The Fine Structure of a Special Type of Nerve Fiber Found in the Ganglia of *Armadillidium vulgare* (Crustacea-Isopoda). By O. Trujillo-Cenóz. (*From the Instituto de Investigación de Ciencias Biológicas, Departamento de Ultraestructura Celular, Montevideo, Uruguay.*)*

In the past few years a large body of experimental data has been amassed on the physiology of the arthropod nervous system (see the review by Roeder (8)) but, unfortunately, the full significance of these data is difficult to assess for lack of information on the fine structure of the arthropod neuropile. Some papers have been published that treat the electron microscopic morphology of the arthropod nervous system (7, 4, 3, 1, 2, 9, 5).

The present work is a brief report of observations on the fine structure of a distinctive type of nerve fiber found in the abdominal ganglia of *Armadillidium vulgare* (Crustacea-Isopoda).

The ganglion chains of adult specimens were fixed for 30 minutes in a 1 per cent OsO_4 solution (veronal buffer pH 7.9) and were embedded, following the usual procedure, in *n*-butyl methacrylate.

Observed under the electron microscope, *Armadillidium* ganglia have the well known appearance of arthropod ganglia in general, that is: neurons and glial cells are arranged at the periphery of the ganglion while the central region is a dense assembly of interwoven fibers called the neuropile. An attentive study of the neuropile reveals that it is formed of a great number of nerve fibers together with thin glial processes. The majority of the nerve fibers have the structural pattern already described in other arthropods. In a few fibers, however, the structural components appear in an unusual arrangement thus constituting a special type of nerve fiber.

Two main features characterize this special type of nerve fiber: (*a*) the existence of regularly spaced and transversely oriented cisternae of the endoplasmic reticulum (ER) and (*b*) the existence of a great number of mitochondria in close contact with the limiting membrane.

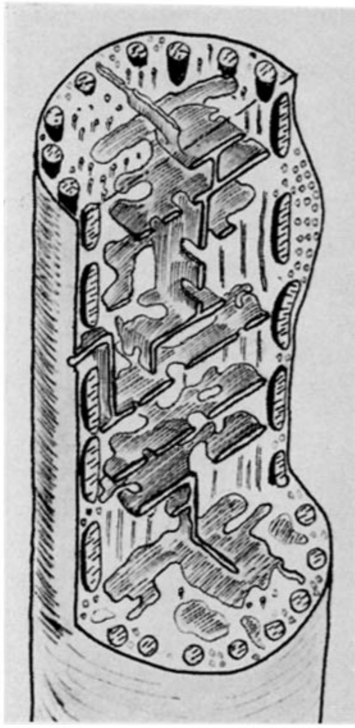
The transverse cisternae lend to this type of fiber a typical cross-striated appearance. These cisternae are not parts of a continuous septa, but rather, fenestrated structures that allow the flow of material within the neuroplasm. Their spatial arrangement can be inferred from images such as those shown in Figs. 1 and 2 in which the transverse cisternae are seen as discontinuous profiles aligned across the fiber. Spaces between the aligned profiles represent short channels communicating with spaces located on both sides of each cisterna.

Images like the one in Fig. 2 suggest that the transverse components are interconnected by means of longitudinal cisternae or tubuli. This inference leads us to consider all the cisternal profiles in these fibers as ramifications of a unique labyrinthine system (Text-fig. 1). Longitudinal filaments surrounded by a cloud of dense material can also be found in the neuroplasm; these filaments probably correspond to the neurofibrils described on the basis of light microscopic investigations. Cross-sections of the fibers show that the filaments are hollow structures similar to those found by Hess in cockroach nerve fibers (3). In longitudinal sections it is possible to observe that some of these tubuli widen and then open into transverse cisternae (Fig. 1, inset). Connections between the ER system and the fiber membrane could not be clearly demonstrated in the present work, but in some cases, as is shown in Fig. 2 (arrow), it is possible to assume a probable continuity of ER elements with the fiber membrane.

