XXXIV. *On the Organization of the* Brachiopoda.

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HAVING been engaged for some time past in the investigation of the anatomy of the Brachiopods, I beg to lay before the Royal Society the results of my labours; and I am the more anxious to do so as some differences of opinion have arisen among naturalists respecting the structure of these interesting animals.

Four years ago I had occasion to dissect *Waldheimia australis*, *Terebratulina caput-serpentis* and *Lingula anatina*, and was then struck with the peculiar appearance of the organs denominated hearts by Baron CUVIER, Professor OWEN, and all subsequent writers on the subject. These so-called hearts seemed to me very unlike any molluscan heart that had ever come under my observation; and on attentive examination it became evident that they give off no arteries as they had been described to do; and moreover that their apices, from which the arteries were stated to pass, appeared to open externally. For these, and for other reasons, I was inclined to disbelieve in their cardiac nature, and to regard them rather as oviducts.

I examined at the same time, with considerable care, the alimentary tube of the *Terebratulidæ*, my attention having been particularly drawn to this matter by Mr. WOODWARD, who pointed out that the intestine appeared to him to terminate, not as described by Professor OWEN, but within the visceral chamber. I found this to be the case; and though I failed to demonstrate an anal outlet, yet was disposed to believe in the existence of a minute anal puncture, and thought the refuse of digestion might possibly make its escape by the foramen of the peduncle. However this might be, it was quite obvious that no anal aperture was situated in the pallial chamber in the two species examined. In *Lingula*, indeed, the anus was easily observed, placed at the right side, between the margins of the mantle. I also examined the muscular apparatus, and likewise the nervous system; and the complicated structure of the mantle was found to invite further investigation.

Other and more urgent matters, however, at that time claimed my attention, and all further inquiry into the structure of the Brachiopods was necessarily deferred. The results obtained were nevertheless partially made known, and have to a considerable extent been substantiated by the more recent investigations of Professor HUXLEY, who in 1854 published a very important paper on the anatomy of the Brachiopods, in the 'Proceedings of the Royal Society.' In this paper the author arrives at the conclusion that in *Waldheimia* and *Rhynchonella* there is no anus at all; but that the intestine terminates in a blind sac within the visceral chamber; that the so-called hearts give off no arteries, and that they possibly open externally. Mr. HUXLEY also describes, for the first time, a system of ramified peripheral channels, and two or three pyriform vesicles, one of which is attached to the stomach, and is in connexion with a series of "ridges" and "bands." Some of these ridges are stated to pass from the so-called hearts to the genitalia; and the whole apparatus is regarded as forming a portion of the circulatory organs.

It is chiefly on the points thus raised by Professor HUXLEY and myself, respecting the vascular and alimentary systems, that there is a difference of opinion,—Professor OWEN maintaining the generally received belief in the existence of an anal aperture situated in the pallial chamber in the *Terebratulidæ*, as well as in *Lingula*; and that the so-called hearts are true vascular centres propelling the blood through arteries to the various organs.

Such being the case, a thorough investigation of the facts had become necessary. I have therefore applied myself most diligently and earnestly to the subject, fully impressed with a sense of the weight of authority opposed to the views I entertain in common with Professor HUXLEY, and with the most anxious desire to establish the truth, as it is of some importance that the anatomy and physiology of these, apparently, much misunderstood animals should be accurately determined.

In a short communication which I made to the Meeting of the British Association held at Cheltenham last year[1], the results up to that time were specified, as far as they related to the matters in dispute. On the present occasion, however, I shall not confine myself to these points; but purpose giving in the following pages, as far as possible, full and complete details of the entire anatomy of such of the Brachiopods as have come under my observation. And here it must be stated that I should never have been able to enter upon this subject, with any chance of success, had I not had at my command an ample supply of specimens, and that I am indebted for this great advantage to the liberality of Dr. GRAY, Mr. WOODWARD, Mr. DAVIDSON, Mr. HUXLEY, Mr. MCANDREW, Mr. ALDER, and Mr. LECKENBY. My best thanks are therefore due to these gentlemen for having placed at my disposal specimens of the following species:—*Waldheimia australis*, *W. cranium*, *Terebratulina caput-serpentis*, *Rhynchonella psittacea*, *Lingula anatina* and *L. affinis*[2]. These are the only forms that I have dissected, though I have enjoyed the opportunity of seeing the animal, in a more or less perfect state, of one or two other species, to which allusion will, occasionally, be made in the following pages.

The shells of the Brachiopods are now so well known that it would seem quite unnecessary to give here any detailed account of them. But it may perhaps be as well to observe that they are formed upon two distinct plans, one having the valves articulated, the other having them unarticulated. *Waldheimia* is a type of the former, *Lingula* of the latter. Those with articulated valves have the hinge generally furnished with teeth and corresponding sockets, which so lock the valves together, that their action is very

[1] Report of the British Association for 1856; Transactions of the Sections, p. 94. [2] Note 1, p. 850.

limited, and that on separating them fracture ensues. In the unarticulated forms the valves do not move upon each other, for when open no part of their margins are in contact; there is no hinge, properly so called, and like the former group their gape is extremely limited; at least such is the case in *Crania*, which has been observed in a living state.

The two divisions of the Brachiopods thus indicated, at the outset of our inquiry, will be found, as we proceed, still more strongly marked by their internal organization.

The valves, as generally acknowledged, are placed on the dorsal and ventral surfaces of the animal; the imperforate being the dorsal, the perforate the ventral valve in the *Terebratulidæ* and their immediate allies[1]. Thus that side which is *below* when the animal is attached by its peduncle is really the back. If this were ever doubted, the discovery of the true heart, as we shall afterwards see, confirms the accuracy of Professor OWEN'S determination of these points. In *Lingula*, the large valve, or that to which the peduncle is attached, corresponds to the perforate or ventral valve of the *Terebratulidæ*, the small one to the dorsal.

To facilitate the examination of the soft parts, it is necessary to reduce the valves by dissolving them in dilute acid. When the calcareous matter has entirely disappeared, and the decalcified shell-membrane has been removed, the transparent tegumentary envelope of the animal is exposed to view; and this, when placed in water, assumes the form of the shell[2]. The pallial lobes extend forward, but do not project beyond the sides of the body, where they become united, the junction being marked by a groove, bordered by a ridge on each side. They are very delicate and transparent, so that the great pallial sinuses can be distinctly traced, even to their terminal ramifications; and the genitalia, which lie within them, appear through their walls of a full yellow colour. Towards the posterior or umbonal region the enlarged extremities of the shell-muscles are always apparent, clustered together, on each side of the antero-posterior line, forming reddish flesh-coloured patches. On the dorsal surface the liver is seen occupying the space between the muscles, and on the ventral, the termination of the intestine makes its appearance as a minute, circular point, immediately behind the central or occlusor muscles in *Waldheimia australis*. In *Rhynchonella* it is seen in the same position enlarged, rounded and doubled upon itself[3].

On turning the pallial lobes back, the arms[4] are found to occupy almost the entire pallial cavity, which is very extensive, reaching backwards for two-thirds the length of the shell; the posterior third being filled up with the body of the animal. The mouth opens upwards, on the median line, in the brachial groove; and on each side of it, a little below, in the anterior wall of the body, there is an opening which leads into the abdominal cavity or perivisceral chamber. These orifices are situated at the apices of the two elongated organs designated hearts by Professor OWEN[5]. These so-called hearts

[1] Note 2, p. 851.
[2] Plates LII. and LIII. figs. 1, 2.
[3] Plate LX. fig. 2.
[4] Plate LV. figs. 1, 2.
[5] Introduction to Mr. DAVIDSON'S 'British Fossil Brachiopoda,' published by the Palæontographical Society, p. 14, 1853.

are partially buried in the parietal membrane, and are generally seen shining through of a yellow colour.

No anal aperture can be detected in any of the articulated Brachiopods that have come under my observation, either at the point where the intestinal tube terminates or within the pallial cavity, or anywhere else. Thus it would appear that in this group there are three external orifices, two being at the apices of the pseudo-hearts, the third is the mouth. In *Rhynchonella*[1], however, there are five openings, this genus having four of the so-called hearts or oviducts, two of which are situated as in the *Terebratulidæ*, and two above the mouth, one being at each side of the liver.

In *Lingula*[2] the body of the animal is depressed, and occupies a much larger portion of the shell-cavity than it does in either the *Terebratulidæ* or *Rhynchonellidæ*. The pallial lobes are rather stout; but the great sinuses are nevertheless distinctly seen through their membranes; they are not united behind, as in the articulated Brachiopods, but are free and extend some distance from the body all round the posterior or umbonal region. The body thus becomes well defined, the lateral walls being at right angles to the dorsal and ventral. The two latter are very delicate, and so transparent that the viscera are quite apparent through them, the liver and genitalia being the most conspicuous. The lateral parietes are strong and muscular, and, having their edges attached to the valves, give a definite form to the enclosed space, which is wide, rounded in front and tapering backwards.

On turning back the ventral pallial lobe[3] the arms are observed occupying the greater portion of the pallial chamber, which is about half the length of the shell. The mouth is situated, as in the *Terebratulidæ*, in the brachial groove; and on each side of it, a little below, are the ovarian outlets, which penetrate the anterior wall of the body. On the right side of the animal, between the margins of the mantle, is placed the anal orifice, which is very distinct and easily detected.

The best view of the viscera is obtained, in the articulated forms, by laying open the dorsal wall of the body, along the central line, from the umbo to the anterior wall. In this way all the organs[4] are seen in their natural positions, lying within the perivisceral chamber. The alimentary tube is observed extending from the front to the posterior extremity of the chamber, the anterior portion, the stomach, being somewhat enlarged, and partially concealed beneath the two lateral divisions of the folliculated liver. The true heart, in the form of a rather large, pyriform vesicle, is appended to the dorsal surface of the stomach; and on each side of the chamber, above and below, is an accessory pulsatile vesicle. A little behind the heart, at the sides, are the oviducts, two large funnel-shaped organs with laminated interiors,—the hearts of Professor Owen. The four genital organs are placed at the sides, above and below, protruding, from the great pallial sinuses, into the perivisceral chamber; and the various muscles are seen arranged at each side of the alimentary tube stretching from wall to wall.

[1] Plates LV. fig. 3; LX. fig. 3.
[2] Plates LXIV. figs. 1, 2; LXVI. figs. 1, 3.
[3] Plates LXIV. fig. 3; LXVI. fig. 2.
[4] Plates LII. fig. 10; LIII. fig. 5; LIV. figs. 1, 2.

On removing the dorsal parietes in *Lingula*[1], the alimentary tube is found to occupy a central position as in the articulated tribes, the anterior portion being buried, as in them, beneath the lobulated liver, which is rather bulky. On displacing the latter, the heart is seen attached to the upper surface of the stomach, and the two dorsal genital organs are entirely exposed, extending nearly the whole length of the perivisceral chamber. At the sides and in front of these are the extremities of the muscles, and behind are the convolutions of the intestine. The pseudo- or Cuvierian hearts are hidden below the genitalia and muscles.

Having taken this general survey of the external and internal parts, we shall now examine, in detail, the various systems of organs, beginning with that of the muscles.

Muscular System.

In the Brachiopods the muscular system is very complicated and peculiar in its arrangement. Five or six pairs of muscles have been described in the *Terebratulidæ*, all of which have relation to the movements of the valves upon each other, or to their attachment to, or movements upon the peduncle. Thus the muscles naturally divide themselves into two groups,—the valvular, and those for adjusting the shell to the peduncle. Of the former there are three pairs, which have been denominated respectively adductors, cardinals and accessory cardinals; of the latter there are likewise three pairs, which have deen designated the dorsal pedicle muscles, the ventral pedicle muscles, and the capsular muscles. The capsulars, however, are generally blended into one, and in this state they have been named "capsularis" by Professor Owen[2].

Before entering upon the description of these several pairs of muscles, it is necessary to say a word or two on the names they have received, which do not appear satisfactory. The epithets cardinal and accessory cardinal given to two of the pairs of valvular muscles are objectionable, for they would seem to imply that these muscles presided exclusively over the movements of the hinge, or that they are exclusively the muscles of the hinge. They open the valves, the adductors close them. In this sense these, as well as the others, might be called cardinal muscles, all being equally related to the hinge; but surely it is improper so to name the first-mentioned muscles, and not the last. And as to the attachment of the first-mentioned to the cardinal process, this should not entitle them to be called cardinals any more than the dorsal pedicle muscles, which, being inserted into the hinge-plate, in most instances, would seem thereby to have equal claim to the title. These epithets will therefore be discarded, and those of divaricator and accessory divaricator substituted. The adductor muscles will be named the occlusors, the present denomination not being sufficiently precise.

With regard to the pedicle muscles, these, as will be afterwards shown, having the office of adjusting the shell to the peduncle, will receive the name of adjustor muscles. This alteration is also rendered necessary because the capsular is really the peduncular muscle, and will be so denominated.

[1] Plates LXIV. fig. 4; LXV. fig. 3; LXVI. fig. 1.

[2] Introduction to Davidson's 'British Fossil Brachiopoda,' p. 8.

In *Waldheimia australis*[1] the occlusors have their inferior or ventral terminations placed close together, forming an elongated oval mass, which is attached to the valve about one-third the length of the shell from the beak or perforate extremity on the median line. From this point they pass diagonally upwards and forwards towards the imperforate or dorsal valve, continuing united for some distance; they then separate, and diverging laterally, become much attenuated and assume the form of tendons. Up to this point they are firmly attached to the anterior wall of the body, but beyond it become perfectly free. Each muscle then almost immediately divides into an anterior and posterior portion, which run parallel to each other, on either side of the alimentary tube and liver, and on reaching the dorsal valve are each attached to it by a distinct, much enlarged extremity, at a little distance from the median line. These two divisions of the occlusor muscles have been denominated by Professor OWEN "adductor longus anticus," and "adductor longus posticus" respectively[2], and in this paper will receive the distinctive appellations of anterior and posterior occlusors. The former is considerably the stouter, and the enlarged attachment of both are seen close together at the surface of the body after the shell has been removed; they are of a pyriform contour, the pointed end of the anterior and larger being inclined inwards and backwards, that of the posterior in the opposite direction. All the four dorsal extremities are of a reddish flesh-colour, resembling muscle; but with this exception, the muscles are throughout dense, glistening and tendon-like, even including the enlarged ventral extremities. These muscles are undoubtedly for the purpose of closing the valves.

The divaricator muscles arise from the ventral valve, one on each side, a little in advance of, and close to the united bases of the occlusors. These extremities are large, fleshy, and of a reddish-yellow colour; they rapidly diminish in size, and attain the appearance of white, glistening tendons; and, having the intestine between them, converge as they pass backwards and upwards towards the cardinal process, into which their superior, attenuated extremities are inserted in close contiguity.

The accessory divaricators are a pair of small muscles which have their enlarged carneous ends attached to the ventral valve on each side of the median line, a little behind the united bases of the occlusors, and the termination of the intestine is seen immediately in front of them. At the surface of the body they appear as two oval reddish discs, and they become, almost at once, reduced into flattened tendons, which, running parallel to each other, incline upwards and forwards, course round the inner extremity of the peduncular capsule, to the upper surface of which they become firmly united, and as they advance blend some of their fibres with those of the divaricators, and go thus united with them to be inserted into the extreme point of the cardinal process.

The function of these two pairs of muscles is obvious enough; it is to open or divaricate the valves. The cardinal process projecting backwards beyond the hinge or fulcrum formed by the teeth and sockets, when these muscles contract the process will be drawn inwards, and consequently the anterior margins of the valves separated, the action being that of a lever of the first order. This peculiar mode of opening the valves

[1] Plates LII. figs. 2, 10; LIV. fig. 1; LVII. figs. 1, 2; LXII. fig. 1.

[2] *Op. cit.* p. 8.

appears to have been first pointed out by Professor QUENSTEDT[1]; and this characteristic feature of the articulated Brachiopods was commented upon and fully appreciated by its discoverer.

Though this is undoubtedly the primary function of the two pairs of divaricators, yet as they are intimately united to the capsule of the peduncle, when in action they will likewise pull it downwards towards the ventral valve, thus giving room for the cardinal process to pass inwards, which it must always do when these muscles are in action. And moreover, from the position of the ventral attachment of the accessory divaricators, and from their coursing round the base of the peduncular capsule to their superior attachment, it is evident that whenever exerted they will have a tendency to thrust out the peduncle. Thus the opening of the valves must always be accompanied by an elevation of the animal upon its support, though this can never be to any great extent.

The peduncle, being the medium by which the Brachiopod becomes attached to foreign bodies, is the fixed point upon which the limited movements of the shell are effected; and the adjustor muscles, having one of their extremities attached to this organ, may be considered as taking their origin in it. It will therefore be well, before describing them, to examine the structure of the peduncle itself. This organ[2] is composed of a dense muscular or semi-cartilaginous mass of a cylindrical form, with one extremity exserted through the foramen of the ventral valve, and the other resting within its umbonal region. The protruded extremity is protected by a thick, horn-like covering of a brownish colour; it is short and stout, possessing little or no elasticity, and has a fibrous expanded base of attachment. The inner extremity is enlarged, and is received into a capsule, which is formed by the invagination of the tegumentary envelope at the margin of the foramen. The peduncle is attached to the bottom of this capsule, through which it sends a wide, narrow belt of muscular fibres, to be inserted into the valve immediately behind the accessory divaricators. This muscle is short and white, like the muscular portion of the peduncle, and appears at the surface of the tegumentary envelope as a narrow, transverse, pale patch, extending almost across the umbonal region. This is, as previously stated, the "capsularis" muscle of Professor OWEN. Its function, however, is not merely to attach the capsule, but is in an especial sense to unite the peduncle to the shell, as proved by the homologous muscle in *Lingula*, and by the direction of its fibres, which are the continuation of those forming the core of the peduncle, or more properly the peduncle itself, running from one end of the organ to the other. When in action, it will have the effect of erecting the shell and steadying it upon the peduncle.

The movements of the shell, however, upon this support, will be chiefly effected by the action of the adjustors, of which we have seen there are two pairs, the dorsal and

[1] "Ueber das Œffnen und Schliessen der Brachiopoden," WIEGMANN's Archiv, vol. ii. pp. 220–222, pl. 4. figs. 4, 5, 6, 1835.

[2] Plate LVII. figs. 2, 3, 4.

ventral. The former of these are attached to the ventral surface of the peduncle, forming a dense mass by the intermingling of their fibres; they pass, one from each side of the peduncle near its inner extremity and just above the origin of the peduncular muscle, through the capsule forwards and upwards, diverging a little and having the divaricators between them, to be inserted into the hinge-plate, one on each side, a little in advance of the cardial process. At the point of insertion each seems as if formed of two portions. These muscles, throughout their whole length, are yellowish, fibrous and fleshy, and not much enlarged at their insertions.

The ventral adjustors pass from the inner extremity of the peduncle, and penetrate the capsule on each side, a little above the dorsal pair; they originate in a firm mass cemented to the dorsal surface of the peduncle, very similar to that which connects the other pair to this organ: the two masses give a bulbous form to the inner extremity of the peduncle. At first the muscles are delicate and tendinous; but coursing downwards and forwards they rapidly enlarge and become attached to the ventral valve, one on each side of, and a little behind, the expanded base of the divaricators. They form the external pair of muscular discs seen, when the shell is removed, clustered together towards the umbonal region of the ventral surface. These discs are of a reddish colour, and in size and shape resemble those of the divaricators, being of an irregular oval form.

The two pairs of adjustor muscles are evidently for the purpose of moving the shell upon the peduncle, and to some extent are antagonistic to each other. When the dorsal pair are contracted and the ventral relaxed, the shell will be depressed, and they elevate it on this action of the two muscles being reversed. But their chief function would appear to be, to rotate the shell from side to side; this will be effected by the right and left muscles of each pair alternately contracting and relaxing. The shell will be firmly fixed and the peduncle withdrawn to the fullest extent, when both these pairs and the peduncular muscle are in a state of contraction.

The arrangement of the muscles is essentially the same in all the articulated Brachiopods that have come under my observation. There are, however, one or two rather interesting modifications of detail, even in the *Terebratulidæ*, which require particular notice. The first of these occurs in a species so like *W. australis*, that I took it, at first, to belong to that form, but am now inclined to think that it must be distinct from it[1]. In this[2] the divaricators and their accessories are united so as to form only a single pair, the attachment of the muscle to the ventral valve extending all the way from the peduncular muscle to considerably in advance of the occlusors. The connecting portion, however, is much attenuated, forming as it were a narrow neck of communication between

[1] It appears that more than one species is included under the name of *Australis*. The specimen above alluded to was very large and fine, with the anterior margins of the valves much and suddenly bent inwards, and the ribs few and very large; it resembled figs. 25 and 28, plate 69, of the 'Thesaurus Conchyliorum' of SOWERBY.

[2] Plates LII. fig. 3; LIV. fig. 1; LXII. fig. 4.

the two, when the muscle is exposed at the surface of the body; thus seen, the extremity has somewhat the shape of a battledoor; and the pair meeting behind almost entirely enclose the occlusors and the terminal extremity of the intestine. Though thus altered and combined into one, the function of this single pair of muscles will be exactly the same as when divided into two, as the areas of attachment are not materially changed. It will, in fact, open the valves and at the same time protrude the peduncle; but on account of the combination, the two actions may perhaps be rendered more harmonious, and probably somewhat invigorated.

Another and more important modification obtains in *W. cranium* and *T. caput-serpentis*[1]. In these two species the dorsal adjustor muscles are not attached to a hinge-plate, as in *W. Australis*, but have their insertions in the valve itself, and are very large and powerful. In both species the superior extremities of these muscles are seen at the surface of the animal, on each side of the median line, elongated in the antero-posterior direction, and extending between the occlusors almost as far forward as their anterior margins. They are enlarged posteriorly, particularly in *T. caput-serpentis*, in which they are of an irregular form.

The divaricators and the accessory divaricators in *W. cranium*[2] are likewise united in the same manner as in the species before alluded to.

The modification of the dorsal adjustor muscles cannot be of much importance in a physiological point of view; it will, however, increase their power in proportion as the area of their insertions is extended. Moreover, these muscles are largely developed as well as the ventral pair. It would therefore seem probable that the movements of the shell upon the peduncle, in these species, may be more extensive and livelier than usual. But to the palæontologist, to whom the muscular impressions in fossils are of great value, these modifications cannot fail to possess considerable interest, evincing as they do to what extent the arrangement of the muscles may be modified without any essential change in the economy of the animal. In the dorsal valve there may be, as in the above examples, as many as six muscular impressions instead of four, and in the ventral there may be two less than usual; facts sufficiently puzzling without the light of anatomical investigation. It is also worthy of remark, that in those species with the dorsal adjustor muscles attached to the valve there is no hinge-plate[3]; and therefore it may be presumed that in the fossil species with this plate deficient the muscles will be arranged in the same manner.

In *Rhynchonella psittacea*[4] the general disposition of the muscles is the same as in *W. australis*, only they are longer and more slender, particularly the occlusors, which, with the exception of their extremities, are thin and tendinous. The surfaces of attachment also vary a little in form, as can be readily seen on removing the shell. The extremities of the muscles are then observed, as usual, at the ventral surface of the animal, clustered together, a little in advance of the umbonal region. The occlusors are almost

[1] Plates LIII. figs. 1, 3, 5; LXII. fig. 2.
[2] Plate LIII. fig. 4.
[3] Plate LII. fig. 5.
[4] Plates LX. figs. 1, 2; LXI. figs. 1, 2.

colourless, narrow and elongated, and have their anterior margins united on the median line; posteriorly they diverge, leaving a space between them, in which the terminal extremity of the intestine is seen. The divaricators are very large, and are placed external to, and in contact with, the occlusors; they are broad and fan-like in front, exhibiting radiating divisions, and meet on the median line, in advance of the occlusors. Behind they are produced and pointed. The ventral adjustor muscles have their extremities narrow and much elongated; they rest against the external margin of the divaricators, are enlarged a little, and converge posteriorly. Unlike *Waldheimia*, there is here *a pair* of peduncular muscles seen at the sides of the umbo, having between them the accessory divaricators, which are of a somewhat triangular form. The dorsal terminations of the occlusors present nothing remarkable in their appearance. All the extremities of the muscles seen at the surface of the animal are of a yellowish-red colour, except those of the peduncular muscles and the ventral terminations of the occlusors.

In the unarticulated Brachiopods, taking *Lingula*[1] as the type, the muscles are exceedingly complex in their arrangement, even more so than in those already examined. In all six pairs have been described, the whole of which, having both extremities attached to the valves, might be denominated valvular muscles; but only a portion of them can be looked upon as the equivalents of those so attached in *Waldheimia*. They have been divided by previous writers into adductors and sliding muscles, the latter being again subdivided into protractors and retractors.

It is necessary to alter these latter epithets, as they imply what appears to be a false theory, namely, the sliding of the valves over each other; and as it is desirable to make still further changes in the nomenclature, the names that the muscles have already received are placed below, with those now proposed for adoption. The names of the homologous muscles of the articulated Brachiopods are appended, so that the relation of these organs in the two groups may be seen at a glance.

Names in use.	Names proposed.	Names of homologous muscles of articulate Brachiopoda.
Anterior retractors . . .	Anterior occlusors . .	Anterior occlusors.
Anterior adductors . . .	Posterior occlusors . .	Posterior occlusors.
Posterior adductors. . .	Divaricators	Accessory divaricators.
Central protractors . . .	Central adjustors . . .	Ventral adjustors.
External protractors . .	External adjustors . .	
Posterior retractors. . .	Posterior adjustors . .	Dorsal adjustors.
Capsular	Peduncular	Peduncular.
	Anterior parietals.	
	Posterior parietals.	

The anterior occlusors are a pair of stout muscles, of about equal thickness throughout; they pass from the ventral valve, one at each side, in front of the visceral mass, close to the lateral walls of the body, and a little behind the transverse centre of the

[1] Plates LXII. fig. 3; LXIV. figs. 4, 5; LXV. figs. 2, 3.

shell; inclining forwards and inwards, they go to be attached to the sides of the central ridge of the dorsal valve, about one-third the length of the shell from the anterior margin. The dorsal extremities are compressed, and have their sides in contact.

The posterior occlusors are rather stouter and much shorter than the anterior pair, and go directly from valve to valve, parallel to each other, one a little on each side of the longitudinal central line. They run internal to the anterior occlusors, and are just sufficiently apart from each other to allow the passage of the alimentary tube, which rises up between the anterior pair. The ventral extremities of the posterior occlusors are placed a little in advance of the corresponding terminations of the anterior pair, and the dorsal extremities of the former are situated a little behind those of the latter. The dorsal ends of the posterior occlusors are partially encircled by the gastro-parietal bands.

These two pairs of muscles are mainly instrumental in closing the valves, and there can be little doubt that they homologically represent the occlusors of the articulated Brachiopods. There are here, however, four distinct muscles; in *Waldheimia* we have seen that the two pairs are blended at their ventral extremities. Both pairs in *Lingula* are attached to a transverse fold of the anterior wall of the body, which is also the case with the occlusors in the articulated species; and in them, and in *Lingula*, the œsophagus is similarly related to these muscles. In the latter species the anterior occlusors are inclined, and in this respect resemble the closing muscles of the *Terebratulidæ*, and particularly the anterior pair, which are the more inclined of the two. The posterior occlusors are peculiar in going direct from valve to valve; but that they are the homologues of the so-named muscles in *Waldheimia*, appears proved by their relation to the gastro-parietal bands, which is the same in both cases.

The divaricator, though forming a single mass, is really two muscles combined. It is stout and short, and is situated at the posterior extremity of the perivisceral chamber, passing directly between the valves, and having its attachments immediately within the umbones: the extremities have a semicircular form, arched behind and slightly bifid in front, indicating its double nature. This muscle is perhaps the equivalent of the divaricators in *Waldheimia*, though it seems more likely that it homologically represents only the accessory divaricators, which in position exactly agree with it. And that portion of the intestine which corresponds to the intestine in the *Terebratulidæ*, terminates in front of it, at the ventral wall of the body, just as the intestine does in them.

The action of the divaricator is to approximate the umbonal regions, and thus, pressing forward the fluid in the perivisceral chamber, to open the valves in front. Other muscles are, however, likewise employed to assist in this office. The lateral walls[1] of the body are thick and strong, being amply supplied with transverse muscular fibres which pass from one valve to the other. The fibres are strongly developed towards the posterior extremity of the chamber, where they form a thick inner layer. These may be denominated the posterior parietal muscles. The walls of the anterior recess of the

[1] Plate LXVI. figs. 1, 3, 4.

perivisceral chamber are also well supplied with fibres. In front a powerful muscular band, in connexion with the parietes, extends along each side, above the oviducts, from the anterior wall of the chamber to behind the dorsal extremities of the adjustors: these are the anterior parietals. As the walls, with which these two sets of muscles are connected, arch outwards when they are relaxed, it is evident that when in action they will straighten the curvature, and thus diminish the capacity of the perivisceral chamber. The posterior parietals will also assist in drawing together the umbonal regions of the valves. Now when the divaricator muscle contracts and the anterior occlusors relax, the fluid contained in this chamber will be pressed forward; the anterior parietals then coming into play compress the space in front, and the lateral walls behind losing their curvature and becoming firm and resistent, from the action of the posterior parietals, the valves will be constrained to open anteriorly. This, there can be little doubt, is the mechanism employed in opening the valves in *Lingula*; and it is probably the same in all the unarticulated Brachiopods: we know that in *Crania* and *Discina* the muscles are arranged after the same plan, and the muscular impressions in the fossil species would seem to indicate that in them also they were similarly disposed.

The pair of central adjustors are attached to the ventral valve, by fine points, between the posterior occlusors in front; they are placed close together, one on each side of the median line: sweeping round the inner border of these muscles they diverge posteriorly, and, increasing in size as they go, ascend towards the dorsal valve, to which they become adherent, one at each side immediately within the parietes of the body.

The external adjustors arise from the ventral valve, at the outside of the posterior occlusors, and in contact with them; they are at first pretty stout, but on passing outwards and backwards they enlarge a little, and ascending are inserted into the dorsal valve, one on each side immediately behind the central pair.

The posterior adjustors are large and powerful muscles, and though they may be considered as a pair, they are asymmetrical, there being two on one side, and only one on the other. As they pass across from valve to valve they intersect each other, the single one passing between the other two. These are the decussating muscles of authors. The single one is as large as the other two put together, and is attached to the left side of the ventral valve about midway between the divaricator and the anterior occlusor. From this point it passes diagonally upwards and forwards between the reproductive organs, having the alimentary canal above it; and on reaching the opposite side of the dorsal valve, has the other end inserted into the latter, immediately within the posterior terminations of the external and central adjustors of the same side. At the points of attachment the three muscles are pressed so close together, that they appear, at first sight, as only one.

The two opposite posterior adjustors take their origin from the right side of the ventral valve, considerably apart; but both of them close to the lateral parietes of the body, one only a little in advance of the divaricator, and the other a short distance further forward. They converge as they penetrate the visceral mass, and, sloping forward, one on each side of the single muscle, with the alimentary tube above them, they ascend to their insertion into the left side of the dorsal valve directly within those of the external and central adjustors. Therefore, at this point, there are the terminations of four muscles in close contact.

The three pairs of adjustors are apparently for the purpose of keeping the valves opposed to each other,—of holding them adjusted; and in this respect they seem well calculated to compensate for the deficiency of a hinge and condyles, which are entirely wanting in *Lingula*. The external and central pairs having their anterior extremities attached to the ventral valve (which as it is fixed to the peduncle is that from which all the muscles act) and their posterior ends to the dorsal, it is evident that they will prevent the latter from being forced backwards; while the posterior adjustors having their posterior terminations united to the ventral or fixed valve, and their anterior to the dorsal, they will act in the contrary direction and guard against any pressure forward. They will also at the same time prevent any lateral displacement of the valves, as their diagonal position will enable them to act transversely as well as longitudinally. And the external and central adjustors will, on account of their oblique arrangement, likewise exert a similar double influence in front.

Indeed the attachments of the various muscles are so distributed around the margin of the perivisceral chamber, that transverse, longitudinal and diagonal movements are alike guarded against. And perhaps their true functions are best understood when thus considered in co-operation; it is then seen that they form a complicated complementary system for the purpose of assisting in adducting the valves, their various points of attachment and different inclinations being so arranged, that, in whatever state of action they may happen to be, they will always keep the valves steadily and accurately opposed to each other. When all these muscles are contracted, and the occlusors and divaricators co-operate, the valves will be forcibly held together and capable of resisting considerable violence.

The adjustor muscles have had, however, a very different office assigned to them by Cuvier[1] and Owen[2], and by all subsequent writers on the subject, who have denominated them sliding muscles, believing that they were for the purpose of moving the valves over each other, and thus opening them. And it must be admitted that they would seem capable of performing the function attributed to them by these distinguished physiologists. But it may be asked, where is the necessity, and what is the probability of the existence of any such sliding motion? In the Lamellibranchs nature seems to have exhausted her ingenuity in a variety of plans to prevent the sliding of the valves; and in the articulated Brachiopods we find extraordinary means adopted to attain the same end. In the latter, the valves are not only not permitted to move over each other, but the teeth of one are so locked into the sockets of the other that their gape is exceedingly limited,

[1] "Mémoire sur l'animal de la Lingule," Mémoires pour servir à l'histoire et à l'anatomie des Mollusques, 1817.

[2] Lectures on Comparative Anatomy, 2nd ed. p. 489, 1855.

as if it were necessary to avoid disturbing the internal parts by a too extensive action even in this direction.

Now, the organization of *Lingula* is so similar to that of the *Terebratulidæ* as to make it difficult of belief that all this precaution, to prevent the displacement of the valves, should be necessary in the one case, and that in the other a special apparatus should be provided to bring it about. As *Lingula* is deprived of a hinge, teeth, and sockets, should we not rather expect to find some especial means provided to compensate for such important deficiencies? And do we not see in the large development and complicated arrangement of these muscles such compensation? This can hardly be doubted; and in corroboration of this opinion it may be stated, that Mr. BARRETT, who has had the opportunity of observing *Crania* alive, states that it opens the valves "by moving upon the straight side as on a hinge without sliding the valve[1]." This would seem almost conclusive.

The homologues of the adjustor muscles cannot be determined with any great degree of confidence, though it would seem probable that they represent the muscles so named in the articulated Brachiopods. From their posterior position this might perhaps be inferred, and the relation of the ventral terminations of the external adjustors to those of the posterior occlusors, is very similar to the relation of the ventral adjustors to the terminations of the occlusors in *Waldheimia*. It would therefore seem likely that the external and central adjustors are the equivalents of the ventral adjustors of that genus. It does not signify much that in *Lingula* these muscles are divided into two pairs; for we have seen in *Waldheimia* the liability of the muscles to become double. If this determination be correct, then the posterior occlusors will be homologous with the dorsal adjustors of the articulated group. Mr. WOODWARD states, in his excellent Manual[2], that some of these muscles in *Discina* are probably inserted into the peduncle, and if so the likelihood of this view of their homology would be greatly enhanced. It is therefore most desirable that the muscular system of this genus should be fully investigated.

Before describing the peduncular muscle it is necessary to examine the peduncle itself. This is enormously developed; in one of the specimens dissected it was upwards of $9\frac{1}{2}$ inches long; it is stout at the upper extremity[3], but suddenly contracts at its junction with the valve; below it tapers considerably. On making a transverse section[4], it is found to be cylindrical and a little flattened, with the walls formed of two thick concentric layers, as described by Dr. C. VOGT in his paper on the Anatomy of *Lingula*[5]. The external layer is homogeneous, semi-pellucid, yellowish, and horn-like; the inner is opake, of a yellow colour, and is composed of longitudinal muscular fibres. This muscular cylinder extends from end to end, and is rather abruptly constricted as it approaches the ventral valve and is transformed into the peduncular muscle; the central channel appears to be continued through the muscle, and is brought into communication

[1] Ann. and Mag. of Nat. Hist. vol. xvi. p. 257, 1855.
[2] Manual of the Mollusca, p. 237, 1854.
[3] Plates LXVI. figs. 6, 7; LXII. fig. 3.
[4] Plate LXII. fig. 10.
[5] "Anatomie de la *Lingula anatina*," Nouv. Mém. Soc. Helv. vol. vii. Neuchâtel, 1845, 4to. plates 1 and 2.

with the perivisceral chamber by a narrow passage which turns round the right side of the divaricator muscle. But as the peduncle had been detached before the specimen came into my possession, I cannot speak with certainty as to these points.

The peduncular muscle itself is rather small and short, and is transversely elongated; it is formed by a continuation of the fibres of the muscular cylinder, and has its insertion immediately within the umbo of the ventral valve and close behind the divaricator; thus in position it exactly resembles the same muscle in the *Terebratulidæ*, and originates in precisely the same manner.

The wall of the peduncle is united to the external surface of the pallial expansion at the umbonal region; and just within the margin, a slight fold[1], which is a little wider than the peduncular muscle, indicates a rudimentary capsule. This organ would at once be formed if the mantle were invaginated at the fold, the peduncle thrust a little inwards, and the attachment of its muscle advanced. In this case the divaricator would also have to be pushed forward, and the adjustors becoming confounded with the peduncle and its capsule, the muscles of *Lingula* would, to a great extent, assume the arrangement of those of the *Terebratulidæ*.

The brachial and pallial muscles still claim attention; but these will be more conveniently described when we come to speak of those parts.

The muscles in the *Terebratulidæ* and *Rhynchonellidæ* are peculiar for their enlarged, fleshy extremities, and for the attenuated, tendinous character of their intermediate portions[2]. The extremities[3] are mostly of a yellow flesh-colour, and are comparatively soft, with the fibres arranged in separate radiating bundles; so that a needle may be passed between them almost as far as the centre of the muscle. The tendinous portions are dense, white, glistening, firm and rigid, and are permeated with blood channels, the larger of which run in the direction of the length of the muscle. On making a transverse section of the occlusors in *W. australis*, several such channels are observed; some of considerable size, with others branching in various directions containing blood-corpuscles. Amidst the fibres of the enlarged extremities similar corpuscles are strewed about. The fibres easily separate from each other; they are cylindrical, homogeneous, transparent and devoid of cross striæ[4], with the exception of those of the posterior occlusors, in which transverse striations[5] are vividly displayed, and give to them a very striking appearance. The fibres[6] are generally formed of three, four or more fibrillæ; but single fibrillæ are frequently observed perfectly isolated, in which the cell-like structure is beautifully distinct. It will afterwards be seen that these muscles, with cross striæ, are richly supplied with nervous filaments.

