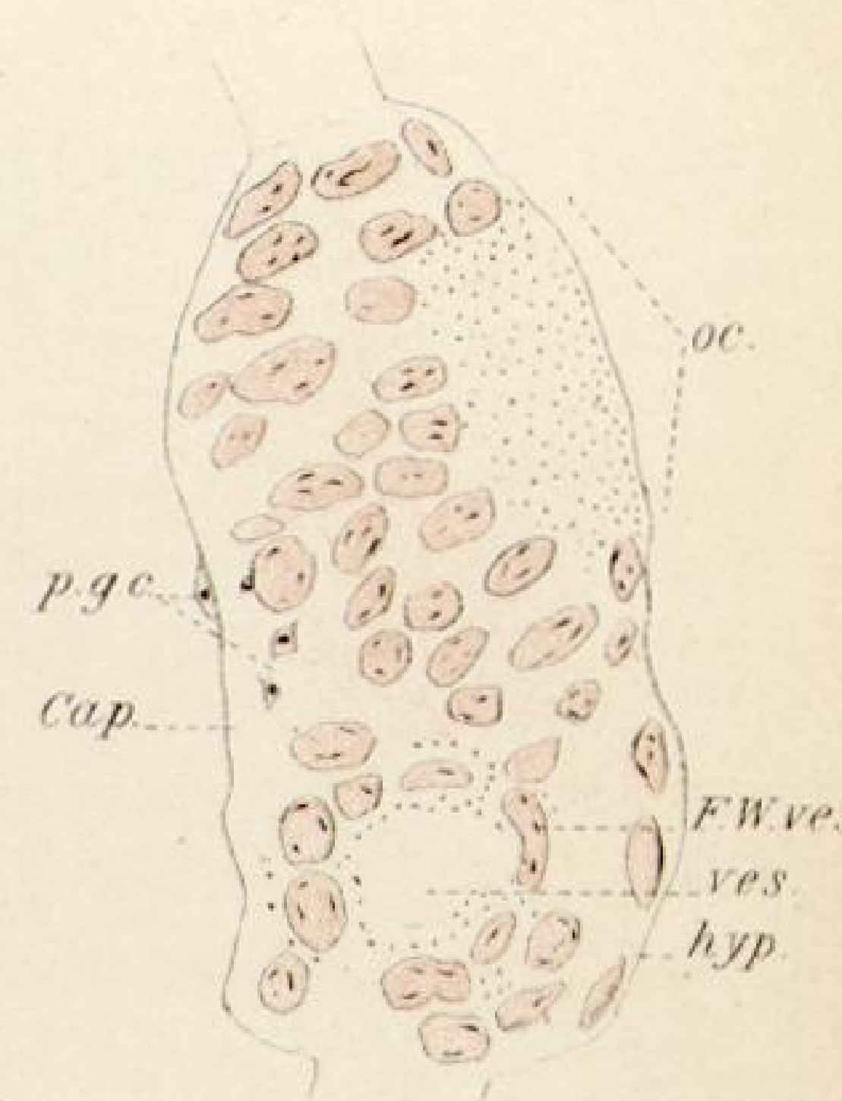

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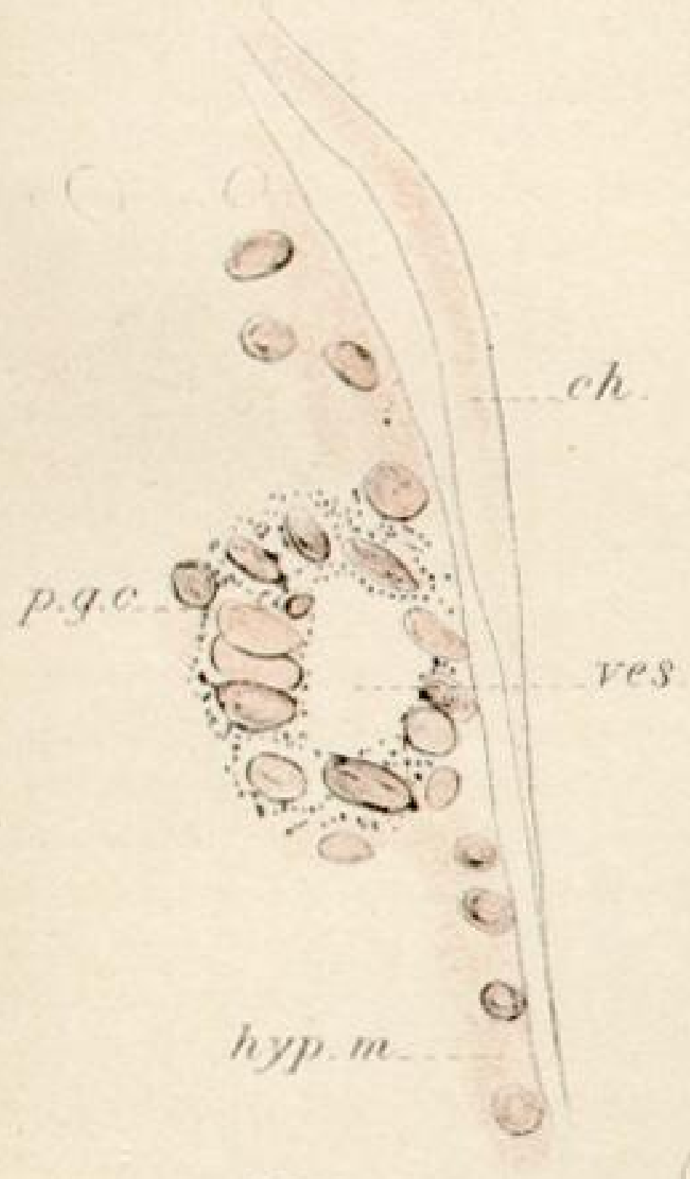

