V. *On the Development of* Lepas fascicularis *and the* "Archizoëa" *of Cirripedia.*

By R. von Willemöes-Suhm, *Ph.D., Privat-Docent in Zoology in the University of Munich, Naturalist to the 'Challenger' Expedition. Communicated by Professor* C. Wyville Thomson, *F.R.S.*

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Burmeister's important discovery that in *Lepas* the larvæ pass through a *Nauplius* and a *Cypris* stage was made on the same *Lepas* which forms the subject of this paper. Burmeister*, however, had evidently only a ball of this *Lepas*, some specimens of which were young in the *Cypris* stage, which had just settled; while others were dismissing young *Nauplii*, which, unless great care is taken, die very soon in captivity. He thus missed the intermediate stages, which, however, were at that time much less important, as the first thing that was wanted then was to establish the general outlines of the Cirriped development. The *Nauplius* of this *Lepas* has since been seen by Darwin†, to whom Hancock showed it, "calling his attention to a proboscidiform projection on the underside of the larva of *Lepas fascicularis* when just escaped from the egg."

Neither J. v. Thompson's nor Pagenstecher's observations refer, as far as I can find out here, to *Lepas fascicularis*; and it seems not to have been taken up again as an object for embryological researches until Claus published his paper on the *Cypris*-like larva (pupa) of the Cirripeds and its metamorphosis into the fixed animal (Marburg, 1869), a paper of which I have unfortunately only an abstract, as given by Nitsche in his embryological report for the year 1872, and by Claus himself in his 'Grundzüge der Zoologie,' which, however, affords nearly all the information necessary for my purpose. My object is to give an idea of the whole development of one *Lepas* as accurately as possible, which seems never yet to have been done, as our whole knowledge of the development of this group consists of fragments, collected mostly in the same way in which Burmeister gained his information.

The materials for this paper were obtained during our cruise from Japan to Sandwich (June to July 1875), as we went along the thirty-fifth degree of latitude, when first very curious *Nauplii*, some of them 12 millims. long, were caught, which I identified at once with the nauplial form to which Dohrn has given the generic name of *Archizoëa*‡. In

* 'Beiträge zur Naturgeschichte der Rankenfüsser,' 1843.

† 'A Monograph of the Subclass Cirripedia: The Lepadidæ.' London, 1851, p. 11.

‡ Dohrn, "Untersuchungen über Bau und Entwicklung der Arthropoden. IX. Eine neue *Nauplius*-form (*Archizoëa gigas*)," in V. Siebold und Kölliker's Zeitschrift für wissenschaftliche Zoologie, Band xx. p. 597, 1870.

the daytime these larvæ were scarcer (many of them came up, however, from a depth of 60 fathoms), but at night they were so common that large bottles could be filled with them. The question (which had been left open by DOHRN) to which Cirriped these extraordinary *Nauplii* might belong, presented itself of course again to us, and we tried to obtain all the Lepadidæ we could. In a day or two we got into large streams of floating Lepads; and now it was an easy thing to get as many as we liked, and to bring up in our globes such stages of the large *Nauplii* as had also been taken by us on the surface, and which clearly belonged to them. Then, again, when catching large quantities of larvæ, we got among them (especially when the net was skimming the very surface of the water), (1) some which were ready for the metamorphosis into the *Cypris* stage, (2) the *Cypris* itself swimming and creeping about or just settled on a dead *Velella*, and (3) the stage in which the *Cypris*-shell is about to be thrown off, in order to make room for the growing valves of the young *Lepas*.

The species to which this barnacle belongs is decidedly the very variable *Lepas fascicularis* as described by DARWIN, *l. c.* p. 92. The formation of the balls, the brittleness of the shell, and the peculiar shape of the valves show this at once; there are, however, some differences which must be mentioned in detail, as possibly this North-Pacific species deviates from the Atlantic one not only by these small differences, but also by possessing another nauplial form, in which case it would be decidedly necessary to separate this Pacific form from it. In most specimens which I dissected I found six teeth in the mandible, not five, as is the ordinary number. Sometimes, however, there are five on one side and six on the other, as in the case which I have figured (Plate 15. fig. 30, *a* and *b*), showing that this difference has no constant value. The maxillæ have sometimes four steps (the regular number as given by DARWIN); but they have more commonly only three steps besides the two large, unequal, upper spines (fig. 29). These are the only differences from an ordinary *Lepas fascicularis* which I can find; and they merely show that this Pacific form is a variety of the Atlantic one, in case there should not be a difference in the development of the two. As we know, however, nothing about the five stages through which the Atlantic form has to pass if it follows the same mode of development as this one, and as no "*Archizoëa*" has as yet been described from the Atlantic, this question must remain an open one until further information.

I will now proceed to give an account of the development of *Lepas fascicularis*, mentioning the publications which refer to certain phases, in their respective paragraphs.

I. *Development of the Egg and of the youngest* Nauplius.

The ovarium, a cellular body at the top of the pedunculus, has a light bluish colour, as in all Lepadidæ. It consists of tubes and their cæca, in which we find the ova in a more or less advanced state of development. In a young specimen one finds the ova sometimes in different stages, but in the older ones nearly all the ova in the ovary (with the exception of those "mother cells" which do not develop) are in the same stage of

development, as are also those contained in the lamellæ. In *Balanus* the ramified cæca of the ovarium show ova in different stages of development. According to BUCHHOLZ*, who saw the youngest ova in the cæca, and describes them as transparent small vesicles with a germinal vesicle and a nucleolus (exactly the same as may be seen in the tubes of *Lepas fascicularis*), these vesicles grow as well as the ova—a statement which, I think, may also be made for the latter. As these vesicles grow they are more and more filled with yelk-granules, until the vesicle is no longer visible and only the nucleolus is seen as a clear spot in the centre of the ovum (Plate 10. fig. 3 and fig. 1, *n*). Evidently the shell round these ova is not yet formed, as they are soft and change their form according to their position in the ovary. Among these large developing ova you may see in this stage small transparent cells, with a vesicle and a nucleolus (fig. 3, *oi*), which do not take up any yelk-granules, and which are, I think, the mother cells from which the next set of ova will be derived as soon as this one has advanced into the ovarian lamella. I looked of course for such cells as have been described in *Sacculina* by VAN BENEDEN†, but never saw any of them budding; nor did I ever see those "cellules accolées" on one of the poles of the growing ovarian cell which he has described. They must be peculiar to the latter genus, where they have been seen by GERBE as well as by VAN BENEDEN, while in *Balanus* BUCHHOLZ seems not to have remarked any thing of the kind.

In our species I think the small cells divide by budding, and give rise to more small ova, which have the same form as the mother cells, and afterwards grow in the way which has been described above.

The spermatozoa are hair-like filaments, which offer no special character (fig. 3, *a*). I have, however, not studied their development.

After the last-described stage (Plate 10. fig. 1, *n*, and fig. 3) the ova leave the ovarium and get into the ovarian lamellæ, which may be easily found on both sides of the body. How they get there has been a subject of much speculation. KROHN'S theory of DARWIN'S auditorial sac being the orifice through which they have to pass, seems to me to be the most likely one; but only carefully done sections of mature specimens will be able, I think, to solve this question, which is not an object of the present inquiry. The ova, as we find them in the lamellæ, are ellipsoidal. They have acquired a shell during their passage through the oviducts, and show no trace of the nucleolus vesiculæ germinalis. They have in this stage a length of 0·26 millim.

BURMEISTER thinks that each of the lamellæ contains about 2000 ova. He also figures some ova, which, judging from their shape, are later stages in which the embryo begins to be visible within. The mature ovum is entirely filled with granular

* J. MÜNTER und R. BUCHHOLZ, "Ueber *Balanus improvisus*, Darw., var. *gryphicus*, Mütr." Berlin, 1869. An abstract is given in GRENACHER'S Report for 1869 in HENLE and MEISNER'S 'Bericht,' &c. (Leipzig, 1871), p. 424.

† "Recherches sur l'embryogénie des Crustacés. III. Développement de l'œuf et de l'embryon des Sacculines," Bull. de l'Acad. Roy. de Belgique, 1870.

yelk-cells, only in the middle some small bodies may be seen reflecting the light very strongly, and looking like minute granules of fat (Plate 10. fig. 4).

About the formation of the embryo there are, or at least there were, two opinions, the one backed by FRITZ MÜLLER, and for some time (according to VAN BENEDEN) also by CLAUS, maintaining that a total segmentation takes place, and that the embryos are developed in full without a preceding "Primitivstreifen," which means a larger gathering of cells on the ventral side of the embryo*, while VAN BENEDEN has seen and figured the latter in *Sacculina*.

BUCHHOLZ mentions, like VAN BENEDEN, the formation of the blastoderm, but does not seem to have seen a primitive streak. According to him one of the two halves, which are the result of the first segmentation, divides again, and its segments overgrow the other half, forming a blastodermic cuticle round it, in which grooves may soon be seen, indicating the future position of the three appendages.

Lepas fascicularis is not a very favourable object for such an inquiry; nevertheless I have arrived at a result which holds somewhat an intermediate place between VAN BENEDEN'S and BUCHHOLZ'S observations. I saw the blastoderm forming very much in the way described by the former, but I was unable to find any definite trace of a primitive streak. The first alteration which takes place is the formation of two segments (fig. 5, where a small third one may be seen between the two), which are unequal in size, whereupon the lower and larger one divides again (fig. 6). In these stages of segmentation you see already two to four large, transparent, nucleated cells, which separate themselves from the yelk-globules in the middle of the ovum, and the number increases very much in the next stage (fig. 7). We find first eight and then twelve. In fig. 7, *y*, *x*, I have given a sketch of two sorts of cells which are now contained in the ovum, and which, after breaking its walls, can be separately inspected: these are large blastodermic cells with a single nucleus, with only a few granules, and small, very granular yelk-globules. Also in VAN BENEDEN'S drawing I do not find a stage between the mulberry stage and the stages of first segmentation; and I must confess that in *Lepas fascicularis* I never could find but indistinct traces of the later stages of segmentation. The large cells seem to break out and include the rest of the yelk, thus forming a blastoderm (fig. 8) consisting of small nucleated cells. This was well enough to be seen with reflected light; but the interior of the ovum is so little transparent that I could not make out whether there is a primitive streak on one side or not. The blastoderm now loses its cellular look, and has the appearance of a granular cuticle, just as it has been seen by BUCHHOLZ in *Balanus*; and then a groove, which was already visible in the last two stages, is seen to become deeper, and on each side of it the first traces of the three pairs of appendages (fig. 9, *a* and *b*) become visible. Very soon the labrum also appears; the tail is differentiated, and setæ may be seen at the top of the foot-joints (fig. 10). In *Sacculina* the embryo throws the egg-shell off before this happens, and is instead (according to VAN BENEDEN)

* FRITZ MÜLLER, 'Für Darwin,' 1864, p. 64.

contained in the enlarged blastodermic cuticle. In our case I have not been able to make any observation of the kind, owing perhaps to the circumstance that in every *Lepas* one finds all the ova in one and the same stage of development, which makes it very difficult and laborious to get at all the different stages. The circumstance that the cuticula (whether egg-shell or blastoderm) which contains the embryo is larger than the ova were (0·29 millim.) is perhaps in favour of such a moulting as has been observed in *Sacculina*, but might also be explained by a certain elasticity of the egg-shell. We find such a case in worms, where, for example in *Distoma megastomum*, the shell is considerably extended*. When working out the first development of that Trematod, I have already remarked that something very like it has been observed. The same thing has been found in *Distomum veliporum* by Guido Wagener, in *Pteromalines* by Ganin, and finally in *Balanus improvisus* by Buchholz. And as in every other respect the first development of *Lepas* has been found to be so similar to that of *Balanus*, I am inclined to think that it is also in this case the egg-shell which the embryo leaves, and not the blastodermic cuticle, which very likely still adheres to the young *Nauplius*.

II. *The successive* Nauplius *stages.*

The *Nauplius*, when escaping from the ovum (Plate 10. fig. 11), has a length of 0·35 millim. It has been figured by Burmeister, but evidently (if it is at all the same as ours) as seen under a very low power, and without giving many details. I do not know whether, judging from this figure, one has a right to state that the variety of *Lepas fascicularis* at which he has been working is the same as ours or not. This being also the case with the figure of the *Cypris* stage, it is unnecessary for me to refer again to his paper, the object of which was more to show that such larval stages existed in Cirripedia, than to give details about their organization.

