A Double-tailed Eulalia.

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With 4 Figures in the Text.

Introduction.

While examining a bowl of rock dredgings from the Mewstone Grounds near Plymouth, on 10th December, 1926, my attention was attracted by a handsome Phyllodocid worm which had evidently crawled out of a crevice in the broken rocks. On closer investigation the worm proved to be of an unfamiliar species and, of much greater interest, to possess a small secondary tail arising ventrally rather more than two-thirds of the way down the body (Fig. 1). Scale drawings, made at the time from the living animal, have recently been carefully checked by examination of the preserved specimen; only a few slight alterations have been found necessary.

A fairly large number of naturally occurring double-tailed and a few double-headed annelids have previously been recorded, especially among earthworms. A number of other double-tailed or double-headed worms have been produced artificially during regeneration experiments. In nearly every instance, however, the bifurcation is lateral and, with tails especially, very few dorso-ventral bifurcations have been obtained. The worm described in this paper is therefore of considerable interest in that the branching is of the latter type. This bifurcation will be considered first and the specific identity of the worm discussed afterwards.

The Bifurcation.

From the head to the 175th segment (the buccal segment carrying the first pair of tentacular cirri is, of course, counted as the first) the worm is perfectly normal. At the posterior ventral border of segment 175 the secondary tail arises. Its first few segments come off almost at right angles to the main body axis, but almost immediately the tail bends back until it is parallel with the primary tail above. In life the secondary tail was generally dragged along below the primary one, but occasionally it would be twisted to the right or to the left as shown in the drawings. It is composed of 28 segments and a pygidium and is about 5 mm. long.

It appears to be a newly grown structure ; its segments are smaller than those of the worm trunk immediately preceding, otherwise they are normally formed. The terminal pygidium has two caudal cirri and an anus.

Viewed from above it will be seen from Figs. 1 and 2 that at the place where the secondary tail arises the main body of the worm perceptibly narrows. The worm is widest about half-way from the head, and for a good

