Observations on the Formation and Enlargement of the Tubes of the Marine Annelid, (*Chaetopterus Variopedatus*).

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Chaetopterus variopedatus is a widely distributed tubiculous annelid of the family Chaetopterida. The individuals of each country and of widely distributed areas in Europe were classified as distinct species till Joyeux-Laffuie showed conclusively, in 1890, that they are really a single species. He also suggested that a close study of the species in foreign seas would probably result in referring them to a single species. A careful comparison of the specimens found at Beaufort, North Carolina, with Joyeux-Laffuie's detailed description of *Chaetopterus variopedatus*, leads me to regard the American representative, which Verrill and E. B. Wilson named *Chaetopterus pergamentaceus*, as identical with the single European form.

This peculiar species of sedentary annelid is found in several localities in the harbor of Beaufort, North Carolina, where the conditions for its existence are afforded by the extensive sand-flats, either covered with a thick growth of diatoms or continually exposed to currents of water heavily charged with these plants. It is here found living within its broadly U-shaped parchment tubes in nearly every portion of the harbor wherever the sand-flats are formed in the quieter waters.

The presence of Chaetopterus may be recognized by the extremities of the U-shaped tubes that usually protrude several centimeters above the level of the shoal (Fig. 3). The extremities of some tubes are concealed by ascidians, colonies of bryozoans or of hydroids, attached to them so that it may be difficult to detect the circular whitish openings within the cluster of attached animals.

The animal remains within its tube during its whole life but, as the animal grows in size, it increases both the length and the diameter of its tube. The horizontal portion of the U is of greater diameter than the conical vertical arms that protrude a few centimeters above the substratum. The simple U-form is often modified in tubes that occur in shoals of sand and shells. The arms may here be so constructed that they turn abruptly aside from large shells that are in their way. Tubes with three arms are frequently found (Fig. 4). These are tubes that have been enlarged by the extension of the horizontal portion and the formation of a new (vertical) arm. A septum at the base of the intermediate arm separates its cavity from that of the horizontal portion. I have found intermediate arms with little or no sand, some completely filled, while many have begun to macerate. Every large tube bears the shreds of one or more of these macerated intermediate arms, or the crescentic scars that mark their former union with the newly formed extension. The annulations near the orifices and the longitudinal strips of thinner, sand-covered, parchment alternating with the thicker portion of the tubes represent successive steps in the formation and enlargement of the tubes.

There is great diversity in the size of the tubes. A very young worm formed a characteristic U-shaped tube three millimeters in diameter at its wider portion, and one and three-fourths millimeters at its orifices. The distance between the orifices measured fourteen and one-half millimeters, and the length of the arms (measured from the lower side of the horizontal portion to its base) was sixteen millimeters. I have collected tubes which ranged in length from six to fifty centimeters and with arms six to twenty-two centimeters long.

The formation of the first tube and the subsequent enlargements was observed on larvae of *Chaetopterus variopedatus* which I was fortunate enough to collect in the tow-net. These larvae, which were transforming from the free-swimming mesatrochae into the creeping individuals, were kept in aquaria of sea water well stocked with diatoms. When the larvae move among the diatoms they leave a trail of mucus that cements the sand and diatoms together. Later they make short, horizontal, mucus-coated tunnels into the mass of diatoms and sand. One of these tunnels may be extended to several times the length of the body and from this simple tunnel of agglutinated sand and diatoms the larvae may build the tube within which it subsequently remains confined.

The first tube in which the larvae lives and feeds for several days is nearly a millimeter in diameter and from eighteen to twenty-two millimeters long. It is either a straight tube or a shallow U whose curved portion is downward.

After an interval of a day or two in the mucus-coated tunnel the young worm, for it is now an adult in miniature, has outgrown it and a new tube is constructed. This is done by splitting the tube at a point where the upright arm meets the horizontal portion, in a U-shaped tube, or near one end, in a straight tube, and then excavating a tunnel obliquely downwards and after nearly doubling the length of basal portion upwards to the surface. This is its first lateral enlargement. The sand which the worm excavates in constructing this extension is expelled from the opposite end of its first tube. The walls of the tunnel are coated with mucus as the tunnel advances, so that the U-shaped tube is completed when the excavation reaches the surface. The tube becomes strengthened from time to time by additional layers of mucus that hardens to form a parchment-like material that gives the older tubes a laminated structure. They are enlarged in the same vertical plane unless prevented from doing so by some obstruction, as a shell, when they turn obliquely along the surface of the obstruction or abandon the new enlargement and construct an enlargement from the opposite end of the tube. Two or three days later the process is repeated, possibly by the extension of the opposite end of the tube. The horizontal portion of each new enlargement is larger in diameter and is buried deeper in the sand than the tube from which it is a branch (Fig. 4). Enlargements are frequently of such length as to double the size of the U-tube, and are completed to the surface of the sand in from twenty-four to forty-eight hours. They are made indifferently at one end or other of the smaller tube. The fate of the intermediate tubes has been discussed in another part of the present paper.