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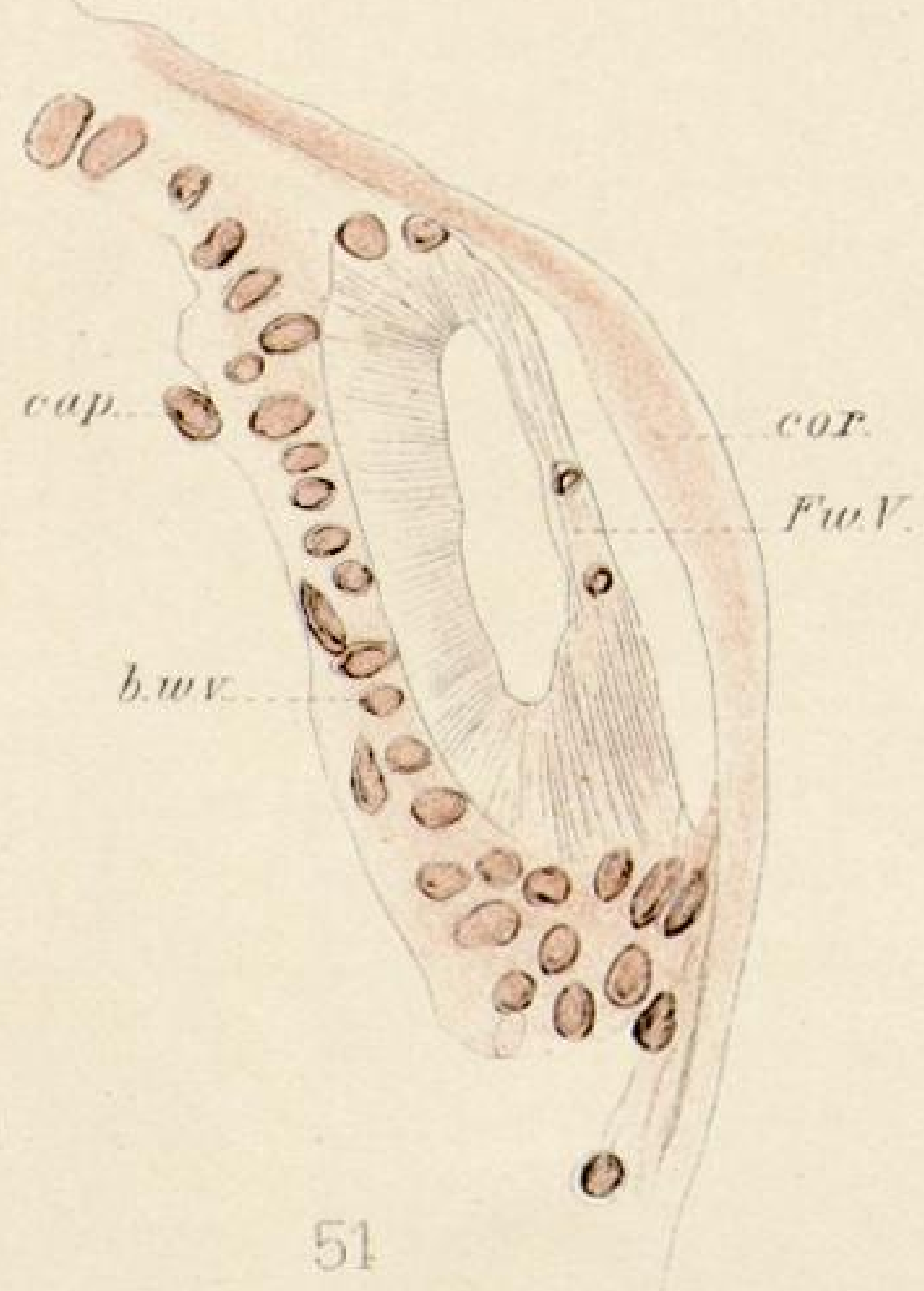