The muscles in *Lingula*[7] are fleshy and of equal thickness throughout, with the single exception of the central adjustors, which taper to their ventral attachments. The bundles of fibres, though very distinct, are not separated as in the *Terebratulidæ*, and in no instance did the fibres display transverse striæ.

[1] Plate LXVI. fig. 2.
[2] Plates LVII. figs. 1, 2; LXI. figs. 1, 2.
[3] Plate LXII. figs. 4, 5, 14, 15.
[4] Plate LXII. figs. 8, 9.
[5] Plate LXII. fig. 6.
[6] Plate LXII. fig. 7.
[7] Plate LXV. figs. 2, 3.

Alimentary System.

It will be convenient to commence the description of the digestive apparatus with that of the brachial appendages,—those beautiful and complicated organs so characteristic of the *Brachiopoda*,—not from any conviction that they are essentially portions of this apparatus, but from their connexion with the sustentation of the animal, and from their position at the commencement of the alimentary tube, it seems the natural course to pursue.

These organs are variously modified in the different families, and in the *Terebratulidæ* are supported upon a calcareous loop, in connexion with the dorsal valve, more or less developed in the different species. In *Waldheimia* this loop[1] originates in the hinge-plate in two necks or processes,—the crura, from which two points project downwards, called the crural processes. The upper or dorsal members of the loop, passing from these two lateral necks, stretch forward for about two-thirds the length of the valve, then bend towards the ventral valve, and turning back upon their course, are united across the median line a short way in advance of the crural processes. The lateral portions of the loop are curved a little outwards. The whole of this calcareous support, including the crura and crural processes, is a product of the inner lamina of the dorsal pallial lobe. This lamina, with the exception of a portion at each side, which is continuous with the similar lamina of the ventral lobe, forming with it the anterior wall of the perivisceral chamber, is turned downwards and forwards, and extends as far as the transverse portion of the loop. It then divides into two lobules, one passing to the anterior extremity of each of the lateral portions of this calcareous support, binding together the dorsal and ventral members. The loop in its sinuous course follows the margins of this bifurcated pallial process, and lies imbedded in its substance.

The arms[2] themselves taper to fine points, having taken their origin at each side of the mouth, which is situated at the back of the pallial chamber in a central position, opening downwards. They pass outwards and forwards in connexion with the calcareous loop and the pallial lobules, running along the outer edge of the dorsal member of the former; they then turn back upon the reflected or ventral part of it, and on reaching the transverse portion bend inwards and doubling sharply upon themselves, again advance and go to form two vertical spirals turned towards the dorsal valve. The spirals are placed parallel to each other, and throughout the coil, consisting of two or three turns, they are united across the median line by a rather wide, stout, semi-cartilaginous membrane, which is attached behind to the transverse portion of the loop.

The arms are normally composed of a membranous tube or canal bearing a semi-cartilaginous grooved ridge[3]. The latter stretches from end to end of the former, and gives support to the fringe of cirri. As far back as the commencement of the spirals the arms are as above stated; but for the entire length of the lateral portions of the loop, where the arms are doubled upon themselves, and where, of course, two tubes or canals might have been expected, there is only one, the two having, as it were, coalesced.

[1] Plate LII. figs. 4, 5. [2] Plates LV. fig. 1; LVII. fig. 2. [3] Plate LVI. fig. 3.

These large canals at the roots of the arms are continuous with those of the spirals, and terminate in blind sacs, one at each side of the œsophagus, close to the mouth. On making a transverse section of this part of the arm[1], the enlarged terminal portion of the brachial canal is seen connected with the external edges of the dorsal and ventral members of the loop; and the pallial lobule, stretching between the inner edges, forms a sort of flattened inner tube. This inner tube opens widely into the perivisceral chamber, is in fact a prolongation of this chamber, and terminates at the anterior extremity of the lateral portion of the loop, forming what may be designated the brachial pouches.

At the proximal extremity of the arms the semi-cartilaginous grooved ridge is continued across the median line[2]. The cirri are inserted into an elevated base behind the groove, and in front of the latter there is a stiffish membranous fold, which runs along with it and the cirri to the distal extremity. This brachial fold rising from the edge of the groove forms it into a deep, narrow gutter, within which the mouth is situated at the posterior junction of the arms, the cirri of course being behind, the fold in front. The cirri are, there can be little doubt, clothed with vibratile cilia as in the *Polyzoa*, and the currents they excite will draw the nutrient molecules down into the gutter, along which they will be hurried to the mouth, the gutter itself being undoubtedly likewise ciliated.

The cirri are very fine, somewhat compressed on the contiguous sides, stiff and rigid towards the base, and tapering and delicate towards the tips, which are rounded; they are close-set and arranged in a double series, the cirri in each alternating. Hitherto they have been generally described as forming only a single series; but this is a matter of such easy demonstration, a single transverse section[3] of the arm being sufficient to prove that there are two, that it is difficult to understand how it ever came to be asserted that there was only one. The series is double throughout, not only in *W. australis*, but in all the other Brachiopods which have been examined on this occasion, namely, *W. cranium*, *Terebratulina caput-serpentis*, *Rhynchonella psittacea*, *Lingula anatina*, *L. affinis*, and *Crania anomala*.

The cirri are undoubtedly contractile to some extent, and are also endowed with the power of motion individually, as proved by the observations of Mr. Barrett[4]. It would likewise appear that the entire fringe of cirri can be elevated or depressed, there being ample means provided for the purpose. The walls of the brachial canal are tolerably well supplied with delicate muscular fibres, which run diagonally round the tube, and are most strongly developed towards the sides near the grooved ridge. An indistinct band of exceedingly delicate, longitudinal fibres may also be observed nearly opposite to it. I have, however, completely failed to discover anything like the double spiral arrangement of fibres described by Professor Owen[5], either in *Waldheimia* or *Rhynchonella*, and cannot but believe that this distinguished anatomist has been misled by the blood-sinuses, which are very numerous in the wall of the brachial canal, form-

[1] Plate LVI. fig. 2. [2] Plate LV. figs. 1, 2. [3] Plates LVI. fig. 3; LVIII. figs. 1, 2.

[4] *Op. cit.* [5] Introduction to Davidson's 'British Fossil Brachiopoda,' p. 10.

ing minute channels which run diagonally across the muscular fibres. And this belief is in some measure confirmed by the fact, that no mention is made of this beautiful and remarkable system of sinuses in any of the several memoirs on the subject published by that observer.

From the feeble nature of these brachial muscles it does not seem likely that in *Waldheimia* the spiral portion of the arms can be unrolled. The true function of the brachial canal would seem to be to sustain the grooved ridge bearing the cirri. As the canal is a closed tube, and as it undoubtedly contains fluid, a very slight contraction of its walls will render it firm and rigid. The coil may also, perhaps, be loosened a little by the same action; thus giving greater freedom to the cirri. The grooved ridge will in this way become firmly seated, so that its movements may be regulated with precision. These are effected by a very complicated piece of mechanism, which is rendered obvious on making a transverse section of the part, when the substance of the ridge is found to be fibrous, and the fibres to be arranged in several distinct groups[1]. One of these groups is situated at the outer margin of the base supporting the cirri, and has the fibres extending from these organs downwards. This is for the purpose of drawing back or elevating the fringe. A belt of similar fibres passes from the inner margin of the cirri, and running downwards, arches conformably with the groove, and passes up the inner side of the brachial fold. These fibres will contract the fold and draw it towards the cirri, thus narrowing the gutter. Another distinct group of fibres passes from this circular belt and the outer wall of the brachial fold, and descends to the lower surface of the ridge, where there is a thin stratum of muscular fibres. The action of this group will be to pull the fold forward from the cirri; and also when fully exerted to draw the cirri themselves forward, depressing them. The thin stratum of fibres will probably assist in the latter act.

The arms of *W. cranium* and *T. caput-serpentis*[2] are disposed in the same manner as in *W. australis*; and in the former the calcareous loop is precisely similar to that of the latter; but in *T. caput-serpentis* it is very much reduced, the extended lateral portions having almost entirely disappeared, little more than the transverse portion existing; and this, together with the crural processes, which are united below across the median line, forms a collar upon which the bases of the arms rest. In this species, therefore, the expanded lateral portions of the arms are without any apophysary support, and accordingly other means are provided for sustaining them. The two produced lobules of the dorsal pallial lobe reach to the ends of these portions of the arms as in *W. australis*; and are stiffened with numerous, imbedded, calcareous spicula to such an extent, that when the soft tissues are removed by maceration the form of the parts remains unaltered. The spicula extend also over the surface of the inner lamina of the pallial lobe, and pervade likewise the walls of the canal, and even the cirri; so that the brachial apparatus becomes firmly fixed, and in this way a substitute is found for the usual apophysary support.

[1] Plate LVIII. fig. 2.

[2] Plate LV. fig. 2.

The arms of *R. psittacea* are[1] totally deprived of calcareous support except at their origin, where they are sustained by the two hinge-processes, or oral laminæ, the points of which reach as far forward as their external margins. They fill up the greater portion of the pallial chamber; and in their arrangement accurately resemble the calcareous spirals of *Atrypa reticularis*, a Silurian fossil, only their approximate sides are not flattened. The arm throughout is composed of a slightly depressed tube or canal, carrying along its outer margin the semi-cartilaginous grooved edge, bearing the fringe of cirri as in *W. australis*. The brachial fold in front of the groove is largely developed, and completely overlaps it. The tube or great brachial canal terminates at the side of the œsophagus in a delicate membranous sac of no great extent, which projects into the perivisceral chamber, as first noticed by Professor HUXLEY. The use of these sacs is not obvious, though perhaps they may be in some way connected with the limited movements of the arms; or it is not altogether unlikely that they are for the purpose of increasing the surface through which the fluids contained in the canal and chamber may act upon each other.

The parietes[2] of the great canal are somewhat stouter than in *W. australis*; the muscular fibres, however, are arranged in the same manner as in it, but are more numerous, particularly the longitudinal ones, which form a well-defined band towards the proximal extremity of the arm. There is not here, any more than in the *Terebratulidæ*, any trace of a double spiral disposition of fibres; nor is there any more reason to suppose that the brachial organs can be unrolled. The primary, if not the only, use of the contractility of the walls of the great canal, would appear to be, in *Rhynchonella* as well as in *Waldheimia*, to reduce the calibre, and by the pressure of the contained fluid to stiffen the organ so that the grooved ridge and cirri may be brought into play. A slight opening of the coil most likely takes place, and the band of longitudinal fibres seems to indicate that the first coil, at least, may be to some extent drawn in, and thus perhaps the whole brought closer up to the posterior wall of the pallial chamber. But it must not be overlooked that longitudinal fibres appear necessary to the complete action of those destined to compress the canal by preventing any tendency to the unrolling of the coil.

Professor OWEN, however, has expressed an opinion that the multispiral arms of *Rhynchonella* and *Lingula* can be unrolled and thrust out of the pallial chamber; and that in the latter genus they probably assist in opening the valves; likewise that the coiled portion of the arms of the *Terebratulidæ* can be so far unrolled, as in like manner to react upon the closed valves of the shell[3]. Such an opinion seems scarcely tenable.

A large development of the brachial apparatus seems necessary in the economy of the animal, and the various ways in which it is folded up and disposed within the pallial chamber are only so many methods of arranging within a limited space the requisite extent of organ. And there is sufficient proof, in several fossil genera, that the unrolling

[1] Plates LV. fig. 3; LX. fig. 3; LXI. fig. 2. [2] Plate LX. fig. 9.

[3] Trans. Zool. Soc. vol. i. p. 150, 1835; and Introduction to DAVIDSON'S 'British Fossil Brachiopoda,' pp. 10, 11.

of these organs is not essential to the performance of their functions. In *Atrypa*, for instance, in which the arms were rolled exactly as in *Rhynchonella*, the calcareous support prohibited not only the unrolling, but any movements whatever of the coil. It would therefore certainly be erroneous to conclude that in the latter it is necessary to the due exercise of their function, that they should be thrust unrolled out of the shell. Such an opinion can only be maintained on the ground that a special apparatus is provided for the purpose, or that direct observation shows it to be correct. We have seen, however, in this form, that no such apparatus is really in existence; and with regard to observation, we have the evidence of Mr. BARRETT[1], who had frequent opportunities of examining the animal alive, but never saw the arms in the least degree protruded.

That the arms are instrumental in opening the valves is equally improbable, as special means are provided for this purpose in both the articulated and unarticulated Brachiopods.

In *Lingula anatina* the brachial organs[2] are strong and fleshy, and rise from the back of the pallial chamber in the usual manner. They are entirely without calcareous support, even at their origin; and form two spiral coils, with six or seven turns each, directed inwards and upwards. The arms are very thick at the base, taper more suddenly than in the articulated species, and terminate in fine points. On making a transverse section[3] they are found to differ in organization from those of *Rhynchonella*, to which, externally, they bear the strongest resemblance. Instead of one, as in that genus, there are two great brachial canals, which may be denominated respectively the anterior and the posterior. The former is the equivalent of the great canal in the other Brachiopods, and, like it, terminates at the side of the œsophagus in a blind sac. It is pretty regularly cylindrical, with the walls excessively thick, being composed, for the most part, of a white cartilage-like substance, which is most developed towards the side opposite the cirri. These latter organs are supported upon a semi-cartilaginous grooved ridge, which is very similar to that in *Waldheimia*, and in like manner supplied with a very ample brachial fold. Muscular fibres are also provided for the movements of these parts; but the fibres, though very similarly arranged, are not so extensively developed. This canal is lined with a muscular stratum, the fibres of which run in a transverse direction in the vicinity of the brachial fold; elsewhere they are longitudinal or slightly diagonal.

The posterior canal is much flattened, and stretches along the inner surface of the arm, extending from the base of the cirri half-way round it. This canal has the appearance of being formed by a process of the pallial membrane similar to that which extends along the lateral portions of the loop in *Waldheimia*. The posterior canals of the two arms terminate at the sides of the œsophagus behind the anterior canals, and are separated from each other by a considerable space, which is divided on the median line by a delicate, membranous septum. The two chambers thus formed communicate with the perivisceral cavity, by two small oval orifices[4] placed one on each side of the septum;

[1] *Op. cit.* [2] Plate LXIV. fig. 3. [3] Plate LXV. figs. 7, 8. [4] Plate LXVI. fig. 4.

these orifices open into the cavity close behind the œsophagus, and directly above a transverse fold of the anterior wall of the body. It is not altogether unlikely that these chambers likewise communicate with the posterior canals, but I have failed to ascertain the fact; and VOGT[1] also states that the two canals of the arm are cut off from the perivisceral cavity. Above the orifices there is another delicate membranous fold or flap, which seems capable of closing them by being pressed down against the parietal fold, to which the occlusor muscles are attached, acting in the manner of a valve.

The membranous wall of the posterior canals is composed of two layers, an outer homogeneous, and an inner muscular layer, each having its proper epithelium. The fibres of the latter layer run, for the most part, diagonally across the canal, becoming transverse towards the part furthest from the grooved ridge. Here there is also projecting into the canal a stout muscular band of a brown colour with the fibres longitudinal, and extending the whole length of the organ. Throughout it is firmly attached to the wall of the canal, and terminates at the root of the arm.

The additional mechanism in connexion with the arms of *Lingula* undoubtedly implies some peculiar function; and in this genus it may be fairly inferred that the brachial organs are capable of being evolved, if not entirely, at least to a considerable extent.

The posterior canals, which are only found in *Lingula*, appear to be the principal agents in this operation. These will be able to act without interfering with the movements of the grooved ridge and cirri; when their walls are contracted and the longitudinal muscular belt relaxed, the fluid, which they undoubtedly contain, will cause the arms to uncoil, and on the walls relaxing and the muscle coming into play, they will again be withdrawn and coiled up. But the animal must be seen in a living state before it can be ascertained to what extent these organs are unrolled and protruded.

This appears to be the explanation of the action of these parts; but whether exactly correct or not, it seems clear enough that the arms of *Lingula* have the power of extension in a greater or less degree. And from the deficiency, in the *Terebratulidæ* and *Rhynchonellidæ*, of the apparatus here employed, it may safely be concluded that in them the brachial organs are deprived of any such movement.

The anterior canals in *Lingula* will perform the same office as the great canals do in the other Brachiopods; that is, they will give firmness to the parts, so that the cirri and brachial fold may be brought into play. When the arms are retracted, the walls of these canals, which it will be remembered are closed tubes, will relax a little to relieve themselves from the pressure of the contained fluid; when they are extended the walls will contract to maintain the required pressure. Thus the cirri and brachial fold will be under the control of their proper muscles, however much or little the arms may be extended.

The arms of *L. affinis*[2] are perfectly similar to those of *L. anatina*, only the thickened portion of the wall of the anterior canal is much more limited.

The mouth[3], in all the Brachiopods, as previously stated, is situated in the brachial

[1] *Op. cit.* [2] Plates LXV. fig. 6; LXVI. figs. 2, 3. [3] Plates LV. figs. 2, 3; LXIV. fig. 3.

groove, at the posterior junction of the arms, and is a simple, oval, transverse slit, or orifice devoid of any armature. In *W. australis* there is, however, a slight bulging out of the posterior wall immediately within the orifice, which is somewhat like the valvular appendage in *Plumatella*, and may perhaps assist in swallowing. The alimentary tube[1] assumes the form of a siphon bent in the vertical plane, the arch turned towards the dorsal valve; the œsophagus represents the short, the stomach and intestine the long arm.

The œsophagus is of no great length; it is depressed as it passes through the wall of the body, and is afterwards slightly compressed; it ascends from the oral aperture, having the points of the crural processes on each side behind, and, inclining backwards, passes between the occlusor muscles; at some little distance from the dorsal valve it suddenly bends backwards and downwards, and opens into the anterior extremity of the stomach, which is of an elongated form, somewhat wider than the œsophagus, and about as long. The stomach contracts gently behind towards the intestine; this latter being at first about as thick as the commencement of the alimentary canal. It continues to descend at the same inclination as the stomach, and tapering downwards passes between the divaricator muscles towards the ventral valve, immediately behind the termination of the occlusors, and in front of the accessory divaricators, where it terminates in a rounded point. This point[2] is attached to the parietes, or lining membrane of the perivisceral chamber, and is imperforate; consequently there is no anal outlet in this species.

The walls of the whole canal are exceedingly firm; they never collapse, and are provided with a fibrous outer coat, and an inner mucous membrane. In the œsophagus the latter is comparatively delicate, and is raised into a few, not very conspicuous, longitudinal folds[3]; in the stomach the plications have also a longitudinal tendency; but they are not numerous, and are somewhat broken up into irregular rugæ. The lining membrane is exceedingly thick in the intestine, and is produced into four or five very large, longitudinal plaits[4], which project almost as far as the centre of the channel. The fibres of the muscular coat of this portion of the alimentary canal are transverse. The whole of the mucous membrane is extremely friable, and is consequently rarely observed entire, especially in the intestine, where, unless the specimens be in a good state of preservation, it is always broken up, and escapes, in fragmentary masses, on opening the tube. The specimens examined by Professor Owen must, in this way, have lost the lining membrane, or the "muco-epithelial lining" could never have been described as "disposed in very delicate transverse plates[5]." And indeed the illustrative figure seems to prove this.

The liver[6], of a greenish colour, is composed of a congeries of ramified cæcal tubes; it lies between the dorsal extremities of the occlusor muscles, concealing the greater portion of the œsophagus and stomach, and is divided into two lateral portions, one on each

[1] Plates LII. fig. 10; LVI. fig. 1; LVII. figs. 1, 2.
[2] Plate LIV. figs. 8, 9.
[3] Plate LVI. fig. 6.
[4] Plate LIV. figs. 10, 11.
[5] Introduction to Davidson's 'British Fossil Brachiopoda,' p. 13. pl. 1. fig. 4.
[6] Plates LII. figs. 1, 10; LVII. figs. 1, 2.

side of the alimentary tube, by a membrane denominated the mesentery. Each portion is subdivided into an anterior and posterior lobe, which pour their secretion through the dorsal wall, into the cardiac end of the stomach, by two or three short, distinct ducts, which are formed by the confluence of the various ramuscules[1] composing the lobes. The terminal cæcal extremities of the tubes are rounded, and as seen at the surface, generally give to the organ the appearance of being made up of globules. The parts, though closely pressed together, are not united, each ramuscule and tube being free. The anterior lobe is much the larger, and extends in front below, into the commencement of the brachial pouches; and above, as far as the opening of the central pallial sinus; the posterior extremity extends below the stomach, reaching backward beyond the pyloric termination. The posterior lobe lies on the dorsal surface of the stomach behind the anterior lobe, and reaches as far backward as the gastro-parietal band.

It has been already stated that the alimentary tube is composed of an inner and an outer membrane; these are its proper walls; there is, however, another membrane external to both, sheathing the entire tube very closely throughout, except at the anterior extremity of the œsophagus. This sheath gives off several delicate membranous bands, which go to the parietes of the perivisceral chamber, suspending the alimentary tube in its centre. These bands have been named respectively by Professor HUXLEY[2], who first described them, the mesentery, the gastro-parietal and the ilio-parietal bands.

The mesentery is divided into two portions, the dorsal and ventral; the latter extends from the lower or anterior face of the intestinal tube and stomach, to the posterior face of the œsophagus and the confluent extremities of the occlusor muscles, and passes above the lower portion of the intestine as a narrow free edge. The dorsal portion extends from the dorsal face of the stomach and anterior wall of the chamber to its upper wall, running along from end to end of the septum of the dorsal valve. The mesentery, therefore, sustains the alimentary canal in the vertical plane, and together with it divides the anterior portion of the chamber into lateral halves.

The gastro-parietal bands are three in number, two lateral and one median. The lateral ones pass from the sides of the stomach, ascending outwards and forwards to the dorsal extremities of the posterior occlusor muscles, around which they form an imperfect sheath. The median gastro-parietal band has hitherto escaped notice; it originates at the upper surface of the stomach, between the lateral pair, and passes upwards and backwards to the dorsal wall, a little in advance of the hinge-plate; it is very short. All these three bands originate in a ridge which stretches from side to side of the dorsal aspect of the stomach.

The ilio-parietal bands are prolongations of two narrow lateral expansions, which extend from the sides of the stomach to some way down the intestine; they pass outwards and upwards, and go to the sides of the chamber a little below the junction of the two pallial lobes. These bands give support to the inner portion of the peculiar organs denominated hearts by Professor OWEN.

[1] Plate LVIII. figs. 9, 10.

[2] Proceedings of the Royal Society, vol. vii. pp. 109, 110 (1854).

It will afterwards be seen that these bands, in connexion with the alimentary canal, have more important functions to perform than that of merely suspending it in the perivisceral chamber.

The digestive organs are so similar in the other two species of the *Terebratulidæ* which have been examined, that it is not necessary to say much in respect to them. In *T. caput-serpentis*[1] there appears to be only two hepatic ducts, and both in it and in *W. cranium*[2] the intestine is very short, terminating in a blind sac before it reaches the ventral wall of the perivisceral chamber. It tapers gradually to a point which is rounded, and suspended in its place by the mesentery[3]. The mucous membrane, lining the intestinal tube of *W. cranium*, is exceeding thick, and produced into five or six excessively stout, longitudinal folds, which in transverse section[4] exhibit a pyramidal contour, their apices almost meeting in the centre of the tube. In *T. caput-serpentis* the lining membrane is also very thick; but from the state of the specimens examined the character of the plaits could not be determined.

In *R. psittacea* the disposition of the alimentary canal[5] is the same as in the *Terebratulidæ*. The œsophagus is, however, considerably longer than in *Waldheimia*, the mouth approaching much nearer to the ventral valve. The liver[6] is larger than usual, and the biliary secretion is conveyed through the lateral walls of the cardiac extremity of the stomach by four short ducts, two at each side, one being placed a little in advance of the other.

The intestine is rather long and gradually tapers downwards. On reaching the ventral valve, directly behind the extremities of the occlusor muscles, it turns backwards and upwards, and, detaching itself from the mesentery, advances a little, and terminates in a much enlarged, rounded extremity, which inclines to the right or left, varying in this respect in different individuals. The termination projects freely into the centre of the perivisceral chamber, and here, as in the *Terebratulidæ*, there is no anus; the bulbous enlargement[7] is entire, exhibiting no opening whatever. This is perfectly obvious in *Rhynchonella psittacea*, in which the facilities of examination are comparatively great, on account of the terminal portion of the intestine being free and projecting into the perivisceral cavity. I have, nevertheless, made every endeavour to find an anal perforation, both in this and in the *Terebratulidæ*. I have made numerous dissections under a powerful doublet; I have removed the part and examined it with the microscope; I have filled the tube with fluid as a finger of a glove with air, and by pressure have attempted to force a passage; I have tried injections; but have equally, on all occasions, failed to discover an outlet, and have only succeeded in demonstrating more and more clearly the cæcal nature of the terminal extremity of the alimentary canal. Therefore, how much soever it may be opposed to analogy and to authority, the fact must be recorded—there is no anal orifice in *Waldheimia*, in *Terebratulina*, or in *Rhynchonella*.

In *Rhynchonella* the gastro-parietal and ilio-parietal bands, particularly the latter, are

[1] Plate LIII. fig. 5. [2] Plate LIV. fig. 2. [3] Plate LIV. figs. 3, 4. [4] Plate LIV. figs. 5, 6, 7.
[5] Plate LXI. figs. 1, 2. [6] Plate LXI. figs. 3, 4. [7] Plate LX. figs. 4, 5.

longer than in *Waldheimia*. The last-mentioned bands, too, are united across the intestine, their posterior margins being continuous and free. And not only these, but the gastro-parietals likewise sustain the inner extremities of two pseudo-hearts, of which in this genus there are four.

The alimentary tube in *Lingula*[1] presents two or three interesting modifications. The mouth is perfectly similar to that of *Waldheimia*, and the œsophagus, which is somewhat elongated, is at first depressed; but on emerging backwards from between the anterior occlusors, becomes compressed. The stomach is short, being almost lenticular, and the transverse dorsal ridge is much produced. In front it is slightly convex, where it receives the œsophagus; behind it is a little produced, and an inconspicuous constriction marks the commencement of the intestine, which running backwards, buried beneath the lobules of the liver, and resting above the posterior adjustor muscles, gradually descends towards the ventral lobe, immediately in front of the divaricator muscle. This straight portion of the intestine corresponds to the entire intestine of the articulated Brachiopods, and it thus appears that in *Lingula*, as well as in them, the first inflection of the intestinal tube is towards the ventral surface. From thence the tube bends to the left, and turning forwards and upwards, forms two large loops at the posterior portion of the perivisceral chamber; it then advances along the right side, and, dipping under the dorsal extremities of the adjustor muscles and the pseudo-heart, opens through a nipple-like anus[2] situated at the right side of the body between the margins of the mantle. The anal orifice is ample, and is very easily distinguished; it is placed considerably nearer to the dorsal than the ventral surface. The calibre of the alimentary canal does not vary much; the stomach only being a little enlarged. The mucous membrane is very stout in the œsophagus, stomach, and anterior portion of the intestine. In the former it is produced into very large, prominent, longitudinal folds, which appear to be continued into the stomach; but this point could not be clearly ascertained; in the anterior or straight portion of the intestine the longitudinal plaits seem almost to have disappeared, but very delicate transverse rugæ are discernible[3]. Similar, though still more minute, rugæ are found in the convolutions, where the lining membrane is thin. The muscular coat of the intestine is well supplied with transverse fibres.

The alimentary tube in *Lingula*, like that in the articulated Brachiopods, is sheathed in a transparent, homogeneous envelope, from which originate certain membranous bands, that pass to the parietes of the perivisceral chamber. These bands are the homologues of those already described in the other forms, under the designations of the mesentery, the gastro- and ilio-parietal bands.

The mesentery in *Lingula* is in a very rudimentary condition, it being represented merely by two narrow membranous expansions stretching along the upper and under surface of the œsophagus, from the biliary ducts to the anterior parietes: the dorsal mesenteric band is prolonged between the anterior occlusors. The gastro-parietal bands pass from the transverse ridge of the stomach, one on each side, to the posterior surface

[1] Plates LXIV. figs. 3, 4; LXV. figs. 1, 3, 4. [2] Plate LXVI. fig. 3. [3] Plate LXIV. figs. 6, 7.

of the dorsal extremities of the posterior occlusors. These bands are less extensive than their counterparts in *Waldheimia*, and do not sheath the muscles as in it. They support, however, stout muscular processes, which pass inwards from the parietes towards the stomach. There is no central gastro-parietal band, the lateral ones being separated by a considerable space. The ilio-parietal bands are very largely developed; they extend along the sides of the straight portion of the intestine, and expanding backwards give off each a process which passes to the side wall of the perivisceral cavity. These processes give support to the pseudo-hearts, and then turning forward stretch along the inner margins of these organs from end to end, forming a broadish expansion, projecting into the perivisceral cavity. The bands themselves terminate behind at the right side of the ventral extremity of the divaricator muscle, tying down the posterior end of the straight portion of the intestine. The terminal extremity of this tube is likewise attached to the lateral wall by a membrane, which extends as far back as the divaricator muscle.

The liver is composed of ramified cæca, and is of a greenish colour, as in all the Brachiopods. The cæca, however, are smaller than usual, and are formed into dense, irregular lobules, which communicate with the alimentary canal by four short, very wide ducts. The largest portion of this organ lies above the canal and behind the stomach, and pours its secretion into the upper end of the intestine by two lateral ducts; that on the left being a little in advance of the other. A duct from a few small lobules, situated between the posterior occlusors and above the œsophagus, opens through the dorsal wall of this portion of the canal, a little in advance of the stomach. A considerable mass of the hepatic organ, lying below the alimentary canal, communicates with the stomach by a large duct, which penetrates its lower wall.

The *Infusoria* appear to be the chief food of all the Brachiopods; perhaps the only food of the articulated species. In the stomach and intestine of the latter siliceous cases of the *Diatomaceæ* are almost always found, and sometimes in abundance. *Lingula*, however, appears to be a more general feeder, its intestine frequently containing a vast variety of matter. Siliceous cases of *Naviculæ* and other *Diatomaceæ* are very common; small crustacea also occur, and the spicula of sponges; besides a large quantity of dark coloured matter mixed with setæ, probably of annulose animals, and apparently with particles of sand or mud; something like vegetable matter may also be detected. The convolutions of the intestine are generally filled with fæcal refuse, rolled into numerous round or oval pellets. No fæces are ever found in the intestine of the articulated Brachiopods.

Reproductive System.

The Brachiopods are usually considered to be diœcious, and the sexual organs, which in the *Terebratulidæ* occupy the great pallial sinuses,—the so-called vascular trunks,—are stated to be ovaries or testes, according to the sex of the individual. There is, however, some reason to doubt the accuracy of this conclusion; though it is to be lamented that nothing of a very positive nature can be brought to bear upon this question.

In *W. australis* the genitalia[1] are formed of thick bands, somewhat convoluted and branched; they are of a full yellow colour, and are thrust into the trunks and main branches of the great pallial sinuses. There are four of these bands, two in each lobe; those in the dorsal lobe are single and occupy the two outer or lateral sinuses, extending from behind the attachment of the occlusor muscles to within a short distance of the anterior margin of the mantle: their posterior extremities reach to the perivisceral chamber. The ventral pair extend as far forward as the dorsal, and are double, that is, each forms a loop, the free extremities of which pass into the outer and inner sinuses of the same side; the looped portions lie within the perivisceral chamber, at the sides below the pseudo-hearts or oviducts.

These genital bands are attached to the inner lamina of the mantle throughout their whole extent, by a membrane[2], which, originating in this lamina, passes into a groove extending along the under surface of the genital band. The genital or pallial artery[3] runs along the edge of this membrane, and has the reproductive organ developed around it. This is the obvious disposition of the parts as apparent on a general examination; but on a closer inspection there can be little doubt that these organs are developed, in reality, between the two membranes, which, it will afterwards be seen, compose the inner lamina of the mantle, and, bulging out the interior of these, become suspended, as it were, in the pallial sinuses.

The organs themselves vary considerably in size and in the extent of their ramifications, chiefly on account, apparently, of their state of development, though not entirely so: as even when the ova are mature there is occasionally a remarkable diversity. In two individuals that were examined, in which the ova were fully developed, the genital bands in one were nearly twice as wide as in the other. In other specimens, in which these organs were comparatively small, ova were distinguishable; but in some none could be seen. Those in which ova are deficient are generally supposed to be the male secreting organ. The form, colour, and general appearance of these eggless bands do not differ from those charged with ova; and they certainly have very much the character of undeveloped ovaries. Moreover, the genitalia are very perceptibly composed of two elements, the yellow, ovigerous substance, which forms the chief mass; and a red material, which is for the most part distributed over the surface of the organ. When the organ is in a low state of development, this red matter forms a narrow, irregular cord[4], which runs along the sides of the band, and is occasionally spread over the surface in spots and blotches. When the ova are mature, this substance can still be traced as small specks on the surface and throughout the mass. From what will be shortly stated, with regard to the genitalia in *Lingula*, it seems probable that this red matter may prove to be the testis.

The minute structure of these organs has not been sufficiently examined; it may be stated, however, that the ova appear to be developed in cells, and that when the yellow mass, which is deficient of eggs, is broken up and placed under the microscope, it is found

[1] Plates LII. figs. 1, 2, 3, 10; LVII. fig. 1.
[2] Plate LV. fig. 1.
[3] Plate LVI. fig. 4.
[4] Plate LIII. fig. 8.

to be composed almost entirely of minute, clear granules. The red substance is likewise found to be made up of large, irregular cells, inclining to oval, very variable in size, and without any apparent nucleus.

In *W. cranium* the genitalia[1] are arranged precisely as in *W. australis*, only the bands do not extend so far forward, and are of a pale yellow colour. The red matter is also present, sprinkling the surface with distant, round spots. The bands are very finely granular, and in no instance have I detected eggs in them. It is therefore probable that those examined were out of season.

T. caput-serpentis exhibits a somewhat different arrangement of these organs[2]. In this species they are placed in large sinuses situated in the pallial lobes, one at each side. These sinuses are, however, nothing more than the enlarged trunks of the so-called pallial vessels or great pallial sinuses. They are four in number, two in each lobe; and the genital band which is placed within them forms a thick, convoluted layer, with small spaces between the folds. The convolutions are grooved throughout on the under surface, and the suspending or genital membrane[3] passes into the groove, as it does in *Waldheimia*; and here, consequently, it forms a complete network. This layer is of a rosy salmon-colour when the animal is alive, but in spirit-specimens is yellow. The walls of the sinuses are held together by numerous muscular ties, which pass directly from the one to the other, through the spaces left between the convolutions of the band. The ventral sinuses are the larger. When in an immature state the bands appear to be composed of rather large, circular vesicles, within which the eggs are probably developed.

The reproductive organs have much the same disposition in *Rhynchonella psittacea*; but the dorsal genital sinuses are not connected with the so-called vascular trunks, while the ventral are. The genital band[4], too, which is yellow, is much more closely convoluted, having sometimes almost the appearance of being fused into one mass, the interstices being just sufficient to permit the passage of the muscular ties, which are stout, and are arranged in imperfect longitudinal and diagonal lines. These ties give a granulated or pitted appearance to the ovarian impression in the shell, and are worthy of the attention of the palæontologist. The sinuses are limited to the posterior half of the lobe, while in *T. caput-serpentis* they advance much beyond the centre. The genitalia in *R. nigricans* are arranged in precisely the same manner as in *R. psittacea*.

In *Lingula*, the only form of the unarticulated Brachiopods in which I have examined the reproductive organs[5], they are withdrawn altogether from the mantle, and are placed in the perivisceral chamber, as they are stated to be in *Discina*. In the former these organs are very bulky, occupying a very large portion of the chamber; they lie for the most part behind the liver, and, as has been already stated, surround the alimentary tube; they form four irregularly lobulated or branched masses, two above and two below the tube; these pairs may be denominated respectively the dorsal and ventral ovaries.

[1] Plate LIII. figs. 3, 4.
[2] Plate LIII. figs. 1, 2.
[3] Plate LV. fig. 2.
[4] Plates LX. figs. 1, 2, 3; LXI. fig. 1.
[5] Plates LXIV. figs. 1, 2, 4, 5; LXV. fig. 3.

When in a highly developed state the lobes or branches insinuate themselves between and around the muscles, so that it is almost impossible to trace the relation of these organs to the other parts; but when immature it is very easy to do so. The dorsal ovaries are then found to be suspended by the ilio-parietal bands, the ventral by the continuation of these bands along the free margins of the pseudo-hearts or oviducts. In both cases the attachment is along the margins of the bands, which are related to the genitalia much in the same manner as the suspending membrane is to the genital bands in *Waldheimia*; and it would seem that in *Lingula* the reproductive organs are really developed between the two layers composing the ilio-parietal bands. There can be no doubt that these masses, which are of a reddish-yellow colour, are the ovaries; they resemble very much in structure the genital bands in the *Terebratulidæ*, and, as in them, they are found occasionally to contain eggs, but are frequently devoid of them. In one, in which these organs were filled with fully-developed ova, the red substance before alluded to was present. In *Lingula*, however, it assumes a different form: in this it is a dendritic or branched organ[1], spread over the external surface of the ovarian masses. On the dorsal ovaries the branches pass from behind forward in two lateral divisions; on the ventral ones in three, one being median, two lateral. The branches, which are quite irregular, do not diminish in thickness towards their extremities. On removing the thin transparent membrane which forms the dorsal and ventral walls of the perivisceral chamber, these dendritic organs came away with it, and I was originally induced to believe that they were organically connected with it; but further experience has led to the conclusion that they are really a portion of the genital mass, and that from the pressure of the valves, on their being closed, they had become accidentally adherent to the membrane.

On examining a portion of this branched organ[2] with the microscope, it was found to be composed of large irregular cells, somewhat elliptical in form, and closely resembling those of the red substance in connexion with the genitalia in *Waldheimia*. The cells, however, in *Lingula* appeared to present different stages of development, varying much in size and form. Some were ovate, others perfectly elliptical; the larger ones were pointed at both ends, and exhibited a double line in the centre, placed longitudinally; while the largest, measuring $\frac{1}{180}$ths of an inch in length, were fusiform, with the extremities more or less sharply pointed. These corpuscles[3] were filled with numerous, delicate, hair-like bodies, resembling spermatozoa. From these facts it can scarcely be doubted that the dendritic organ is the testis, and that the fusiform cells are fully developed spermatophora, containing spermatozoa. It would thus seem fair to conclude that *Lingula*, at least, is androgynous; and if the red matter in connexion with the genitalia in the articulated Brachiopods should prove to be the same as the dendritic organ in the former, then in them also the sexes are combined.

