



Membranes and membrane transport

Revision notes • IB Biology B2.1: lipid bilayers, simple diffusion, osmosis and aquaporins, channels and pumps, the fluid mosaic model and HL membrane transport.

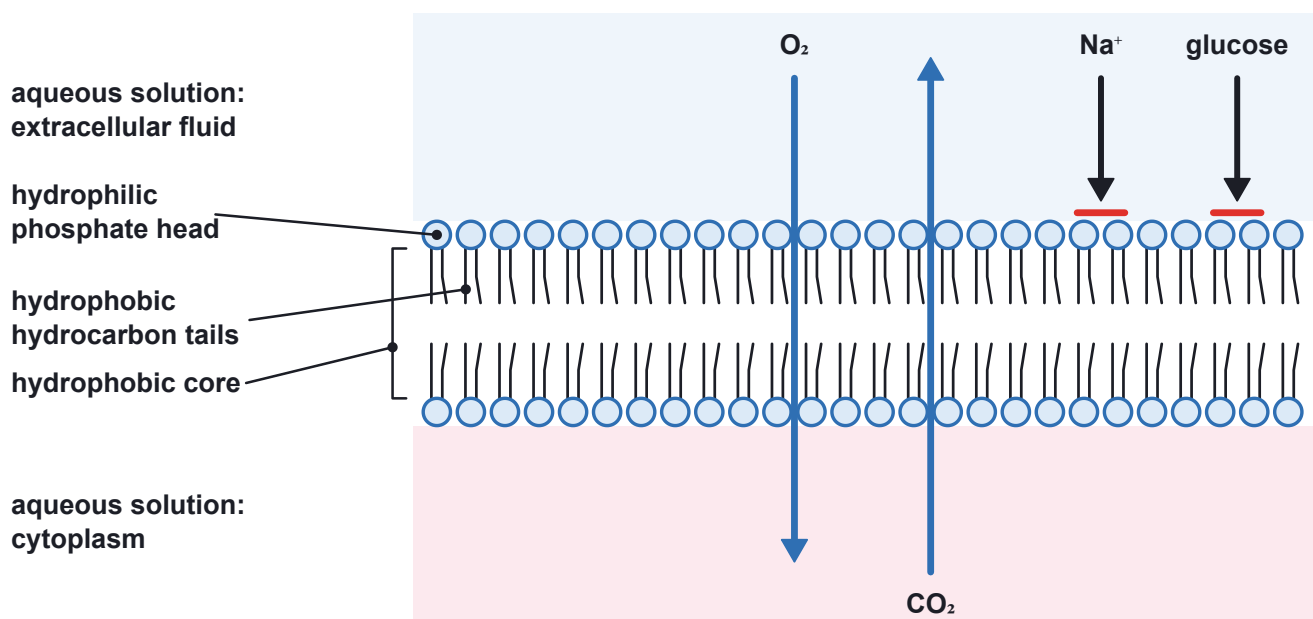
For IB Diploma Biology, Standard Level and Higher Level (first assessment 2025). **HL only** is additional higher level content, for HL students only.

Membranes and membrane transport Spec B2.1

Lipid bilayers, barriers and simple diffusion Spec B2.1.1-B2.1.3

A phospholipid is **amphipathic**: it has a hydrophilic (water-attracting) phosphate head and two hydrophobic (water-repelling) hydrocarbon tails. Other membrane lipids, such as cholesterol and glycolipids, are also amphipathic.

In water, phospholipids naturally arrange themselves into a **lipid bilayer**. The heads face outwards into the water on both sides and the tails point inwards, away from the water. The bilayer forms continuous sheets, which close up so that no tails are left exposed at an edge. No energy input is needed. This bilayer is the basis of every cell membrane.



O_2 and CO_2 diffuse between the phospholipids;
 Na^+ and glucose cannot enter the hydrophobic core

[\(opens full size in a new tab\)](#)

Small non-polar O_2 and CO_2 cross the **hydrophobic core**; ions such as Na^+ and polar molecules such as glucose cannot.