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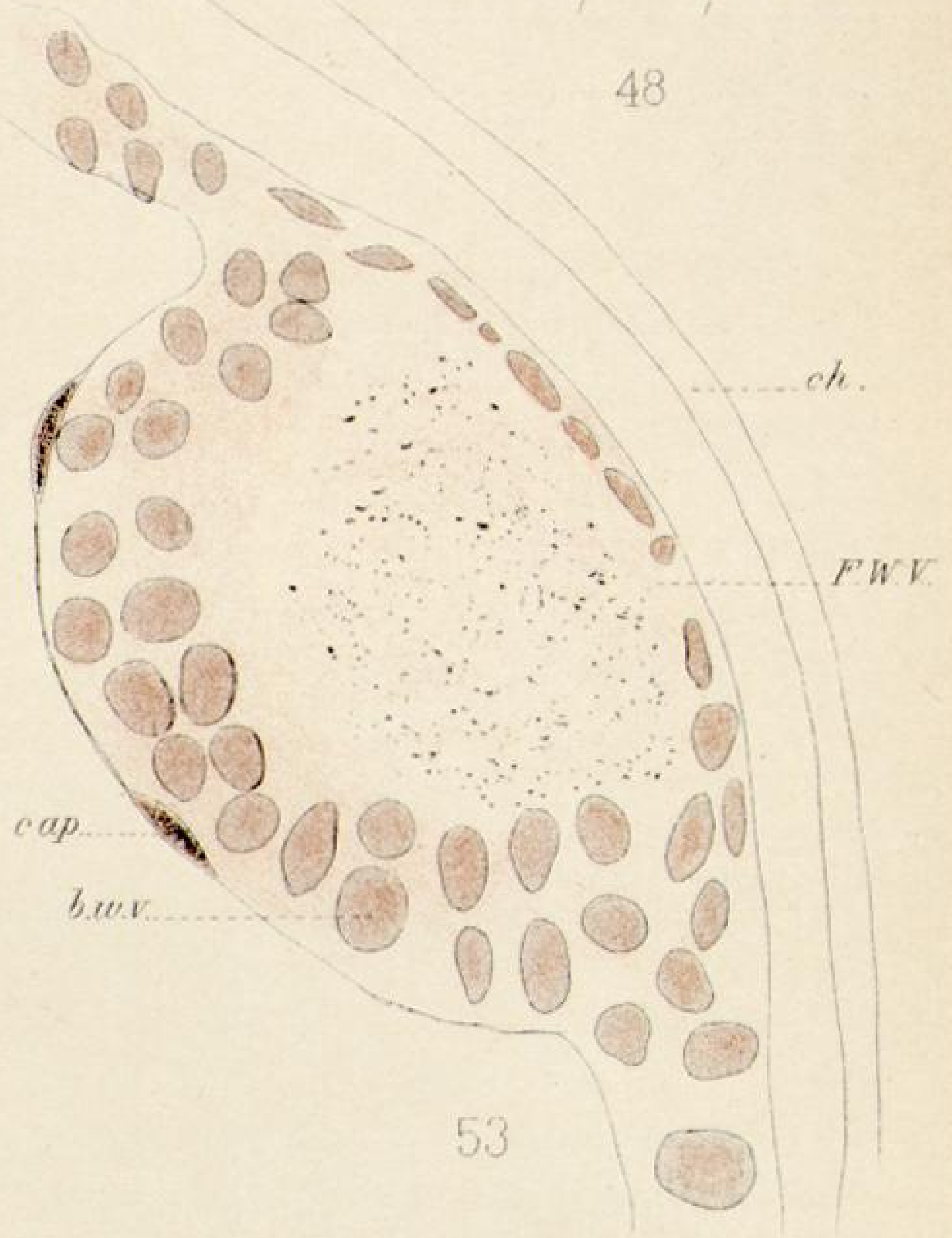

