XIII. *On the Anatomy of the Genus Appendicularia, with the Description of a new Form.*
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(Plate XLVII.)

Read December 3rd, 1868.

THE structure and habits of *Appendicularia* have for some time attracted the attention of biologists both at home and abroad; but few new facts bearing upon its anatomy have been added to English science since the observations of Professor Huxley, in the Philosophical Transactions of 1851.

My attention was first directed to these interesting little animals by the capture of a single specimen between Gibraltar and Malta; and the paper just alluded to was found of the greatest assistance in deciphering the particulars of its anatomy. As many specimens have since been from time to time obtained, some fresh points worthy of notice have presented themselves. The disjointed character of the following remarks must be accounted for by the peculiar difficulties of study at sea, the minute size and transparency of the *Appendiculariæ*, their extreme activity while alive, and the almost instantaneous disorganization of their delicate tissues in the moment of death. An average specimen carefully removed from a glass of sea-water, by the aid of a pipette, and placed in a cell a quarter of an inch wide and a line deep, will live about ten minutes. The rapid vertical undulations of its appendix, only intermitting for an instant, until the shrivelling of its external tunic, and occasionally the exfoliation of a layer of the same tunic from the body, immediately precede dissolution.

The forms of *Appendicularia* which have come under my notice may be conveniently divided into the short- and the long-bodied, which seem respectively to represent the Branchial and Intestinal groups of compound Tunicaries. The former presents an elliptically shaped body, especially when surrounded by an unshrunk external tunic, and an appendix formed on the plan common to all *Appendiculariæ*, but slightly varying in outline in different specimens, attached hæmally with its plane horizontal to that of the body.

The Atlantic and Mediterranean members of this group, which includes the *A. cophocerca* and *A. cærulescens* of Gegenbaur, as well as the new form described below, vary in length from the thirtieth to the third of an inch, and are therefore rather smaller than those described by Professor Huxley in the paper before referred to. The external tunic is always conspicuously developed; in some specimens it presents two tubular processes projecting from the body in the neighbourhood of the ciliated respiratory openings. When such processes exist, they, together with a delicate layer of the tunic, are invariably shed before the death of the animal. The posterior lip of the branchial orifice is occasionally furnished with minute tentacula; and imbedded in the substance of the lip, a short

distance below the orifice, two clear circular cells lie symmetrically on either side of the endostyle (figs. 3 and 4, H). The heart lies between the stomach and the base of the appendix, and, contracting vermicularly, propels the blood at the rate of about 250 pulsations a minute, in a broad stream over the surface of the testis, and in a still pulsating current through the appendix, down one side and up the other, in canals lying on either side of the muscular plane (figs. 1, 2, 3, and 5, A):

The nervous systems of both groups of *Appendiculariæ* present such similarities of structure and development, that a single description will suffice for both. The ganglion (figs. 1, 2, 3, 4, and 5, L) is imbedded in a depression in the anterior paries of the branchial sac; a horseshoe-shaped arc springs from its upper part, and gives origin to a pair of branches which encircle the orifice and supply its sphincter. Right and left, branches pass from the lower extremity of the ganglion obliquely round the branchial chamber to the ciliated respiratory openings. The main trunk descends anterior to the pharynx, curves round between the lobes of the stomach, and divides into two delicate nerves, which pass along the appendix on either side of the central axis inside the muscular bands, and exhibit alternate dilatations, increasing in size, at intervals which lessen, as they approach the tip (figs. 1, 2, 3, and 5, C). The muscular tissue supplied by these nerves is very finely and distinctly striated, with minute lacunæ between its fibres, its general appearance being not unlike the muscular structure of the human heart.

In the second group of *Appendiculariæ*, the length of the body is increased by the separation of the branchial chamber from the viscera by a stalk of considerable length.

At the oral extremity a jug-like dilatation of the internal tunic contains the branchial sac, with its two postero-lateral ciliated respiratory openings, a minute and shortened endostyle between and above these openings, and in the anterior wall a ganglion, with an otolithe attached to its left side.

