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XXXI.—*Notes on the Cuvierian Organs of Holothuria nigra.*
By E. A. MINCHIN, B.A., Assistant in the Department of
Comparative Anatomy, Oxford.

[Plate XVII.]

THE observations here recorded were made by me in the summer of 1890, when I had the honour to occupy one of the British Association tables in the Marine Biological Laboratory at Plymouth, during the months of July, August, and September. For the greater part of the time I was engaged in studying the Gregarines of various marine animals, but especially of *Holothuria nigra*. Of these I obtained an abundance of living specimens, and so was able to observe the Cuvierian organs in the fresh and living condition. It was my intention at the time to work out fully the structure and function of these remarkable organs; but as it has been impossible for me, owing to other work, to carry out my purpose, it seemed best to publish at once the few scattered observations I was able to make.

1. *Anatomical Relations.*—The account of these organs given by Bell (1) is inaccurate in certain details, which is not to be wondered at, since he was only able to examine spirit-specimens. He states (p. 375) that the organs arise from the cloaca and that they differ from any yet described by the fact that they are closely united together into a firm bundle. Both these statements are erroneous and are due to

the fact that when the organs are placed in spirit they become at first exceedingly sticky, and adhere to one another and to everything they touch; so that in spirit-specimens perfectly misleading appearances are obtained.

If a *Holothuria nigra* be opened fresh in sea-water, it is easily seen that the Cuvierian cæca are each quite separate from one another and arise independently from the left respiratory tree (Pl. XVII. fig. 9, *c.o.* and *l.rsp.*). In the normal condition they are cylindrical, tapering to a point at their distal extremity. For the most part they are of a pure white colour, but a few are pinkish in tint. The latter are probably freshly formed as outgrowths from the respiratory tree. A healthy animal always contains an enormous number of tubes, and they take up a very large space in the body.

2. *Phænomena of Elongation.*—The most curious property of these organs is their power of elongating to a relatively enormous extent. I will first describe what is seen in the living animal.

If a healthy *Holothuria nigra* be pricked with a needle it first draws in its tentacles and ceases to move. If the stimulation be continued it slowly curls the posterior part of the body up towards the part affected. In a few moments a number of white threads are seen to emerge from the anus and to run about swiftly in all directions. At the end of each thread is a thicker portion or head (*h*, figs. 1 *a* and *b*), which is easily seen to be the cause of the movement; for the thread itself is formed continuously from it at the point *x*, and the head gets smaller and smaller during the process. When first ejected the head averages about 2 centimetres in length. Since the head produces perhaps twenty times its own length of thread or more, it rushes through the water by its own activity. One might compare the head to a rocket and the thread to the trail of sparks emitted by it. Moreover, as the head is generally slightly curved, it runs in any direction. The result is that the irritating body gets enveloped in a network of delicate but exceedingly tenacious and sticky threads. As is well known to the Plymouth fishermen, even animals as large as lobsters become so firmly entangled that they are unable to move. Meanwhile the Holothurian, if the irritation has ceased, walks quietly away, and the Cuvierian threads, as we may call them, being now firmly fixed to some foreign body, break off at their attachment to the respiratory tree. As a rule only a small portion of the tubes contained in the body are emitted at a time, and a healthy Holothurian can emit them five or six times in succes-

sion. The only object which they do not appear to adhere to is the slimy body of the *Holothurian* itself.

With regard to the cause of this elongation, all the statements known to me in the literature of the subject attribute it to one of two causes, or to a combination of them—(1) to liquid being forced into the tube, (2) to an unwinding of the spirally wound connective tissue in the walls of the tube. Semper (7, p. 139) examined *Bohadschia marmorata*, in which ejection of the Cuvierian organs was not observed, but in which they showed power of elongation. A freshly caught animal was quickly cut open, so that the viscera came out of the wound, without the intestine breaking away from the cloaca. When the cloaca was stimulated at the point where the lowest Cuvierian organs were fixed they all shortened themselves by about a half. In the same way they elongated voluntarily, and became then very long and at the same time thicker. Hence the author concluded that they must possess a contractility of their own and that elongation could only be brought about by an influx of blood. No blood-vessels, however, were observed, and it is quite certain that none exist.

