Somatic Musculature of *Trichodorus porosus* and *Criconemoides similis*[1]

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Abstract: The somatic musculature of *Trichodorus porosus* is transversely striated, and that of *Criconemoides similis* is obliquely striated. The species also differ in configuration of the myofibrils, arrangement of the filaments within the myofibrils, and abundance of sarcoplasmic reticulum. Both species are platymyarian and meromyarian. The muscle cells are composed of myofibrils, sarcoplasm, sarcoplasmic reticulum, and various organelles. The myofibrils of both species contain actin and myosin filaments.
Key Words: Trichodorus porosus, Criconemoides similis, Somatic musculature, Ultrastructure.

Until recently little was known about the structure and composition of the somatic musculature of species of *Trichodorus* Cobb and *Criconemoides* Taylor. Hirumi *et al.* (7) reported the pharyngeal muscles and somatic muscles of *T. christiei* Allen consisted of thick and thin myofilaments approximately 220 A and 80 A in diameter. The thick filaments contained sub-units 50 A in diameter. Bird (2, 3) made a preliminary report on somatic musculature and described the rectal muscles of *T. porosus* Allen. Hirumi *et al.* (8) compared the ultrastructure of the somatic muscles of *T. christiei* and *Longidorus elongatus* (DeMan) Thorne & Swanger. Raski *et al.* (12) described labial, longitudinal pharyngeal, perpendicular pharyngeal, and odontostyle protractor muscles in a study of the anterior portion of *T. allius* Jensen. In 1969 Bird and Bird (1) published a review of nematode musculature, and Hope (9) illustrated obliquely striated platymyarian, coelomyarian, and circomyarian nematode musculature. Huxley (10) summarized the present theories on the mechanism of muscular contraction.

The objective of the present study was to describe and compare the structure and composition of the somatic musculature of *T. porosus* and *Criconemoides similis* (Cobb) Chitwood. This is of particular importance since the locomotion of these two species differs substantially. *Trichodorus porosus* moves by dorso-ventral undulatory motion which is a common characteristic of most nematodes. *Criconemoides similis* is propelled by wave-like contractions passing along the body from the posterior to anterior end, like that described by Streu *et al.* (13) for *C. curvatus.*

MATERIALS AND METHODS

Females of *T. porosus* and *C. similis* were heat-relaxed and then fixed for 1.5 hr at room temperature in a mixture of 3% glutaraldehyde and 3% acrolein in 0.1 M sodium cacodylate-buffer solution. They were post-fixed in 1% osmium tetroxide in a dilute salt solution for one hr, given three 15-min washes of dilute salt solution, and dehydrated in a graded ethanol series with a final dehydration in 100% propylene oxide. For embedding they were first placed in a 1:1 mixture of propylene oxide resin (1:1 mixture of Araldite 6005 and dodecanyl succinic anhydride) for 12 hr at 35 C and then transferred to 100% resin at 35 C for 8 hr. Solutions were changed by allowing the nematodes to settle to the bottom of containers and decanting the supernatant liquid. Embedding was carried-

Received for publication 28 May 1970.

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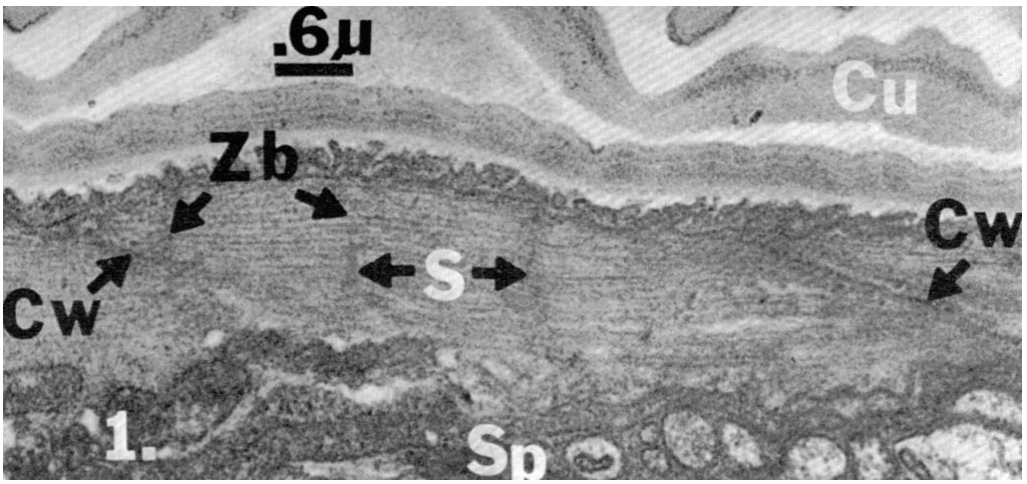

