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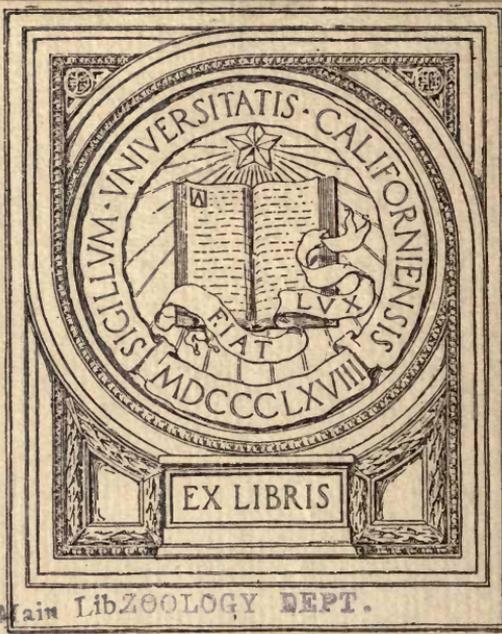
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**AN UNDESCRIBED ACRANIATE: *ASYMMETRON*  
*LUCCAYANUM*.** By E. A. ANDREWS. With Plates XIII  
and XIV.

While the Johns Hopkins Marine Station was located at Alice Town, North Bemini, Bahamas, in June and July, 1892, a small amphioxus or lancelet came under observation and was at once recognized as quite different from those commonly known.

Owing to the very great morphological interest attached to our knowledge of the acraniate vertebrates, this new member of the group has been studied and compared with the known lancelets to determine to what extent it adds to the present conception of acraniate anatomy. The result, as presented in the present article, is that this Bahama lancelet is generically distinct, though morphologically but little removed from the others in the main features that make the acranians isolated from all higher forms.

Before stating what are these generic characters the habits and habitat of the living animal, as far as known, may serve as a hint of the possible explanation of some of those anatomical peculiarities.

Examination of the very strong current that passes out from the lagoon to the Gulf-stream between North and South Bemini frequently resulted in the capture of large numbers of these small lancelets. They were taken in the tow-net while swimming at or near the surface; most abundantly at the early part of the ebb-tide when it had been high tide about nine o'clock in the evening; rarely in the daytime or late at night or on the rising tide. They were also obtained buried in the sand-flats that furnish the characteristic fauna of this ebb-tide current, but only a few could be found here and there at the western end of Stokes Cay and also half a mile to the east of East Point, East Wells. They may, however, be much more abundant in these flats than would appear from the above statement, since their small size and the soft permeable nature of the purely calcareous sand would make their detection much more difficult than it would be for such large lancelets as *Branchiostoma caribæum* which we had taken in great numbers in the firm continental sands of Tampa Bay, Florida.

The specimens taken in June were larger, often sexually mature, while those taken later were generally immature or larval forms.

In captivity they live like the European lancelet; occasionally leaving the sand and swimming about with considerable velocity, but soon falling to the bottom and resting upon one side as if exhausted or else burrowing instantly into the sand within which they move about with great celerity. As long as the water be pure they rarely leave the sand in the daytime and then quickly return when stimulated to motion by a slight touch or jar.

In flat glass dishes without sand they arrange themselves with reference to light in a manner suggesting that we have here amongst these simple, eyeless vertebrates an example of heliotropic movement such as plants and many non-vertebrates exhibit. At the end of some hours of alternating periods of active locomotion and lethargic rest most of the individuals are found collected upon one side of the dish, that furthest from the light.

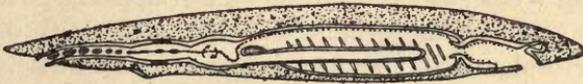
The same distribution ultimately results when the dish is turned through  $180^{\circ}$ . When carried to the door of the laboratory and exposed to the direct rays of the sun a most violent commotion immediately followed and soon resulted in the collection of all the passive individuals upon the side of the dish most remote from the source of light.

Finally when the dish was placed in the centre of a small square room lighted by a window on the north and one on the east and either window opened, the animals collected in the part of the dish most remote from that window. When both windows remained open the position of the lancelets was vaguely that part of the dish most remote from both windows.

As far as these experiments go they may be taken to indicate that we have a case of negative heliotropism in these simple vertebrates: that the lancelets move away from the source of light along the direction of its rays: that the directive action of the sun's rays is as in the numerous non-vertebrates studied by Dr. J. Loeb.

Though small, the largest not exceeding a length of 16 mm., many were sexually mature, yet individuals kept for many weeks did not discharge ova, except in one collection taken early in June; in this case some of the ova were naturally fertilized and a few developed as far as the gastrula stage, when they were destroyed by an accident.

As the animal is small and translucent the course of food and carmine granules may be traced through most of the digestive tract. The strong current of water setting into the pre-oral chamber seems to be controlled by the longitudinal, ciliated ridges of Müller's "Räderorgan" which pass forward from the velum on the inside of each lateral wall of the pre-oral chamber. Thus the carmine granules pass rapidly along these ridges towards the velum where they are turned inward towards the aperture, mouth, at the centre of the velum. The granules pass along in strings as if held together by a thin mucous; once through the mouth they do not pass out through the pharyngeal slits but continue along the median dorsal pharyngeal groove, the hyper-pharyngeal groove, still adhering to one another in strings. In actual longitudinal and cross sections these strings of granules may still be recognized in the ciliated hyper-pharyngeal groove.



Explanation of diagram. The dotted line indicates the course of food passing through the digestive tract which is divided into pre-oral chamber, pharynx, stomach with diverticulum and first and second intestinal regions.

This groove leads into what may be called the stomach within which the current of granules, or the granule containing mucous strand, turns abruptly downwards and forwards as indicated in the above diagram, yet does not enter the diverticulum but, still under the control of the active cilia lining the digestive tract, passes back again through the centre of the stomach. It is now revolving rapidly in a constant direction from right to left and continues to do so throughout the next division of the digestive tract, the first or larger section of the intestine. In this part of the intestine the granules, diatoms, etc., collect into clumps separated by the clear part of the continuous mucous-like strand. In this region the intestinal epithelium is especially modified in a zone that became very prominent when staining reagents are used.

The second, final and smaller part of the intestine, contains pellets of detritus that become successively larger towards the anus where

they have the form of elongated, not spherical masses that are discharged from the anus as the anal sphincter relaxes from time to time. The mucous strand is here broken, the granular aggregates becoming isolated from one another. These balls or pellets move along but slowly and give up the revolving motion seen in the first part of the intestine and in the stomach.

The time elapsing from the addition of carmine to the water to the discharge of carmine containing pellets may be much less than one hour.

Though no carmine was seen to enter the diverticulum, yet after twenty-four hours its walls became pink from the accumulation of fine granules that, in sections, are seen to lie within the epithelial cells of this part of the digestive tract. When the animal is kept long in sand and water to which carmine is added from time to time, this is taken up by many cells on the branchial arches as well as by the cells of the stomach and intestine. Moreover, as demonstrated by Weiss (24) for the European *Amphioxus*, many cells of the atrium take up the carmine, notably those forming the so-called nephridial ridges and those in the pigmented, dorsal atrial pouches. The nephridia, however, could not be recognized in sections of such individuals.

After some weeks the pre-oral organ was found darkly stained by the carmine, but not uniformly so: the closed deep lying part contained most of the red in the form of radiating spherules as if in gland cells while the tubular part of the organ opening into the pre-oral chamber had a decidedly yellow color with only diffused red in the free ends of the cells and very few red granules in their basal parts. This appearance of the pre-oral organ suggested at the time that it might have a nephridial function.

When Bismarck brown is added to the water in which the live animals are kept, they soon became darkly stained. On sectioning, this stain is found to be due to fine spherules in the cells of the epidermis, digestive tract, atrium and testis and also in the cells lining lymph spaces. Here again the method failed in revealing nephridia.

The vitality of injured specimens is very great; even those cut into two live for some days. In such cases some regeneration of lost parts may be initiated. Thus when the tail was cut off just

posterior to or at the anus, a blunt process grew out from the healed-over wound. On examination by sectioning, this process was found to contain notochord, anus and nerve tube and to be covered by a complete new epidermis. Here, as in the tadpole or salamander, there seems to be a regeneration of each tissue to form new tissue of its own kind. The epidermis was continuous with the old one and underlaid by a delicate connective tissue lamella continuous with the much thicker one under the old epidermis. The nerve tube was a collection of a few large cells continuous with the walls of the old nerve cord and surrounding a relatively large central lumen. The notochord had grown out very much as in the figures of Siredon given by Barfurth and was enclosed in a delicate sheath continuous with the stout sheath of the old cord. The digestive tract was continued to the surface of the body where its lining cells became continuous with the outer epidermis. The muscles of the last pair of myotomes appeared to be broken down into an amorphous mass that was continuous with a new mesodermal formation in the new tail. This mesoderm mass consisted of a loose sponge-work of cells arranged in the proximal part of the new growth so as to surround segmentally-placed cavities. Large blood, or cœlomic, spaces full of coagulum or lymph also occurred in this part of the new outgrowth.

With sufficient care the specimens might well have regenerated complete post anal regions—as far as could be surmised from these few observations.

Coming now to the chief anatomical peculiarities of this new Acraniate we find them expressed in the asymmetry of the reproductive organs and in the character of the fins.

In the living animal the reproductive organs, ovaries and testes, may be easily seen through the body-wall, but much more readily from the right side (Fig. 1) than from the left (Fig. 2). This is due to the fact that the gonads form a single series present only upon the right side of the animal and are not paired as in all other Acraniata and in most all Craniata. From the right this single series of gonads shows plainly through the wall of the atrium while from the left it is more or less concealed by both sides of the pharynx, the left wall of the atrium and, in part, by the caecal pouch that lies on the left of the animal.