Bilayers as barriers

The hydrocarbon chains that form the core of the membrane are non-polar. Hydrophilic particles cannot easily enter this region, so the core has **low permeability** to large molecules and to hydrophilic particles,

including ions (such as Na^+ and Cl^-) and polar molecules (such as glucose). Membranes are therefore effective barriers between two aqueous solutions, such as the cytoplasm and tissue fluid.

Permeability of a lipid bilayer without membrane proteins		
Particle	Example	Crosses the hydrophobic core?
Small non-polar molecule	O_2 , CO_2	Yes, readily
Small polar molecule	H_2O	Slowly
Large polar molecule	Glucose	Hardly at all
Ion	Na^+ , K^+ , Cl^-	Hardly at all (charged)

Simple diffusion

Simple diffusion is the net movement of particles from a region of higher concentration to a region of lower concentration, caused by their random movement. It is passive: no energy from ATP is used. Oxygen and carbon dioxide are small and non-polar, so they diffuse directly between the phospholipids. In a respiring cell oxygen is used up, so it diffuses in; carbon dioxide is produced, so it diffuses out.

Common mistake: Particles do not move because of the gradient. They move randomly in all directions, but more cross from the side with the higher concentration, so the net movement is down the gradient.

Osmosis, channel proteins and pump proteins Spec B2.1.5-B2.1.8

Osmosis

Osmosis is the net movement of water molecules across a partially permeable membrane from a region of lower solute concentration to a region of higher solute concentration.

1. Water molecules move randomly and cross the membrane in both directions.
2. The membrane is impermeable to the solute, so solute particles stay on their own side.
3. On the side with the higher solute concentration, solute particles take up part of the solution, so the concentration of water molecules free to move across the membrane is lower there.
4. More water molecules therefore cross from the side with the lower solute concentration than move back, giving a net movement of water towards the higher solute concentration.
5. Osmosis is passive and continues while the difference in solute concentration remains.

Water is polar, so it crosses the lipid bilayer only slowly. **Aquaporins** are integral channel proteins that let water molecules pass through in single file, increasing the permeability of the membrane to water many times over. The pore is too narrow for most solutes, and charges inside it repel ions, so only water passes. Cells that move large volumes of water, such as kidney collecting duct cells and root cells, have many aquaporins.

Channel proteins and facilitated diffusion

Facilitated diffusion is passive diffusion of particles through a membrane protein. A **channel protein** is an integral protein with a hydrophilic pore through the membrane. The diameter of the pore and the charges lining it allow only specific ions (for example K^+) to pass. Many channels are gated: ions diffuse through when the channel is open but not when it is closed, so the cell can control permeability.

Pump proteins and active transport

Active transport is the movement of particles across a membrane against a concentration gradient, using energy from ATP. Pump proteins bind a specific particle on one side, use energy from ATP to change shape, and release the particle on the other side. Pumps move particles in one direction only, so they can build up concentration gradients.

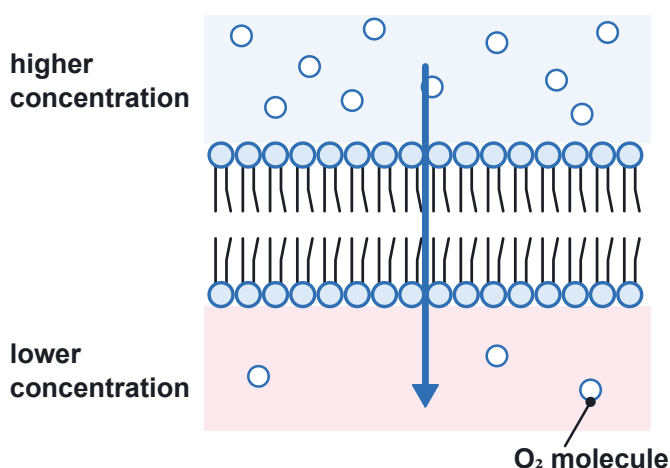
Comparing transport across membranes			
Feature	Simple diffusion	Facilitated diffusion	Active transport
Direction	Down the concentration gradient	Down the concentration gradient	Against the concentration gradient
Energy from ATP	No	No	Yes
Membrane protein	None (between phospholipids)	Channel protein	Pump protein
Selective?	No: depends only on size and polarity	Yes: specific ions	Yes: specific particles
Example	O ₂ and CO ₂	K ⁺ through a potassium channel	Mineral ions into root hair cells