Hérouard (3) attributes their elongation entirely to water being forced in from the cloaca. Having studied *Holothuria catanensis*, he describes them as hollow tubes attached to a dilatation of the respiratory tree and provided with sphincters at their orifices. When the water which is contained in the dilatation of the respiratory tree is compressed by the contraction of its walls it penetrates into the tubes. This can be shown by ligaturing the anus and cutting the body-wall, so as to expose the Cuvierian organs. Certain of the tubes can then be seen to dilate gradually from the base upwards, until equilibrium of pressure is restored. When set free into the surrounding water they dilate by a process analogous to that described above.

Jourdan (4, pp. 49, 50), on the other hand, attributes the whole process (in *H. impatiens*) to the stretching and unrolling of the bundles of connective tissue, commencing at the basilar region. The muscular layers seem to break up and let the connective tissue loose. The tubes are only sticky when ejected. Cuénot (2) steers a middle course, and attributes their elongation within the body (also of *H. impatiens*) and ejection to pressure of liquid from the cloaca, with Hérouard; but after they are ejected the spirally wound muscles and connective tissue unroll, so that the tube elongates, and at the same time the external epithelium changes

into a sticky matter. Bell (1, p. 565), like Jourdan, attributes the elongation of the organs in our form to the unrolling of a spiral thread of connective tissue.

However well this explanation of the elongation as due to the pressure of liquid may apply to Semper's *Bohadschia*, and possibly also to *H. catanensis*, it is totally inapplicable to *H. nigra*, and I believe also to *H. impatiens*. This is shown by the fact that in *H. nigra* an isolated Cuvierian organ can be made to elongate by itself. If in a living animal one of the Cuvierian organs be pricked or otherwise stimulated it will, as Jourdan (4, p. 43) has already observed, go off of itself and elongate in the same manner as those normally thrown out by the animal. My experience in trying to preserve these organs for histology shows this still plainer. Wishing to preserve material for a study of the minute structure of these organs, I carefully removed from freshly opened animals the portion of the respiratory tree to which they were attached and transferred the organs so removed to various preserving liquids. In the process of removal great care was necessary, as the organs, if shaken or pricked, were liable to go off. But I found that in very few preserving fluids was it possible to preserve the organs in their normal form. For instance, the instant they were placed in a saturated solution of corrosive sublimate every single organ commenced at once to elongate rapidly, and it was some seconds before the killing action of the fluid overcame the tendency to elongate. The same result came about whether the solution was warm or cold, and also in Kleinenberg's picric, in corrosive and acetic mixtures, and in various strengths of chromic. The latter reagent was most useless of all, as it was a long time before the activity of the tubes was overcome. After trying a great many things I was only able to preserve the organs in their normal condition in 1 per cent. osmic acid and in a mixture of corrosive sublimate and osmic acid. Jourdan (4, p. 43) mentions some similar experiences.

It is obvious that here there can be no question whatever of the elongation being due to pressure of fluid. The Cuvierian tubes each possess a sort of automatic power of rapidly elongating, the explanation of which must be sought for in the structure of the organs themselves, and which therefore I am not able at present to give. Hence I mistrust Hérouard's experiment, for in *Holothuria nigra* the organs can be made to elongate whether the cloaca be ligatured or not. Nevertheless it would seem, from the combined evidence of Semper and Hérouard, that in some forms the Cuvierian organs are capable of dilating and contracting in response to

pressure of fluid from the cloaca; but that is certainly not the case in *Holothuria nigra*. In this form the organs elongate entirely of themselves in response to stimuli, which may be applied to the organs themselves or to the peripheral sense-organs of the animal, which is the normal process. Moreover, when once the organ has elongated it cannot be again retracted, but is cast off, a constant supply of such organs being kept up by outgrowths from the respiratory tree. Examination of isolated organs shows that the elongation and the formation of the sticky thread commence at the base, and that the "head" which rushes about so wildly in the water is the remains of the original Cuvierian organ. In normal healthy cases the head becomes entirely used up in the formation of the sticky thread; but often its power slackens and stops while a great deal is still unused. As the energy gets less the thread produced is not straight, but wavy, as in fig. 1 *b*. This can well be seen by putting the organs in corrosive sublimate or Kleinenberg's picric, when the wavy appearance is produced as the reagent gradually overcomes the power of elongation.