The burrowing is done by the anterior region of the worm. Its setigerous segments dislodge the sand and pass it to the middle and posterior regions of the body, and they convey it backwards into the tube by the combined contraction and expansion of the body, and the rythmic movements of the palettes and lobes of the segments. The worm ceases burrowing at intervals of a few minutes and expels the accumulated sand at one end of the tube around which it falls and forms a mound; the other end, or intermediate tube, is the incurrent tube so long as the burrowing is in progress, but when the new burrow is complete a septum of parchment is formed across the base of the intermediate tube and it ceases to be of any use to the worm.

The worms which form their tubes in aquaria with a thin layer of sand

and diatoms on the bottom conform to the U-habit, though in a horizontal plane, with one side of the tube cemented to the floor of the vessel.

The linear extensions of the tubes are formed at such intervals as the rapid growth of the worm requires. The length of the tubes, and the dates on which the enlargements were completed by two worms which I reared from larvae taken in the tow-net are as follows:*

Specimen No. 2.		Specimen No. 4.	
Distance between arms.	Date.	Distance between arms.	Date.
20 mm.	August 7, 1905.	20 mm.	August 7, 1905.
38 mm.	August 10, 1905.	32 mm.	August 9, 1905.
60 mm.	August 15, 1905.	61 mm.	August 16, 1905.

Early in September of 1905 I collected three worms whose tubes averaged fifty-one millimeters between the orifices and five whose recently discarded intermediate arms were sixty millimeters from the ends with which they formed the smaller U-shaped tubes. The horizontal extensions increased their length to fifteen centimeters in the smallest and twenty-two and one-half in the longest specimen. Many thick-walled tubes are found with scars of intermediate arms which indicate that they were increased from about this size to about forty centimeters. The longest tubes show that they were increased, by a linear extension of ten centimeters, to fifty centimeters.

The tubes also undergo an enlargement in diameter as the animal grows in thickness. This splitting and enlargement of one of its arms I observed in specimen No. 4 during one night in September of 1905. The worm pushed the rim of the buccal funnel nearly to the margin of the orifice, and slowly moved the ends of the tentacles over the rim of the tube. (In order to enter this narrow portion of the tube from below the edges of the buccal funnel and anterior region of the body was curved dorsalwards and considerably contracted till they become conical in form.) The animal remained in this position in the tube about five seconds then slowly withdrew into the deeper portion. This was repeated in thirty seconds but this time it withdrew only to the level of the sand. Here the worm suddenly

*Both worms enlarged their tubes to 76 and 71 millimeters, respectively, between September 12th, when they were brought to the Biological Laboratory of the Johns Hopkins University, and my return, October 4, 1905. The worm in No. 4 had extended its tube to the glass wall of the aquarium on May 8–9, 1906. The U-shaped tube now measured 85 millimeters between the orifices.

expanded the first pair of setigerous segments and split the tube longitudinally at its outer side, then withdrew quickly into the deeper portion of the tube. Fifteen or twenty seconds later the worm reappeared at the level of the sand, extended the rent a little higher and withdrew. This action was repeated five times in extending the rent, seven millimeters, to the end of the tube. The rent was produced by means of the expansion of the muscular setigerous region and not by the sharp lance-shaped setae as one might suppose. The rent occurred in a position opposite the ventral surface of the body. When the tube was split to its extremity the worm thrust one side of the anterior region through the cleft and removed the sand about it by means of its setigerous notopodia. They pressed a portion of the sand aside but some was removed backwards into the tube and later discharged at the other end.