Professor Owen supposes that the ova, when mature, escape by the dehiscence of the pallial membranes[4]. So long as no passage was discovered leading externally from the

[1] Plate LXIV. figs. 1, 2. [2] Plate LXVI. fig. 8. [3] Plate LXVI. figs. 9, 10.

[4] Introduction to Davidson's 'British Fossil Brachiopoda,' p. 22.

perivisceral chamber, this would appear to be the only possible conclusion, but can now be no longer maintained, for it has been ascertained that more than one such passage exists. The natural inference would therefore seem to be, that the eggs will find their way through these passages, which may consequently be looked upon as oviducts.

These curious organs were originally described by CUVIER as hearts, in his well-known memoir on *Lingula anatina*[1], and subsequently by Professor OWEN in the Brachiopoda generally, in his equally celebrated paper "On the Anatomy of the Brachiopoda," published in the Transactions of the Zoological Society[2]. And up to the present time these organs are generally considered as the blood-propelling instruments. They open, however, as before stated, externally, and therefore can have nothing to do with the vascular system. Any one who has the opportunity, and will take the necessary pains, may satisfy himself of this fact; but he must not be discouraged by a failure or two, for unless the specimens be in excellent condition, he will find the determination of even this simple point attended with considerable difficulty. The epithelium, which is very deciduous and brittle in spirit-specimens, is liable to be crumpled in the vicinity of the external orifices. It is consequently a matter of no little nicety, under such circumstances, to ascertain if the openings pass through the epithelium. It was on account of my inability to prove this that I hesitated with regard to these orifices for some time, even after they had been traced through the membrane circumscribing the perivisceral chamber. And as the subject had been investigated by anatomists of the very highest reputation, it was necessary, before calling in question the accuracy of their conclusions, to have the most positive evidence. I therefore persevered, not only until the passage was demonstrated over and over again, but until the exact position and form of the aperture were determined beyond the possibility of doubt.

There are two of these oviducts in all the Brachiopods that have come under my observation, except in *Rhynchonella*, in which there are four, as first pointed out by Professor HUXLEY. In the *Terebratulidæ* they lie within the ventral valve[3], and may be described as tubes of no great length, composed of two well-marked portions, one being expanded and laminated, the other more strictly tubular[4]; these parts are respectively the auricle and ventricle of Professor OWEN. The latter is placed between the two membranes forming the anterior wall of the perivisceral chamber, is curved a little inwards, and, tapering to an obtuse point, opens externally a short way below the mouth, at some little distance from the central line[5]. These orifices are by no means minute, and are in the form of slits placed diagonally, having the occlusor muscles between them. The laminated portion lies within the perivisceral chamber, and is much expanded, the lips turning over like those of a trumpet, and having the inner surface covered with strong, radiating, pectinated laminæ. In *W. cranium* the laminæ are smaller than usual, and are very regular. The expanded portions are placed one at each side of the intestine,

[1] *Op. cit.* p. 8.

[2] Likewise in the Introduction to DAVIDSON's 'British Fossil Brachiopoda,' pp. 14, 15.

[3] Plates LII. fig. 10; LIII. fig. 5; LIV. figs. 1, 2; LVI. fig. 1; LVII. figs. 1, 2.

[4] Plate LIII. figs. 9, 10.

[5] Plate LV. figs. 1, 2.

their inner margins being supported by the ilio-parietal bands, and their outer soldered to the lateral walls of the body; they open upwards and backwards in the plane of the dorsal or posterior surface of the intestine.

On laying these organs open, the laminæ of the expanded portion are found not to extend far down, and to end abruptly; the lining of the tubular portion is thick, slightly wrinkled longitudinally next the laminated portion, and raised into minute, obtuse villi. The whole of the organ is of a yellow colour, except in *W. australis*, in which the tubular portion is reddish.

It has been already stated that in *Rhynchonella* there are four oviducts[1], two within the ventral, and two within the dorsal valve; both pairs are precisely similar, and are of a yellowish colour. The tubular portion, or that which lies between the two layers of the parietes, is ovate-oblong, and has the lining membrane raised into strong, principally longitudinal, wrinkles[2]. The expanded extremity, though comparatively small, is well marked, being placed rather laterally, and separated from the broad, rounded end of the tubular portion by a constriction; the laminæ are few and branched. The ventral pair[3] correspond to the two in the *Terebratulidæ*, and open externally at the pointed extremity, through a slit situated as in them; and the inner expanded portion opens through the ilio-parietal bands, near to their junction with the walls of the body, being held within them, as aptly remarked by Professor HUXLEY, like a landing-net in its hoop. The dorsal ones[4] lie on each side of the liver, and their external orifices, which are above the mouth, open downwards as in the other pair. Their expanded extremities are suspended by the gastro-parietal bands close to the walls of the chamber; they open upwards and forwards.

In *Lingula*[5] the oviducts are rather peculiar in form, though essentially the same as in the articulated Brachiopods; they are two in number, and are the homologues of the ventral pair in *Rhynchonella*, and consequently equivalent to those in the *Terebratulidæ*. They lie, to a great extent, between the two layers of the ilio-parietal bands, and are stretched along the lateral walls of the perivisceral chamber from the front to behind the dorsal attachment of the adjustor muscles, and are so concealed by the viscera and muscles that very little of them can be seen until those parts are removed. The expanded portions open upwards and towards the lateral walls of the body through the processes of the ilio-parietal bands close to the side walls of the chamber. They are of a yellowish colour, small in proportion to the other part, puckered a little, and irregularly and widely laminated in the interior. The tubular portions are united posteriorly to the former by exceedingly short, constricted necks, and are much flattened or depressed; behind they are enlarged and angulated, and are attached by their outer margins to the parietes of the chamber; their inner margins projecting inwards give support to the folds of the ilio-parietal bands, which suspend the ventral ovaries; they taper gradually forward, and, curving in conformity with the anterior wall, penetrate its substance

[1] Plate LXI. figs. 1, 2.
[2] Plate LX. figs. 7, 8.
[3] Plate LX. fig. 3.
[4] Plate LV. fig. 3.
[5] Plates LXIV. figs. 2, 5; LXV. fig. 1.

as two rather delicate tubes; and thus buried run for some distance towards each other, and terminate at the external surface in two small diagonal slits[1], one a short way on either side from the median line, a little below the mouth. The expanded portion is yellowish, and the tubular of a full red colour. The walls have a glandular appearance, the inside being velvety from the numerous minute villi which crowd the surface.

From the nature of these organs it seems probable that the ova, on their passage outwards, may receive some external covering; or perhaps, having to subserve the function of renal organs, as suggested to me by Professor HUXLEY, their walls are necessarily glandular. Be this, however, as it may, they seem to be primarily for effecting the discharge of the eggs, and therefore the denomination of oviducts appears appropriate. In corroboration of this view of their function it may be stated, that in two instances, in which the ova were mature, they were found in vast numbers strewed about the perivisceral chamber, and in one of the oviducts several had penetrated almost to the external orifice. The expansion of the inner aperture may be for the better securing the ova as they fall into the chamber; and it is not improbable that ciliary currents may direct their course to this receptacle. Arrived there, they are probably carried onward by some peristaltic action of the parts, for such would seem necessary; as the tubular portion, being buried in the parietes, will be kept in a state of collapse by the pressure of the fluid in the perivisceral chamber. The passage is undoubtedly so constructed as to be opened and closed as the economy of the animal requires.

CIRCULATORY AND RESPIRATORY SYSTEMS.

The circulatory apparatus has been, up to a very recent period, entirely misunderstood. Professor HUXLEY's paper, which appeared in the Proceedings of the Royal Society in 1854, threw the first gleam of light upon this most intricate portion of the anatomy of these animals. In 1852 I had discovered that the Cuvierian hearts open externally, and in my communication on the subject submitted to the British Association in 1856[2], it was stated that these organs were really oviducts, or perhaps kidneys, and formed no part of the circulatory apparatus, but that the true blood-propelling organ was the pyriform vesicle, described by Professor HUXLEY as appended to the stomach. Further research has only tended to confirm the accuracy of these views, which now appear to be incontrovertible.

This vesicle or heart is present in all the *Brachiopoda* that I have examined, and when in an expanded state is of considerable size. In the articulated species it is appended to the middle line of the stomach, immediately behind the central gastro-parietal band, and projects freely into the perivisceral cavity, reaching down almost to the anterior margin of the oviducts: the free extremity is the larger one. When in this state, the walls, though rather thin, are firm, smooth, opake, and do not collapse; they are composed of two layers, the inner of which is distinctly muscular, the fibres running in various directions, but principally radiating from centres; the outer layer is delicate,

[1] Plate LXIV. fig. 3.

[2] Transactions of the Sections, p. 94.

transparent and homogeneous. The interior is entirely devoid of carneæ columnæ, and is perfectly smooth. When this organ is in a contracted state, its size is very much reduced, the surface is occasionally wrinkled a little, and the walls, of course, are much thickened.

This unilocular heart[1] in *W. australis* receives a large blood-channel or vessel[2] in front, which, running forward along the dorsal ridge of the stomach, within the membrane denominated mesentery, communicates on each side by several minute openings with the gastric lacunes, which are situated between the walls of the viscus and the membranous sheath. The anterior extremity[3] of this channel passes down the dorsal surface of the œsophagus, and dividing into two lateral trunks, opens at each side into a system of large lacunes placed around the root of the alimentary tube. These lacunes will be more particularly noticed afterwards. The channel is the afferent cardiac channel, or branchio-systemic vein.

A little behind the point where the heart receives this channel two aortic vessels pass off laterally, which are united at their origin across the median line. The two orifices communicating with those vessels are guarded by sphincture valves, resulting apparently from the protrusion inwards of the lining membrane; but from the minuteness of the parts I was unable to determine the exact structure of the valve. These two arterial trunks are adherent to the walls of the stomach, and, diverging backwards, each divides at the side of this viscus into two branches; one of which turns forward, and advancing to the lower margin of the gastro-parietal band runs along it, and coursing round the dorsal extremity of the posterior occlusor muscles reaches the inner wall of the outer pallial sinus, near to its commencement; it then bends forward, and entering the groove in the genital band glides along the edge of the suspending membranous fold, and is continued beyond the genital organ to the termination of the minutest ramifications of the sinus. A little in advance of the point where this artery leaves the gastro-parietal band it appears to give off a branch, which, running forward, goes to the margin of a membranous fold that stretches along the inner wall of the inner pallial sinuses; but this was not determined with sufficient accuracy. This fold is similar to those suspending the genitalia.

The other division of the artery passes backwards along the lateral margin of the ilio-parietal band, and then running across the under surface of the laminated portion of the oviduct next the median line, bifurcates. One of the branches passes inwards, the other outwards; the former, uniting with its fellow from the other side, runs along the free border of the mesenteric membrane, which extends from the dorsal aspect of the intestine, and passes into the base of the peduncle. This branch seems to supply that organ, but is much reduced in size before it reaches its destination. The branch, which passes outwards, continues adherent to the oviduct, and coursing over it, at the junction of the two portions, reaches the anterior wall of the perivisceral cavity; it then sinks downwards and advances to the loop of the genital band, where it again divides into

[1] Plates LII. fig. 10; LIV. fig. 1; LVI. fig. 1; LVII. figs. 1, 2.
[2] Plate LVI. figs. 5, 7.
[3] Plate LVI. fig. 6.

two portions, which are continued into the outer and inner sinuses of the ventral pallial lobe, accompanying the genitalia in the manner above described, and in the same way extending to the terminal ramifications of the sinuses.

At the point where these latter genital arteries divide, there is situated a pyriform vesicle[1], which is apparently formed by the bulging out of the arterial wall; there is also a similar vesicle at the commencement of each of the dorsal genital arteries. There are consequently, in addition to the central vesicle or heart, four lateral vesicles, which seem to be accessory pulsatile organs. They are smaller than the heart, and their walls are more delicate. In some individuals there is also a small supplementary vesicle near to each of those of the ventral genital arteries; but whether or not these are abnormal it is impossible to say. They have been seen only in one or two instances; and the whole of these accessory vesicles are so delicate, that, unless the specimens be in the best possible condition, they are liable to disappear altogether. These supplementary vesicles may therefore be constant though seldom observed.

This is the condition of the central portion of the blood-system as determined in *W. australis*. In *W. cranium* no accessory pulsatile vesicles have been seen; but the heart and the afferent cardiac channel, or branchio-systemic vein, together with the dorsal and ventral pallial arteries, are all as above described[2]. In *T. caput-serpentis*[3] the heart is more decidedly pyriform than in the other species, and it is placed a little further back, the branchio-systemic vein passing for some distance down the stomach beyond the central gastro-parietal band. A single accessory pulsatile vesicle has been observed in connexion with one of the ventral genital arteries; others most probably exist.

The central portion of the blood-system in *Rhynchonella*[4] is arranged much as in the *Terebratulidæ*. The aorta, however, is not at once divided into two branches, but leaves the heart as a single trunk, which passes backwards as far as the pylorus before it bifurcates; and as the genitalia in this genus, as well as in *Terebratulina*, are much reticulated or convoluted, and as the suspending membrane follows the reticulations, there can be no doubt that the genital arteries in these two genera form an extensive open network. And when the genital sinuses give off branches to the pallial margin, arterial twigs are continued down them in the usual manner, as indicated by the continuation of the base of the genital membrane. When, however, no such branches exist, the artery appears to terminate in the plexus. The arteries have not been actually followed through the network, but they have been traced into the genitalia, so that there can be little doubt that they run the course above described. There is an accessory pulsatile vesicle attached to each dorsal genital artery as it enters the reproductive organ, and two in connexion with each of the ventral genital arteries; they are not large, and one is much smaller than the other, the smaller being undoubtedly equivalent to the supplementary ones in *W. australis*.

[1] Plates LVI. fig. 1; LXIII. figs. 3, 4.
[2] Plate LIV. fig. 2.
[3] Plate LIII. fig. 5.
[4] Plate LX. fig. 4; LXI. figs. 1, 2.

The existence of the genital arteries has not, I believe, been hitherto fully demonstrated. Professor OWEN, indeed, inferred their presence so long ago as 1833[1] from the ridges seen at the surface of the mantle accompanying the sinuses; in which ridges the membranes suspending the genitalia take their origin. This inference, however, has been controverted on the ground that the ridges only indicated the base of the suspending membrane. The presence of the genital artery is not, however, by any means difficult of proof. A cross section[2] of the genitalia divides the artery and exposes it to view. From its walls delicate membranes pass into the substance of the genital organ, which latter almost entirely encloses the artery. The true nature of the artery has been determined in this way as it passes from the heart, when in connexion with the parietal bands, and likewise in other places.

The central organs of circulation[3] have been observed in both *Lingula anatina* and *L. affinis*, and found to differ very slightly from those of the articulated species. The heart, which has been seen only in a state of contraction, is situated on the posterior slope of the stomach, exactly as in *Waldheimia*. It is pyriform, rather elongated, with the small end tapering gradually forward. The branchio-systemic vein originates in the dorsal mesenteric membrane, and communicates apparently through it, and two lateral membranes attached to the œsophagus, with a system of lacunes which surround that tube at its origin, much in the same way as in *Waldheimia*. The channel as it runs backwards passes between the divisions of the hepatic ducts, and is here rather enlarged; it soon assumes the form of a distinct, isolated vessel, and in this condition reaches the transverse dorsal ridge of the stomach from which the gastro-parietal bands originate, and at this point opens into the anterior apex of the heart. The aorta, as a single trunk, leaves the under surface of the large or posterior extremity of the organ, and in this respect differs from that of the articulated species; here the heart assumes more the character of a mere enlargement of the vessel. The aorta passes a considerable way down the straight portion of the intestine before it divides into two lateral stems. The heart and the aortic trunk are not closely adherent to the alimentary tube as in the other species, but are attached to the margin of a narrow membrane, which rises up from the external sheath of that viscus. The lateral stems pass outwards, and on reaching the ilio-parietal bands are again subdivided in the usual way, one branch running forward, the other backward in connexion with those bands. The former has been traced along the sides of the stomach as far as the gastro-parietal bands, the latter to the laminated portion of the oviducts; and thence there is apparently a branch running along the membrane, skirting the free border of these organs.

Besides these, there are, at each side, two arterial trunks[4], which penetrate the muscles. These, which may be termed respectively the internal and external, have not been traced throughout their entire course; but there can be little doubt that they are the continuations of the posterior branches of the lateral divisions of the aorta. The external

[1] Trans. Zool. Soc. vol. i. p. 154.
[2] Plate LVI. fig. 4.
[3] Plates LXIV. fig. 4; LXV. figs. 1, 3, 4; LXVI. fig. 1.
[4] Plate LXV. fig. 2.

ones have been followed right through the substance of the posterior adjustor muscles. That on the right side enters the posterior margin of the large single muscle, near to the point where it is in contact with the ilio-parietal band, and thence it goes directly to the opposite margin; it then becomes isolated and stretches forward between the dorsal and ventral ovaries of the same side, and, passing round the external surface of the anterior occlusors, turns inward, and a short way before it reaches the median line penetrates the lining membrane of the anterior wall, immediately below the ridge attached to the occlusor muscles[1]. It here apparently communicates with the lacunes situated between the two membranes of the parietes. The external trunk of the other side runs a similar course after passing through the two small posterior adjustors. These two trunks probably represent the ventral pallial or genital arteries of the articulated species. The internal are most likely connected with the external trunks; they pass from the anterior margins of the posterior adjustors, go directly through the central adjustors, and are lost amidst the fibres of the external adjustors, where they seem to branch.

These four lateral trunks have been described by Professor OWEN[2] as part of the nervous system, and indeed they bear a strong resemblance to nerves. But I can find no ganglia from which they originate, and the external ones undoubtedly pass into the anterior wall of the body as described: at this point, certainly, there are no ganglia nor anything like a nervous collar. The trunks themselves are composed of an inner and an outer tube; the latter is a continuation of the lining membrane of the perivisceral chamber; the inner is formed of a very delicate membrane, which, by the contraction of the outer tube, is thrown into longitudinal folds or wrinkles, having somewhat the appearance of nerve-tubes. These trunks, in fact, exactly resemble, in these respects, the free or isolated portion of the branchio-systemic vein[3], which has an outer envelope and a delicate internal tunic longitudinally wrinkled. So like are the two, that either might be figured or described for the other.

Having said so much with regard to the central organs, it will now be necessary to examine the peripheral portion of the blood-system. To do this we shall have to look to the parietes of the perivisceral chamber, and particularly to the lobes of the mantle, to the various membranous bands in connexion with the alimentary tube, and likewise to the brachial organs. In all these parts will be found the extensive system of lacunes, or blood-channels originally described by Professor HUXLEY[4].

First, with regard to the walls of the perivisceral chamber: these[5] are composed of two membranous layers, an outer and an inner, between which the lacunes are situated. The outer layer[6], of the dorsal and ventral walls, is made up of two very delicate membranes, the internal of which is pellucid and homogeneous; the external one is reticulated in a peculiar manner, as if it were formed of epithelial scales. The reticulations appear to correspond to the bases of the prismatic columns composing the shell. It is in this external membrane that the cæcal prolongations of the mantle originate, and the bases

[1] Plate LXVI. fig. 4. [2] Introduction to DAVIDSON'S 'British Fossil Brachiopoda,' p. 12.
[3] Plate LXV. fig. 5. [4] *Op. cit.* p. 115. [5] Plate LIX. fig. 3. [6] Plate LIX. fig. 4.

of these enigmatical organs are distinctly visible rising up from the surface as short, delicate cylinders. And it may here be observed, that, contrary to expectation, they do not appear to penetrate even this external membrane, and consequently can have no communication with the lacunes or blood-channels lying between the two layers of the wall, or within those of the pallial lobes, as stated by Dr. CARPENTER[1]. This interesting point will be more particularly adverted to in the sequel. The inner layer of the wall is thin, transparent, and minutely granular, and is lined with a granular epithelium. Through these transparent layers the blood-channels, which lie between them, are seen, in well-preserved specimens, in all their details.

The anterior wall of the chamber has likewise its blood-channels between two layers, both of which are clothed with a granular epithelium. The lacunes of this portion of the tegumentary envelope form an open network, with the meshes elongated in the direction of the arms.

The pallial lobes[2] are each composed of two laminæ, an external and an internal one. The external lamina of both the dorsal and ventral lobes is a continuation of only the external layer of the upper and under walls of the body; the internal lamina is an expansion, in like manner, of the anterior wall. But those portions of the laminæ that form the walls of the great pallial sinuses are composed of both layers of the parietes. Hence the pallial lobe consists, above and below the sinuses, as well as in the spaces between them, of two layers, and the lacunes are situated everywhere between the layers, and intercommunicate. In other words, the pallial lobe may be described to be formed of a fold of the external layer of the parietes, the internal layer lining the great pallial sinuses throughout.

The external lamina of the mantle is formed of two membranes, exactly resembling those of the parietes of the body, the outer being reticulated, the inner transparent and homogeneous. The membrane of the internal lamina is of the same character as the latter; but it exhibits a few large, scattered, oval, granular cells. The pallial nerves are in connexion with this membrane, which is provided, on its external surface, with a stout, granular epithelium[3]. The layer lining the great pallial sinuses presents two different characters; that portion which lies next the shell is clear and homogeneous, that which rests on the lower wall or floor is slightly granular, and almost entirely composed of transverse muscular fibres. This layer is lined throughout with a granular epithelium.

The blood-channels or lacunes lying immediately below the external layer, and which may be called the outer pallial lacunes, are continuous with those in the parietes of the body; and throughout this extensive superficial system they have the same peculiar character. The channels are exceedingly wide, and in the spaces between the great pallial sinuses they are of considerable depth; in fact the whole of this system may be considered as one vast lacune, the walls of which coming together are united at certain

[1] Proceedings of the Royal Society, vol. vii. p. 34 (1854). [2] Plates LIX. fig. 1; LVIII. figs. 5, 7.
[3] Plate LXI. fig. 5.

points. These points of union are circular, and are arranged in groups of various forms and sizes, generally more or less rounded.

When the specimen is in good condition, this beautiful system of peripheral lacunes is well displayed, the channels or spaces being then for the most part filled with blood-corpuscles, which give to the lacunes an opake, yellowish hue, rendering them as distinct and sharp as though they had been injected. And as the circular points of union of the two walls are transparent, and are consequently liable to appear of a darkish tint, they show like spots on a light ground, not altogether unlike the markings on a leopard's skin. In other lights the whole has a beautiful lace-like delicacy. These lacunes occasionally assume a branched or dendritic character, particularly as they approach the margin of the mantle, where they become minute and run almost parallel to each other. These minute twigs pass on to the external margin of the lobe.

The inner lacunes, or those of the inner wall or floor of the great pallial sinuses, have a very different character; they resemble, however, considerably the lacunes in the anterior wall of the body with which they are in direct communication. They are in the form of numerous, narrow channels, which, anastomosing at various points, compose a network of very long, transverse meshes; thus most of the channels cross the direction of the sinuses and run parallel to each other. They communicate at the sides of the sinuses with the other system of pallial lacunes, and along the centre with that of the membrane suspending the genitalia. This membrane, like all the others, consists of two layers, and has its own system of anastomosing lacunes, which, on the one hand, is in connexion with the genital or pallial artery; and on the other, as just stated, with the inner pallial lacunes.

The lacunes in the floor of the inner sinuses of the dorsal lobe exhibit a slight modification; here they are not in regular transverse order, but form a pretty even network.

A few words more will complete the description of the pallial lobes. The margins[1] of these organs are complicated in their structure. Both the membranes of the external lamina seem to extend to the extreme edge of the shell, and the margin of the outer reticulated one is apparently continuous with the periostracum. A little within the edge of the shell the inner lamina is thickened and forms a fold, which is free in front and capable of extension and contraction. It is within this fold that the marginal setæ are developed; they originate in follicles, from which occasionally two or three setæ issue, though more frequently only one, and project from depressions in the margin. In connexion with the inner membrane of the external lamina, numerous muscular fibres are formed, which, increasing in number as they extend forward, pass into the marginal fold, and when in action will withdraw its free border; while a narrow muscular cord, which runs round immediately within the margin of the lobe, will probably control the lateral movements of the setæ. The setæ[2] themselves, which are placed a little apart from each other, taper gradually to exceedingly fine points, and are transparent, glisten-

[1] Plates LVIII. figs. 5, 6; LIX. fig. 1.

[2] Plate LVII. fig. 5.

ing, stiff and bristle-like; they are marked in a peculiar manner with transverse, dusky lines, perhaps indicating the progressive steps of growth.

The margin of the mantle has the same character in all the Brachiopods, and in all it is armed with setæ, which, however, vary considerably in length in the different species. In *W. cranium*[1] the edge of the marginal fold is entire, and the setæ are of various lengths, and rather minute and delicate; rarely more than two issue from the same follicle, generally only one. The setæ in *T. caput-serpentis*[2] are placed rather far apart from each other, and issue from the mantle at the points corresponding to the marginal crenulations of the shell; these crenulations give to the pallial membrane a scolloped appearance. The setæ are rather robust; the marginal fold is deep, and the follicles are of considerable length and rather wide, with their bases surrounded with glandular matter, forming a roundish, red-coloured spot at the end of each seta. Similar glandular matter is observed at the bases of the follicles in *W. australis*; but in that species it is elongated backwards. In *R. psittacea*[3] the setæ are slender, short and finely pointed; they vary in length, as they do indeed in all the species, and occasionally three or four issue out of one follicle. In all the species the setæ are marked with rather distant, transverse bars. In *Lingula*[4] the setæ are very long, and close-set, crowding the marginal fold, which is much thickened, and exceedingly deep, forming a wide border around the pallial lobe. They extend entirely round the dorsal lobe, and in the ventral one are interrupted only for a short space behind, at the point where the peduncle is attached to it. They are marked with numerous, rather close, transverse bars, from every one of which a narrow edge projects forward encircling the setæ, giving them the appearance of being jointed, and, as VOGT[5] observes, rendering them very like the stems of an Equisetum.

Some time ago Professor SCHMIDT[6] discovered calcareous spicula or plates in the mantle, arms, and cirri of *T. caput-serpentis*; and more recently Mr. WOODWARD[7] exhibited, at a meeting of the Zoological Society, not only spicula in the pallial lobe of this species, but also in that of *Terebratula vitrea* and of *Megerlia truncata*. This gentleman has also found indications of imbedded calcareous matter in the mantle of *Argiope decollata* and *Crania*.

In *T. caput-serpentis*[8] the spicula are large, much branched, colourless, glass-like and pellucid, somewhat like the antlers of a Deer, only the branches are all in the same plane, and are flattened or depressed a little. They are, however, frequently much complicated, forming a central network, with irregular, radiating branches; in others, again, the branches pass from a simple perforate centre. These spicula lie in the outer layer of the inner lamina, and are crowded to such a degree, that the tips of the branches are almost in contact; thus forming an extensive, though incomplete network of calcareous

[1] Plate LIII. figs. 3, 4. [2] Plates LIII. figs. 1, 2; LVII. figs. 6, 7. [3] Plate LX. figs. 1, 2, 3.
[4] Plates LXIV. figs. 1, 2; LVII. figs. 8, 9. [5] *Op. cit.*
[6] DAVIDSON, Ann. and Mag. of Nat. Hist. vol. xvi. p. 440, 1855.
[7] Proceedings of Zool. Soc. 1856, p. 368. [8] Plates LII. figs. 6, 7, 8; LX. fig. 12.

matter over the trunks of the great pallial sinuses. Elsewhere they are sparingly distributed, except towards the margin of the lobes, where they are rather numerous.

In *Megerlia truncata*[1] the spicula have much the same character, but the branches are so much flattened or spread out, that they become extensively fused, so as to form plates of irregular forms; and as the margins of these plates are in contact, the whole compose a tolerably compact shield with sharply defined borders, corresponding very closely in form to the pallial sinuses, to which, no doubt, they give protection, resisting the pressure of the external fluid.

In both species the spicula are continued from the mantle into the arms, where the branches become interwoven so as to compose a sort of sponge-like tissue of calcareous matter, which firmly supports these organs. In the cirri the spicula retain their branched character, and curving round them enclose their lower portions in an open network. Were these species fossilized, it is quite possible that their arms might be so preserved as to give the appearance of their having been sustained by some apophysary apparatus; and in that case the roots of the cirri would be found projecting much in the same way as the salient spines or processes on the calcareous spirals of the fossil *Spiriferina rostrata*; and perhaps these spines were formed by similar imbedded spicula. No spicula are found in *Waldheimia*, *Rhynchonella*, or *Lingula*.

From the description already given of the peripheral lacunes, it would seem that the walls of the body, and the laminæ of the pallial lobes, present one great system of blood-channels or lacunes, the various parts of which freely communicate with each other. There still remains, however, to be examined the peripheral system in the membranous bands of the perivisceral chamber, and in the brachial apparatus; but in the first place it will be well to refer to the sheath of the alimentary tube. As before stated, this tube is encased from end to end in a close-fitting membranous sheath; between which and the proper walls of the tube, the blood, which nourishes this viscus, undoubtedly flows in lacunes; but from the opacity of the parts the exact character of the channels could not be determined. Blood-corpuscles, however, were found strewed about between the sheath and the walls of the organ, apparently occupying a network of channels. Towards the root of the œsophagus, where the sheath is not so much constricted, large blood-channels or lacunes[2] are situated between it and the walls of the tube. These may be denominated the great œsophageal lacunes; while those of the other portion of the alimentary tube may be named the visceral lacunes, as they seem to form part of a system which extends to the liver and heart.

Now, all the bands which pass from the alimentary tube to the parietes are, in fact, duplicatures of this sheath, and accordingly they are found to be composed of two layers, each with its proper epithelial covering. The layers are exceedingly delicate, transparent, and homogeneous; and between them are situated numerous blood-lacunes, which are narrow anastomosing channels. Those in the gastro-parietal bands run[3], for the most part, in the direction of their length, and communicate at one extremity with the visceral

[1] Plates LII. fig. 9; LIII. figs. 6, 7. [2] Plate LV. fig. 4. [3] Plate LVI. fig. 8.

lacunes, and at the other with the posterior portion of the outer pallial system of the dorsal lobe. The lacunes in the ilio-parietal bands connect the lower portion of the visceral lacunes with the posterior portion of the outer pallial system of the ventral lobe. The mesenteric lacunes[1] have the same character as those in the other bands, and run principally in a longitudinal direction, and maintain a communication between the visceral lacunes and those of the walls of the body.

The liver has no doubt its proper system of blood-channels communicating with those of the other viscera; and though they have not been demonstrated, it appears pretty certain that they lie between the walls of the numerous ramifications of this viscus and a membranous envelope, an expansion of the sheath of the alimentary tube, which has the appearance of being reflected from the stomach upon the hepatic ducts, and is, there can be little doubt, continued throughout its various subdivisions.

The muscles seem likewise to be sheathed in a membrane which apparently penetrates the interstices between the bundles of fibres, so strikingly displayed at their enlarged extremities. The blood, which goes to nourish these organs, will, for the most part, pass from the lacunes of the parietes to within the sheaths, and has its course defined in lacunary channels, which can be easily observed on making a transverse section of the occlusor muscles. The occlusors being in connexion with the mesenteric membrane and the anterior parietes its blood-channels, will be also in direct communication with the visceral system. It would then appear that the visceral system of lacunes is connected with the parietal and pallial systems through the instrumentality of the several parietal bands; and what may be denominated the muscular lacunary systems are probably in communication with all three.

The blood-system of the brachial apparatus next claims attention. This is beautifully developed, and presents considerable variety in the character of the several plexuses of which it is composed. The walls of the great canal, the ridge supporting the cirri, the membranes that unite the upper and lower members of the loop, that which connects the spirals, and those which form the small canal or channel at the base of the cirri, as well as that forming the sheath of the apophysary support,—all have their system of lacunes which intercommunicate and compose the brachial system.

The processes of the inner lamina of the mantle which pass along the lateral brachial folds, and within the margins of which the calcareous support is developed, are formed of two layers; and the network of lacunes of the inner pallial system is continued between them. This continuation of these lacunes is in connexion with the brachial system. The lacunes in the walls of the great brachial canal also communicate with those of the same inner pallial system. There is likewise a small canal which runs along the arm from base to point immediately below the brachial fold: The blood-channels of the anterior wall of the body communicate with the extremity of this conduit, and as it passes along it pours its contents into the plexus of the great brachial canal. This, which may be denominated the afferent brachial canal, was not very

[1] Plate LIV. fig. 8.

distinctly observed in *W. australis*, but is sufficiently conspicuous in *R. psittacea*[1], in which it was traced from the junction of the arms to a considerable distance along them, charged with blood-corpuscles. In this species the channels of the anterior wall of the body run in the direction of these canals.

The walls of the great brachial canal[2], like those of the body, are composed of two layers, the inner displaying muscular fibres, as already stated, the outer being homogeneous: both are clothed with an epithelium. That lining the canal[3] is distinctly formed of irregular polygonal scales with scattered granules. The external epithelium is stouter than the other, and is more crowded with granules. In the space between the two layers there are numerous lacunes resembling those in the anterior parietes; but they form pretty regular parallel channels of limited width, which occasionally anastomosing run diagonally round the canal. These channels take their origin in a minute plexus situated directly above the membrane connecting the spirals. The afferent canal runs along at the other side of or below this membrane, and the network of channels excavated in its substance, which is thick and of a semi-cartilaginous appearance, becomes the medium of communication between the afferent canal and the minute plexus just mentioned. At the points of communication the channels in the membrane form minute networks. Towards the interior of its substance the meshes are much enlarged. After winding round the canal, the brachial blood-channels are again lost in a similar minute plexus situated at the base of the semi-cartilaginous ridge supporting the cirri. This plexus is in connexion with another system permeating the substance of the ridge, which conducts the blood through amidst the roots of the cirri to a peculiar network of channels, in like manner excavated in the substance of the ridge next the brachial fold. This, the great brachial plexus[4], is supplied with central trunks which give off branches; some of these pass towards the base of the ridge, and, anastomosing as they go, result in a regular series of transverse channels, which, on reaching the small canal running along at the bases of the cirri, attain proper walls, and as distinct vessels[5] pass through the wall of this canal, and, turning in the direction of the cirri, enter the bases of these organs in regular parallel order. These vessels are the afferent brachial arteries.

The small canal at the bases of the cirri is situated within the large brachial canal, and is apparently formed by a duplicature of the lining membrane of the latter. The septum, thus dividing the two canals, is composed in the usual way of two layers, and is provided with its system of anastomosing channels which open into those of the great canal. The small one is the efferent brachial canal. The bases of the cirri, which are situated in a groove, open freely into it in a double series. The cirri themselves[6] are tubular with their apices rounded and imperforate; they are a little flattened at the approximate sides, and are apparently lined throughout by the continuation of a delicate granular epithelium which coats the efferent canal. Towards the base the walls are stout, and have a ridged, horny character; they gradually become attenuated

[1] Plate LX. fig. 10.
[2] Plate LIX. fig. 2.
[3] Plate LXI. fig. 6.
[4] Plate LVIII. fig. 1.
[5] Plate LVIII. fig. 3.
[6] Plate LVIII. fig. 4.

upwards, and are very delicate for about one-third of their length from the apices, their extremities being frequently curled in spirit-specimens: this portion is undoubtedly to some extent contractile. The surface is coated with a rather thick, opake, granular epithelium, which probably sustains vibratile cilia. Upon the removal of this, the walls becoming transparent exhibit double transverse lines; and an internal ridge is seen to extend up one side from the base almost to the apex. Externally there is a deep, membranous keel, or wing, projecting apparently from the same side. The bases of the cirri sink, for some depth, into the substance of the supporting ridge, and open into the efferent canal through gradually expanding mouths. The afferent brachial arteries, originating in the great brachial plexus, enter these expanded orifices, and pass up the interior of the cirri attached to the side next the brachial fold apparently in connexion with the internal ridge; they advance to the apices, where they seem to terminate in open mouths; they do not occupy more than about half the calibre of the channel. The blood therefore poured out of the vessels within the apices of the cirri will find its way down them to the efferent canal of each arm. These canals running backwards to the sides of the œsophagus terminate there, each in a considerable sinus, the efferent brachial sinuses[1], which are somewhat wider than the root of the œsophageal tube, and are of a semi-lunar form, each bearing on its wall a peculiar opake, flattened tubercle; the sinuses pass backward beyond the tube, and are separated behind by the insertion of another large sinus[2], which lies within the layers of the mesenteric membrane, and abuts against the under side of the alimentary tube. The efferent brachial sinuses communicate with this median sinus by numerous apertures, as they do also with the system of large lacunes previously pointed out as being placed round the commencement of the œsophagus, and into which we have seen that the branchio-systemic vein[3], extending along the dorsal ridge of the stomach, opens by two branches.

Traces of the peripheral system have been found in the other species examined; but in none of them has it been so fully observed as in *W. australis*, and in this form it is frequently very indistinct, owing to the condition of the specimens. In *R. psittacea* the vessels leading to the cirri from the great brachial plexus are arranged exactly as in *Waldheimia*; and very distinct indications of the lacunary channels have been observed in the other parts of the economy of this species.

The peripheral lacunes have not been examined in *Lingula*, with the exception of the outer pallial system[4], which is composed of parallel channels freely communicating with each other, and which to some extent are arranged conformably to the great pallial sinuses. It cannot be supposed, however, that in the peripheral system any important difference exists, as it has been shown that in this form the central organs are similar to those in *Waldheimia*. The efferent brachial canal[5] is nevertheless somewhat modified. In *Lingula* it is not formed, as it were, by a septum cutting off a portion of the great brachial canal, but it is excavated in the substance of the semi-cartilaginous ridge at the

[1] Plate LV. fig. 4.
[2] Plate LVII. fig. 2.
[3] Plate LVI. fig. 6.
[4] Plate LXVI. fig. 5.
[5] Plate LXV. fig. 8.

base of the brachial fold. This canal, which is of no great size, is close to the roots of the cirri, which are somewhat expanded, and open into it at the side; it also communicates with cellular interspaces situated in the thickness of the brachial fold. Further than this I have not succeeded in determining the anatomy of these parts, owing to their opacity and minuteness.

Having now gone over all that I have been able to ascertain with respect to the central and peripheral portions of the circulatory apparatus, and having also examined the lacunes and blood-canals of the brachial organs, it will not be difficult to follow the flow of the blood throughout its entire course in *Waldheimia*; and as it is in it, so will it be, in all probability, in all other Brachiopods.

