Quiz 6

Single neuron & Hodgkin-Hoxley model

October 31, 2023

1. (Inactivation Gate) When the axon is depolarized, imported sodium can propagate not only resting region but also repolarizing region. Then repolarizing region can be depolarized again. (Fig1) However, this situation is prevented in animal. Guess the reason.

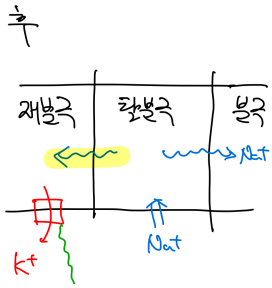


Figure 1: Highligthed arrow

2. (Threshold) What happens if external [Na^+] is not sufficient to make -55mV? (e.g. -60mV,...) This is called 'Threshold'.

3. (Equilibrium potential) By using Nernst equation to answer the following questions.

$$V_{out} - V_{in} = 0.0592 \log \frac{[Ion]_{in}}{[Ion]_{out}} \tag{1}$$

(a) Assuming that there is only K^+ (i.e. when the permeability of Na^+ is 0), the measured K^+ concentration is given by $[K^+]_{in} = 150\text{mM}$, and $[K^+]_{out} = 5\text{mM}$. Calculate the potassium equilibrium potential.

(b) Similar to (a), now consider only the Na^+. If the measured Na^+ concentration is given by $[Na^+]_{in} = 15\text{mM}$ and $[Na^+]_{out} = 145\text{mM}$, calculate the sodium equilibrium potential.

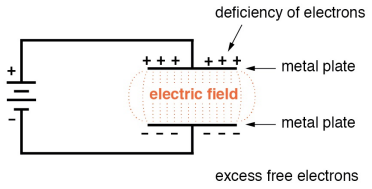
(c) Now consider both Na^+ and K^+. When the permeability of ions are $P_K = 50$ and $P_{Na} = 1$, calculate the membrane potential.[1]

[1] [Hint: You should get the result of $\sim -70\text{mV}$!]

4. (Hodgkin-Hoxley model) Write the Hodgkin-Hoxley model following the steps. (Do not see your notes. Just memorizing it or 'argue' it!)

(a) Write all the current generators. (e.g. membrane currents) And express total current with the sum of individual current generators (i.e. $I_{total} = I_{mem} + ...$). This means 'charge' conservation or Kirchhoff's law. Note that current is given by $I = \Delta q/\Delta t$, which means passing charge per unit time.

(b) (Membrane current) Due to Na-K pump, the intracellular region is kept negative at equilibrium. Generally, two region (intracellular / extracellular) has different charge. Express the membrane currenet by using Capacitance $C = c\frac{A}{d}$. where A is area of membrane, d is thickness of membrane.[2]



(c) (Ion flow) By using Ohm's Law, express the ion current with resistance $R = \frac{d}{gA}$ where the g is conductivity.[3]

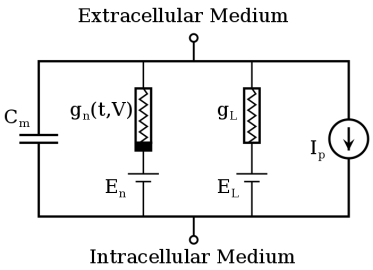


Figure 2: H-H model diagram

5. (Simple network) Now considering small network consisting some single neurons. Suppose that there are N single neuron is connected to one neuron (receiver). If the weight (connection strength) is given by w_i $(i = 1, ..., N)$, write the output neuron's current equation. Assuming that 'one-way' interaction (i.e. N neurons only send the information, and receiver only receives its.)

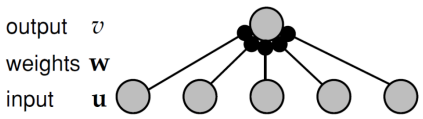


Figure 3: Small network

[2]Why this relation is satisfied? Rationally argue $C = c\frac{A}{d}$!
[3]repeat foot note 2 for R