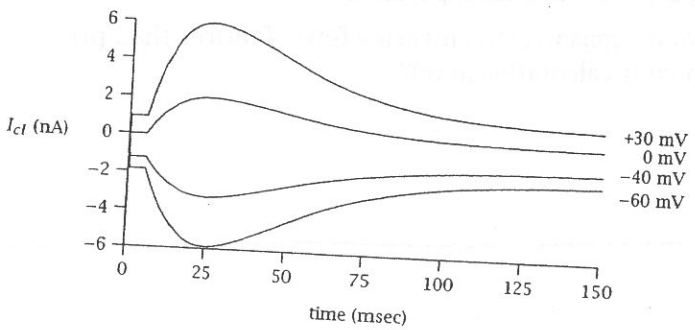
MCB 166 Problem Set #6

1. The traces shown in the figure below represent synaptic currents measured under voltage clamp. The given voltages are the holding potentials with respect to the resting potential.



(a) What are the conductance and the reversal potential for this synaptic input?

(b) Is the synapse likely to be excitatory or inhibitory?

(c) What is the approximate input resistance of the cell?

(d) What is the approximate decay time constant of the synaptic current?

(e) Is the decay time constant voltage dependent? Show the calculations that led to your answer.

(f) If V_{rev} is not equal to E_s, what does this tell you about this synapse?

2. You are voltage-clamping a neuromuscular junction at −80 mV (perfect space clamp), and you measure the following end-plate currents in response to low-frequency nerve stimulation: (EPCs, in nA) 0.3, 0.5, 0.7, 1.1, 1.5, 1.1, 0.9, 1.3, 1.1, 0.5, 0.5, 0.7, 0.7, 1.1, 0.5, 0.5, 0.9, 1.3.

(a) If you assume that $E_S = 0$ mV, what is the approximate synaptic conductance?

(b) Without any knowledge about miniature EPCs, what is the mean number of quanta released per stimulus?

(c) From your answer in (b), what is the predicted number of failures during a 1000-stimulus experiment?

(d) What are two reasons why you measure fewer failures than predicted from your calculation in (c)?

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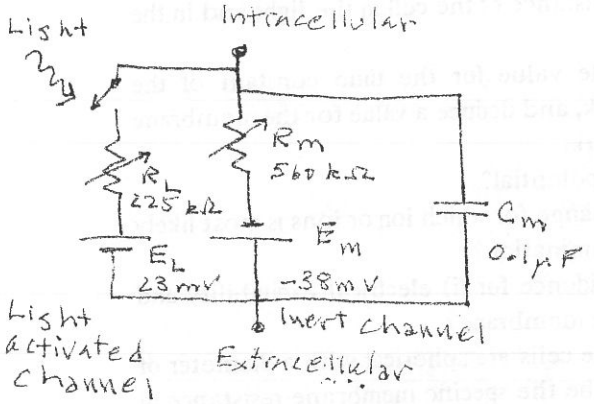
3. You have found that two putative neurotransmitters (X and Y) cause depolarization of isolated retinal horizontal cells and that both responses reverse at 0 mV. You want to determine whether X and Y use the same or different ligand-gated channels. You obtain the following results. In voltage clamp at V_{rest}, a saturating concentration of X alone causes a 2 nA inward current, and a saturating concentration of Y alone also causes a 2 nA inward current. Also, $G_{rest} = 10$ nS and $V_{rest} = -100$ mV. Assume that there is no desensitization and that the neuron is passive (no voltage-dependent conductances).

(a) If X and Y use the same channels, calculate the expected membrane potential (under current clamp) with X alone, with Y alone, and with X and Y together. Similarly, calculate the expected total current under voltage clamp at V_{rest} when X and Y are applied together.

(b) Repeat part (a) for the expected results if X and Y use different channels.

4. Analysis of Receptor Potentials

For this problem, it is convenient to think about an equivalent circuit of the receptor cell that illustrates the action of stimulating light.