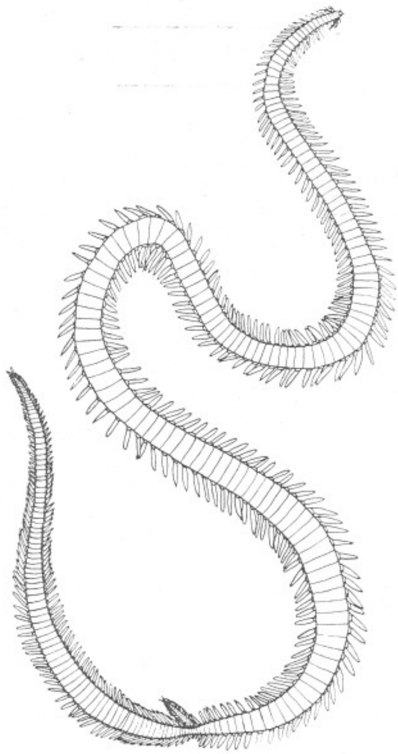
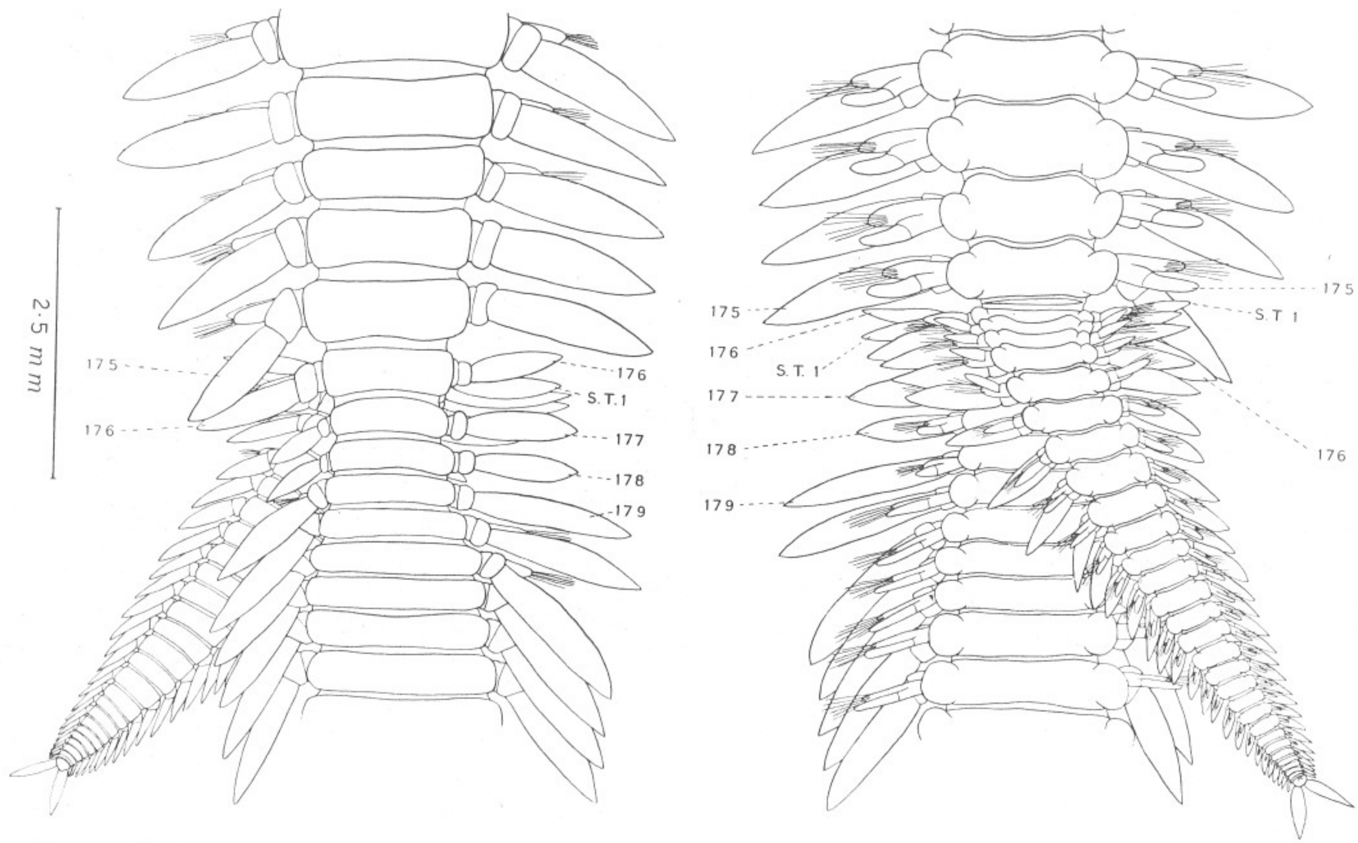


FIG. 1.—Sketch to show general proportions of the worm. From life $\times 1\frac{1}{2}$ approx.

many segments before it bifurcates the body width decreases gradually ; this is varied in life by the contractile movements used in crawling. At the fork the main body narrows abruptly owing to the comparatively small size of segments 176 to 179. Succeeding segments are of normal width (except for a slight slenderness of 180, 181 and possibly 182) continuing the interrupted gradual taper of the body to the anus. It should be noted that in Figs. 2 and 3 the normal segments of the primary tail are drawn as shortened, and therefore widened, by longitudinal contraction. The primary tail consists in all of 87 segments.



FIGS. 2 and 3.—Dorsal and ventral views of the secondary tail region. Drawn mainly from life. Main body segments 175–179 or their parapodia are numbered. The first segment of the secondary tail or its dorsal cirri are indicated by the lettering S.T. 1.

The parapodial details of the narrowed region provide a clue as to what has happened and will be considered in some detail.

Segment 176. The left parapodium was evidently normal in size or nearly so. Unfortunately it has broken off in the preserved specimen and therefore cannot be checked. The scar can be seen. The right parapodium is smaller than normal, but is complete with bristles and ventral cirrus.

Segment 177. The left parapodium consists only of a very small dorsal cirrus, the other parts of a normal parapodium being absent. The right parapodium, like the one in front of it, is of medium size and is complete with bristles and ventral cirrus.