We saw these embryos in our globes as soon as a ball of *Lepas* had been put into them. At this time of the year there are in every bunch some specimens which continually dismiss from their ovarian lamellæ large numbers of embryos. These swim slowly about, until they undergo their first metamorphosis, which consists in casting off a very thin skin enveloping their body and in pushing out their tail and their caudal spine, which, enclosed by that cuticle, have hitherto been pushed in like the tubes of a telescope and unable to extend to their full length (fig. 11, and fig. 11 *b*). I was at first, when I had not noticed this cuticle, very much puzzled by this; for I saw that the tail ended in two spines, and the caudal spine in a single spiny process. When, however, the covering-glass had been pressing a little on the embryo, I noticed a long tail and a long caudal process, the longer the more it had been forced out from the animal's body by the pressure exercised upon it; then I discovered in animals which were perfectly unhurt the cuticle which envelops the animal's body, and which is also clearly visible at the

* "Ueber einige Trematoden und Nemathelminthen, von R. v. Willemöes-Suhm," Zeitschrift für wiss. Zool. Bd. xxi.

end of the lateral horns. These are in the young embryo not yet erected, but still hanging down. On the extremities of the appendages, however, I observed nothing of the kind. They are three in number (fig. 11, *a*, *b*, *c*), and indicate already all the peculiarities which will be described in the full-grown *Nauplius*, and which in this stage can best be understood from the figure. The upper lip (fig. 11, *la*) is already plainly visible; and, apparently, also the œsophagus, on both sides of which we find a group of cells in the place where we afterwards see two glands, which perhaps lead into the stomach. The intestine shines through the body of the larva, in which there are as yet a great many yelk-granules, which prevent you from seeing the intestines, upper and lower portion.

The first change is undergone by the *Nauplius* very soon after it has left the ovum. In a globe into which I had put a ball of barnacles, and in which at first all the larvæ were in the stage just described, I had some difficulty in finding any of them half an hour afterwards, as the greater number had already cast off the cuticle, pushed their tails and spirals out, and erected their horns. I have been thinking whether this cuticle is not perhaps the blastoderm adhering to the embryo, which leaves it very much as a *Botriocephalus* embryo leaves its ciliated larval skin. For reasons which I have given when describing the development within the ovum, I am, however, not quite sure about this, and shall only be able to decide the question when I have studied other Lepadidæ which may be caught on the surface during the progress of our voyage. In the first *Nauplius* stage I saw a lens above the eye (fig. 11), which I did not, however, see in every case when I looked for it, and which in the later stages was seen no more.

After the first moulting the embryo has grown very much, having already a length of 0·6 millim., but showing only few differences in its organization, as all the spines on the tail, and especially the first two movable ones (Plate 11. fig. 13, *sp*), existed previously. At the end of the lateral horns we do not yet find those fine hairs which distinguish the later stages, but only a few small setæ and a larger one (fig. 13, *cp*). Muscles are seen running up to the horns; but the glandular system which is beginning to form inside the body, indicated by small granulated cells, is not yet in connexion with them. In the upper lip, the sides of which are covered with fine hairs, indications of the teeth may be seen; but as yet the whole of the intestinal tract shows no progress, except that the anus is now clearly visible. On both sides of the eye we find two tentacles, well-known sense-organs the function of which is very doubtful and likely to remain so.

The carapace shows as yet no protuberances, with the exception of the lateral horns and two small spines at the base (fig. 13, *z*). In the appendages the setæ are very much larger, especially the one which springs from the segmented ramus of the third pair, which is as long as the tail itself. After the larvæ had reached this stage in our globes they invariably died, which has also very likely been the case with those of former observers, as nobody seems to have ever seen the very interesting (*Archizoëa*) stages which I am now going to describe, and which were found on the surface with the

preceding ones. There is accordingly no doubt about their being stages of the development of one and the same animal. This, besides, is shown clearly enough by the similarity in the tail, its spine, and the labrum of the two forms, which have been figured on Plate 11.

Before I give, however, the description of the stages through which the Cirriped has now to pass, I must explain the name *Archizoëa*. It has been given by DOHRN to a *Nauplius* which has a length of 4–5 millims., a height of $1\frac{1}{2}$–2 millims., and has the shape of a Chinaman's hat. It has a large caudal spine and a dorsal one, six movable spines on the tail, besides many fixed ones, a large labrum, and a very spiny caparace. These *Nauplii* have been caught off the coasts of Chili, and been described by DOHRN in a most perfect way. Why, however, he gave to it a generic and a specific name, though he clearly knew that it was a Cirriped *Nauplius*, I do not know; for he could have published his ideas about the "complete *Zoëa*, which as a perfect larval form has vanished from the development of Cirripeds," and the remains of which may be found in the dorsal spine and perhaps in some movable spines on the tail, without doing so. I have also caught the larvæ which he has called *Archizoëa gigas*, and may at once add that I have good reasons to believe them to be the *Nauplii* of *Lepas australis*. Thus I was able to study these two different forms alive, and have come to the conclusion that they are true *Nauplii*, and have nothing whatever to do with a *Zoëa*. "*Archizoëa gigas*" has a length of 4–5 millims., and is chiefly distinguished from our *Nauplius* by the shortness of its spines, the multitude of gland-openings in processes (spines) all over the carapace, and by the number of spines on the labrum (five on each side, in our case two). I got some specimens from the surface off the southern coast of Australia, which I believe to belong to *Lepas australis* for the following reasons:— *Lepas fascicularis*, to which undoubtedly our *Archizoëa* belongs, is (to use DARWIN'S words) "certainly much the most distinct of any in the genus; and Mr. GRAY has proposed to separate it under the name of *Dosima*; but considering the close similarity of the whole organization of the internal parts, together with the transitional characters afforded by *L. australis*, I think the grounds for this separation are not quite sufficient." And in describing *Lepas australis* he says, "this species has some affinity to *L. pectinata*, but it is much more closely related to *L. fascicularis*. I believe this species is confined to the Southern Ocean, and perhaps there represents *L. fascicularis* of the northern seas." Now larvæ which are very nearly allied to those of *L. fascicularis* have been found in the Southern Ocean; and it seems to be almost certain, after what has been said about the relations of *L. australis* to *L. fascicularis*, that the *Nauplii* in question belong to the former species. This is all the more probable as the pupa stage of *Lepas australis*, which has been described by DARWIN as having a length of 2–3 millims. (0·067–0·1 of an inch), corresponds in size to the large *Nauplii* described by DOHRN, and resembles very closely in all points of its organization the pupa of *Lepas fascicularis*, which I am going to describe below. We ourselves caught these large *Cyprides* of *Lepas australis* and the young barnacles of the

same species together with those *Nauplii* when we were south of Australia; but I had unfortunately not examined at that time the first stages of *Lepas australis*, which would doubtless have led me to the young "*Archizoëa*." However I have a good chance as we go through the straits of Magellan to get them again, and hope that I shall have the embryos of *Lepas australis* in our globes.

I shall now proceed with the description of our larvæ.

After the second moulting (or the third if one counts the throwing-off of the thin cuticle) two great changes occur which totally alter the look of the *Nauplii*. In the first place we find on the back (which was hitherto somewhat conical, but had no protuberance) a large spine (Plate 11. fig. 14, *ad*), which has already very nearly the length of the caudal one, with which it is now growing in equal proportion. In the second place the carapace, which formerly exhibited only two small spines (figs. 13 & 14, *z*), shows now six acute processes, two of which are situated in the front line between the two horns, and two others, a smaller and a larger one, on each side. These processes are not spines, in so far as they are not closed at the top; they have an opening there, and the chitinous substance is pushed in a little into them up to the point where it meets the duct of the glands, which are to be seen at the base of all these processes.

These glands are as yet unicellular, the same as they were in the last stage. Dohrn says, in describing his *Nauplius*, that he suspects the ramified glands to have been preceded by unicellular ones—a supposition which is borne out by the facts. The appendages show as yet no change, nor do the tail and its spine, in which there are as yet only two of the large secondary movable spines (Plate 11. fig. 14).

On both sides of the eye, between the two tentacles or feelers, there is a granulated substance, which I thought at first was the brain; but afterwards I found the ganglia underneath it (fig. 14, *cer*), and have never been able to make out what this granulated band represents.

The upper lip now not only includes the œsophagus, but also two glands or cæca (fig. 14, *coe*), in the place of which we saw in the last two stages an assemblage of slightly granular cells. There are now two strong spines on both sides of the edge of the labrum, which has very much the form which it retains during the whole *Nauplius* stage.

Also the top of the lateral horns (fig. 14, *cp*) has changed. We find two pointed chitinous prolongations, and between them a great many fine setæ occupying the edge of the rounded margin. The dimensions of the embryo in this stage are as follows:—

	millim.
Width of carapace	0·25
Length of cornua parietalia	0·21
Length of carapace	0·32
Length of tail	0·66
Total length	0·98
Width of frontal line	0·11

The young *Nauplius* is now in full vigour, evidently taking in plenty of food and rapidly growing. Every time it moults it gets one more movable spine on the tail (Plate 12. fig. 15, sp^1), on which there is, a little lower down, another large curved spine (sp^2), and lower down still a straight one, besides a number of small and middle-sized spines. In the full-grown *Nauplius* (the carapace of which has a diameter of 2 millims., and the larger spines are 12 millims. long) there are *six* movable pairs of spines on the tail. It gets these only after the fifth moult, the last it has to undergo in the *Nauplius* stage of its life. The number of spines is the chief test of its age, and will be found to correspond exactly to its size. When in possession of three or four of them it is only half the size of one which has six. After this, however, it in most cases gets six spines at once. I have figured in the accompanying Plates two stages—one with four and the other with six spines, and have represented in each of these figures different organs so as to show its anatomy without crowding them too much. In giving a description of the *Nauplius* in the adult stage, I shall of course frequently refer to the "*Archizoëa gigas*," but must first mention that DOHRN, though his figures of the three appendages are excellent, has evidently taken the second for the third appendage, so that in comparing our drawings with each other this must be borne in mind. When I remarked it, I looked at the *Nauplii* of both species again, to see whether I had not perhaps myself made the mistake (which, as one separates the appendages from the body, is very excusable); but I found that certainly my drawings are correct, and that of all the appendages the second (as is also the case in the *Nauplii* of several other Cirripeds which I have studied) are the largest.

The carapace of this *Nauplius* has the form of an hexagonal cover, with a very long handle to it springing from its middle, which is a little raised (Plate 10. fig. 12). Besides the central spine there are on the carapace two posterior lateral processes, two processes in front of the eye between the horns, six large processes (one at each angle of the hexagon), and several smaller spines (two to four) between each pair of these. Altogether there are on the carapace one dorsal spine, two lateral horns, eight larger, and from twenty-five to thirty smaller processes, all of which, with the exception of the spine, have a gland opening at the top.

In "*Archizoëa gigas*" there are also eight large processes (*vide* DOHRN'S fig. 1 on tab. 28, *l. c.*, and my fig. 23 on Plate 14) with glandular openings; but besides there are a vast quantity of very small spines between them, covering the whole upper surface of the larva and the margins of its carapace. The greater part of these, or rather all, with the exception of some small hairs or hair-like spines, have openings at the top, and ducts from the glands, which densely fill the whole carapace, may be easily seen running up to them.

The dorsal spine is movable, and a large muscle may be seen running into it. This has been represented in Plate 12, for which I have on purpose taken a specimen which was soon going to moult, and in which the muscles inside the large spines have grown so much that they cannot stretch out, but are obliged to coil themselves up.

The lateral horns (Plate 13. fig. 17) are said by CLAPARÈDE and BUCHHOLZ to be movable. In our case they certainly are provided with muscles, running up to them from the dorsal centre of the carapace, and fixing on a chitinous ring which looks like a septum in the upper portion of the horn (Plate 13); but I have never seen a movement in these horns, though I examined many living specimens. Their outer chitinous covering is inverted at the top (where it has two prolongations and many setæ attached to it), and runs inside up to the place into which the glands pour their contents, and which is also the place of attachment for the muscles (fig. 17, *q*). Here two large glands and two smaller ones terminate. Whether these large glands, the bottoms of which are fixed to the carapace by threads of connective-tissue, are in communication with the general glandular system of the carapace I doubt, as I never saw such a communication. With all the smaller glands, however, which run up to the different processes (fig. 16, *gl* and *pr*, fig. 17, *pr*, and fig. 22, *gl*), this is undoubtedly the case; they form a large glandular network all through the carapace, just as DOHRN has already described in *Archizoëa gigas*.

On the lateral horns we remark a few very small spines, the only spines which have not a gland opening at the top.

