Unit 1 Exercise Questions

(1) Which mechanism is responsible for creating the gradient of Na^+ ions, and K^+ ions over membranes? What are the resulting approximate intracellular and extracellular concentrations of the two ions?

- Na^+/K^+ ATPase:

$$2\,K^+ \underset{ADP + P_i}{\overset{ATP}{\rightleftharpoons}} 3Na^+$$

⇒ Maintain the concentration gradients of Na^+ and K^+ (background activity)

- -

	$[X^+]_{intra}$	$[X^+]_{extra}$
Na^+	10 mM	145 mM
K^+	140 mM	3 mM

(2) Calculate the equilibrium potentials for K^+ ions (E_K), for Na^+ ions (E_{Na}) and for Cl^- (E_{Cl}) using the ion concentrations given in lecture.

Assume a temperature of 36 °C =36 +273 K = 309 K

Ions	Intracellular Concentration (mM)	Extracellular Concentration (mM)
K^+	140	~3
Na^+	~10	145
Cl^-	~5	125
Ca^{2+}	10^{-7} M	1.6

Nernst equation

$$E_K = \frac{RT}{zF} \ln \frac{[K^+]_o}{[K^+]_i}$$

Gas constant: $R = 8.314\ J\ K^{-1}\ mol^{-1}$

Faraday's constant $F = 9.648 * 10^4\ C\ mol^{-1}$

Elementary charge $e = 1.602 * 10^{-19}\ C$

J = C*V (Energy = electrical charge*voltage)

- $$E_{K^+} = \frac{8.314 \left(\frac{J}{K * mol}\right) * 309\ (K)}{96480 \left(\frac{C}{mol}\right) * (+1)} \ln \frac{3}{140}$$

$$= -0.102 \left(\frac{J}{C}\right)$$

$$= -0.102\ \text{(V)}$$

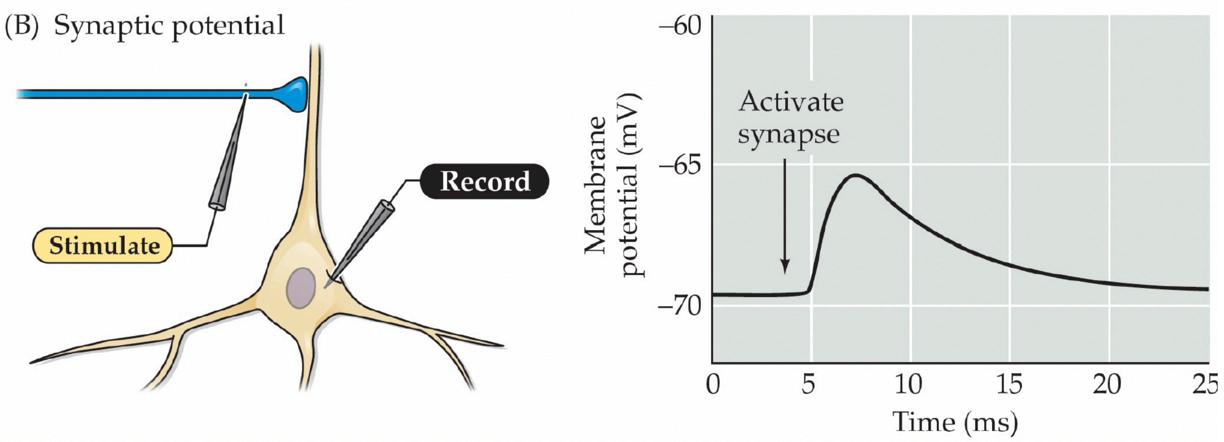
$$= -102\ \text{(mV)}$$

- $$E_{Na^+} = \frac{8.314 * 309}{96480 * (+1)} \ln \frac{145}{10} = +71.2\ \text{(mV)}$$

- $$E_{Cl^-} = \frac{8.314 * 309}{96480 * (-1)} \ln \frac{125}{5} = -85.71\ \text{(mV)}$$

(3) What is the "resting membrane potential" of a neuron? What is its typical value? Which ion is responsible for creating resting membrane potential?