It has been shown that the heart[1] is a simple, unilocular, pyriform vesicle, suspended from the dorsal aspect of the stomach, and projecting freely into the perivisceral chamber; that there is neither auricle nor pericardium, unless the membrane which closely invests it can be so called; that it is hardly more complex in structure than the pulsatile vessel of the Tunicata; and that in *Lingula*, indeed, it scarcely at all differs from the heart of those lowly organized mollusks. This vesicle, or heart, propels the blood through four arterial trunks or channels to the reproductive organs and mantle, and probably also to the alimentary tube, and is apparently assisted by four or more pulsatile vesicles in connexion with these principal trunks. The blood thus conveyed by the genital or pallial arteries will escape by the lacunes in the membranes suspending the genitalia, into the plexus in the floor of the great pallial sinuses. Thence it will find its way into the outer lacunary system of the pallial lobes, and into that of the dorsal and ventral walls of the body, as well as into the lacunes of the anterior parietes. Having saturated all these parts of the peripheral system, it will divide itself into two currents, one of which will set backwards in the direction of the membranous bands connecting the alimentary tube to the parietes, and will flow through their channels into the system of visceral lacunes, which encircle the alimentary canal within the sheath, and which probably carry blood to the liver. This current will also supply the lacunes nourishing the muscles. The blood thus directed will reach the branchio-systemic vein, either by the great œsophageal lacunes, or through the foramina which penetrate the sides of the channel as it runs along the dorsal ridge of the stomach.

The other blood-current will set forward in the direction of the base of the arms, and some of it will pass into these organs through their general system of lacunes; but the principal portion will be carried by the afferent brachial canal to the extensive plexus of lacunes in those parts, and will circulate, in the manner before pointed out, within the walls of the great brachial canal. The blood will then be drawn up one side of the cirri through the vessels,—the afferent brachial arteries,—originating in the great brachial plexus, and returning down the other, will be poured into the efferent brachial canal, and thus reach the lateral efferent sinuses at the root of the œsophagus. Thence it will

[1] Plate LXIII. fig. 1.

enter the great œsophageal lacunes, and there meeting with the other current of returning blood from the visceral lacunes, will be carried to the heart by the branchio-systemic vein along the dorsal side of the stomach.

Thus it is perceived that the blood finds its way back to the central organ in a mixed condition. That which is conveyed by the gastro-parietal and other bands will be imperfectly aërated, having only flowed through the pallial membranes, which must be looked upon as but accessory oxygenating agents. The arms undoubtedly perform the office of gills, and are true respiratory organs. The blood which circulates through them will consequently be returned in a perfectly aërated condition, to be mixed, however, with that in a less pure state from the visceral lacunes before it enters the heart. This mixed state of the blood is not by any means peculiar to these animals, for it obtains in many of even the higher mollusks.

To prove that the brachial organs subserve the function of gills, as well as that of sustentation, it is only necessary to refer to the manner in which the blood circles round the arms and is carried to the cirri; but more particularly to its circulating through these latter organs, and to its return direct from them to the heart. There can be no doubt that the cirri are provided with vibratile cilia, and indeed this fact seems to be established by the observations of Mr. BARRETT[1]; and a considerable portion of their extremities is sufficiently delicate to admit of the blood being aërated through their walls. The inner lamina of the mantle, and more particularly that portion of it forming the floor of the great pallial sinuses, will undoubtedly assist in purifying the blood; but like the mantle of many of the Nudibranchs, it can only play a secondary part. This may fairly be inferred from the distribution of the blood-channels within the lamina. In *T. caput-serpentis*[2], however, this portion of the mantle is so filled with calcareous spicula, that in this instance it must, even in this secondary capacity, have its efficiency much impaired; and in *Megerlia truncata*[3] the floor or inner wall of the trunks of the great sinuses is completely filled with spicula to such an extent, that the membrane seems entirely displaced.

It is generally asserted that the mantle in *Lingula* has assumed the character of a rudimentary gill; and in this genus, indeed, it perhaps attains its highest development as an accessory breathing organ. I find, however, nothing agreeing to the so-called vascular loops of Baron CUVIER[4] and Professor OWEN[5]. The mantle[6] does not appear to differ at all from that of the articulated Brachiopods, except that the inner walls of the pallial sinuses are bulged out, forming, as it were, transverse or radiating plaits: there are, however, no branchial loops; but the surface over which the inner lacunes are distributed being thus increased, the lobes of the mantle in *Lingula* may, to this extent, be considered specialized breathing organs. Nevertheless there is no reason for supposing any modification in the internal arrangement of the blood-channels, that there

[1] *Op. cit.* [2] Plate LII. fig. 6. [3] Plate LII. fig. 9. [4] *Op. cit.* p. 5.
[5] Trans. Zool. Soc. vol. i. p. 157. pl. 23. fig. 16. [6] Plates LXIV. fig. 3; LXVI. fig. 5.

are any afferent and efferent trunks leading directly to and from these so-called rudimentary gills. In fact, in most of the Brachiopods the inner lamina of the pallial sinuses is more or less bulged out; it only happens that in *L. anatina* the bulging is to a greater extent, and the sinuses, being parallel, assume a plaited or laminated character. In *L. affinis* the sinuses are branched[1], and consequently the gill-like structure is not by any means so distinct, though the walls of the sinuses are much inflated[2].

This modification of the inner lamina of the mantle is much of the nature of those various modes of increase of surface observed in the pallial fringes and processes of various mollusks, all of which, there can be little doubt, assist in aërating the blood.

The great extent of brachial organ is also worthy of remark. In *R. psittacea*, for instance, the arms, when stretched out, are $4\frac{1}{2}$ inches long, being upwards of four times the length of the shell; and they give support to about 3000 cirri. To account for the enormous development of these organs, it is necessary to look to something beyond the sustentation of the animal; and the conclusion seems a natural one, that they are destined for the oxygenation of the blood. Analogy would also lead to the same conclusion, whether we look to the *Polyzoa*, to the *Tunicata*, or to the *Lamellibranchiata*.

With regard to the cæcal prolongations of the mantle, it has already been stated that they can scarcely have anything to do with respiration, as has been supposed. Such an opinion rests upon the assumption that they open into the outer pallial lacunes. Now, so far as my observations go, they have no communication at all with them: on the contrary, they seem to originate in the external reticulated layer of the mantle, and do not even penetrate it; the reticulations can be seen passing across their bases[3]. But should they actually perforate this layer, there is still the homogeneous layer separating them from the pallial lacunes. Such is the result of a very attentive examination of this point; and yet it is with some hesitation that it is enunciated, as Dr. CARPENTER, than whom no one is more able to determine this question, entertains the contrary opinion. He appears to have examined the membranes whilst in connexion with the shell; my observations were made after the shell had been reduced by acid. The difference of our results may perhaps arise from the different modes of investigation; at all events, the subject is worthy of further attention.

It must, however, be acknowledged that the corpuscles, almost always found in these cæca, strongly resemble blood-corpuscles; they are of the same colour and form; but in one instance they had undergone a very marked change as to the former character. On placing a fine individual of *W. australis* in acid as soon as the periostracum was removed, the shell was observed to be marked with large patches of dark purplish brown. These patches continued to increase in intensity until the shell was entirely reduced, when the coloration was found to arise from the contents of the pallial cæca, which were made up of the so-called blood-corpuscles, all of which were of a rich purple-brown colour. In other parts, where no coloration existed, the contents of the cæca had their usual appearance, being of a yellowish hue.

[1] Plate LXVI. figs. 1, 2, 3. [2] Note 3, p. 851. [3] Plate LIX. fig. 4.

It is not easy to explain this phenomenon on the supposition that the corpuscles are really blood-globules; but the difficulty would at once disappear if it were assumed that some local disease had produced this abnormal condition in the contents of the cæca; in which case it must be concluded that the corpuscles form an integral part of the cæca themselves, or rather that they are permanently placed within these organs, and do not flow through them, as they must do were the cæca connected with respiration.

It is also a significant fact, that the *Terebratulidæ* are liable to be covered with extraneous matter. Several of the individuals of *W. australis* that have passed through my hands were extensively encrusted with zoophytic and other parasitic growths; and one or two of *T. caput-serpentis* had both valves entirely enveloped in a dense downy coat of some species of sponge. This appears, from what FORBES and HANLEY state in their 'British Mollusca,' to be frequently the case, and to have gained for the specimens so clothed the specific name of *pubescens*. Were the cæca respiratory organs, even in a secondary capacity, this would hardly be the case.

The best mode of investigating these organs[1] is to dissolve the shell, and then they are exposed, in various stages of growth, adhering to the margin of the mantle. They are arranged in rows, and are cylindrical, with the distal extremity obtusely rounded, and are pedunculated from the first; the peduncle is long and narrow; the cæca at the extreme edge are small, but rapidly increase in size backward; the terminal or enlarged portion is almost constantly stuffed full with the so-called blood-corpuscles. When observed in this way, these organs have very much the character of secerning follicles, but what function they really subserve is difficult to determine; it may be that they have something to do with the growth and reparation of the shell, though it is not easy to understand how. They are probably, as suggested by Professor HUXLEY[2], the homological representatives of the vascular processes that penetrate the test of the Ascidian; and if so, it would seem likely that they have lost much of their functional importance; and in fact their entire absence in forms closely allied to those in which they are highly developed, augurs that they are not of any high functional signification. It may therefore be here, as it is in the *Ascidiæ*, that they maintain a vitality in the external covering or shell; low, indeed, in comparison to that of the test of the latter, but sufficient, perhaps, to repair the shell should it be fractured; and as the Brachiopods do not, to any great extent, thicken their shells by successive internal layers, some such provision appears necessary for the purpose.

The reticulated membrane, which is closely adherent to the homogeneous layer beneath, and in which the cæca originate, has very much the character of an epithelial layer. It is therefore not unlikely that they may be productions merely of the epithelium.

From the foregoing account of the circulatory apparatus, it is evident that the perivisceral chamber, and its various so-called vascular ramifications in the mantle, are not

[1] Plate LVIII. fig. 8.

[2] Introduction to DAVIDSON'S 'British Fossil Brachiopoda,' p. 30.

connected with the blood-system. This is no doubt a startling fact. I commenced the present investigation fully imbued with the opinion that these parts were blood-reservoirs and channels, and I only relinquished it when it became no longer tenable. Step by step the points relied on had to be abandoned, until at length the full conviction was arrived at, that I had been seeking to establish a fallacy. I have been unable to discover any communication between the true blood-system and the pseudo-vascular ramifications in the mantle, or the perivisceral chamber. Injections were thrown into this chamber, but none of the fluid found its way into any part of the lacunary system. The pallial lobes were removed, and the great pallial sinuses distended to their fullest capacity, with exactly the same result; and it was not until great pressure was applied, and the tissues ruptured, that a little of the injected matter was extravasated into the peripheral lacunes. The perivisceral chamber, then, and all its various ramifications, are in no way connected with the true blood-system. They must have some other peculiar and important office to serve in the economy of the animal. What is this office? This shall be discussed by and by, and in the meantime it is necessary to revert to the structure of the peripheral lacunes themselves.

These, which answer to the veins and capillaries of the higher animals, are of a very peculiar character. They are for the most part, as we have seen, placed between two membranous layers, or between one such layer and the walls of the viscera. In the former case they can be readily examined, and are found, how various soever their forms may be, to be constructed in the same manner. With regard to those of the outer system of the mantle, it has been shown that they are nothing more than intercommunicating spaces left between two membranes, which are only partially united. In this way they are all formed, but in some the channels take a linear disposition, and compose more or less open networks of various degrees of minuteness, always sharply defined. In well-preserved specimens the lacunes are perfectly distinct, and are generally well charged with blood-corpuscles, which are liable to adhere to each other, forming oval pellets[1]. These channels, moreover, do not appear to be entirely free, but to be encumbered with cellular tissue; so that, when one of the membranes is removed, the coagulated blood remains adherent to the other, retaining the form of the channels in all their distinctness[2].

It has been pointed out that the alimentary canal is encased within a sheath forming the system of visceral lacunes, and that it apparently coats the liver, following all its minute subdivisions. Now, it is the continuation of this sheath, reflected upon the walls of the perivisceral chamber, that forms the lining membrane or inner layer between which and the true walls of the body the parietal lacunes are situated. And moreover it is pretty evident that this membrane also sheaths the muscles, and is continued throughout the great pallial sinuses, enclosing the genitalia within a fold. The various bands, too, passing from the sheath of the alimentary tube to the parietes are

[1] Plate LX. fig. 11. [2] Plate LIX. fig. 3.

duplicatures of this membrane. Thus it appears that the various systems of peripheral lacunes may be considered as one great, continuous blood-reservoir, notwithstanding the multiplicity of its parts. Those of the brachial apparatus may perhaps be an exception to this, and form, to some extent, a distinct system, though they undoubtedly communicate with the lacunes of the parietes. This distinctness, however, is probably more apparent than real, and the great canals of the arms are perhaps only prolongations of the general cavity, though they are cut off from it by a delicate membrane. The two membranes composing the walls of these canals would seem to indicate this.

It is also worthy of remark, that the channels which have been denominated arteries soon lose the appearance of having proper walls. At their origin in the *Terebratulidæ*, they seem to be within the visceral sheath, bulging it out; and as they pass over the parietal bands, they have a peculiar texture and are somewhat different in colour. After reaching the genitalia their character is a little changed, they having assumed the appearance of being formed by the membrane suspending these organs, as if they had become mere channels left within the two layers composing it. This is also the character of the branchio-systemic vein, which seems to be nothing more than a space left between the layers of the mesenteric membrane, though, as it approaches the heart, it has probably proper walls. The efferent brachial canal has all the appearance of being formed by a duplicature of the lining membrane of the great brachial canal; but in *Lingula* it is excavated in the substance of the brachial ridge. There can be little doubt, however, that the vessels which have been termed afferent brachial arteries, those vessels which drain the great brachial plexus and pass up the cirri, have true walls.

This latter fact seems to favour the opinion that the lacunes themselves may have proper walls, and that all these channels are connected from end to end with the central organs by continuity of tissue; to favour, in fact, JOHN HUNTER'S views with regard to the blood-sinuses in the lower animals. I have failed, however, to discover any such continuity of tissue demanded by the hypothesis of our great anatomist. If such had any other than a hypothetical existence, it ought, one would think, to be demonstrable in the *Terebratulidæ*; for perhaps in no other molluscous animal are the peripheral blood-channels so beautifully displayed, and, from the peculiarity of their arrangement, so easily submitted to examination by even the highest powers of the microscope. The tissues are very transparent, and the blood-channels or lacunes most distinctly defined; the only problem being, are these latter lined with a membrane? They contain apparently cellular tissue; does the membrane of continuity thread the meshes of this tissue? or may the tissue itself turn out to be the required walls? These questions must for the present remain unanswered, and in the meantime it would appear best to denominate the channels lacunes, as has been done throughout this communication, for to use the term sinus would be to imply that they had true or proper walls; a matter, to say the least, of extreme doubt.

Perivisceral Chamber.

The great cavity[1] placed close to the hinge of the valves, in which the viscera are lodged, is limited above and below by the dorsal and ventral walls of the body, and in front by the inflection of the inner lamina of the pallial lobes. There are no openings leading into this chamber, except those of the oviducts, which have been already sufficiently described. The œsophagus penetrates the anterior wall; and in the *Terebratulidæ* there are two anterior prolongations of the cavity extending to the extremity of the lateral brachial loops. These prolongations, the brachial pouches, are formed, as before explained, by processes of the inner lamina of the mantle. In *Rhynchonella* there are no such prolongations. The great pallial or genital sinuses open freely into this chamber; they are merely continuations of it, and lie between the two laminæ of the lobes. In *W. australis*[2] there are four of these sinuses in each lobe, two on each side of the median line; they extend from the front of the chamber to the anterior border of the lobe. The external ones are very wide, and give off eight or nine branches from their outer margins, which dividing three or four times dichotomously, result in small twigs, that appear to terminate in a vessel running round the edge of the lobe just within the roots of the marginal setæ; they seem, however, sometimes to end in blind sacs before they reach this vessel. The inner sinuses are comparatively narrow, and on approaching the anterior border of the lobe divide into two short branches similar to those already described. The inner dorsal sinuses, which never contain genital bands, are smaller than the inner ventral ones, and taper gradually forward.

The circumpallial vessels of the two lobes were not very satisfactorily determined; they appear, however, to communicate with the terminal twigs of the great sinuses, to unite posteriorly at the junction of the lobes, and as two lateral trunks to open into the perivisceral cavity, one at each side of the peduncle immediately behind the cardinal process.

There is no modification to note in the perivisceral chamber in any of the *Terebratulidæ* that I have had an opportunity of examining. The pallial sinuses, however, vary in the several species. Thus in *W. cranium*[3], though there are still four such sinuses in each lobe, the trunks are proportionately smaller, and more nearly of a size; the branches are fewer and more attenuated, but, as in the other species, divided dichotomously twice or thrice, without any very marked symmetry.

In *T. caput-serpentis*[4] the four trunks may still be recognized; but a considerable change, as previously noted, has taken place. Here the trunks are fused so as to form in each lobe two large, lateral semi-lunar sinuses, in which the genitalia are placed. The external margins of these sinuses give off numerous, rather delicate branches, which dividing dichotomously run to the pallial margin; the branches next the middle line, which correspond to the inner sinuses, pass off from their internal margins, and divide once or twice.

[1] Plates LII. fig. 10; LVII. figs. 1, 2; LXI. figs. 1, 2.

[2] Plates LII. figs. 1, 2; LIX. fig. 1.

[3] Plate LIII. figs. 3, 4.

[4] Plate LIII. figs. 1, 2.

In *Rhynchonella*[1] a further change is perceptible; there are, however, as in the last species, four genital sinuses of much the same character; but the two in the dorsal lobe give off no branches. These would seem to correspond to the outer sinuses in *Waldheimia*. The inner ones are represented by two trunks which come from the perivisceral chamber, one on each side of the median line, between the expanded bases of the occlusor muscles; they diverge, and turning outwards and backwards circle round a little in advance of the anterior margin of the genital sinuses, giving off numerous branches. The branches divide three or four times, and as the ultimate twigs approach the marginal vessel they invariably bifurcate. The sinuses of the ventral lobe have their anterior margins next the median line prolonged each into a stout trunk, which soon divides into two portions, one of which advancing inclines inwards, the other directed outwards and backwards turns round a little in front of the genitalia. These two portions give off several branches to the pallial margin similar to those of the other lobe.

The perivisceral chamber of *Lingula anatina*[2], though constructed precisely as in the other Brachiopods, is considerably modified in form. It is much larger than usual, extending forward nearly half the length of the shell; and is depressed and elongated, with the dorsal and ventral walls very delicate, transparent and membranous; the lateral ones strong, opake, and muscular. The latter are firmly attached by their margins to the valves, defining with great distinctness the exact boundaries of the chamber. The anterior wall slopes forward towards the dorsal valve to accommodate the advanced position of the occlusor muscles; thus forming a sort of anterior pouch or recess, through the centre of which the œsophagus passes.

There are four pallial sinuses, two in each lobe, which open into the cavity in front, one at each side between the attachments of the posterior occlusors and the adjustor muscles. These sinuses pass forward, converging until at the anterior margin of the lobe they almost meet on the median line. Long, however, before they reach their terminations they suddenly contract, and lose the character of trunks. They give off from their outer margins numerous close-set, simple, parallel branches, which vary in size, generally alternating, large and small, and pass towards the circumference in a radiating manner. On reaching the thickened border of the mantle they abruptly contract[3], and, as much-attenuated twigs, terminate apparently in blind sacs a little within the free margin. These branches are much bulged out into the pallial chamber, and when not distended with fluid assume the form of plaits, giving to the mantle a regular laminated appearance. Small branches also proceed from the inner margin of the main trunks, which for the most part pass inwards and backwards, and end in cæcal extremities. There is also a posterior branch which springs from the root of the great trunk and turns immediately backwards, runs along the lateral expansion of the mantle outside the adjustor muscles, and terminates behind the divaricator muscle, giving off, all the way from either

[1] Plate LX. figs. 1, 2, 3.

[2] Plates LXIV. figs, 1, 2, 4, 5; LXV. figs. 1, 3.

[3] Plate LXIV. fig. 3.

side, numerous irregular ramuscules. The outer ones stretch to the free edge of the pallial border, the inner extend almost to the lateral wall of the body.

In *L. affinis* the branches of the pallial sinuses[1] taper gradually and are a good deal subdivided, and though considerably bulged out do not assume the appearance of laminæ. The two main trunks of the ventral lobe turn suddenly inwards, and meet on the median line, forming, as it were, an arch from which the branches radiate to the pallial border.

The branches of the pallial sinuses are frequently choked up with a reddish-brown matter, which on examination with a microscope is found to be entirely composed of large, roundish, scale-like bodies, no doubt from the epithelial lining of the chamber and its ramifications, which lining in all the Brachiopods is exceedingly deciduous, and rarely observed in its natural position. In the *Terebratulidæ* the sinuses are also not unfrequently clogged with matter, which has been taken for coagulated blood; but on attentive inspection it is found to be made up of similar epithelial scales.

It has been already stated that this complicated chamber is lined throughout with a membrane as well as all the ramifications of the pallial sinuses; and that folds of this membrane form the various bands which pass from the parietes of the body to the visceral sheath, which is itself apparently an involution of the same membrane. The muscles are likewise sheathed by it. To arrive at an understanding of the function of this chamber, so formed, it is necessary in the first place to determine the nature of this lining membrane. Where shall we look for its homologue? Does it form an essential element in molluscan organization? For answers to these important questions I am indebted to Professor HUXLEY, a gentleman from whom I have derived much and important information in connexion with the subject of this paper, and who has with the utmost candour and liberality communicated to me his views on these very interesting points,—interesting, for they relate to all that is most anomalous in the anatomy of these animals, consequently to that which particularly demands our attention.

Before these questions can be solved it is necessary to refer to the *Ascidiæ*, which rank with the lowest organized Mollusks. These animals are provided with several envelopes or tunics; in the first place there is the external covering or test; next the lining membrane or outer tunic; and within it the third tunic enclosing the space termed the atrium by Professor HUXLEY[2]. The space thus circumscribed communicates externally through the excurrent tube; and the blood flows between the outer tunic on the one hand, and the third tunic and the intestine on the other.

Now in the Brachiopods we have the shell which is equal to the test of the Ascidian; then comes the mantle in the place of the outer tunic; but there is nothing to represent the third tunic, unless the lining membrane of the perivisceral chamber does so; and that it is really the homologue of the third tunic there can be little doubt. We have seen that the blood flows between this lining membrane and the mantle, and between

[1] Plate LXVI. figs. 1, 2, 3.

[2] Report Brit. Assoc. 1852, Transactions of the Sections, p. 76.

an involution of it and the viscera, exactly as it would do if, in the Ascidian, the atrial membrane were a little more extensively developed; only in the former case the membrane closely invests the viscera, and is in contact with the mantle, leaving defined blood-channels or lacunes. In both cases the space circumscribed by this membrane opens externally, and in both cases, too, it receives the products of the genitalia on their passage outwards. Much more might be urged in confirmation of this view; but it is not intended, on the present occasion, to enter upon the details of this branch of the subject. Indeed my knowledge of the anatomy of the *Ascidiæ* is too limited to permit me to do so satisfactorily. I can therefore only hope that Mr. HUXLEY will shortly publish his researches bearing upon this matter, for assuredly no one is better prepared than he is to discuss it, as no one has a more extended knowledge of the morphology of the *Mollusca*, and a more complete and accurate acquaintance with the anatomy of the *Ascidiæ*.

Taking it for granted, then, that the atrium and the perivisceral chamber are homologous, the question arises, what light does this fact throw upon the function of the latter? In the *Ascidiæ*, the atrium communicating freely with the surrounding element might be considered as a sort of rudimentary water-system, by those who believe in the existence of such a system. Its function, however, seems to be that of excretion. That portion of it denominated the cloaca is for the outlet of the branchial currents, and at the same time for the discharge of the fæces, and of the ova or spermatozoa, according to the sex of the individual. But the other portion must have some special office to perform; and as its walls are washed by the blood, it would seem probable that it is for carrying out of the system the deleterious or effete nitrogenous matters. At the same time it seems not unlikely that this extension of the atrium may be to facilitate the discharge of the redundant fluid, which having entered the blood, is supposed to pervade the tissues of these animals. Thus the atrium may be viewed as performing the two great functions of a renal apparatus.

This atrial membrane is found in the most rudimentary condition in the *Polyzoa*, for instance, in *Fredericella sultana*. In this species the membrane lining the polyzoon, or that corresponding to the mantle or outer tunic, is invaginated at the orifice of the cell and encloses the upper portion of the animal with a third tunic. When the polype is exserted, this is only partially everted. It must be through the agency of this membrane that the effete, nitrogenized matter is eliminated, as well as the superfluous water, if any such discharge takes place.

The Ascidians, as has been shown, exhibit the next step of development in the arrangement of this membrane into the form of an atrium, into which the water is admitted. Then come the Brachiopods, in which the atrium is largely developed, and considerably modified; but now the external communication is much restricted. The most interesting change, however, is in the structure of the excretory channels or oviducts, which have assumed a glandular character. Thus one portion of the atrial membrane has become specialized, and probably performs one of the functions of a kidney; whilst the other, that is, the lining membrane of the perivisceral chamber, and its various ramifications, must execute the complementary renal office. It has been pointed out that this chamber is everywhere in connexion with the various systems of blood-lacunes; the ramifications in the mantle follow these systems even to the circumpallial vessel, which also lies in the midst of blood-channels. It therefore seems impossible not to conclude that this peculiar arrangement and excessive development of the atrium is to facilitate the evacuation of some matter from the blood, probably little more than pure water.

Some fluid undoubtedly fills the perivisceral chamber, and as it communicates externally, it might be supposed that water would be received in this way. It has been stated, however, that the passages are so constructed that they would not readily admit fluid, though it might easily be discharged by them, the arrangement being very similar to that which obtains at the points of entrance of the ureters into the bladder of the higher animals. And, moreover, the ramifications of this chamber into the pallial lobes are inexplicable, unless it be assumed that they are connected with the discharge of some matter from the blood-system. It must be admitted, nevertheless, that the perivisceral chamber with its ramifications is apparently the equivalent of that which in the other Mollusks is usually denominated the water-system, and into which the external water is supposed to be admitted.

The atrial membrane will probably be found in all the *Mollusca* in various states of development, in some performing the two functions above distinguished by separate portions, in others having these portions, and therefore their functions, more or less united or blended together, as is probably the case in *Doris*, in which the great sinus, designated the kidney[1], stretching along the liver, and following the ramifications of the arteries, is throughout more or less glandular. This renal sinus is also remarkable for the richness of the vascular network in its membranous walls, reminding us forcibly of the peculiar condition of the parietes of the perivisceral chamber.

Again, in the Cephalopods, the renal follicles appended to the venous trunks in the so-called pericardium appear to perform the office of a kidney, while the extension of this cavity is probably the equivalent of the perivisceral chamber and its prolongations, having perhaps to discharge fluid eliminated from the blood instead of receiving it from the exterior. Without wishing to press unduly this suggestion, for it is little more, it may be asked, whence the necessity for supposing that water is admitted direct into the so-called water-system?

Be this, however, as it may, it may perhaps be concluded that the atrial wall of the Ascidian, and the lining membrane of the perivisceral chamber in the Brachiopod, are the homologues of the kidney and membrane composing what is usually designated the water-system in the *Mollusca* generally.

[1] Hancock and Embleton, "On the Anatomy of Doris," Philosophical Transactions, 1852, pp. 227, 228.

Nervous System.

This, like all the other organs, has been hitherto imperfectly described, though its examination does not present any peculiar difficulties; on the contrary, the nerves are very distinctly displayed, and can be easily traced. The nervous element, however, on the whole, exhibits a rather low state of development, lower, undoubtedly, than that of the Lamellibranchs, and not very much higher than that of the Ascidians. As in all true Mollusks, the ganglionic centres are placed in connexion with a nervous collar surrounding the œsophagus.

In *W. australis* the collar[1] is situated at the commencement of the alimentary tube, and there are five nervous centres, three of which, on account of their superior size, may be assumed to be the principal œsophageal ganglia. These lie amidst blood-lacunes, between the two membranes forming the anterior wall of the perivisceral cavity immediately below the œsophagus, or rather, on account of the mouth being bent down, behind it. One, the largest, is central and anterior; the other two form a pair, and are lateral and posterior. The former is flattened or depressed, and elongated transversely across the median line; the anterior and posterior margins are parallel, the sides slope inwards and backwards; at each side in front it is prolonged into a stout nerve, which immediately divides into an upper and a lower trunk. The latter is considerably the smaller, and goes to supply the brachial apparatus, running along the brachial ridge below the cirri.

The other trunk does not send any of its branches to the ventral pallial lobe, as it has been stated to do; but it supplies all the nerves of the dorsal lobe, besides others to the anterior wall of the perivisceral chamber and to the occlusor muscles. A single nerve or two only are sent to the wall of the chamber, and these pass from the root of the trunk; the trunk then advances upwards within the parietes, and on reaching the external margin of the muscles the filaments separate and form a loop[2], from which numerous twigs, dividing and subdividing, enter both sides of the extremity of the posterior occlusor, richly supplying it. This rather peculiar and beautiful arrangement of nerves has hitherto escaped observation, although the loop has been described and figured[3]. The trunk-nerve is continued from the end of the loop round the outer margin of the anterior occlusor muscle, giving to it a few twigs similar to those supplied to the posterior occlusor. It then gives off seven pallial nerves; other two pallial nerves pass off from the loop; thus there are nine sent to each side of the dorsal lobe, all of which run in a radiating manner in connexion with the outer layer of the inner lamina, dividing dichotomously three or four times, though not very regularly. I have entirely failed to detect the circumpallial nerve described by Professor Owen[4], and cannot but suppose that the delicate muscular cord[5], previously mentioned as running within the margin at

[1] Plates LII. fig. 10; LVI. fig. 1; LVII. fig. 2; LXII. fig. 11; LXIII. fig. 2.

[2] Plate LXII. figs. 14, 15.

[3] Introduction to Davidson's 'British Fossil Brachiopoda,' p. 12. pl. 2. fig. 2.

[4] Ibid.

[5] Plate LVIII. fig. 6.

the roots of the setæ, has misled this distinguished anatomist. The terminal twigs have been followed, with the aid of the microscope, until from extreme tenuity they could no longer be seen. Had such a nerve existed it could hardly have escaped detection.

The two lateral or posterior ganglia are fusiform, being elongated in the antero-posterior direction; they are placed one at each side of the median line, a little apart from each other, and are attached by one extremity to the posterior margin of the central ganglia. These extremities have the appearance of being united across the middle line by a cord or commissure, which is more distinct than usual in *W. cranium*. The other extremities are prolonged, and assuming the character of nerves, converge backwards, and at the point where the wall of the perivisceral chamber is attached to the occlusor muscles, they each divide into two trunks,—the ventral pallial, and the posterior or peduncular nerves. The latter, running backwards, one on each side of the middle line, pass from the parietes, and penetrating these muscles, run downwards in the midst of their fibres; on reaching their extremities they turn outwards, and running under the base of the ventral adjustor muscle, stretch backwards in connexion with the wall of the body[1]; they then pass one on each side of the peduncular muscle and divide into two branches, one of which becoming applied to the peduncular capsule, supplies it with two or three twigs, which can be traced to the border of the foramen. This branch also gives off a twig, which is lost in the substance of the peduncle. The other branch runs backwards in connexion with the parietes, and dividing two or three times, sends its twigs to the margin of the foramen.

The pallial nerves, which are larger than the peduncular, pass outwards, running in the walls of the body; they each divide immediately into two portions, both of which turning forward reach the ventral lobe; they then divide again four or five times dichotomously, and distribute numerous twigs to the margin, supplying it as richly as the dorsal nerve does the dorsal lobe. The main branches of the pallial nerves of both lobes run for some distance between the trunks of the great pallial sinuses, which they ultimately cross diagonally; but afterwards the branches of the nerves do not in the least conform to the ramifications of the sinuses. Four or five other nerves pass from the outer side of the lateral ganglia to supply the anterior wall of the body. Each of these takes its origin by two or three delicate roots.

The lateral ganglia, with the two peduncular nerves, appear to have escaped notice up to this time, unless two delicate filaments mentioned by Professor OWEN[2] "as coming off from the lower part of the œsophageal circle near to the origin of the pallio-branchial trunk" may be supposed to represent them, though they are more probably the nerves which supply the anterior wall of the body.

The central ganglion forms the under side of the collar, and the cord which completes it is apparently a simple delicate nervous filament, the extremities of which are united to the ganglion, one at each side, near to the point where the brachial and dorsal pallial nerves separate. At each side close to the ganglion the cord swells a little and forms a

[1] Plate LII. figs. 2, 3. [2] Ibid.

minute round ganglion, from which issues a delicate filament; but these cannot be traced far on account of the large blood-lacunes situated at the root of the gullet; and indeed neither these ganglia nor the filaments, which are all that has been observed of the visceral nervous system, have been determined with sufficient accuracy. On the upper or anterior portion of the collar there are two inconspicuous ganglia, which are small, though considerably larger than those just alluded to; they are elongated transversely, and are placed considerably apart, one on each side of the median line; they give off a few minute filaments, which go to the parts immediately about the mouth, but their exact destination could not be determined, as the tissues are very opake and the filaments excessively minute. These ganglia are apparently the homologues of the labial ganglia of the Lamellibranchs, and probably of that portion of the cerebroids in the encephalous *Mollusca* which gives nerves to the lips and channel of the mouth. The cord with these two pairs of minute ganglia, as well as the large subœsophageal ganglia, lie between the two membranes composing the parietes of the body; so it would appear that these important organs are bathed in the blood flowing in the peripheral lacunes.

No material variation has been observed in the ganglia or nerves in any of the articulated Brachiopods. In *W. cranium*[1], however, the subœsophageal ganglia are slightly altered in form. The central one is narrower than in the other species, and the lateral pair are thickest in front and taper backwards.

In all, the nerves are distinctly striated, as if composed of nerve-tubes, and each is apparently provided with a neurilemma. By far the greater portion of the ganglionic mass, as already pointed out, is placed below the alimentary tube. This is not, however, by any means exceptional in the *Mollusca*; and the ganglia do not exhibit that distinct globular structure so common in these animals, but seem to be composed of minute granules. The structure, however, of the central portions of the system is difficult to observe, on account of the thickening of the membranes with which they are in connexion.

No organs of special sense have been observed, and if any such exist they will probably be in a very rudimentary condition. Indeed, sight, hearing or smell could be of little use to animals like the Brachiopods, deprived of locomotion, and firmly fixed for the whole period of their lives to one spot. Messrs. FORBES and HANLEY, in their 'British Mollusca,' regard as ocelli and otilitic capsules the red spots at the bases of the setigerous follicles in the mantle of *T. caput-serpentis*; but these are probably nothing more than glandular matter in connexion with the growth of the setæ. I have not, however, examined this animal alive, an advantage that these naturalists have apparently enjoyed.

I have not succeeded in detecting the œsophageal ganglia in *Lingula*. Professor OWEN[2] speaks of the subœsophageal ganglia, and they are also mentioned by Dr. C. VOGT[3]; but from what is stated in the memoir, it is pretty evident that the latter physiologist did not satisfactorily demonstrate their existence. The pallial lobes are copiously sup-

[1] Plate LXII. figs. 12, 13. [2] Ibid. [3] *Op. cit.*

plied with nervous filaments, which stream in a radiating manner towards the margin; those more particularly mentioned by Professor OWEN as supplying the muscles, have been described as blood-channels for reasons previously given.

Having now gone over the whole anatomy of these animals, it is necessary to make a few concluding remarks as to their affinities. But before entering upon these, a word or two may be said respecting the growth of the shell; to add anything on its structure would be mere supererogation, Dr. CARPENTER[1] having fully and accurately treated on this interesting portion of the subject. In respect to the increment, this takes place, as in all mollusks, mainly at the margin of the shell, and here the mantle in the *Terebratulidæ* presents a peculiar appearance. When the shell is dissolved in acid, the free border, which projects beyond the marginal fold, and which is applied to the extreme edge of the shell, can be examined with advantage. The pallial cæca are then completely exposed appended to the membrane in various stages of development, and the spaces between them are found studded all over with rather large, clear, oval, cell-like spots[2], which are arranged with considerable regularity in rows, so that those in the approximate rows alternate. These spots apparently correspond to the bases of the prismatic columns of the shell; and if it be allowed that they represent spaces in which calcareous granules had been accumulated, it is easy to understand how the fibrous or columnar structure is formed. A succession of layers of such accumulated granules, deposited one after the other, would result in the peculiar shell formation of the *Brachiopoda*.

It has been stated by Dr. CARPENTER[3], and the statement is perfectly correct, that the extremities of the prisms are not visible on the external surface. He supposes that this arises from the incorporation of the periostracum with the terminations of the prisms. But there appears to be a thin, homogeneous, external layer or stratum of calcareous matter observable at the margin of the valves in young individuals, particularly of *T. caput-serpentis*, in which this layer is apparently thicker than usual. If this be correct, and I can scarcely doubt it, the shell of some species, at least, is composed of two layers, in which the structure is different; and thus in the Brachiopods the outer and inner layers of the Lamellibranchs would seem to be represented.

It may likewise be remarked that this investigation appears to establish that there are two great types of form in the *Brachiopoda*, namely, the articulated and the unarticulated; which are characterized, not merely by the presence of a hinge in the one, and the deficiency of it in the other, but by several other important points in their structure. In the articulated division, the valves are opened by the muscles acting through the agency of a lever; in the unarticulated, by the pressure of fluid contained in the perivisceral cavity; hence the difference in the muscular arrangement previously described. In the former, too, the intestine terminates in a blind sac, while in the latter there is an ample anal aperture. These and many other points might be cited,

[1] Introduction to DAVIDSON's 'British Fossil Brachiopoda,' p. 23.

[2] Plate LVIII. fig. 8.

[3] *Op. cit.* p. 26.

showing the propriety of dividing these animals into two great groups, as was proposed in 1836 by M. DESHAYES[1]. Some objections might, perhaps, be raised to this, on account of *Productus* and *Aulosteges*, as neither have teeth or sockets, though both undoubtedly belong to the articulated group. But notwithstanding these deficiencies, the valves are related to each other as if hinged, and the cardinal process is so locked into the beak of the opposite valve, as to have prevented any lateral movement. The distinctive feature, however, is not in the mere fact of articulation, but in the mode of opening the valves; and in these two genera there was apparently no deviation in this respect from the rest of the group.