A question which has been left open by DOHRN is the innervation of these different organs, about which he could say nothing, having only spirit-specimens at his disposal. I have examined the larvæ alive under the highest power, and have arrived at the following result. The only exterior appendages, which are very likely sensitive, are small reflecting hairs (figs. 16 & 17, *y*), to the base of which runs a somewhat varicose nerve-fibre. No sensitive appendages are to be found at the top of the lateral horns nor of any of the processes. The glands, however, are in connexion with nerves, and it is by no means difficult to find nerves sending off branches in all directions. One may trace these easily to the base of glands which terminate in the larger processes. In one case (fig. 16, *c*) I have also seen a ganglionic cell close to one of these processes, sending apparently a fibre up to it, but not being connected with the large lower nerve (fig. 16, *n*) which gave a branch to the gland.

Neither the small nervous hairs nor the innervation of the glands is at all extraordinary, as in many of the lower animals, which are favourable objects from their transparency, something of the same kind has been observed.

DOHRN, when speaking about these lateral horns, says that as CLAPARÈDE and BUCHHOLZ have declared them to be movable, and described muscles running up to them, and as on the other side the evidence given for a transformation of the first appendages into the antennæ with the sucker seems not to be sufficient, he is inclined to think that these organs are modifications of the lateral horns. He adds that they must have a very important function, because otherwise their complicated structure would not be intelligible. Nevertheless my observations, as I shall show below, make me think that KROHN, MECZNIKOW, PAGENSTECHER, and CLAUS, who maintain against BURMEISTER and DARWIN the first-mentioned way of metamorphosis, are perfectly

right, and that the lateral horns have nothing to do with the antennæ of the *Cypris*. For what reason all these glands terminate in the two horns and their processes is another question, to which I can give no answer. The secretions of these glands during the *Nauplius* stage may be continually seen coming out of them; in the *Cypris* all these processes have been dropped, and the gland appears as a shell-gland; and later, when the *Cypris* has fixed itself, this shell-gland, I think, is the one that furnishes the materials for the valves.

The centre of the nervous system consists of two ganglia, which may be seen below the central eye, but which are often somewhat hidden by the upper part of the lip (Plate 13. fig. 18, *cer*). Above them, between the pigment-spot and the two feelers, there is a dotted band of a substance which might be nervous, but about the nature of which I am not able to give an opinion.

The *feelers* (Plate 13. fig. 18, and Plate 14. fig. 22, *x*) consist of a basal joint, to which muscles are attached, and of a flexible upper one, into which a nerve goes. At their top I found no special terminating bodies, though I examined them repeatedly under high powers. These feelers are movable in a limited way.

When the *Nauplius* has moulted for the seventh time, and the time for the metamorphosis into the *Cypris* stage arrives, we see the large lateral eyes in the process of formation. At first they are a pair of roundish bodies (Plate 14. fig. 22, *o*) reflecting the light and dotted with black pigment. Very soon the black pigment becomes more intense; about eight lenses appear at their surface, and above each lens a cornea is formed. This stage is figured in fig. 23 for the southern larva, but is in our case so similar that I did not think it necessary to give another figure for it. However, it takes a long time to find a specimen among the largest larvæ which have got these eyes, as they seem to throw off their Nauplial appendages as soon as the preparations for the metamorphoses are ready underneath. Among all the larvæ which I examined I found only one in the stage figured on Plate 14; but I have no doubt that many might be discovered among the vast quantity of larvæ which have been kept in our bottles.

The organ *y* (Plate 14. fig. 23) is not, as may appear at first sight, a ganglion, but a patch of vesicular tissue, of which several may be seen in a specimen which has been killed in absolute alcohol and preserved in Canada balsam. The glandular substance in this specimen (easily recognizable from being more stained by carmine than the surrounding tissue) has been somewhat contracted, and patches of vesicles have appeared which clearly belong to a network of connective-tissue between the glands.

The *labrum*, which in Plate 12. fig. 15 is represented as turned upwards, and in Plate 14. fig. 22 in the position in which the larva generally keeps it, is a very long and wide organ, being nearly two thirds of the diameter of the carapace in length. Its edges are very densely covered with small spines, and at the top there are invariably on each side two large spines. In older larvæ, however, I frequently saw three spines (fig. 15), and in one case even four on both sides. It resembles on the whole very

much the labrum of the southern larva, in which, however, there are five large spines and three small ones on each side.

At the top of the labrum is the round opening for the mouth, leading into an œsophagus which runs through the middle of the labrum. At the point of attachment this œsophagus is covered by a large pigment-spot (fig. 15, *pi*), on both sides of which two glands are seen, which first seemed to me to run into the stomach (fig. 15, *coe*); but afterwards I could never find any communication between the two, and I am very much inclined to see in these two glands those which in the *Cypris* are to be seen close to the stomach, and which send their ducts up into the antennæ. DOHRN has seen these glands, but has not been able to identify them as such, as his specimens were rather badly preserved.

The œsophagus leads into a stomach, or stomachial intestine; for the stomach is not so strictly separated from the intestine as might appear from fig. 15, which, however, is quite correct, in so far as in animals which are alive there is a strong constriction to be seen. Especially the upper portion is covered with a strongly pigmented epithelium, which in our drawing (fig. 15) has come out a little diagrammatically, as in reality the hexagons are not so regular as they appear there. I found the upper portion of this intestine filled with small algæ allied to coccoliths &c. In the lower portion the pigment of the cells is less intense, which makes it appear more even, less dark, and of a light brown colour. The *intestinum rectum* is, as a rule, filled with granulated excrements, and leads to the anus, which may be easily discovered by getting a side view of the tail between it and the caudal spine (fig. 15, *as*). On both sides of the rectum there is a glandular coating, and another larger gland, which is enclosed in the tail (fig. 15, *gl*), is seen to go into the lower portion of the intestine.

Both the tail and the large caudal spine get their muscles from the upper centre of the carapace, where they are attached near those of the dorsal spine.

The caudal spine is covered, like the dorsal, with recurved spines. In old *Nauplii* this spine is more than double the length of the tail. Between the two there is a bunch of red feathery hairs, just in the same place where three such hairs have been described by DOHRN (see his pl. 29. fig. 6). Here there are four of them, one of which is very much longer than the others.

In the tail (Plate 12. fig. 15, and Plate 14. fig. 22) we find (1) six pairs of movable spines, each of which has muscles running to it; (2) somewhat lower down a pair of spines which are not movable, but recurved; (3) a pair of large, nearly straight spines, and between these last two (4) patches of exceedingly minute and forked spines (Plate 14. fig. 22, *ay*). The remaining part of the tail is covered with the ordinary sort of spines which have just been mentioned in the large caudal and dorsal spines.

After the third of the movable spines has come out (*i. e.* after the fourth moult), one may find, in those specimens which are ready to moult again, seven segments under the skin, each of them with an appendage which looks very much like a future swimmerette (Plate 13. fig. 19, sp^2). The same thing may also be found in those speci-

mens which have already got four movable spines, and I have no doubt also in those with five and six spines. At first I thought that these segments and their appendages were indeed the future pleopods of the *Cypris*; but I found no traces of these *Nauplii* being otherwise prepared for the great change, indications which are invariably only to be found in those larvæ which are provided with six movable spines.

The underlying spines are therefore nothing but the future six large spines of the adult *Nauplius*.

How the pleopods develop in this latter stage before the change into the *Cypris* form takes place I do not know, having never been able to find a *Nauplius* in which they were clearly visible underneath; but judging from what we have seen in other Cirripedia, and from what we know about the development of the large spines, I have no doubt that they develop very much in the same way as these.

Although a certain segmentation under the *Nauplius*-skin cannot therefore be denied in the course of the development of the larva, no trace of this is visible as soon as the underlying skin becomes the external one, and the *Nauplius* of *Lepas fascicularis* never shows on the outside any segmentation in its tail. The movable spines simply mark the place where, later on, we find the segmented abdomen of the *Cypris*.

On our southern cruise, when we get into the regions of *Lepas australis*, I shall take up this subject again, and will make sure about this point, which is the only one of any consequence in the development of *Lepas fascicularis* which I have not quite been able to clear up.

The three appendages of the adult *Nauplius* have been, as I have said, very accurately described by DOHRN in his "*Archizoëa*," except that he has considered the third pair to be the second, and *vice versâ*.

The first antennæ are simple, with only one branch and six joints (Plate 12. fig. 15, *a*). On the first three joints there are no hairs, but on the second and third a few small spines may be seen, which have not been described in the southern larva. The fourth segment is the largest in both species; it has three long hairs on one side and one on the other. The last two segments are very small, the fourth with two, and the fifth with three long hairs.

During the metamorphosis of the *Nauplius* into the *Cypris* stage this is the only pair of appendages which remains; and in old *Nauplii* you may already find stages in which the sucker is being developed within. I have represented, in Plate 14. fig. 22ª, a stage in which a large number of nucleated cells is contained in the very much enlarged fourth segment, showing that something is going to be formed within (fig. 22ª, 4, *acet*). In the same figure traces of the two large joints of the *Cypris*-antenna may be seen, one of them being already visible in the first and second segment underneath the skin, and the second (the one that will have the sucker at the top) being formed inside the third and fourth. The last two segments have very much the same shape in the *Cypris* which they had in the *Nauplius*, only the number of hairs and setæ at the top differs considerably in the two stages.

I have never seen in these antennæ glandular ducts; but if I am right in supposing that the glands in the upper lip do not go into the stomach, a communication with them would be easily established when the great revolution takes place which changes the *Nauplius* into a *Cypris*.

The appendages of the second pair are the largest and are branched (Plate 12. fig. 15, *b*); the appendage has some setæ and a strong manducatory process (fig. 15, *r*) on the second segment; and on the third also there is a sort of manducatory organ with a very hairy surface, somewhat larger than the corresponding process figured by Dohrn in his *Archizoëa*. The branch which starts from this segment has in our case nine (not seven) segments. The fourth segment is covered on its inferior side with very strong hairs; the fifth is very long, and the sixth the shortest, with two long hairs at the top.

The appendage of the third pair (Plate 12. fig. 15, *c*) is also branched. It has on its second joint a conical process with a very strongly feathered short hair. Its branch, which starts from the third joint, consists of three segments, all of which have, as well as the fifth and sixth segment, long feathery hairs attached to them.

During these *Nauplius* stages the embryo has been rapidly growing, and has taken in plenty of food, consisting of small algæ which float at the surface. After the fifth moult it begins to accumulate materials for the pupa or *Cypris* stage, which it will now have to undergo, and during which no food is taken. Large masses of fat fill the space between the stomach and the carapace (Plate 14. fig. 22, *cl*), and make it appear quite opaque, while the developing *Cypris*-shell under the *Nauplius*-carapace gives to these old *Nauplii* a darker brownish colour.

Every thing is now ready for the next (sixth) metamorphosis, which diminishes the size of the larva in a most extraordinary way, and which is the most remarkable one which it has to undergo.

The carapace with its long spine, the tail and the caudal spine, the second and third pairs of appendages, and the large labrum are now all cast off, and the *Cypris* underneath is ready to swim about.

III. *The* Cypris *stage.*

The changes just mentioned take place evidently very suddenly, for I could never find a *Nauplius* which was just in the process of moulting, though I found plenty of empty and cast-off skins. After the metamorphosis the newly born *Cypris* takes to a different mode of life to that which was led by the *Nauplius*. The *Nauplii* come at night to the surface, but live in the daytime mostly in a depth of 60 fathoms, while the *Cyprides* are to be met with on the very surface, swimming in a lively way round the *Velellæ*, and trying to fix as soon as possible on dead individuals of these siphonophores. I should think that this *Cypris* stage lasts only a very short time; for in the same places where hundreds or thousands of *Nauplii* were caught we obtained only a few *free-swimming Cyprides*, but saw them in crowds on the young *Lepas* colonies, on

which they had settled wherever there was the smallest place left for them. The *Cypris* evidently attaches itself on the very first occasion, preferring for its future domicile *young* colonies of *Lepas* or *Velella*-shells on which there are as yet only *Cyprides* and no *Lepades* at all. This is the reason why the worst places for collecting them are old colonies of the barnacles, in which most of the specimens are about of the same age, and in which only here and there younger or just-fixed *Cyprides* may be found.

Lepas fascicularis is one of the barnacles which were studied by CLAUS when he worked out the last stages of the Lepadidæ; and I have no doubt he has seen and partially already described the same things which I am about to describe. In details, however (supposing the *L. fascicularis* of the Pacific to differ from the Atlantic one), there may be some differences.