Segment 178. The left parapodium again consists only of a very small dorsal cirrus, but the right parapodium is of medium size and is complete.

Segment 179. Both parapodia have normal dorsal cirri, but bristle lobes, bristles and ventral cirri are smaller than normal.

On the left ventral sides of segments 178 and 179 the body wall is ruptured. During life a number of eggs, of which the body was full, escaped through the hole, while in the preserved specimen a small portion of the gut protrudes.

Discussion.

There can be little doubt as to how the secondary tail and other abnormal structures came to be formed. It is almost certain that they were due to an injury, perhaps from a fish bite, that had removed a piece of tissue consisting of the ventral body wall of segments 176–179, the left parapodium of segment 176, all the parapodia of segments 177 and 178, and the ventral cirri and bristle lobes of segment 179. With it the nerve cord, together very probably with a ventral portion of the gut as well, would be removed in those four segments. The tail from segment 180 onwards would thus remain attached to the front part of the body only by a strip of dorsal body wall and a portion of the dorsal wall of the gut. For some reason the body did not break finally into two separate portions at this place, as it might very well have done ; instead the wound began to heal. Possibly the left side of the body wall of segments 177 and 178 was cut away at a higher level than on the right side where perhaps only the parapodia had been removed. This would account for the less completely regenerated parapodia on the left where more new tissue had to be formed before they could begin to grow again. It might also be responsible for the hole in the body wall on that side, the gap not yet having closed up. On the other hand the hole may be a new injury in what presumably would be weak new tissue, but I think the first explanation is the more likely.

If the hypothesis just advanced be correct, the appearance of a secondary tail is not at all surprising and might, indeed, have been predicted. We know from the work of others that in annelids regeneration of a new head or a new tail frequently takes place from the cut ends of a worm that has been divided into two portions, although the capacity to regenerate heads and tails varies with the level of the cut and in different species. If this Eulalia had been completely divided by its injury there is no doubt that the anterior portion would have grown a new tail in the ordinary way, and there would then have been nothing abnormal to record. It is merely that the old tail by remaining attached to the anterior portion has complicated the regenerative processes and brought about the formation of a double-tailed monster.

Holmes (1931) and others have demonstrated that in posterior regeneration the presence of the cut end of the ventral nerve cord at wound level is all important if normal regeneration is to follow. In some way the nervous elements govern organization of the new tissues into a properly formed new structure. In an injury such as has been postulated this necessary condition would have been fulfilled and regeneration of a tail would proceed from the region of the cut end of the cord at the anterior border of the wound. That a head did not simultaneously form near the severed nerve cord at the posterior border of the wound scarcely demands explanation, for we know (Berrill, 1928 ; Berrill and Mees, 1936) that in some worms the capacity to regenerate a new head is either confined to the anterior segments or does not exist at all, and Eulalia very likely belongs to one or other of these categories (Okada, 1934, p. 374). In Myxicola, however, Okada (1934) has shown that if the ventral nerve cord be transected artificially, in a manner similar to that which we have supposed to have happened in the present instance, a new head usually appears where the wound is made, generally more readily in the posterior region than in the anterior. In Myxicola it is the capacity to regenerate a tail from such a wound that appears to be almost entirely lacking. Very recently Zhinkin (1936) has produced in the Oligochaete Rhynchelmis secondary ventral tails in the middle of the body by operative removal of a portion of the ventral nerve cord, the operation resembling that of Okada on Myxicola. The artificial wound made by Zhinkin would be closely similar to the natural wound in my Eulalia. Incidentally Morgan many years before had supposed (1902, p. 372) that a double-tailed worm would result from such a mutilation.

I do not propose to mention individually the fairly numerous double-tailed worms with lateral bifurcation which have been described. A good bibliography of these can be found in Leloup (1931). In them it is the rule for the ventral nerve cord, and often the gut also, to fork and to pass into both branches of the worm. Dorso-ventral bifurcation, on the other hand, has rarely been seen, especially in naturally occurring examples, but

Andrews (1894) has described a number of bifid specimens of this type, all of the same species, *Podarke obscura*. They are closely comparable with my Eulalia. In them the intestine divided and passed into both branches, but the ventral nerve cord passed from the main anterior trunk into the ventral branch only. The dorsal branch contained its own ventral nerve cord which ended abruptly at the place where the bifurcation took place. Andrews came to the conclusion that the dorsal branch was the original tail of the worm and that the ventral branch was a new structure formed after injury to the ventral nerve cord. His operative experiments made in an attempt to prove this gave negative results. As we have seen Zhinkin has since been successful in an Oligochaete.