Neurons have a negative "resting" membrane potential



- a microelectrode is inserted into a neuron
- note the *negative* resting membrane potential, ~ -70 mV before stimulation
- resting Vm, usually -60 to - 80 mV
- stimulation of an excitatory synapse causes a small EPSP, graded V_m change

V_m = membrane potential unit: [V], usually [mV]

- Resting Membrane Potential is the voltage (charge) difference across the cell membrane when the cell is **at rest**.
- typically –40 to –90 mV
- K^+

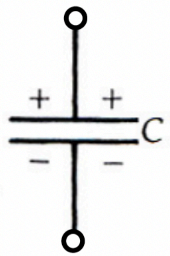
Which ion channel is responsible for creating resting membrane potential?

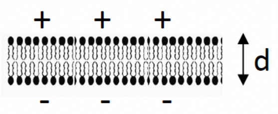
- K^+ leak channels

(4) Explain the electrical equivalent circuit of a simple neuron. Which structures of the cell membrane are equivalent to Cm and Rm ?

Analogy of the **phospholipid bilayer** to a **plate capacitor**
(I.e., impermeable to ions, can separate charge)

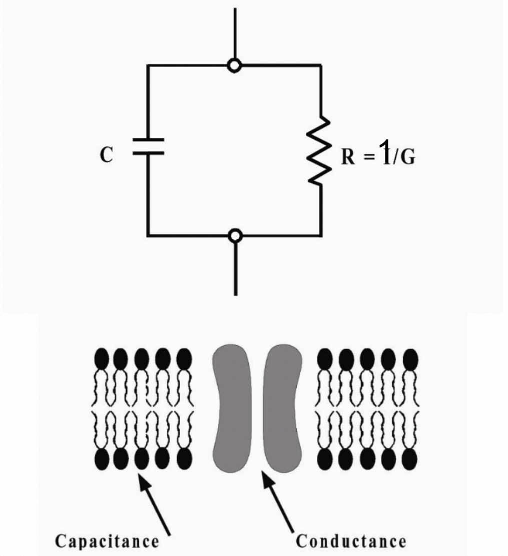
A plate capacitor separating electrical charge





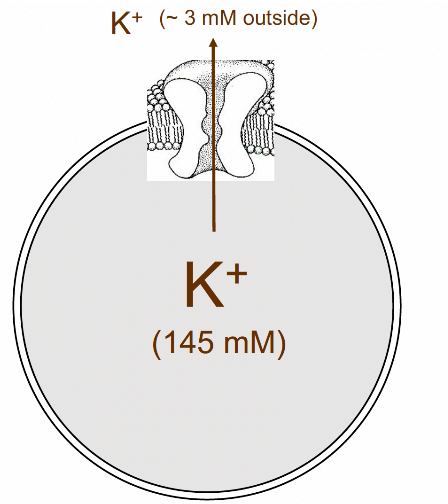
Phospholipid bilayer separating electrical charge

The **equivalent electrical circuit** of a cell:
parallel arrangement of capacitance (C_m) and resistance (R_m)



Phospholipid bilayer

Sum of all ion channels



$$I = G\,(Vm - E_{k+})$$

Summary of Unit 1: Important concepts and keywords

- Phospholipid bilayer permeability
- Concentrations of major ions (anions & cations) inside & outside of the cell
- Na^+/K^+ ATPase
- Equilibrium potential for an ion X; Nernst equation
- Resting membrane potential:
  - how is it measured?
  - how is it generated? (K^+ channel)
- Terminology:
  - depolarization, hyperpolarization
  - threshold
- Passive membrane properties
  - equivalent electrical circuit of a spherical cell
  - C_m and R_m
  - membrane time constant