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 this problem.

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. <u>Calculate the transmembrane potential for this system at equilibrium</u>. (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.

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

(a) <u>Calculate the amount of charge stored across one cm^2 of membrane when the cell is at Gibbs-Donnan equilibrium</u>. Give your answer in coulombs per cm^2.

(b) <u>Calculate the number of mols of C^+ per cm^2 of membrane</u>. You will need the following constant:
1 Faraday of charge = 1 mol of univalent charged particles = 96,500 coulombs

(c) 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 ($10 * 10^{-5}$ meters).

Therefore, in this section, the axon has the following <u>**surface area**</u>:

= length * area = L * diameter pi = $1*10^{-2}$ m * pi * $1*10^{-5}$ m

$= 3.142 * 10^{-7}\ m^2 = 3.142 * 10^{-3}\ cm^2$

What is the number of charged particles stored in a membrane capacitor of this surface area?

(d) How many charged particles are present in the cytosol of this same bit of axon (1 cm with a 10 micron diameter)?
The internal concentration of C^+ was given at the start as 0.1 M. We can calculate the volume as:

= cross sectional area * length = $(\text{diameter}/2)^2$ * pi * L

= $(5*10^{-5}\ m)^2 * pi * 1*10^{-2}\ m = 7.85 * 10^{-13}\ m^3$

and since 1 cc = 1 ml = $10^{-6}\ m^3$ then the volume is, in ml:

= $7.85 * 10^{-7}$ ml

So, how many C^+ particles reside in this tiny volume if the concentration of C^+ is 0.1 M?

(e) 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?

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