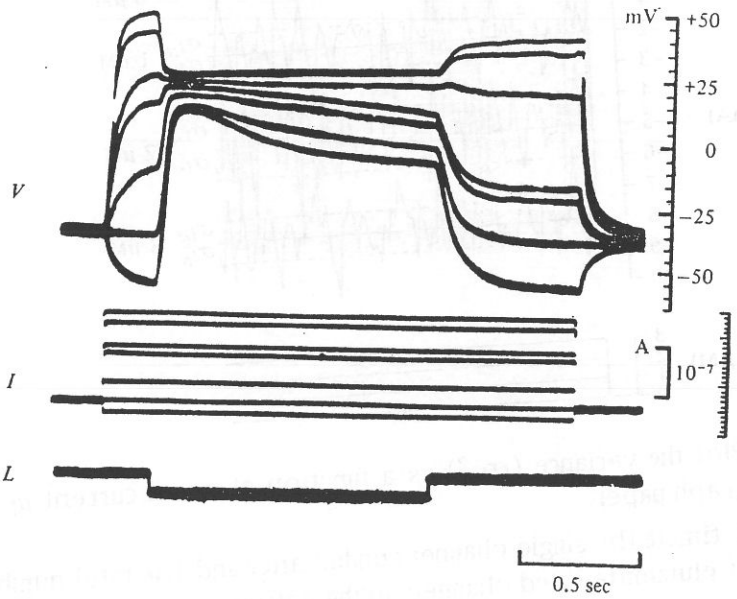
The values for the equivalent circuit parameters, are some of the answers to the problem, but you have to show how you get them from the data.

This problem concerns single visual cells in the ocellus of a barnacle (Brown, Hagiwara, Koike & Meech, 1970). Two glass microelectrodes were inserted into the cell, one to record membrane potential and the other to pass inward or outward current pulses. At the same time a standard flash of light could be given (Fig. 13.5).

Questions:

(a) Draw a text-figure graph of membrane potential against stimulus current, plotting curves for the receptor in the dark and after 0.5 sec in the light during the flashes.

Fig. 13.5. Membrane potential changes (V) during long constant-current pulses. Light flashes (L) were applied during the electrical stimuli. The middle trace (I) records the strength of the current (outward current is shown as an upward deflexion). (From Brown *et al.*, 1970.)



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(b) What is the input resistance of the cell in the light and in the dark?

(c) Give an approximate value for the time constant of the membrane in the dark, and deduce a value for the membrane capacitance in the dark.

(d) What is the reversal potential?

(e) What conductance change for which ion or ions is most likely to be the effect of illumination?

(f) Is there any clear evidence for (i) electrical excitability and (ii) rectification in the membrane?

(g) If you assume that the cells are spherical with a diameter of 100 μm, what would be the specific membrane resistance in the dark?

(h) Microvilli are known to be present on the cells; how would this fact affect your estimate of specific membrane resistance?

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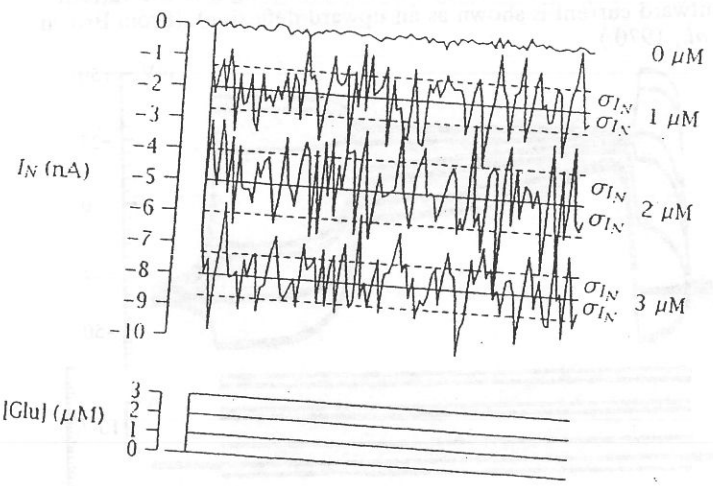
5. A neuron contains N identical channels that are gated by the neurotransmitter glutamate. Glutamate opens these channels and results in an inward Na^+ current (E_{Na} = +50 mV). The glutamate-induced currents in this neuron under voltage-clamp conditions (V_P = 10 mV) are given in the following diagram:



(a) Plot the variance ($\sigma_{I_N}^2$) as a function of mean current μ_I on graph paper.

(b) Estimate the single-channel conductance and the total number of glutamate-gated channels in the neuron.