9 Extracellular Potentials and Spike Sorting

We return first to the issue of propagation in cables. The presence of loss by the shunting of voltages through the membrane, leads to the appearance of extracellular potentials that may be used to infer changes in the intracellular potentials. Let's consider a simple example to get the scale, and for the moment we consider subthreshold but possibly active membrane currents.

Let ΔV_{in} be the voltage drop across an axon that is one space constant, λ, long. Then all the current that flows inside the axon must return through the extracellar space. The current in the axon is confined to a radius of a, while that in the extracellular space is confined to a radius of $\dim \lambda$. Equating these currents gives

$$\frac{\Delta V_{in}}{\rho_c \frac{\lambda}{\pi a^2}} = \frac{\Delta V_{out}}{\rho_c \frac{\lambda}{\pi \lambda^2}} \tag{9.1}$$

or

$$\Delta V_{out} \sim \Delta V_{in} \left(\frac{a}{\lambda}\right)^2 \approx \Delta V_{in} \frac{\rho_c a}{r_m} \tag{9.2}$$

which is essentially a voltage divider. We are back at our original argument that the space constant is a measure of the divider length (rather the square root of that length). The practical issue is that internal voltage drops of 10 mV turn into 1 μV to 100 μV in the extracellular space. The smallest changes are too small to detect, although synchronous activity of many cells are provide a means of to "amplify" these signals.

FIGURE - chapt-9-buzsaki.eps

The stuff of brains is tortuous, and appears to have an impedance that is significantly capacitive, so it is difficult (for me, anyway!) to do a detailed calculation of the expected extracellular potentials. But the simple estimates gives the correct order of magnitude.

FIGURE - chapt-1-braitenberg.eps

FIGURE - chapt-1-dendrites.eps

FIGURE - chapt-9-axons.eps

A final bit of business is the use of extracellular measurements of measure current flow in the external solution. This provides a means, for example, of measuring the currents that flow into synapses, something that is complementary to an intracellular measurement. The quantity we seek is the divergence of the current. In one dimension, this is

$$\frac{\partial I(x,t)}{\partial x} = A\frac{\partial}{\partial x}J(x,t) \tag{9.3}$$

$$= \frac{\partial}{\partial x}gE(x,t)$$

$$= \frac{\partial}{\partial x}\left(-g\frac{\partial V(x,t)}{\partial x}\right) \tag{9.4}$$

$$= -gA\frac{\partial^2}{\partial x^2}V(x,t)$$

This term has a funny name, the current source density (CSD), possibly because the equation of continuity equates the divergence of the current with the time-rate-of-change of the charge density. What we learn from the CSD is the flow of current into a cell. In principal, this could be used to measure the current flow as an action potential propagates down an axon, although no one has yet done this.

FIGURE - chapt-9-csd.eps

Our final topic is the detection and identification of spikes - high frequency extracellular siganls that result from nearby action potentials.

FIGURE - spike-sorting-mbl-neuroinformatics (14)