E10: Block B recap, oral-exam style

Week 15. Due Wed 21 Apr 23:59, reviewed Thu 22 Apr

About 2 hours. This set rehearses the final oral exam. Choose **three** of the topics below. For each, prepare a 5-minute explanation at the board, and hand in one page with the figure you would draw, the key equations, and one number you would calculate. On Thursday, a few of you will give your explanation and get questions.

You may use an LLM to prepare, as you will before the exam. But check every equation and number yourself: the questions on Thursday go one step further than the prepared answer.

Topics

1. **Osmosis.** Derive the van 't Hoff relation from the picture of a dilute solute as an ideal gas, and then from the chemical potential of water. Why does only the number of particles count? Calculate the osmotic pressure of physiological saline against pure water.
2. **Chemical potential and diffusive equilibrium.** What is μ, and why does it, not concentration, decide where particles go? Show how an external potential enters, using the barometric formula or sedimentation as the example.
3. **Charges at membranes.** A membrane separates two NaCl solutions of different concentration and only Na can cross it. Draw how the ions, the charge density and the potential are distributed across the membrane. Where is the charge? How thick are the charged layers?
4. **Donnan equilibrium.** Set up and solve the equations for a cell with trapped macroions. Why is the result a problem for animal cells, and how do they solve it?
5. **Entropic forces.** Explain how a force can come from entropy alone, with two examples: the depletion force and the polymer spring. Why does a rubber band get stiffer when heated?
6. k_BT **and soft matter.** Compare k_BT with the energy of a covalent bond, a hydrogen bond, ATP hydrolysis, and the Born energy of an ion in a membrane. What does each comparison tell you about which structures in the cell are stable, which fluctuate, and which processes need a free energy source?