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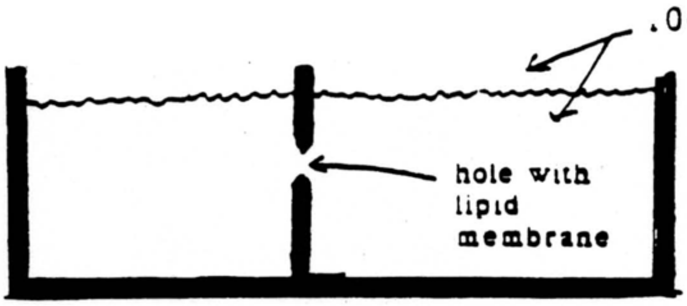
Problem Set 1

1. You are given a 10V battery, a *very* sensitive current meter, some wire, a switch, and the two-chamber plastic apparatus illustrated below. The two chambers are filled with 100 mM potassium chloride solution, and the circular, 1 mm diameter hole between chambers is spread with a planar artificial lipid bilayer membrane.



a) Describe how you would measure the resistance of the membrane. Suppose the resistance was 10 megohms ($10^7\Omega$); how would you arrange your circuit?

b) Suppose the diameter of the hole between chambers were doubled to 2 mm. What would you expect the new resistance to be?

2. You are given the equipment above plus a sensitive voltmeter and a small, thin pane of glass that is permeable only to H^+ ions. Describe how you would make the pH meter (pH = -log [H^+]). You have a standard solution of pH 7 and an unknown solution. Describe what parameter you would measure and write an equation for it that expresses the pH of the unknown solution in terms of the number you measure. What numerical reading would you get, for example, if you unknown solution is pH = 4? pH = 10?

3. a) You are a neurophysiologist recording action potentials from a squid axon, and your mother-in-law is due to visit your lab in ten minutes. She has indicated that she wishes to see "big, big" action potentials, overshooting 140 mV above the resting potentials What would you do to satisfy her whim?

b) Later, still unimpressed, she snidely retorts, "I still don't see how these tiny voltages (< 0.02V) can open and close conductance channels in membranes." What is your most impressive counterargument?

4. We will deal here with a certain identified synapse in the CNS of the mooncalf (*Bos lunaris*). The postsynaptic cell has voltage-sensitive channels like the squid axon -- a rapidly depolarizing, inactivating channel which conducts only sodium ions, and a slowly-depolarizing, non-inactivating channel which conducts only potassium ions. For our purposes, these are the only channels present in this neuron.

Ionic concentrations for mooncalf blood and and for the cytoplasm of this neuron are given below.

Ion	Cytoplasm of Neuron	Mooncalf Blood
Na	5 mM	500 mM
K	300 mM	30 mM

The membrane of this neuron at resting has a conductance to sodium ions, g_{Na}, of 0.10 mS/cm^2 and a conductance to potassium ions, g_K, of 1 mS/cm^2.

After a large, rapid depolarization the maximum (peak) sodium conductance is 50 mS/cm^2, and the peak potassium conductance is 50 mS/cm^2

What is the maximum depolarization of the membrane above threshold? (Your answer need be accurate only within ±2 mV).

What is the maximum hyperpolarization of the axon below resting? (Within ±2mV).

What is the highest value of dV/dt -- the slope of the voltage curve -- that you could possibly observe at the moment that the voltage trace crosses 0 mV during the depolarizing phase of an action potential. Assume that the membrane capacitance = 1 $\mu F/cm^2$.

5. a) What electrical properties of the squid axon membrane are responsible for the refractory period?

   b) What molecular properties of protein(s) in the membrane bring about these electrical properties?

   c) List a treatment (enzymatic or phamacological) that would eliminate the refractory period.

   d) Give a Darwinian (selective) argument why axons might have evolved with a refractory period.

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