

Cambridge AS & A Level · Biology 9700 · Notes

Cell membranes and transport AS

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Read first: [Biological molecules](#), [Cell structure](#)

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What you need to know

By the end of this topic you should be able to:

Fluid mosaic membranes

1. **Describe the fluid mosaic model** of membrane structure, explaining how hydrophobic and hydrophilic interactions make phospholipids form a bilayer, and how the proteins are arranged in it.
2. **Describe where cholesterol, glycolipids and glycoproteins sit** in a cell surface membrane.
3. **Describe what each component does:** phospholipids, cholesterol, glycolipids, proteins and glycoproteins, in terms of stability, fluidity, permeability, transport (carrier proteins and channel proteins), cell signalling (cell surface receptors) and cell recognition (cell surface antigens).
4. **Outline the main stages of cell signalling:** a cell secretes a specific chemical (a ligand), the ligand is carried to target cells, and it binds to receptors on their cell surface membranes, leading to a specific response.

Movement into and out of cells

5. **Describe and explain** simple diffusion, facilitated diffusion, osmosis, active transport, endocytosis and exocytosis.
6. **Investigate diffusion and osmosis** using plant tissue and non-living materials such as dialysis (Visking) tubing and agar.
7. **Calculate surface areas and volumes** of simple 3-D shapes (cubes, cuboids, cylinders) to show that the surface area to volume ratio gets smaller as size increases.
8. **Investigate how the surface area to volume ratio affects diffusion**, using agar blocks of different sizes.
9. **Investigate plant tissue in solutions of different water potentials** and use the results to estimate the water potential of the tissue.
10. **Explain the movement of water** between cells and solutions in terms of water potential, and the different effects on plant cells and animal cells. (Solute potential and pressure potential are not needed.)

Understand it

Phospholipids make a bilayer

A phospholipid has a **hydrophilic head** (glycerol joined to a phosphate group, which is polar and charged) and two **hydrophobic tails** (fatty acid chains, which are non-polar). See Biological molecules for the structure.

Put phospholipids in water and they arrange themselves so that the heads touch the water and the tails are hidden from it. In a cell there is water on both sides (tissue fluid outside, cytoplasm inside), so they form **two layers**: in each layer the heads face outwards into the water and the tails point inwards, towards the tails of the other layer. This is the **phospholipid bilayer**. It forms by itself because of these hydrophilic and hydrophobic interactions, and it reseals itself if torn.

A triglyceride cannot do this: it has three fatty acid tails and no polar head, so it has no end that is attracted to water.

The bilayer is about **7–10 nm** thick. In an electron micrograph a membrane looks like a "railway track": two dark lines (the heads) with a paler line between them (the tails).

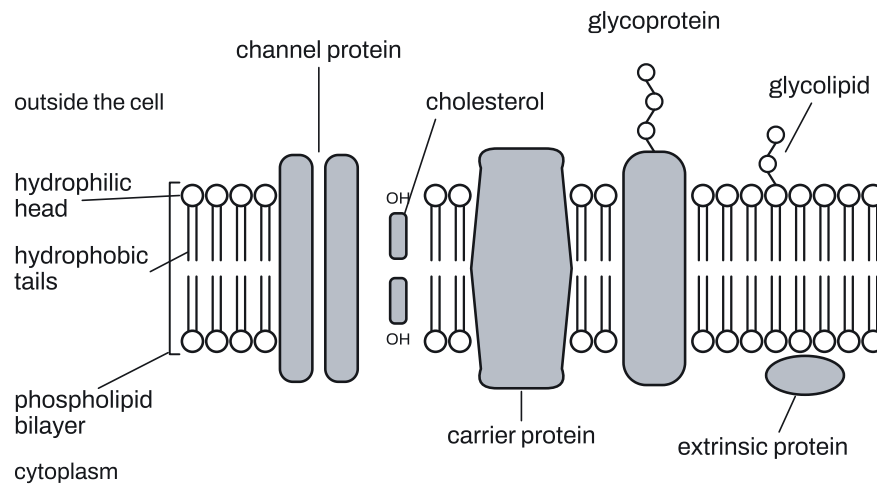
The fluid mosaic model

The model has two parts to its name.

- **Fluid**: the phospholipids are not fixed. They move sideways within their own layer all the time, and so do many of the proteins. In one experiment, the surface proteins of a human cell and a mouse cell were stained two different colours; when the cells were fused, the colours were completely mixed after about 40 minutes, so the proteins had drifted through the bilayer.
- **Mosaic**: proteins of different sizes and shapes are scattered through the bilayer like the tiles of a mosaic.

Some proteins span the whole bilayer (**intrinsic** or **transmembrane** proteins, such as channel and carrier proteins). The part of such a protein that sits among the fatty acid tails has amino acids with **hydrophobic (non-polar) R groups**, which interact with the tails and hold the protein in place; the parts that stick out into the water on each side, and the lining of a channel, have **hydrophilic (polar or charged) R groups**. Other proteins sit only on the inner or outer surface (**extrinsic** proteins).

