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The metabolic energy cost of action potential velocity PATRICK CROTTY, University of Virginia Health System, THOMAS SANGREY, Emory University, WILLIAM LEVY, University of Virginia Health System — Voltage changes in neurons and other active cells are caused by the passage of ions across the cell membrane. These ionic currents depend on the transmembrane ion concentration gradients, which in unmyelinated axons are maintained during rest and restored after electrical activity by an ATPase sodium-potassium exchanger in the membrane. The amount of ATP consumed by this exchanger can be taken as the metabolic energy cost of any electrical activity in the axon. We use this measure, along with biophysical models of voltage-gated sodium and potassium ion channels, to quantify the energy cost of action potentials propagating in squid giant axons. We find that the energy of an action potential can be naturally divided into three separate components associated with different aspects of the action potential. We calculate these energy components as functions of the ion channel densities and axon diameters and find that the component associated with the rising phase and velocity of the action potential achieves a minimum near the biological values of these parameters. This result, which is robust with respect to other parameters such as temperature, suggests that evolution has optimized the axon for the energy of the action potential wavefront.

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