Membranes and membrane transport

B2.1 · SL and HL

One boundary must separate, exchange and respond

A barrier can also provide selective pathways

Potato tissue can gain or lose mass in a solution. A nerve cell admits ions through one protein and expends energy to export ions through another.

Common content: bilayers, membrane proteins, simple and facilitated diffusion, osmosis, pumps, surface carbohydrates and selective permeability.

AHL: fluidity, vesicles, gated channels, sodium–potassium pumps, sodium-dependent glucose cotransport and cell adhesion.

Numerical datasets and calculations are invented teaching examples.

Put water on both sides of the bilayer

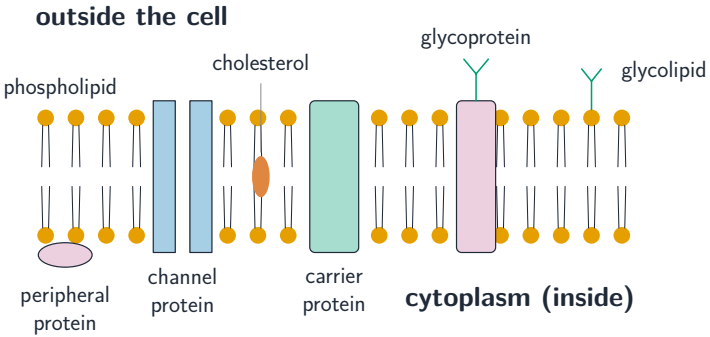
Amphipathic molecules form a hydrophobic interior

Hydrophilic phospholipid heads contact water outside and in the cytoplasm. Hydrophobic tails face inward, away from water.

The core restricts ions and many large polar molecules. Small non-polar molecules such as oxygen and carbon dioxide can cross more readily.

The membrane is selectively permeable, rather than completely impermeable. A plant cell wall is a separate structure and cannot replace this boundary.

Locate each component and identify its role



Integral proteins are embedded; peripheral proteins attach at a surface; carbohydrate branches face outward.

Fluid and mosaic describe different properties

Movement and diversity coexist with constraints

Many lipids and proteins move within the membrane plane. Attachments can restrict movement; not every protein drifts freely everywhere.

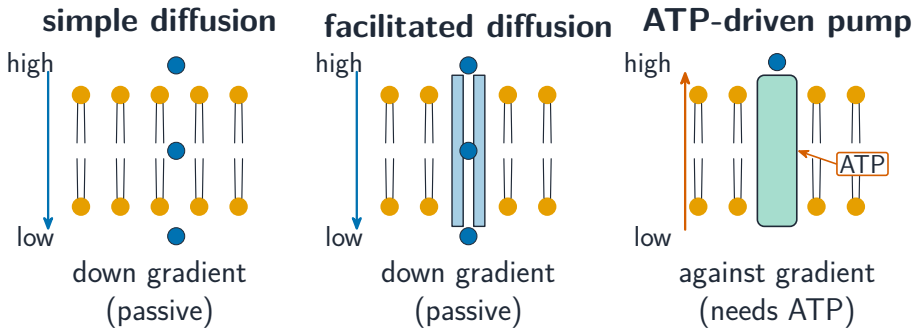
Integral proteins occupy one or both lipid layers; a transmembrane protein spans the bilayer. Peripheral proteins attach at a surface.

Proteins can act as channels, carriers, pumps, receptors, enzymes or attachment sites. A drawn shape alone does not establish a particular function.

Reverse a concentration gradient and predict net movement

1. **Oxygen higher outside.** Individual molecules move both ways, but more cross inward than outward. Net diffusion is inward under comparable conditions.
2. **Oxygen higher inside.** Net movement reverses. Oxygen is not permanently labelled an incoming substance.
3. **Equilibrium.** Random movement continues. Equal opposing transfers give no net concentration-driven transfer; molecules do not stop.

Distinguish a lipid pathway, a channel and an ATP-driven pump



Protein-mediated movement can be passive: a pathway through a protein does not by itself prove active transport.