When the tube was split to its end the worm spread the basal portion of the rent by a slight expansion of the ventral side of its lower lip and the foremost portion of the anterior region. The worm remained in this position for fifteen or twenty seconds then withdrew into its tube for a half minute, after which it took a position a little nearer to the orifice of the tube. The performance was repeated till the edges were reunited by a wedge-shaped insertion of parchment that widened to three millimeters just below the level of the sand. I could not determine which region of the body was most active in the secretion of the mucus, which becomes parchment-like, but I observed that it was shaped by the lower lip of the buccal funnel, and that the parchment film had advanced a little higher each time the animal applied its ventral lip to the cleft. The splitting of the tube and the closure of the rent were completed in thirty-five minutes.

The splittings occur indifferently on any portion of the circumference of the tube, but they are found chiefly on the upper side of the horizontal portion. When they are extensive it is indicated by the abundance of sand discharged at long intervals from one arm of the tube. I have found some large tubes that had strips of thin parchment two centimeters wide and as long as the horizontal portion of the tube.

The new portion of the wall is thin and membranous at first and, while it becomes thicker with age, can be observed, long after its formation, as a strip somewhat thinner than the remaining portions of the wall. Its inner surface is smooth, like the inner wall of the other portion, and its outer surface is similarly covered with sand. The wide, horizontal portion of nearly every tube bears one or more of these strips inserted between the edges of a thicker laminated wall. This was true even in the smallest specimens, No. 2 and No. 4, which I mentioned on page 131. The diameter of their tubes was twice enlarged while they were thirty-eight and thirty-two millimeters long, respectively, and before they constructed the next linear enlargement.

The outer surface of the tubes is everywhere coated with sand, excepting about the terminal portions that protrude above the sand flats in which they are imbedded. These terminal portions have one or more annulations that give them the appearance of being formed of rings that diminish regularly in size upwards, so that the bases of the smaller rings are overlapped by the top of the rings next below. Each ring represents the successive height of the orifice, though not its diameter, for they are split from time to time as I have just mentioned. They are moulded, like the other portions of the tube, by the ventral lip of the buccal funnel, and the length of each ring represents the height to which the lip was extended when the ring was formed. The rings are, at first, very thin and transparent but they become laminated by successive additions of mucus to their inner walls. The laminae of which they are the free ends may be separated with ease from those next below.

SUMMARY.

The principal points that I have attempted to bring out in this paper are:

1. The tubes are formed by the worm from mucus secreted by certain cells of the body. Before the mucus hardens to a parchment-like material it is molded by the ventral lip of the buccal funnel.

2. The tubes are first formed as tunnels in the diatoms, but later they have the form of a U.

3. The tubes are enlarged either in length or diameter or by a combination of both these methods.

PLATE I.

Fig. 1. View of dorsal side of female Chaetopterus Variopedatus. (½ Nat.)

Fig. 2. Dorsal view of male Chaetopterus removed from its tube. (½ Nat.)

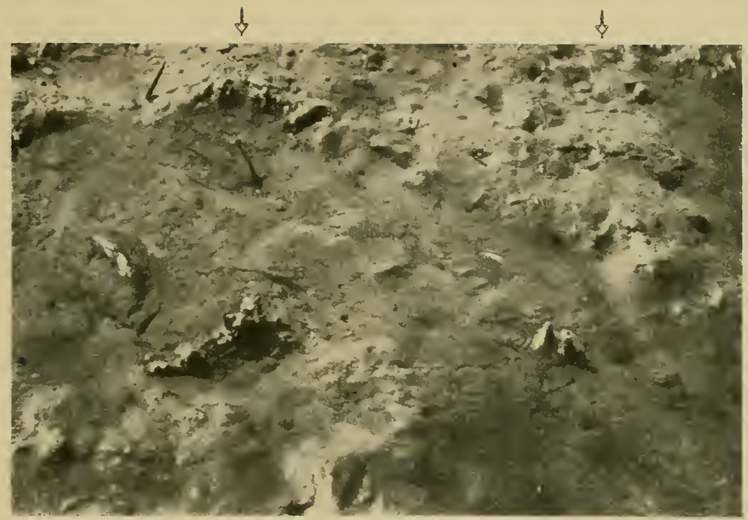

PLATE II.

Fig. 3. View of two orifices of the tube of Chaetopterus at low tide.

Fig. 4. Photograph of tube to show lateral enlargement and position of the discarded intermediate arm. (½ Nat.)