BMC Neuroscience

Poster presentation

The costs of axonal communication

William Levy* and Patrick Crotty

Address: Department of Neurological Surgery, University of Virginia Health System, Charlottesville, VA 22908, USA

Email: William Levy* - wbl@virginia.edu

* Corresponding author

from Sixteenth Annual Computational Neuroscience Meeting: CNS*2007
Toronto, Canada. 7–12 July 2007

Published: 6 July 2007

BMC Neuroscience 2007, **8**(Suppl 2):P163 doi:10.1186/1471-2202-8-S2-P163

Previously we evaluated the metabolic cost inherent in action potential velocity and found squid sodium channel density to be at an energy-efficient, optimal level [1]. However, in addition to velocity it is sensible to conjecture that metabolic energy must also pay for information transmission. Indeed Levy and Baxter [2] used an optimization perspective that demonstrated the average firing rate of forebrain cortical neurons corresponds to an optimized value of bits per unit of metabolic energy.

These two distinct optimizations force us to ask: (1) Are these two optimizations distinct, and (2) how – in the biophysical sense – has Nature (natural selection) addressed these two optimizations.

The key insight, which can be seen in [3], is that a substantial fraction of metabolic energy must be devoted to ion fluxes that seem to do nothing. Specifically, the overlapping sodium and potassium currents are neutralizing but the ion fluxes themselves must, eventually, be reversed by the Na-K ATPase pump. We will present biophysical simulations showing that velocity and the energy devoted to velocity can be separated from the energy devoted to information. At the heart of this answer is the presumed ability of Nature to evolve voltage-dependent potassium channels with a range of possible onset delays and the possibility of action potentials that need little if any voltage-dependent potassium channels.

When we create a variable artificial delay of potassium channel activation, we affect both the information rate and the metabolic costs with little or no effect on velocity or its cost. In particular, by altering the delay of the voltage-dependent potassium conductance, we alter the neutralized currents without altering the sodium current of the wave front. Thus nature can independently evolve signalling systems that pay for velocity and independently pay for information.

The cost of higher information rates is an increasing function of neutralized currents. Thus we conclude the two optimizations are separately evolvable and it is easy to identify distinct examples in nature.

References

1. Crotty P, Sangrey T, Levy WB: **Metabolic energy costs of action potential velocity.** *J Neurophysiol* 2006, **96:**1237-1246.
2. Levy WB, Baxter RA: **Energy efficent neural codes.** *Neural comput* 1996, **8:**531-543.
3. Hodgkin AL, Huxley AF: **Aquantitive description of membrane current and its application to conduction and excitation in nerve.** *J Physiol* 1952, **117:**500-544.