Practice Problems for Membrane and Membrane Potential Lectures

1. Consider a frog living in a Vancouver pond. What are **two** differences you might expect to see in the composition of the cell membranes of this frog on a cool day in April (13°C) and on a warm day in August (30°C)? Clearly explain why you would expect to see **each** of these differences.

2. Consider two cells, X and Y. Both are epithelial cells, located in different regions of the same human body, but X has a faster rate of sucrose transport than Y. Suggest **two** possible reasons for this difference. Clearly explain why **each** difference could make sucrose transport faster in X than in Y.

3. You are studying flight muscle cells in bees, and have just discovered a new cell membrane protein in these cells. You think that this protein is involved in transporting fructose into these cells, but you are not sure what type of transport protein it is. What are two ways that you could distinguish between a pump (for primary active transport) and a permease?
Just for fun extra problem: Design a simple experiment that would allow you to clearly distinguish between these two options. (No technical details necessary, just describe what you would measure, what you would modify, and what results you would expect from a permease versus a pump. This sort of question is a good mental exercise, but would be too long and involved for a midterm question.)

4. The following table shows the intracellular and extracellular concentrations of four ions for an animal cell.

Ion	Intracellular concentration	Extracellular concentration
Potassium	400 mM	12 mM
Sodium	55 mM	450 mM
Calcium	0.0001 mM	10 mM
Chloride	56 mM	550 mM

a) Calculate the equilibrium potential (E_{ion}) for each of the ions listed in the table. The temperature is 20°C.

b) At rest, this cell membrane is only permeable to K^+, Na^+, and Cl^-. Calculate the membrane potential (E_m) for this cell using the above ion concentrations and the following ion permeabilities:
$P(K^+)= 1.0$
$P(Na^+)= 0.05$
$P(Cl^-) = 0.55$

c) If you wanted to depolarize this cell, which of the following manipulations would have the largest effect? (Hint: calculate E_m for each of these possibilities to see which causes the largest depolarization) Explain your answer.

1) Doubling external K^+
2) Reducing permeability of K^+ to 0.75
3) Increasing external Na^+ by 10 mM
4) Doubling Na^+ permeability
5) Decreasing the temperature to 1°C

5. The table below gives the intracellular and extracellular ion concentrations and membrane permeabilities for a human neuron. Normal human body temperature is 37°C.

Ion	Intracellular concentration (mM)	Extracellular concentration (mM)	Membrane permeability at rest
K^+	140	4	1
Na^+	15	145	0.05
Cl^-	4	110	0.1
Ca^{2+}	0.0001	5	0

a. What is the resting membrane potential of this neuron (in mV)?

b. This neuron contains ligand-gated Ca^{2+} channels. What will happen to the membrane potential of this neuron if neurotransmitter (the ligand) binds to these channels? (Be quantitative in your answer; what is the **maximum** possible change in membrane potential?)

c. During extreme dehydration, extracellular $[K^+]$ can increase to as high as 10mM. What would the membrane potential of this neuron be under these conditions? (Assume that all other ion concentrations remain unchanged. The Ca^{2+} channels are closed.)

d. In a condition called hypernatremia, extracellular $[Na^+]$ can increase to as high as 160mM. What would the membrane potential of this neuron be under these conditions? (Assume that all other ion concentrations remain unchanged. The Ca^{2+} channels are closed.)

6. Oxalate ($C_2O_4^{2-}$) is an anion that can contribute to the formation of kidney stones in mammals under certain conditions. Some epithelial cells of the small intestine contain a Cl^- / $C_2O_4^{2-}$ exchanger which excretes oxalate into the lumen of the small intestine. Consider the following concentrations for an epithelial cell of a human small intestine (temperature 37°C) with a resting membrane potential of -60mV:
Extracellular [Cl^-]: 200mM, Intracellular [Cl^-]: 15mM
Extracellular [$C_2O_4^{2-}$]: 0.062mM, Intracellular [$C_2O_4^{2-}$]: 0.00025mM

a. Calculate the equilibrium potential (E_{ion}) for each of these ions.

b. If Cl^- channels open under these conditions, will Cl^- ions move into or out of the cell? Clearly explain why.

c. How much energy (in Joules) would be generated if one mole of Cl- were to move in this direction (the direction you predicted in part b.)? Explain your answer.

d. How many molecules of Cl- must be transported down the electrochemical gradient in order to transport one molecule of oxalate out of the cell?

e. Is the exchanger Cl^- / $C_2O_4^{2-}$ electrogenic? Explain why or why not.

*Make sure to also try the "Question for Practice at Home" posted with the Clicker Questions for Lecture 5. The sample solution for this problem is posted with the question.