A channel is selective rather than simply a wide hole

Ion movement depends on electrical as well as concentration differences

An open channel provides a hydrophilic pathway through the membrane core. Its molecular environment selects suitable particles.

An uncharged solute follows its concentration gradient during facilitated diffusion. Ion movement depends on the electrochemical gradient.

An open channel does not guarantee net entry. A closed channel does not remove the existing gradient.

Carriers bind solutes and change shape. Some mediate facilitated diffusion; others form part of active transport systems.

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Aquaporins allow rapid water movement without pumping it

State the pressure and permeability assumptions

Osmosis is net water movement through a selectively permeable membrane in response to a water-potential difference.

At equal pressure, with a solute that cannot cross, net water movement is generally from the more dilute toward the more concentrated solution. Pressure can oppose this tendency.

Aquaporins are water channels, not ATP-driven water pumps. Some water also crosses the lipid bilayer directly.

At zero net movement, opposing crossings can balance. A plant cell wall can resist expansion and generate pressure; an animal cell lacks that wall.

A stable concentration difference can require continuous energy

Balance in rates does not imply absence of transport

Active transport couples movement to an energy source and can move a substance against its gradient.

An ATP-driven pump binds particles and changes conformation through an energy-coupled cycle. It is not an open downhill channel.

Continuous pumping can balance leakage. Concentrations can remain approximately steady while transport and energy use continue.

Place carbohydrate chains on the extracellular face

Glycoproteins and glycolipids have different attachments

Glycoproteins have carbohydrate linked to protein; glycolipids have carbohydrate linked to lipid. Their external chains contribute recognition and interactions.

Some surface molecules help cells attach. Recognition, adhesion and transport are different functions; a surface carbohydrate is not automatically a channel.

Selective permeability emerges from the lipid core together with specific proteins, their distribution and their state.

Normalize a mass change to its initial mass

1. **Formula.** $\%$ change $= 100(\text{final} - \text{initial})/\text{initial}$.
2. **Examples.** $2.50 \to 2.75$ g gives $+10\%$; $4.00 \to 3.60$ g gives -10%; $6.40 \to 8.00$ g gives $+25\%$.
3. **Compare.** A gain of 0.25 g from 2.50 g is 10%; a gain of 0.40 g from 8.00 g is 5%. The larger raw gain is not the larger proportional gain.

Control sampling and handling before interpreting mass

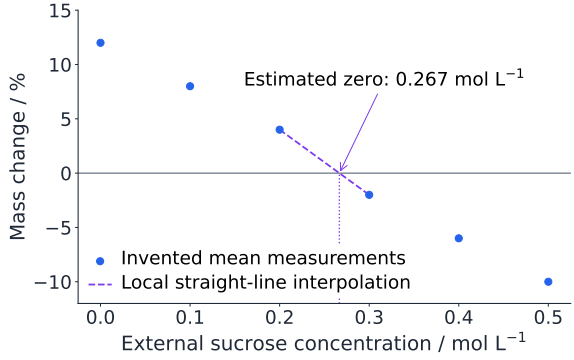
A tissue measurement depends on experimental assumptions

Control cylinder dimensions and source tissue, solution volume, temperature, time and the blotting procedure. Use independent repeats.

Assume intact membranes and a short enough interval for mass change to be dominated by water movement. Solute uptake or tissue breakdown can undermine that interpretation.

Blot external solution consistently. Repeats help estimate variability, but do not correct a miscalibrated balance or systematically misprepared solutions.

Interpolate locally between a gain and a loss



The zero estimates no net tissue mass change under the stated experimental conditions, not exact cytoplasmic composition.

Calculate and limit the interpolated zero

1. **Bracket.** At 0.20 mol L^{-1} mass change is $+4\%$; at 0.30 mol L^{-1} it is -2%.
2. **Interpolate.** $0.20 + [4/(4+2)](0.10) = 0.2667 \approx 0.267$ mol L^{-1}.
3. **Interpret.** Assume a locally linear relation and comparable samples. Water still moves at the zero; pressure and solute permeability limit any inference about internal concentration.