This is obvious in transverse sections (Fig. 14) where the gonad, in this case an ovary, though having the normal relation and position of those found in a common *Amphioxus* and so developed as to crowd the digestive organs out of place, is yet found only upon the right side. Longitudinal sections show the entire series of gonads all upon the right side so that there is no question of alternate crowding of left and right gonads into a single series. Both testes and ovaries alike exhibit this asymmetrical development, though otherwise like those of other lancelets.

That this single right series corresponds to the right series of *Amphioxus* without admixture of the left is indicated by its presence as a single right series in the youngest individuals observed. Thus in a specimen 6 mm. long (Fig. 5) the gonads are a single, right series of minute collections of few large cells, the sex as yet unrecognizable, having the same position and character as the early stages of the gonads on right or left of the common *Amphioxus* as figured by Boveri (25 Fig. 8).

It is thus evident that the asymmetry of the reproductive organs goes back to an early stage and is probably due to the lack of development of the left series found in other *Acraniata*. Whether there is at the first any start of this missing left series cannot be determined at present.

The gonads differ from those of the known lancelets in being somewhat more numerous on the right side. Thus while the European form has according to Lankester (23) but 26 gonads on the right (and as many on the left) this Bahama form has 29 as seen in Fig. 1. They begin at the fifteenth myotome, gradually increase greatly in size, become consequently crowded together (since each corresponds to a myotome), rather suddenly decrease in size posterior to the branchial region and end anterior to the atriopore by a very small gonad like the first of the series, lying in the forty-third metamere.<sup>1</sup>

No observations were made upon the method of discharge of sexual products, but in sections ova and sperm are found in all parts of the digestive tract, in the pre-oral chamber, stomach, intestine and extreme end of the rectum. In some cases the ova in the

<sup>1</sup>In Fig. 1 the correspondence between myotomes and ovaries has not been correctly represented.

intestine show the first cleavage spindles, having been fertilized. As all these cases were specimens kept in confinement we infer that these sexual products were probably swallowed and give no evidence as to the method of discharge from the gonads. None were found free in the atrium; and in some cases the individual with ova in its digestive tract was sexually immature.

Even more conspicuous than this asymmetry of the reproductive organs is the character of the fins at the posterior end of the animal.

As seen in Figs. 1, 2, 4, there is a long slender caudal process extending posterior to the last myotome. This process is composed of the rather low dorsal and ventral median fins which become continuous at its tip but are elsewhere separated by the supporting notochord that extends nearly to the very tip of the caudal process. Moreover the nerve cord runs back in this caudal process as a slender tube just dorsal to the notochord and finally diminishing to a few cells surrounding a lumen at the extreme tip of the process. In a transverse section (Fig. 23) taken about the region *h* of Fig. 4 the dorsal and ventral fins are almost identical in size and structure. Each is a clear matrix of connective tissue permeated by irregularly radiating, anastomosing canals lined by cells that may nearly fill them, as represented to the extreme right in Fig. 25. This clear substance is concentrated as a sheath about the notochord and serves peripherally as a support for the single layer of epidermal cells covering the caudal process as all other parts of the body. The minute nerve cord has ganglion cells but no pigment. The numerous nerves branching through the caudal process come for the most part, if not altogether, from the neural tube anterior to the caudal process.

In the youngest forms found, having a length of 6 mm. and 22 branchial clefts on a side, the caudal process is very much shorter, not narrowed, but on the contrary expanded as the characteristic, rounded, larval tail-fin (Fig. 5). Soon, however, this rounded tail-fin becomes pointed, as seen in a specimen with twenty-seven branchial slits (Fig. 3), and subsequently elongated as in the sexually mature individuals.

Where the caudal process springs from the myotome region the ventral and the dorsal median fins both suddenly increase in height, the ventral much more than the dorsal.

If we now trace the dorsal fin anteriorly in the region of the posterior myotomes we find that the lymph canals that penetrate its substance become arranged in definite, parallel lines radiating upward from near the neural cord. Several of these canals occur opposite each myotome and some connect with large lymph spaces now appearing just above the neural cord. As seen in Fig. 25, a surface view from an animal living in sand with Bismarck brown, granules of brown substance occur in large cells lining the canals and the lymph cavities. These cavities become larger and more regular anteriorly and form the fin-ray spaces of the dorsal fin, three or four for each myotome. Henceforth the dorsal fin becomes more and more predominantly made up of these lymph spaces which succeed one another in a constant crowded series as seen in Figs. 1, 2, 3, 4 and in Fig. 17.

The lymph canals still remain and at places open into the fin-ray spaces, from the summits of which they extend out into the fin. Though at first nearly vertical (Fig. 25) these canals bend backwards more and more until, anteriorly, they come to run nearly parallel to the dorsal edge of the fin and will appear in transverse sections as in Fig. 22.

The fin-ray spaces are lined by a membrane with distinct cells projecting into the lumen (Fig. 17). Though at first quite near the nerve cord the spaces gradually rise, anteriorly, as the muscles become vertically deeper, and thus come to be separated from the nerve cord by a considerable space as seen in Figs. 22, 14, 12.

Projecting into each well formed fin-ray space, but not into the imperfect posterior ones represented in Fig. 25, there is a ventral mass of solid connective tissue, the so-called fin-ray. These fin-rays (Fig. 17) vary much in size and shape in differently prepared specimens but never appear as prominent as in some species of *Amphioxus*. They are not paired but single, median upgrowths from the ventral wall of each fin-ray space.

About the middle of the branchial region the proportions of the fin-rays and fin-ray spaces are as in Fig. 17, but posteriorly they become more crowded and deeper vertically, most so over the region of the atriopore and just posterior to that region. Anteriorly the spaces become more shallow and longer till finally the fin-rays cease to exist over the pre-oral chamber while the fin-ray spaces

continue as flattened cavities. Anterior to the pre-oral chamber only a few very small irregular median spaces remain as representatives of the fin-ray spaces. As seen in Fig. 10, the most anterior of these opens into a large unsegmented, median space that comes down abruptly into proximity with the brain, where it ends dorsal to the pigment spot that limits the anterior end of the brain.

As is evident from the figure this space opens into at least one of a series of long lymph canals passing back dorsal to the fin-ray spaces in the substance of the dorsal fin. Such canals are seen cut in cross section in Figs. 1, 3, 15, 21, 22, 23. Many of these canals arise still further forward from vertical, radiating canals anterior to the brain, canals that differ from those in the posterior part of the body (Fig. 25) chiefly in having no swollen base, or incipient fin-ray space. In the anterior region there is, however, what may be regarded as a representative of an undifferentiated series of fin-ray spaces developed as a single unsegmented space lying immediately above the notochord and extending forward from the brain almost to the extreme tip of the notochord. This terminal space has no connection with the one dorsal to the brain and is hence cut off from the series of fin-ray spaces by an interval above the pigment spot.

In this interval lies a minute intermediate lymph space, as shown in Fig. 10.

Anteriorly the terminal space appears constricted into partially separate, minute spaces near the tip of the notochord. A transverse section taken near the tip of the notochord (Fig. 11) shows this terminal space and a few of the lymph canals imbedded in the small amount of connective tissue that makes up the dorsal fin.

Throughout the dorsal fin the lymph canals have a nearly vertical position at the anterior and posterior ends but elsewhere become more nearly horizontal. Those from the anterior region running backward (Fig. 10) incline more and more and diminish in number (Fig. 17), while those from the posterior end turning forward supply all the posterior part of the fin.

If now the ventral median fin be traced forward from the caudal process it will be found to present the same structure as the dorsal fin with the important exception that it contains no fin-rays nor fin-ray spaces: thus it differs from the ventral fin of other lancelets.

The radiating vertical canals are very long in the deep fin beneath the posterior myotomes and present slight proximal swellings in the region just posterior to the anus; swellings that are like those more posterior ones of the dorsal fin represented in Fig. 25.

Anterior to the anus, however, these spaces are not continued as fin-ray spaces similar to those of the dorsal fin; in fact there are no representatives of such spaces and the lymph canals cease to form parallel, vertical channels and anastomose in an irregular way.

There are thus no double fin-rays in the region between the anus and atriopore though such are believed to exist in all other *Acraniata*: a striking and important difference.

At the extreme anterior tip of the animal the ventral fin has the same structure as the dorsal, with which it is continuous around the anterior end of the notochord (Fig. 10).

In this region the ventral fin has also a large median lymph space that anteriorly is somewhat sub-divided near the tip of the notochord, but posteriorly expands vertically as a large median space that penetrates some distance into the ventral fin and then rises again to end abruptly anterior to the pre-oral chamber opposite the posterior end of the second myotome (Fig. 10). In transverse section, near the tip of the notochord, this ventral space (Fig. 11) is smaller than the dorsal space, but in sections posterior to the brain it is in every way larger than the dorsal spaces above the nerve cord.

Between this anterior end of the median fin and the posterior part in the caudal process important modifications of the median fin, in fact its entire disappearance as a median fin, are brought about in connection with the openings of the digestive and branchial cavities. These modifications are the departure of the median fin from a true median position, and the substitution of the paired metapleural folds in place of a median fin throughout the length of the branchial region.

The appearances seen in the youngest specimens favor that explanation of the formation of the atrium given by Willey (26) so that we may adopt the terms sub-atrial ridges for the horizontal outgrowths of the metapleural folds and abandon the older idea of extensive epipleural downgrowths. The complete metapleura have the same structure and relationship as in the common amphioxus,

starting from the pre-oral hood they run back parallel with one another as far as the atriopore, thus forming the lateral limits of the floor of the atrium. They do not stop at the atriopore, but as seen in Figs. 1, 2, 3, 4, 5, continue posteriorly, the left one but a short distance, the right one, however, becoming continuous with the median ventral fin. This continuity of the median ventral fin and the right metapleuron can be seen in surface views (Figs. 1-5), and also demonstrated in serial sections.