FIG. 1. Longitudinal section of somatic muscle cell of *Trichodorus porosus*: cuticle (Cu), cell wall (Cw), Z-bands (Zb), sarcomere length (S), sarcoplasm (Sp). × 15, 800.

out under a dissecting microscope. The final embedding medium of 98% resin and 2% DMP-30 was cured at room temperature for 15 hr, 8 hr at 35 C, 16 hr at 45 C, and finally at 60 C for 24 hr.

Cooled resin blocks were trimmed, and oriented, and ultrathin (silver-gold) transverse and longitudinal sections were cut on a MT-2 ultramicrotome with a diamond knife. Two ribbons of ten serial sections were placed on each coated grid. The sections were stained for 15 min in saturated uranyl acetate and for 3 min in lead citrate. Sections were observed and electron micrographs taken on Zeiss 9S and 9A electron microscopes.

RESULTS

The somatic musculature of *T. porosus* was divided into four regions by the dorsal, ventral, and lateral chords. The number of muscle cells between the chords varied from one to four, depending on location within the body. The most frequent number of cells between chords was two, indicating that *T. porosus* is basically meromyarian. In longitudinal section the muscle cells were transversely striated, as indicated by the presence of transversely oriented Z-bands which are obliquely oriented filaments connecting actin filaments of adjoining sarcomeres (Fig. 1). The cells were elongate, 3.5–8.5 μ in length, ranging from fusiform to parallelogram-like, with the angles of the parallelogram-like cells about 45 and 135°, and contained several sarcomeres which were approximately 1.5 μ in length (Fig. 1). In the posterior portion a single dorsal somatic muscle cell was present, extending across the dorsal chord (Fig. 2).

Each somatic muscle cell of *T. porosus* contained a myofibril region, nucleus, sarcoplasm, sarcoplasmic reticulum, and various organelles (Fig. 2). The cells were basically platymarian with the myofibrils adjacent to the body wall and the sarcoplasmic portion extending into the pseudocoelom (Fig. 2). In some transverse sections, however, the contractile region was two myofibrils thick. At the widest point, most cells contained a single row of six or eight adjacent myofibrils, separated by thin areas of sarcoplasm. The myofibrils were bundle-like and non-angular. Only the center myofibrils extended the full