With regard to the affinities of the Brachiopods, it is impossible not to be struck with the strong resemblance that exists between the organization of these animals and that of the *Tunicata* and *Polyzoa*. In the first place, they are all three, with a few exceptions, attached to foreign bodies; and in all, the respiratory organ is appended to the mouth, serving at the same time the purpose of sustentation. The intestine has a neural flexure in the *Brachiopoda* and *Polyzoa*, and the arms of the former are constructed upon the same plan as those of a Hippocrepian Polyzoon, as is at once obvious on the examination of the lophophore of *Plumatella*, for instance. It is interesting to mark the gradual change of these organs from their simplest form to their full and complete development in the *Brachiopoda*. In the lower forms of the *Polyzoa* the cirri or tentacles are arranged in a simple circle around the mouth, but in *Fredericella* the base upon which they are supported is angulated a little at each side. In *Plumatella* the angles are produced so as to give to the base a horseshoe form; in fact, to provide two rudimentary arms, along both sides of which the cirri are arranged in a single series. In the next step in the development of these organs the cirri of the two sides are approximated, forming a close-set double series; the arms are much elongated and spirally coiled, and they are thus at once transformed into the brachial apparatus of the Brachiopod: the arms of *Lingula* and *Rhynchonella* are complete, only they are turned forward instead of backward.

The relation of the two forms is also manifested by the muscular system. The polype retractors and the opercular muscles of *Paludicella* seem to be homologous with the adjustor muscles, their position being very similar; and it is also interesting to find that their function is not altogether different, for in addition to the retraction of the polype, they have the power of depressing and moving from side to side the lophophore, much in the same way as the adjustors move the shell in the *Terebratulidæ* upon the peduncle. It has likewise been pointed out by Professor HUXLEY[2], that the occlusor and divaricator muscles of these latter animals act in exactly the same manner as the muscles similarly named, which open and close the beaks or valves of the avicularium or bird's-head process of the Cheilostomatous *Polyzoa*. Thus in these curious organs we see the same peculiar disposition of muscles which characterizes the articulated division; and

[1] LAMARCK, Animaux sans Vertèbres, 2me ed. tom. vii. p. 309.

[2] English Cyclopædia, Nat. Hist. vol. iii. column 859, 1855.

in *Paludicella* there is a set of muscles[1] which acts in the same way as the parietals, or those so instrumental in opening the valves of the unarticulated Brachiopods, as exhibited in *Lingula*. The set alluded to have been likewise denominated parietal muscles, and they are in connexion with the mantle or lining membrane of the cell, their extremities being attached to the cell-wall. By their contraction they diminish the space within which the polype lies, and thus the contained fluid forces it upwards, and at the same time unrolls the tubular orifice; just as the fluid in the perivisceral chamber is made to open the valves by the contraction of the anterior and posterior parietes. From their position and function there can be little doubt that these muscles in *Lingula* and *Paludicella* are homologous. It is also worthy of remark, that the punctures in the cell walls of *Lepralia* resemble the perforations in the shell of the *Brachiopoda*, as has been pointed out by Dr. CARPENTER[2].

The Brachiopods are also very closely connected with the *Ascidiæ*, though the former are more highly organized, as evinced by the greater completeness of the nervous system. In both, the principal ganglionic masses are below the alimentary canal. The relations are however best displayed by the circulatory system, which is developed on the same plan in both forms; the only difference being that the large blood-lacunes of the Ascidian are reduced in size, and are formed for the most part into minute, narrow channels by the development of the atrial membrane, and by its collapse upon the viscera, and its extension and reflexion upon the walls of the body. In these respects, however, the genus *Phallusia* will bear comparison with the Brachiopods. In both, too, there is the same unilocular heart, imperfect arterial system, and almost complete deficiency of veins. The breathing organ in the Ascidian has undergone a considerable change; but whether it is or is not morphologically the same as the arms of the *Brachiopoda*, these organs in both forms are similarly related to the mouth.

The affinity of the Brachiopod to the Ascidian is also seen in the intimate connexion that exists between the mantle and the shell; and the cæcal processes of the former, which penetrate the shell, are probably the homologues of the vascular prolongations which nourish the test of the latter.

The inferiority of the Brachiopods to the Lamellibranchs is evinced alike by the digestive, the circulatory and respiratory organs, and by the nervous system, notwithstanding that the muscular apparatus might be assumed to be developed upon a higher type.

Notes added February 1859.

No. 1.—I have been under the necessity of naming this species, for it does not agree, as far as can be ascertained, with any described form. It was received along with two or three specimens of *L. anatina*, and it was only after the shell had been removed, and the

[1] HANCOCK, "On the Anatomy of the Freshwater Bryozoa," &c., Ann. and Mag. Nat. Hist. vol. v. p. 173 (1850).

[2] Proceedings of the Royal Society, vol. vii. p. 36 (1854).

mantle carefully examined, that its distinctive character was observed. It is, however, smaller, considerably narrower in proportion to its length, and has the shell of a brighter green colour than the species with which it was associated; but the most important character is found in connexion with the pallial lobes, in which the pallial sinuses do not assume the form of gill-like plicæ arranged in parallel order; on the contrary, they are much branched (Plate LXVI. figs. 1 and 2), resembling the pseudo-vascular ramifications of some of the articulated Brachiopods.

The specimen examined was 2 inches long and $\frac{7}{8}$ths of an inch broad.

No. 2.—The valves of the Brachiopods are undoubtedly related anatomically, as stated in the text, though perhaps they ought both to be considered dorsal as well as those of the Lamellibranchs, as has been pointed out by Professor HUXLEY. If this view be correct, the only difference in the arrangement of the valves of the two classes will be that, while in the latter they are united *along* the dorsal ridge, they are articulated *across* the back in the Brachiopods.

No. 3.—Dr. VOGT, in his well-known paper 'On the Anatomy of *Lingula anatina*,' previously quoted in the text, has given a minute, though erroneous description of the so-called gill-organ, having apparently entirely misunderstood the anatomy of the part. He has certainly failed to recognize the true nature of the great pallial sinuses, is not aware that they communicate with the perivisceral chamber, and what he describes as the vascular ramifications of the "gill-leaf" are not vessels at all; the "gill-leaf" itself is a portion of the inner pallial lamina, and the "cilia-leaf" is the remainder of the mantle, being chiefly composed of the outer lamina.

In both the species of *Lingula* that I have examined there is a white line running along the outer wall of the pallial sinuses (Plates LXIV. figs. 1 and 2 *d*; LXVI. fig. 1 *c*, *e*), which, upon a cursory inspection, might be erroneously supposed to be of the nature of a similar line which is observed in the articulated Brachiopods, and which in them is produced by the base of the membrane suspending the genitalia. In *Lingula*, however, this line is, as just stated, in connexion with the *outer* pallial lamina, while in the articulated Brachiopods it is connected with the *inner* lamina. And moreover these lines in the central and lateral sinuses of the latter are united to that of the trunk-sinus, but they are not so united in *Lingula*; those of the lateral branches in it reach no further than the margins of the trunk-sinus, a considerable space being left between their terminations and the line in that sinus. This fact is conclusive against these lines being vascular ramifications, and yet it would seem that they are the vessels of the "gill-leaf," according to Dr. VOGT, for there is nothing else to be found in connexion with the mantle that at all answers to his description, which is sufficiently accurate on this point. These vascular ramifications are, says this eminent anatomist, "surrounded by a translucent space, which is produced by a hollow canal in which the vessels lie." This is exactly the appearance the white lines assume in relation to the pallial sinuses when seen through the pallial membrane. Dr. VOGT likewise points out that the inner and outer branches of the so-called vessels do not appear to join the trunk-vessel, but supposes that this may be owing to their having been broken off on tearing up the specimen. His description, therefore, clearly answers to that of these white lines; he appears, however, to have examined them only from the surface. When the sinuses are laid open, the white lines are found to be produced by a solid, granular substance adhering to, and standing up in relief from, the outer walls. This substance is formed apparently by a thickening of the epithelial lining of the sinus, and has probably some function to serve in connexion with the perivisceral ramifications, but certainly is in no way connected with the blood-circulation.

The bladder-shaped enlargements (Plate LXIV. fig. 3 *e*, *e*) of the lateral pallial sinuses, alluded to by Dr. VOGT, are nothing more than swellings occasioned by the contraction of the pallial or marginal fold, which, pressing upon the extremities of the sinuses, throws their walls into wrinkles, and hence this peculiar appearance. But I have seen nothing like the ramifications of the so-called vessels described by him on the inner surface of these bladder-shaped enlargements, and am inclined to conclude that he has been misled by some fragments of the external epithelium which had been left adhering to their walls.

EXPLANATION OF THE PLATES.

PLATE LII.

Fig. 1. Dorsal view of *Waldheimia australis*, the shell having been removed:—*a*, pallial lobe; *b*, body; *c*, peduncle; *d*, great inner pallial sinuses giving branches to the margin; *e*, outer ditto, ditto; *f*, genitalia seen through the pallial membrane; *g*, red matter of ditto; *h*, marginal fold; *i*, setæ; *j*, circumpallial vessel; *k*, extreme pallial margin; *l*, median fissure, corresponding to longitudinal plate in valve; *m*, depression occasioned by the hinge-plate and the bases of the crura; *n*, orifices for the passage of the crura; *o*, ridge formed by the union of the pallial margins; *p*, extremities of anterior occlusors; *q*, ditto of posterior occlusors; *r*, ditto of divaricators; *s*, ditto of dorsal adjustors; *t*, liver seen through the wall of the body.

Fig. 2. Ventral view of the same; the letters up to and including *k* correspond to those of fig. 1:—*l*, extremities of occlusor muscles; *m*, ditto of divaricators; *n*, ditto of accessory divaricators; *o*, ditto of ventral adjustors; *p*, ditto of peduncular muscles; *q*, cæcal extremity of intestine, seen through the wall of the perivisceral chamber; *r*, peduncular nerves.

Fig. 3. Ventral view of variety of *W. australis*: the letters correspond to those of fig. 2. The divaricators and their accessories are united.

Fig. 4. Internal view of dorsal valve of *W. australis*, showing the calcareous loop:—

a, hinge-plate; *b*, dental sockets; *c*, hinge-process; *d*, longitudinal plate or septum; *e*, crura; *f*, crural procesess; *g*, upper or dorsal member of loop; *h*, lower ditto; *i*, transverse portion of ditto.

Fig. 5. Portion of dorsal valve of *W. cranium*:—*a*, dental sockets; *b*, hinge-process; *c*, crura of loop; *d*, crural processes; *e*, portion of upper or dorsal member of loop; *f*, impression of dorsal adjustors.

Fig. 6. Lateral half of ventral pallial lobe of *Terebratulina caput-serpentis*, exhibiting arrangement of spicula:—*a*, marginal fold; *b*, setæ; *c*, spicula overlying great pallial sinus; *d*, *d*, ditto overlying the branches of the sinus.

Figs. 7, 8. Two spicula highly magnified.

Fig. 9. Lateral half of ventral pallial lobe of *Megerlia truncata*, exhibiting arrangement of spicula:—*a*, marginal fold; *b*, genitalia; *c*, *c*, spicula.

Fig. 10. General view of the viscera of *W. australis*, the perivisceral chamber having been laid open from above:—*a*, portion of dorsal pallial lobe; *b*, ditto of ventral lobe; *c*, peduncle; *c'*, capsule of ditto; *d*, extremities of anterior occlusor muscles, that on the right partially removed; *d'*, ditto of posterior occlusors, the right one also partially removed; *d''*, ventral extremities of occlusors; *e*, divaricators; *e'*, extremities of the same attached to cardinal process; *e''*, accessory divaricators; *f*, *f*, dorsal adjustors, cut through; *g*, ventral adjustors; *h*, œsophagus; *i*, stomach; *j*, intestine; *k*, ducts of the right hepatic lobes, the latter having been removed; *k'*, anterior hepatic lobe of the left side, seen through the wall of the perivisceral chamber; *k''*, posterior ditto; *l*, lateral gastro-parietal band; *m*, central ditto; *n*, ilio-parietal ditto; *o*, dorsal mesentery; *p*, ventral ditto; *q*, laminated portions of oviducts (auricles of the pseudo-hearts); *r*, orifice leading into ditto; *s*, *s*, *s*, *s*, genital organs, those on the right partially removed; *t*, heart, dilated; *t'*, *t'*, *t'*, accessory pulsatile vesicles; *u*, branchio-systemic vein bringing the blood from the arms or gills and the rest of the body to the heart; *v*, *v*, *v*, ventral pallial or genital arteries; *v'*, *v'*, dorsal ditto; *x*, œsophageal ganglia, giving off nerves.

PLATE LIII.

Fig. 1. Dorsal view of *Terebratulina caput-serpentis*, deprived of the shell:—*a*, pallial lobe; *b*, body; *c*, peduncle; *d*, *d*, great pallial or genital sinuses; *e*, *e*, ramifications of ditto; *f*, muscular ties passing between the walls of ditto; *g*, genitalia seen through the walls of ditto; *h*, marginal fold; *i*, setæ; *j*, extreme pallial margin; *k*, depressions corresponding to the bases of the crura; *l*, ridge formed by the union of the pallial margins; *m*, edge of dorsal mesentery; *n*, *n*, liver seen through the walls of the perivisceral chamber; *o*, extremities of anterior occlusors; *p*, ditto of posterior occlusors; *q*, ditto of divaricators; *r*, ditto of dorsal adjustors.

Fig. 2. Ventral view of the same; the letters up to *j* agree with those of fig. 1:—*k*, extremities of occlusor muscles; *l*, ditto of divaricators; *m*, ditto of ventral adjustors; *n*, ditto of peduncular muscle; *o*, *o*, peduncular nerves.

Fig. 3. Dorsal view of the animal of *W. cranium*:—*a*, pallial lobe; *b*, body; *c*, peduncle; *d*, *d*, great inner pallial sinus; *e*, outer ditto; *f*, genitalia, appearing through the walls of the sinuses; *g*, marginal fold; *h*, setæ; *i*, circumpallial vessel; *j*, extreme pallial margin; *k*, two lobes corresponding to cavities at the sides of the foramen; *l*, similar lobes corresponding to cavities in the umbonal region of dorsal valve; *m*, ridge resulting from the union of the pallial margins; *n*, extremities of anterior occlusors; *o*, ditto of posterior occlusors; *p*, ditto of dorsal adjustors; *q*, ditto of divaricators.

Fig. 4. Ventral view of the same; the letters up to *k* as in fig. 3:—*l*, extremities of occlusor muscles; *m*, ditto of divaricators; *m'*, portions of ditto corresponding to the accessory divaricators; *n*, ditto of ventral adjustors; *o*, ditto of peduncular muscle; *p*, *p*, peduncular nerves.

Fig. 5. General view of perivisceral chamber of *T. caput-serpentis* seen from above:—*a*, portion of dorsal pallial lobe; *b*, peduncle; *c*, capsule of ditto; *d*, ridge formed by the union of the pallial margins; *e*, stomach; *f*, intestine; *g*, *g*, lateral lobes of the liver; *h*, laminated portions of oviducts; *i*, orifices leading into ditto; *j*, anterior occlusor muscles; *k*, posterior ditto; *l*, *l*, *l*, dorsal adjustors cut through; *m*, ventral ditto; *n*, divaricators; *n'*, extremities of ditto attached to cardinal process; *o*, dorsal mesentery; *p*, ventral ditto; *q*, lateral gastro-parietal bands; *r*, ilio-parietal bands; *s*, heart, dilated; *t*, accessory pulsatile vesicle; *u*, branchio-systemic vein; *v*, ventral pallial artery; *w*, dorsal ditto; *x*, peduncular artery.

Fig. 6. Enlarged view of a portion of the mantle of *Megerlia truncata*, exhibiting the spicula undisturbed:—*a*, *a*, spicula.

Fig. 7. One of the spicula more highly magnified.

Fig. 8. Much enlarged view of a portion of the genitalia of *W. australis*:—*a*, pallial membrane; *b*, *b*, yellow ovigerous substance; *c*, *c*, red matter supposed to be the male secreting organ.

Fig. 9. Oviduct of *W. cranium* as seen through the wall of the perivisceral chamber:—*a*, portion of genital organ; *b*, genital or pallial artery; *c*, internal laminated portion of oviduct; *d*, tubular portion of ditto; *e*, external orifice.

Fig. 10. Oviduct of *W. australis*:—*a*, portion of anterior wall of perivisceral chamber; *b*, ditto of ilio-parietal band; *c*, laminated portion of oviduct (auricle of pseudo-heart); *d*, orifice leading into ditto from perivisceral chamber; *e*, tubular portion of organ; *f*, external orifice seen through the wall of the chamber; *g*, ventral pallial artery; *h*, accessory pulsatile vesicle in contracted state.

PLATE LIV.

Fig. 1. General view of the viscera of variety of *W. australis*, seen from above:—*a*, portion of dorsal pallial lobe; *b*, *b*, great inner pallial sinuses, that on the left laid open; *b'*, outer ditto; *c*, genitalia; *d*, peduncle; *e*, capsule of ditto; *f*, *f*, anterior occlusors; *f'*, *f'*, posterior ditto, the left one partially removed to exhibit gastro-parietal band; *g*, divaricators; *h*, *h*, dorsal adjustors cut through; *i*, ventral adjustors; *j*, ventral extremities of occlusors; *k*, stomach; *l*, intestine; *m*, right lobes of the liver, seen through the wall of the perivisceral chamber; *m'*, portion of anterior hepatic lobe of left side; *n*, *n*, hepatic ducts of anterior and posterior lobes of the same side; *o*, dorsal mesentery; *p*, one of the lateral gastro-parietal bands; *q*, central gastro-parietal band; *r*, heart, dilated; *s*, ventral accessory pulsatile vesicles; *s'*, one of the dorsal ditto, contracted; *t*, branchio-systemic vein; *u*, dorsal pallial artery; *v*, ventral ditto; *w*, peduncular artery; *x*, posterior extremities of ventral genitalia; *y*, laminated portion of oviducts; *z*, orifice leading into ditto.

Fig. 2. General view of the viscera of *W. cranium*, seen from above; the letters agree with those of fig. 1 up to and including *l*:—*m*, hepatic lobes; *n*, dorsal mesentery; *o*, lateral gastro-parietal bands; *p*, ilio-parietal ditto; *q*, heart in contracted state; *r*, branchio-systemic vein; *s*, *s*, dorsal pallial artery; *t*, ventral ditto; *u*, peduncular artery, running along margin of ventral mesentery; *v*, posterior extremity of right dorsal genital organ; *w*, posterior extremities of ventral genitalia; *x*, laminated portion of oviducts.

Fig. 3. Intestine of the same, enlarged:—*a*, upper extremity; *b*, posterior cæcal extremity; *c*, *c*, portions of oviducts; *d*, ventral mesentery; *e*, *e*, thickened ridges of ditto; *f*, peduncular artery.

Fig. 4. Cæcal or lower extremity of the same intestine seen in the compressor:—*a*, walls of intestine; *b*, cavity of ditto; *c*, ventral mesentery; *d*, *d*, thickened ridges of ditto.

Fig. 5. Transverse section of intestine a little below the stomach:—*a*, *a*, portions of ilio-parietal bands; *b*, portion of ventral mesentery; *c*, external sheath of intestine; *d*, muscular layer of ditto; *e*, *e*, folds of mucous membrane.

Fig. 6. Another section of the same intestine a little lower down.

Fig. 7. A third section a little above cæcal extremity; the letters of the two last correspond to those of fig. 5.

Fig. 8. Side view of lower portion of intestine of *W. australis*:—*a*, *a*, ventral mesentery; *b*, lacunes or blood-channels, between the layers of ditto; *c*, cæcal extremity of intestine; *d*, ridges in mesentery.

Fig. 9. Cæcal extremity of intestine seen through the dorsal wall of the perivisceral chamber:—*a*, portion of dorsal wall of chamber; *b*, bases of the pallial cæca; *c*, imperforate extremity of intestine.

Figs. 10, 11. Transverse sections of intestine: letters as in fig. 5.

PLATE LV.

Fig. 1. Animal of *W. australis* deprived of the shell, and the pallial lobes turned back so as to expose the brachial apparatus and anterior wall of the body:—*a*, portion of ventral lobe; *b*, dorsal ditto; *c*, *c*, genitalia appearing through the walls of the pallial sinuses; *d*, base of membrane suspending genitalia; *e*, *e*, umbonal region; *f*, peduncle; *g*, spiral portion of brachial apparatus; *h*, lateral portions of ditto; *i*, *i*, *i*, cirri; *j*, brachial fold, a few cirri having been removed to expose it and the anterior wall of the body; *k*, position of mouth, which is concealed under the fold; *l*, occlusor muscles seen through the anterior wall; *m*, left oviduct lying within the anterior wall; *n*, orifice leading into oviduct.

Fig. 2. View of brachial apparatus and anterior wall of the body of *Terebratulina caput-serpentis*:—*a*, portion of ventral pallial lobe; *b*, ditto of dorsal lobe; *c*, *c*, genitalia, seen through the walls of the pallial sinuses; *d*, base of suspending membrane of genitalia forming a reticulated line; *e*, muscular ties uniting the walls of pallial sinuses; *f*, umbonal region; *g*, peduncle; *h*, lateral portions of arms; *i*, spiral portions of ditto; *j*, cirri; *k*, *k*, roots of cirri that have been removed; *l*, *l*, brachial fold; *m*, groove formed by ditto; *n*, mouth; *o*, occlusor muscles appearing through the anterior wall; *p*, divaricators ditto; *q*, ventral adjustors ditto; *r*, liver ditto; *s*, right oviduct ditto; *t*, orifice leading into oviduct.

Fig. 3. View of brachial apparatus and anterior wall of the body of *Rhynchonella psittacea*:—*a*, ventral pallial lobe; *b*, dorsal ditto; *c*, *c*, genitalia imperfectly developed; *d*, base of suspending membrane of ditto appearing as a reticulated line; *e*, muscular ties passing between the walls of the genital sinuses; *f*, umbonal portion of animal; *g*, peduncle; *h*, the left arm partially uncoiled; *i*, base of the right arm, the arm itself having been removed; *j*, cirri; *k*, brachial fold; *l*, mouth; *m*, occlusor muscles, seen through the anterior wall; *n*, divaricators ditto; *o*, liver ditto; *p*, œsophagus ditto; *q*, edge of dorsal mesentery ditto; *r*, *r*, *r*, *r*, oviducts ditto; *s*, orifices leading into oviducts.

Fig. 4. Transverse section of root of œsophagus of *W. australis*, exhibiting the great œsophageal blood-lacunes:—*a*, *a*, base of arms; *b*, *b*, efferent brachial sinuses; *c*, two tubercles on the walls of ditto, function not known; *d*, *d*, efferent brachial canals; *e*, dorsal mesentery; *f*, ventral ditto; *g*, mucous membrane lining œsophagus; *h*, muscular wall of œsophagus; *i*, outer sheath of ditto; *j*, *j*, great œsophageal lacunes; *k*, large sinus within the layers of the mesenteric membrane; *l*, portion of the central œsophageal ganglion; *m*, *m*, roots of dorsal pallial nerves; *n*, œsophageal collar.

PLATE LVI.

Fig. 1. General view of the viscera of *W. australis*, the perivisceral chamber completely laid open:—*a*, portion of dorsal pallial lobe; *b*, peduncle; *c*, *c*, capsule of ditto; *d*, *d*, extremities of anterior and posterior occlusors, those of the right partially removed; *d'*, ventral extremities of occlusors; *e*, *e*, *e*, divaricators, that of the right side divided; *e'*, accessory divaricators; *f*, *f*, *f*, ventral adjustors, that on the right cut through; *g*, *g*, dorsal adjustors, cut through; *h*, peduncular muscle; *i*, œsophagus; *j*, stomach, with the biliary ducts exposed on the right, the hepatic lobes of that side having been removed; *k*, *k*, left hepatic lobes seen through the wall of the perivisceral chamber; *l*, intestine; *m*, dorsal mesentery; *n*, ventral ditto; *o*, ilio-parietal band; portions of the gastro-parietal bands are seen attached to the stomach; *p*, *p*, *p*, *p*, genitalia, those of the right side have their posterior extremities removed; *q*, oviduct; that on the right partially cut away so as to expose the tubular portion of the organ lying within the anterior wall of the chamber; *r*, heart, dilated; *s*, *s*, *s*, *s*, accessory pulsatile vesicles, also dilated; *t*, branchio-systemic vein; *u*, aorta giving off dorsal and ventral pallial arteries; *v*, peduncular artery; *w*, œsophageal ganglia; *x*, loop of pallial nerve giving branches to mantle, and occlusor muscles; *y*, pallial nerves; *z*, *z*, peduncular ditto.

Fig. 2. Transverse section of the base of the arms of *W. australis*:—*a*, portion of dorsal pallial lobe; *b*, ditto of ventral lobe; *c*, root of œsophagus seen through the anterior wall of the perivisceral chamber; *d*, liver ditto; *e*, anterior occlusor muscles ditto; *f*, *f*, bases of the lateral portions of the arms; *g*, *g*, ditto of spiral portions of ditto; *h*, membrane uniting the spirals; *i*, *i*, great brachial canals of ditto; *j*, *j*, small or efferent brachial canal; *k*, *k*, great brachial canal of lateral portions, that on the left laid open to show its connexion with the same canal of the spiral; *l*, *l*, *l*, *l*, small or efferent brachial canals of lateral portions; *m*, *m*, brachial pouches, opening into the perivisceral chamber; *n*, *n*, *n*, *n*, sheaths of calcareous loop; *o*, *o*, *o*, grooved ridge; *p*, *p*, *p*, brachial fold; *q*, *q*, cirri.

Fig. 3. Transverse section of spiral portion of arm much enlarged:—*a*, great brachial canal; *b*, small or efferent ditto; *c*, grooved ridge; *d*, bases of cirri; *e*, brachial fold; *f*, groove; *g*, membrane uniting spirals.

Fig. 4. Transverse section of genital organ:—*a*, *a*, lobules of ditto; *b*, genital or pallial artery; *c*, membrane suspending genitalia in pallial sinus; *d*, inner wall of sinus.

Fig. 5. Dorsal view of stomach, exhibiting the branchio-systemic vein laid open:—*a*, œsophagus; *b*, stomach; *c*, commencement of intestine; *d*, lateral gastro-parietal band; *e*, central ditto; *f*, heart; *g*, dorsal pallial artery; *h*, ventral ditto; *i*, branchio-systemic vein laid open; *j*, *j*, orifices leading into the gastric or visceral lacunes; *k*, hepatic ducts.

Fig. 6. Anterior or dorsal aspect of root of œsophagus, showing the connexion of the branchio-systemic vein with the great œsophageal lacunes:—*a*, outer sheath of œsophagus; *b*, muscular wall of ditto; *c*, mucous membrane of ditto; *d*, ventral mesentery; *e*, large sinus between the layers of ditto; *f*, *f*, dorsal pallial nerves; *g*, œsophageal collar; *h*, *h*, efferent brachial canals; *i*, *i*, efferent brachial sinuses; *j*, two tubercles on the walls of ditto, function unknown; *k*, *k*, great œsophageal lacunes; *l*, branchio-systemic vein laid open.

Fig. 7. Enlarged view of the heart attached to the stomach:—*a*, stomach; *b*, commencement of intestine; *c*, lateral gastro-parietal band; *d*, central ditto; *e*, dorsal mesentery; *f*, heart in contracted state; *g*, *g*, branchio-systemic vein opened to show its connexion with the heart; *h*, aorta; *i*, dorsal pallial artery; *j*, ventral ditto; *k*, portion of oviduct.

Fig. 8. Portion of lateral gastro-parietal band, exhibiting blood-channels or lacunes:—*a*, dorsal pallial artery; *b*, lacunes between the layers of membrane; *c*, *c*, the two layers composing the band.

PLATE LVII.

Fig. 1. Posterior view of the viscera of *W. australis*, the umbonal region having been removed:—*a*, dorsal surface of animal; *b*, ventral ditto; *c*, anterior occlusors; *c'*, posterior ditto; *c''*, ventral extremities of occlusors; *d*, divaricators; *d'*, accessory ditto; *e*, ventral adjustors; *f*, *f*, portions of dorsal ditto; *g*, stomach, the liver having been removed from the left side, the roots of the hepatic ducts are exposed; *h*, right hepatic lobes; *i*, intestine; *j*, *j*, lateral gastro-parietal bands; the central band is seen immediately above the heart; *k*, fissure corresponding to the longitudinal plate or septum of the dorsal valve; *l*, upper portion of ventral mesentery; *m*, *m*, genitalia; *n*, oviducts, attached to the intestine by the ilio-parietal bands; *o*, heart in contracted state, giving off two lateral arteries; *p*, *p*, accessory pulsatile vesicles; *q*, ventral pallial arteries; *r*, peduncular artery; *s*, orifices for the passage of the crura of the loop; *t*, brachial cirri; *u*, *u*, orifices leading into inner pallial sinuses; *v*, outer dorsal pallial sinus partially laid open; *w*, ventral ditto, ditto.

Fig. 2. Lateral view of the viscera of the same:—*a*, dorsal surface of animal; *b*, ventral ditto; *c*, *c*, anterior wall of perivisceral chamber; *d*, brachial spiral, the left lateral portion of the arm having been removed; *d'*, right lateral portion of ditto; *e*, great brachial canal; *f*, small or efferent ditto; *g*, brachial grooved ridge; *h*, sheath of transverse portion of calcareous loop; *i*, *i*, dorsal extremities of anterior and posterior occlusors; *j*, ventral portion of ditto; *k*, divaricators; *k'*, accessory ditto; *k''*, extremities of ditto attached to cardinal process; *l*, *l*, portions of ventral adjustors; *l'*, *l'*, portions of dorsal ditto; *m*, peduncle; *n*, peduncular capsule; *o*, peduncular muscle; *p*, œsophagus; *q*, stomach,

with the roots of the biliary ducts exposed, the left lobes of the liver having been removed; *r*, right lobes of the liver seen through the dorsal mesentery; *s*, intestine; *t*, portion of gastro-parietal band; *t'*, central ditto; *u*, ventral mesentery; *u'*, upper portion of ditto; *v*, right oviduct, the left one is almost entirely removed; *w*, heart; *x*, dorsal pallial artery; *y*, ventral ditto; *y'*, blood-sinus in mesenteric membrane; *z*, œsophageal ganglia.

Fig. 3. Longitudinal section of peduncle:—*a*, distal extremity; *b*, foreign matter adhering to ditto; *c*, horny sheath; *d*, muscular mass; *e*, *e*, walls of capsule; *f*, *f*, walls of perivisceral chamber; *g*, margin of orifice leading into capsule; *h*, peduncular muscle; *i*, right ventral adjustor; *j*, muscular enlargement attaching ditto to peduncle; *k*, right dorsal adjustor; *l*, muscular enlargement uniting the latter to peduncle.

Fig. 4. Ventral aspect of peduncle, the capsule laid open:—*a*, peduncle; *b*, muscular mass of ditto; *c*, horny sheath of ditto; *d*, walls of capsule; *e*, margin of orifice leading into ditto; *f*, *f*, irregular plications of the inner surface of ditto; *g*, extremity of peduncular muscle; *h*, ditto of accessory divaricators; *i*, portion of ventral wall of perivisceral chamber; *j*, ditto of dorsal wall of ditto.

Fig. 5. One of the setæ from the pallial margin of *W. australis*, much enlarged.

Fig. 6. A marginal seta of *T. caput-serpentis*:—*a*, follicle from which the seta originates; *b*, enlarged extremity of follicle, containing red glandular matter.

Fig. 7. Portion of the same seta more highly magnified.

Fig. 8. Two marginal setæ of *Lingula anatina*.

Fig. 9. Portion of the same, greatly enlarged, exhibiting transverse ridges.

PLATE LVIII.

Fig. 1. Transverse section of the brachial grooved ridge of *W. australis*:—*a*, base supporting cirri; *b*, brachial fold; *c*, groove; *d*, *d*, walls of great brachial canal; *e*, small or efferent ditto; *f*, *f*, *f*, epithelium; *g*, *g*, roots of cirri exhibiting their biserial arrangement; *h*, expanded bases of ditto, opening into the efferent brachial canal; *i*, *i*, plexus of blood-channels communicating with that in the wall of the great brachial canal; *j*, *j*, great brachial plexus; *k*, afferent brachial arteries leading from ditto into cirri; *l*, *l*, the same arteries passing up cirri.

Fig. 2. Transverse section of the same brachial grooved ridge, exhibiting its muscular system; the letters up to and including *h* correspond to those of fig. 1:—*i*, *i*, group of muscular fibres for elevating the cirri; *j*, *j*, ditto for contracting the groove and brachial fold; *k*, *k*, ditto, partially antagonistic to the last group, and for bringing forward or depressing the cirri; *l*, *l*, thin layer of muscular fibres, from which group *k* originates; *m*, epithelial lining of efferent brachial canal.

Fig. 3. Portion of brachial ridge, exhibiting the orifices leading into the cirri, the wall

of the efferent brachial canal laid open:—*a*, *a*, portions of the wall of this canal; *b*, orifices leading into the cirri; *c*, *c*, afferent brachial arteries; *d*, transverse channels of great brachial plexus; *e*, portion of the wall of great brachial canal; *f*, minute plexus at the base of brachial ridge.

Fig. 4. Terminal portions of two cirri deprived of their epithelium:—*a*, longitudinal ridge supporting afferent brachial artery; *b*, external lamina or keel; *c*, *c*, blood-corpuscles.

Fig. 5. Diagram of longitudinal section of marginal portion of valve in connexion with the mantle:—*a*, margin of valve; *b*, shell exhibiting prismatic structure; *c*, *c*, pallial cæca penetrating ditto; *d*, great pallial sinus; *e*, marginal vessel; *f*, outer lamina of mantle; *g*, external reticulated layer of ditto, in which the pallial cæca take their origin; *h*, homogeneous layer of outer lamina; *i*, inner lamina of mantle; *j*, epithelium; *k*, *k*, membrane lining pallial sinus; *l*, epithelium of ditto; *m*, outer pallial lacunes; *n*, inner ditto; *o*, marginal fold; *p*, one of the setæ; *q*, follicle of ditto; *r*, prolongation of glandular matter of follicle; *s*, marginal muscles; *t*, extreme pallial margin.

Fig. 6. Portion of pallial margin, the inner lamina partially removed:—*a*, extreme margin; *b*, marginal fold; *c*, *c*, setæ; *d*, follicles of ditto; *e*, prolongations of the glandular matter of the follicles; *f*, circumpallial muscular belt; *g*, *g*, marginal muscles; *h*, outer lamina of mantle, exhibiting through the inner homogeneous layer the bases of the cæca, *i*, *i*, and the reticulations of the external layer.

Fig. 7. Diagram of transverse section of a portion of the mantle:—*a*, outer lamina; *b*, external reticulated layer of ditto; *c*, homogeneous layer of ditto; *d*, bases of pallial cæca; *e*, inner lamina of mantle; *f*, epithelium of ditto; *g*, great pallial sinus; *h*, membranous lining of ditto; *i*, epithelium of ditto; *j*, genital organ; *k*, membrane with its epithelium coating ditto; *l*, membrane suspending genitalia; *m*, genital or pallial artery; *n*, outer pallial lacunes; *o*, inner ditto; *p*, lacunes connecting the latter with the genital artery.

Fig. 8. Portion of the extreme pallial margin, exhibiting pallial cæca in various stages of growth:—*a*, pallial membrane; *b*, clear spots, apparently corresponding to the bases of the testaceous prisms; *c*, *c*, enlarged portions of cæca; *d*, slender, duct-like portions of ditto; *e*, marginal fold.

Fig. 9. A branch of one of the hepatic lobes:—*a*, duct, exhibiting minute internal laminæ; *b*, terminal cæca.

Fig. 10. A ramuscule of the same branch a little enlarged:—*a*, duct; *b*, *b*, cæca.

PLATE LIX.

Fig. 1. External view of lateral half of the dorsal pallial lobe of *W. australis*, exhibiting the blood-lacunes:—*a*, *a*, anterior and lateral margins of lobe, armed with setæ; *b*, *b*, great pallial sinuses laid open; *c*, *c*, portions of the genitalia;

d, pallial or genital artery cut through; *e*, *e*, membrane along which the artery runs, and which suspends the genitalia; *f*, a similar membrane, probably also connected with an artery; *g*, *g*, nodules of reddish coloured matter attached to ditto, resembling that in connexion with the genitalia; *h*, *h*, *h*, nerves; *i*, portion of epithelium covering inner surface of mantle; *j*, external homogeneous layer, which, together with its epithelium, forms the inner pallial lamina; *k*, *k*, membrane lining the great sinus; *l*, portion of epithelial lining of sinus left adhering to the inner wall; *m*, *m*, *m*, external lamina of lobe; *n*, outer reticulated layer of ditto; *o*, *o*, *o*, blood-lacunes, forming the outer pallial lacunary system; *p*, *p*, points of union of the two layers between which the lacunes are situated; *q*, *q*, inner pallial lacunes or blood-channels communicating with the genital arteries, through the suspending membrane, and with the outer pallial lacunes; *r*, circumpallial vessel.

Fig. 2. Portion of the great brachial canal laid open, exhibiting the blood-channels or lacunes in its walls:—*a*, semi-cartilaginous or grooved ridge bearing the cirri, *b*, and the brachial fold, *c*; *d*, portion of stout membrane uniting the spirals; *e*, supposed afferent brachial channel; *f*, plexus of lacunes communicating with ditto, and probably with great brachial plexus; *g*, minute plexus at the point of union between the channels, *h*, that encircle the arm and those in the membrane connecting the spirals; *h'*, plexus situated at the other extremity of the encircling channels, and communicating with those of the grooved ridge or great brachial plexus, *i*; *j*, transverse channels of great brachial plexus; *k*, afferent brachial arteries; *l*, *l*, ditto entering cirri; *m*, orifices leading into cirri; *n*, *n*, wall of small or efferent brachial canal cut through and laid back.

Fig. 3. Portion of dorsal wall of the perivisceral chamber, the inner surface turned up, and the epithelium removed:—*a*, granular lining membrane; *b*, external reticulated layer, in which the pallial cæca originate; *c*, delicate homogeneous layer in contact with ditto; *d*, *d*, bases of pallial cæca; *e*, *e*, blood-channels or lacunes charged with blood-corpuscles and cellular tissue; *f*, contents of blood-channels left adhering to the homogeneous layer on removing the lining membrane.

Fig. 4. Portion of the external reticulated and homogeneous layers much magnified:—*a*, outer reticulated layer; *b*, homogeneous ditto; *c*, *c*, bases of the pallial cæca.