Such sections show that the fin retains its solid structure up to point anterior to the atriopore where it, or the metapleuron as we may now call it, acquired the usual hollow condition known in other lancelets. The left metapleuron likewise is solid and identical with a fin in structure at its posterior end. In a section across the middle of the body (Fig. 14) we see two hollow metapleura, but at the level of the atriopore (Fig. 15) there are two fins, the left the smaller. Following a few sections forward from the atriopore the thick connective mass of the fins is found to continue as the thick sub-epidermal layer on the outer side of the metapleura, while a new cavity, the large lymph space of the metapleura, gradually extends downward from the basal part of each fin, or metapleuron.

This continuity of the right metapleuron with the median fin is unlike the condition found in the European *Amphioxus* and leads to an interesting departure of the fin from its true median position. In passing forward from the tail process the median fin departs decidedly to the right, even before the anus is reached, and becomes attached along the right edge of the ventral aspect.

Where the anus opens out on an anal papilla (Fig. 22) the fin is on the right side. We see here that though the digestive tract discharges to the left of the median fin it is not at all asymmetrical with reference to the median plane of the animal: it is the fin which is placed on the right, while the digestive tract remains a median structure. Yet the actual orifice of the rectum may, as in the figure, be turned to one side and lie to the left of the median plane; the papilla with its sphincter muscles is not accurately bisected by the median plane, but this does not justify us in regarding the anus as morphologically out of the median plane.

Immediately anterior to the anus the rectum is median (Fig. 21) and the fin is on the right side; but before the atriopore is reached it approaches the median line and appears as a true median structure as far as its free portion is concerned. The basal part, however, even when the free edge is median, extends up to an attachment to the muscular region of the right, much as is seen in Figure 21. Even its free part is median only for a short space and soon projects again from the right side, becoming thus continuous with the right metapleuron posterior to the atriopore, as is shown in Fig. 15, where the left metapleuron is seen in a similar fin-like state and the posterior tip of the atrioporal spout is enclosed between the two.

The departure of the median fin from a true median position is correlated with the breaking through of the median rectum: anterior to the anus the fin becomes more nearly median in proportion as the rectum rises up from its superficial ventral position or is more and more enclosed by the downward extension of the lateral muscles, passing from the opening seen in Fig. 22 through a stage shown in Fig. 21 to a position shown in Fig. 15. Here, however, the atrial formations again interfere with the median position of the fin, and it becomes lost in the right metapleuron.

The continuity of right metapleuron and fin suggests that the fin may not be primarily a median structure, but one of a pair of longitudinal folds of which the left forms only the left metapleuron while the right is more extensive and comes to lie in the median plane, as a locomotor organ, whenever the atrium and digestive tract are not at the surface to render such a position difficult.

The idea that the median fin is but a form of the right metapleuron would not harmonize with the view suggested by Lankester (23), that the double ventral fin of amphioxus may be the fused epipleura, but that view would require re-stating if we accept the formation of the atrium as recently described (26).

As we have seen the median ventral fin of the caudal process continue around the end of the notochord, thence along the whole dorsal median line and finally become continuous with a median ventral fin beneath the anterior end of the notochord, nowhere showing any trace of a double or paired character, we might expect that it would become continuous with the right metapleuron

anteriorly as well as posteriorly. According to Lankester (23) this is the case in amphioxus if we regard the right half of the pre-oral hood as a continuation of the right "epipleuron." But in the Bahama amphioxus both metapleura seem to be continuous with the side of the hood, these with the edges of the anterior part of the pre-oral chamber and these in turn with the single median fin (Fig. 6).

In Fig. 13, which is a section across the base of the hood, the connective tissue mass joining the shrunken-in hood membrane to the lateral muscle mass of each side is a direct continuation of and is some sort a representative of the metapleuron of each side. Again in the section Fig. 12, anterior to the free edge of the hood the same connective-tissue masses now project freely and form edges to the pre-oral chamber. They are much like the fins, or metapleura, posterior to the atriopore (Fig. 15).

Even if we may thus regard the metapleura as continuous with the sides of the pre-oral hood and the anterior edges of the pre-oral chamber, we are puzzled by the fact that they meet at the anterior end of the pre-oral chamber and become continuous with the median fin (Figs. 6, 20). At the same time the right predominates here also and it is chiefly the right side of the pre-oral chamber which is fringed by a continuation of the median fin. As the median fin is thus posteriorly continuous with a single paired structure, the right metapleuron, and anteriorly continues with what appears to be two paired structures, both metapleura, we see no sure ground for inferring its origin, either from the loss of one, or from the fusion of both of a primitive pair of organs. Yet the indications are that the median fin is not so much single by fusion as by loss of its fellow.

As illustrating the ease with which paired lateral structures may pass to a median ventral position and *vice versa*, this case is of interest with reference to the origin of appendages of fishes from lateral fins and their connection with a median fin.

The disappearing metapleura on the sides of the pre-oral chamber are intimately associated with the pre-oral hood. This structure is much more extensive than in the common Amphioxus, forming a deep shovel-shaped or inflated membrane suspended from the posterior and lateral margins of the pre-oral depression; when expanded it appears as in Fig. 6.

From a side view (Fig. 1, 2, 3, 4) it extends forward ventrally over the pre-oral chamber like a hood, with cirri like those of other lancelets. These cirri, however, are perfectly smooth as shown in Fig. 19 and do not present the denticulate outlines due to the special sense-organs found on the cirri of other Acraniata. The number of cirri is 15 to 21, the small lateral, anterior ones being involuted dorsally with the membrane and not seen from a ventral view (Fig. 6). There may be a median cirrus and an equal number of paired cirri on each side, as seen in the view of the macerated skeleton (Fig. 24). Each cirrus is supported by a special cartilage-like rod springing from a common curved and jointed basal arch, as in the common lancelet. Each rod, it will be observed, springs from the distal end of one of the basal pieces composing the common basis for all the rods. The hood differs from that of the European form, and from that of the Florida form also, in having the membrane continued up over nearly the whole length of the cirri, leaving but their tips free. Moreover the median cirrus is so long, and the most lateral so short that there is no reason to doubt that the latter are the youngest as has been shown to be the case in *Amphioxus* (27) although before the embryological facts were known the examination of the adults had led Lankester (23) to the opposite conclusion.

If we were justified in regarding the lateral edges of the pre-oral chamber as continuations of the metapleura, it is tempting to suppose that the hood membrane, lying between those continued metapleura and posteriorly continuous with the floor of the atrium (Fig. 6) may be homologous with the sub-atrial ridges, may have been originally an anterior continuation of those parts of the metapleura which now unite posteriorly to form the floor of the atrium. Such a view may be supported by the fact that in *amphioxus*, as Willey has discovered (27), the oral hood arises from two beginnings one right and one left: while other facts that militate against it may be explained as secondary acquisitions connected with the remarkable asymmetry of the oral region of the Acraniata.

In addition to the above peculiar features of the reproductive organs and fins, the Bahama lancelet presents some few minor anatomical features which may now be described in comparison with the similar structures in the European forms.

The true mouth is at the centre of a transverse velum provided with a strong sphincter muscle and a series of oral tentacles that are not, apparently, quite as numerous as in the European lancelet though having the same arrangement.

The capacious pre-oral chamber bears upon its side wall the so-called "Räderorgan," consisting of three large ridges of specially thickened, ciliated epithelium, passing forward on each lateral wall (Figs. 1, 2) to end in rounded lobes in the posterior half of the chamber above the basal part of the pre-oral hood. These ridges might be regarded as one continuous ridge folded back and forth into three chief loops with smaller lobes interpolated between them at the posterior end. All the ridges continue posteriorly as a ciliated area leading to the velum and out on it towards its central aperture, the mouth. An important part of the structure is a special ridge found only upon the right side, high up towards the notochord, so that it appears median from a side view (Fig. 1). In sections anterior to the above paired ridges (Fig. 13) this right, azygos ridge continues to end only at the extreme anterior angle of the pre-oral chamber. Here it is associated with the conspicuous pre-oral pit found on the right side in the position shown in Fig. 12, but continues as a special ciliated ridge even anterior to the pit (Fig. 18) as well as posteriorly to join the other ridges at the velum.

The pit has the form of a glandular tube, somewhat bent, opening out into the pre-oral chamber in the azygos ridge and histologically divided into two regions. The terminal part is ciliated, the internal closed end has an epithelium of what appear to be gland cells casting out a coagulable substance into the lumen. As already stated the two regions of the organ behave differently when the animal is fed with carmine.

That the pit has either an excretory function or, more probably, may serve to secrete slime to aid in entangling food particles to be swept back to the mouth, is an idea suggested by its action towards carmine and strengthened by its anatomical relations to a large blood vessel or space. This vessel passes along close beneath the azygos ridge for its whole length (Figs. 12, 13) and is the "aortic arch" of Langerhans (28) as figured by Ralph (29) and described by Lankester (23) and recently called a "glomus" by van

Wijhe (32), who regards it as of excretory function. It seems to be much less complex than in the European form; though it presents some branches anteriorly it is not to be regarded as a glomus here. Posteriorly it passes between the velum and the lateral muscles but could not be traced into connection with other vessels. Anteriorly it passes between the walls of the pit and the azygos ridge, close to each end bends up dorsally between the tip of the pit and the end of the ridge. Here it immediately unites, at the anterior end of the pre-oral chamber, with a large branch of the left aorta, forming thus a median aortic trunk that runs forward a short distance, close beneath the notochord, bifurcates, and ends in the ventral sheath of the notochord. This left aorta is notably smaller than the "right arch" (Figs. 12, 13) and branches just before the anterior end of the pre-oral chamber is reached, sending the larger branch to fuse with the "right arch," as above stated, and the smaller branch forward a short distance to branch in turn and, perhaps, to connect with the large median lymph space beginning here and lying under the notochord as seen in Fig. 10.