Selectivity in membrane permeability

Facilitated diffusion and active transport give membranes **selective permeability**: the channel and pump proteins present decide which ions and molecules can cross. Permeability by simple diffusion is not selective. It depends only on the size of a particle and whether it is hydrophilic or hydrophobic.

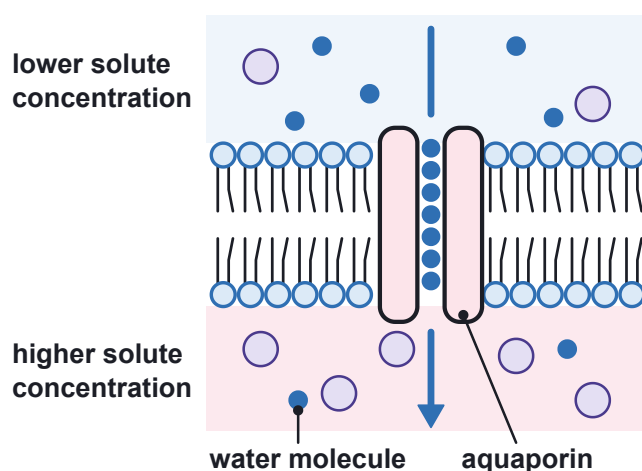
1 Simple diffusion

passive



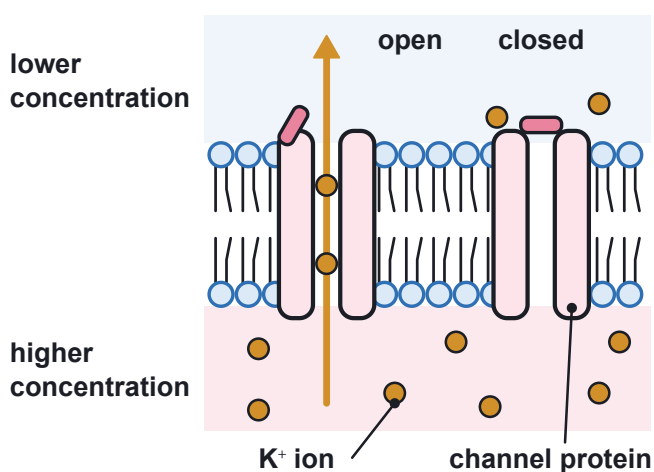
2 Osmosis (aquaporin)

passive



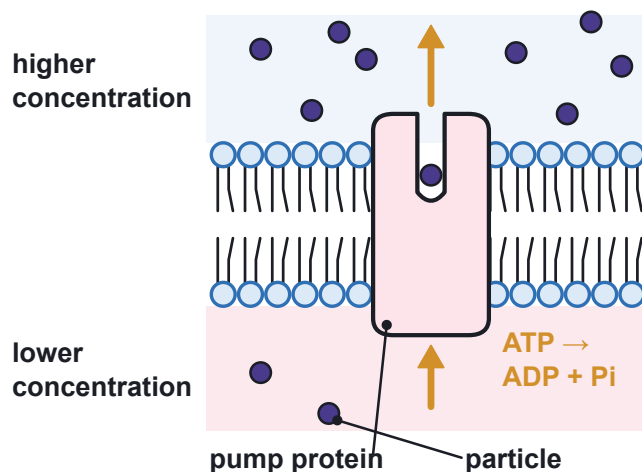
3 Facilitated diffusion

passive



4 Active transport

active



[\(opens full size in a new tab\)](#)

Diffusion, osmosis and facilitated diffusion are **passive**; pump proteins use ATP for **active transport** against the gradient.