Moreover we have the classical description which DARWIN* has given of the *Cypris* stage in *Lepas australis*, which from its large size (0·1 of an inch, about 3 millims.) is especially favourable for such a study, and which corresponds nearly in every detail with that of *Lepas fascicularis*. I shall therefore be very short in my description of the *Cypris*, as well as in that of the transition stage to the adult *Lepas*, in order not to repeat things at large which have already become the property of science; but I must give an account of the chief changes which occur in order to make my description of the *Lepas* development complete.

The size of the *Cyprides* is variable; some of them have a length of 1·3 millim. and a width of 0·7 millim.; but some specimens may be found to be a little larger and some a little smaller.

The yellowish and rather transparent shell has an oval shape, but is pointed at the posterior end (Plate 15. fig. 24). When alive the whole animal's body is so much expanded by the cells of adipose matter, that scarcely any thing but the antennæ, the eye, and the setæ of the feet can be seen. But after having been put into absolute alcohol and then made transparent every thing comes out very well, and one gets, even without dissection, a good idea of its anatomical peculiarities.

The valves of the shell are kept chiefly together by a large *musculus adductor* (fig. 24, *ma*), which partly covers the parts of the mouth if you look at the entire shell. The muscle occupies a very large spherical place of attachment, and keeps the valves very strongly together.

The other muscles are those which run from the dorsal portion of the shell to the origin of the antennæ, and those which attach the upper portion of the body, and especially the head, to the upper portion of the shell. Two small muscles move continually the capsules which include the large compound eyes (fig. 24, *m*).

The Appendages.—Between the antennæ there are still remains of the two feelers which I saw when dissecting the pupa, but which I never could observe *in situ*. The *antennæ* (Plate 15. fig. 24, *a*, and fig. 27) are very large and powerful organs. How they originated in the first appendages of the *Nauplius* has been already described. In

* *Loc. cit.* ii. p. 14.

the free-swimming *Cypris* they are to be seen in connexion with a gland (fig. 24, gl^1), which may be easily seen on the ventral side of the stomach, often filled with granular secretions, which make it appear dark when seen by transmitted light. The duct of this gland runs up through the first and second joints of the antennæ and opens in the centre of the sucker (fig. 27, *dgl* and *acet*).

The antenna itself consists of four joints, not of three, as was formerly supposed by Darwin, who very likely had not seen the minute third one generally hidden by the sucker. Claus, however, and very likely Pagenstecher, have already described the right number. The first joint attaches with a forked base to the muscles of the body, and has a strong curved spine. The second joint is nearly as long as the first. Its largest muscles run all towards the sucker, which is attached by a short peduncle to its exterior side. The diameter of the sucker is 0·1 millim. It has a depression in the middle to receive the duct of the gland, and round this depression a wall of chitinous substance, on which seven large spines, two small spines, and four setæ are attached. Another seta is found below the sucker on the second joint, in the same place where in the *Nauplius* we saw a feathered hair. The third joint, almost hidden by the sucker, is very small; and the fourth only somewhat larger, but distinguished by four setæ and two olfactory hairs, between which there is a broad paddle-shaped appendage which I cannot well classify (fig. 27, *u*). Under an immersion-power you see a double contour line running up into it, but no hairs nor appendages of any kind at the top. Darwin has observed the same number of setæ, hairs, and also this peculiar appendage in the pupa of *Lepas australis**.

The second and third appendages of the *Nauplius* stages are entirely lost, and so is the large labrum; only a small helmet-like prominent organ is to be seen where formerly we found such a huge appendage, the two lateral glands of which have now very likely been converted into shell-glands. There are three parts of the mouth besides the upper lip (fig. 32, *a*, *b*, *c*), all very rudimentary. I have been unable to separate them quite satisfactorily, though I have tried ever so many times to get at them with fine needles. Claus, however, has succeeded in doing so, and has shown, when comparing the whole of the *Cypris* stage with the Copepods, that these parts correspond to the maxillæ and maxillipeds of these Entomostraca.

I think there is no reason to doubt the disappearance of the third appendages; for I have looked very carefully whether any remains of them could be found, but did not succeed, and I think that if any thing developed itself at all in these large appendages it would be easily seen. The parts of the mouth, it is true, are very small; but with the exception of the labrum, which is easily found, they are all new formations.

There are six pairs of branched natatory feet, five of which have been compared by Claus to the natatory feet of the Copepods, and the last pair to their genital appendages. These feet are adorned with a short seta, which is directed upwards, on the front of the last segment, and with long, very densely feathered setæ at the end.

* Darwin, *loc. cit.* tab. 30. fig. 8.

They offer nothing at all peculiar, and consist of three joints, the first of which is the one from which the two branches start. Each of these consists accordingly of two joints.

Between these natatory feet slender chitinous lamellæ are seen running up on both sides of the abdomen (fig. 24, *la*), which separate the spaces from each other, in which after a short while the large cirri of the *Lepas* will develop, after the temporary feet of the *Cypris* have been deprived of the plastic substance which they contain. This shows out extremely well in one of my preparations, a *Cypris* which has just begun to give the first signs of metamorphosis; also in fig. 25 this is still sufficiently visible.

The two-jointed appendages of the tail are mostly turned upwards, and have setæ on their last joints, similar to those on the natatory feet.

The Organs of Sense.—Between the antennæ, and a little behind them, two small protuberances might be observed, which CLAUS calls the "Stirnhöcker," and which are very likely the remains of the lateral horns. No function seems, however, to be assigned to them now, as they have neither terminating glands nor any appendages which might be organs of touch.

As sense-organs we have in the first place to claim the two olfactory hairs on the last joint of the antennæ, and as organs of touch the setæ and the peculiar elongate and flattened appendage which has been represented in fig. 27, *u*; also the setæ on the sucker and the one on the second segment are very likely used as such.

The nervous system is represented by two large ganglia (Plate 13. fig. 21, *cer*), which are of an oval shape, and very likely united by a nervous bridge, which in our figure has been given with some doubt. These ganglia, in which nucleated cells may be observed, send large nerves to the base of the large compound eye, which consists of a black pigment body, eight to ten lenses and their cornea. The eye is at the bottom of a large capsule, very likely containing fluid, and attached to one of the valves by small muscles which enable it to move in different directions. Besides these large eyes we still find the *Nauplius* eye in the same place in which it was before, between the two antennæ, a little above their points of attachment.

Organs of Digestion and Glands.—The parts of the mouth which have been already described lead through a short œsophagus into the stomach, on both sides of which I saw, when dissecting the pupa, small glands, which seem to lead into the œsophagus as they do in the full-grown *Lepas*.

The stomach is now rather collapsed, never distended by food like that of the *Nauplius* stage. It passes into an intestine, which is much longer than that of the latter, and ends most likely with an anus at the base of the last pair of natatory feet. I have, however, not been able to see this opening, nor could I find as yet a trace of the excretory cæca, which in the adult *Lepas* terminate on both sides of the rectum.

Besides the œsophageal glands there are the cement-glands, which lead into the antennæ and which have been traced from their first origin in the upper lip and described with the antennæ. Very conspicuous as lying under the shell in the dorsal

part of the pupa is the large shell-gland (fig. 24, gl^2), the function of which is to supply first the materials for the five primitive valves of the shell, and then the shells themselves, which, according to CLAUS's and my own observations, are formed after those small valves and separately from them, so that the former always remain in the shell and are easily recognized by their peculiar cellular structure.

Traces of an ovary have also been found in the pupa stage, and figured as seen under a low power in fig. 28.

IV. *The metamorphosis of the* Cypris *into the* Lepas.

The pupæ swarm round the dead *Velellæ*, and settle by means of their hooks and suckers as soon as they find a suitable place. None of the metamorphoses, therefore, are easier to study than these, as one young colony caught during the season of their development shows all the stages—the pupa which has just settled and not yet changed its form (Plate 15. fig. 24), the same after its head had grown out and when its *Cypris*-shell and natatory feet are just going to be cast off (fig. 25), and the perfect young *Lepas* (fig. 26). Still what happens within is more difficult to observe, as the transparency, which hitherto guided us in our researches, is less and less to be found as the pupa develops.

The growing out of the head and the appearance of the feet in that part of the abdomen which in the *Cypris* (fig. 24, *la*) is divided by ridges and chitinous lamellæ, is the first thing that happens; and now one may also see very faint traces of the cellular tissue of the primitive valves. The eyes, however, are still in their position, and the *Cypris*-shell still covers the body. The next stage (fig. 25) is the loosening of the *Cypris*-shell and of the moulted natatory feet, which in fig. 25 may be seen just coming off. Underneath six pairs of cirri (*p*) may be seen, which still differ from those of the adult *Lepas* in being less segmented and not so hairy. The three primordial valves are now fully formed, and are very striking from their regular network of cellular tissue. The eyes of the *Cypris* stage have already lost their proper position, but may still be seen as black pigment-spots, which are about to be absorbed; they look like pictures which have lost their frames, and will soon entirely disappear. The upper lip is now very prominent, and the organs of digestion are shining through the valves in formation.

From the two large glands underneath the mouth, in front of the stomach, ducts filled with granular secretion may be seen going down to the antennæ (fig. 25, *a*), which by-and-by have to form a gelatinous ball which finally absorbs the fragment of *Velella*.

In this stage the upper portion is 1 millim. long, the grown-out head having a length of 0·7 millim. It now throws off entirely all the larval remains; the valves of the *Cypris*-shell drop with the old feet and caudal appendages, and round the primordial valves, which indicated already the position of the larger ones, a more solid skeleton

is formed. The cirri have acquired a greater number of segments (fig. 26); and the young *Lepas*, which has now a length of 4 millims., is complete.

Conclusion.

The chief object of this paper has been to give a complete history of a *Lepas* development which hitherto had never been worked out. The first and the last stages were known in some species, and in another species the intermediate pelagic stages had been described by DOHRN; but it was not even known to what family of Cirripedia these *Nauplii* belonged. This is quite natural, as all the work for such a complete development must be done under conditions which scarcely ever had been realized before this ship left the shores of England.

There are only few points in this paper which will enlarge our ideas about the morphological relations of Cirripedia very much, in so far as each of the larval stages were known to exist before; but it settles the question to which of the Cirripedia the large pelagic *Nauplii* belong, and it gives further details about their intimate structure. It also gives certain indications which allow us to say, almost to a certainty, to which of the *Lepas* species the larvæ belong which DOHRN got in the south, and which have been taken by ourselves to the south of Australia; but it likewise gives evidence that there are no traces of a *Zoëa* stage in the course of the *Lepas* development. The *Nauplii* are very highly organized, but there are no essential differences between them and the other embryonic forms which we have been accustomed to call *Nauplii*. The name of *Archizoëa* might, I think, be left to keep up the remembrance of DOHRN'S discovery of the interesting *Lepas* larvæ; but speaking of the Lepadidæ in general, I think it would only confuse matters if it were said that they pass through an *Archizoëa* stage. This would imply that the later *Nauplius* stages of *Lepas* have a different morphological value from those of *Balanus* or other genera, which I think they have not.

DESCRIPTION OF THE PLATES.

PLATE 10.

Fig. 1. Development of the ovarium (*m*): *n*, the ovum nearly filled with yelk, still showing the germinal spot.

Fig. 2. Ovarian tube with young ova in the beginning of their development.

Fig. 3. Ovarian tube with nearly mature ova. Among them some undeveloped cells (*oi*), perhaps the mother cells of the ova.

Fig. 4. Complete ovum, before the beginning of the segmentation, taken from the ovisac. The germinal vesicle is not visible. Nat. size, 0·26 millim.

Figs. 5 & 6. First stages of segmentation. Four blastodermic cells have formed themselves.

Fig. 7. Segmentation of the yelk goes on, but is not clearly visible. More blastodermic

cells in the interior. On the right side the yelk gives way at the place where afterwards there will be a groove between the appendages: *y*, blastodermic cell; *x*, yelk-globules.

Fig. 8. The blastoderm has spread all over the ovum and enclosed the yelk. Reflected light.

Fig. 9 *a*. Front view; fig. 9 *b*, side view. First formation of the three pairs of appendages (*a*, *b*, *c*).

Fig. 10. The embryo in its thinner and enlarged (? blastodermic) cuticle, length 0·28 millim.: *a*, *b*, *c*, the three pairs of appendages; *la*, labrum.

Fig. 11. The *Nauplius* having just come out. Dorsal view: *a*, *b*, *c*, the three appendages; *cp*, the lateral horns; *la*, labrum; *oes*, œsophagus; *c*, cauda; *prc*, processus caudalis, or the spine attached to the tail's posterior side. These two are invaginated and enveloped by a very thin cuticle, as also are the ends of the lateral horns (figs. 11 *a* & 11 *b*). Natural size: length 0·35 millim.