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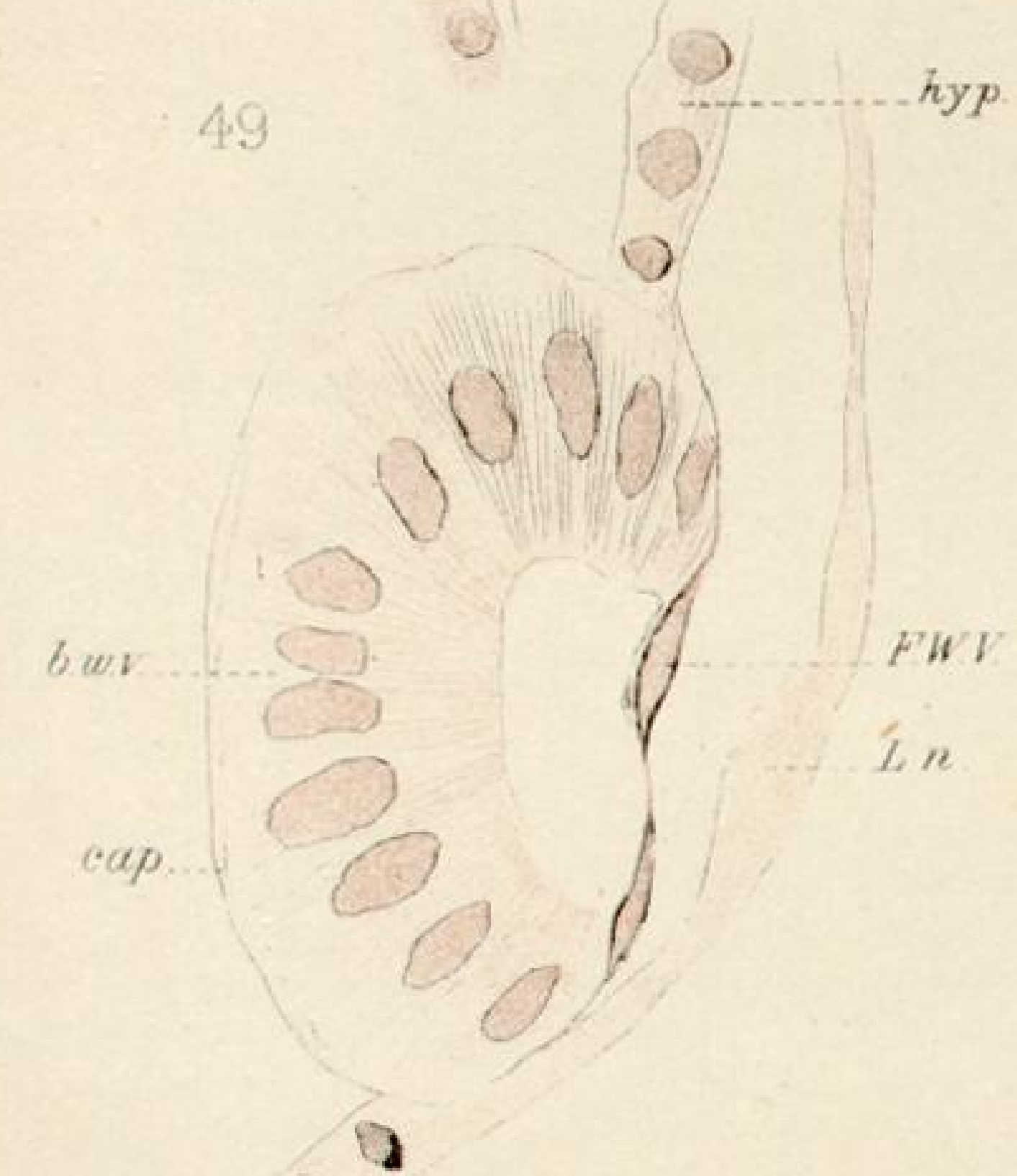

