B: Entropy, ions and membranes

Weeks 10–15

Why does a cell burst in pure water? How can entropy create forces and order? Why is there a voltage across every cell membrane, and why does it cost the cell so much energy to keep it? We build up from multiplicity and the Boltzmann distribution to free energy, entropic forces, osmosis, the Nernst potential, Donnan equilibrium and ion pumps.

Reading

- Nelson, chapters 6–7 and sections 11.1–11.2
- Entropy, free energy and entropic forces (lecture notes)
- Processes at membranes: osmosis, osmotic flow, screening, Nernst and Donnan (lecture notes)
- Membrane potentials and ion pumps (lecture notes)
- Background, not curriculum: J. Liphardt et al., Reversible unfolding of single RNA molecules by mechanical force (2001), a two-state system measured one molecule at a time

Project 2: choose one elective

Choose by Sunday 14 March. Kick-off Tuesday 16 March, report due Sunday 25 April, defense Tuesday 27 April.

- 2A Freezing cells: the physics of cryopreservation
- 2B Nerve signals: from Nernst to Hodgkin–Huxley
- 2C Active cell layers: from Vicsek to epithelia

Weekly exercises

	Topic	Due
E6	Free energy, equilibration, the polymer as an entropic spring	Wed 17 Mar
E7	Osmotic pressure, oedema, depletion forces	Wed 24 Mar
E8	Cell volume, Debye screening, membrane capacitance, Born energy	Wed 7 Apr
E9	Donnan equilibrium in Python, the pump–leak steady state	Wed 14 Apr
E10	Recap in oral-exam style	Wed 21 Apr