Fig. 12. An adult *Nauplius* (*Archizoëa*, Dohrn) seen from the side. × 12 nat. size.

All the figures, with the exception of fig. 12, were drawn under a high power. (Hartnack $\frac{1}{7}$ or $\frac{1}{8}$.)

PLATE 11.

Fig. 13. *Nauplius* after the first moult. Drawn from specimens kept in globes as well as from those caught on the surface. *a*, *b*, *c*, the three appendages; *cp*, cornua parietalia; *la*, labrum; *oes*, œsophagus; *sp*, the first one of the large spines on the tail; *ac*, the caudal spine; *x*, feelers; *z*, spines of the carapace. Natural size of this embryo:—

Length of the whole animal	0·61 millim.
Length of front of embryo	0·17 „
Length of cornua parietalia	0·26 „
Length of carapace	0·19 „
Length of tail	0·42 „

Fig. 14. *Nauplius* after the second moult. From the surface of the Pacific. Letters the same as in the last figure, except:—*cer*, first formation of the ganglia; *coe*, glandular bodies; *pr*, processes of the carapace, into which the unicellular glands send their ducts; *ad*, dorsal spine.

PLATE 12.

Fig. 15. *Nauplius* (*Archizoëa*, Dohrn) after the fifth moult. From the surface. The tail with its large dorsal spine has been bent over a little to the side to show the end of the intestine and the glands; also the labrum has been turned over a little to show the mouth and the narrow channel by which it is in communication with the œsophagus. The muscles in the tail and the caudal and dorsal spines have grown, and, not being able to stretch out, are taking

turns like a corkscrew. In the tail there is a gland (*gl*) which seems to have its opening into the lower part of the stomach. The epithelium in the upper part of the stomach is a little diagrammatic, not being in reality quite so regular, and the cells being more darkened by granules than they are in the figure.

Letters the same as in the last figures, except:—sp^2, immovable large spine; *pi*, pigment-spot, just above the entrance of the stomach; *as*, anus; *r*, processus mandibularis. Natural size:—

Diameter of carapace	1·0 millim.
Length of tail	4·0 millims.
Length of processus caudalis	6·0 „

Fig. 15[a]. Enlarged view of the manducatory process of the second antenna. High power.

PLATE 13.

Fig. 16. One of the processes on the carapace of the *Archizoëa* (later *Nauplius* stage), showing the glands terminating in them and the nerves in connexion with these glands. Observed on a living specimen under very high power (Hartnack no. 10). *gl*, the large and main gland opening into *pr*, the process of the carapace; *m*, outer margin of the carapace; *y*, a sense-hair on the same; *n*, varicose nerve running up to it; *n*, nervous stem sending a branch to the bottom of the gland, *gl*; *c*, a ganglionic cell.

Fig. 17. One of the lateral horns seen from above. H. $\frac{1}{8}$. From a living specimen. *gl*, the large glands, the bottoms of which are fastened by fibres of (?) connective-tissue or muscles; *pr*, processes in connexion with smaller glands; *q*, ring for the attachment of the muscles; *ch*, inverted portion of chitinous cuticula; *y*, a sense-hair; *z*, hairs at the top of the lateral horn, very likely in communication with a nerve, which, however, could not be found.

Fig. 18. Eye of a young *Nauplius* after its fifth moult, and on both sides the feelers with their nerves. Underneath the two ganglia. Very high power. H. $\frac{1}{10}$. *x*, feeler; *n*, varicose nerve; *cer*, ganglia; between the eye and the feelers a granular (? nervous) substance.

Fig. 19. Portion of the tail of a *Nauplius* after its fourth moult. Only three large flexible spines have as yet come out (*sp*), but seven spines (sp^2) may be seen ready to come out under the skin. The seventh is the future large immovable spine. High power.

Fig. 20. The tail of an adult *Nauplius* (last *Archizoëa* stage) showing the muscles going to the movable spines. High power.

Fig. 21. The ganglia (*cer*) of the *Cypris* stage; the nerve going to one of the compound eyes (*oc*), and the capsule round the latter. High power. The connecting dotted line (*hy*) between the two ganglia indicates that it is a hypothetical one, not observed.

PLATE 14.

Fig. 22. An adult *Nauplius* after its fifth moult (last *Archizoëa* stage). The labrum is in its ordinary position. All the appendages have been removed, in order to show the glandular system inside the carapace and the masses of adipose pigment accumulating there. The latter are only shown on one side in order not to confuse the drawing. From the surface. H. $\frac{1}{7}$. *ac*, caudal spine; *ad*, large dorsal spine; *ay*, small forked hooks on the middle line of the tail (fig. 22, *ay*, the same seen under very high power); *coe*, cæca in the upper lip leading into the stomach; *cl*, adipose body (fat-cells); *cp*, lateral horns; *dr*, glands in the interior of the carapace; *gl*, glands terminating in the processes of the carapace; *nc*, nervous cell; *n*, nerves; *o*, first formation of the lateral eye, which very soon will present the same aspect as those drawn in fig. 23, *o*; *oes*, œsophagus; *pr*, processes of the carapace, with an opening of the gland at the top; sp^1, movable spines; sp^2, immovable spine; *x*, feelers. Natural size:—

Diameter of the carapace	2 millims.
Length of the tail	8 „
Length of the caudal spine . . .	12 „

Fig. 22ª. First antennæ of an adult *Nauplius* near its last moulting into the *Cypris* stage. 1–6, the joints; *a*–*δ*, the underlying joints of the *Cypris* antenna; *acet*, the cells which build up the sucker.

Fig. 23. Anterior part of the *Nauplius*, last *Archizoëa* stage of a Cirriped from the surface of the Antarctic sea (? *Lepas australis*, described by Dohrn as *Archizoëa gigas*), in order to show the processes into which the glands terminate all over the carapace, and the state of the lateral eyes before the moulting for the *Cypris* stage takes place. From a preparation in Canada balsam. H. $\frac{1}{7}$. *la*, labrum; *gl*, glandular system inside the carapace; *pr*, processes; *cp*, lateral horns; *y*, vesicular connective-tissues, patches of which are to be found in the glandular substance of the carapace; *x*, the feelers; *o*, the two compound lateral eyes of the *Cypris* stage into which this *Nauplius* was preparing to moult. Natural size:—

Length of carapace	2·0 millims.
Width of carapace	1·50 millim.

PLATE 15.

Fig. 24. Free-swimming *Cypris* stage (after the sixth moult), from the sea-surface. Antennæ and feet retracted into the shell. Partly from living specimens, partly from Canada-balsam preparations. H. $\frac{1}{7}$. *a*, the antennæ, with the sucker; *m*, different muscles; *ma*, musculus adductor; gl^1, gland leading into the antennæ; gl^2, gland of the shell (visible in nearly all prepared speci-

mens); *dgl*, duct of the gl^1, leading into the sucker of the antenna; *oc*, the large compound eye in its capsule and the muscles attached to the latter, by which its continual vibrating movement is effected; *pl*, the abdominal feet; *c*, the caudal processes. Natural size:—

Length	1·30 millim.
Width	0·70 „
Diameter of eye	0·09 „
Diameter of lenses	0·02 „
Diameter of sucker	0·10 „

Fig. 25. The *Cypris* stage, having fastened itself by means of a sucker on the "sail" of a dead *Velella*, in the act of throwing off its *Cypris*-shell and feet, of losing the compound eyes, and of forming the primordial valves. The end which in fig. 24 is the upper one is here the lower, from which the "plastic" parts of the body have retired towards the top. The animal has been taken off from the *Velella*, and the drawing has for the most part been made from a Canada-balsam preparation. H. $\frac{1}{7}$.

I. *The young* Lepas.

a. The antennæ, with the sucker.
ped. The pedunculus of the young *Lepas*.
o. The mouth.
p. The newly formed feet (cirri).
ta^1, ta^2, ta^3. The primordial valves.

II. *The Remains of the* Cypris *which are thrown off*.

pl. The dropping feet of the *Cypris* stage.
c. The caudal appendage of the *Cypris* stage.
oc. The compound eyes, already dropped and going to be absorbed.
v. The valves of the shell.

Natural size:—

Length of upper portion of the young *Lepas* (not counting the *Cypris*-shell)	1·0 millim.
Length of lower portion (formerly the head of the *Cypris*)	0·7 „
Height of ta^1	0·7 „
Length of ta^2	0·2 „
Height of ta^3	0·8 „

Fig. 26. Young *Lepas* fixed on the sail of a dead *Velella* (*Ve*). Low power. H. $\frac{1}{4}$. *a*, antennæ, with sucker sticking to the *Velella*-sail; *ped*, pedunculus; *ca*, carina; ta^1, ta^2, primordial valves. The reticulated structure is here only

indicated by dots, as coming out well only when a higher power is used. Natural size:—

Length of pedunculus	1·0 millim.
Length of upper portion	3·0 millims.
Total length	4·0 „
Height of ta^1	0·4 millim.
Length of ta^2	0·3 „

Fig. 27. The antenna of the *Cypris* stage. 1, 2, 3, 4, the four joints; *acet*, the sucker; *sp*, spine at the base of the joint which is attached to the body; *dgl*, duct of the gland; *m*, muscles; *set*, setæ; *cs*, olfactory hairs; *u*, flat, doubtful appendage, enlarged in fig. 27, *u*.

Fig. 28. First formation of the ovary in the *Cypris* stage, got by dissecting the animal when alive.

Fig. 29. First maxilla of the adult *Lepas*.

Fig. 30. The mandibles of an adult *Lepas*. *a*, the right mandible, with five teeth; *b*, the left mandible, with six teeth.

Fig. 31. Half of the labium (second maxilla) of an adult *Lepas*. H. $\frac{1}{4}$.

Fig. 32. The organs of the mouth, as seen *in situ* in a dissected *Cypris*. As I did not succeed in separating them well, they may not have come out quite accurately. High power. *a*, mandible; *b*, first maxilla; *c*, second maxilla.

[Note.—The author of this paper, a young naturalist of the highest promise, died on board the 'Challenger' on the voyage from the Hawaiian Islands to Tahiti. In correcting this his last scientific paper for the press I have made as few changes as possible, only altering the arrangement here and there to make the English run more smoothly; and, in memory of his industry and enthusiasm, I have allowed several passages to stand referring to his hopeful anticipations for the future.—C. Wyville Thomson.]