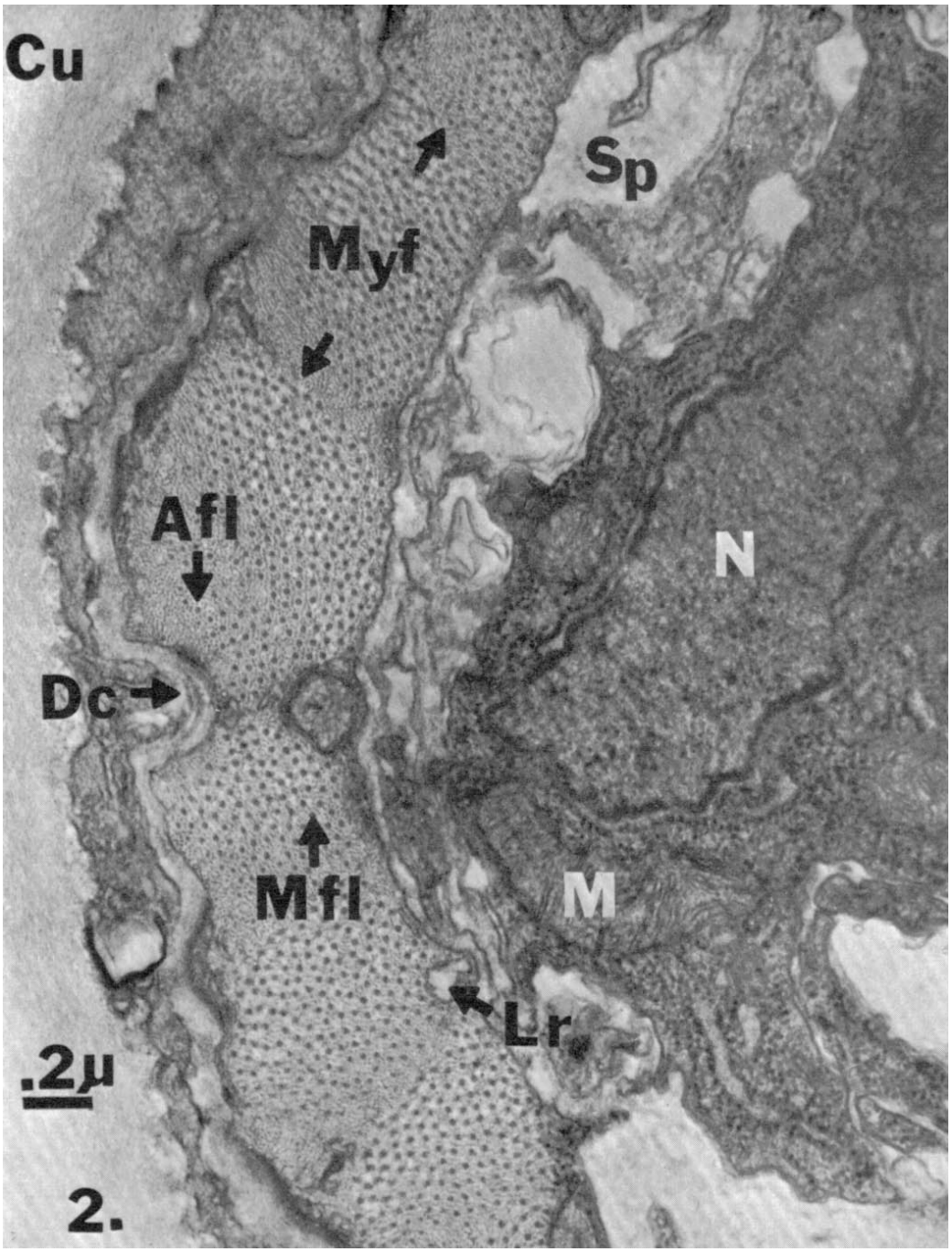

FIG. 2. Transverse section of posterior dorsal somatic muscle cell of *Trichodorus porosus*: cuticle (Cu), sarcoplasm (Sp), myofibril boundaries (Myf), Actin filament (Afl), nucleus (N), dorsal chord (Dc), myosin filament (Mfl), mitochondrion (M), longitudinal sarcoplasmic reticulum (Lr). × 50,000.

