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Exercise 9 in FYS381 Biological Physics

Problem 1: Through one's pores (problem 7.1 in Nelson)

a) You are making strawberry shortcake (see Figure 1). You cut up the strawberries, then sprinkle on some powdered sugar. A few moments later, the strawberries look juicy. What happened? Where did this water come from?

b) One often hears the phrase "learning by osmosis". Explain what's technically wrong with this phrase, and why "learning by permeation" might describe the idea better.

Figure 1: Strawberry shortcake

Problem 2: Experimental pitfalls (problem 7.3 in Nelson)

You are trying to make artificial blood cells. You have managed to get pure lipid bilayers to form spherical bags of radius 10 μm, filled with hemoglobin. The first time you did this, you transferred the "cells" into pure water and they promptly burst, spilling the contents. Eventually you found that transferring them to a 1 mM salt solution prevents bursting, leaving the "cells" spherical and full of hemoglobin and water.

a) If 1 mM is good, then would 2 mM be twice as good? What happens when you try this?

b) Later you decide that you don't want salt outside because it makes your solution electrically conducting. How many moles per liter of glucose should you use instead?

Problem 3: Osmotic estimate of molecular weight (problem 7.4 in Nelson)

Earlier in the course we have discussed the use of centrifugation to estimate macromolecular weights, but this method is not always the most convenient.

a) The osmotic pressure of blood plasma proteins is at body temperature (303 K) usually about 28 mm of Hg where Hg stands for mercury. Note that 752 mm of Hg equals $1.01 \cdot 10^5$ Pa. The quantity of plasma proteins present has been measured to be about 60 g/L. Use these data to estimate the average molar mass M in g/mole for these plasma proteins, assuming the validity of the dilute limit.

b) The filtration coefficient of capillary membranes is sometimes quoted as $L_p = 7 \cdot 10^{-6}$ cm s^{-1} atm^{-1}. If we put pure water on *both* sides of a membrane with a pressure drop of Δp, the resulting volume flux of water is $L_p \Delta p$. Assume that a normal person has rough osmotic balance across his capillaries but that in a particular individual, the blood plasma proteins have been depleted by 10 %, as the result of a nutritional deficiency. What would be the total accumulation of fluid in interstitial space (liters per day), given that the total area of open capillaries is about 250 m^2? Why do you think starving children have swollen bellies?

Problem 4: Depletion interaction estimates (problem 7.5 in Nelson)

A typical globular protein can be viewed as a sphere of radius 10 nm. Cells have a high concentration of such proteins. For illustration, suppose that they occupy about 30 % of the interior volume.

a) Imagine two large, flat objects inside the cell (representing two big macromolecular complexes with complementary surfaces). When they approach each other closer than a certain separation, they will feel an effective depletion interaction driving them still closer, a force caused by the surrounding suspension of smaller proteins. Draw a picture, assuming that the surfaces are parallel as they approach each other. Estimate the separation at which the force begins. [Note: This is essentially a repetition of what we went through in the lectures.]

b) If the contact area is 10 μm^2, estimate the total free energy reduction when the surfaces stick. You may neglect any other possible interactions between the surfaces. As always, assume that you can use the van 't Hoff (dilute-suspension) relation for osmotic pressure. Is the total free energy reduction significant relative to $k_B T_r$?