To resume, the following appears to be the normal process. Irritation of the skin of the Holothurian is transmitted ultimately, along what nerve-paths I cannot say, to the base of Cuvierian organs. Certain of these commence to elongate with great rapidity, in what way is not clear—most probably as described by Jourdan, but certainly not as the result of pressure of fluid. As a result they soon find their way out of the body and continue to elongate outside, being generally directed by the animal, so that some of the tubes are almost certain to come in contact with, and stick to, the irritating body or foe. After this they break off at their point of attachment to the respiratory tree, and new organs grow to replace them.

The next point to examine is the

3. *Ejection of the Cuvierian Organs*.—The problem here may be briefly stated as follows. The Cuvierian organs are attached to the respiratory tree and lie entirely in the body-cavity, with their free ends pointing away from the anus. When ejected they emerge from the anus with the free end foremost. To do this it is obvious they must in some way pass through the wall of the gut.

According to Semper (7) they come through an opening in the wall of the cloaca with their free end foremost. It is left an open question whether the opening they pass through is pre-formed or arises by dehiscence at the time the organs are thrown out. Ludwig (5, p. 401) considers that our anatomical knowledge

points to the latter view. Hérouard seems to agree with Semper, for he states that the whole process is the first act of expulsion of the digestive tract, and that when the wall of the cloaca is torn the Cuvierian organs, being nearest to it, are thrown out.

On the other hand, Cuénot (2, p. 371) has a more complicated theory. He says:—"As Hérouard has shown, the water enclosed in the cloaca penetrates into the basilar vesicles [which in *Holothuria nigra* do not exist], and from thence gradually into the tubes, which dilate little by little, this dilatation coinciding with the contraction of the irritated animal. The pressure in the interior of the body increases; the tubes tend to be rejected to the exterior; at this moment, it is a point which escapes direct observation, they break at their base of insertion on the basilar vesicle, which presents probably a *locus minoris resistentie*, pass through it and the cloaca, and are rejected by the anal orifice. The basilar vesicle then contracts, the strong muscular walls apply themselves to one another, so interrupting all communication between the *cœlome* and the exterior."

If I have understood this description properly I gather that the Cuvierian organs break off completely at their bases of insertion and then pass bodily through the hole thus made. I further infer from it that the Cuvierian organs should emerge with their bases foremost. All these statements are negatived by the facts observed in *Holothuria nigra*. The organs do not emerge with their bases foremost and they do not break off from their attachment until they have spent themselves and are firmly fixed to some object, when they are violently broken away from their attachments to the respiratory tree by the animal's movements.

I have had many opportunities of studying the method in which these organs are rejected, and can completely confirm Semper's account. While opening *Holothurians* to obtain gregarines a great number of Cuvierian organs were always ejected by them, and in such specimens an aperture in the dorsal wall of the cloaca could always be found, and very often Cuvierian organs would be found in the aperture. After many attempts I was able to make and draw the dissection shown in Plate XVII. fig. 9, in the following manner:—A fresh *Holothurian* being obtained, it was placed on a sheet of cork and made to eject some Cuvierian organs. Then with a sharp knife the body was opened on the right side by a longitudinal cut and the integument pinned out right and left. Weak spirit was then poured on to the surface of the water, in order to subdue the action of the powerful body-

muscles, which tend by their contraction to curl up the cut integument and pull out the pins. When the muscles were thus stupefied the dissection was carefully proceeded with, and when finished placed in strong spirit. In this manner the result was obtained shown on Plate XVII. fig. 9. The Cuvierian organs (*c.o.*) are seen lying in a great mass attached to the left respiratory tree (*l.rsp.*). Some of them (*c.o.*) have detached themselves from the main body and have passed through an opening in the dorsal wall of the cloaca and out through the anus to the exterior.