Exam tip: Linking question: what processes depend on active transport? Think of mineral ion uptake by roots, nerve impulses and the absorption of glucose in the gut.

Membrane proteins, glycoproteins and the fluid mosaic model Spec B2.1.4, B2.1.9, B2.1.10

Integral and peripheral proteins

Membrane proteins have diverse structures, locations and functions. **Integral proteins** are embedded in one or both of the lipid layers. Those that span both layers have hydrophobic regions in contact with the hydrocarbon core and hydrophilic regions facing the water on each side. **Peripheral proteins** are attached to one or other surface of the bilayer, often bound to an integral protein, and do not enter the hydrophobic core.

- Transport: channels and pumps (integral proteins).
- Receptors: bind signalling chemicals such as hormones or neurotransmitters.
- Enzymes: catalyse reactions at the membrane surface.
- Cell adhesion: bind cells to each other.
- Cell recognition: identify a cell to other cells.

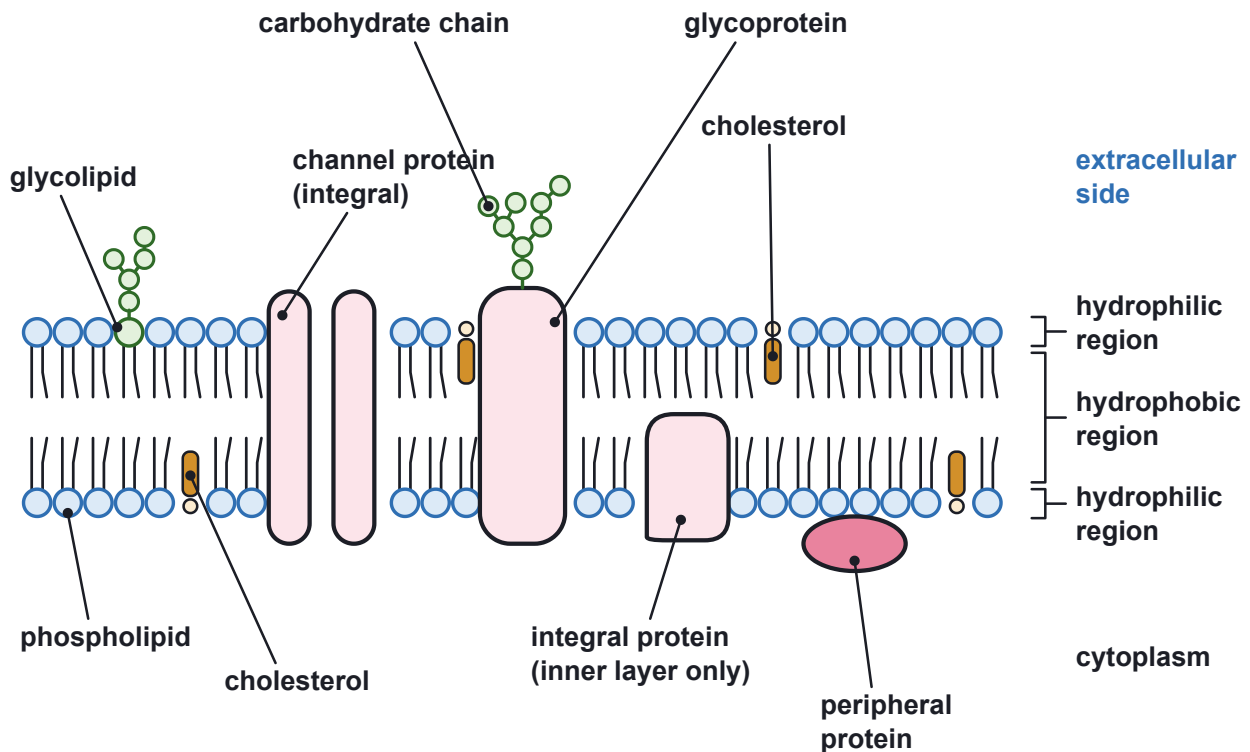
Glycoproteins and glycolipids

Glycoproteins are proteins with carbohydrate chains attached, and **glycolipids** are lipids with carbohydrate chains attached. In the plasma membrane the carbohydrate is always on the **extracellular side**, where it forms a sugary coat on the cell surface.

