

## Recitation 2 Worksheet

- 1) Thinking of an action potential in a squid axon, which contains voltage gated Na channels and voltage gated K channels, discuss the Na and K conductance in terms of:
- Mechanism of conductance increase
  - Kinetics of conductance increase
  - Mechanisms of inactivation
- 2) In a squid axon, at a time point ( $t_1$ ) early in an action potential, the membrane voltage,  $V_m$ , is -40 mV. At this time the membrane conductance to sodium ions,  $g_{Na}$ , is  $10 \text{ mS/cm}^2$ . The conductance of the membrane to potassium ions,  $g_K$ , is  $1 \text{ mS/cm}^2$ . You may assume for this problem that there is no chloride or leakage conductance. The membrane capacitance  $C_m$ , is  $1 \text{ } \mu\text{F/cm}^2$ . For this axon  $E_{Na} = +55 \text{ mV}$ , and  $E_K = -80 \text{ mV}$ . What is the membrane voltage at time  $t_2$ , 0.01 milliseconds after  $t_1$ ?

Answers:

- 1) The conductance of both voltage gated Na channels and voltage gated K channels increases with membrane depolarization (through the opening of activation gates). The conductance of Na channels increases much more rapidly, while the K channel shows a marked delay. Na channels have an inactivation gate (ball-and-chain model) which swings into the channel pore to block ion conductance, while for K channels, inactivation is indirect, when the membrane becomes sufficiently repolarized that one of the activation gates closes. (It is important to note that this is the case for the Hodgkin and Huxley voltage gated K channels, but that there are also other K channels that inactivate using a ball-and-chain mechanism).
- 2) For the answer to this question we take a turn around the predictive cycles used by Hodgkin and Huxley, going from conductance to current to  $dV/dt$ . One then multiplies  $dV/dt$ , the rate of voltage change, by the time interval to get the total change in the interval ( $t_2-t_1$ ) and adds it to the old voltage to get the new value

**First:**

$$I = g_{Na}(V_m - E_{Na}) + g_K(V_m - E_K)$$

$$I = 10 \frac{mS}{cm^2} (-40mV - 55mV) + 1 \frac{mS}{cm^2} (-40mV + 80mV)$$

$$I = -950 \frac{mS}{cm^2} * mV + 40 \frac{mS}{cm^2} * mV$$

$$I = -910 \frac{mS}{cm^2} * mV$$

$$I = -910 \frac{\mu A}{cm^2}$$

(Note that  $mS * mV = \mu A$  ( $10^{-3}S * 10^{-3}V = 10^{-6}A$ ))

**Second:**

$$I = -C * \frac{dV}{dt}$$

$$\frac{dV}{dt} = -\frac{I}{C} = \frac{910 \frac{\mu A}{cm^2}}{1 \frac{\mu F}{cm^2}} = 910 \frac{V}{sec} = 910 \frac{mV}{msec}$$

**Third:**

$$V_1 = V_0 + \frac{dV}{dt} * t$$

$$V_1 = -40mV + 910 \frac{mV}{msec} * 0.01msec$$

$$V_1 = -30.1mV$$

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