Of the two aortic trunks found in the pharyngeal region it is only the left that connects, as above, with the "right arch." The right aorta seems to disappear in the velum.

No attempt has been made to trace out the rest of the vascular system though the chief aortic trunk, the vessels of the branchiae, and the numerous vessels on the posterior intestine and caecum seem, in sections, to be much as described for the common *Amphioxus*.

The branchial apparatus is like that of the known forms; but as seen in Figure 2 the first gill-slit may be small and only partly divided by a tongue bar, while in the European species van Wijhe (32) finds that the first gill slit has no tongue bar. In macerations of the branchial skeleton we find the usual primary bars and tongue bars represented by rods that are double in the former, divaricating at the lower end and deeply cleft lengthwise, but apparently single in the latter, though marked longitudinally by cavities and grooves.

Primary rods and tongue bar rods unite dorsally, so that they form a series of three-tined forks.

The usual number of horizontal connecting bars pass across the tongue bar from one primary to the next. Dorsally the processes

of the primary rods called by Spengel (30) the "Bügelstücke" are very large and prominent; ventrally, however, the endostylar plates could not be demonstrated by maceration or by section. Such sections give the usual marked difference between the primary and secondary bars, but on account of their small size would make difficult any attempt to trace the exact course of the blood vessels as determined by Lankester (23) or by Spengel (30).

In the digestive tract of this Bahama amphioxus there is a marked zone of small, crowded cells that take up stain readily and form a dark band posterior to the stomach region as indicated in Fig. 5. This is found in the Florida specimens of *Branchiostoma caribæum*, but appears not to have been noticed in the European Amphioxus.

The atrial chamber has the usual longitudinal, ventral ridges that have been regarded as of excretory function, but a long search for the nephridial tubules found by Boveri (31) was without success, probably owing to the small size of the specimens and the distortion due to preservation. The live specimens were not examined for this purpose. Surface preparations of preserved specimens of the Florida *B. caribæum* showed nephridia like those obtained by Boveri by this method, but none were made out in the small Bahama animals. This atrial chamber differs from that of European forms in the extent of its posterior portion. Thus while Lankester (23) finds a single pouch running back of the atriopore "as far back as the anus" there are here two short pouches, the right longer than the left, that seem to have pushed themselves back on either side of the atrial outlet and then, very soon, stopped growing. Both are shown in Figure 15, which is posterior to the base of the atrioporal spout, though showing its tip; further back Figure 21 shows no representative of the atrium.

In the Florida *B. caribæum* there is a large post-atrioporal pouch on the right, but it does not reach as far as to the anus.

In the youngest individuals taken, the floor of the atrium is but imperfectly formed, the two sub-atrial ridges being incompletely fused on the median, ventral line.

Here there is an interesting segmented arrangement of the muscle fibers such as has not been noticed before, I believe. The transverse muscle of the atrial floor (Fig. 14) begins as a series of

fibers in each sub-atrial ridge before they unite; there is thus a double series of transverse fibers that subsequently unite with one another across the middle line. In each half of the series, on the right and on the left, the fibers have the peculiar grouping seen in Figure 16. There are three or four groups for each myotome, each group being due to a special centre of growth about which the fibers are arranged in pairs and become gradually longer as they adjoin the other groups. Eventually all the fibers seem to become of equal length so that this segmentation is obliterated.

The agreement of the groups upon opposite sides of the median line is also noticeable as a marked case of bilateral symmetry in the arrangement of individual cells upon disconnected, opposite sides of the body.

No thorough examination of the nervous system was attempted, but it seems to present no marked difference from the state of things found in the common amphioxus. There are dorsal and ventral nerves and amongst the former a large one, seen in Fig. 10, that arises from the posterior part of the brain, branches freely and is distributed to the anterior part of the median fin where there seem to be terminal organs in the living specimen. Two slender nerves continued from the anterior end of the brain, along the notochord are sometimes seen to have a hollowed out base which may be an indication of what Ayres (34) has described as optic diverticula or lobes in the common lancelet, which, however, seem here to be rather the results of distortion in preparation than normal conditions.

The ventricle of the brain has in longitudinal median section very much the form and proportion represented by Küpffer (33), Figs. 21-22, but the posterior ventral diverticulum could not be recognized as a cavity though indicated by a non-nucleated, clearer region.

In transverse sections we have successively the appearances seen in Figs. 7, 8, 9, which represent the ventricle at its anterior, middle and posterior portions with the relative size of lumen and wall.

The pigment spot at the anterior end of the brain presents nothing to suggest that it is in any sense an eye. It is not placed exactly as in the above figures of Küpffer but forms a terminal cap-shaped deposit in the conical tip of the brain, is a collection of pigment in the conical tip of the ventricle wall and is thus cut as a ring of

pigment in a few, very thin, sections immediately posterior to the extreme tip of the ventricle, Fig. 7.

As far as could be observed in surface views of both living and preserved specimens and in transverse and longitudinal sections of both young and adults no anterior neuropore or "nasal pit" exists, nor any such connection of the anterior part of the brain with the epidermis.

The pigment spots of the neural tube are very conspicuous in life and in sections as large cap-shaped masses about individual ganglion cells of the ventral part of the cord near the base of the median fissure or canal.

The spots begin a short distance posterior to the brain and soon become more crowded to form a series, on each side, that ends posteriorly before the caudal process is reached. There is throughout a disposition to aggregation in linear groups suggesting a metameric arrangement, but the short lines of pigment spots are not actually arranged with reference to the myotomes.

This pigment is very resistant, as attempts to remove it in Grenacher's depigmenting liquid were not successful after many days' immersion.

In summarizing the above account of the Bahama amphioxus, we find that its peculiar structures, asymmetry of the reproductive organs and great extension of the tail fin, do not throw light upon the morphology of the acraniate, but are such characters as may be explained as secondary departures from a type more like the common European form. Thus the lack of the left gonads is no doubt a loss of what was at one time present. The extension of the tail is also a secondary feature; for we will see later that the actual number of myotomes has not been decreased, on the contrary there are 66 here as compared with 61 in the European lancelet, so that we have no ground for supposing that the caudal process was once accompanied by myotomes. It is rather a posterior outgrowth of use in swimming, a true caudal process. Yet the presence of the neural tube in this non-muscular region does suggest the former existence of muscles; on the other hand the extension of the brain beyond the anterior myotomes (Fig. 10) furnishes evidence as to the possibility of nerve tube and notochord extending out together into new terminal structures.

Both the character of the fins and the diminution in bulk of the gonads, by loss of one series, may be explained on the assumption that they favor more active locomotion outside the sand. We have evidence that this species is, to some extent, free-swimming in habit.

In order to determine what taxonomic value should be attached to the anatomical features of this Bahama lancelet it will be necessary to review our knowledge of known Acraniates as far as it concerns the systematic work upon members of the group and the closely associated facts of geographical distribution.

#### HISTORICAL.

As is well known the first recorded account of *Amphioxus* was that of Pallas (1), who in 1774 described a preserved specimen that came from the Cornish coast. Though the fish-like characters of this undoubted *Amphioxus* were recognized by Pallas ("quodque prima facie referet Piscem Leptocephalum Gronovii") it was described and figured as a mollusc, *Limax lanceolatus*.

This error was corrected by Costa (2) who more than half a century later re-discovered the animal, on the shores of the Mediterranean, and misled by the gill-like appearance of the pre-oral cirri, named it *Branchiostoma lubricum*. There seems to be no doubt that this account was published in 1834, though in a paper so difficult of access that it is chiefly the author's statements made in the two complete, illustrated descriptions (3) of 1838 and 1843 that we rely on in selecting this name *Branchiostoma* as preferable to the one commonly used, *Amphioxus*.

This latter was given in 1836 by Yarrell (4), who included in his "British Fishes" an illustrated account of a single specimen taken by Mr. Couch, at Polperro on the Mediterranean, where it happened to be lying with its tail protruding from under a stone.

Not knowing the work of Costa, though acquainted with the description of Pallas, Yarrell invented the name *Amphioxus lanceolatus* under which the animal soon became an object of much interest and subject of many anatomical investigations.

The older generic term was used again by J. E. Gray (5), in description of a new species *B. Belcheri* from Borneo. This was obtained at the mouth of the river Lundu by Capt. Belcher of H.

M. S. "Samarang" and "as what appears to be a new species of Lancelet," is described in a rather vague and unsatisfactory way from a single specimen. Another was sent to Dr. Clarke, R. N., for anatomical study, which appears never to have been made public.

Moreover the author compared this new form with specimens from Cornwall and from the Mediterranean and concluded they were all three different species. This opinion was maintained again in the subsequent Catalogue of the British Museum (6) where Gray calls the Naples form *B. lubricum*, that from Borneo *B. Belcheri* and those from Polperro and S. W. England as well *B. lanceolatum*.

In the following year Sundewall (7) added to the knowledge of the group by his description of the specimens in the Museum of Stockholm. Amongst these he distinguished a new species *A. elongatus*, sent by Capt. Wårngren from Chinchaoarna, Peru, from *A. lanceolatus*, from the German Ocean as well as from the coast of Cornwall. He included Gray's Borneo species in the genus *Amphioxus*, as *A. Belcheri*.

Soon afterwards (8) he recast these descriptions and, for the first time, introduced the counting of the myotomes, or the muscle-segments, as a means of distinguishing species of Acraniata, counting not only the entire number of segments but also the number anterior to the atriopore, between that and the anus and posterior to the anus, thus defining the relative positions of these important structures.