To confirm the results so obtained I employed another method. In the store of the Marine Biological Association there were a great number of specimens of *Holothuria nigra* preserved in spirit, many of which had in dying partially ejected their Cuvierian organs and were to be seen with a bunch of these organs protruding from the anus. Selecting such a specimen, I cut a series of thick sections through the cloacal region with the hand, using a sharp razor and arranging the sections in order. I obtained nine such sections through the cloaca and the base of the respiratory trees, and in figs. 2-8 on Plate XVII. seven of them are diagrammatically represented.

In the first section (fig. 2) the cloaca (*cl.*) is seen filled with Cuvierian organs (*c.o.*) and attached to the body-wall (*int.*) by radiating muscles. The five longitudinal muscles are just visible. The third and fourth sections (figs. 3 and 4) are similar but larger, and the number of Cuvierian organs is greater. In the fifth section (fig. 5) the Cuvierian organs are now close up against the dorsal wall of the cloaca; a few appear also entangled in the cloacal muscles to the left and ventrally. In the sixth section (fig. 6) the wall of the cloaca is wanting on the dorsal side, and the gap is filled by Cuvierian organs which are oval in section, showing that they are cut obliquely and are hence passing downwards and backwards. The seventh section (fig. 7) passes through the spot where the cloaca gives off a branch, the left respiratory tree (*l.rsp.*), to which the Cuvierian organs are beginning to be attached. It is noteworthy that dorsally some of the Cuvierian organs are cut twice in the section, and can be seen in fact to bend backwards, curving slightly to the right. In the eighth section (fig. 8) the respiratory tree is quite distinct from the rectum, which is placed more ventrally and attached by a mesentery between the median and right ventral longitudinal muscles. A great number of Cuvierian organs are attached to the respiratory tree, and a similar curving back can be observed in some of them to that pointed out in

the preceding section. The ninth section (not figured) was almost precisely similar to the eighth. In all the sections the delicate right respiratory tree has been lost, having been probably torn away by the razor.

The conclusion I draw from these preparations is as follows:—The Cuvierian organs, after commencing to elongate within the body in the manner described above, are in some way directed to the dorsal wall of the cloaca, which they break through. It may be that the powerful contraction of the body-walls, compressing the liquid contained in the celome, causes the wall of the body-cavity to break at its weakest point, which is presumably the dorsal wall of the cloaca, through which the organs are then forced. Bell has also observed Cuvierian organs in the cloaca of one of his specimens of this form (1, p. 375). They thus reach the anus, from which they issue point foremost, to elongate in the surrounding water. I have frequently found that pieces of the cloacal wall, recognizable by their radiating muscles, are ejected with the organs, and have no doubt that the aperture in the cloaca through which they escape is temporary. An interesting experiment would be to stimulate a Holothurian to eject its Cuvierian organs after first ligaturing the anus, so that they would be unable to escape by the usual path, and would be obliged either to find some other mode of exit or remain within the body-cavity.

4. *Function of the Cuvierian Organs.*—The greater number of authors consider them as organs of defence. Peach (6, p. 173) described in 1845 how the animal “is extremely irritable, and on being touched or disturbed throws out a bunch of white tapered threads about an inch in length and one eighth in thickness; these soon become attenuated, either by the agitation of the water or the coming into contact with something; they stick to everything they touch, and from that the animals are called ‘cotton-spinners’ by the fishermen.” Ludwig, in his magnificent work ‘*Echino-dermata*’ (5, p. 401 *et seq.*), sums up the views of different authors and inclines to the view that they are organs of defence, though a little uncertain as to whether that is their primitive function, owing to the statements of Hérouard. Cuénot also argues strongly that they are a means of defence (2, p. 372 *et seq.*). Hérouard alone of recent writers expresses his views to the contrary in the following words (3, p. 673):—“Les tubes de Cuvier sont considérés actuellement comme étant des organes de défense. Partisans des causes finales, les auteurs ont attribué à ces organes de telles fonctions, parce qu’ils adhèrent remarquablement aux objets qui les