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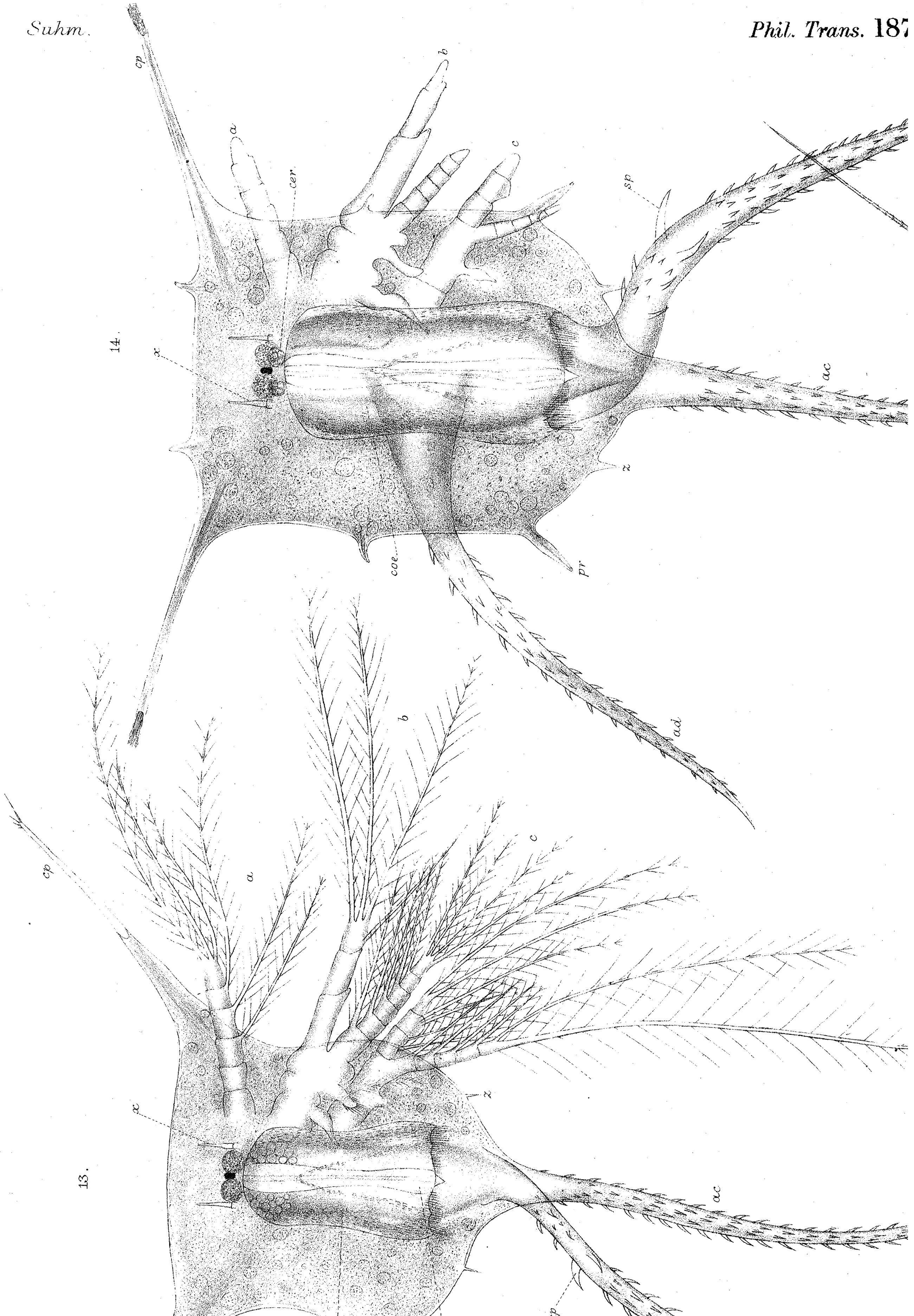
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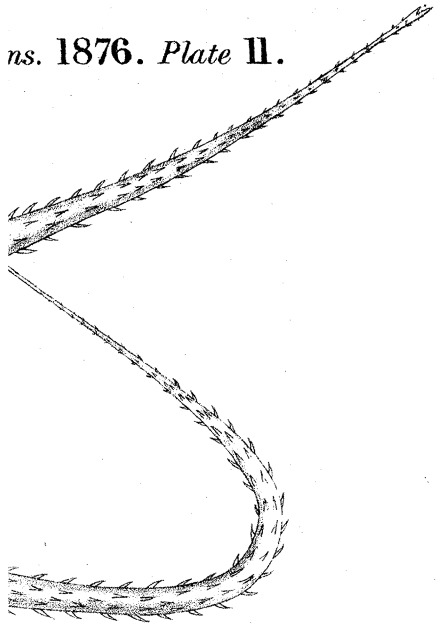

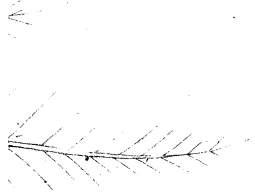

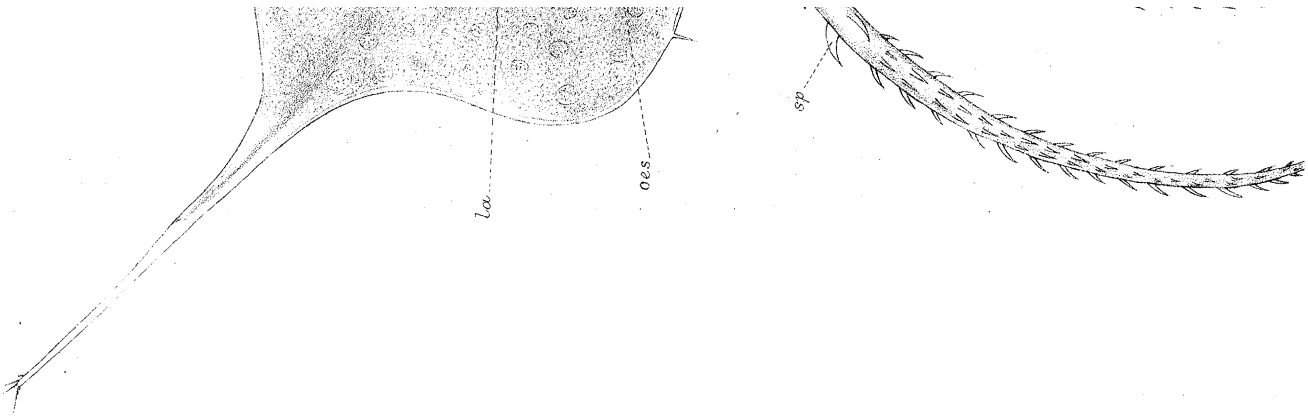
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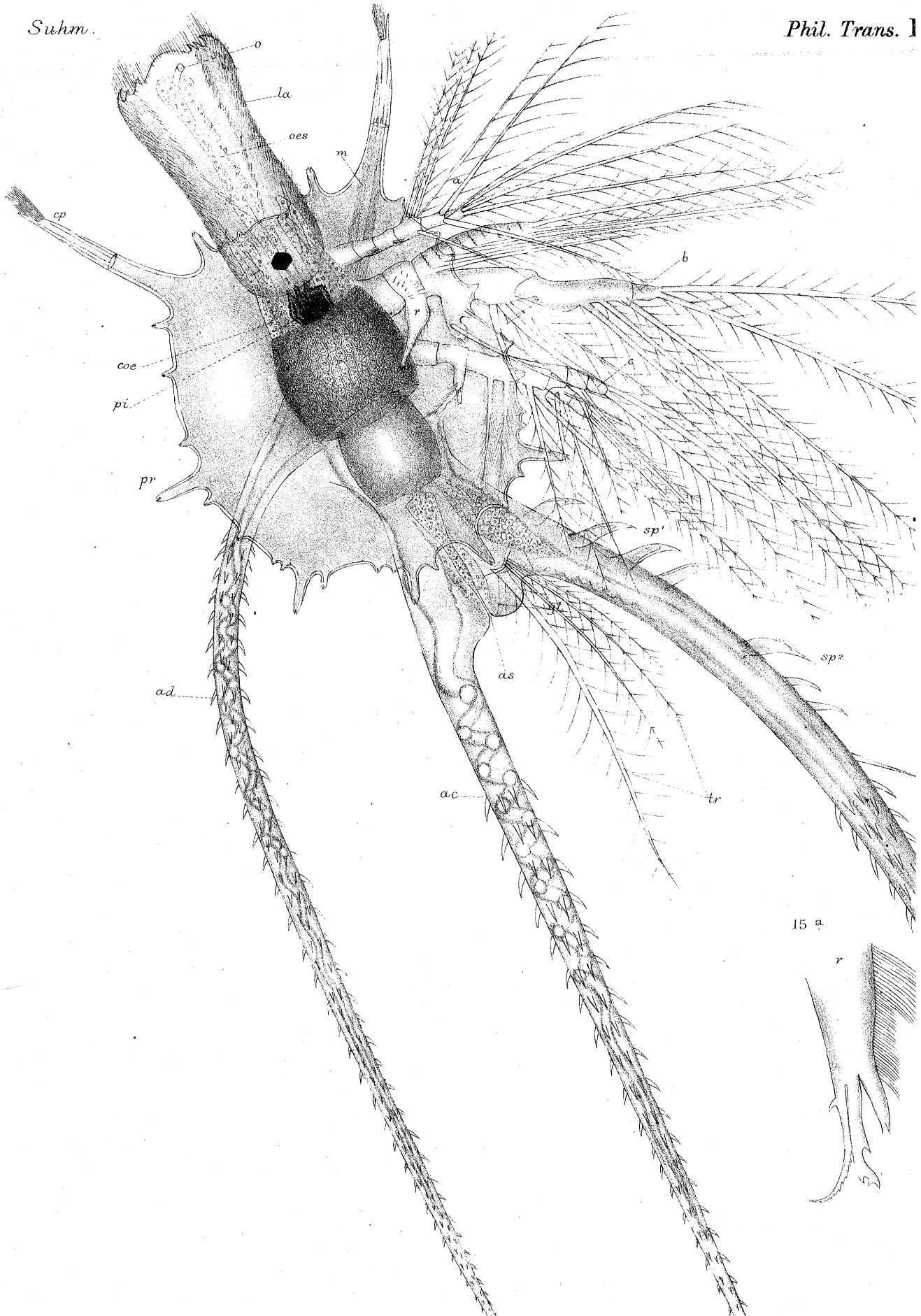
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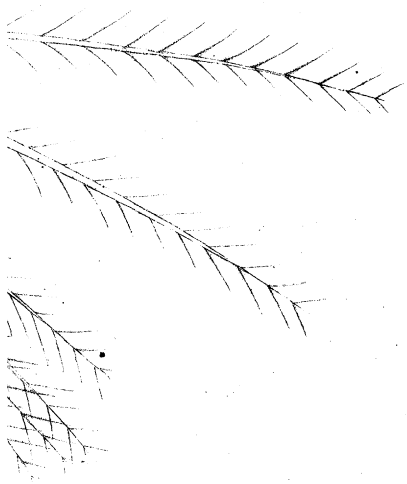

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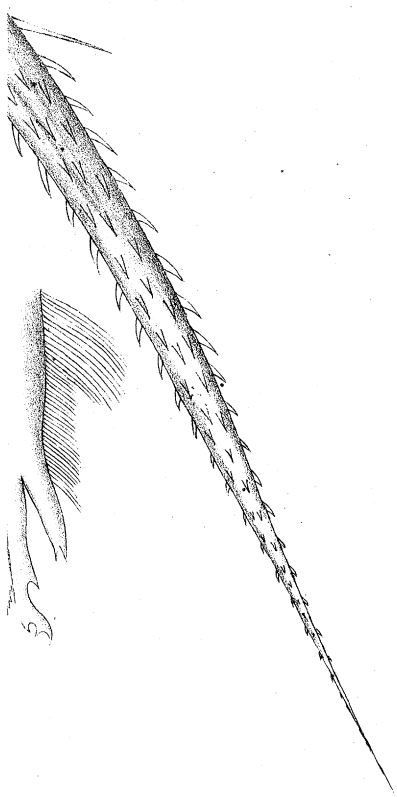

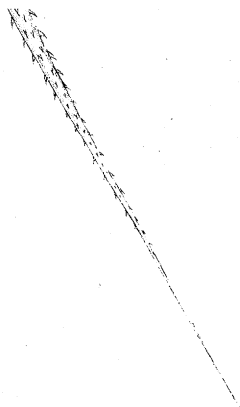

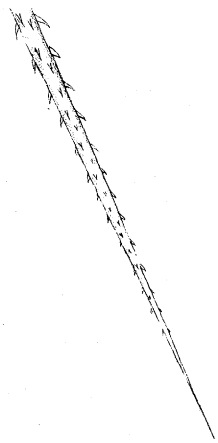

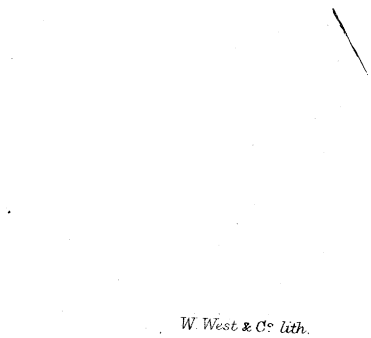

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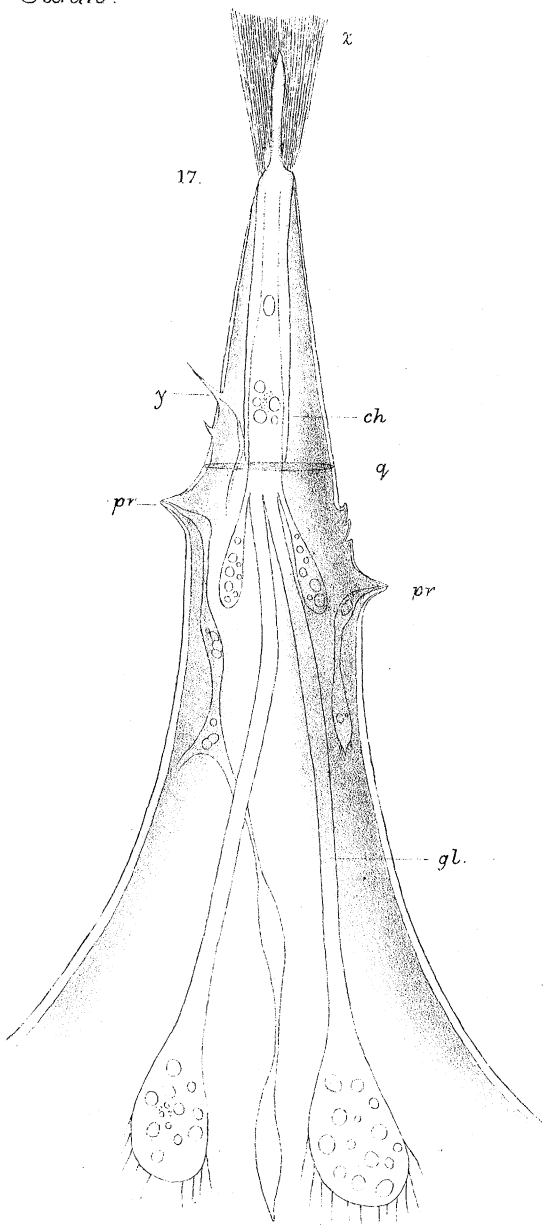