In my specimen the internal anatomy cannot be definitely determined without sectioning and I have preferred to keep the specimen intact. There can be little doubt, however, that it is closely similar to what Andrews found in Podarke, and this conclusion is supported by the results of stimulation experiments made on the worm while it was alive. By work on an annelid Bailey (1930) has shown that " impulses for locomotor movements travel only in the ventral nerve cord " and that a cut through the cord stops the passage of a contraction wave down the body. On this principle it is possible to test for places of interruption in the cord. When the primary tail of the Eulalia was anywhere stimulated with a needle the whole of it would contract, but the wave of contraction did not pass forwards beyond the bifurcation or into the secondary tail. Stimulation of the latter structure brought about a contraction that spread into the worm body anterior to the place of forking, but which did not affect the primary tail. Stimulation of the worm anterior to the bifurcation caused a contraction that did not spread to the primary tail. From these observations it seems a reasonably safe conclusion that the ventral nerve cord of the anterior part of the body is continued into the secondary tail, and that the cord of the primary tail is isolated from the rest of the worm. This agrees with the arrangement in Andrews' specimens of Podarke and with his similar stimulation experiments. Incidentally his paper was not seen by me until after my worm had been preserved.

The arrangement of the gut in my Eulalia is not known, but very probably it bifurcates and supplies both tails, each of which has an anus. Faeces can be seen inside that portion of the gut which protrudes in segments 178 and 179.

Finally it may be advisable to mention that although McIntosh gives a figure (1908, Plate XLIX, Fig. 1) which appears at first sight to represent a *Phyllodoce lamelligera* Linn. bearing a secondary tail essentially similar to that of my Eulalia, I consider this figure to be merely an unfinished drawing of a normal worm. In his text McIntosh says nothing whatever about the peculiar position in which the tail is represented. Okada

(1934, p. 374), however, seems inclined to interpret the figure as that of a worm with a secondary tail. If Okada were now to substitute my record for this very doubtful one from McIntosh his argument would still hold good.

The Specific Identity of the Worm.

The specific identity of the worm is puzzling. It definitely belongs to the genus Eulalia, but I have not been able to decide as to the species. It is quite unlike any Eulalia I have seen during ten years of watching and I cannot satisfy myself that it agrees with the published description of any species. At the same time I am reluctant to propose a new species on the basis of this single specimen, already abnormal in part ; indeed, I do not consider such a course advisable in the present unsatisfactory state of the systematics of the genus itself. The worm would not have been mentioned but for the interest aroused by its secondary tail, and I therefore do not feel called upon to do more than to give a full description of it, leaving its status to be decided on some future occasion.

In the preserved and somewhat contracted condition the worm measures about 13 cm. long with a maximum width (excluding the feet) of about 2 mm. There are 262 segments between head and pygidium, 4 of which are abnormal where the secondary tail of 28 segments arises. The body tapers towards both ends.

The prostomium is well rounded, being broader than long. In the preserved condition the anterior portion bearing the tentacles is more distinctly constricted off from the posterior portion by a transverse groove than it was during life. Four of the five tentacles are relatively long, but the fifth or median tentacle appears as though the tip had been cut off accidentally. This tentacle is set level with the front of the eyes. The eyes are large, brown-black in colour.

The first segment bears a pair of tentacular cirri ; their proportions are indicated in Figure 4. The dorsal tentacular cirri of the second segment are very long ; the ventral cirri are shorter and rather flattened. The fourth pair of tentacular cirri are nearly as long as the preceding dorsal cirri. In the preserved specimen all cirri are somewhat contracted. In Bergstrom's formula the tentacular segments are expressed as follows :—

$$1+O\frac{\mathrm{ol}}{\mathrm{a1}}+B\frac{\mathrm{ol}}{\mathrm{aN}}$$

This is based on a dissection of the left side where bristles cannot be seen on the second segment, but it is just possible they have fallen out. Bristles cannot be seen on the right side of this segment either, but as this side has not been dissected it is more difficult to be certain that none is present.

The parapodia vary little from one end of the body to the other. The dorsal cirri are large, leaf-like and pointed. The bluntly rounded ventral cirri do not project beyond the end of the bristle lobe, at least in the preserved state. The bristle lobe has well-rounded lips.

The bristles have swollen denticulate ends to their shafts. On each side one tooth is more prominent than the others. The slender curved blade is finely toothed along its inner edge.

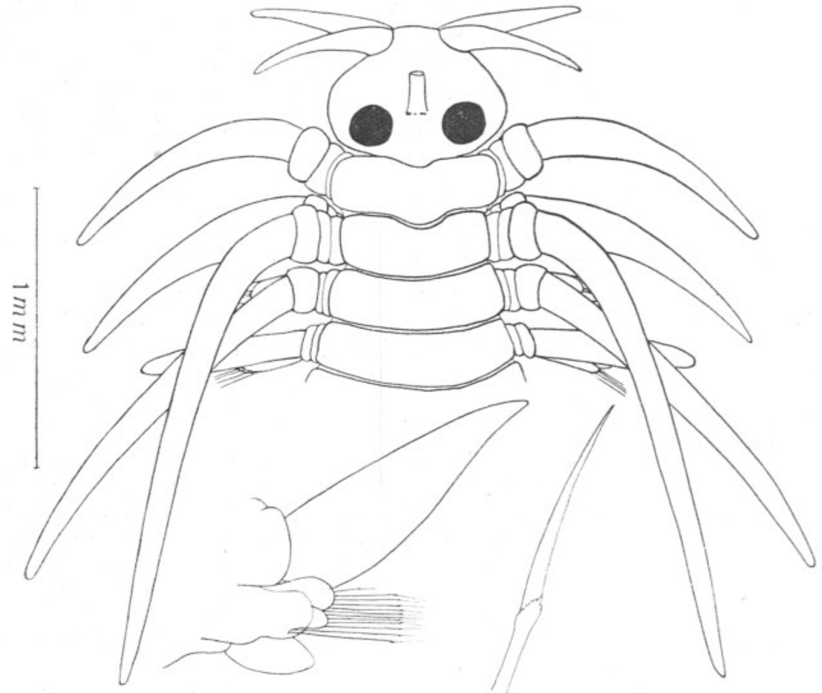


FIG. 4.—Head of the double-tailed Eulalia, from life. The scale is given alongside. Below are drawn an eighty-second parapodium ×25 approx. and one of its bristles × 310 approx. after mounting in Farrant's Medium.

The tiny pygidium carries two large anal cirri similar to those on the secondary tail (Figs. 2 and 3).

The proboscis is, unfortunately, not everted.

In life the prostomium, tentacles and tentacular cirri were yellow. The dorsal surface of the body anteriorly was brownish yellow changing to green farther back, to become rapidly yellow again in the last thirty segments. The green colour was due to the body being filled with large numbers of green eggs underlying the yellowish skin. The inter-segmental folds were blue-green, giving a transversely barred effect. An ill-defined dusky band ran down the mid-dorsal surface from the head ; it gradually became lighter than the surrounding colours and continued to the tail as a faint band of lighter shading. The dorsal cirri were bright yellow, sometimes with a green tinge and with a few brown specks on most of them. The bristle lobes and ventral cirri had also one or two brown spots, and a few were present on the sides of many segments close to the insertions of the parapodia. Ventrally the colour was similar to that dorsally, except that two dark blue-green bands ran along on each side of the middle line over the greater length of the body.

The colour pattern of the secondary tail resembled that of the main body. It was greenish near its insertion, owing to contained eggs, but turned to yellow towards its extremity.

The preserved specimen (in alcohol) is very pale pinkish brown. The dark brown spots mentioned above can be seen.

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