- **Cholesterol** molecules sit between the phospholipids in **both** layers. Its small polar **OH group** lies next to the phosphate heads and its non-polar ring structure lies among the fatty acid tails.
- **Glycolipids** (a lipid with a carbohydrate chain) and **glycoproteins** (a protein with a carbohydrate chain) have their carbohydrate chains on the **outer surface only**, sticking out into the tissue fluid. Together these chains form a sugary coat called the glycocalyx.



What each component does

Component	Roles
Phospholipids	Form the bilayer, a barrier to ions and polar molecules (they can't cross the hydrophobic core) while small non-polar molecules pass through; their movement makes the membrane fluid, so it can bend, fuse with vesicles and pinch off (endocytosis, exocytosis, cytokinesis)
Cholesterol	Stability: it regulates fluidity. At high temperatures it holds the phospholipids together and stops the membrane becoming too fluid; at low temperatures it keeps them apart and stops the membrane becoming rigid. It also makes the bilayer less permeable to ions and polar molecules
Channel proteins	A water-filled pore that lets specific ions or polar molecules through (facilitated diffusion); some can open and close (gated)
Carrier proteins	Bind a specific molecule or ion and change shape to move it across (facilitated diffusion, or active transport when they use ATP, often called pumps)
Other proteins	Receptors, enzymes, and attachment to the cytoskeleton inside
Glycoproteins	Receptors for signalling molecules such as hormones (cell signalling); antigens for cell recognition (the immune system recognises "self" and "non-self"); stick cells together to form tissues
Glycolipids	Antigens for cell recognition; help cells stick to each other to form tissues; some act as receptors

Fluidity and permeability

How easily the phospholipids move decides how fluid the membrane is, and a more fluid membrane is usually more permeable.

- **Unsaturated fatty acids** have C=C double bonds that put **kinks** in the tails. Kinked tails can't pack closely, so the hydrophobic interactions between them are weaker and the membrane is **more fluid**. Saturated tails are straight and pack tightly.
- **Shorter fatty acid chains** have fewer interactions with their neighbours, so they also make the membrane **more fluid**.
- **Temperature**: warmer phospholipids have more kinetic energy and move more, so fluidity and permeability rise. Very high temperatures also **denature** membrane proteins, leaving gaps. Cold makes membranes stiffer.
- **Cholesterol** evens out these changes (see the table). Organisms that can't control their temperature, such as bacteria, yeast and fish, change the make-up of their membranes instead: more unsaturated or shorter fatty acids in the cold, fewer in the warm.
- **Solvents** such as ethanol dissolve lipids and denature proteins, so the membrane leaks.

A classic practical uses **beetroot**: the red pigment is held inside the vacuole by the tonoplast and the cell surface membrane. Discs heated to higher temperatures, or put into ethanol, let more pigment leak into the water, which you can measure with a colorimeter.

Cell signalling

Cells communicate with chemicals. The stages are:

1. A cell **secretes a specific chemical, the ligand** (for example a hormone or a peptide), often by exocytosis.
2. The ligand is **transported to target cells**, for example in the blood, or by diffusion through tissue fluid to cells nearby.
3. The ligand **binds to a receptor** on the cell surface membrane of the target cell. The receptor is usually a glycoprotein whose binding site has a shape **complementary** to the ligand, so only cells with that receptor respond.
4. Binding makes the receptor **change shape**, which **triggers events inside the cell** (signal transduction), often a chain of reactions in which one activated molecule activates many others, amplifying the signal. This leads to a **specific response**, such as secreting a hormone or switching on an enzyme.

The same ligand can cause different responses in different kinds of cell, because the events after the receptor are different. Lipid-soluble ligands such as steroid hormones can pass straight through the bilayer and bind to receptors inside the cell instead.

Diffusion

Diffusion is the net movement of molecules or ions from a region of higher concentration to a region of lower concentration, down a concentration gradient, as a result of their random movement. It is **passive**: the energy is the particles' own kinetic energy, not ATP. It carries on until the concentrations are equal (then particles still move, but equally in both directions).

Simple diffusion through the bilayer works for molecules that are **small and non-polar** or **lipid-soluble**, such as oxygen, carbon dioxide and steroids: they dissolve in the hydrophobic core.

The rate of diffusion is faster with a **steeper concentration gradient**, a **larger surface area**, a **shorter distance** (thinner membrane or barrier), a **higher temperature**, and **smaller** or more **lipid-soluble** particles.

The first three combine as

$$\text{rate of diffusion} \propto \frac{\text{surface area} \times \text{concentration difference}}{\text{thickness of the surface}}$$

Facilitated diffusion

Ions (such as Na^+ , K^+ , Cl^-) and polar molecules (such as glucose and amino acids) are repelled by the hydrophobic core, so they need a **transport protein**:

- **Channel proteins** have a pore lined with hydrophilic R groups. Each is specific to particular ions or molecules.
- **Carrier proteins** bind the molecule, change shape, and release it on the other side.