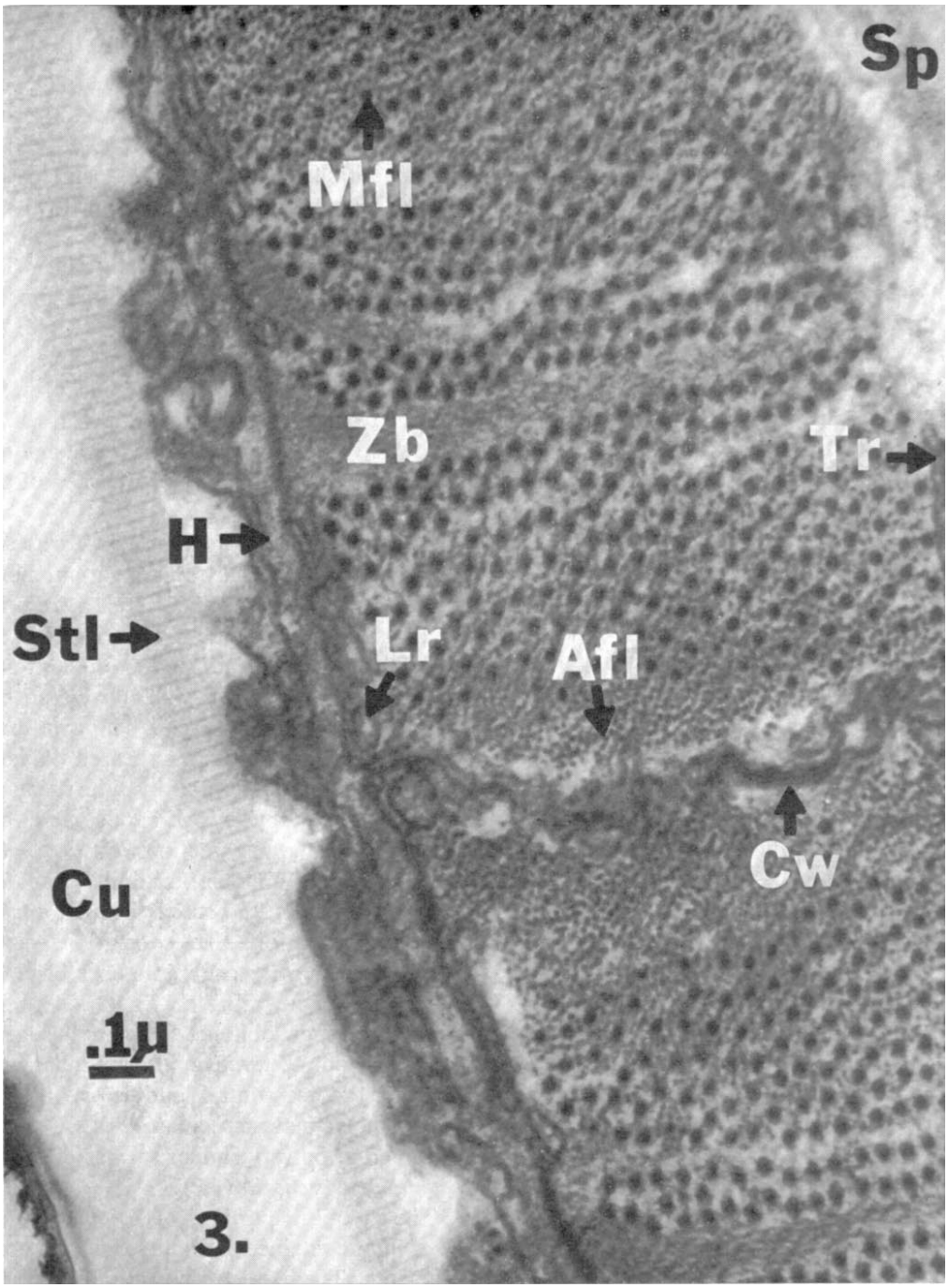

FIG. 3. Transverse section of portions of two somatic muscle cells of *Criconemoides similis*: sarcoplasm (Sp), myosin filament (Mfl), Z-band (Zb), transverse sarcoplasmic reticulum (Tr), hypodermis (H), longitudinal sarcoplasmic reticulum (Lr), actin filament (Afl), basal striated cuticle layer (Stl), muscle cell wall (Cw), cuticle (Cu). × 90,000.

length of the cell. Both longitudinal and transverse sarcoplasmic reticulum systems were present.

