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Macromolecular Arrangement within Muscle

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Electron microscopy has already given much information about the macromolecular components of striated muscle (*1*, *4*). Thus it is shown that myofibrils of teased muscle are ribbons composed of parallel arrays of filaments associated with an amount of seemingly amorphous material that is greatest in the anisotropic regions.

For the present work, strips of psoas muscle separated from a rabbit at death were tied *in situ* to strips of wood at their resting length, then cut out and immediately fixed in formalin. Pieces of this fixed muscle were dehydrated by passage through alcohols, embedded in methacrylate, and thinly sectioned for electron microscopy by the procedures recently outlined by Neumann, Borysko and Swerdlow (*2*) and finally shadowed with gold-Manganin.

In favorable instances an astonishingly regular macromolecular arrangement can be seen in these sections. At a moderate magnification a section of a fiber cut nearly at right angles to the long axis will appear as in Fig. 1. The macromolecular filaments constituting the myofibrillar blocks are seen almost end-on as either dots or short rods. Their diameters correspond to those of the fila-

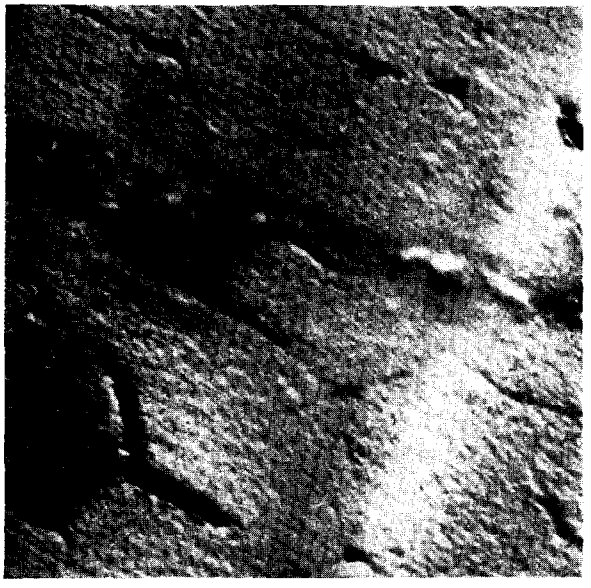

FIG. 1. A transverse section through a muscle fiber nearly normal to the fiber axis showing several myofibrils. Magnification, × 30,000.

FIG. 2. A transverse section through muscle at a higher magnification. Magnification, × 50,000.

Though the study of such teased preparations has much to say about the macromolecular structure of muscle, it does not and cannot be expected to tell much about the relation between these thin strips or ribbons and the way they are built up in three dimensions in the intact myofibrils. This can be done only by the investigation of transverse and longitudinal sections. We are here reporting certain preliminary results of such an investigation.[2]

ments seen in electron micrographs of teased preparations. The order that is obvious in the arrangement of these macromolecules is clear at the higher magnification of Fig. 2. The section here is almost exactly normal to the fiber axis, the molecular net is approximately hexagonal, and therefore the filaments must be fairly close-packed in the fiber itself.

Longitudinal sections also have shown regularity in particle arrangement (Fig. 3). The macromolecular filaments, which run nearly vertical in this figure, have an obvious beaded structure and the beads of adjacent filaments are regularly aligned to give a net which might be rectangular if the section were cut exactly parallel to the fiber axis. The existence of such a net in longitudinal section, together with the hexagonal net seen in transverse

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[2] Electron micrographs recently published (*3*) of sectioned rat muscle have been interpreted to mean that the intact myofibril is a hollow cylinder or tube of which the teased-out ribbon is the shell or outer layer. As the accompanying photographs demonstrate, our results do not point to such a structure.

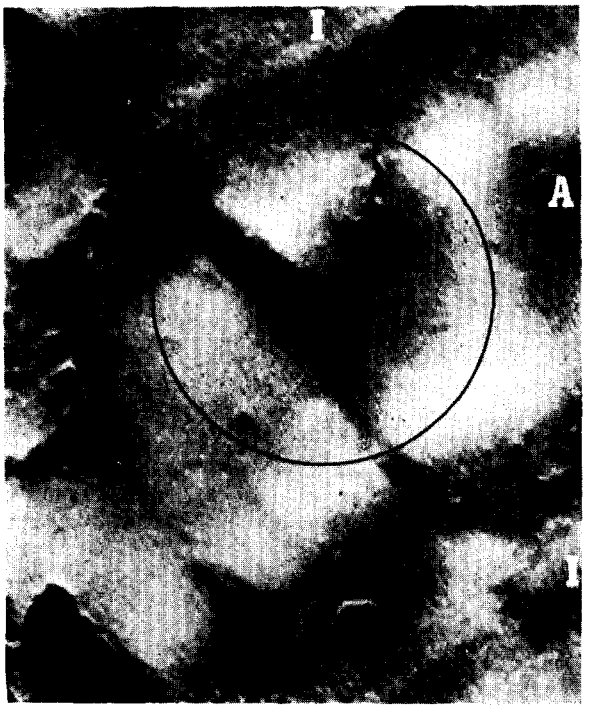

FIG. 3. A longitudinal section through part of a muscle fiber. Regions adjacent to I and A correspond to isotropic and anisotropic bands. Order in particle arrangement is best preserved in regions enclosed by the inked-in circle. Magnification, × 27,250.

section, demonstrates that there is three-dimensional, and by definition crystalline, order in the arrangement of the macromolecular components of the fibrils of this striated muscle. The regularity is most pronounced in the anisotropic bands.

An awareness of this high degree of order in its structure is obviously important for an understanding of muscle and of the way it functions. We are continuing this investigation to find out more about the nature and fine structure of the particles which display this order and to see how they are changed by muscular contraction.

References

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