Homework is due at the beginning of Lecture (8:15AM) on Thursday, February 6th, 2020.

1. The ratio of open to closed forms of the acetylcholine receptor channel containing zero, one, and two bound acetylcholine molecules is $5\cdot10^{-6}$, $1.2 \cdot 10^{-3}$, and 14, respectively.

   a) By what factor is the open-to-closed ratio increased by the binding of the first/second acetylcholine molecule?
   b) What are the corresponding free-energy contributions to channel opening at 25 °C?

2.

Ions	**C_a (mM)**	**C_i (mM)**
Na^+	110	9.2
K^+	2.5	130
Cl^-	100	4

   a) Using the Nernst equation, calculate the individual potentials of the ions given in the table above. Assume RT/F = 61.5mV.
   b) To account for multiple ions, the Nernst equation has to be modified and the result is given by the *Goldman-Hodgkin-Katz* equation:

$$V_M = \frac{RT}{F} \cdot \ln \frac{P_{\mathrm{Na}} \cdot [\mathrm{Na}^+]_a + P_{\mathrm{K}} \cdot [\mathrm{K}^+]_a + P_{\mathrm{Cl}} \cdot [\mathrm{Cl}^-]_i}{P_{\mathrm{Na}} \cdot [\mathrm{Na}^+]_i + P_{\mathrm{K}} \cdot [\mathrm{K}^+]_i + P_{\mathrm{Cl}} \cdot [\mathrm{Cl}^-]_a}$$

   For a typical neuron at rest, P_K: P_{Na}: P_{Cl} = 1: 0.05: 0.45. Calculate the potential of nerve cell membrane.
   c) Is the value obtained from *Goldman-Hodgkin-Katz* equation equal to sum of individual ion potentials? Why or why not?

3. The resting membrane potential of a cell is about -70 mV at 37°C, and the thickness of a lipid bilayer is about 4.7 nm.
   a) What is the strength of the electric field across the membrane in V/cm? What do you suppose would happen if you applied this voltage to two metal electrodes separated by a 1-cm air gap?
   b) What is the equilibrium concentration ratio of extracellular to intracellular K^+?

4. Voltage clamp experiments, similar to the original Hodgkin and Huxley studies of squid giant axon were conducted, wherein the membrane potential starts in the resting state ($V_m = 0$) and is then instantaneously stepped to a new clamp voltage V_c.

a) Initially, with $Vm = 0$, the state variable n has a steady-state value (i.e., when $dn/dt = 0$) and when Vm is clamped to a new level Vc, the gating variable n will eventually reach a new steadystate value. Recall that the differential equation governing the state variable n is given by:

$$\frac{dn}{dt} = \alpha_n(V)(1-n) - \beta_n(V)n$$

What is the time course of the state variable n that controls gating of the K^+ channel, under these circumstances?

b) In neural simulation software packages, the rate constants in Hodgkin Huxley-style models are often parameterized using a generic functional form:

$$\beta(V);\alpha(V) = \frac{A + BV}{C + H\exp(\frac{V+D}{F})}$$

What values of the constants (A, B, etc.) should be substituted in the software package to obtain solutions for α_n, β_n, α_m, β_m, α_h, β_h as determined in the original Hodgkin and Huxley studies. Refer to their original paper for the actual values - *J. Physiol.* (I952) I I7, 500-544