- Cell recognition: the carbohydrate chains act as markers, so other cells, such as cells of the immune system, can recognise a cell as self or non-self.
- Cell adhesion: carbohydrate chains help cells attach to each other to form tissues.

The fluid mosaic model

The membrane is described as **fluid** because phospholipids and many proteins can move sideways within each layer, and **mosaic** because proteins are scattered through the bilayer like tiles in a mosaic.



[\(opens full size in a new tab\)](#)

The fluid mosaic model: carbohydrate chains only on the **extracellular side**, cholesterol among the tails in the **hydrophobic region**.

Exam tip: In a drawing, put carbohydrate chains only on the outside, draw cholesterol among the tails, and label the hydrophilic and hydrophobic regions, not just the heads and tails.

Membrane fluidity, cholesterol and vesicles Spec B2.1.11-B2.1.13 HL only

Fatty acids and fluidity

Unsaturated fatty acids have one or more cis double bonds, which put kinks in the hydrocarbon chain. The chains cannot pack closely, so they have **lower melting points** and the membrane stays fluid, and therefore flexible, at the temperatures the cell experiences. **Saturated fatty acids** have straight chains that pack tightly. They have higher melting points and make membranes stronger at higher temperatures.

Organisms adapt membrane composition to their habitat. Fish adapted to the near-freezing waters around Antarctica have a higher proportion of unsaturated fatty acids in their membrane phospholipids than related fish from warmer waters, so their membranes do not become too rigid in the cold. Bacteria such as *Escherichia coli* increase the proportion of unsaturated fatty acids in their membranes when they grow at lower temperatures, and the proportion of saturated fatty acids when they grow at higher temperatures.

Cholesterol

In animal cell membranes, **cholesterol** sits within the bilayer. Its hydroxyl (-OH) group lies among the phosphate heads, and its rigid steroid rings and hydrocarbon tail lie among the fatty acid tails. Cholesterol acts as a **modulator** (adjustor) of membrane fluidity.

- At higher temperatures it restricts the movement of the phospholipid tails, stabilising the membrane.

- At lower temperatures it stops the tails packing closely together, preventing the membrane from stiffening.

Vesicles: endocytosis and exocytosis

Because the bilayer is fluid, membranes can bend, pinch off and fuse with each other, then reseal without leaking. Endocytosis removes a small area of plasma membrane as a vesicle; exocytosis adds the vesicle membrane back to the plasma membrane.

Endocytosis	The plasma membrane folds inwards around material outside the cell and pinches off to form a vesicle inside the cell. Example: phagocytosis of bacteria by white blood cells.
Exocytosis	A vesicle moves to the plasma membrane, fuses with it and releases its contents outside the cell. Examples: secretion of digestive enzymes by pancreatic cells; release of neurotransmitter at a synapse.

Common mistake: Do not just write that cholesterol makes membranes less fluid. It reduces fluidity at high temperatures but prevents stiffening at low temperatures.

Gated ion channels, sodium-potassium pumps and cotransporters Spec B2.1.14–B2.1.16

HL only

Gated ion channels in neurons

A **gated ion channel** opens or closes in response to a stimulus. Neurons use two kinds: neurotransmitter-gated and voltage-gated channels.

