Excitable Cell Physiology -- Problem Set #1:
Does the Migration of Ions from one Compartment to Another During the Establishment of a Donnan Equilibrium Significantly Affect Ionic Concentrations?

Review the concept of capacitance before attempting the second problem. Note that problem #2 is not like anything you will see on an exam but your ability to do it will mean that you have a good understanding of the ionic basis of the resting potential in cells.

Assume that we have a very simple cell where the cation (C^+) is the only diffusible species.

Further assume that the concentrations of C^+ are:

$[C^+]_{inside}$ = 0.1 M

$[C^+]_{outside}$ = 0.0019 M

and the temperature is 20° C.

1. Calculate the transmembrane potential for this system at equilibrium. (To make later calculations simple, round your answer to a whole number.)

2. The capacitance of a cell membrane is always normalized to area: it is expressed as farads/area. This is obviously necessary since bigger cells with bigger membranes would have larger capacitances (since capacitance is determined by the area of the conductors and the dielectric constant). For a typical biological membrane, the capacitance is about: 1 mF/cm^2, i.e., 10^{-6} Farads/cm^2.

$$\text{Recall that 1 Farad} = \frac{\text{coulomb}}{\text{volt}}$$

(a) Calculate the amount of charge stored across one cm^2 of membrane. Give your answer in coulombs per cm^2.

(b) For the Gibbs Donnan equilibrium you calculated above, find the number of mols of "missing" (on inside) or "excess" (on outside) C^+ per cm^2 of membrane. In other words, how many positive ions are out of position to establish the voltage seen at equilibrium for the situation described in the earlier problems? An alternative way to put this is that you are going to find the number of excess A- on the inside or C+ on the outside.

You will need the following constant:

1 Faraday of charge = 1 mol of univalent charged particles
= 96,500 coulombs/mol

(c) Use your answer in (b) to calculate the total number of excess – or missing + charges (univalent ions) on the inside (and vice versa on the outside) per cm^2.

(d) Now, assume that for this typical axon, we are concerned with a:
1 cm($1 * 10^{-2}$ m) long section with a
diameter of 10 μ ($1 * 10^{-5}$ meters).
What is the **number** of charged particles stored in a membrane capacitor of this surface area?

(e) How many charged particles are present in the cytosol of this same bit of axon (1 cm with a 10 micron diameter)?

(f) What is the ratio of the number of charges separated in the establishment of the Gibbs-Donnan Equilibrium to the # number of ions still inside the cell?

(g) In the establishment of a Gibbs Donnan equilibrium, is there any meaningful change in the concentrations of the ions inside the cell?