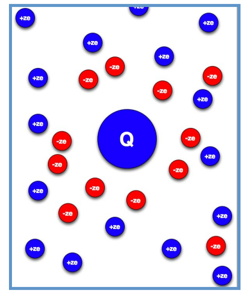
March 25, 2013 Physics 132 Prof. E. F. Redish

- **Theme Music:**
  Theory of Mind
  Time, Distance, Shielding
- **Cartoon:**
  Mark Parisi
  Off the Mark

Foothold ideas: Electric charges in fluids

- ***Electroneutrality*** – Opposite charges in materials attract each other strongly. Pulling them apart to create a charge unbalance costs energy. This tends to make small volumes of fluid electrically neutral.
- ***Energy-Entropy balances*** – When there are situations of non-uniformity, electrical forces (energy) can balance or be balanced by random thermal motion (entropy). Two important cases are:
  - **Debye shielding** – introduced unbalanced charge
  - **Nernst potential** – non-uniform concentrations of ions

Debye length equations



- Charge imbedded in an ionic solution.
  - Ion charge = ze
  - Concentration = c_0
  - Temperature = T
  - Dielectric constant = κ
- The ion cloud cuts off the potential

$$k_B T \sim \left[\frac{1}{\kappa}\frac{k_C q^2}{\lambda_D}\right]\left[c_0 \lambda_D^3\right] = \left[\frac{k_C q^2 c_0}{\kappa}\right]\lambda_D^2$$

$$\lambda_D = \sqrt{\frac{\kappa k_B T}{k_C q^2 c_0}}$$

$$V(r) = \frac{k_C Q}{\kappa r} e^{-r/\lambda_D}$$

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Reading question

- I am confused by this statement, "If the undisturbed concentration c_0 of salt ions increases, then the number of ions that have to be moved away from an even distribution in order to form the screening cloud is a smaller fraction of the total." What exactly is the undisturbed concentration?
- Why does the Debye length decrease as the concentration of salt ions increases? Shouldn't the length also increase because there would be more molecules present causing the screening cloud to be larger?

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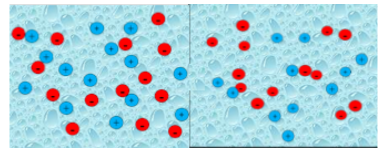
Nernst potential equations



- Different concentrations of ions across a membrane that is more permeable to one sign of ion than the other.
- More ions of that sign diffuse across building up a (small) charge difference which sets up and E field that eventually stops the flow of excess charges.

$$\frac{c_1}{c_2} = e^{-\Delta U / k_B T}$$

$$\Delta U = q\Delta V$$

$$\Delta V = \frac{k_B T}{q} \ln\left(\frac{c_1}{c_2}\right)$$

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Reading questions

- I know in neurons there are Sodium and Potassium channels that allow Sodium in (positive current inwards) and Potassium out (positive current outwards). Would these channels essentially be considered the battery because it controls voltage drop? Then, wouldn't the amount of channels have a bigger effect that the actual concentration of ions in and out because it would be like adding more batteries to the system?

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Reading questions

- How are the ion's tendency to move to one side of the membrane converted to a quantifiable number of probability? What is measured to say a certain ion has a certain probability to move across a membrane (so we can use in the Boltzmann distribution.) Are we characterizing the energy, entropy, or speed (or something else) that tells us about that molecule's likelihood to move in a certain direction across a membrane?

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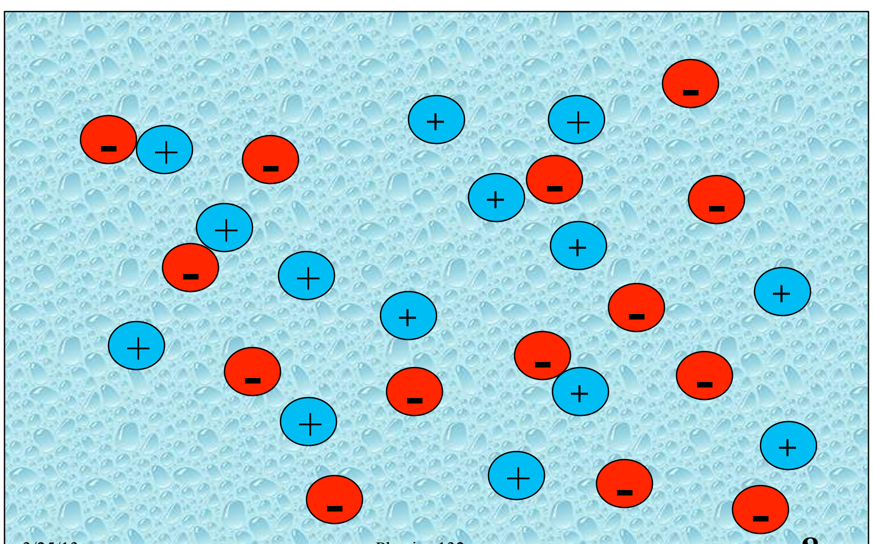
Fluid with K^+Cl^- dissolved.



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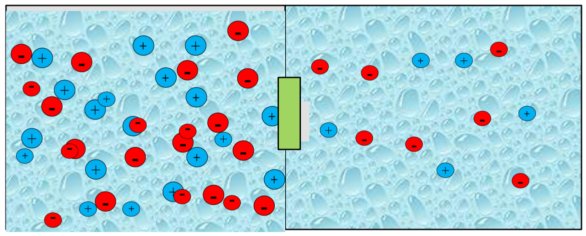
Does a concentration difference
lead to an electrostatic potential?



Does this concentration difference
lead to an electrostatic potential
if we open a **selective** ion channel?

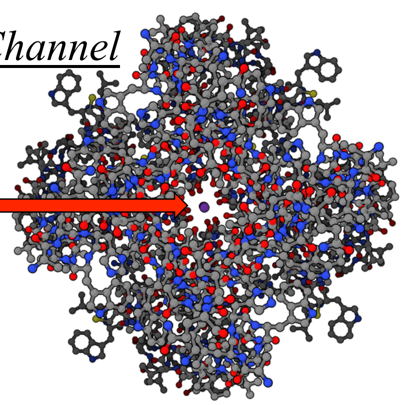
Biology Background:

Ion Channels that only let Sodium through
(channels for other types of ions also exist)

http://www.rcsb.org/pdb/explore/jmol.do?structureId=1BL8&bionumber=1

Top view of Na Channel

Ion in Channel!



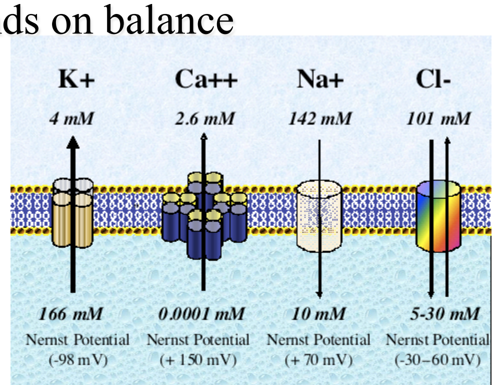
Nernst Equation

- Diffusion: Concentration gradient in the presence of ion channel → ions flow to equilibrate concentration
- Electrostatic potential: only one ion species can pass → electrostatic potential builds up → makes it less likely for ions to keep diffusing across channel

$$\Delta V = \frac{k_B T}{q} \ln\left(\frac{c_2}{c_1}\right)$$

Ions in a Cell

- Nernst potential requires ion specific channels (or pumps)
- Depends on balance



http://www.dev.urotoday.com