*Branchiostoma lanceolatum* (as he now calls it) has  $36 + 14 + 11 = 61$  myotomes in specimens from Northern Europe. *B. elongatum*, from Peru,  $49 + 18 + 12 = 79$ , while a new form, *B. caribæum*, found at St. Thomas, at Rio de Janeiro and at the mouth of the Plata has  $37 + 14 + 9 = 60$ .

The four forms thus far described were not, however, regarded, generally, as specifically distinct. Thus Guenther (9) in 1870 in his catalogue of the specimens in the British Museum included all known forms under the single species *B. lanceolatum*.

However, in 1876 some new specimens were brought from Moreton Bay, Peale Sound, Northeast Australia, by Captain Schleinitz of S. H. S. Gazelle and described by Peters (11) as generically different from all known forms. As far as could be

determined from alcoholic specimens, the anatomy of this new *Epigonichthys cultellus* was the same as in *Branchiostoma*. No enumeration of the muscle segments was made, but the character of fins and the apparent median position of the anus were regarded as of generic value.

Subsequently Guenther (10), in the only complete comparison of all known forms of *Amphioxus* that has thus far been attempted, was able to examine specimens of this new genus brought from Thursday Island, Australia, by Dr. Copinger. Comparing these with other *Acraniata* he referred them back to the genus *Branchiostoma*.

Moreover, Guenther now regarded the others as specifically distinct, so that in this list of the *Acraniates* in the British Museum we find the above form appearing as *B. cultellum* then *B. lanceolatum* from Europe and from the Atlantic Coast of North America, *B. elongatum* from Peru (on the authority of Sundevall), *B. Belcheri* of Gray, represented also by new specimens brought by Dr. Copinger from Prince of Wales Island, Torres Straits, and finally *B. caribæum*, which Van Beneden got in large numbers at the Bay of Botafago and which furnished the material for Moreau's study of the neural cord (possibly this is the same as *Amphioxus Mülleri* of Kröyer's MSS.).

In addition to these previously known forms this revision adds a new one, *B. bassanum*, from Bass Straits; this was formerly regarded by Guenther as *B. lanceolatum*. Of these six species five are represented by specimens in the British Museum.

About this same date, 1884 or '85, as my friend Dr. S. Watase informs me, Professor Matsubara of the Medical Department of Tokio University read to the Zoölogical Society of Tokio an account of an *Amphioxus* found at the island of Kinshin, in the western part of Japan.

Whether this is a new species or not remains to be seen.

Earlier than that, in the winter of 1877-8, as appears from a brief note by Professor Brooks (19), an assistant in the Smithsonian Institution found some sort of *Amphioxus* at the Bermuda Islands.

The knowledge of the distribution of Sundevall's *Branchiostoma caribæum* was extended in 1891 by the discovery of small miniature specimens swimming at the mouth of Kingston Harbor,

Jamaica. These specimens were taken by the Johns Hopkins Marine Laboratory and merely mentioned as *Amphioxus* (21), but subsequent examination has proved their identity with the forms previously known from St. Thomas, South America and the Southern United States.

As early as 1887 the same Laboratory while at Nassau, N. P., obtained miniature swimming forms in the harbor. These were taken again by us in July of 1892 at the same place, and proved to be immature specimens of what we will call *Asymmetron lucayanum*, so that we may regard this form as probably occurring all through the Bahama Islands.

Meanwhile there had appeared brief mention of the occurrence of Acraniates at various points upon the coast of North America.

Thus, in an account of the Zoölogy of California (12) published in 1868, J. G. Cooper mentions the occurrence of *Branchiostoma*—? found in the sand at San Diego, California, and gives a popularized characterization that leaves no doubt as to the acraniate character of the creature. From the notice of Gill (13) it appears that these Californian lancelets were dredged at a depth of ten fathoms, and that only three specimens were found. One of these is now in the collection of the Smithsonian Institution, labelled *B. californiensis*. As this and many others from the same locality have an arrangement of myotomes unlike that of described species, we may conclude that it is specifically distinct though it has been referred to as *B. lanceolatum*, by Jordan and Gilbert (14), who had, however, not seen the specimens, and regarded (15) all American forms as not specifically distinct from the European, as far as had been proven.

On the Atlantic coast Coues and Yarrow (16) dredged a dozen or more specimens on Bird Shoal, Beaufort, N. C. They identified these as *Branchiostoma caribæum*. This discovery was, however, spoken of by Jordan and Gilbert in their list of Beaufort Fishes (17) under the name *Amphioxus caribæus*, though later, as above mentioned, all American forms were regarded as undistinguished from the European.

At the same place *Amphioxus* was collected by members of the Johns Hopkins University in 1880-1-2-4-5.

They also found adult and larval forms in 1878, by dredging in water 12 to 15 feet deep near Ft. Wool, at the mouth of the Chesapeake.

Larval forms were taken at the surface in July and August. These were figured and described by Rice(18) as *Amphioxus lanceolatus*.

From his statement it appears that one specimen had been previously found upon the Eastern Shore of Virginia by Mr. P. R. Uhler, and that it was then known that *Amphioxus* had previously been found in Florida as well.

Yet the first published notice of the occurrence of Acraniata in Florida seems to be that of A. A. Wright(20) who obtained large numbers at Port Tampa in March 1890. Its previous discovery in Florida rests upon the above statement of Rice and upon the presence of specimens in the Smithsonian Museum.

Acting upon information kindly furnished by Prof. Wright, members of the Johns Hopkins Laboratory obtained large numbers of adult and larval *Branchiostoma caribæum* at Port Tampa in June 1892, which enables us to extend the distribution of this species as will be seen in the summary of geographical distribution.

From the above review it will be seen that there is but one genus of Acraniates, *Branchiostoma*, and that the various species from different parts of the world have been distinguished by the only marked differential characters seen in alcoholic specimens; the number and arrangement of the myotomes. Lankester(23) leaves the question as to the fixity of these numerical characters, an open one. So great is the difficulty of accurate counting, where the terminal myotomes may be very small and vaguely demarked in preserved specimens, that we do not know the limits of variation in any one species. Successive counts of one specimen of *B. caribæum* have given me such numbers as 35. 14. 9; 35. 13. 10 and 35. 15. 9; for the anal and atrial openings are also not precisely localizable in preserved specimens.

In the first appendix to this paper I have given all the enumerations of myotomes that could be found in the systematic literature and in addition a considerable number made upon specimens in the Smithsonian Institution and elsewhere. From a consideration of

these, there is no doubt, I think, that such enumerations may be relied upon as giving safe specific criteria though they should not by any means be the only ones, if live specimens can be observed. This in spite of the great difficulty in making accurate counts and allowing for the probable, slight variations within the species. Until the various forms can be monographed from a study of living specimens such characters will be most useful.<sup>1</sup>

Admitting that the number and arrangement of the myotomes furnish criteria of specific value in the group Acraniata, we must concede that such peculiarities of the fins and reproductive organs as we have found in the Bahama *Amphioxus* are of at least generic value and justify the establishment of a new genus to be characterized as follows :

*Asymmetron* g. n.<sup>2</sup>

Gonads present only upon the right side.

Ventral fin with no fin rays or successive fin-ray chambers. A long caudal process.

The only known species, *Asymmetron lucayanum*,<sup>3</sup> may be characterized as follows :

Right metapleuron continuous with the median ventral fin, which passes to the right of the anus. Pre-oral hood extensive, the cirri united by the membrane throughout the greater part of their length and smooth, without sensory papillæ. Gonads on the right 29, extending from the 15th to the 43d myotomes inclusive. Myotome formula  $44.9.13 = 66$ . Length 13 mm. "Olfactory pit" apparently absent; nephridia and brown canals not demonstrated.

Adults and young swimming at surface in the evening in June and July at Bemini and Nassau, Bahamas. Also taken buried in the calcareous sand.

With this addition we may form the following summary of our knowledge of the classification of the group Acraniata.

<sup>1</sup> For the aid of any who may wish to know of the existence of preserved specimens, a list of those in the Smithsonian Museum is given in Appendix II.

<sup>2</sup> ἀ-σύμμετρος, ση = wanting symmetry.

<sup>3</sup> From the Lucayas; the islands discovered by Columbus in 1492, now the Bahamas.

## ACRANIATA.

Genus BRANCHIOSTOMA. Gonads present on both sides; ventral fin with fin-rays; no caudal process.

1. *B. lanceolatum*: formula  $36 \cdot 14 \cdot 12 = 61$ , length 37 mm. Distribution, Scandinavia, England, Mediterranean, Chesapeake Bay? Fiji Islands?
2. *B. caribæum*: formula  $35 \cdot 14 \cdot 9 = 58$ , length 43 mm. Distribution, Mouth of La Plata, Brazil, St. Thomas, Jamaica, Tampa Bay and Gulf of Mexico, Beaufort, N. C.
3. *B. cultellum*:<sup>1</sup> formula  $32 \cdot 11 \cdot 10 = 52$ , length 23 mm. Distribution, Moreton Bay and Thursday Island, Australia.
4. *B. bassanum*: formula  $44 \cdot 14 \cdot 17 = 75$ , length ——. Distribution, Bass Straits, Australia.
5. *B. belcheri*: formula  $37 \cdot 14 \cdot 14 = 65$ , length 65 mm. Distribution, Borneo and Torres Straits, Australia.
6. *B. elongatum*: formula  $49 \cdot 18 \cdot 12 = 79$ , length 60 mm. Distribution, Chinchaoarna, Peru.
7. *B. Californiense*: formula  $44 \cdot 16 \cdot 9 = 68$ , length 70 mm. Distribution, San Diego, California.

Genus ASYMMETRON; Gonads present only on right; ventral fin with no fin-rays; a long caudal process.

