Assignment 6
Applications of Goldman Voltage and Current Equations
Professor: Eric Schwartz – EC500

1 Permeability and Action Potential

In the squid axon, the ratio of permeabilities at rest is p_K to p_{Na} is 1.0:0.04. Use the following estimates of ionic concentrations: Intracellular K=400mM, Extracellular K=10 mM. Intracellular Na = 50mM. Extracellular Na = 460mM. Intracellular Cl = 60 Mm, Extracellular Cl=540mM

- Use the Goldman voltage equation to estimate the membrane potential, assuming that chloride is passively distributed, i.e. is in Nernst equilibrium. (Remember that the GCE describes a relation between current flux and concentrations for an ion.)
- At the peak of the action potential, the sodium permeability increases by a factor of 500. Estimate the peak voltage of the action potential, also using the GHK equation(s) and the above values for concentrations. Sketch the action potential implied by these calculations.

2 Current flux and the Goldman Equation

Using radioisotope tracers, ion fluxes were measured from isolated frog muscle fibers. The results were an observed sodium influx of $3.5 \cdot 10^{-12} mol \cdot cm^{-2} sec^{-1}$ and a potassium outflux of 8.8 (same units), and a potassium influx of 5.4 (same units). The membrane voltage was -90mv. The concentrations were $Na_{in} = 9.2mM$, $Na_{out} = 120mM$, $K_{in} = 140mM$,$K_{out} = 2.5mM$.

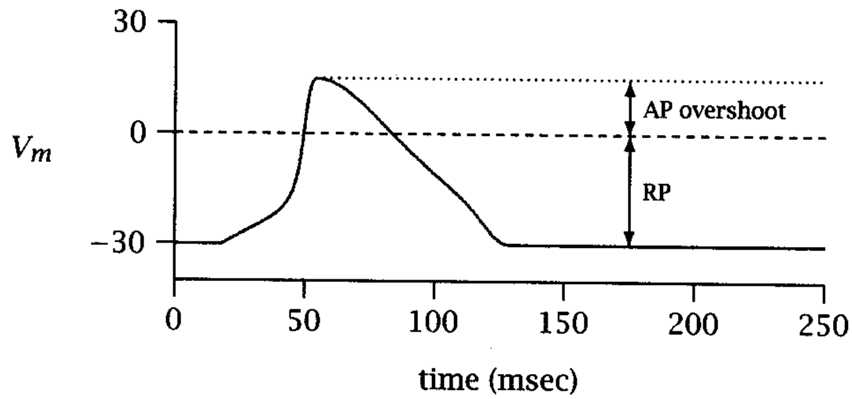
- Calculate the potassium and sodium permabilities from this data, using the GHK current equation. (Remember to use the form of the GCE that is appropriate for molar flux, rather than Amp flux).
- What is the resting potential of this cell if the membrane is permeable to K^+, Na^+ and Cl^-, but the Cl^- is distributed passively (i.e. at

equilbrium Nernst potential: hint, what is the current expected at Nernst equilibrium for an ion, and how did we use currents to derive the Goldman Voltage Equation?).

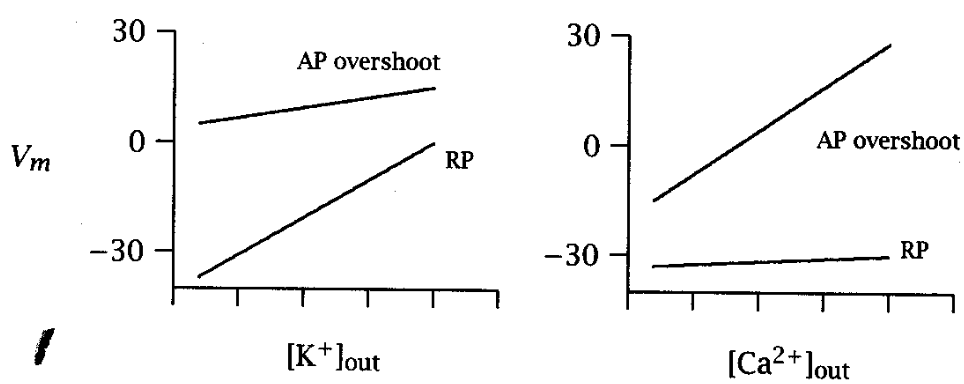
- Repeat for p_K/p_{Na}=0 and p_K/p_{Na}=1

3 Qualitative Action potential

The unicellular organism *Paramecium caudatum* shows a resting potential (RP) and an action potential (AP) that are similar in mnay repsects to neuronal resting and action potentials. With the cell in "typical pond water", the following measurements were made with an intra-cellular electrode:



If one varies $[K^+]_{out}$ only, or $[Ca^{+2}]_{out}$ only, one observes the following:



In the following questions, assume that the membrane of *P. caudautum* is normally permeable only to K^+, Ca^{+2}, and water.

a.) In the resting state, which of these is true? Explain concisely.

- $P_K > P_{Ca}$
- $P_K = P_{Ca}$
- $P_K < P_{Ca}$

b.) Which of the above three choices is true during the peak of the AP. Explain concisely.

c.) Compared to the ionic concentrations of "typical pond water," is $[K^+]_{in}$ greater than, equal to, or less than $[K+]_{out}$? Explain briefly.

d.) Compare also $[Ca^{+2}]_{in}$ to $[Ca^{+2}]_{out}$.

e.) When the organism is mechanically tapped, the membrane transiently hyperpolarizes. What permeability changes might be responsible? Explain briefly.is point, we have looked at three major derivations: