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Observations on the tail movements and the contractions of the dorsal blood vessel and intestine in an anomalously double-tailed worm of Oligochaeta, *Branchiura sowerbyi* Beddard. A case report with implications for physiological mechanisms of contractility

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Abstract

Waving movements of the tails and contractions of both the dorsal blood vessel and intestine were observed in an anomalously double-tailed worm of the species *Branchiura sowerbyi* Beddard. The two tails of the worm waved asynchronously, indicating that the waving movements originated and were regulated within the tails proper. Both contraction waves of the dorsal blood vessel and of the intestine started from their tail ends and ascended the body stem a long distance, but descended the opposite tail via the forked segment only a short distance. It is likely that there exists a polarity in the propagation of contraction in these organs. Defecation movements of the intestines in the respective tails occurred independently. This implies that such movements are locally controlled within the tail region.

Introduction

There are descriptions of anomalously double-tailed worms of Oligochaeta (Stephenson, 1930; Harnly, 1932; Dumnicka, 1977; Dumnicka and Kasprzak, 1979). Last year, a double-tailed earthworm was collected in the Kitasanbe Junior High School, Shimane, Japan (Masafumi Kono; personal communication).

We also obtained a fully matured double-tailed worm of the species *Branchiura sowerbyi* Beddard from a small drain near our college together with about 25,000 normal worms of the species. The double-tailed worm was kept for about 2.5 months in the laboratory and the oscillatory waving movements of the tails and contractions of both the dorsal blood vessel and intestine were observed. We report here the results of the observations. Although anomalous individuals form a minor percentage of any species, they often provide us with important information. To our knowledge anomalous oligochaete worms have not been described previously from a physiological standpoint.

Methods

The double-tailed worm was kept together with nine normal worms in a petri-dish of 16 cm in diameter on the bottom of which shallow mud was laid. Once a day some crumbs or TetraMin flakes for fish (Tetra Werke, Melle, Germany) were given as food. Observations were made directly with the naked eye, or under a binocular dissecting microscope or a low power compound microscope. For the microscopic observations, the worm was transferred from the stock petri-dish to a smaller petri-dish or to a shallow trough as has been previously described (Naitoh, 1983). Time-lapse photographs with an interval of 0.25-2.0 sec were taken with a motor-driven camera (Olympus OM-2N equipped with a motor drive unit) to supplement the observations. Room temperature ranged from 15.0 to 23.1°C, but was 20.0 to 23.0°C during observations.

Observations

General profiles of the double-tailed worm

Morphological and behavioral profiles of the double-tailed worm were basically the same as those of normal one described by Beddard (1892) except for the bifurcation of the body.

The worm, including its dorsal blood vessel and intestine, branched into two at its 108th segment; the worm had two tails (Figs. 1 and 2). The right tail consisted of 74 segments, and the left 39 segments. Left tail was slightly shorter than the right one. A small posterior part of the left tail had probably been lost when the worm was obtained. It was noticed that the regeneration of the end of left tail was in progress and continued during the term of this study. The intestine in the left tail was slightly thinner than in the right one. A pair of gills in the segments of both tails were well developed. No abnormal behavior in the worm was observed. When the worm was stationary, either both tails protruded out of the same hole in the mud or separately, out

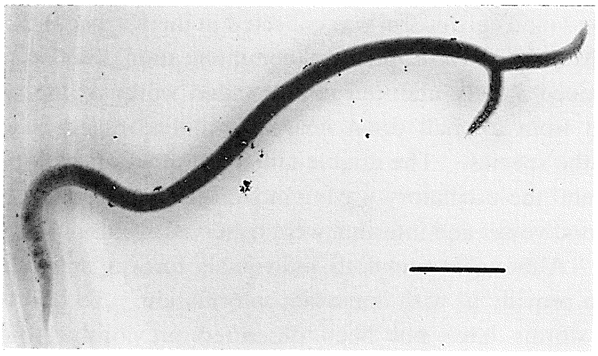

Fig. 1. Anomalously double-tailed *B. sowerbyi*. Scale: 0.5 cm

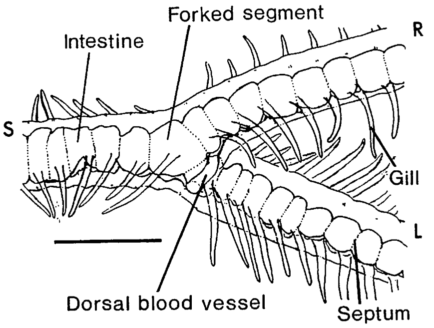

Fig. 2. Forked site of the body in dorsal view. S: body stem, R: right tail, L: Left tail. Scale: 1 mm

of two holes, two to three millimeters apart. On some occasions, only the longer tail was visible, the shorter tail being left in the mud. The tails extended from the mud up to 15 mm, the same length as noted in normal worms. Defecation mostly occurred at the longer tail, therefore, feces were heaped around it. Expulsion of the feces was accompanied by slight bending of the tail at a right angle to the dorso-ventral plane and ceasing or weakening of the waving movements as in normal worms. During defecation, however, the shorter tail continued to wave normally in its own rhythmic fashion.

Rhythm of the waving movements of tails

In the double-tailed worm, tail movements were not synchronized. A rhythm of 32.5 ± 4.6 (mean ± SD, n = 116) sec and 37.8 ± 6.6 (n = 116) sec per 50 waves were obtained in the shorter and longer tails, respectively. These rhythms were within the range shown by nine normal worms; ranging between 21.4±0.8 (n=35) sec and 53.7± 7.0 (n=15) sec per 50 waves on average. When the waving movements of both tails were weaker, the body stem was quiescent or moved only slightly. When one of the two tails moved more robustly, the body stem followed its rhythm. When both tails were strongly swaying, the body stem showed movements caused by the interference of the waves propagated from both tails.

Propagation of the rhythmic contractions in the dorsal blood vessel

Recurrent contractions of the dorsal blood vessel travelled from the tail end towards the hearts. Rhythms ranged from 28.6±3.5 (mean±SD, n=33) to 54.4±12.8 (n=27) sec per 20 contractions in normal worms, and 46.5 ± 11.2 (n = 92) sec in the shorter tail and 47.2 ± 10.0 (n = 90) sec in the longer tail of the double-tailed worm. Because the contractions originating in the respective tails of the double-tailed worm were able to ascend the body stem, and furthermore they were not synchronized with each other, contraction rhythm at the body stem was seemingly irregular and shorter than that in either one of the tails: 34.5±8.8 (n=93) sec/20 contractions. In the tails, caudal propagation of the contractions, which were propagated from the opposite branch via the forked segment, sometimes occurred, but waned and disappeared in one to seven segments. When one of them met an ascending contraction, both disappeared at the site of wave collision.

Movements of the intestine

Two types of movements, ascending contraction waves (Stephenson, 1913; Naitoh, 1983) and defecation movements (Naitoh, 1983), were observed in both branches of the intestine in the tails of the double-tailed worm as well as in that of normal worms, though feces were mostly expelled by the longer tail.

Contraction waves in normal worms were recurrently propagated from the posterior end to the anterior part of the intestine with the rhythm ranging between 13.6 ± 3.0 (mean ± SD, n = 17) sec and 33.5 ± 17.1 (n = 17) sec per 10 contractions. The generation and rostral propagation of contraction waves in the double-tailed worm were the same as in normal worms. Contractions in both tails propagated to the body stem. However, because the contractions in the shorter tail were less frequent than in the longer one, and because the contractions propagated from the shorter tail frequently joined those from the longer tail at the forked segment, contraction rhythm in the body stem was close to that of the longer tails; 27.1 ± 8.0 (n = 48) sec in the body stem, 27.1 ± 7.9 (n = 50) sec in the longer tail and 28.5 ± 6.1 (n = 46) sec in the shorter tail per 10 contractions, respectively. On the other hand, propagation of the contractions from the left tail to the right one or vice versa via the forked segment appeared to be infrequent, because it was usual that the contraction did not antidromically pass through the septum between the forked segment and the tail (Fig. 3). If the contraction passed through the septum antidromically, they descended only one to three segments and usually disappeared at the septum. In general, contraction activity of the intestine in the shorter tail was low.

When the intestine of the tail region in both normal worms and the double-tailed worm was filled with feces, defecation movement, rapid propagation of a contraction in caudal direction, was induced and a bulk of feces was expelled with a rush. In the double-tailed worm, this type of movement was observed in the posterior half to one-third of the longer tail, which was the same contraction length of the intestine as that in the defecation of normal worms, and in about half of the shorter tail. Because contents mostly passed into the longer tail, however, defecation movements occurred much more frequently in the longer tail than in the shorter one. When defecation movements were regularly repeated in the longer tail, intervals between them were about two to four minutes, which did not differ from those of the normal worms. Defecation movements in either one of the tails did not affect the intestinal movements of the other tail.

Discussion

The 'normal' behavior of the double-tailed worm suggested that the branching of the tail did not seem to seriously disadvantage it.

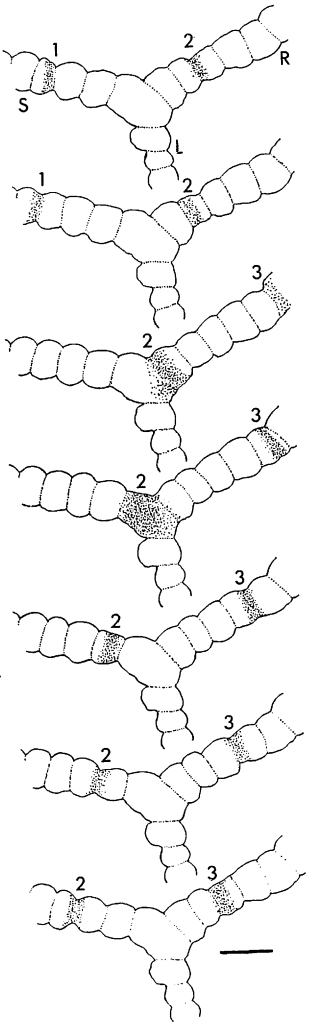

Fig. 3. Propagation of the contraction waves of the right branch of intestine. S: body stem, R: right branch, L: left branch. Dotted sites with numerals: contractions. An ascending contraction of the right branch propagates postero-anteriorly to the body stem but not antero-posteriorly to the left branch. Drawn from the time-lapse photographs with 0.5 sec interval. Scale: 0.5 mm.

Waving movements of the posterior parts of the body in aquatic oligochaetes assist in respiration (Alsterberg, 1992; Dausend, 1931). Asynchronous movements of the two tails suggests that they originated and were regulated at the tail region of the body.

Rhythmic contractions of the dorsal blood vessel are universal in Oligochaeta (Stephenson, 1930; Avel, 1959; Laverack, 1963), including *Branchiura sowerbyi* (Beddard, 1892). The present double-tailed worm was not exceptional. However, the contractions propagated from either one of the tails descended antidromically only seven segments of the opposite tail at best, even though they easily travelled orthodromically up the body stem to the hearts. It is probable that there exists a polarity of the blood vessels in the propagation of contraction. Kawasaki (1968) reported that the action potential conducts only orthodromically at the intersegmental region of the vessels in *Pheretima* sp.

In the double-tailed worm, contraction waves of the intestine propagated from the longer tail easily moved upward in the body stem, while they spread downward only a short distance in the opposite tail via the forked segment. This implies that the intestine also possesses a polarity in the propagation of contraction as is the case in the dorsal blood vessel. The contractions directly propagate between neighboring muscle cells in the cell-to-cell manner through non-polarized cell connections (Naitoh and Matsuno, 1985). Frequent disappearance of contraction waves at the septum may indicate that the septum is at least in part responsible for the polarity.

Defecation movements occurred independently in both branches of the intestine in the double-tailed worm. This suggests that the generation and direction of the defecation movements, which are neurogenic rather than myogenic (Naitoh, 1983), are locally regulated in the posterior part of the body.

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