Gated ion channels in neurons			
Channel	Type of gate	What opens it	Effect
Nicotinic acetylcholine receptor	Neurotransmitter-gated	Acetylcholine binding to the receptor in the post-synaptic membrane	Positive ions, mainly Na ⁺ , diffuse in, depolarising the membrane
Voltage-gated sodium channel	Voltage-gated	Depolarisation of the membrane to the threshold potential	Na ⁺ diffuses in rapidly, depolarising the membrane further; the channel soon closes again
Voltage-gated potassium channel	Voltage-gated	Depolarisation (it opens more slowly than sodium channels)	K ⁺ diffuses out, repolarising the membrane

In each case the ions move by facilitated diffusion, down their concentration gradients. The gate only controls when the channel is open.

The sodium-potassium pump: an exchange transporter

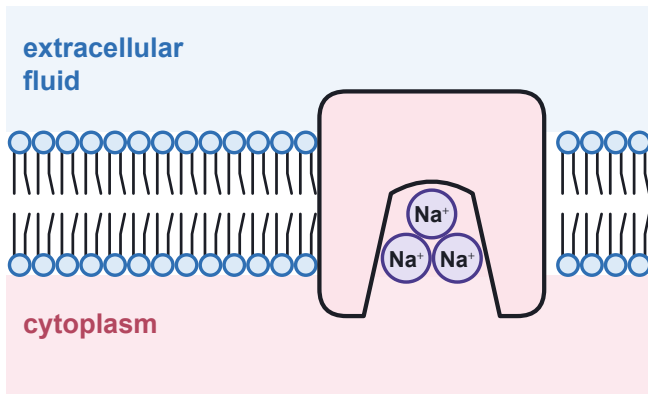
The **sodium-potassium pump** is an **exchange transporter**: in each cycle it moves two different ions in opposite directions, using energy from ATP.

1. Three Na⁺ ions from the cytoplasm bind to the pump.
2. ATP transfers a phosphate group to the pump. This changes its shape so it opens to the outside and releases the three Na⁺.
3. Two K⁺ ions from outside the cell bind to the pump.
4. The phosphate is released and the pump returns to its original shape, opening to the inside.

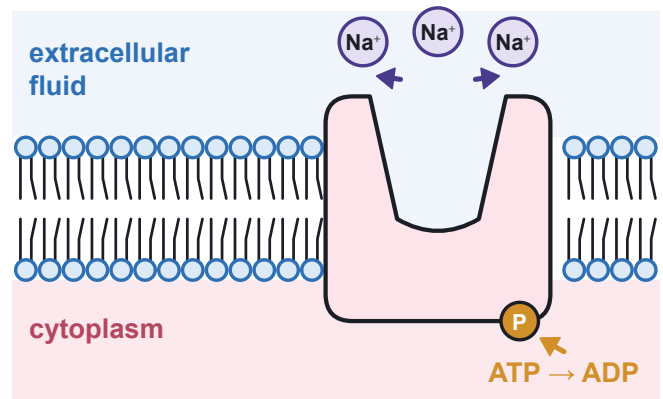
5. The two K^+ ions are released into the cytoplasm and the cycle repeats.

Each cycle removes one net positive charge from the cell and builds concentration gradients of Na^+ (high outside) and K^+ (high inside). This is how the pump helps to **generate membrane potentials**, including the resting potential of about -70 mV in neurons. The Na^+ gradient is also a store of energy that other transporters can use.

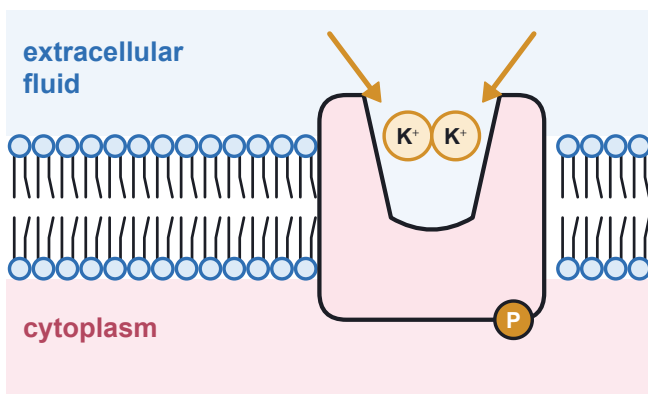
**Step 1: pump open to the cytoplasm:
3 Na^+ from the cytoplasm bind to the pump**



