LETTER TO THE EDITOR

[Brief letters to the Editor that make specific scientific reference to papers published previously in THE JOURNAL OF GENERAL PHYSIOLOGY are invited. Receipt of such letters will be acknowledged, and those containing pertinent scientific comments and scientific criticisms will be published.]

The Radial Variation of Potential in the Transverse Tubular System of Skeletal Muscle

Dear Sir:

Costantin (1970) controlled the potential across the surface membrane of a skeletal muscle fiber and studied the radial spread of shortening as this surface membrane potential was varied. He found that the surface depolarization necessary to elicit shortening of axial myofibrils could be *less* than that necessary to produce movement of the entire cross-section, a result which implies that the depolarization of axially located T tubules was greater than that of the more superficial tubules. The reversal of the expected potential gradient within the T system was taken as evidence for a net membrane current in the T system in the opposite direction from that which would occur in a passive system, and thus for the presence of an action potential-like mechanism in the T system. This note provides a more formal basis for that conclusion.

We assume that the resting transmembrane potential is uniform throughout the T system. Depolarization of the T system will be considered as a positive displacement of tubular transmembrane potential and will result, in a passive membrane, in the flow of positive current from the sarcoplasm to the T system lumen.

For a fiber of radius a in which depolarization of the axially located T tubules, $V(0)$, is greater than the depolarization of the tubules at the fiber surface, $V(a)$, we have:

$$\frac{V(a) - V(0)}{a} < 0 \tag{1}$$

and, by the mean value theorem of the calculus (Courant, 1937)

$$\left.\frac{\partial V}{\partial r}\right|_{r=\xi} = \frac{V(a) - V(0)}{a} \tag{2}$$

where $0 < \xi < a$.

The radial derivative of potential, $\partial V/\partial r$, is related to the radial component of current flow in the tubular lumen, i_r, by a form of Ohm's law:

$$\frac{\partial V}{\partial r} = \frac{i_r}{2\pi r \bar{G}_L}. \tag{3}$$

This equation is given by Adrian et al. (1969, equation 6), whose system of units we adopt here. It should be noted that the effective radial conductance, $\bar{G}_L$, has a complicated physical significance and depends, at least in principle, on the geometry and pattern of current flow in the T system. Thus by equations 1, 2, and 3 we conclude that the radial current in the tubular lumen is negative at $r = \xi$, that is to say, the radial current flows from the surface to the axis of the fiber.

The relation between this radial current and the current flowing across the tubular membranes, i_w, is given by the expression for the conservation of current (Adrian et al., 1969, equation 7):

$$i_w = \frac{\partial i_r}{\partial r}. \tag{4}$$

Integration of equation 4 from $r = 0$ to $r = \xi$ shows that the current flowing in the lumen of the tubules at a distance $r = \xi$ from the center of the cell is simply the total current crossing all the membranes between the center of the cell and the radius $r = \xi$. Thus, if the radial derivative of potential is negative at some point ξ, then the current in the lumen of the tubules is negative at that point, and the net current across the membranes within $r = \xi$ must be negative, namely inward.

We have shown then that the finding of Costantin (1970) that $V(0)$ is more positive than $V(a)$ implies that there is a net inward membrane current during depolarization, so there must be an action potential–like mechanism in the tubular membranes. It is important to note that our analysis is true at all times, and has made no assumptions of linearity or time independence in the electrical properties of the T system.

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