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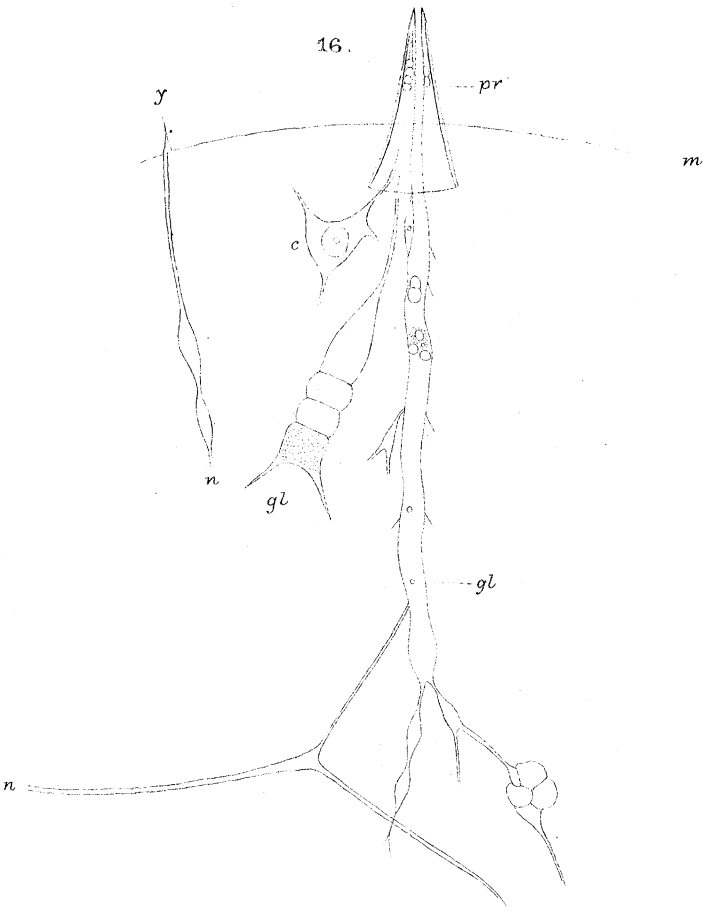

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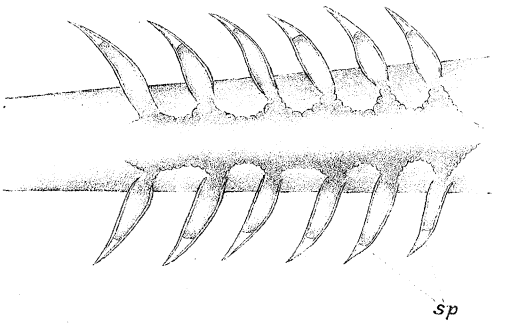

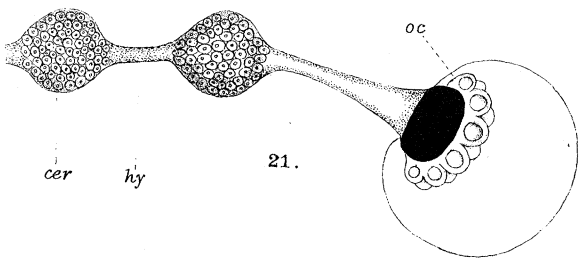

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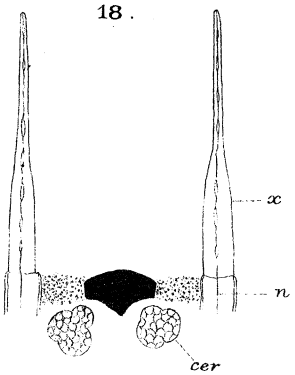

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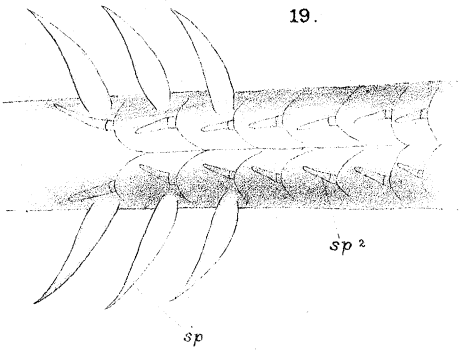

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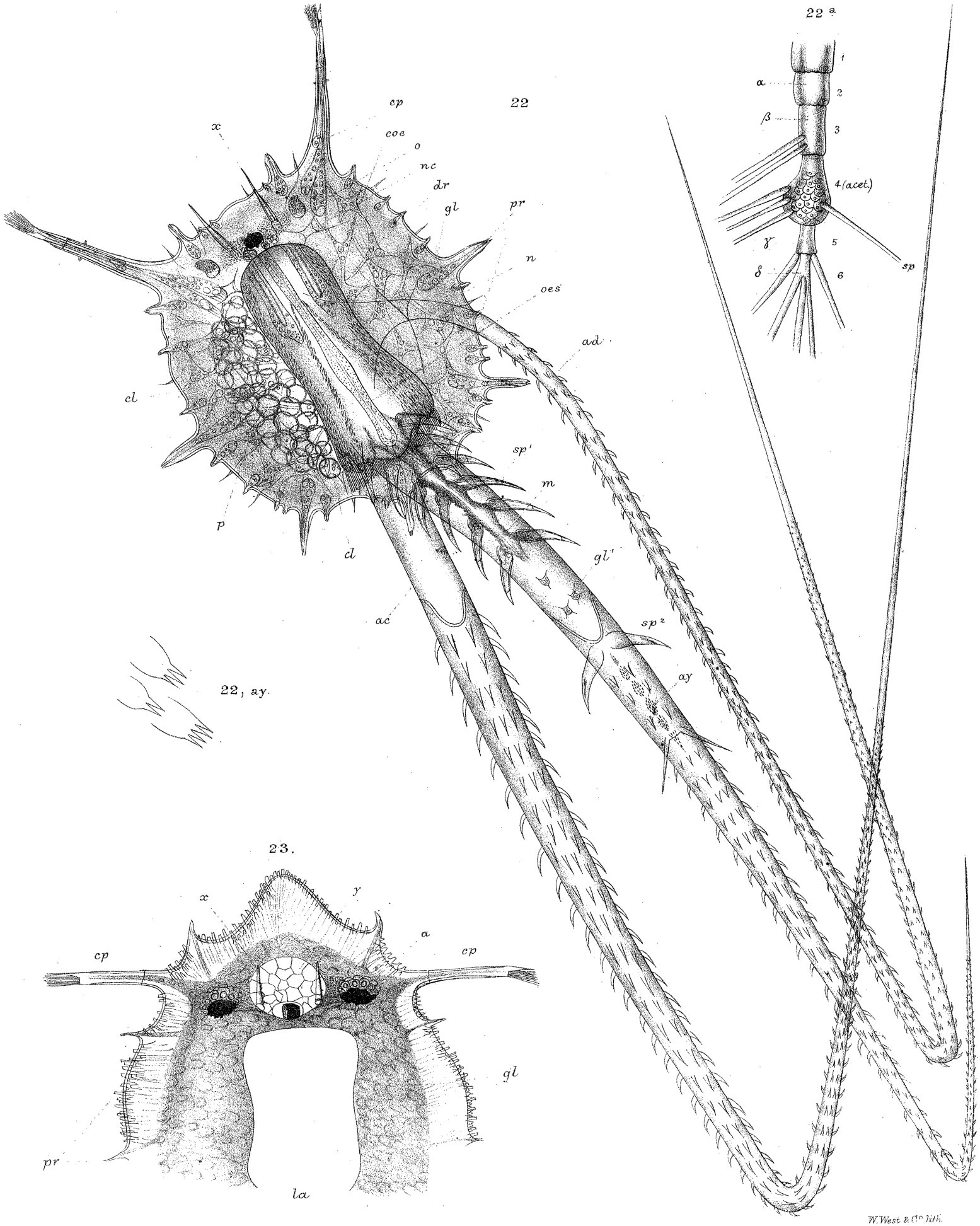

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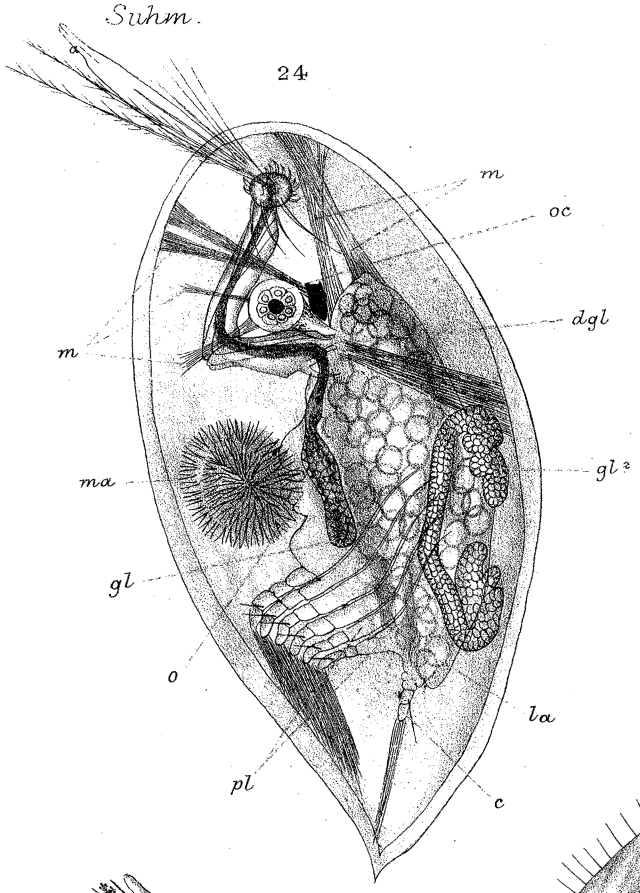

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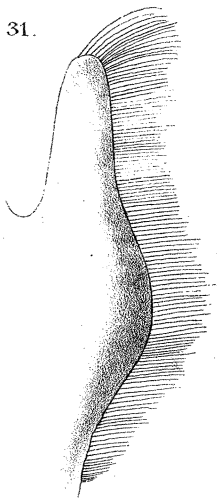

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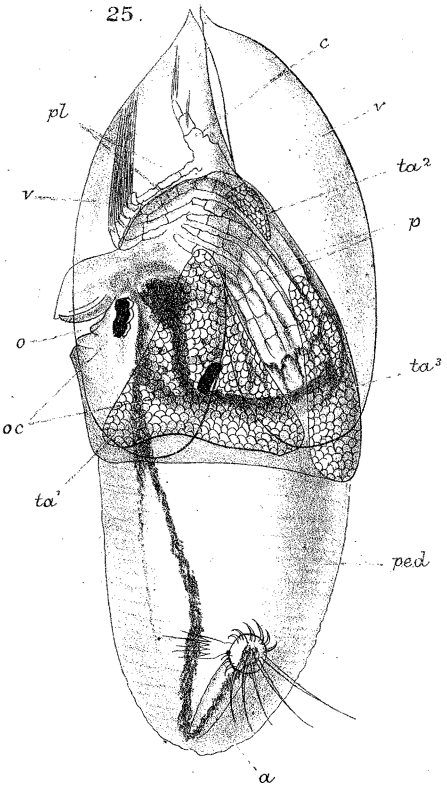

