

MCB166 — Fall 2017— Problem Set 4

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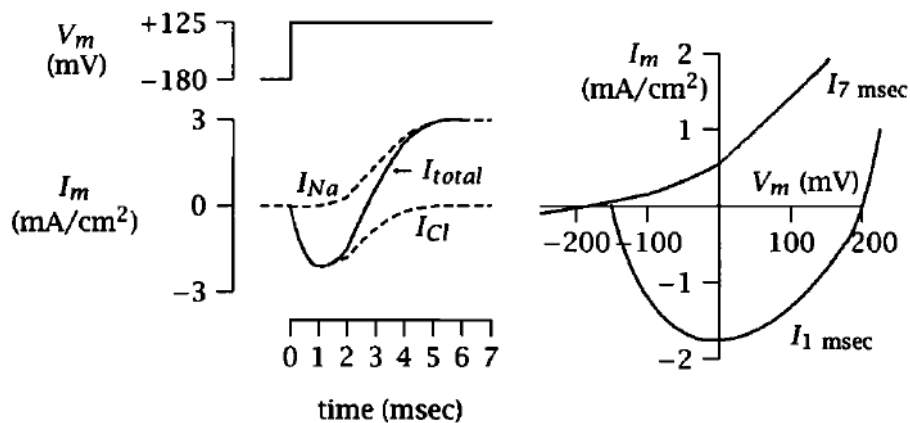
1. Hodgkin-Huxley axon. Conditions for a potassium negative conductance.
 - (a)
 - (b)
 - (c)
 - (d)

2. An alga *Chara globularis* is known to generate positive-going action potentials. The major ions in both its cytoplasm and the pond water it lives in are Na^+ , K^+ , and Cl^- , and their concentrations are as follows:

	Cytoplasm (mM)	Pond Water (mM)
Na^+	57	0.031
K^+	65	0.046
Cl^-	112	0.040

The resting potential of the cell is -182 mV , and the peak amplitude of the action potential is $+198 \text{ mV}$.

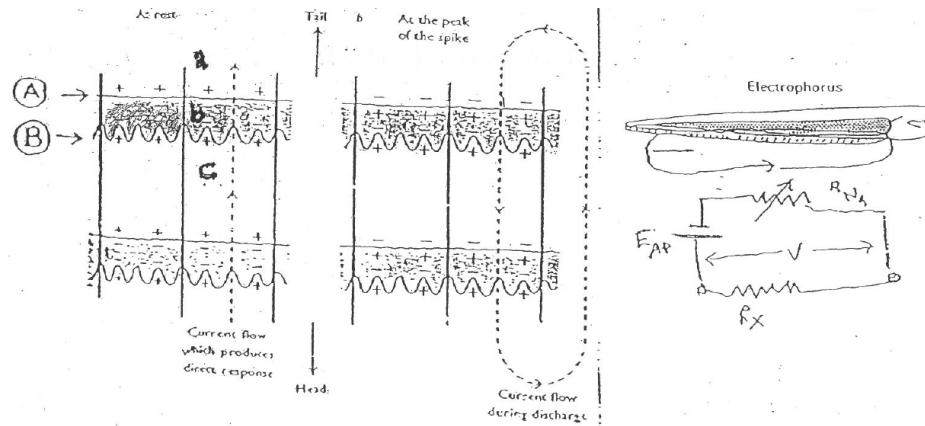
- What is (are) the primary permeable ion(s) for this cell at rest?
- What is (are) the primary permeable ion(s) for this cell during the peak of an action potential?
- In a pump that pumps both Na^+ and Cl^- into the cell at a ratio of 1 : 1, what is the contribution of this pump to the resting potential of the cell?
- The voltage-clamp analysis of this cell reveals the following results:



What are the values of g_{Cl} and g_{Na} at $V_m = -50 \text{ mV}$ and at $V_m = +150 \text{ mV}$?