The inhalant orifice possesses a broad sphincter, and is guarded by six active tentacula with bulbous bases.

A closely ciliated pharyngeal tube forms the greater part of the stalk, and leads from the lower part of the branchial sac to the stomach. A second dilatation of the inner tunic, occupying the centre of the body, contains the heart and intestinal apparatus. The rectum terminates posteriorly and rather on the right side, close above the point of attachment of the appendix. This organ projects from the centre of the body at a considerable angle, and is shaped like a cordate leaf, a peduncle and midrib being represented by the central axis, surrounded by muscular fibres spread out on either side in flat longitudinal bands. The lower half of the body is occupied by a globular mass of compressed yellow cells, and below them by a tapering ovary containing, in some specimens, upwards of 400 ova about $\frac{1}{800}$ inch in diameter.

In addition to the otolithe and oral tentacula, all the varieties of *Appendicularia* possess an organ of sense analogous to that of *Salpa* and *Doliolum*, in the form of a pear-shaped ciliated sac (figs. 1, 2, 3, J) lying to the right of and attached to the ganglion in nearly the position in which Gegenbaur has figured the unsymmetrical ciliated opening in his *A. furcata*.

I have lately captured a new short-bodied form in the warm surface-water of the

Atlantic, near the Line, and occasionally as far north as off the coast of Portugal. It can be distinguished at first glance from any of its Appendiculate brethren by the peculiar scroll-like manner in which its slender lanceolate flabellum is rolled upon itself when the animal is at rest.

When examined under a magnifying-power of about 100 diameters, the internal economy of this form is seen to differ widely, as regards its respiratory arrangements, from any of the known species. The oval half of the globular body contains a large branchial sac, with a ganglion and otolith in the usual positions in its anterior paries, but with its posterior lining-membrane folded into a gill-like structure (fig. 5, v), wide in the centre and tapering to either end, extending from the posterior lip of the branchial orifice to a point close to the insertion of the appendix, and presenting a double series of narrow transverse slits, which give the whole structure a general resemblance to the respiratory diaphragm of *Doliolum*, though on a lengthened and much more minute scale. The last curve of the intestine lies transversely across the centre of the body, above a globular ovary, and terminates on the right side in a papilla, through which the rectum opens.

The main nervous trunk, descending from the ganglion, curving round the stomach, and entering the appendix, presents no distinctive peculiarities.

In many specimens of *Appendicularia*, pear-shaped organisms have been found, attached by slender stems to various parts of the outer tunic, so like the pallio-vascular stolons of Compound Tunicaries as to suggest the existence of an ascidium at some developmental stage, and that possibly the "enigmatical 'Haus' of Mertens" might be in some way connected with such an ascidium; but further observation has convinced me that these pseudo-stolons, as well as an irregularly papillated condition of the outer coat sometimes met with, are merely parasitic growths, and that the "Haus" is an exfoliation of the tunics connected with a yet unknown vital process. Both groups of *Appendiculariæ* possess the power of forming the "Haus;" but that evolved by the long-bodied is small and so extremely delicate as only to be seen under the most favourable conditions. The following notes have therefore been principally gleaned from observations of the behaviour of members of the short-bodied group.

When the animal is about to form a "Haus," its rapid jerking movements cease, and after about a minute's rest, a transparent membrane is seen to project beyond the outline of the tunic over the upper part of the body; it soon after flexes its appendix until the tip touches the newly evolved structure, then, slowly extending it, draws the gossamer-like membranes completely over both body and appendix. If, however, the animal is disturbed during the process of evolution, it at once shakes itself free, and the structural details of the immature formation thus obtained are more distinct and compact than when fully extended; the annexed illustration (fig. 7) has therefore been sketched from a "Haus" thrown off when the tenant had just commenced to incurve its appendix. The general shape of the fully formed "Haus" may perhaps be described by comparing it to a thick-winged butterfly, the little Tunicate swimming, branchial orifice upwards, between the viscid alæ, and slowly propelling the whole mass by the undulations of its iridescent flabellum, which projects backwards between the wings. Even in a large aquarium the little animal seldom remains more than an hour in the "Haus;" a second one, as Mer-