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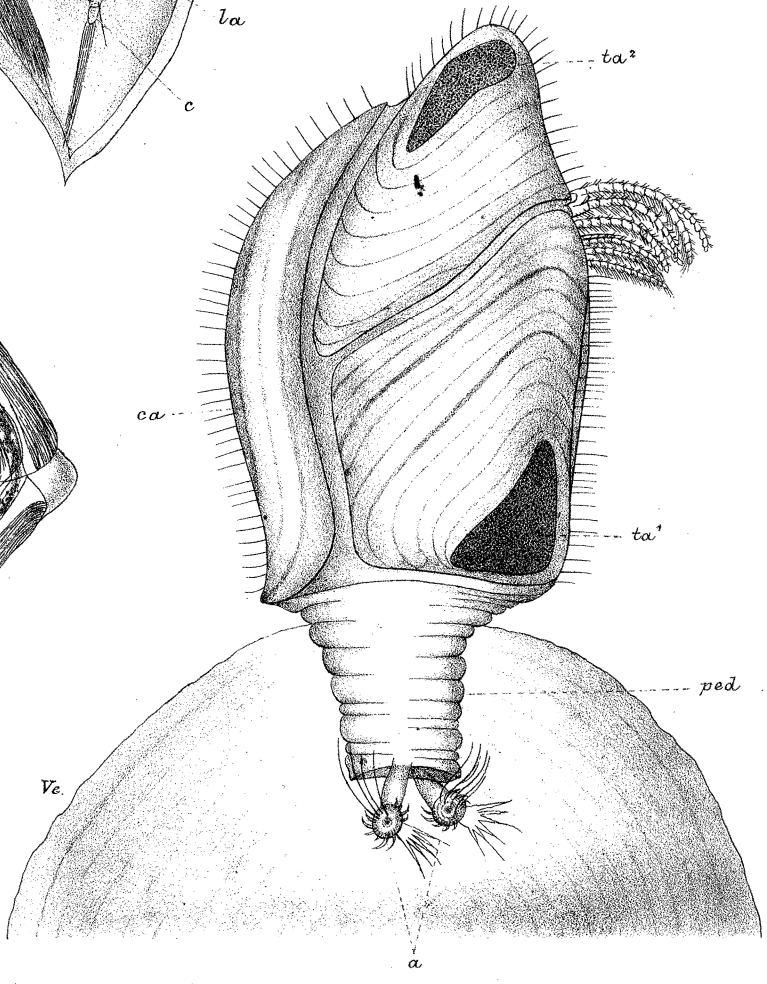

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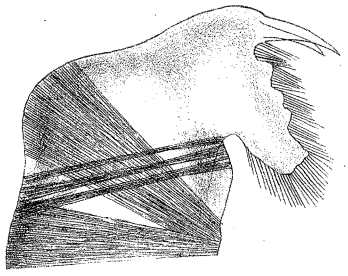

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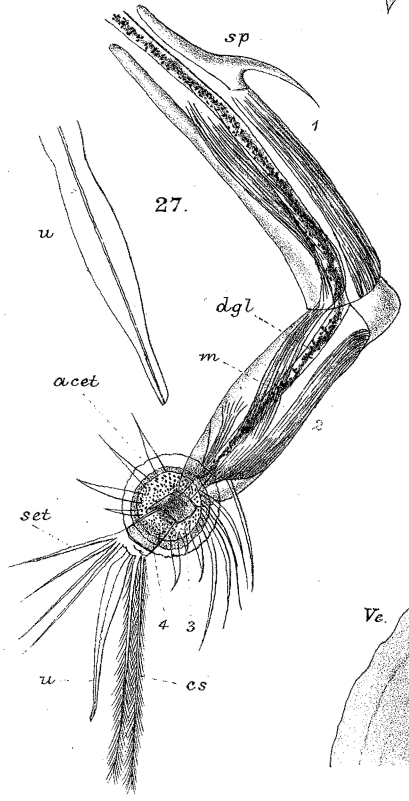

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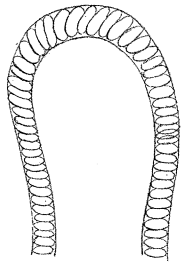

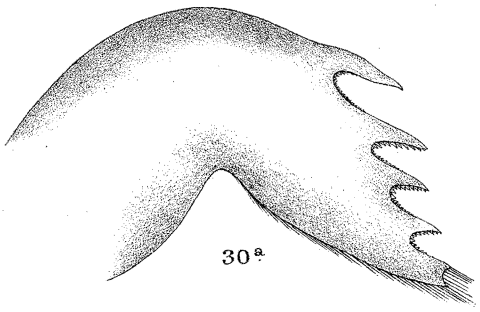

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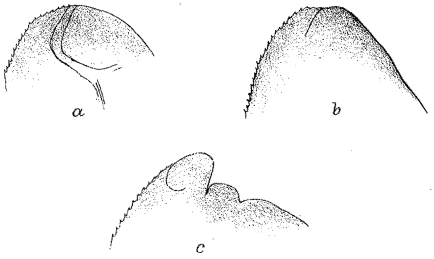

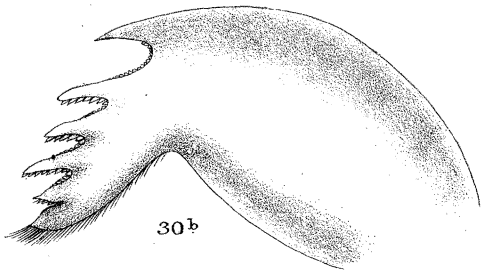

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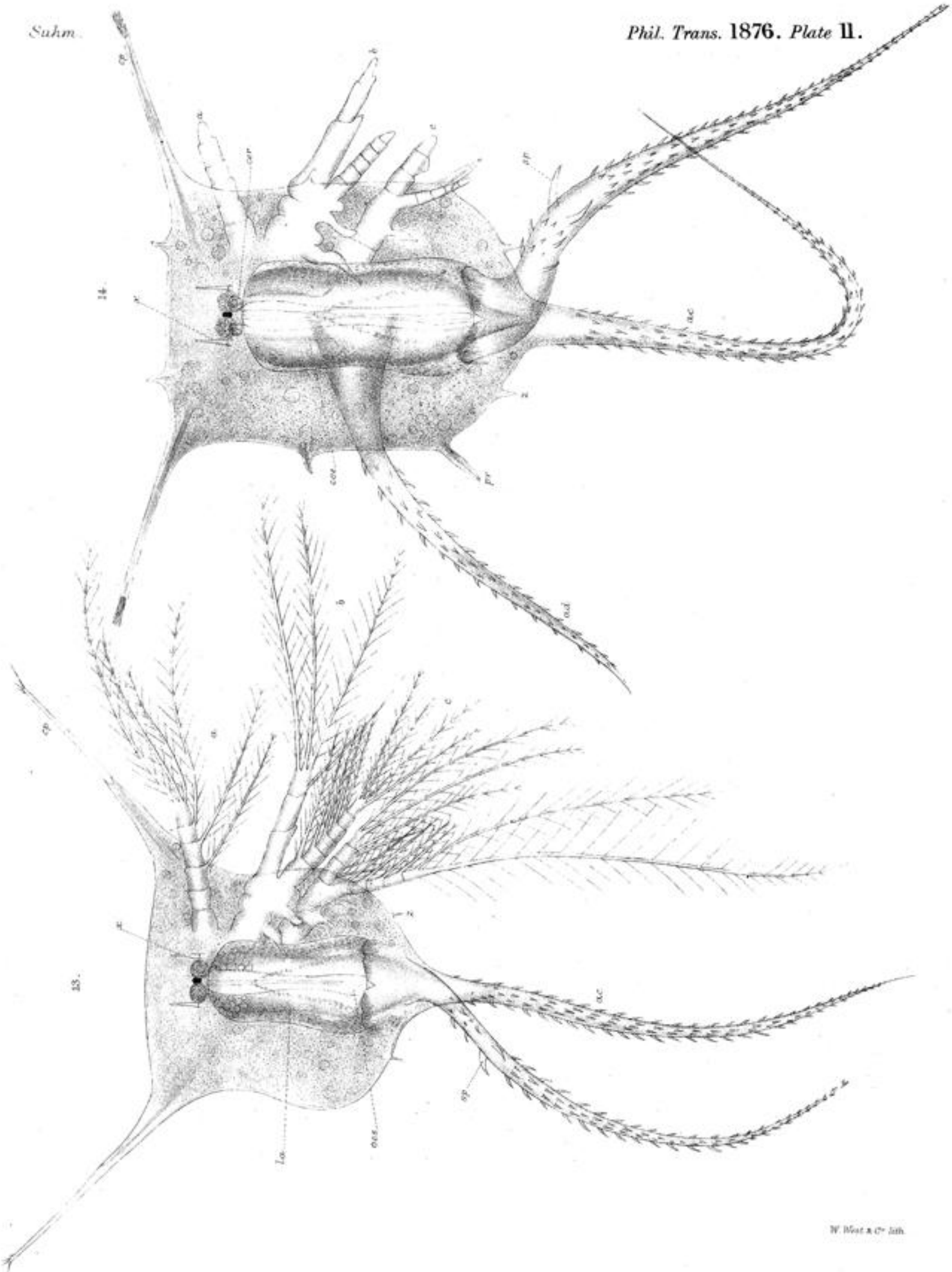

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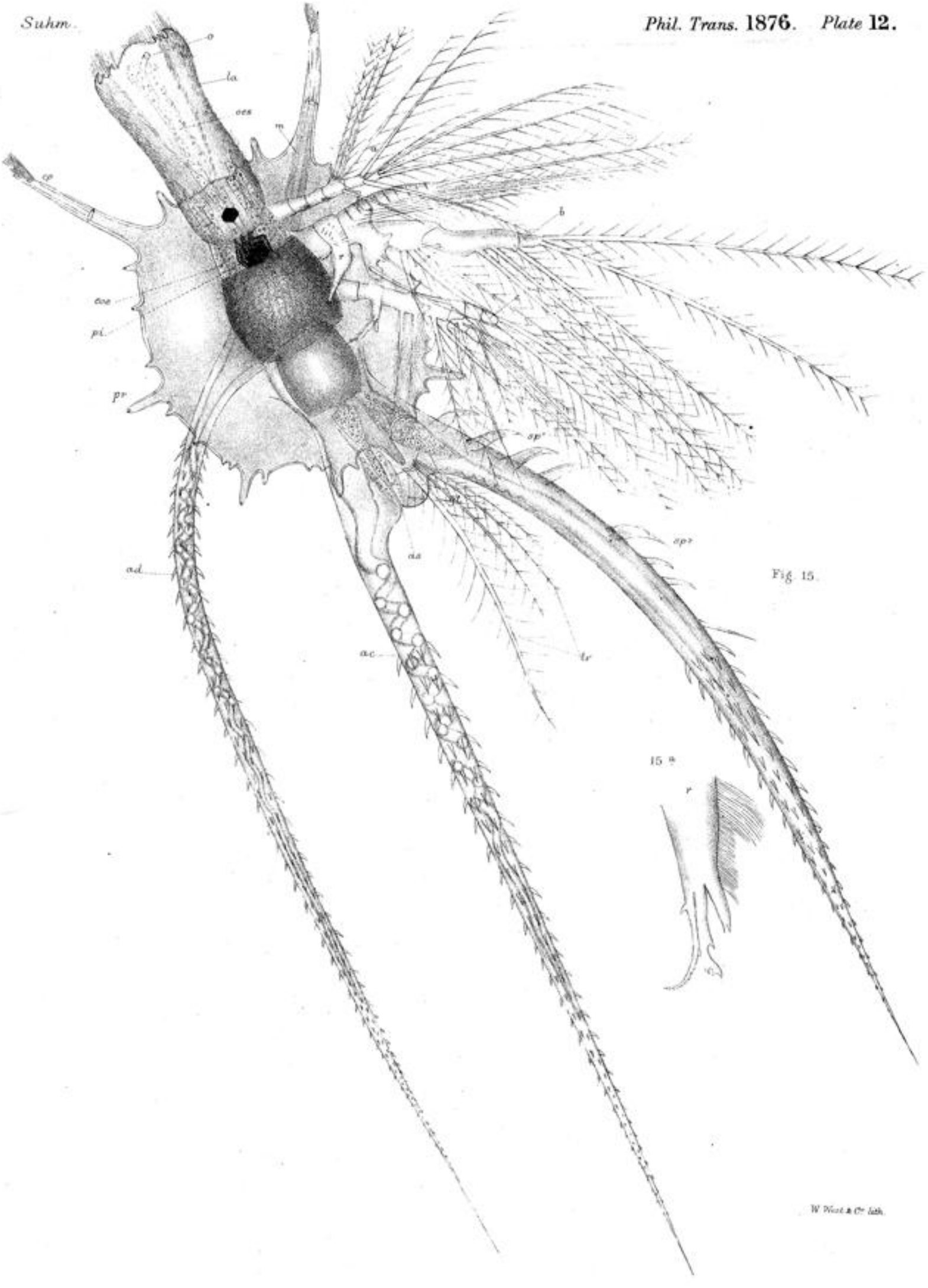

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