Match packing and temperature without a universal rule

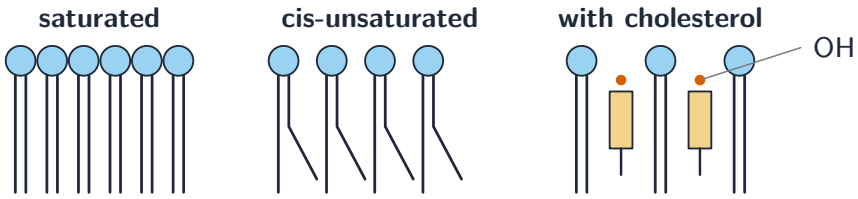
Cis unsaturation and cholesterol have different effects

Cis double bonds disrupt tight tail packing: shorter, more unsaturated tails help keep fluidity at low temperature; long saturated tails pack more readily.

Escherichia coli grown at higher temperatures makes more saturated, long-chain fatty acids: evidence from an organism, not an instant response of every membrane.

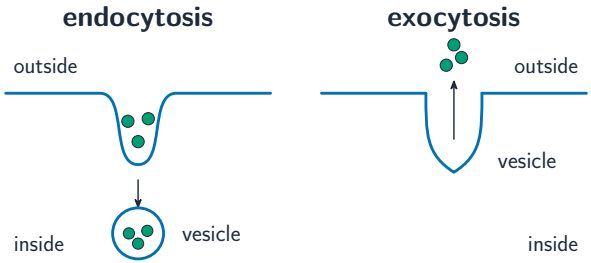
Cholesterol (OH near the heads, rings among the tails) restricts movement when warm and interferes with close packing when cold: it buffers fluidity, depending on temperature and membrane composition.

Tails and cholesterol set fluidity



Cholesterol steadies fluidity across temperatures

Track enclosed material rather than drawing it through a pore



Endocytosis encloses cargo in a vesicle; exocytosis releases vesicle contents when membranes fuse.

A vesicle lumen is an enclosed compartment

Distinguish membrane reshaping from molecular transport across it

A phagocyte can engulf a particle by endocytosis. The cargo initially enters an internal compartment, rather than freely entering cytosol.

Secretory vesicles release insulin by exocytosis. Fusion joins vesicle membrane to the cell surface and opens the enclosed contents to the exterior.

The boundary line in the schematic represents a bilayer. Vesicles and channels are different routes; a large particle does not pass through a small ion pore.

Compare two channel gates

Gate	Mechanism and consequence
Ligand-gated	A ligand binds and alters channel opening. Nicotinic acetylcholine receptors conduct cations.
Voltage-gated	Opening depends on membrane potential; voltage-gated sodium and potassium channels are examples.
Direction	An open ion channel conducts according to the electrochemical gradient. Gating is not ATP-driven pumping.

An acetylcholine receptor is not a sodium pump

Channel identity and electrical conditions determine current

Nicotinic acetylcholine receptors are cation channels, not sodium-only pumps. At a typical negative resting potential, their opening produces a net inward positive current and depolarization.

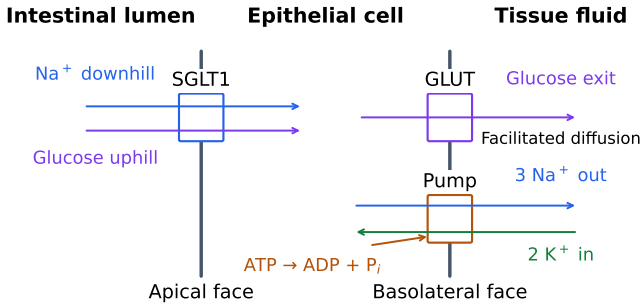
Voltage-gated channels respond to changes in membrane potential rather than to acetylcholine binding.

An ion does not require an ATP hydrolysis for each channel crossing. ATP-dependent pumps help maintain gradients used by these currents.