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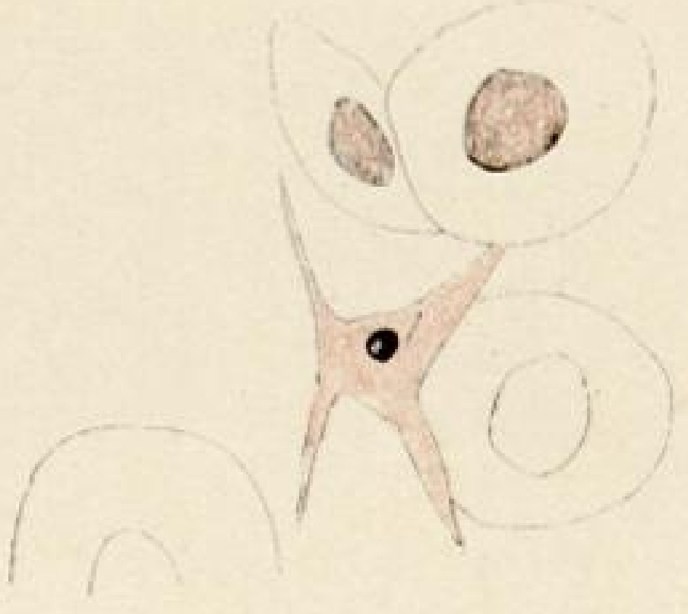

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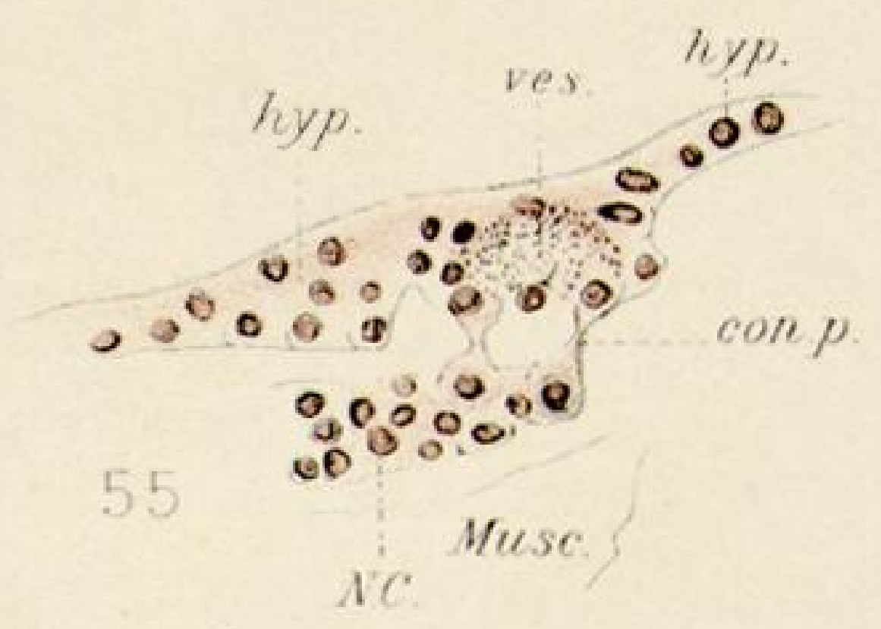

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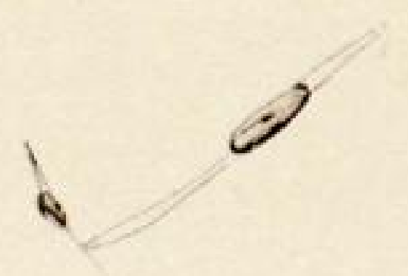

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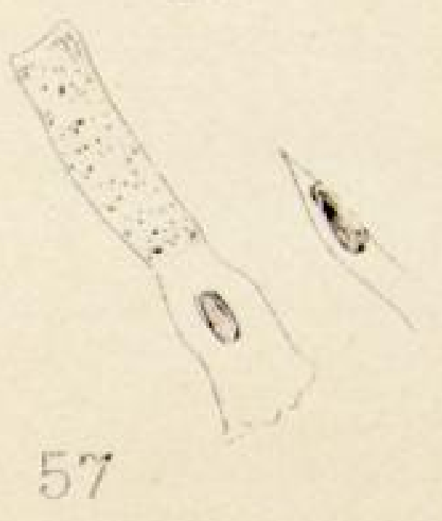

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PLATE 30.