As has been noted, these fibers are also characterized by the existence of a great number of mitochondria forming a discontinuous layer beneath the fiber membrane. This disposition is similar to that encountered by Pease and Quilliam (6) in the sensory fiber innervating the Vater-Pacini organs (intracorpuscular portion) where, as in the fibers described here mitochondria form a palisade along the membrane. A cumulus of minute vesicles as well as small granules is seen there, intermixed with mitochondria. The same material can also be recognized in the central regions of the fibers or inside outpocketings of the membrane.

At present, on the basis of morphological features alone, the precise functional significance of this type of fiber cannot be understood. As a working hypothesis, however, certain considerations are pertinent: the contiguity of mitochondria and membrane suggests high energy requirements by the latter; the peculiar spatial disposition of the endoplasmic reticulum conveys the idea of a

* *Received for publication, October 24, 1959.*



TEXT-FIG. 1. Three-dimensional view of a fiber of the type shown in Figs. 1 and 2. The drawing represents the transverse ER cisternae and their longitudinal intercommunications.

stable molecular system interrelating the central and peripheral fiber regions and also different segments of the nerve fiber. The significance of microvesicles, relative to nerve function, has been discussed in a previous paper (9).

Nerve fibers as a class are usually considered to be similar in structure irrespective of their localization or origin. In neurophysiological studies, the nerve cell is considered to have a polarized membrane limiting an electrically homogeneous content; functional differences are ascribed principally to the morphological feature of difference in diameter. Future observations may indicate other physiological characteristics and suggest correlations with structure.

Limitations inherent in thin sectioning technique prevent a study of the complete pathway of these fibers inside the ganglion. At the present time, therefore, the origin of this particular type of fiber cannot be determined.