touchent. L'observation des faits contredit cette manière de voir. Les tubes de Cuvier sont simplement des organes arborescents transformés, éminemment extensibles et contractiles, adaptés à des fonctions glandulaires spéciales."

At the risk of being considered by M. Hérourard as a "partisan of final causes," I must express my opinion that in the Cuvierian organs we have to do with organs of defence. I do not hold this belief because these organs are remarkably sticky, any more than I believe that a pistol is a weapon of defence because it is hollow; but because I have seen them in action, which M. Hérourard does not seem to have done. After denying them a defensive function, M. Hérourard terms them glandular organs; but, as Ludwig (5) remarks, it is difficult to reconcile this idea with their structure, since the glandular layer is separated from the lumen by connective tissue. Moreover, the ejection of these organs in *Holothuria nigra* is in no way a pathological process, as M. Hérourard supposes, but a perfectly normal act. There can be no reasonable doubt, it appears to me, that in the species here under consideration the Cuvierian organs function only as weapons of defence*. Nevertheless it is quite possible that they may not have this function universally in the group of Holothurians and may have primitively served some other function. In fact the Cuvierian organs of *Bohadschia marmorata*, as described by Semper (7, p. 139), can hardly be used for defence in the same way as those here described.

In considering the question it should be borne in mind that, while these organs may be highly developed in one Holothurian, they may be altogether wanting in another closely allied form. Thus they are quite wanting in *Holothuria tubulosa*, which is a close ally of our form. This fact seems to me to go against the idea that they represent in any way a morphological rudiment, *i. e.* an organ which formerly had some other very different function. Their position and mode of growth shows them to be simply outgrowths of the respiratory trees. In some Holothurians they are, as is well known, racemose or "traubenförmig." In such forms therefore they would appear to be less differentiated from the remainder of the respiratory tree than in forms like *Holothuria nigra*, where they are highly specialized. These facts

* In Naples I was able to observe the large *Holothuria sanctori*, which emits its organs in the same manner as *H. nigra*. The Cuvierian organs are smaller in this form than in *H. nigra*, and, owing to the great thickness and muscular power of the integument, they are more difficult to study in the living animal.

point to the Cuvierian organs being simply, as Hérourard supposes, a modified portion of the respiratory tree.

The habit possessed by so many Holothurians of ejecting the intestines when stimulated is too well known to require description. This evisceration seems to be almost a normal habit, since viscera of Holothurians are frequently fished up by fishermen. At Plymouth I often offered ovaries and other portions of the viscera of Holothurians to anemones and other animals in my tank. I did not keep any careful record of my experiments; but I can only say that the viscera were often immediately swallowed by anemones or seized hold of by other animals, but always rejected again in a few minutes. The impression I obtained was that these viscera were extremely unpalatable to the majority of animals. I think this idea, if carried out by further experiments, would give us some clue as to the use of this curious habit. If any rapacious dogfish or other animal attacked a Holothurian and caused it to eject its viscera, it would in all probability, after tasting them, never repeat the experiment*. The Holothurian, on the other hand, appears to suffer but little harm from its evisceration, since it is certain that the whole of the viscera can be regenerated under normal conditions. Nevertheless the habit of throwing out all the viscera must be an exceedingly expensive one, and the view I take of the Cuvierian organs is that they are simply *a portion of the viscera specially modified for ejection*. Their position, near the base of the respiratory tree, is one where they would be the first organs to be ejected, as Hérourard has remarked. Their anatomical relations show them, as stated above, to be only specially modified portions of the respiratory tree. Possibly they at first retained their respiratory function and were only distinguished by the possession of an external layer of mucous secreting gland-cells, which increased their unpalatability. At first merely passively offensive, they ultimately by further modification became aggressively so, as in *Holothuria nigra*. The steps from such an hypothetical initial stage to the highly modified organs of the latter form it is not in my power to trace. Before that could be done more information is necessary as to their structure and the exact method in which their elongation is brought about in this and other forms.