Count particles and net charge separately

1. **One usual cycle.** The pump exports 3 Na^+, imports 2 K^+ and hydrolyses 1 ATP. Binding, phosphorylation and conformational changes are coupled.
2. **Eight cycles.** 24 Na^+ out, 16 K^+ in, 8 ATP hydrolysed. Net positive charge exported: $24 - 16 = 8$ elementary charges.
3. **Function.** The pump maintains ion gradients and contributes to membrane potential. It is not the rapid sodium entry that produces an action-potential upstroke.

Trace the energy chain through a polarized epithelial cell



The pump maintains the Na^+ gradient; SGLT1 does not itself hydrolyse ATP.

ATP powers the basolateral pump; the sodium gradient couples to glucose uptake at the apical face.

Indirect energy coupling explains sodium–glucose cotransport

Keep apical and basolateral proteins distinct

At the apical intestinal surface, sodium moving downhill through a cotransporter can drive glucose uptake uphill from the lumen into the epithelial cell.

The basolateral sodium–potassium pump exports sodium to tissue fluid. A separate basolateral GLUT carrier allows glucose exit by facilitated diffusion when the gradient favours it.

SGLT does not directly hydrolyse ATP; it depends on the sodium gradient maintained using ATP. Removing ATP can therefore eventually impair uptake indirectly.

In the kidney proximal tubule, analogous transport reabsorbs glucose from filtrate toward blood. Different cotransporters can have different coupling ratios.

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State the coupling model before calculating

1. **Specified model.** For intestinal SGLT1, use 2 sodium ions entering per glucose molecule transported. Do not assume this ratio for every nephron transporter.
2. **Calculate.** 25 glucose molecules require $2(25) = 50$ Na^+ through this cotransporter in the model.
3. **Limit.** This is cotransporter accounting, not a complete ATP budget for an epithelium. Other sodium movements and cellular energy demands also occur.

Attachment has a different job from transport

Cell adhesion molecules help cells hold position and communicate

Cell adhesion molecules support attachment between cells or between cells and extracellular material. Specific interactions contribute tissue organization and mechanical stability.

Adhesion and junctions can help preserve epithelial barriers and distinct membrane faces. A transporter does not automatically perform this structural role.

Separate recognition, adhesion, channel opening, pumping and vesicle movement when explaining a membrane protein.

Common practice: structure and pathways

1. **Questions 1–4.** Draw both aqueous environments, classify integral/peripheral proteins, reverse an oxygen gradient and explain selective ion passage.
2. **Answers.** Heads face water, tails inward; an embedded protein differs from a surface-attached protein. Net oxygen diffusion reverses with its gradient; random crossings continue at equilibrium.
3. **Channel.** Its pore has selective chemical properties. Ion direction depends on voltage and concentration together, not merely which side has more ions.

Common practice: mass, zero and evidence

1. **Questions 5–11.** Explain aquaporins, pumps and glyco-conjugates; calculate percentage changes and a zero; evaluate controls and protein-mediated entry.
2. **Numbers.** Mass changes: $+10\%, -10\%, +25\%$; proportional gains 10% versus 5%; local zero 0.267 mol L^{-1}.
3. **Evidence.** Net zero does not stop water movement. Repeats do not remove systematic bias. A protein and downhill uptake do not establish active transport; ATP depletion may act indirectly.

AHL practice: lipid packing, gates and energy coupling

1. **Questions 12–13.** Explain low-temperature fluidity and cholesterol buffering; contrast vesicle routes, ligand gates and voltage gates.
2. **Question 14.** Eight pump cycles give 24 Na^+ out, 16 K^+ in, 8 ATP and net 8 positive charges out. A 2:1 cotransporter carries 50 Na^+ with 25 glucose.
3. **Explain.** ATP maintains a sodium gradient, which powers cotransport. Glucose exits by a separate carrier. Adhesion proteins support attachment rather than serving as the same transport pathway.

Check yourself

Use a mechanism rather than a membrane keyword

Put water on both sides and carbohydrate on the exterior. Distinguish integral and peripheral proteins.

Use initial mass in percentage change. A zero is an estimate under experimental assumptions, and a stable concentration may require continuing transport.

Protein-mediated uptake can be passive. State the evidence needed before assigning active transport.