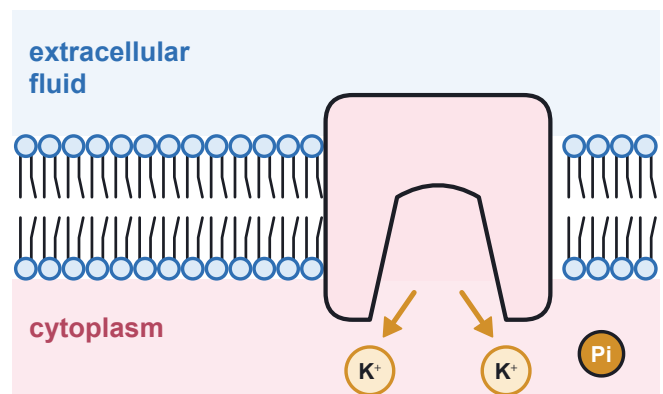
Step 2: ATP → ADP; phosphate attaches; the pump opens to the outside and releases 3 Na^+



**Step 3: 2 K^+ from the extracellular fluid
bind to the pump**



Step 4: phosphate released; the pump opens to the cytoplasm and releases 2 K^+



Na^+ concentration high outside the cell

K^+ concentration high inside the cell

each cycle: 3 Na^+ pumped out, 2 K^+ pumped in, 1 ATP used

[\(opens full size in a new tab\)](#)

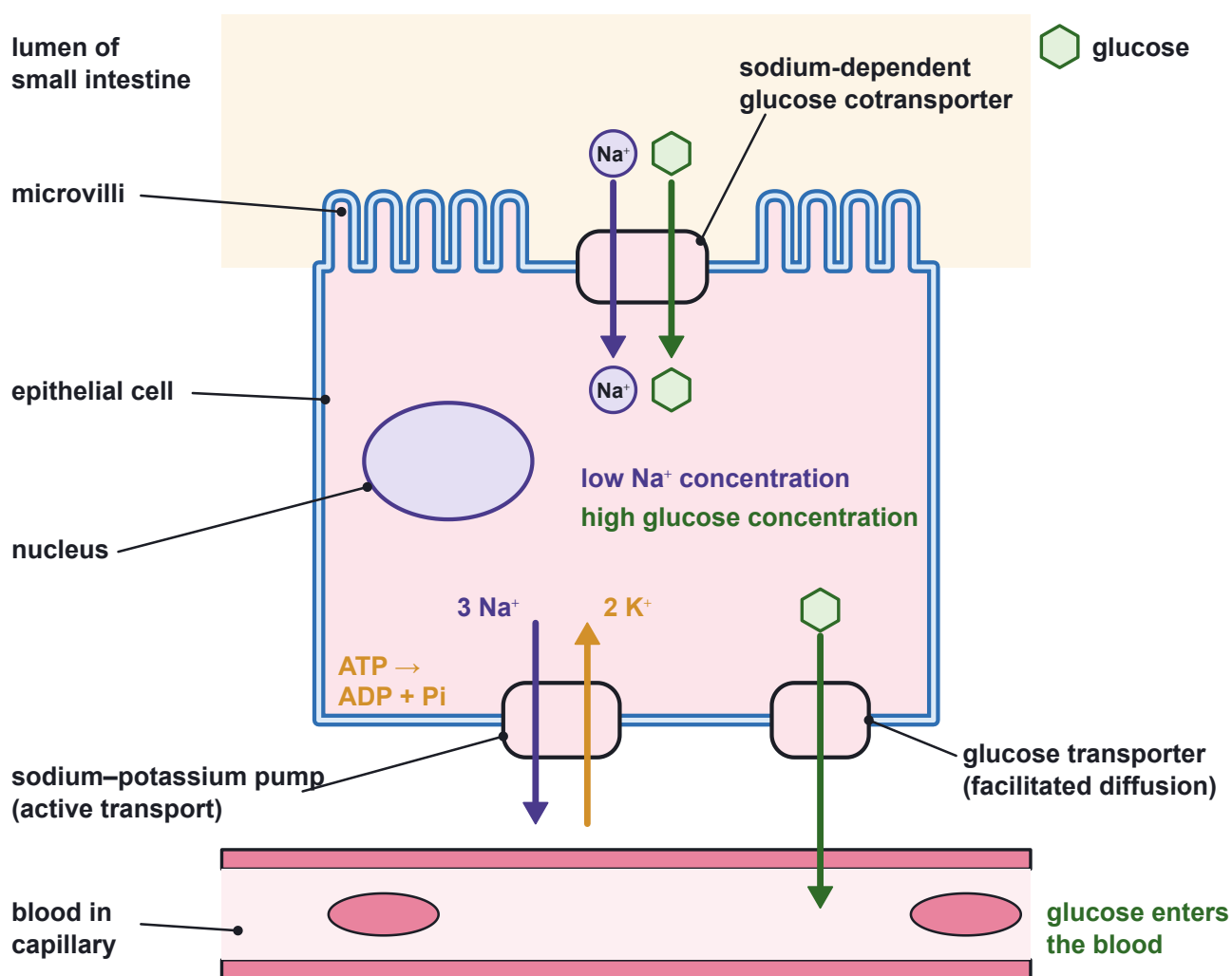
Each cycle pumps **3 Na^+ out and 2 K^+ in** using one ATP, keeping Na^+ high outside and K^+ high inside.