8. *A. lucayanum*: formula  $44 \cdot 9 \cdot 13 = 66$ , length 13 mm. Distribution, Bimini and Nassau Harbor, Bahamas.

In addition to the species enumerated above there are records of lancelets found in other regions that extend the area of geographical distribution and may modify our conception of the number of specific forms when all these specimens shall be re-studied. At present, then, the geographical distribution of the Acraniata may be summarized as follows:

EUROPE. Scandinavian, British, and Italian Coasts: (1) *B. lanceolatum*.

ASIA. Borneo: (1) *B. Belcheri*. Japan: (2) ———? (3) Ceylon; ———?

<sup>1</sup>Mr. Arthur Willey of Columbia College informs me that he finds only right gonads in this species; so I judge it should be referred to the genus Asymmetron, in a future revision of the Acraniata.

AUSTRALASIA. North Australia: (1) *B. cultellum* and *B. Belcheri*. East Australia: (1) *B. cultellum*. South Australia: (3) *B. bassanum*. Fiji Islands: (4) *B. lanceolatum*? (Rohon (22) quoting C. Hesse of Hamburg.)

AMERICA. Pacific Coast: (1) *B. elongatum*, Peru; and (2) *B. Californiense*, California. Atlantic Coast: (3) *B. caribæum*, South America and Southern United States; and (5) *B. lanceolatum*? mouth of Chesapeake Bay. West Indies: (3) *B. caribæum*, Antilles; and (4) *A. lucayanum*, Bahamas. Bermudas: — — ?

## APPENDIX I.

(Formulas marked \* were determined more accurately than others.)

*Branchiostoma lanceolatum*.

				mm.				
				23-44.				
36.	14.	11.	61.		Northern Europe:	Sundevall (8).		
35.	12.	12.	59.		Polperro	: Günther (10).		
34.	13.	13.	60.		Naples	"		
35.	12.	13.	60.		"	"		
35.	15.	10.	61.		Naples	: Lankester (23).		
35.	14.	13.	62.		"	"		
35.	14.	12.	61.		"	"		
35.	16.	10.	61.		"	"		
36.	15.	11.	62.		"	"		
36.	13.	12.	61.	37.	Stavanger, Norway	(Smith. Mus.)	E.A.A.	
37.	13.	12.	62.	27.	"	"	"	"
35.	13.	10.	58.	27.	"	"	"	"
35.	12.	13.	60.	27.	"	"	"	"
36.	13.	12.	61.	37.	"	"	"	"
36.	15.	10.	61.	52.	Sicily: J. H. U. Mus.			"
35.	14.	11.	60.	52.	"	"		"
35.	14.	11.	60.	35.	Naples: (Bryn Mawr Mus.)			"
36.	14.	11.	61.	38.	"	"		"
36.	13.	13.	62.	37.	"	"		"
37.	14.	11.	62.		"	"		"
36.	13.	11.	60.	36.	"	"		"
33.	14.	12.	59.	42.	"	"		"
35.	13.	13.	61.	40.	"	"		"
36.	14.	12.	62.	42.	"	"		"
35.	14.	12.	61.	42.	"	"		"
35.	14.	11.	60.	45.	"	"		"
36.	14.	12.	62.	44.	"	"		"
36.	14.	11.	61.	40.	"	"		"
36.	13.	11.	61.	43.	"	"		"
36.	14.	12.	62.	42.	"	"		"
36.	13.	12.	61.	44.	"	"		"
35.	14.	13.	62.	37.	Italy?	"		"
35.	14.	12.	59.	34.	"	"		"

				mm.		
36.	14.	13.	63.	37.	Italy? (Bryn Mawr Mus.)	E.A.A.
36.	14.	12.	62.	36.	" "	"
36.	14.	13.	63.	36.	" "	"
35.	13.	12.	60.	36.	" "	"
36.	13.	12.	61.	37.	Naples:	"
35.	14.	11.	60.	37.	" "	"
37.	13.	13.	63.	39.	" "	"
37.	13.	12.	62.	37.	" "	"
38.	13.	13.	64.	36.	" "	"
37.	14.	12.	63.	43.	" "	"
35.	13.	12.	60.	40.	" "	"
36.	13.	13.	62.	38.	" "	"
36.	13.	12.	61.	50.	" "	"
35.	14.	11.	60.	34.	Naples?	"
36.	13.	15.	64.	53.	{ Chesapeake, Ft. Monroe (J. H. U. Mus.)	
					{ E.A.A.	
36.	13.	13.*	62.*	51.	{ Chesapeake, Ft. Monroe (J. H. U. Mus.)	
					{ E.A.A.	
36.	13.	12.	61.	28.	{ Chesapeake, ————— (J. H. U. Mus.)	
					{ E.A.A.	
37.	13.	11.	61.	34.	Chesapeake, Willoughby Sandspit. E.A.A.	
36.	16.	7.	59.	20.	{ Chesapeake: 4 m. East Sewell's Point	
					{ (Smithsonian Mus.) E.A.A.	
33.	14.?	12.?	59.	40.	Ceylon (Smith. Mus.) E.A.A.	
35.6	13.6	11.8	61.	38.4	Average.	
36.	14.	12.	61.	37.	Most frequent.	

*Branchiostoma caribæum.*

				mm.		
37.	14.	9.	60.	21-51.	{ St. Thomas and Rio de Janeiro: Sundevall (8).	
37.	14.	9.	60.			
37.	13.	9.	59.		{ Botafago, Janeiro and Mouth of La Plata: Guenther (10).	
36.	13.	9.	58.	42.	{ Florida, St. Martin's Reef (Smith. Mus.)	
					{ E.A.A.	
34.	15.	9.	58.	32.	Gulf of Mexico (Smith. Mus.) E.A.A.	
36.	15.	8.	59.	31.	" " "	
36.	14.	9.	59.	45.	{ Florida, Port Tampa (J. H. U. Mus.)	
					{ E.A.A.	
35.	14.	9.	58.		{ Florida, Port Tampa (J. H. U. Mus.)	
					{ E.A.A.	
36.	15.	8.	59.	43.	{ Florida, Port Tampa (J. H. U. Mus.)	
					{ E.A.A.	
35.	15.	10.	60.	45.	{ Florida, Port Tampa (J. H. U. Mus.)	
					{ E.A.A.	
36.	15.	9.	60.	38.	23 r-22 l gonads (J. H. U. Mus.) E.A.A.	
35.	14.	8.	57.	30.	" "	
35.	14.	9.	58.	46.	26 r-26 l " "	
36.	14.	9.	59.	43.	26 r-26 l " "	
35.	14.	9.	58.	40.	27 r-24 l " "	
35.	14.	9.	58.	43.	26 r-26 l " "	
35.	14.	9.	58.	30.	24 r-23 l " "	

32.*	15.	10.	57.		} Florida, Port Tampa (J. H. U. Mus.) Knower.
32.*	15.	10.	57.		
35.	17.	7.	59.		
33.	12.	9.	54.	8.5	} Florida, Port Tampa (J. H. U. Mus.) Knower.
27.*	12.	9.	48.	8.†	
36.	12.	9.	57.	13.	
					} Jamaica, Kingston (J. H. U.) E.A.A. " " " "
34.8	14.	8.9	57.8	33.6	Average.
35.	14.	9.	58.	43.	Most frequent.

*Branchiostoma Belcheri.*

37.	14.	13.	64.	Borneo	: Guenther (10).
37.	14.	14.	65.	Prince of Wales Islands:	Guenther (10).
37.	14.	13.5	64.5		

*Branchiostoma cultellum.*

mm.					
32.	10.	10.	52.		Thursday Island: Guenther (10).
31.	11.	10.	52.	13-23.	Moreton Bay: Peters (11).
31.5	10.5	10.	52.		

*Branchiostoma Californiense.*

44.	16.	9.	69.	57.	} California, San Diego (Cooper's type, Smith. Mus.) E.A.A.
44.	13.	9.	66.	70.	
45.	15.	8.	68.	70.	} California, San Diego (Smith. Mus.) E.A.A.
44.	16.	9.	69.	68.	
43.*	16.	9.	68.+	70.	} California, San Diego (Smith. Mus.) E.A.A.
42.	16.	8.	64.	65.	
43.	16.	8.	67.	57.	} California, San Diego (Smith. Mus.) E.A.A.
43.8	15.4	8.5	67.3	65.3	
44.	16.	9.	68.	70.	Most frequent.

*Branchiostoma bassanum.*

44.	13.	18.	75.	Bass Straits: Günther (10).
43.	15.	17.	75.	" " "
45.	14.	17.	76.	" " "
44.	14.	17.3	75.3	Average.

*Branchiostoma elongatum.*

49. 18. 12. 79. 39-60. Peru, Chinchaoarna: Sundevall (7 and 8)

*Asymmetron lucayanum.*

				mm.				
43.	8.	14.	65.	12.5	Bahamas, Bemini (J. H. U. Mus.)	E. A. A.		
45.	9.	12.	66.	12.5	"	"	"	"
44.	9.	11.	64.	12.	"	"	"	"
44.	9.	13.	66.	12.5	"	"	"	"
44.	9.	13.	66.	10.	"	"	"	"
43.	9.	12.	64.	11.	"	"	"	"
42.	8.	12.	62.	10.	"	"	"	"
45.	8.	13.	66.	13.	"	"	"	"
43.	9.	14.	66.	13.	"	"	"	"
42.	9.	13.	65.	9.	"	"	"	"
44.	9.	12.	65.		"	"	"	"
44.	8.	14.	66.	12.5	"	"	"	"
44.	8.	13.	65.	12.	"	"	"	"
43.	9.	13.	65.	7.5	"	"	"	"
46.	9.	13.	68.	12.5	"	"	"	"
44.	9.	12.	65.	13.	"	"	"	"
45.	8.	13.	66.	14.	"	"	"	"
43.	9.	12.	64.	14.5	"	"	"	"
44.	9.	13.	66.	14.5	"	"	"	"
43.	9.	12.	64.	14.	} dug.	"	"	"
44.	9.	13.	65.	16.		"	"	"
46.	9.	13.	68.	14.		"	"	"
43.8	8.7	12.7	65.3	12.4	Average.			
44.	9.	13.	66.	13.	Most frequent.			