REFERENCES

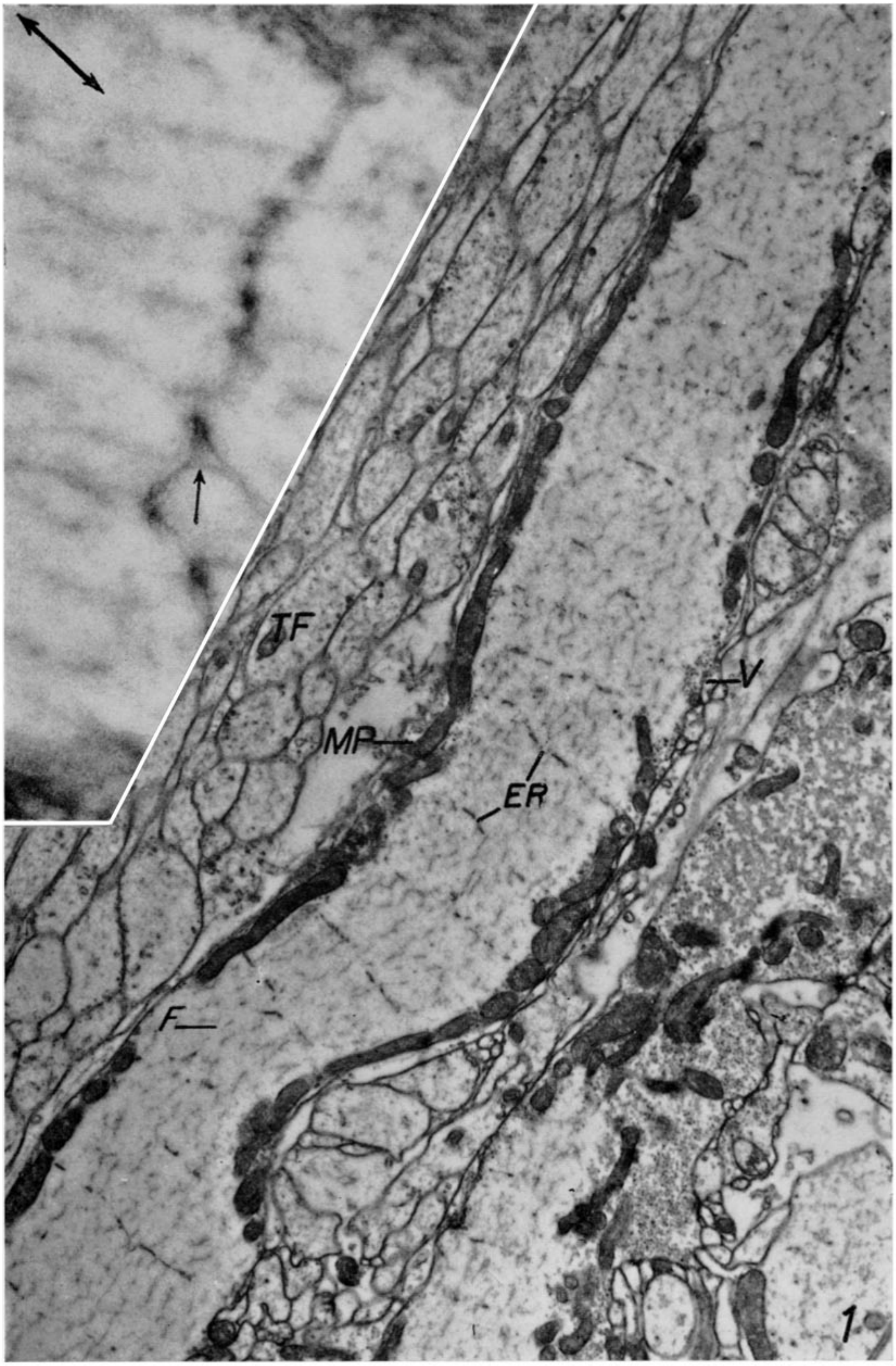
1. Edwards, G. A., Ruska, H., and de Harven, E., Electron microscopy of peripheral nerves and neuromuscular junctions in the wasp leg, *J. Biophysic. and Biochem. Cytol.*, 1958, **4**, 107.
2. Edwards, G. A., Ruska, H., and de Harven, E., Neuromuscular junctions in flight and tymbal muscles of the Cicada, *J. Biophysic. and Biochem. Cytol.*, 1958, **4**, 251.
3. Hess, A., The fine structure and morphologic organization of the peripheral nerve fibres and trunks of the cockroach (*Periplaneta americana*), *Quart. J. Micr. Sc.*, 1958, **99**, 333.
4. Hess, A., The fine structure of nerve cells and fibers, neuroglia, and sheaths of the ganglion chain in the cockroach (*Periplaneta americana*), *J. Biophysic. and Biochem. Cytol.*, 1958, **4**, 731.
5. Hodge, M. H., and Chapman, G., Some observations on the fine structure of the sinus gland of a Land Crab, *Gecarcinus lateralis*, *J. Biophysic. and Biochem. Cytol.*, 1958, **4**, 571.
6. Pease, D. C., and Quilliam, A., Electron microscopy of the Pacinian corpuscle, *J. Biophysic. and Biochem. Cytol.*, 1957, **3**, 331.
7. Robertson, J. D., Ultrastructure of two invertebrate synapses, *Proc. Soc. Exp. Biol. and Med.*, 1953, **82**, 219.
8. Roeder, K. D., The nervous system, *Ann. Rev. Entomol.*, 1958, **3**, 1.
9. Trujillo-Cenóz, O., Study on the fine structure of the central nervous system of *Pholus labruscoe* (Lepidoptera), *Z. Zellforsch.*, 1959, **49**, 432.

EXPLANATION OF PLATES

PLATE 98

FIG. 1. Longitudinal section through part of a large intraganglionic fiber. It shows several transverse profiles of the endoplasmic reticulum cisternae (*ER*) regularly spaced along the fiber. Filaments (*F*) can be seen running between the transverse cisternae. This material corresponds to thin tubuli which are not visible at this low magnification. Numerous mitochondria can be seen forming a palisade along the fiber membrane (*MP*). A cumulus of vesicles (*V*) and isolated vesicles is also seen in close contact with the fiber membrane. In the lower right corner of the picture it is possible to recognize a section of another nerve fiber showing a great number of vesicles and granules occupying its whole diameter. *TF*, thin nerve fibers. × 18,000.