Sodium-dependent glucose cotransporters

Indirect active transport uses a concentration gradient made by one pump to move another particle against its own gradient. In a **sodium-dependent glucose cotransporter**, Na^+ diffuses into the cell down its concentration gradient and the protein uses this to carry glucose in at the same time, against the glucose concentration gradient. ATP is used only by the sodium-potassium pumps that keep the Na^+ concentration inside the cell low.

- Small intestine: cotransporters in the membrane of epithelial cells facing the lumen absorb glucose from digested food. The glucose then leaves the other side of the cell by facilitated diffusion and enters the blood.

- Nephron: cotransporters in proximal convoluted tubule cells reabsorb glucose from the filtrate, so normally no glucose is lost in urine.



[\(opens full size in a new tab\)](#)

Indirect active transport: the **sodium-potassium pump** keeps Na^+ low in the cell, so the **cotransporter** can bring glucose in against its gradient.

Exam tip: Call it **indirect active transport**: the cotransporter itself does not use ATP, but it depends on the ATP-driven sodium-potassium pump keeping Na^+ low inside the cell.

Adhesion of cells to form tissues Spec B2.1.17 HL only

In multicellular organisms, cells must stick together to form tissues. **Cell-adhesion molecules** (CAMs) are membrane proteins, usually glycoproteins, that project from the cell surface and bind to CAMs on neighbouring cells.

There are **different forms of CAM** for different types of **cell-cell junction**. Some junctions seal adjacent cells tightly so that fluid cannot leak between them, as in the epithelium lining the gut. Others anchor cells firmly so a tissue can withstand stretching, as in skin and heart muscle.

Exam tip: You need the term **cell-adhesion molecules (CAMs)** and the idea that **different CAMs form different junctions**. Names and details of individual CAMs and junctions are not required.

Quick check

1. Which part of a phospholipid is hydrophobic?
2. Name the channel protein that lets water cross membranes rapidly.
3. What does a pump protein use to move particles against a concentration gradient?
4. On which side of the plasma membrane are the carbohydrate chains of glycoproteins?
5. **HL only** How many Na^+ and K^+ ions does the sodium-potassium pump move in one cycle?

Quick check answers

Membranes and membrane transport

1. The two hydrocarbon (fatty acid) tails.
2. Aquaporin.
3. Energy from ATP.
4. The extracellular side.
5. Three Na^+ out and two K^+ in.