## APPENDIX II.

*Catalogue of Specimens of Amphioxus in the Smithsonian Museum, with numbers and names as there attached.*

- (1): 39380. 242. *Amphioxus lanceolatus*. One small specimen from St. Martin's Reef, Florida. Jeff. F. Moser.
- (2). 43555-8. *Branchiostoma caribæum*. 18 spec. obtained by U. S. F. C. Schooner Grampus, dredging at stations 5064, 5068, 5066, 5111, in 1889.
- (3). 27763. *Amphioxus lanceolatus*. About 50 small spec. obtained by Dr. Bessels 4 miles east of Sewell's Point, Virginia (Chesapeake).

- (4). 4372. 244. *Branchiostoma lanceolatum*. 21 very large specimens from San Diego, California. L. C. Bragg.
- (5). 39646. 242. *Branchiostoma lanceolatum*. 2 spec. (one macerated) from San Diego, California. H. Hembhill.
- (6). 8407. 244. *Branchiostoma Californiensis*. One specimen from San Diego, California. Cooper.
- (7). 23020. 242. *Branchiostoma lanceolatum*. 3 spec. from Stavanger, Norway. R. Collett.
- (8). 22083. 242. *Branchiostoma lanceolatum*. 2 spec. from Stavanger, Norway. R. Collett.
- (9). 34003. 244. *Amphioxus*. Five soft specimens from Ceylon. Dr. Francis Day.

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## EXPLANATION OF PLATES.

All the figures are reduced from camera lucida drawings of *Asymmetron lucayanum*.

## PLATE XIII.

Figure 1. Right side of an adult having  $45 \cdot 8 \cdot 14 = 67$  myotomes; reduced to  $\frac{1}{3}$  the diameter of the original drawing from the living specimen.

Figure 2. Left side of the same specimen; from a drawing made a day later than the above.

Figure 3. Left side of a preserved immature specimen having  $43 \cdot 8 \cdot 15 = 66$  myotomes and 27 gill-slits. The small ventral caecum is shown at c.

Figure 4. Left side of an opaque, preserved specimen 14 mm. long, having  $44 \cdot 8 \cdot 13 = 63$  myotomes, gill-slits from the 10th to 35th myotomes and 28 gonads extending from the 16th to the 43d myotomes. The lines *a-h* indicate the regions of the transverse sections shown in Figs. 11-15 and 21-23 of Plate 2.

Figure 5. Left side of one of the youngest larvæ. A preserved specimen 6 mm. long with 22 gill-slits and  $51 \cdot 13 = 64$  myotomes. The caecum is not yet formed.

Figure 6. Ventral view of anterior region: from an immature preserved specimen having the pre-oral hood expanded.

Figure 7. Transverse section of brain cut  $12 \mu$  posterior to its anterior tip; showing the pigment bordering this end of the ventricle.

Figure 8. A section of the same series  $40 \mu$  posterior to the tip of the brain, where the ventricle is at its widest.

Figure 9. From the same series,  $52 \mu$  posterior to tip, where the ventricle is coming rapidly to a close.

Figure 10. Left side of the anterior extremity of a mature specimen macerated in Haller's liquid. The relative positions of lymph spaces and canals are shown. The dotted line is the anterior limit of the muscle fibers of the first myotome.

## PLATE XIV.

Figure 11. Transverse section of anterior end of body near extreme tip of notochord, at line (a) Fig. 4.

Figure 12. Transverse section at anterior end of pre-oral chamber, line (b) Fig. 4: the pre-oral pit, ciliated ridge and blood vessel are shown on the animal's right, the tips of some cirri within the chamber.

Figure 13. Transverse section at the posterior part of the pre-oral chamber, line (c) Fig. 4, showing the right ciliated ridge and blood vessel of the *Räderorgan*.

Figure 14. Transverse section of the middle of the body, at (d) Fig. 4, showing the position of the ovary on the animal's right side. The pharyngeal basket and the lining of the atrium are indicated diagrammatically.

Figure 15. Transverse section at (e) Fig. 4, where the atrium is ending in a spout, the free tip of which is shown. Two post-atrioporal pouches are seen within the coelome.

Figure 16. Grouping of muscle fibers in the right and the left sub-atrial ridges of a young larva; from longitudinal, horizontal sections. The limits of a myotome are marked by crosses.

Figure 17. Optical longitudinal section of three dorsal fin-rays and fin-ray spaces, from a preserved specimen stained alive by Bismarck brown. Certain large cells at the top of each chamber and parts of two dorsal lymph canals are shown.

Figure 18. Right ciliated ridge, pre-oral pit and anterior end of pre-oral chamber seen in horizontal, longitudinal section.

Figure 19. Optical, longitudinal section of the free part of a pre-oral cirrus with its axial skeletal rod. From a preserved specimen.

Figure 20. Transverse section of the anterior union of the ventral, metapleura-like ridges bounding the edges of the pre-oral chamber.

Figure 21. Transverse just anterior to anus, at line (f) Fig. 4, showing the median fin extending down from the right towards a median position.

Figure 22. Transverse section at the anus, (g) Fig. 4, with the median fin still on the right of the animal.

Figure 23. Transverse section of the caudal process near its tip, (*h*) Fig. 4, showing existence of nerve cord and notochord, but the absence of muscles.

Figure 24. Skeleton of the pre-oral hood, somewhat flattened out. From macerations in Haller's liquid.

Figure 25. Optical, longitudinal section of the dorsal fin about the region (*g*) Fig. 4. Incipient fin-ray spaces and radiating lymph canals as seen in a preserved specimen stained by Bismarck brown when alive. Some epidermal cells containing colored spherules are shown at a higher focus.

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Fig. 1

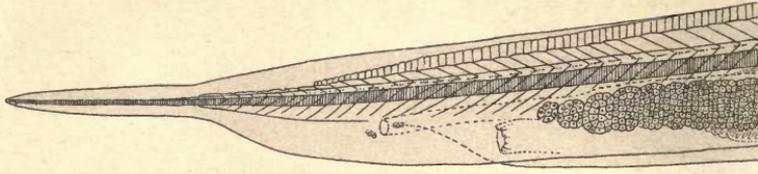


Fig. 2

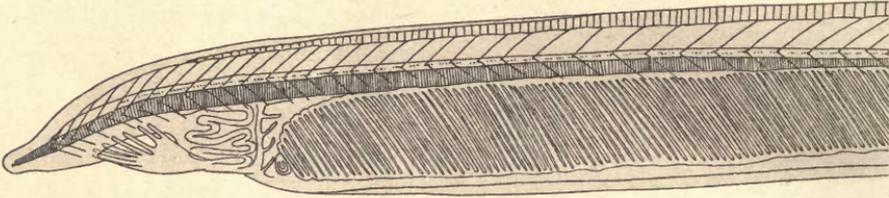


Fig. 3

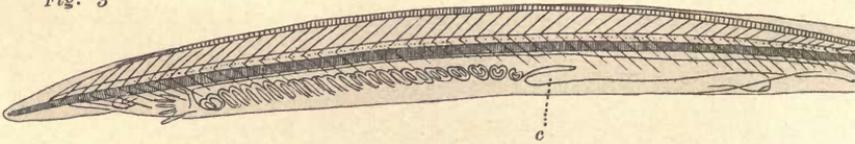


Fig. 4

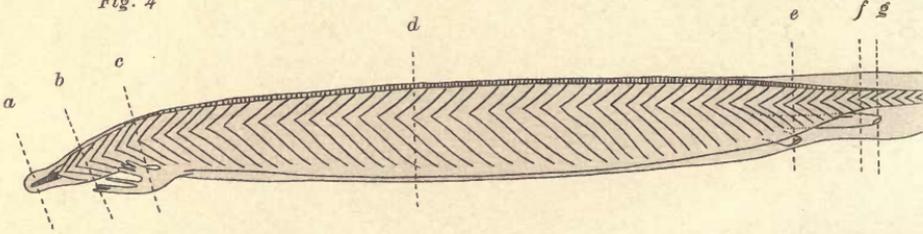
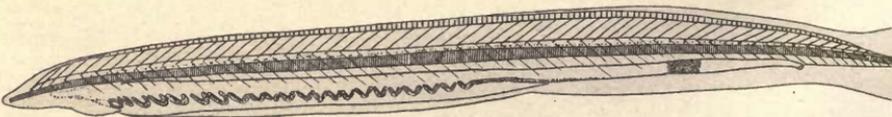