* Here one may draw attention to the intensely bright coloration of the internal organs of Holothurians, which are certainly exceedingly conspicuous objects when ejected. May not this probably be a case to be brought under the heading of "warning coloration"?

The above theory of the function and origin of the Cuvierian organs is, I am well aware, an hypothesis only, and requires much more foundation before it can be accepted. Nevertheless, on the principle that the test of an hypothesis is its power of explaining facts, I venture to bring it forward as a suggestion as to the true nature and homologies of these very curious and interesting organs.

Oxford,
July 1892.

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EXPLANATION OF PLATE XVII.

Figs. 1 a & b. Two Cuvierian organs as seen during the process of elongation and production of the sticky thread. *h*, “head” or remains of the original organ, which is being used up to form the thread (*thr.*) at the point *x*. *1 b* is drawn from an organ which had gone off on being placed in Kleinenberg's picric. Natural size.

Figs. 2-8. Seven sections taken from a series of nine thick sections through the posterior end of a *Holothurian* which had commenced to eject its Cuvierian organs on being placed bodily in spirit. Represented somewhat diagrammatically and slightly enlarged. Lettering for all the figures:—*int.*, integument; *l.m.*, longitudinal muscles; *cl.*, cloaca; *c.o.*, Cuvierian organs; *l.rsp.*, left respiratory tree; *r.*, rectum.

Fig. 9 represents the posterior part of a specimen of *Holothuria nigra*, opened while in the act of rejecting some of its Cuvierian

organs. The body was opened a little to the right of the mid-dorsal line. In the middle are seen the three longitudinal muscles of the trivium (*tr.*). On the right is the right muscle of the bivium (*r.br.*), and on the left is the left one (*l.br.*). The Cuvierian organs (*c.o.*) are seen forming a great mass attached to the left respiratory tree (*l.rsp.*), which is attached by a mesentery to the rectum (*r.*). Some of the Cuvierian organs (*c.o.*) are seen passing through an aperture in the wall of the cloaca (*cl.*) and protruding from the anus (*an.*). On the right is seen the right respiratory tree (*r.rsp.*), the extremity of which has been loosened from its attachments and hangs over the side of the dissection.

XXXII.—*Descriptions of some new Species of African Lepidoptera.* By W. J. HOLLAND, Ph.D., F.E.S., Pittsburgh, U.S.A.

RHOPALOCERA.

Nymphalidæ, Swains.

Genus *Thaleropis*, Staudinger.

1. *Thaleropis trigona*, sp. n.

♂. Antennæ black above, brown below. Front white; eyes brown; palpi black above and whitish below; collar and thorax black, spotted with yellow. The end of the abdomen is yellow above and tipped with black. The underside of the body is bluish grey. The anterior wings are strongly arched on costa, produced and rounded at apex, strongly excavated upon the outer margin, with the outer angle scarcely rounded and the inner margin straight. The costa of the posterior wing is one fourth shorter than the inner margin of the anterior wing; the outer margin is very convex and produced at the anal angle in the form of a short and broad tail. The markings of the upper surface resemble those of *T. kinugnana*, Grose Smith, but the macular bands of yellow traversing the median area of both wings differ from those of all other species hitherto described in that they are subtriangular in form, increasing in width from the costal region towards the inner margins of the wings; and there are no subcostal yellow spots as in *T. kinugnana* and *T. uhelda*. The markings of the underside are much as in *T. (Pseudacrea) uhelda*, Mabille, but the base of the posterior wing is umber and the median transverse band of this wing