PLATE LX.

Fig. 1. Dorsal view of the animal of *Rhynchonella psittacea*:—*a*, pallial lobe; *b*, body; *c*, peduncle; *d*, *d*, great pallial sinuses giving branches of the margin; *e*, marginal fold; *f*, circumpallial vessel; *g*, extreme pallial margin; *h*, *h*, genitalia; *i*, *i*, muscular ties uniting the walls of the genital sinuses; *j*, *j*, brachial apparatus

appearing through the mantle; *k*, two lobes of the ventral surface corresponding to cavities at the sides of the foramen; *l*, two depressions occasioned by the bases of the crural processes or oral laminæ; *m*, *m*, extremities of anterior and posterior occlusors; *n*, liver; *o*, longitudinal depression for the reception of the dorsal septum; *p*, ridge formed by the union of the pallial margins.

Fig. 2. Ventral view of the same; the letters up to *j* agree with those of fig. 1:—*k*, bulbous extremity of intestine seen through the wall of the body; *l*, edge of the ventral mesentery; *m*, extremities of occlusor muscles; *n*, ditto of divaricators; *o*, ditto of accessory divaricators; *p*, ditto of ventral adjustors; *q*, *q*, ditto of peduncular muscles; *r*, peduncular nerves; *s*, two lobes corresponding to cavities at the sides of the foramen.

Fig. 3. View of pallial chamber of the same, the ventral pallial lobe turned back:—*a*, dorsal pallial lobe; *b*, ventral ditto; *c*, *c*, great pallial sinuses giving branches to the margin; *d*, *d*, genitalia; *e*, *e*, muscular ties passing between the walls of the sinuses; *f*, base of the membrane suspending the genitalia, forming a reticulated line; *g*, circumpallial vessel; *h*, marginal fold; *i*, anterior margin of divaricators; *j*, occlusors; *k*, ventral oviducts; *l*, external orifices leading into ditto; *m*, brachial apparatus; *n*, brachial fold; *o*, position of the mouth concealed by ditto; *p*, cirri, contracted and curled; *q*, œsophagus.

Fig. 4. Portion of the alimentary canal:—*a*, stomach; *b*, intestine; *c*, lower, imperforate, bulbous extremity of ditto; *d*, hepatic ducts; *e*, dorsal mesentery; *f*, gastro-parietal bands; *g*, central band; *h*, ilio-parietal bands; *i*, laminated portions of oviducts; *j*, heart in contracted state; *k*, branchio-systemic vein; *l*, aorta; *m*, ventral pallial arteries.

Fig. 5. Intestine of another specimen:—*a*, imperforate bulbous extremity, the longitudinal plications of the mucous membrane appearing through the walls; *b*, a transparent line or ridge corresponding to a groove in the mucous membrane; *c*, ventral mesentery; *d*, portions of ilio-parietal bands.

Fig. 6. Transverse section of intestine:—*a*, muscular wall, the external sheath is not represented; *b*, mucous membrane, exhibiting large, longitudinal plicæ; *c*, longitudinal transparent line; *d*, ventral mesentery.

Fig. 7. Oviduct as appearing from the perivisceral chamber:—*a*, laminated portion, opening into the perivisceral chamber; *b*, tubular portion; *c*, wrinkles of the lining membrane appearing through the surface; *d*, apex opening externally; *e*, accessory pulsatile vesicle; *f*, genital artery; *g*, ditto, following the reticulations of the suspending membrane.

Fig. 8. Transverse section of tubular portion of oviduct:—*a*, lining membrane.

Fig. 9. Transverse section of arm:—*a*, wall of the great brachial canal; *b*, thickened portion of ditto; *c*, grooved ridge; *d*, brachial fold; *e*, roots of cirri; *f*, expanded orifices of ditto, opening into the efferent brachial canal, *g*.

Fig. 10. Base of one of the arms laid open, exposing the inner surface of the great

brachial canal:—*a*, *a*, walls of ditto; *b*, grooved ridge; *c*, brachial fold; *d*, cirri; *e*, efferent brachial canal, the orifices leading into the cirri appearing through its wall in a double series; *f*, afferent brachial channel, charged with coagulated pellets of blood-corpuscles.

Fig. 11. Pellets of coagulated blood-corpuscles from the tissue of the brachial grooved ridge.

Fig. 12. One of the smaller spicula from the mantle of *T. caput-serpentis*.

PLATE LXI.

Fig. 1. General view of the viscera of *Rhynchonella psittacea*, seen from behind, the umbonal portions having been removed:—*a*, dorsal pallial lobe; *b*, ventral ditto; *c*, *c*, anterior wall of perivisceral chamber; *d*, *d*, anterior occlusor muscles; *d'*, *d'*, posterior ditto; *e*, *e*, ventral extremities of divaricators; *f*, *f*, ditto of ventral adjustors; *g*, portion of the œsophagus; *h*, stomach, exhibiting two of the orifices of the hepatic ducts, the left lobes of the liver having been removed; *i*, right anterior and posterior hepatic lobes; *j*, intestine; *k*, bulbous termination of ditto; *l*, dorsal mesentery; *m*, portion of ventral ditto; *n*, *n*, lateral gastro-parietal bands; *o*, central gastro-parietal band; *p*, *p*, ilio-parietal bands; *q*, heart in contracted state; *r*, aorta, giving off two lateral branches; *s*, *s*, dorsal pallial or genital arteries; *t*, *t*, ventral ditto; *u*, *u*, *u*, *u*, pulsatile vesicles in connexion with the pallial arteries; *v*, *v*, *v*, *v*, dorsal and ventral pairs of oviducts; *w*, *w*, *w*, *w*, genital organs lying within the pallial sinuses; *x*, *x*, muscular bands or ties passing between the walls of the sinuses; *y*, sheaths of the crural processes or oral laminæ; *z*, orifices leading into ditto; *z'*, portions of the dorsal adjustor muscles.

Fig. 2. Side view of the viscera of the same:—*a*, anterior wall of perivisceral chamber; *b*, *b*, brachial organs; *c*, ventral terminations of occlusor muscles; *c'*, *c'*, dorsal terminations of anterior and posterior occlusors; *d*, *d*, divaricators, the left one cut through; *d'*, ventral wall of perivisceral chamber; *e*, peduncle; *e'*, capsule of ditto; *f*, peduncular muscle; *g*, one of the dorsal adjustors; *h*, one of the ventral ditto; *i*, œsophagus; *j*, stomach, exhibiting the two openings of the left hepatic ducts, the liver having been removed from this side; *k*, right lobes of the liver; *k'*, posterior lobe; *k''*, anterior ditto; *l*, dorsal mesenteric membrane; *m*, *m*, ventral ditto; *n*, lateral gastro-parietal band; *o*, central ditto; *p*, *p*, ilio-parietal bands; *q*, heart; *r*, branchio-systemic vein; *s*, aorta; *t*, *t'*, dorsal and ventral pallial or genital arteries; *u*, right ventral oviduct; *u'*, portion of left ditto cut through; *v*, œsophageal ganglia; *w*, sheath of crural process or oral lamina; *x*, orifice leading into ditto; *y*, portion of ditto of the opposite side; *z*, terminal sac of the left great brachial canal; *z'*, ditto of the right or opposite arm, seen through the mesenteric membrane.

Fig. 3. Side view of the stomach and liver:—*a*, cardiac extremity of stomach; *b*, pyloric ditto; *c*, transverse ridge, to which the gastro-parietal bands are attached; *d*, *d*, hepatic ducts; *e*, *e*, branched cæca composing the liver.

Fig. 4. Stomach laid open:—*a*, œsophagus; *b*, intestine; *c*, *c*, folds of the lining membrane; *d*, *d*, orifices of hepatic ducts; *e*, groove corresponding to the external transverse ridge.

Fig. 5. Portion of epithelium from the mantle of *W. australis*, much magnified.

Fig. 6. Portion of epithelium lining the great brachial canal.

PLATE LXII.

Fig. 1. Diagram of the muscular system of *W. australis*:—*a*, dorsal valve; *b*, ventral ditto; *c*, peduncle; *d*, capsule of ditto; *e*, calcareous loop; *f*, hinge-plate; *g*, alimentary tube; *h*, heart; *i*, anterior occlusors; *j*, posterior ditto; *k*, divaricators; *l*, accessory ditto; *m*, dorsal adjustors; *n*, ventral ditto; *o*, peduncular muscle; *p*, cardinal process.

Fig. 2. Diagram exhibiting muscular arrangement of *W. cranium*:—*a*, dorsal valve; *b*, ventral ditto; *c*, peduncle; *d*, capsule of ditto; *e*, calcareous loop; *f*, dental socket; *g*, *g*, anterior and posterior occlusors of the right side, those of the left having been removed; *h*, *h*, areas of attachment of dorsal extremities of the left occlusors; *i*, *i*, divaricators and their accessories combined; *j*, ventral adjustors; *k*, *k*, dorsal ditto; *l*, peduncular muscle; *m*, cardinal process.

Fig. 3. Diagram of the muscular system of *Lingula anatina*:—*a*, dorsal valve; *b*, ventral ditto; *c*, *c*, alimentary tube, the convoluted portion of intestine removed; *d*, heart; *e*, *e*, a double line, indicating the margin of the lateral and anterior walls of the perivisceral chamber; *f*, area of attachment of the posterior parietal muscles; *g*, anterior occlusors; *h*, posterior ditto; *i*, divaricators; *j*, central adjustors; *k*, external ditto; *l*, *l*, *l*, posterior ditto; *m*, muscular cylinder of peduncle deprived of its horny sheath; *n*, peduncular muscle.

Fig. 4. Divaricator muscles of variety of *W. australis*, showing them combined with their accessories:—*a*, portion of peduncular capsule; *b*, peduncular muscle; *c*, portion of ventral adjustor; *d*, portion of dorsal ditto; *e*, portion of occlusors; *f*, divaricators; *g*, portion of ditto, corresponding to the accessory divaricators; *h*, extremities attached to cardinal process.

Fig. 5. Ventral extremity of anterior occlusor of *W. australis*:—*a*, fleshy contractile portion; *b*, *b*, white tendinous ditto.

Fig. 6. A little of the fleshy portion of the posterior occlusor, much magnified, exhibiting transverse striæ.

Fig. 7. A fibre and two fibrillæ of same, more highly magnified:—*a*, fibre; *b*, *b*, fibrillæ, exhibiting cell-like structure.

Fig. 8. A little of the fleshy portion of one of the non-striated muscles, much magnified.

Fig. 9. A fibre and a few of the fibrillæ of the same, greatly magnified:—*a*, fibre; *b*, *b*, fibrillæ.

Fig. 10. Transverse section of peduncle of *Lingula anatina*:—*a*, central channel; *b*, muscular cylinder, exhibiting radiating divisions; *c*, external horny sheath.

Fig. 11. Œsophageal ganglia of *W. australis*:—*a*, central or anterior ganglion; *b*, *b*, lateral or posterior ganglia; *c*, labial ditto; *d*, commissure completing œsophageal collar; *e*, a pair of minute ganglia giving filaments apparently to œsophagus; *f*, dorsal pallial nerve; *g*, *g*, *g*, nerves supplying anterior wall of perivisceral chamber; *h*, two nerves supplying dorsal adjustor muscles; *i*, *i*, ventral pallial nerves; *i'*, *i'* branches of ditto; *j*, peduncular ditto; *k*, brachial nerves.

Fig. 12. Œsophageal ganglia of *W. cranium*, seen from above; the letters correspond to those of fig. 11:—*l*, bundle of muscular fibres. The brachial nerves are not displayed.

Fig. 13. View of the under side of the same ganglia: letters as in fig. 11.

Fig. 14. View of the loop of the dorsal pallial nerve:—*a*, anterior occlusor; *b*, posterior ditto; *c*, pallial nerve; *d*, loop of ditto; *e*, *e*, branches supplying muscles; *f*, *f*, ditto supplying pallial lobe.

Fig. 15. The same, more enlarged:—*a*, posterior occlusor; *b*, loop; *c*, *c*, *c*, *c*, nerves supplying muscle; *d*, pallial nerve.

PLATE LXIII.

Fig. 1. Diagram exhibiting central portion of vascular system of *W. australis*:—*a*, portion of dorsal pallial lobe; *b*, ventral ditto; *c*, *c*, anterior wall of perivisceral chamber; *d*, *d*, areas of attachment of anterior and posterior occlusors; *e*, ditto, of ventral extremities of ditto; *f*, *f*, ditto of divaricators; *g*, *g*, ditto of ventral adjustors; *h*, *h*, ditto of accessory divaricators; *i*, *i*, peduncular muscle; *j*, peduncular capsule; *k*, peduncle; *l*, alimentary tube; *m*, *m*, gastro-parietal bands; *n*, *n*, ilio-parietal bands; *o*, orifice leading into oviduct; *p*, heart; *q*, branchio-systemic vein; *r*, aorta; *s*, *s*, dorsal pallial or genital arteries; *t*, *t*, ventral ditto; *u*, *u*, *u*, *u*, accessory pulsatile vesicles.

Fig. 2. Diagram of the nervous system of the same; the letters up to *k* correspond to those of fig. 1:—*l*, *l*, *l*, genitalia; *m*, root of œsophagus; *n*, anterior or central œsophageal ganglion; *o*, *o*, posterior or lateral ganglia; *p*, collar; *q*, *q*, labial ganglia; *r*, *r*, dorsal pallial nerves; *s*, *s*, *s*, branches of ditto to pallial lobe; *t*, loop of pallial nerve, giving off numerous minute twigs to occlusor muscles; *u*, *u*, *u*, ventral pallial nerves; *v*, *v*, posterior or peduncular nerves; *w*, peduncular branches of ditto; *x*, capsular branches of ditto; *y*, parietal branch of ditto; *z*, nerves to anterior wall of perivisceral chamber; *z'*, *z'*, two nerves to dorsal adjustor muscles.

Fig. 3. Accessory pulsatile vesicle of the ventral pallial artery:—*a*, artery; *b*, *b*, pallial branches of ditto; *c*, vesicle.

Fig. 4. Ventral pallial artery, with two pulsatile vesicles attached:—*a*, artery; *b*, pallial branches of ditto; *c*, pulsatile vesicle; *d*, supplementary ditto.

PLATE LXIV.

Fig. 1. Dorsal view of the animal of *Lingula anatina*, the shell having been removed:— *a*, pallial lobe; *b*, body; *c*, great pallial sinuses; *d*, a white line running along the outer wall of ditto, function unknown; *e*, *e*, orifices, seen through the pallial membrane, leading into the lateral branches of the sinuses; *f*, central branches of ditto; *g*, posterior branches of ditto; *h*, *h*, ramuscules of posterior branches; *i*, marginal fold; *j*, extreme pallial margin; *k*, setæ; *l*, *l*, liver, seen through the wall of the perivisceral chamber; *m*, portion of intestine; *n*, dorsal ovaries; *o*, *o*, testis; *p*, extremities of anterior occlusor muscles; *q*, ditto of posterior occlusors; *r*, ditto of central adjustors; *s*, ditto of external adjustors; *t*, ditto of posterior adjustors; *u*, ditto of divaricators; *v*, ditto of posterior parietals; *w*, edge of the lateral and anterior walls of the body.

Fig. 2. Ventral view of the same; the letters as in fig. 1:—*x*, extremity of peduncular muscle; *y*, oviducts.

Fig. 3. View of the pallial chamber of the same, the ventral pallial lobe turned back: —*a*, ventral lobe; *b*, dorsal ditto; *c*, *c*, great pallial sinuses; *d*, *d*, lateral branches of ditto; *e*, *e*, puckers of lateral branches, occasioned by contraction of the pallial margin; *f*, *f*, terminal extremities of lateral branches; *g*, *g*, central branches of the great sinuses; *h*, marginal fold; *i*, a few of the setæ; *j*, extreme pallial margin; *k*, brachial apparatus; *l*, *l*, cirri; *m*, brachial fold; *n*, mouth; *o*, *o*, external orifices of oviducts.

Fig. 4. Dorsal view of the viscera of a young individual of *L. anatina*, the perivisceral chamber laid open:—*a*, *a*, great pallial sinuses; *b*, openings of ditto into the perivisceral chamber; *c*, posterior branches of ditto; *d*, anterior occlusors; *e*, posterior ditto; *f*, central adjustors; *g*, external ditto; *h*, *h*, posterior ditto; *i*, divaricators; *j*, posterior parietals; *k*, *k*, anterior and lateral walls of the perivisceral chamber; *l*, œsophagus; *m*, stomach; *n*, straight portion of intestine; *o*, convoluted portion of ditto; *p*, *p*, hepatic ducts, the dorsal lobes of the liver having been removed; *q*, dorsal ovaries; *r*, ilio-parietal bands; *s*, gastro-parietal ditto; *t*, heart, contracted; *u*, branchio-systemic vein; *v*, aorta, giving off two lateral trunks, which divide into anterior and posterior branches; *w*, external arteries or blood-channels,—nerves of OWEN,—supplying anterior wall of the perivisceral chamber; *x*, internal ditto.

Fig. 5. Ventral view of the viscera of the same; the letters up to *k* correspond to those

of fig. 4:—*l*, peduncular muscle; *m*, portion of intestine; *n*, ventral lobe of liver; *o*, *o*, *o*, ventral ovaries; *p*, tubular portion of oviducts.

Fig. 6. Transverse section of straight portion of intestine:—*a*, membranous sheath; *b*, muscular wall; *c*, mucous membrane; *d*, *d*, portions of ilio-parietal bands; *e*, transparent line corresponding to groove in mucous membrane.

Fig. 7. A small portion of the intestine laid open, exhibiting the plicæ of the mucous membrane:—*a*, *a*, transverse plicæ.

PLATE LXV.

Fig. 1. Dorsal view of the perivisceral chamber of young specimen of *L. anatina*, most of the muscles, the liver and genitalia having been removed:—*a*, dorsal extremities of anterior occlusors; *b*, ditto of divaricators; *c*, *c*, anterior parietals; *d*, posterior ditto; *e*, *e*, anterior and lateral walls of chamber; *f*, œsophagus; *g*, stomach; *h*, straight portion of intestine; *i*, transparent line or ridge; *j*, convoluted portion of intestine; *k*, *k*, *k*, hepatic ducts; *l*, gastro-parietal bands; *m*, muscles attaching ditto to valve; *n*, ilio-parietal bands; *o*, margin of ditto, extending along oviducts; *p*, heart, contracted; *q*, aorta; *r*, posterior artery; *s*, anterior ditto; *t*, oviducts,—the so-called hearts; *u*, laminated portion of ditto, that on the left side has the margin turned back; *v*, orifice leading into oviduct.

Fig. 2. Dorsal view of the muscular system of the same, all the viscera having been removed:—*a*, posterior parietal muscles; *b*, anterior ditto; *c*, *c*, lateral and anterior walls of the perivisceral chamber; *d*, muscles supporting the gastro-parietal bands; *e*, anterior occlusors; *f*, posterior ditto; *g*, divaricators; *h*, central adjustors; *i*, *i*, external ditto; *j*, *j*, *j*, posterior ditto; *k*, external arteries or blood-channels; the dotted lines mark their path through the muscles; *l*, internal ditto.

Fig. 3. Dorsal view of the viscera of *L. affinis*, the dorsal hepatic lobes and ovaries having been removed:—*a*, anterior occlusors; *b*, posterior ditto; *c*, divaricators; *d*, central adjustors; *e*, external ditto; *f*, *f*, *f*, posterior ditto; *g*, posterior parietals; *h*, *h*, margins of the lateral and anterior walls of the perivisceral chamber; *i*, *i*, ventral ovaries; *j*, œsophagus; *k*, stomach; *l*, straight portion of intestine, exhibiting longitudinal ridge; *m*, convoluted portion of intestine; *n*, terminal portion, or rectum; *o*, membrane uniting ditto to the wall of the perivisceral chamber; *p*, heart in contracted state; *q*, branchio-systemic vein; *r*, aorta; *s*, gastro-parietal bands; *t*, muscles supporting ditto; *u*, ilio-parietal bands; *v*, external blood-channels or arteries.

Fig. 4. Lateral view of alimentary canal:—*a*, mouth; *b*, œsophagus; *c*, stomach; *d*, straight portion of intestine, exhibiting longitudinal ridge; *e*, convoluted portion of ditto; *f*, terminal portion of ditto; *g*, anus; *h*, *h*, hepatic ducts;

i, dorsal mesentery; *j*, *j*, portions of gastro-parietal bands; *k*, ilio-parietal ditto; *l*, heart in contracted state; *m*, branchio-systemic vein; *n*, enlarged portion of ditto; *o*, aorta; *p*, one of the lateral branches of ditto, dividing into anterior, *q*, and posterior, *r*, arteries; *s*, lateral œsophageal membrane.

Fig. 5. Portion of branchio-systemic vein, as seen in the compressor:—*a*, outer envelope or sheath; *b*, delicate internal tunic; *c*, fold or wrinkle of ditto.

Fig. 6. Transverse section of arm:—*a*, anterior or great brachial canal; *b*, posterior ditto; *c*, *c*, longitudinal muscle situated in ditto; *d*, small or efferent canal; *e*, grooved ridge; *f*, bases of cirri; *g*, brachial fold; *h*, blood-channels in ditto; *i*, *i*, epithelium; *j*, *j*, thickened cartilage-like portions of the walls of the brachial canals.

Fig. 7. Transverse section of arm of *L. anatina*; the letters correspond to those of fig. 6.

Fig. 8. Transverse section of grooved ridge:—*a*, brachial fold; *b*, *b*, bases of cirri; *c*, small or efferent brachial canal; *d*, orifices leading from ditto into cirri; *e*, blood-channels; *f*, *f*, *f*, *f*, muscular bands for the movements of the parts; *g*, anterior or great brachial canal; *h*, posterior ditto; *i*, *i*, epithelium.

Fig. 9. Corpuscles found in the pallial membranes of *W. australis*, supposed to be muscular.

PLATE LXVI.

Fig. 1. Dorsal view of the animal of *L. affinis*, the perivisceral chamber partially laid open:—*a*, pallial lobe; *b*, great pallial sinuses; *c*, a white line running along the outer wall of ditto; *d*, *d*, outer or lateral branches of sinuses, exhibiting a similar white line, *e*, in their external wall; *f*, *f*, central branches of sinuses; *g*, posterior branches of ditto; *h*, ramuscules of posterior branches; *i*, marginal fold; *j*, extreme pallial margin; the setæ are not represented; *k*, *k*, *k*, liver, a portion of which is removed to expose the heart, *l*; *m*, portion of alimentary canal; *n*, *n*, dorsal ovaries; *o*, *o*, two coils of the intestine seen through the wall of the perivisceral chamber; *p*, extremities of anterior occlusors; *q*, ditto of posterior ditto; *r*, ditto of central adjustors; *s*, ditto of external adjustors; *t*, ditto of posterior adjustors; *u*, ditto of divaricators; *v*, ditto of posterior parietals; *w*, *w*, margins of lateral and anterior walls of the perivisceral chamber.

Fig. 2. Ventral view of the same, the pallial lobe, *a*, turned back to expose the pallial chamber; *b*, dorsal pallial lobe; *c*, great pallial sinuses; *d*, *d*, outer or lateral branches of ditto; *e*, inner branches of ditto; *f*, ramuscules of posterior branches of ditto; *g*, extremity of peduncular muscle; *h*, marginal fold; *i*, extreme pallial margin; *j*, marginal setæ; *k*, *k*, attenuated cæcal extremities of the lateral pallial sinuses; *l*, brachial apparatus; *m*, cirri; *n*, *n*, brachial fold; *o*, mouth partially concealed by ditto.

Fig. 3. Side view of the same; the dorsal pallial lobe divided longitudinally, and one half of it turned back, so as to expose the pallial chamber; the marginal setæ are not represented:—*a*, *a*, pallial sinuses; *b*, marginal fold; *c*, liver seen through the wall of the perivisceral chamber; *d*, dorsal ovaries; *e*, *e*, intestine; *f*, lateral wall of the body, or perivisceral chamber; *g*, anal nipple; *h*, brachial apparatus; *i*, cirri; *j*, adjustor muscles; *k*, divaricators; *l*, anterior wall of body.

Fig. 4. View of the walls of the perivisceral chamber of *L. anatina*:—*a*, posterior parietal muscles; *b*, anterior ditto; *c*, muscular lining of anterior wall; *d*, muscles in connexion with the gastro-parietal bands; *e*, divaricators; *f*, root of œsophagus; *g*, fold of anterior wall to which the occlusors are adherent; *h*, two orifices leading from the perivisceral chamber to a cavity situated between the bases of the arms; *i*, external arteries or blood-channels entering anterior wall.

Fig. 5. Transverse section of pallial lobe of the same:—*a*, marginal fold; *b*, one of the setæ; *c*, extreme pallial margin; *d*, circumpallial lacune; *e*, *e*, peripheral or outer pallial lacunes; *f*, ties binding the walls of ditto together; *g*, *g*, channels of the lateral branches of the great pallial sinus; *h*, channels of intermediate small branches of ditto.

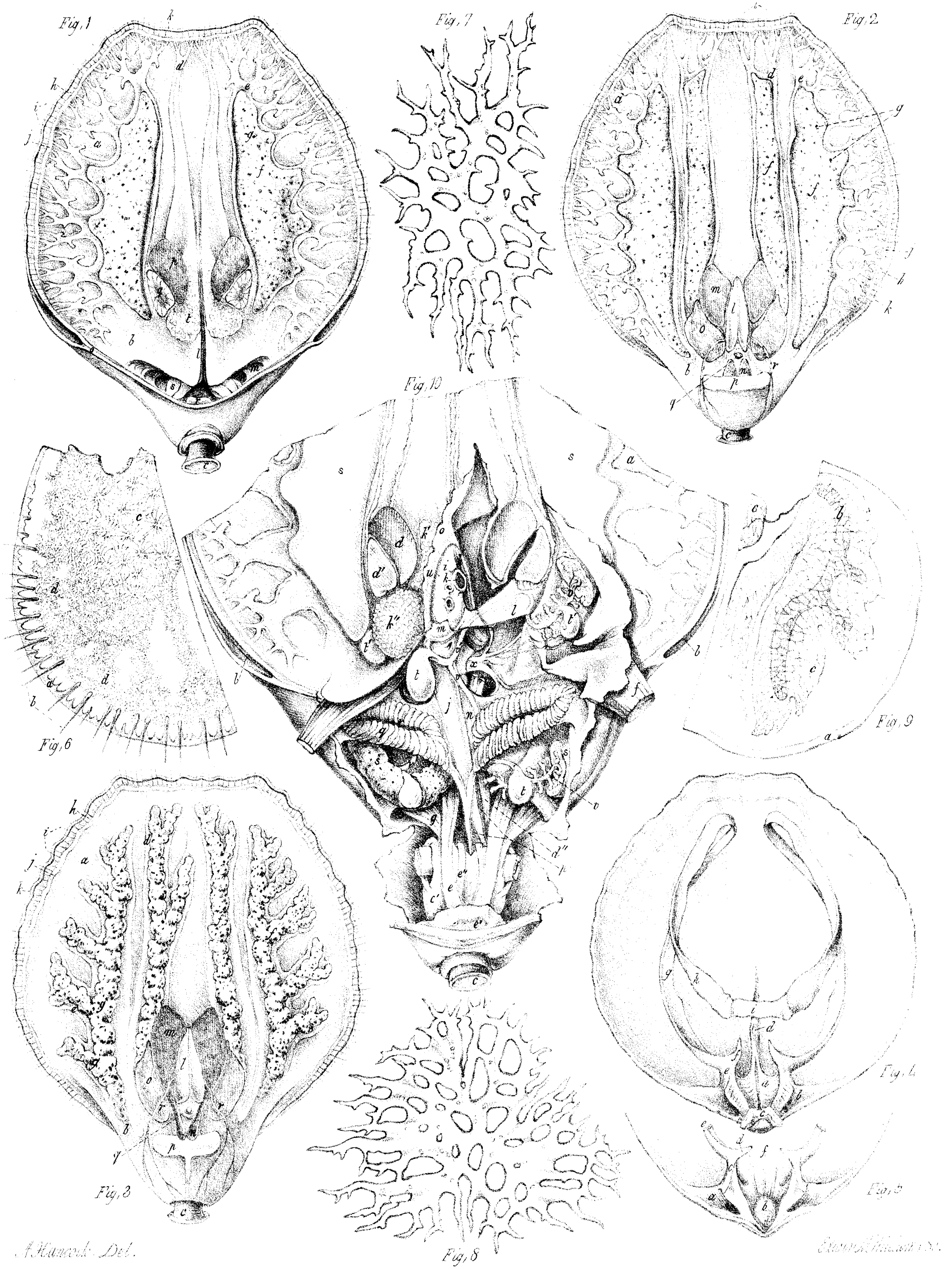
Fig. 6. Proximal extremity of peduncle:—*a*, horny sheath; *b*, muscular cylinder seen through ditto; *c*, extremity of muscular cylinder or peduncular muscle; *d*, triangular process of horny sheath, fitting into a corresponding depression in the umbo of the ventral valve.

Fig. 7. The same extremity of peduncle, with the horny sheath laid open:—*a*, horny sheath; *b*, muscular cylinder; *c*, *c*, delicate membrane coating ditto.

Fig. 8. Portion of the wall of the perivisceral chamber, with part of the testis adhering: —*a*, wall of chamber; *b*, testis, exhibiting spermatophora in various stages of development.

Fig. 9. Three spermatophora, highly magnified:—*a*, *a*, two of ditto, apparently fully developed, containing spermatozoa; *b*, one, immature, exhibiting a double line in the interior.

Fig. 10. Two spermatophora, in an early state of development.



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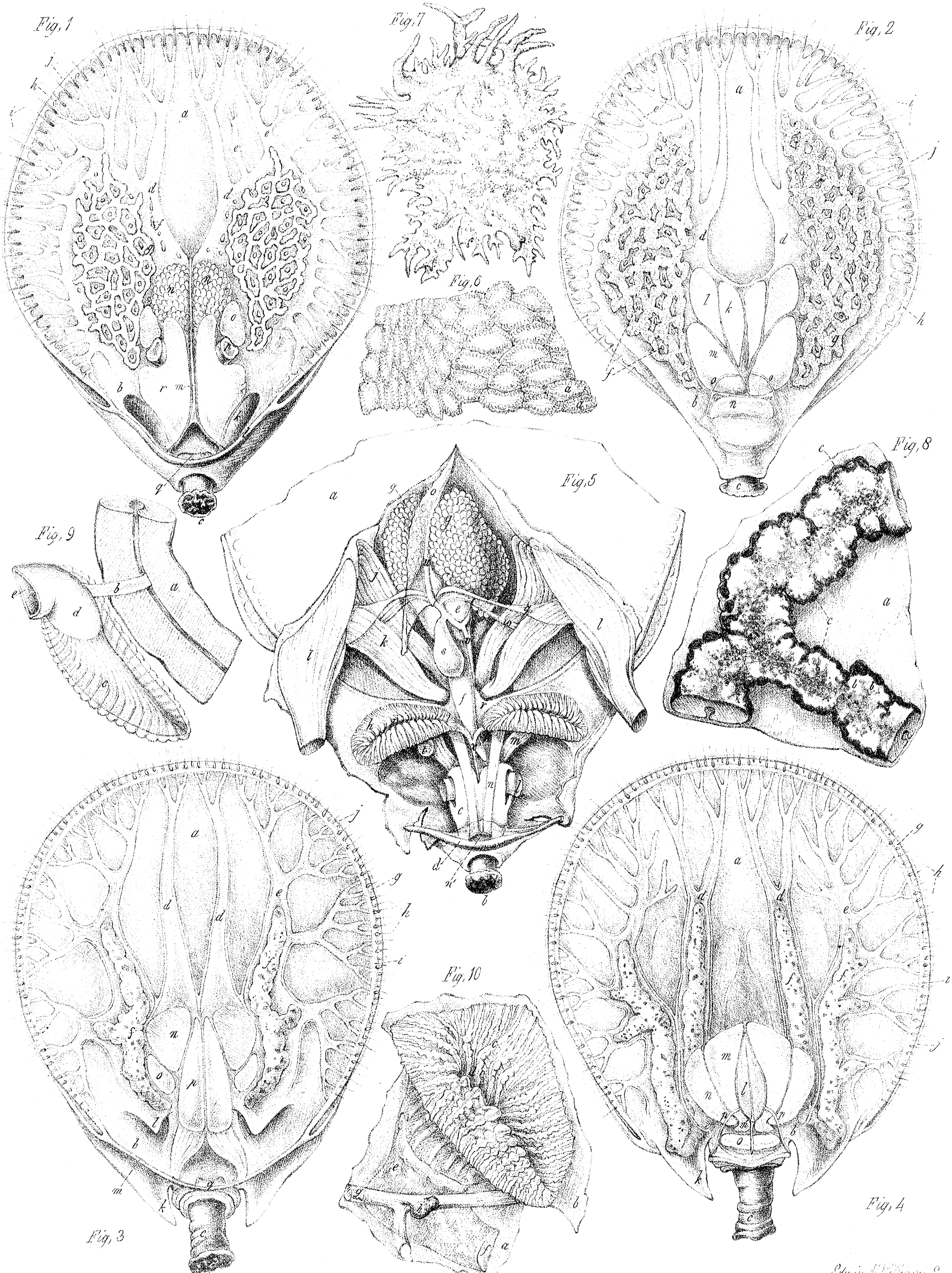

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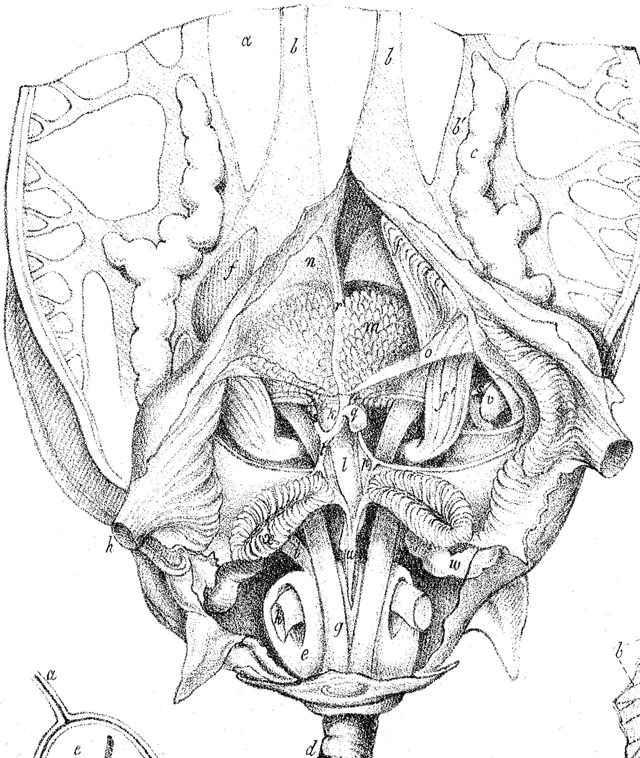

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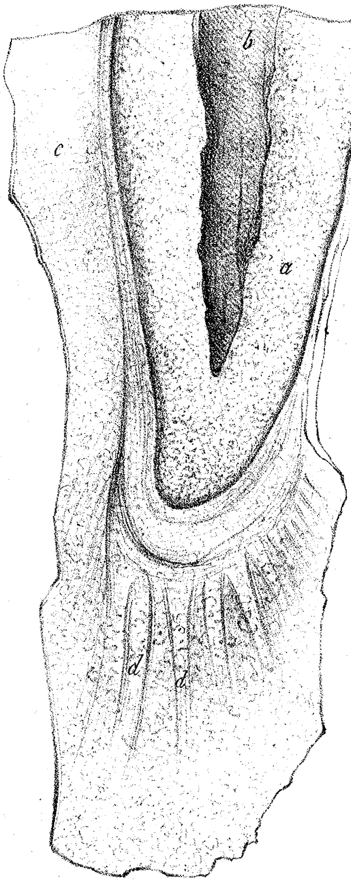

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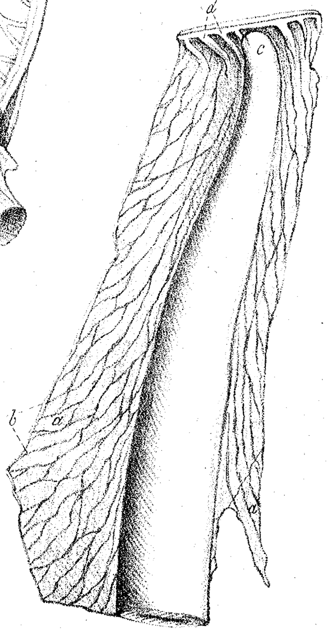

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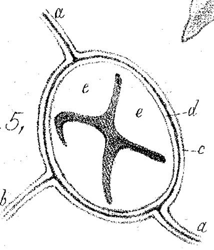

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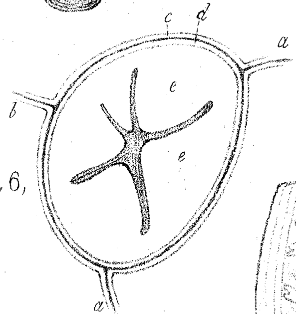

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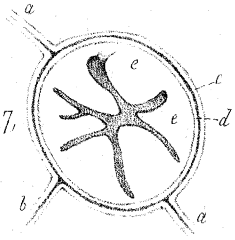

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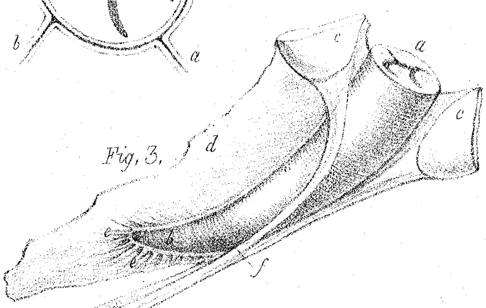

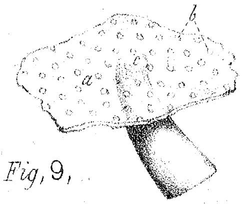

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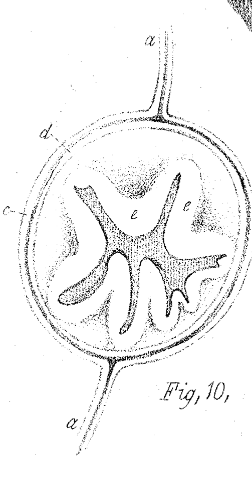