Fig. 5



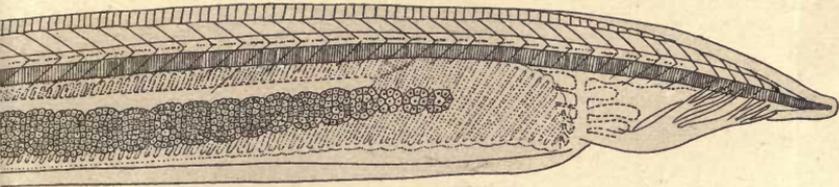


Fig 6

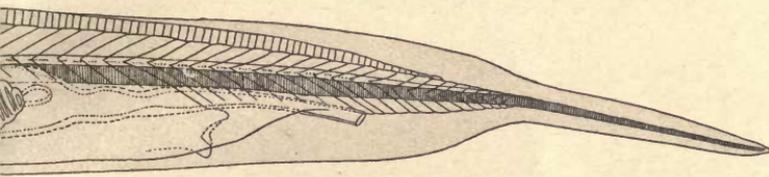


Fig. 7

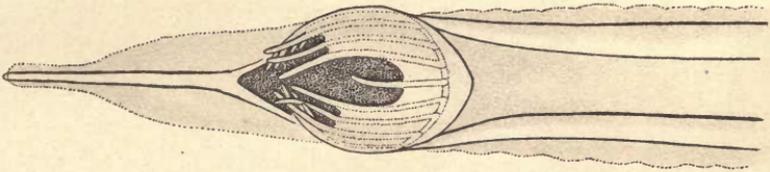


Fig. 8

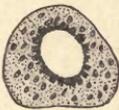


Fig. 9

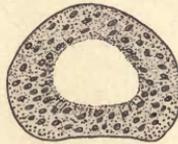
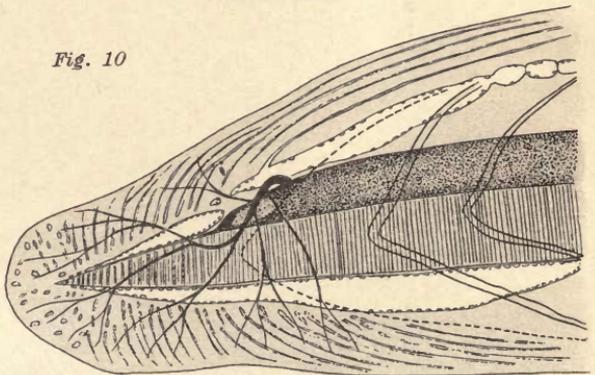
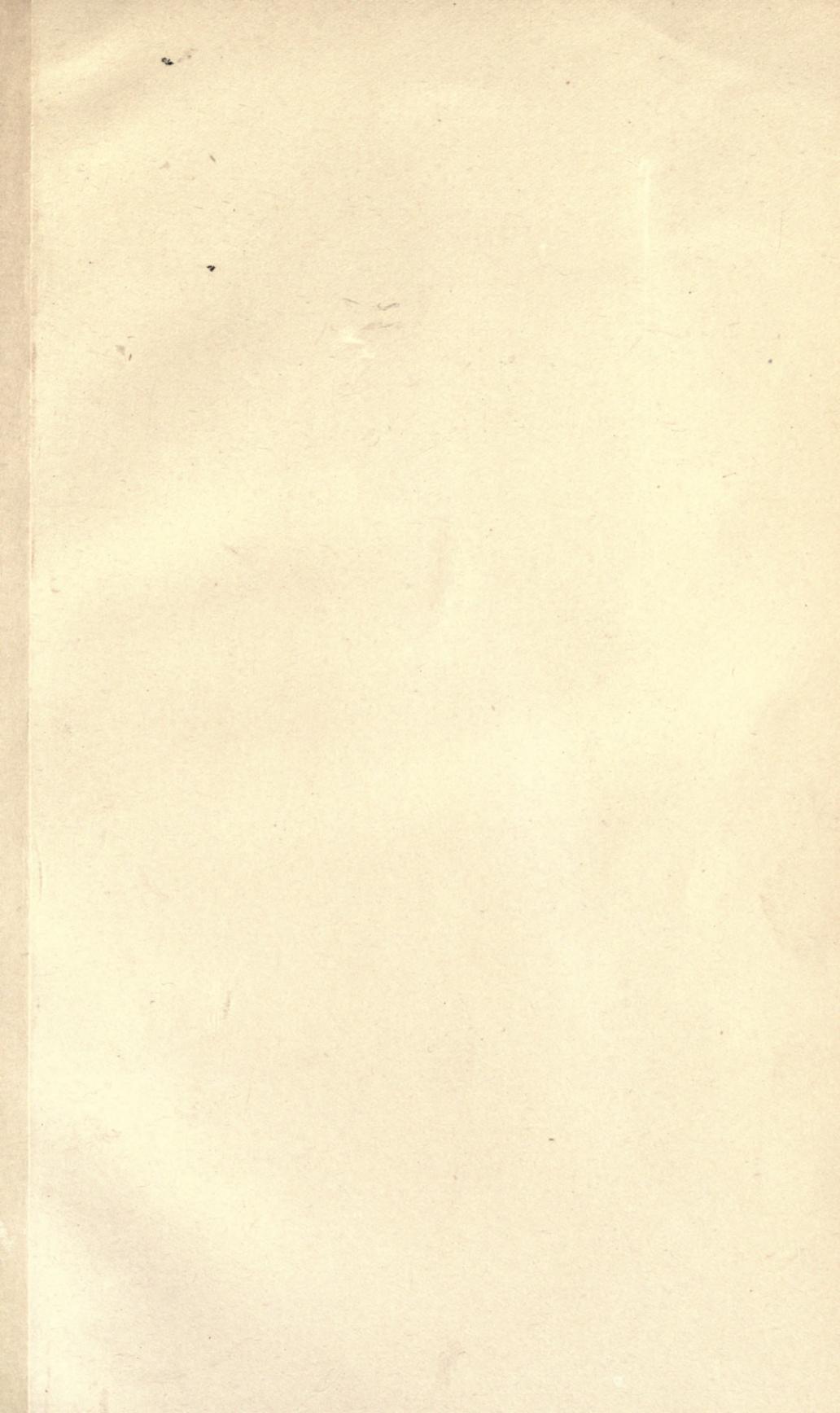


Fig. 10







STUDIES FROM BIOL. LAB.

Fig. 11



Fig. 12

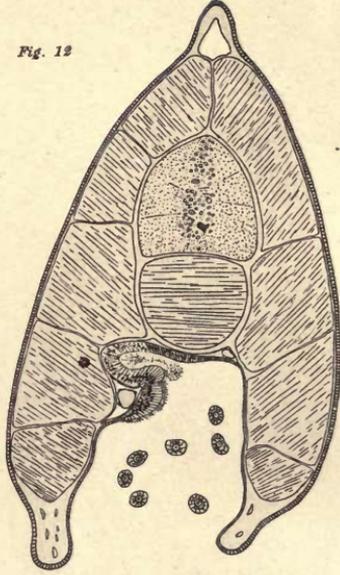


Fig. 13



Fig. 16



Fig. 17

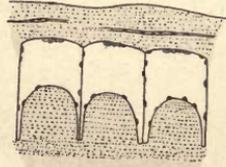


Fig. 18

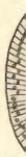


Fig. 21

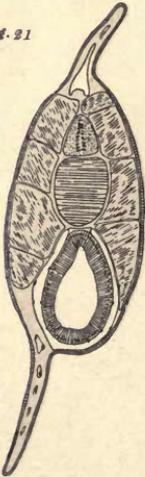


Fig. 22



Fig. 23



Fig. 14

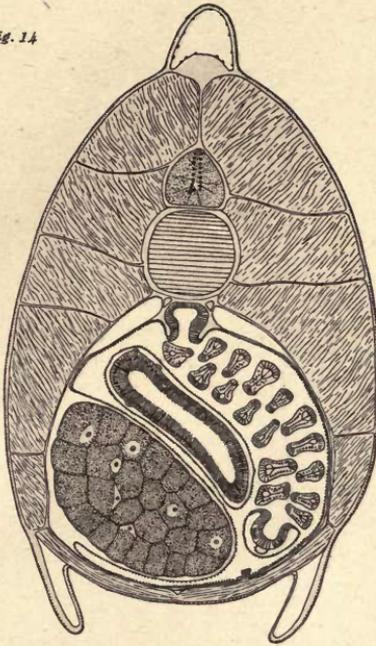


Fig. 15

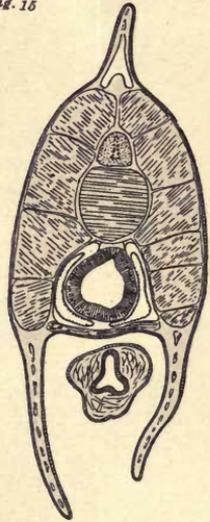


Fig. 19

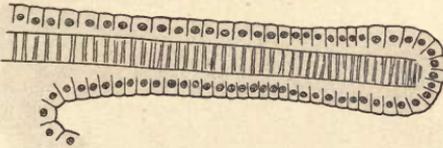


Fig. 20

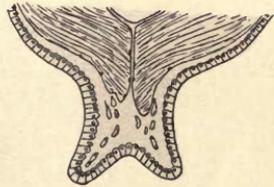
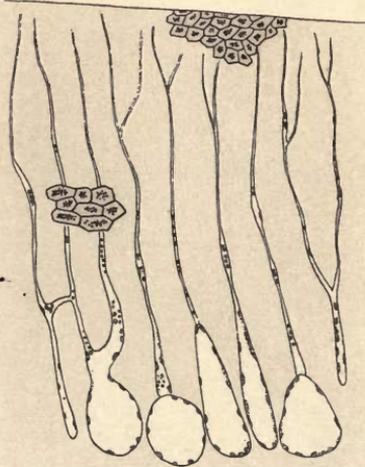
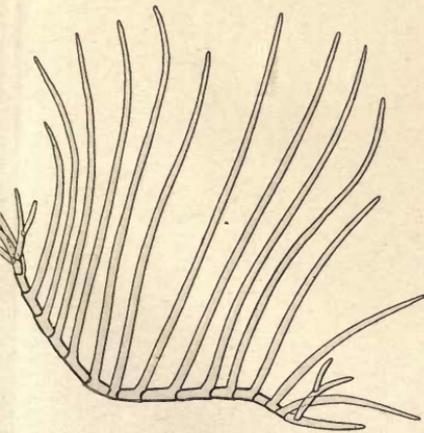


Fig. 25



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