Fig 40. ($\frac{1}{15}$ Reichert *Oc.* 2.) Transverse section through adult heart, showing ostium. *Os.* Ostium. *Mus.* Muscles of ostium.

Fig. 41. ($\frac{1}{15}$ Reichert *Oc.* 2.) Part of a section through a forming heart, to show the formation of the external coat and suspensory muscle.

Fig. 42. ($\frac{1}{15}$ Reichert *Oc.* 2.) Part of a longitudinal section through an adult heart, to show the arrangement of muscles in alternate broad and narrow bands. *Int.* Internal coat. *B.mus.* Bands of muscles. *Sus.m.* Attachment of a suspensory muscle.

Fig. 43. (Reichert $\frac{1}{15}$ *Oc.* 2.) Structure of external coat of adult heart; from a longitudinal section.

Fig. 44. A, B, C. Three consecutive sections through the beginning of the first eye-spot. The hypodermis is slightly thickened round the beginning ocellus. *Pg.* Pigment. *Oc.* Beginning of ocellus.

Fig. 45. Section through further advanced ocellus. *Mes.c.* Mesoblast cell in body cavity. *Cap.c.* Cell of forming connective tissue capsule. *Pg.c.* Pigment cells. *Ves.* Vesicle.

Fig. 46. About same age as last. *P.c.* Pigment cells. *No.c.* Nerve from ocellus. *Ves.* Vesicle.

Fig. 47. Further advanced ocellus. *Ves.* Vesicle. *F.w.ves.* Front of vesicle. *Oc.* Ocellus.

Fig. 48. Section through advanced ocellus, and cutting a more complete ocellus obliquely. *Oc.* Advanced ocellus, cut obliquely. *F.w.ves.* Front wall of vesicle. *Ves.* Vesicle. *Hyp.* Hypodermis. *P.g.* Pigment cells.

Fig. 49. Further advanced ocellus. *Ch.* Exoskeleton. *Hyp.m.* Hypodermis. *Ves.* Vesicle. *Pg.c.* Pigment cell.

Fig. 50. 150 diameters. Head of young *Julus.* *Oc.* 1. Advanced ocellus. *Oc.* 2. Beginning ocellus.

Fig. 51. *Cor.* Thickened chitin, the beginning of the cornea. *F.w.v.* Front wall of vesicle from which the corneal lens is increased. *B.w.v.* Back wall of vesicle. *Cap.* Capsule.

Fig. 51. (Reichert $\frac{1}{15}$ *homogen. Oc.* 1.) The lens is beginning to be formed. *B.w.v.* Back wall of vesicle. *Cap.* Capsular membrane. *Hyp.* Hypodermis. *Ln.* Lens.

Fig. 53. Section through advanced ocellus. The section is taken through the side of the ocellus, and not through the middle line. *Ch.* Chitinous exoskeleton. *F.w.v.* Front wall of vesicle. *Cap.* Capsule. *B.w.v.* Back wall of vesicle.

Fig. 54. Pigment cell inside ocellus, to show size relative to surrounding cells. About 700 diameters.

Fig. 55. (Reichert $\frac{1}{15}$ *homogen. Oc.* 1.) Early stage of ocellus, to show junction between the cells of the vesicle and the nerve-cells. *Hyp.* Hypodermis. *Ves.* Vesicle. *Con.p.* Process connecting the nerve-cell and the vesicle cell. *N.C.* Nerve-cord.

Fig. 56. Single cell from nearly adult ocellus.

Fig. 57. Cells from retina of nearly adult ocellus.

Fig. 58. Part of transverse section through adult exoskeleton and hypodermis. *Ch.* Exoskeleton. *Hyp.m.* Hypodermic matrix. *Pg.* Pigmented part of hypodermic matrix cells.