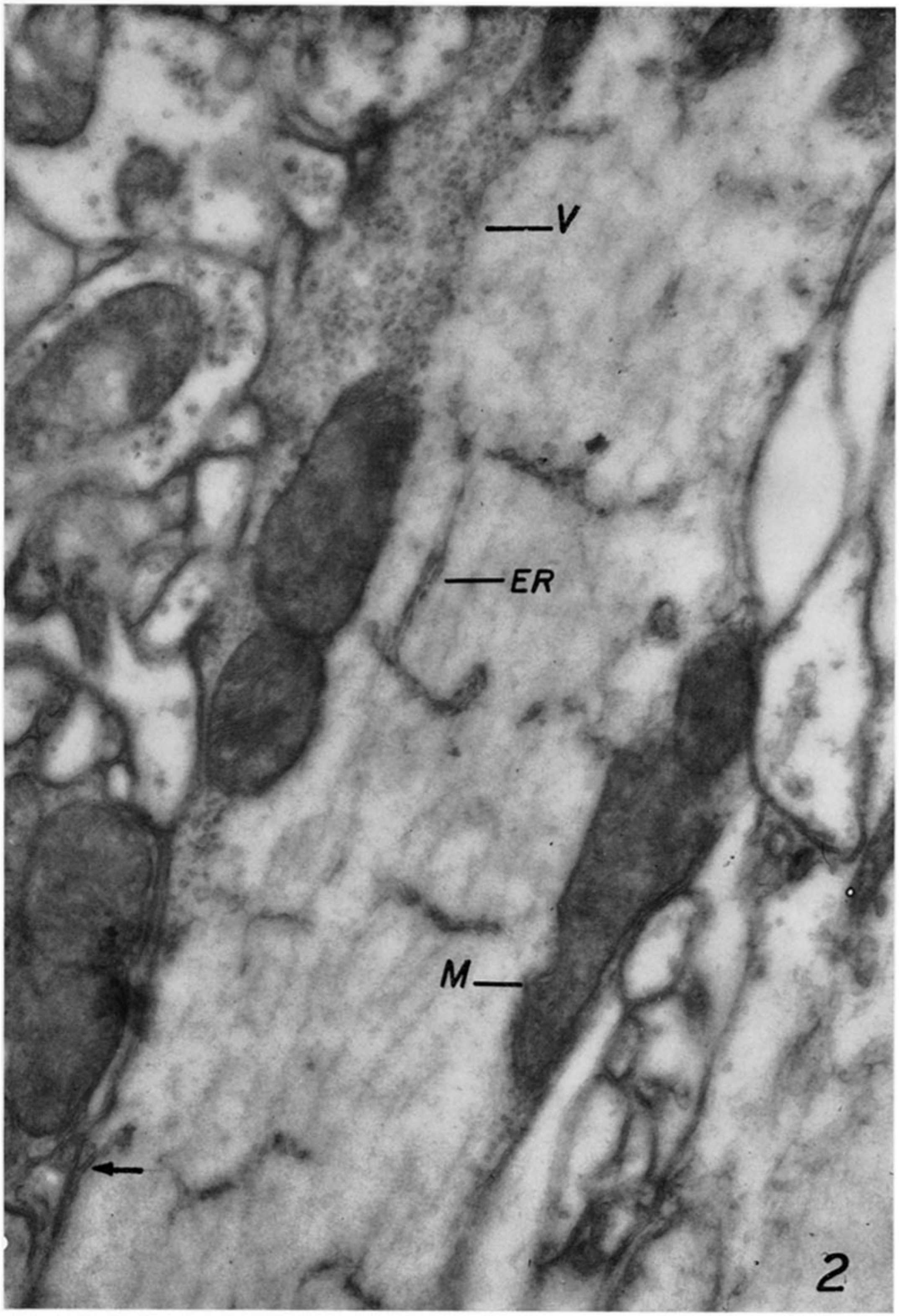
The inset shows at a higher magnification (× 85,000) the point at which (arrow) a thin longitudinal tubule widens and opens into a transverse cisterna. (The double-headed arrow indicates the fiber axis).



(Trujillo-Cenóz: Fine structure of nerve fiber)

PLATE 99

FIG. 2. High magnification electron micrograph showing a longitudinal section of a neuropile nerve fiber. In this picture the connection between transverse and longitudinal profiles of ER cisternae is evident. The arrow marks a point at which probable continuity exists between the fiber membrane and a cisterna of the ER. *V*, vesicular material; *M*, mitochondria. $\times$ 58,000.



(Trujillo-Cenóz: Fine structure of nerve fiber)