The myofibrils of *T. porosus* contained two types of filaments, myosin and actin (Fig. 2). The myosin filaments were approximately 200 A in diameter while the actin filaments were 70 A in diameter. In transverse section through an A-band, the myosin filaments were approximately 300–400 A apart in a hexagonal pattern, and each myosin filament was surrounded by 12 actin filaments. Only actin filaments of I-bands were observed near the margins of the myofibrils. Z-bands were rarely observed in transverse sections.

As seen in transverse section, the somatic musculature of *C. similis* was divided into four regions by the dorsal, ventral, and lateral chords. *C. similis* was basically meromyarian with two to four muscle cells between each chord. The cells were obliquely striated, similar to that illustrated by Hope (9., Fig. 19). Each contained a myofibril region, nucleus, sarcoplasm, sarcoplasmic reticulum, and various organelles. They were platymyarian with the myofibrils adjacent to the hypodermis and the sarcoplasmic portion extending into the pseudocoelom (Fig. 3). Extensive systems of both transverse and longitudinal sarcoplasmic reticulum were present (Fig. 3).

In transverse section the myofibrils of *C. similis* were angular, oriented perpendicular to the body wall, and contained actin and myosin filaments. The myosin filaments were approximately 220 A in diameter and the actin filaments 70 A in diameter. The myosin filaments were arranged in hexagonal or triangular patterns in columns which were frequently perpendicular to the body wall (Fig. 3). In transverse sections each myosin filament in an A-band was surrounded by 12 actin filaments. Only the actin filaments of I-bands were observed near the margins of the myofibrils. In transverse sections there were numerous Z-bands perpendicular to the body wall (Fig. 3).

Discussion

The *Criconemoides* used in this study fitted the description of *C. similis* better than that of any other described species and was identified as such even though Tarjan (14) regarded *C. similis* a *species inquirenda.* The only major difference between the present population and those described by Cobb (5) and Chitwood (4) was that the stylet was shorter. The last annule of the tail formed a rounded button similar to that described by Chitwood (4), and there were fine longitudinal striations on the posterior edges of the annules of juveniles.

The muscle cells of both *T. porosus* and *C. similis* were basically platymyarian, meromyarian, and contained several myofibrils. In transverse section the myofibrils, H, A, I, and Z-bands of *C. similis* were oriented perpendicular to the body wall, characteristics of obliquely striated muscle. The myofibrils of *T. porosus,* however, appeared as nonangular bundles separated by thin sheets of sarcoplasm. Numerous Z-bands were observed in transverse sections of *C. similis* because of the oblique striation, while few were observed in *T. porosus* because of the transverse striation. No conclusions could be drawn in regard to the influence of plane of striation or myofibril configuration on locomotion, since oblique striation has been found in both *C. similis* and nematodes propelled by dorso-ventral undulatory motion (9). The somatic musculature of *C. similis* appeared to be very similar to that of *Hemicycliophora arenaria* (11).

The myofibril portions of *T. porosus* and *C. similis* contained both myosin and actin filaments. The filaments were similar in both species with the exception that the myosin filaments of *C. similis* were slightly larger. In both species the myosin filaments of the

A-bands were surrounded by 12 actin filaments. The arrangement of the filaments in the myofibrils differed because of the different types of striation and myofibril configuration. The myosin filaments of *T. porosus* were arranged in a hexagonal pattern, while those of *C. similis* were arranged in either hexagonal or triangular patterns, since frequently there were not enough myosin filaments between Z-bands for a complete hexagonal pattern. It is possible but not considered probable that the difference in the arrangement of the myosin filaments plays a role in the vastly different types of locomotion of these species.

Both the transverse and longitudinal sarcoplasmic reticulum systems of *C. similis* were more extensive than those of *T. porosus*. This difference may also play an important role in the mechanism of locomotion, since it has been shown that sarcoplasmic reticulum has an influence on the activation of the muscle contractile apparatus (6).

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