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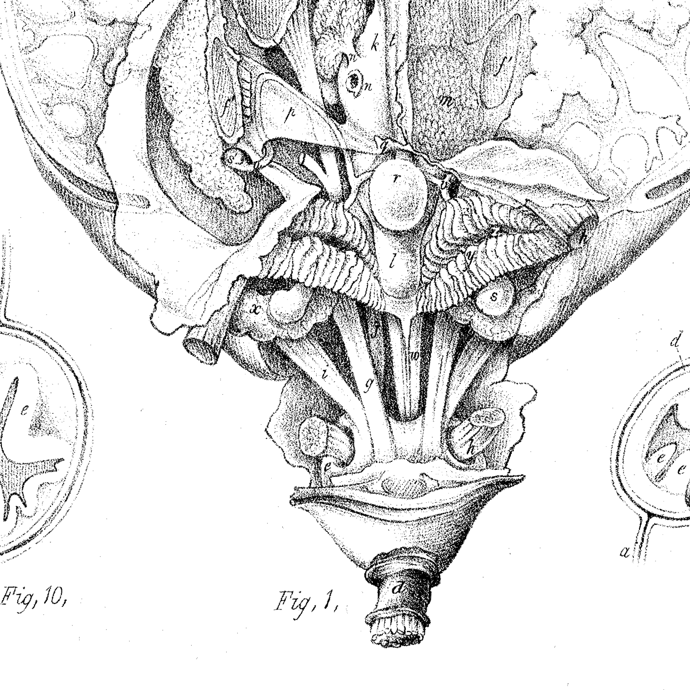

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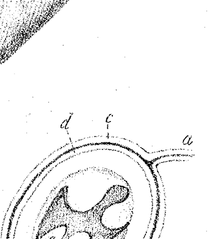

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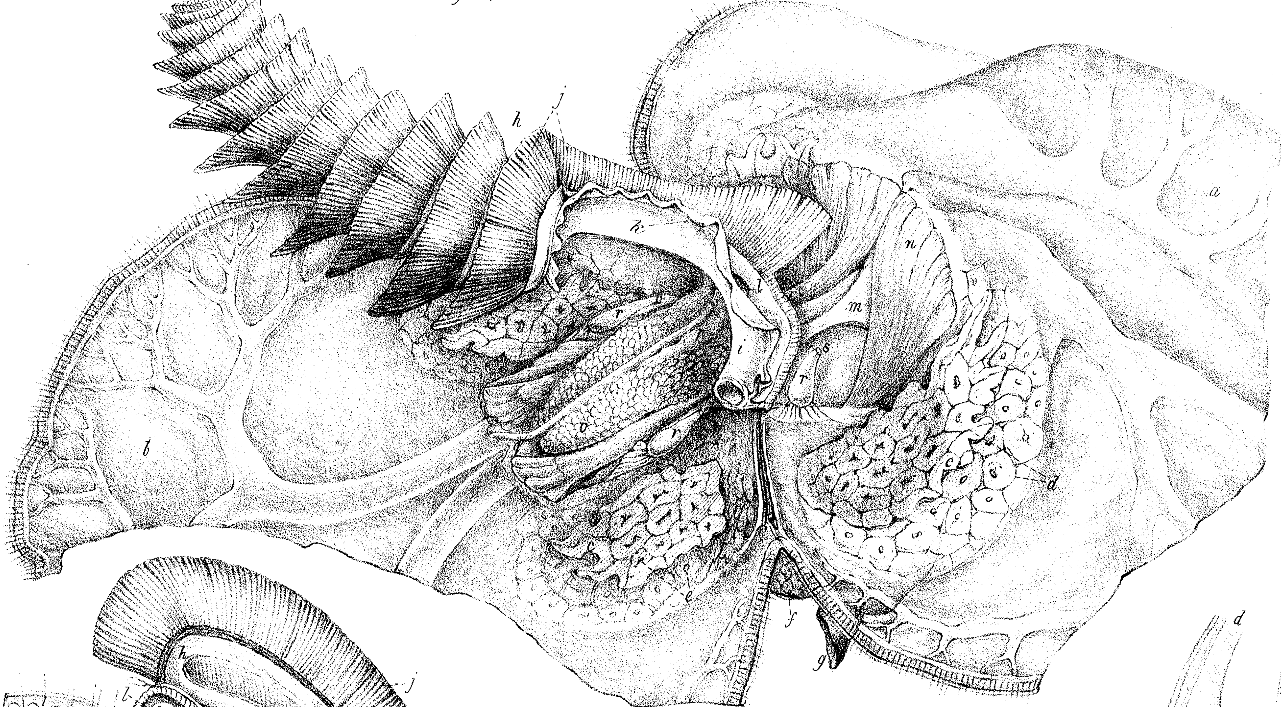

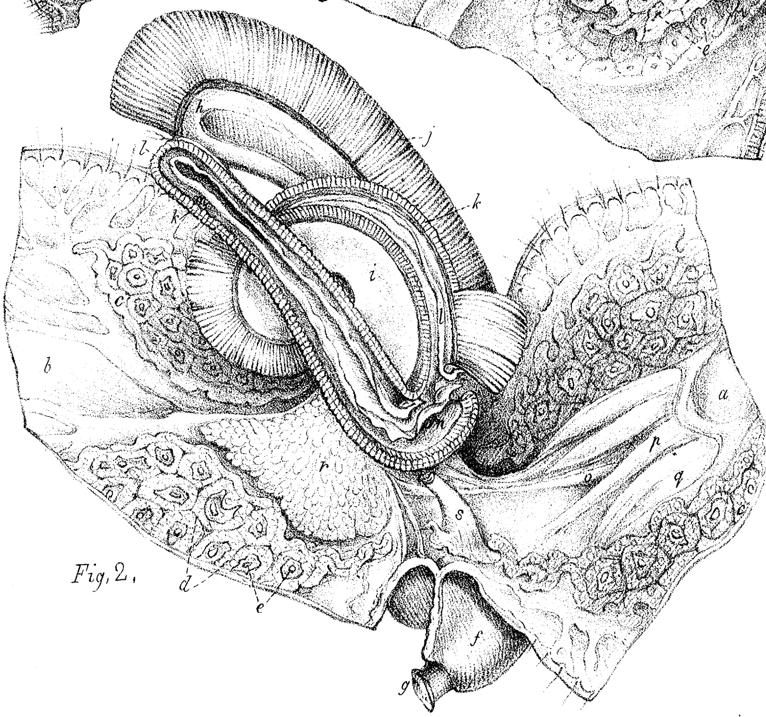

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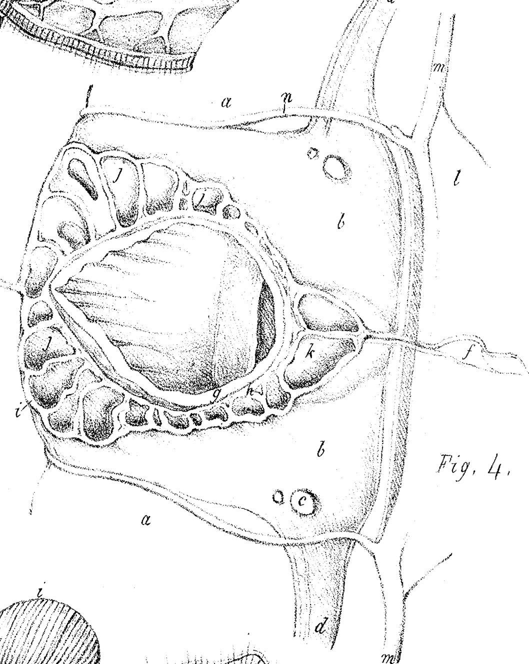

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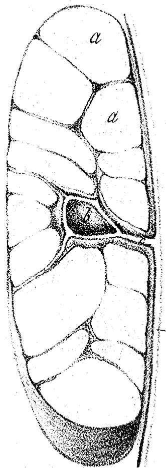

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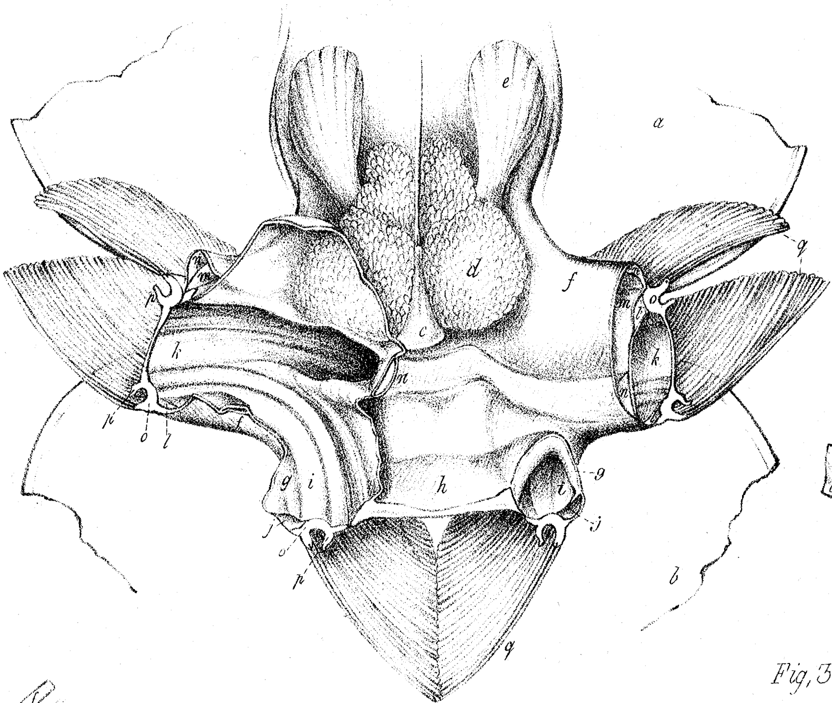

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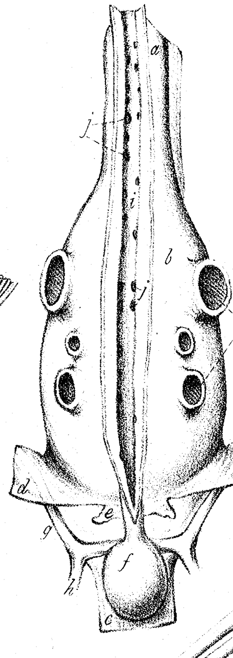

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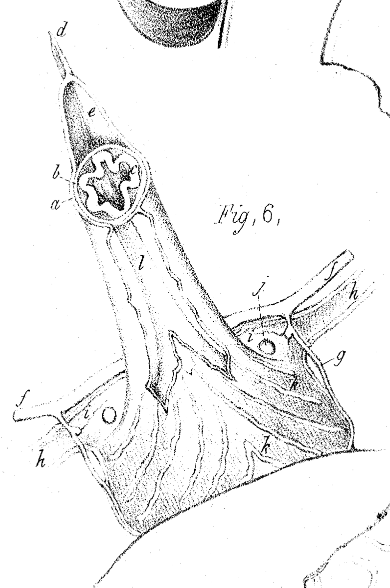

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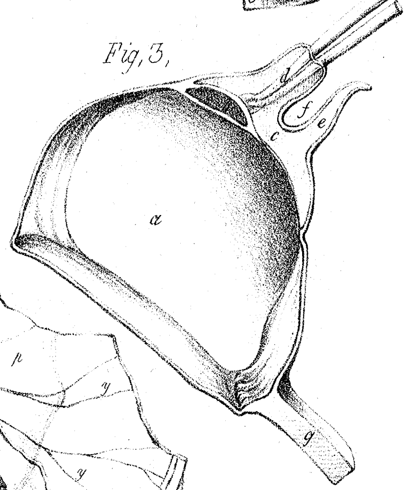

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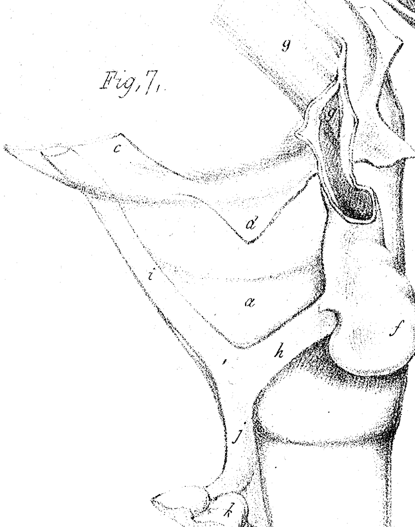

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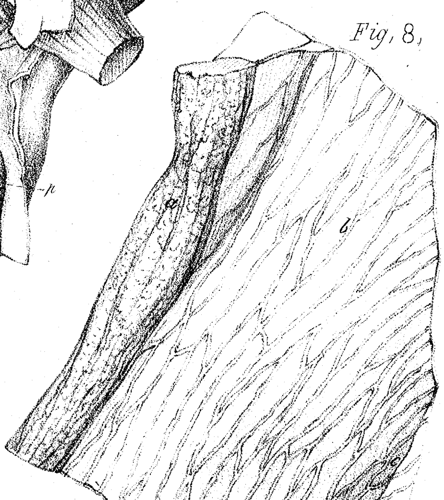

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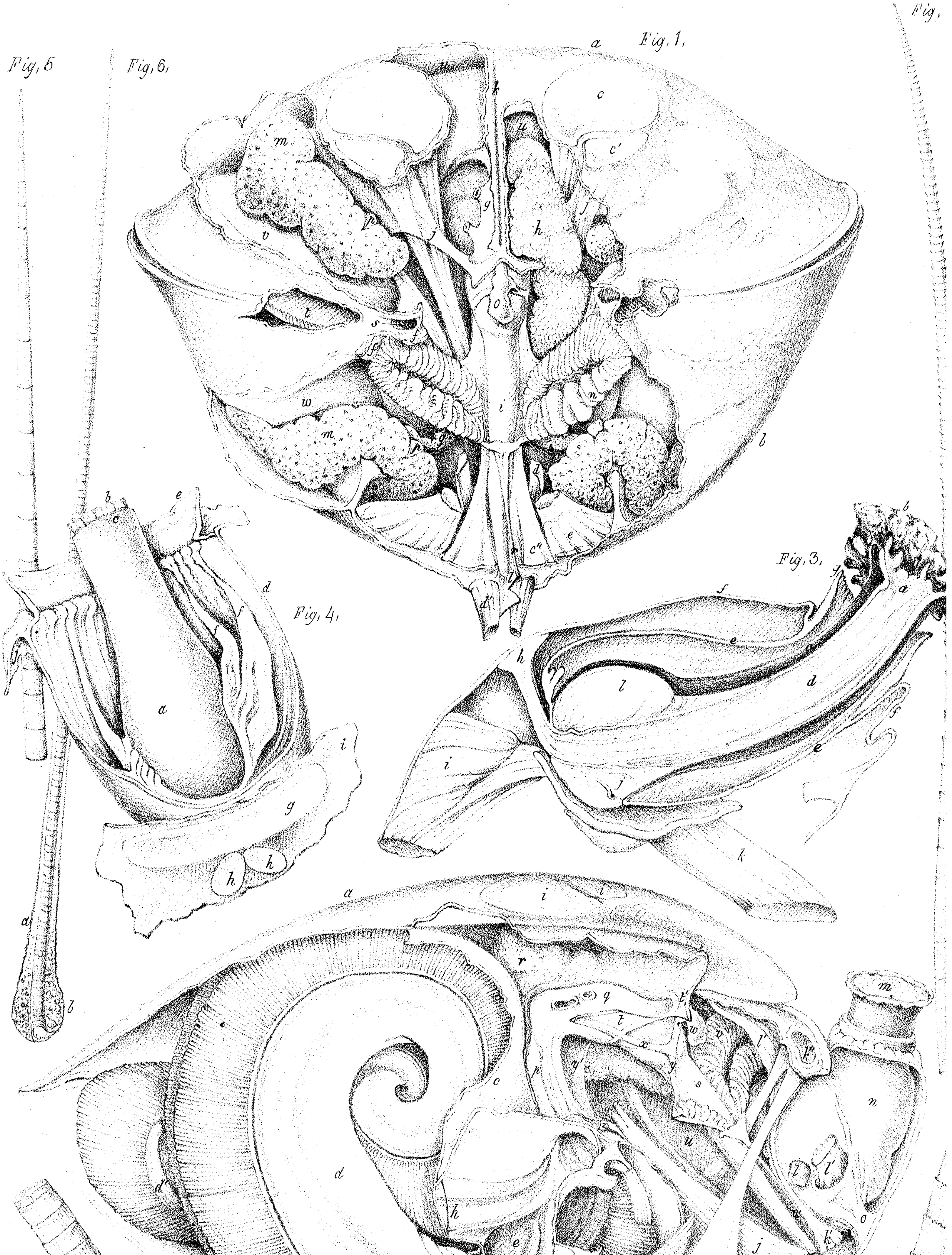
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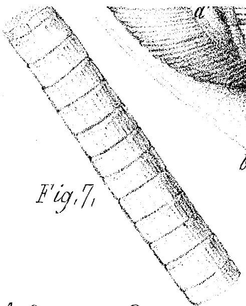

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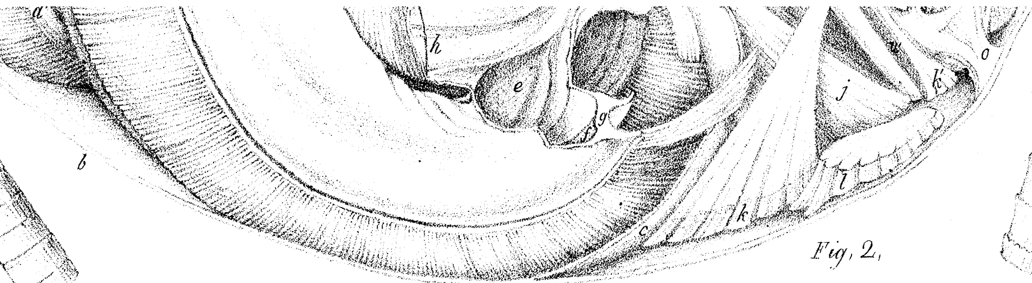

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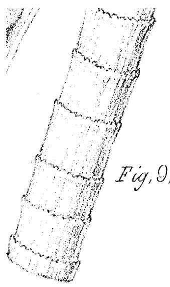

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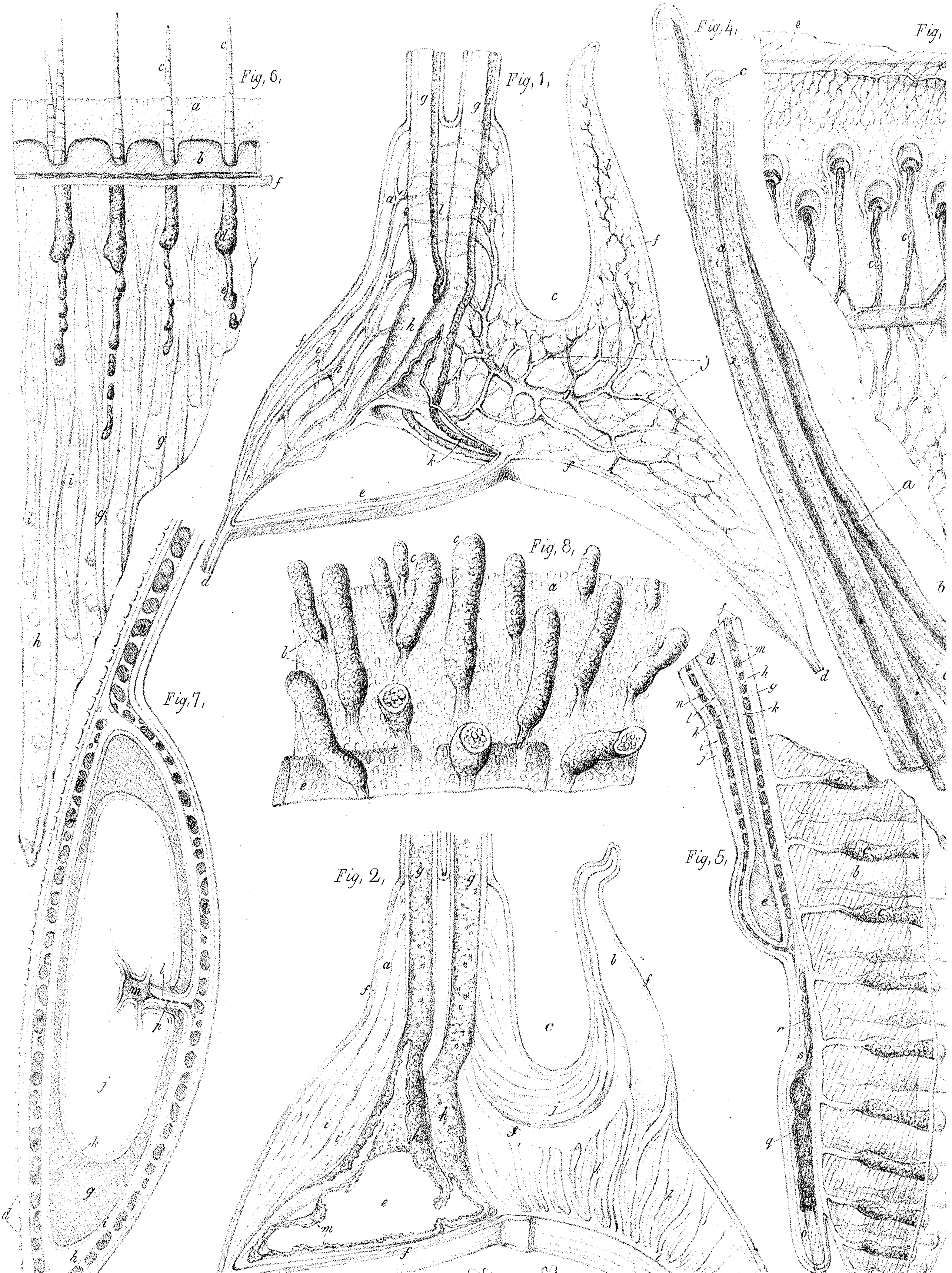
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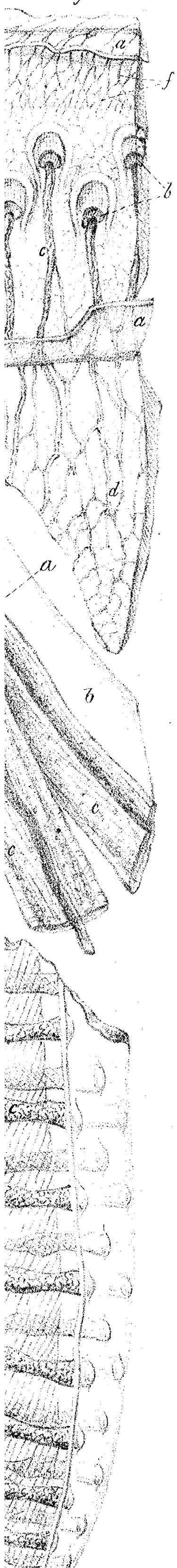

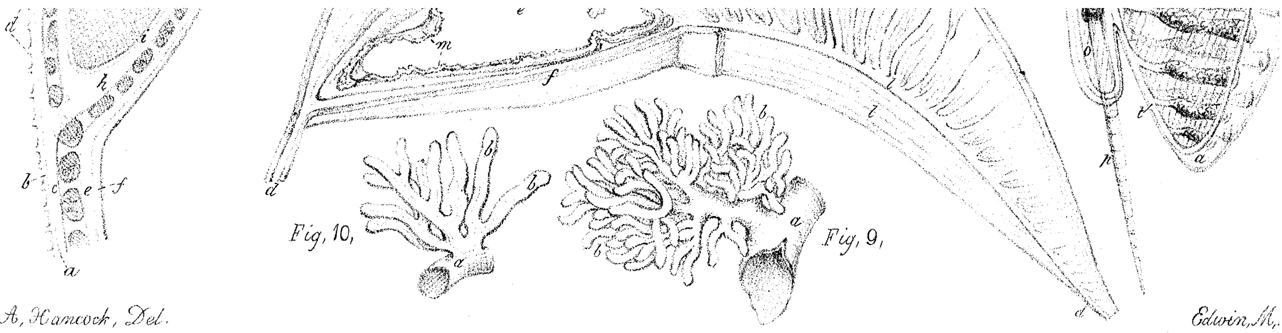

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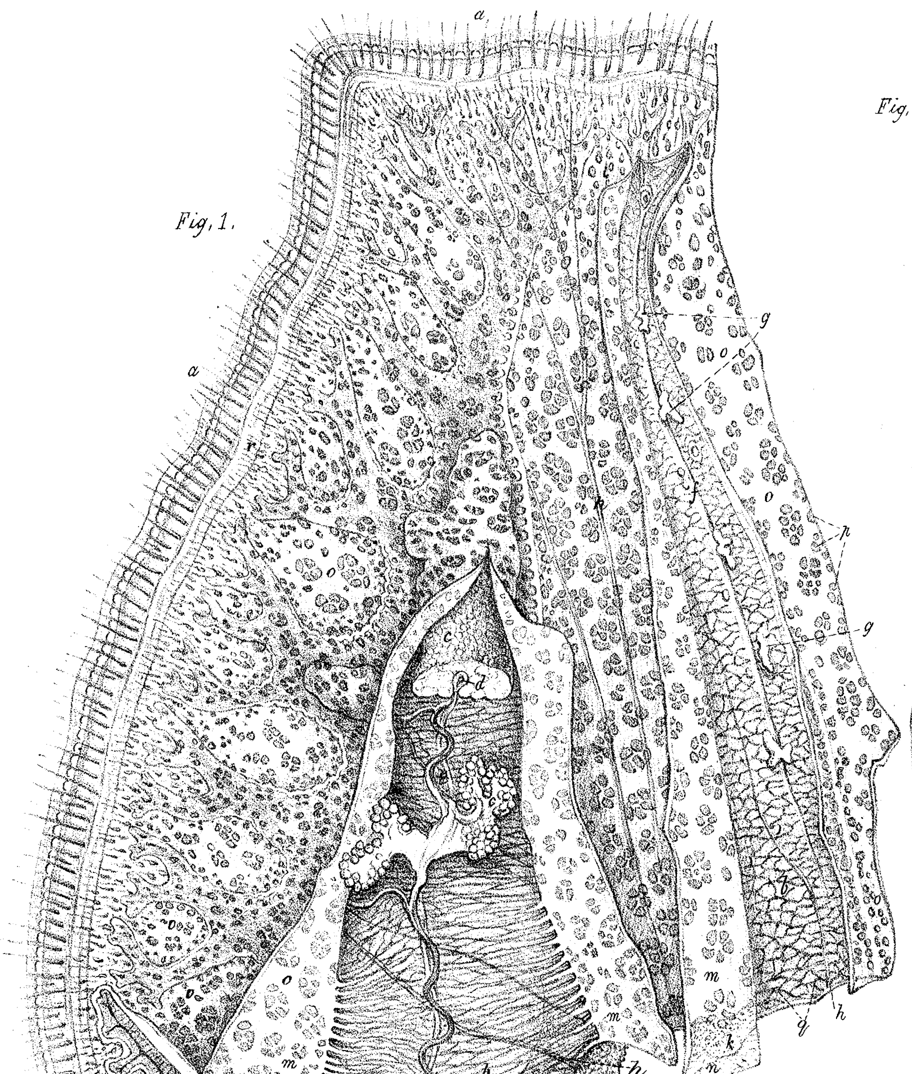

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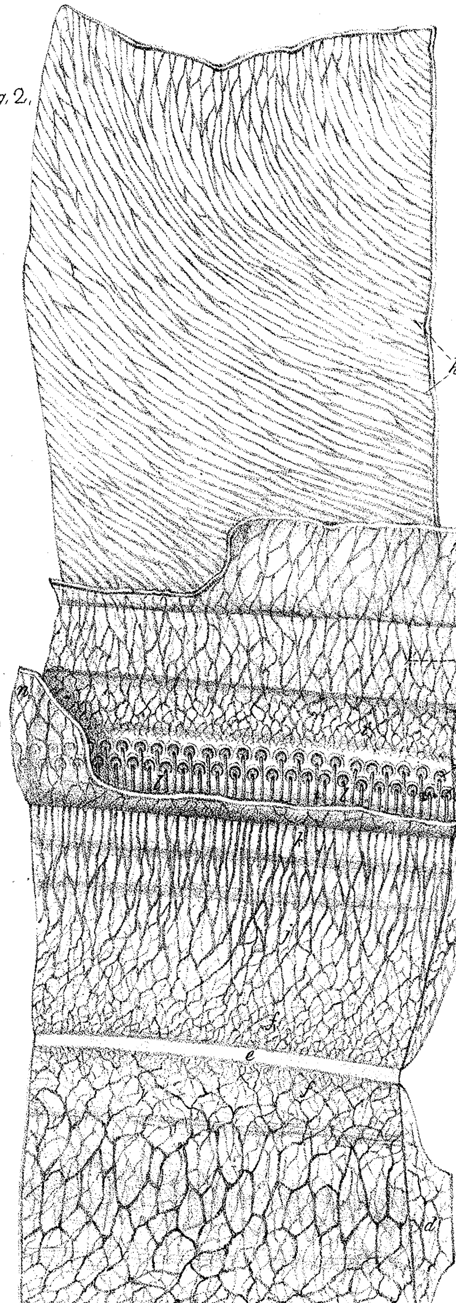

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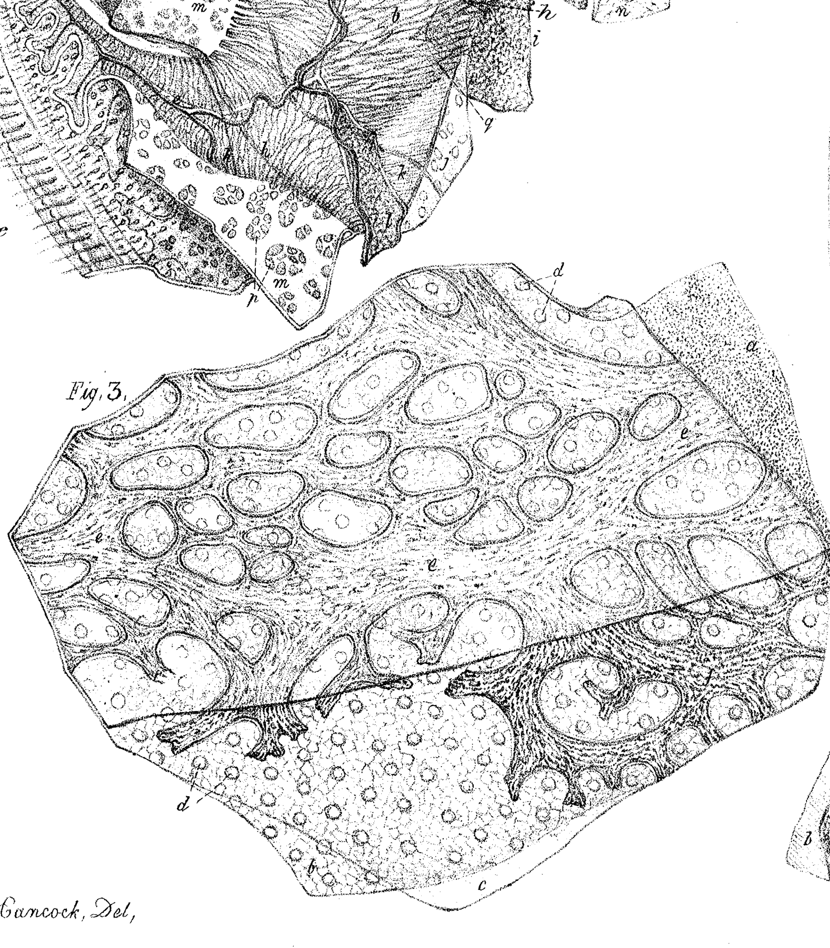

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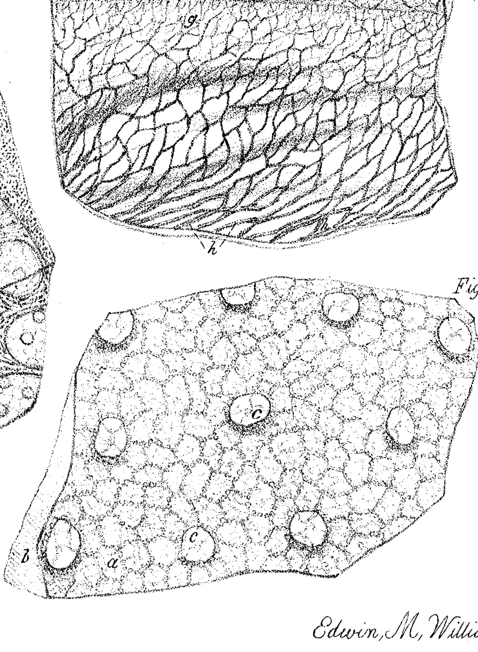

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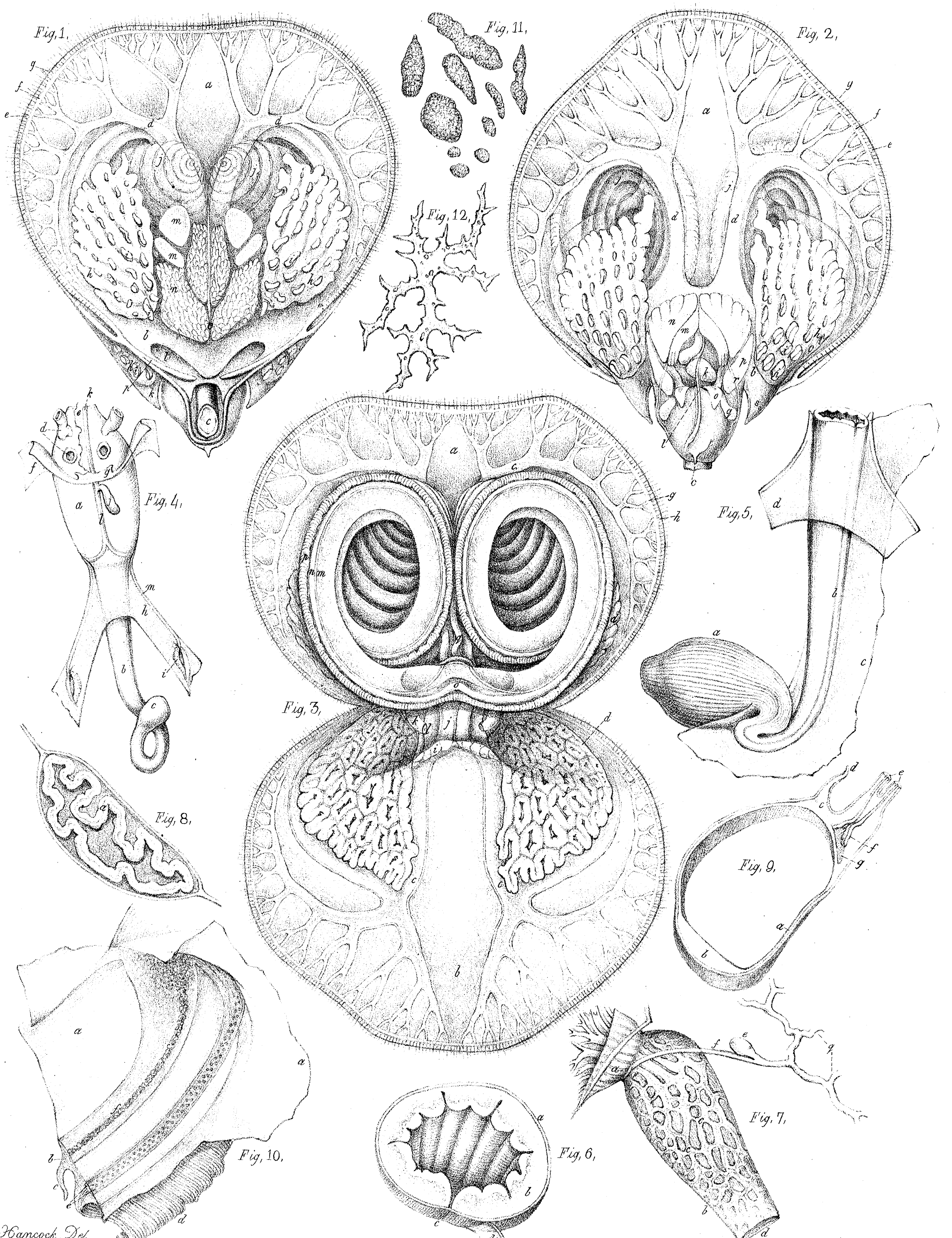

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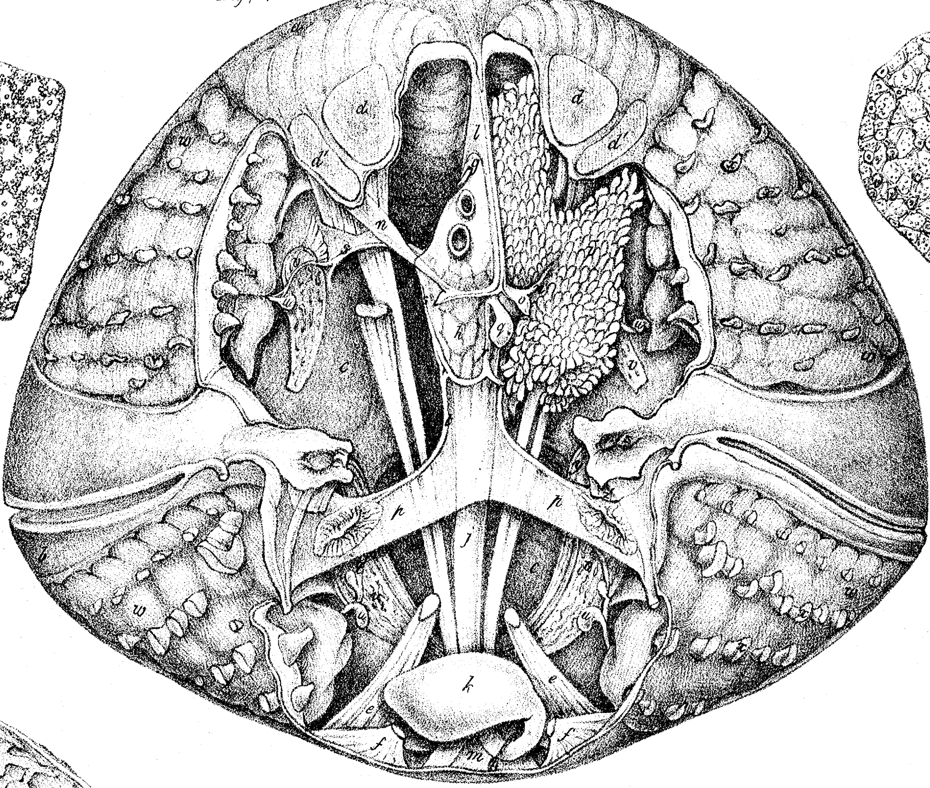

