E7: Depletion forces and osmotic pressure

Week 11. Due Wed 24 Mar 23:59, reviewed Thu 25 Mar

About 2 hours. Theory: Entropic forces, Osmosis and Nelson chapter 7.

1. Artificial blood cells

You make lipid bilayer vesicles of radius 10 µm filled with haemoglobin solution. Put in pure water, they burst. In 1 mM NaCl they stay spherical and intact (Nelson, Problem 7.3).

a. If 1 mM is good, is 2 mM twice as good? What happens to the vesicles in 2 mM NaCl?
b. You want no salt outside, so that the solution does not conduct electricity. What concentration of glucose should you use instead?

2. Molar mass from osmotic pressure, and oedema

a. The osmotic pressure of the proteins in blood plasma at body temperature (take 303 K) is about 28 mm Hg (752 mm Hg = 1.01×10^5 Pa). The plasma contains about 60 g/L of protein. Assuming a dilute solution, estimate the average molar mass of the plasma proteins (Nelson, Problem 7.4).
b. The capillary walls let water through: a pressure difference ΔP across them drives a volume flux (volume per area per time) $L_p \Delta P$, with $L_p = 7 \times 10^{-6}$ cm s^{-1} atm^{-1}. Normally the osmotic pressure of the plasma proteins roughly balances other forces across the capillaries. In an undernourished person, the plasma proteins are reduced by 10 %. How much fluid accumulates outside the capillaries per day, if their total open area is about 250 m^2? Why do starving children get swollen bellies?

3. Depletion forces in the cell

A typical globular protein is a sphere of radius about 10 nm. Suppose such proteins fill about 30 % of the cytoplasm (Nelson, Problem 7.5).

a. Two large, flat macromolecular complexes with matching surfaces approach each other face to face. Draw the depletion zones and estimate the separation at which a depletion force begins to act.
b. The contact area is 10 µm^2. Estimate the free energy gained when the surfaces stick, using the van 't Hoff relation for the osmotic pressure of the proteins. Compare with $k_B T$.
c. Is the van 't Hoff relation a good approximation here? Would the real depletion attraction be stronger or weaker?