tens observed, is sometimes formed, but is invariably more transparent and delicate than its predecessor. When the *Appendicularia* has remained long in the structure, its upper part generally contains a few oval excrementitious masses, adhering to its viscid membrane; and as such masses are less frequently met with in the "Haus" formed under observation than in that found floating tenantless in the ocean, it is probable that the animal in its natural state makes a more lengthened residence in it than might otherwise be supposed. When microscopically examined, the "Haus" is found to be a sac of extreme tenuity, with a deep longitudinal groove ending above, where the animal was attached, in a torn fissure, and pierced below in the middle line by two small openings with projecting funnel-shaped lips. On either side the sac opens into a short tube of considerable diameter, marked with parallel longitudinal ridges. The membranes of the sides of the above-mentioned fissure are the most readily seen parts of the structure; in them two sets of parallel bars cross each other at right angles, and thus form a reticulation of great beauty and regularity—so regular, indeed, as closely to resemble the markings on a micrometer (fig. 7, c). In a large "Haus" in which this structure was first observed, the areolations measured $\cdot0018$ by $\cdot0037$ of an inch. During the process of evolution the terminations of the more finely marked bars are attached to the lips of the branchial orifice. The netted membranes are folded upon themselves in such a way as to look like a pair of lateral sacs, except when seen from above, when they present the fan-like appearance shown in the "Haus" figured by Professor Allman in the 'Journal of Microscopical Science for 1859.'

Some interest may perhaps attach to the chemical constitution of the "Haus." It gives no nitrogenous smell when burnt, and is insoluble in water, alcohol, ether, solution of potash, or the dilute mineral acids; in a word, it possesses the negative characters of Tunicin.

The geographical range of the *Appendiculariæ* is at least as extended as that of any of their pelagic brethren. Their discoverers found the first specimens in Behring's Straits and in the South Pacific; and those which gave materials for this paper were captured in the Mediterranean and the Gulf of Mexico, as well as over a large Atlantic area extending from the southern Tropics to the cold green waters of the Labrador current.

Fig. 6.

The "Hans," magnified three times.

Fig. 7.

Immature "Haus," magnified about 60 diameters.

A, median groove; B, small funnel-shaped opening; C, lateral reticulations; D, fissure where the *Appendicularia* was attached; E, lateral tubular openings.

EXPLANATION OF PLATE XLVII.

- Fig. 1. *Appendicularia furcata*, front view.
 Fig. 2. *Appendicularia acrocerca*, side view.
 Fig. 3. Common short-bodied *Appendicularia*, front view.
 Fig. 4. Side-view of fig. 3.
 Fig. 5. New form, oblique view—the ganglion and otolithe (K) being in the middle line of the body anteriorly, the gill (U) and attachment of appendix posteriorly.

Significations of the letters the same in all.

A, vascular canal of the appendix.	L, ganglion.
B, muscular bands of the appendix.	M, principal nervous trunk.
C, nervous cords of the appendix.	N, ciliated branchial openings.
D, central axis of the appendix.	O, ciliated pharynx.
E, oral tentacula of lateral lips.	P, heart.
F, oral tentacula of posterior lip.	Q, rectum.
G, branchial orifice.	R, stomach.
H, endostyle and neighbouring symmetrical cells.	S, ovary. S', doubtful, in common short-bodied
I, nervous branches surrounding the branchial orifice.	<i>Appendiculariæ</i> .
J, ciliated sac.	T, testis.
K, otolithe and its sac.	U, gill-like structure in the new form of <i>Appendicularia</i> .