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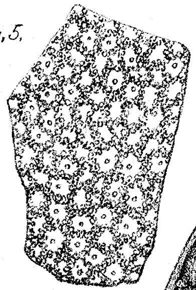

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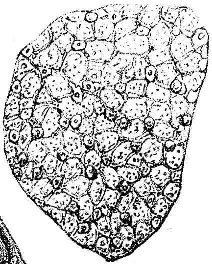

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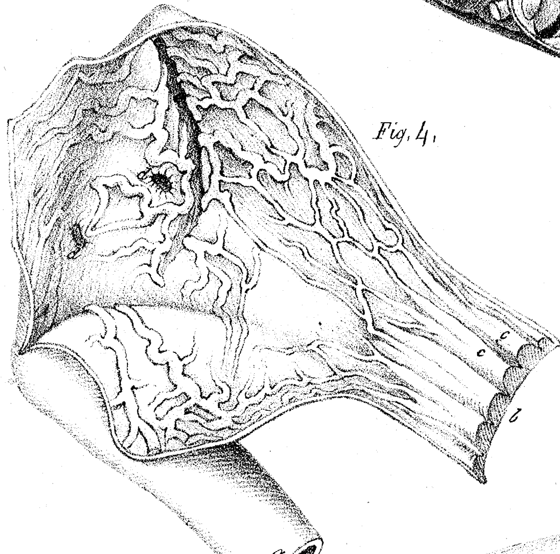

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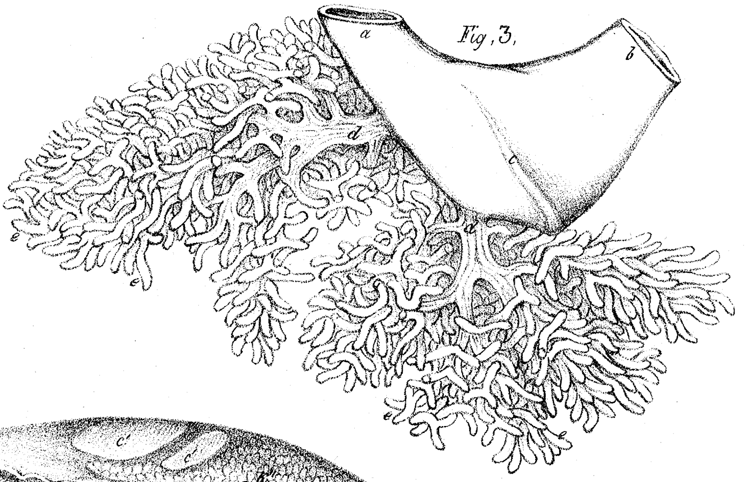

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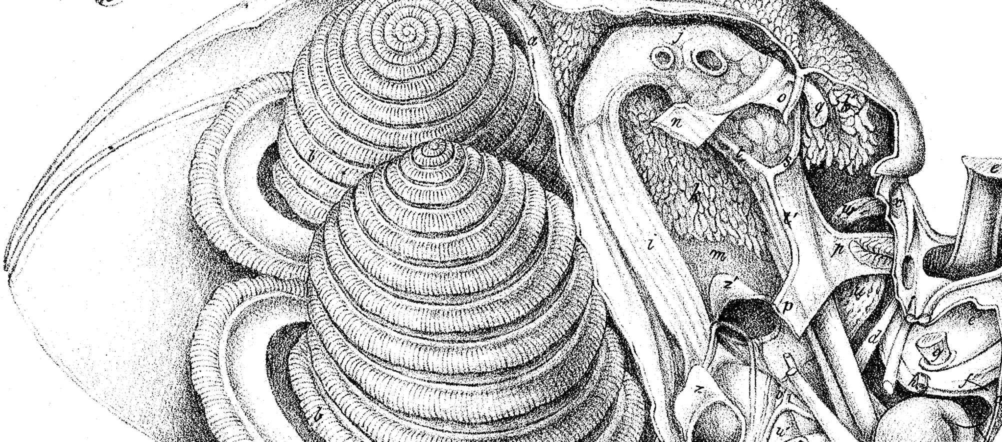

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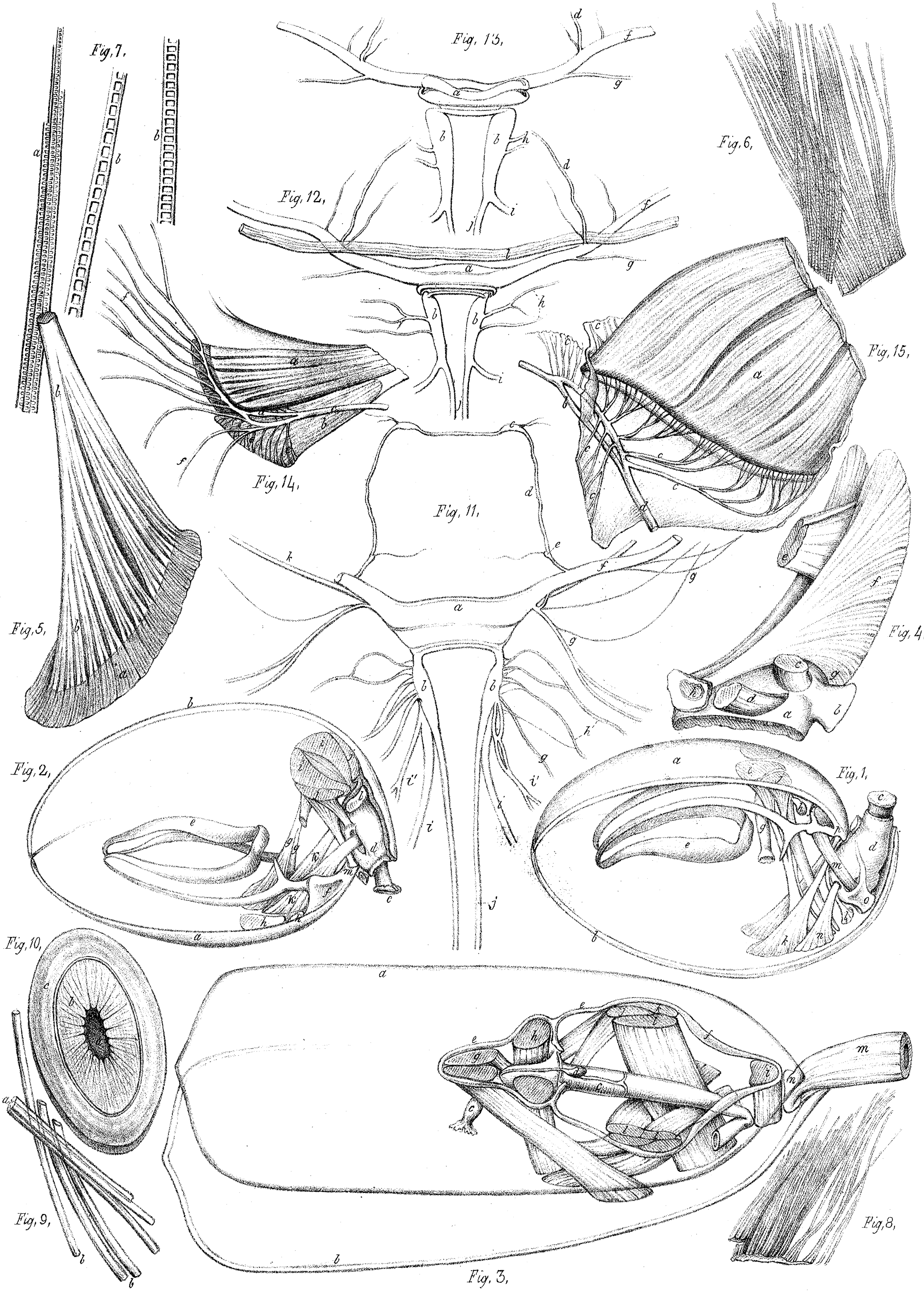

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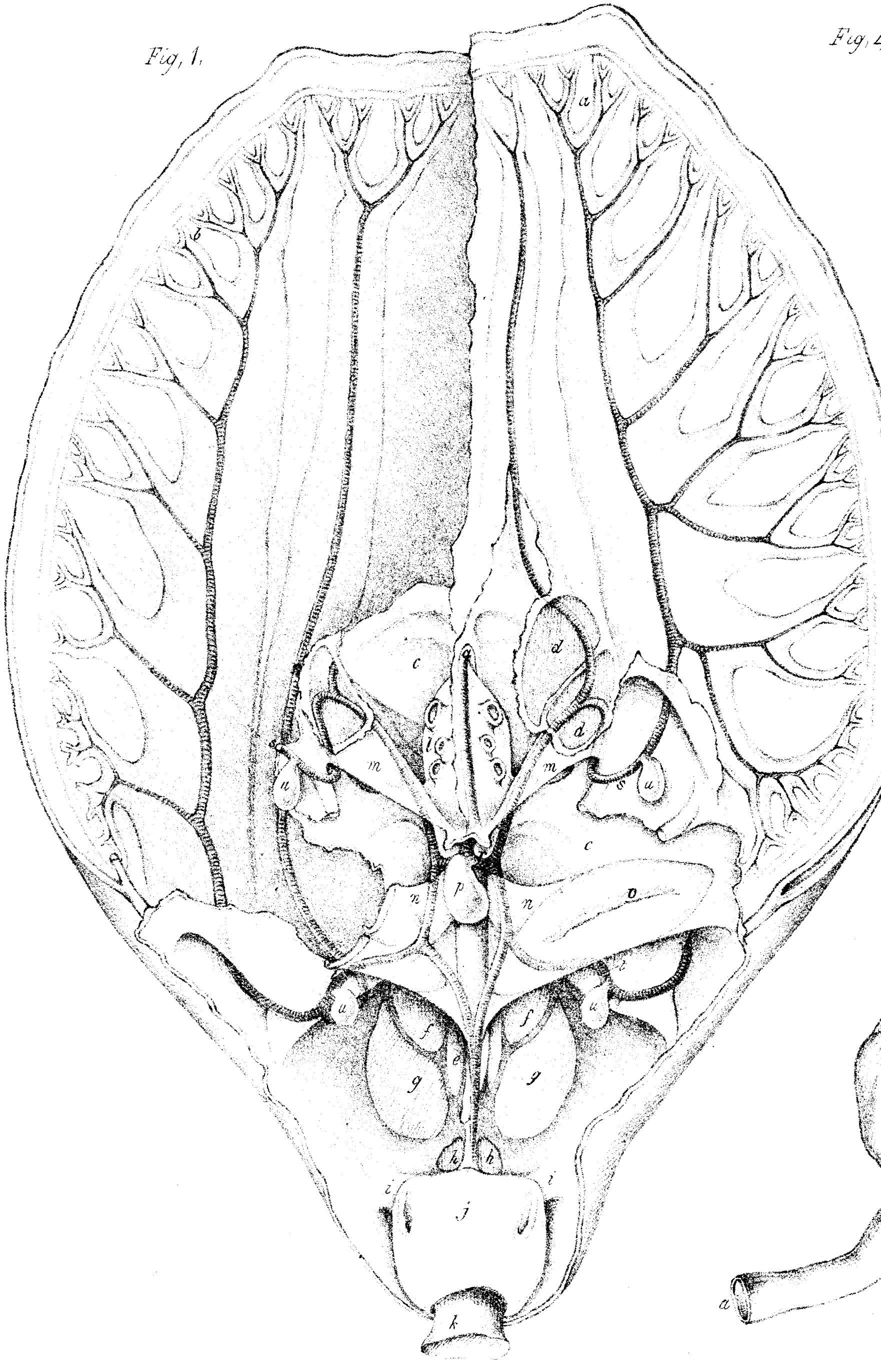

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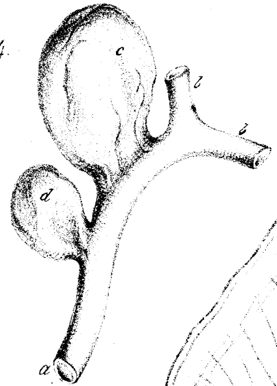

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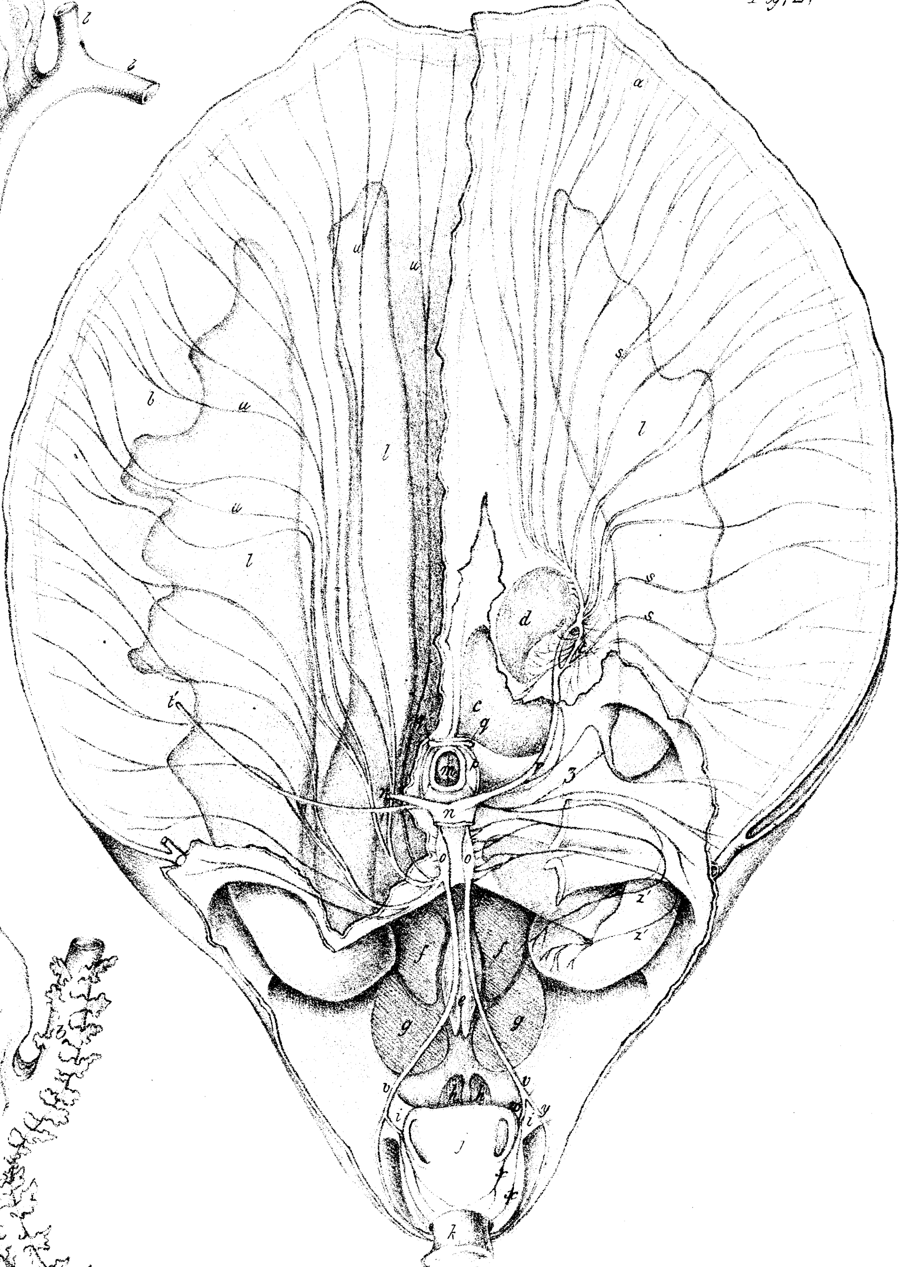

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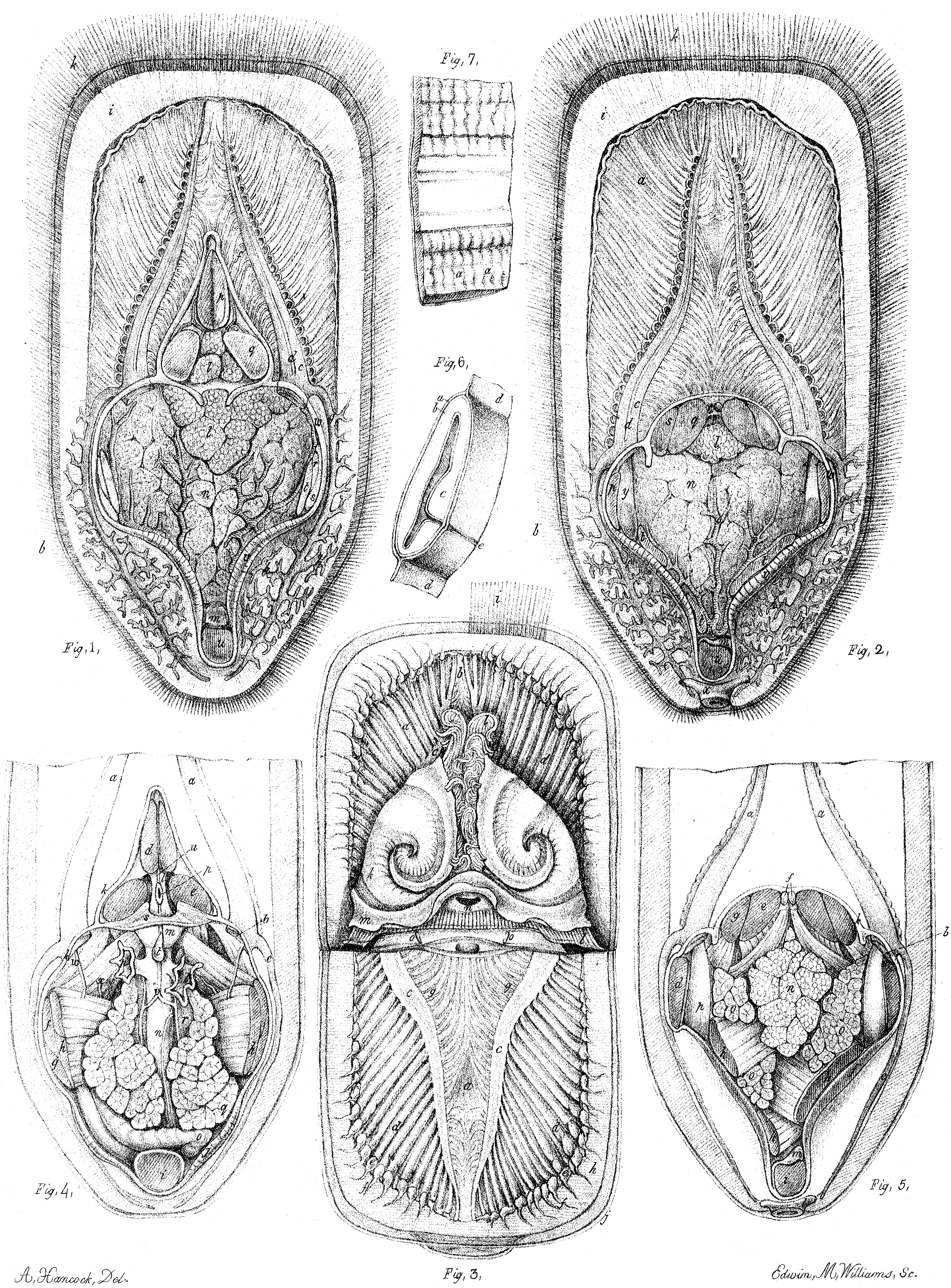

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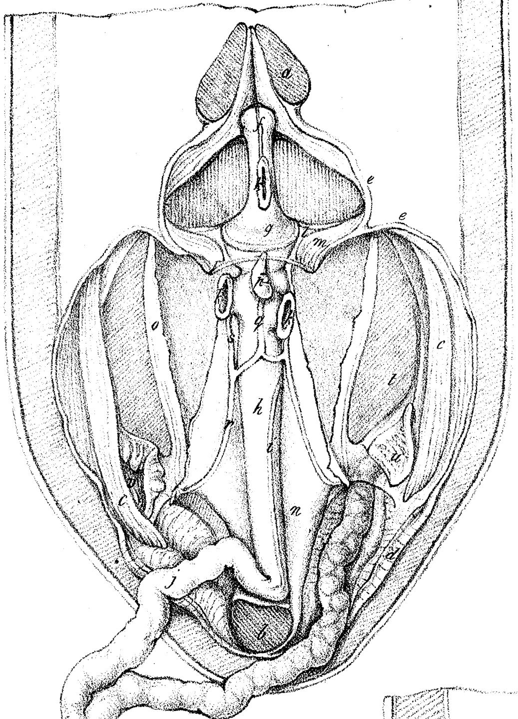

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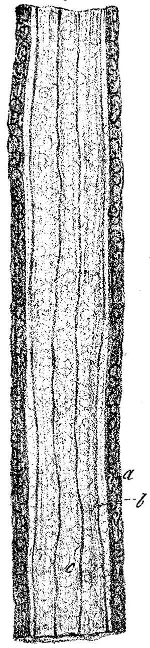

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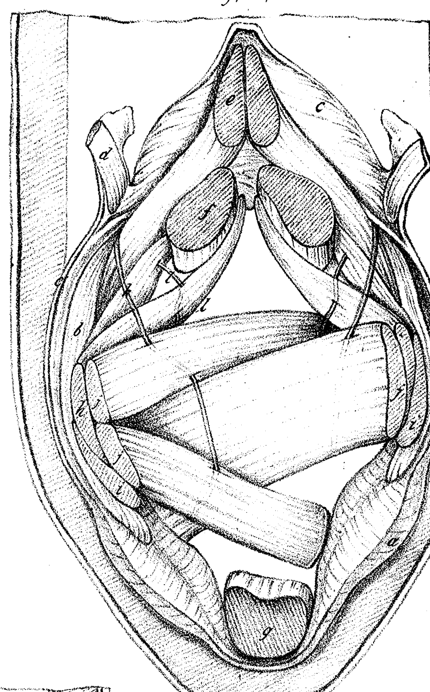

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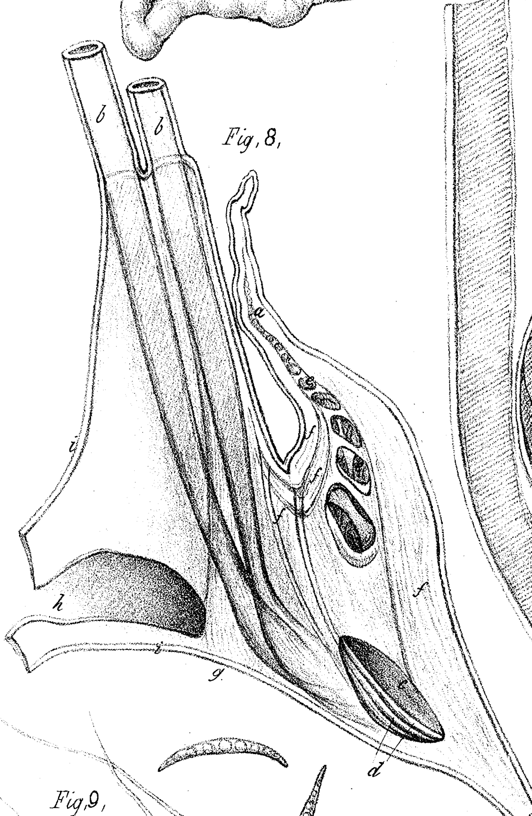

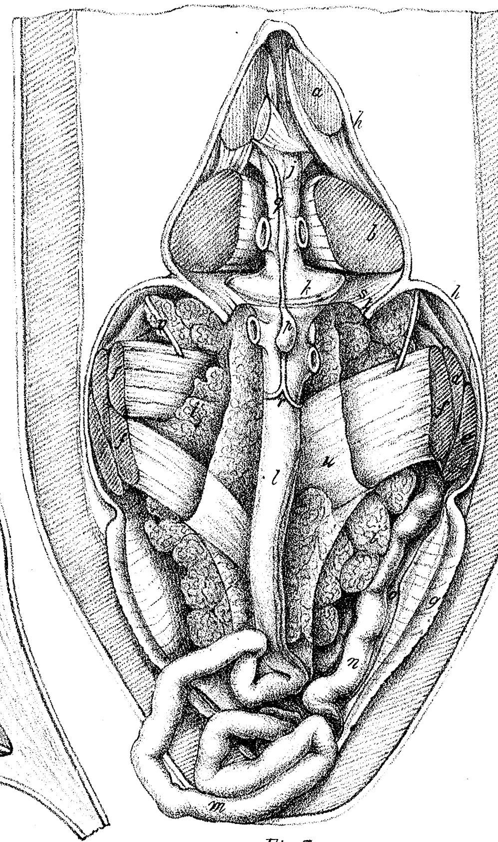

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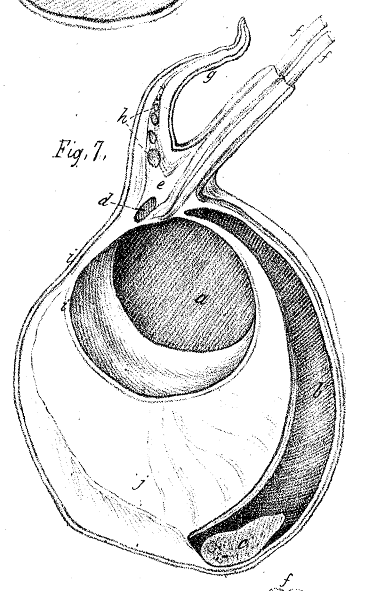

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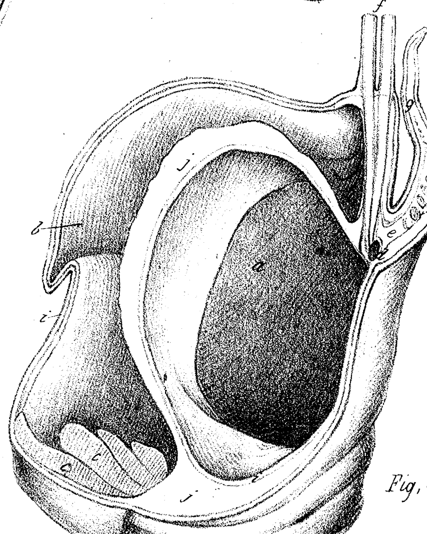

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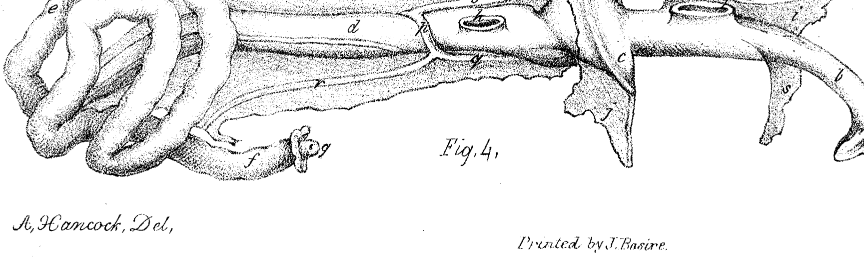

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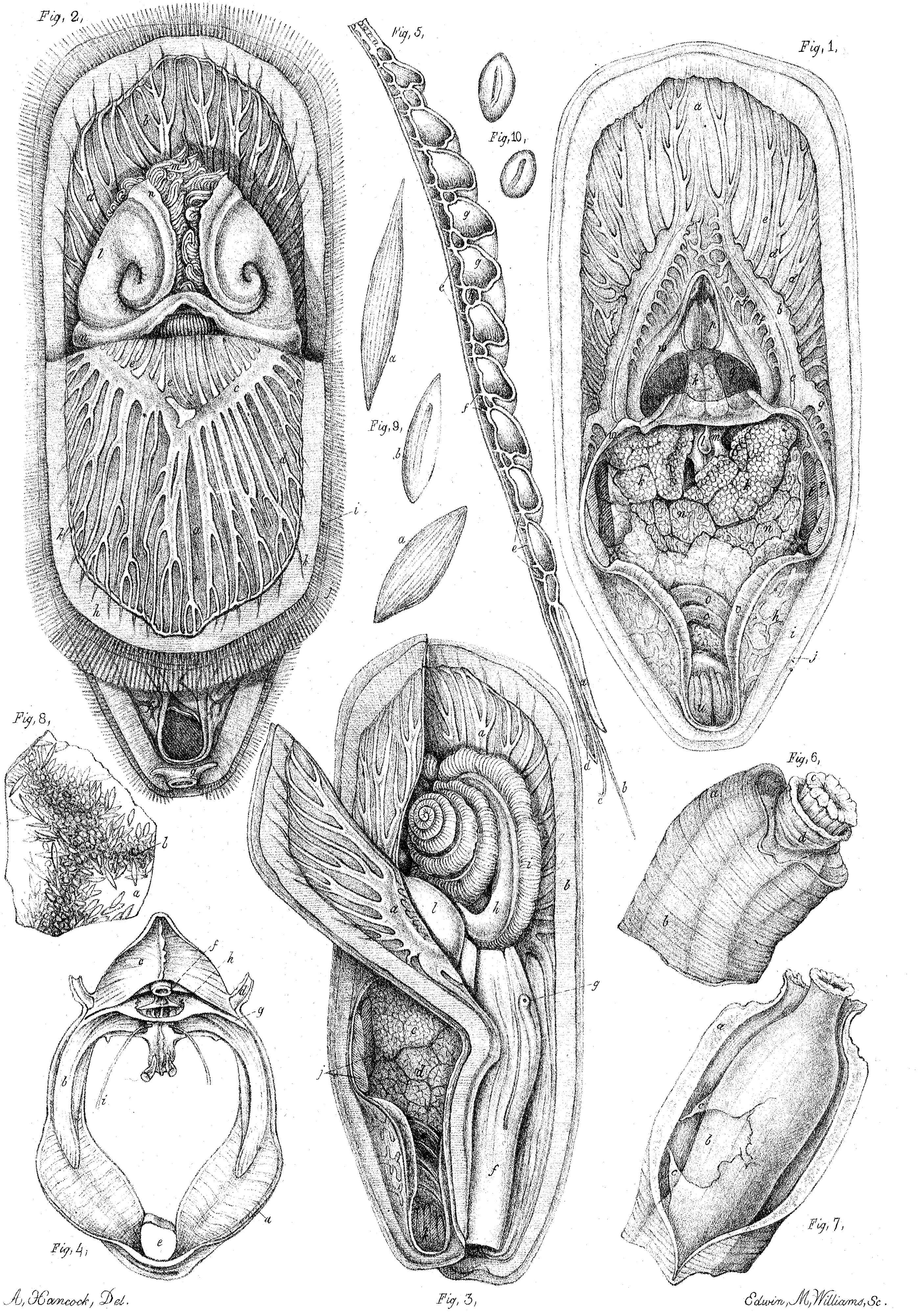

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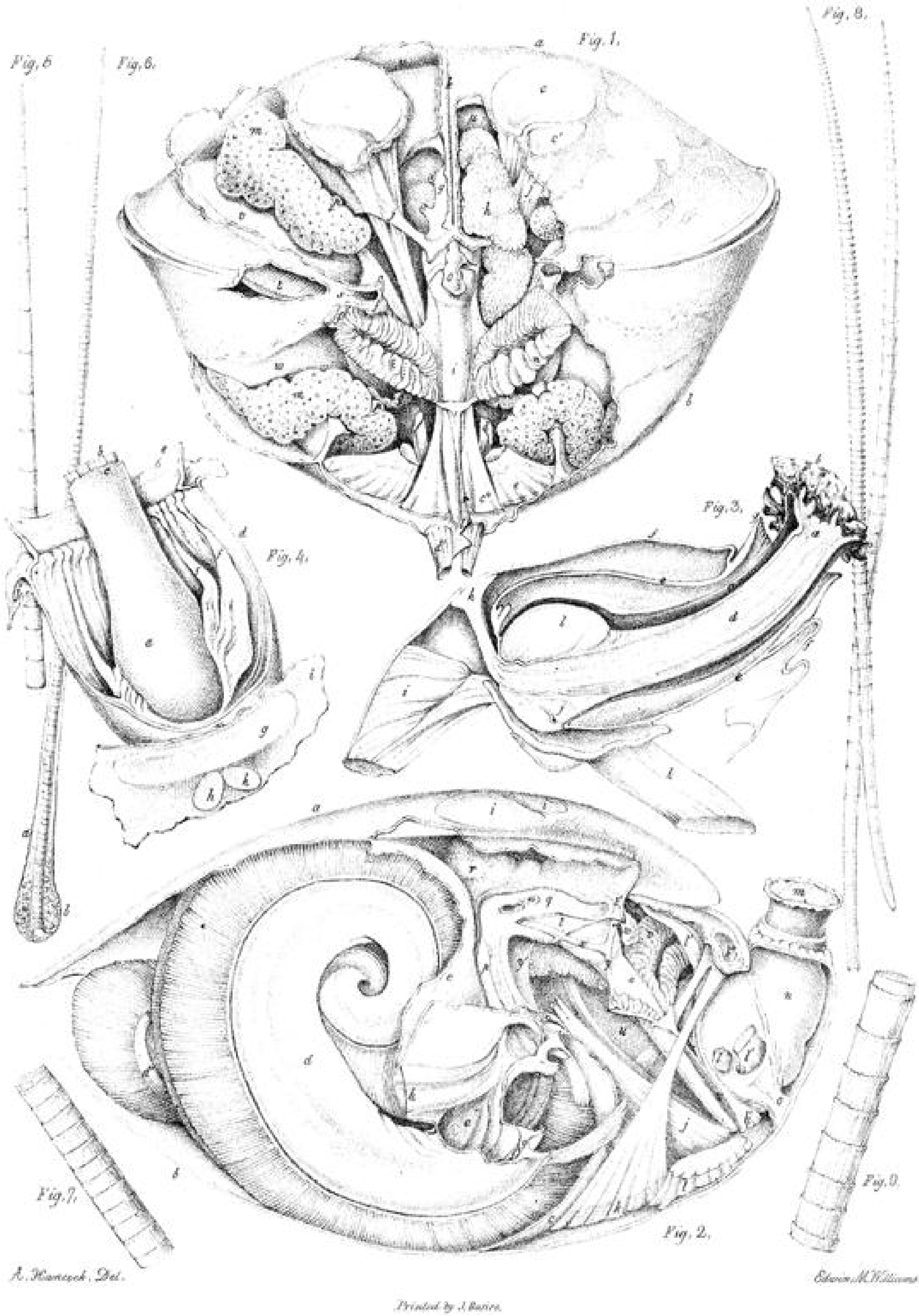

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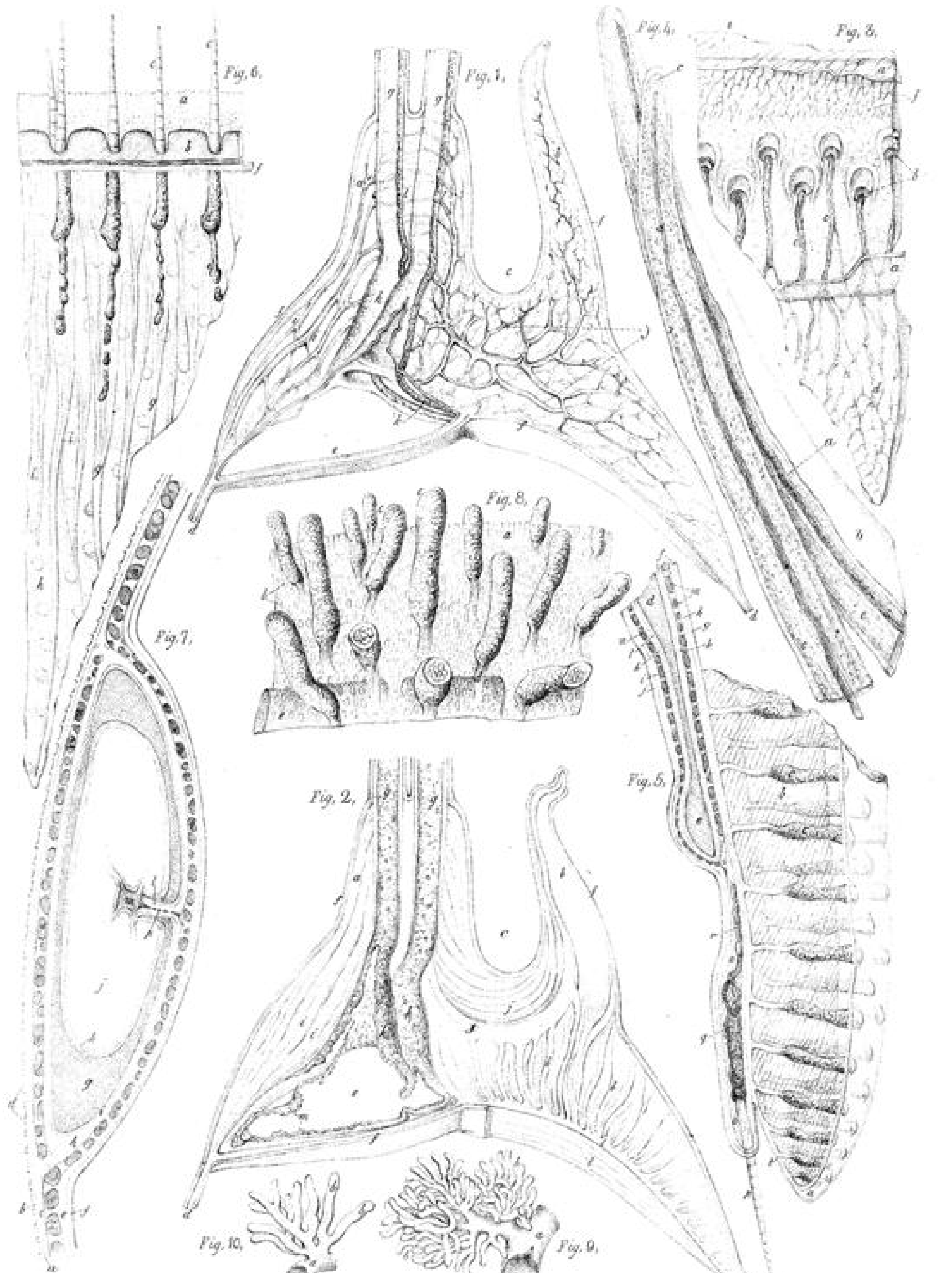

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