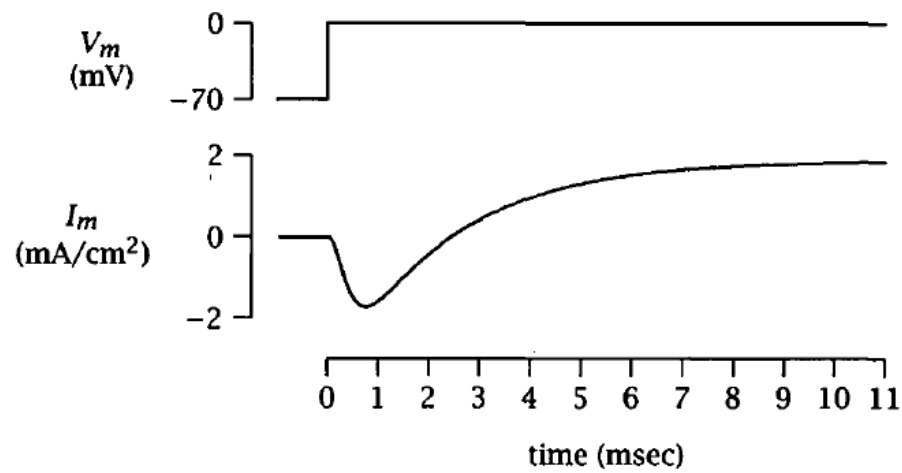
3. Which of the Hodgkin-Huxley variables, m , h , or n is primarily responsible for each of the following phenomena: Explain your choice in one short sentence.
- (a) Sharp threshold for excitation (for short-duration stimuli).
 - (b) Rapid repolarization at the end of an action potential.
 - (c) Undershoot after an action potential, ie. voltage is temporarily hyperpolarized beyond rest.
 - (d) Anode-break excitation, ie. membrane has lowered threshold after hyperpolarizing pre-pulse.

4. The electric organ of the electric eel can generate a 600 volt discharge. It is made up of stacks of about 4000 asymmetric disc-shaped cells called electroplaques. The entire stack is surrounded by an insulating sheath, as shown in Fig. 1. Each electroplaque has two different faces — A and B in the figure. At rest, both faces are permeable to K^+ and have relatively high resistance. At the peak of the action potential, face A has many activated Na^+ channels, and thus has a low resistance and is permeable to Na^+ . Face B is transiently activated by postsynaptic (acetylcholine) channels to trigger the action potential in face A. The acetylcholine channel is equally permeable to Na^+ and K^+ and has a reversal potential near zero. During activity this face also shows a low resistance.



- Draw an equivalent circuit for the cell at rest and at peak activity representing the two membranes in series and using $V_{Na} = +50mV$ (inside relative to outside) and $V_{rest} = -90mV$ (inside relative to outside). Calculate the resting potential and the action potential peak amplitude measured between microelectrodes placed at points a and b, and then between electrodes placed at a and c. [amplitude of AP = $V_{AP} - V_{rest}$].
- Using the circuit diagram for a single electric cell, draw and label the equivalent circuit for the entire stack of 4000 cells. Calculate the voltage drop across the stack at rest and at the action potential peak. Explain why the electric organ can generate such high voltages (sufficient to light up neon lights in aquariums). Why is it unlikely that a single excitable cell can be designed to generate voltages much higher than a few hundred millivolts?
- Complete the equivalent circuit for an electric organ composed of 4000 electroplaques at peak discharge by sending current through an external resistance, R_x , the resistance of the medium through which the fish swims. Write an expression for the voltage the electric fish can utilize to stun its prey. There are both marine and fresh-water electric fish. Explain why the fresh-water types are more effective at stunning their prey. In fact, marine electric fish have only the excitable synaptic face with no electrically excitable face.
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5. When a normal, healthy squid axon is voltage-clamped in artificial sea water, one obtains the following membrane current record in response to a step change in membrane potential from $V_m = -70mV$ to $V_m = 0mV$.



Draw similar plots of I_m vs. t (when V_m is stepped from $-70mV$ to $0mV$) when the recordings are made under each of the following experimental conditions. For each of your plots, explain in one or two sentences how and why your graph differs from that drawn above.

- (a)
- (b)
- (c)
- (d)
- (e)