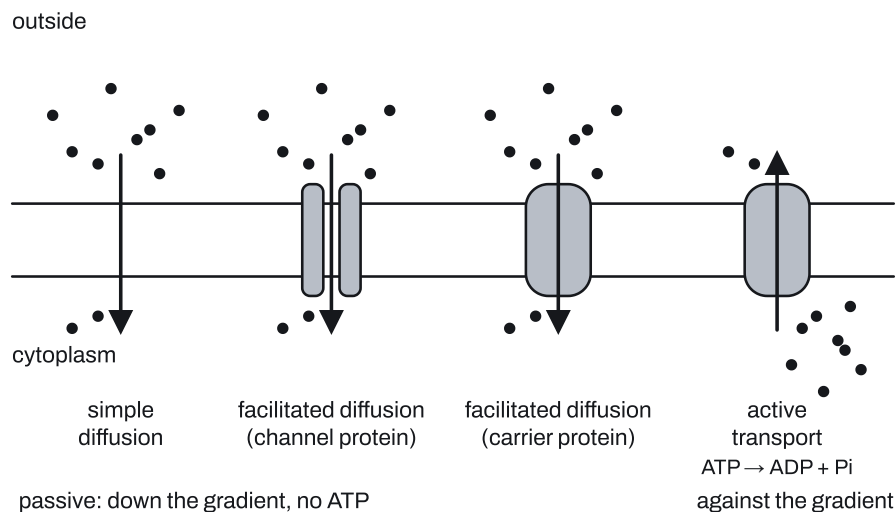
This is still diffusion: **down the concentration gradient, passive, no ATP**. Because each protein is **specific** and there are only so many of them, the rate rises with the concentration difference only until all the proteins are in use; then it levels off (a plateau). Adding more transport proteins raises the plateau.

Active transport

Active transport moves molecules or ions **against their concentration gradient** (from lower to higher concentration), using energy from **ATP** made in respiration. It uses **carrier proteins** (pumps), never channels. The ion or molecule binds, ATP is hydrolysed to ADP and phosphate, and the carrier **changes shape** to release it on the other side. Each carrier is specific.

A well-known example is the sodium–potassium pump. Cells that do a lot of active transport have many mitochondria. Anything that stops respiration (lack of oxygen, or a poison such as cyanide) stops active transport, and the ions then diffuse back down their gradients.

Some carriers move two substances together (**cotransport**): one moves down its gradient and drags the other up its gradient, as when companion cells in the phloem take up sucrose: proton pumps use ATP to move H^+ out of the cell, and the H^+ diffusing back in through a cotransporter protein carries sucrose in with it, against the sucrose gradient.



Endocytosis and exocytosis

These move **large amounts** of material, or large molecules, in **vesicles**. Both need **ATP** (to move the membrane and the vesicles) and neither depends on a concentration gradient.

- **Endocytosis** brings material **into** the cell. The cell surface membrane folds in or flows around the material and pinches off to form a vesicle inside the cell. **Phagocytosis** takes in solids (a phagocyte engulfing a bacterium); **pinocytosis** takes in liquid.
- **Exocytosis** releases material **out** of the cell. Vesicles bud off the Golgi body, move to the cell surface along microtubules, **fuse with the cell surface membrane** and release their contents outside. The vesicle membrane becomes part of the cell surface membrane, so the membrane area increases. Digestive enzymes, mucus, hormones such as insulin, collagen and cell-wall materials are all secreted this way.

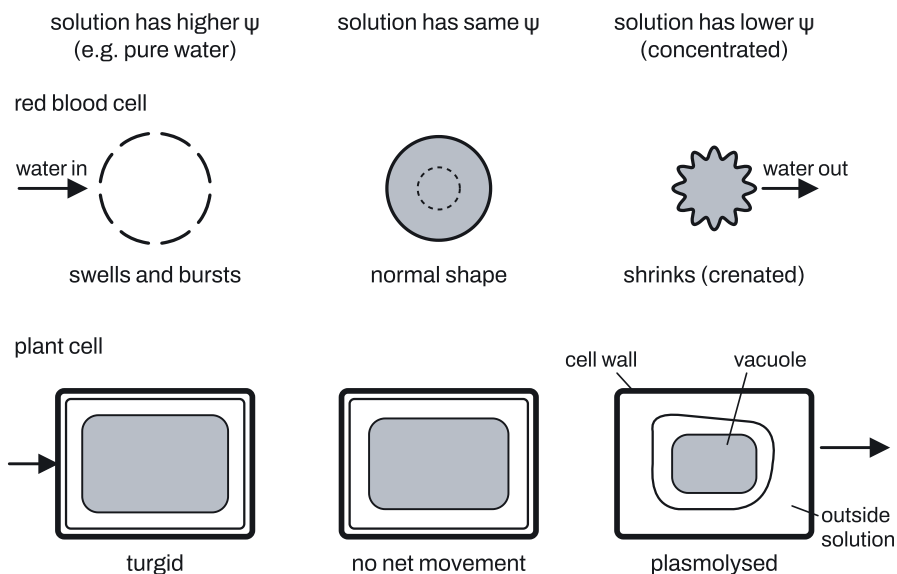
Water potential and osmosis

Water potential (ψ , measured in kPa) is the tendency of water to move out of a solution. **Pure water has the highest water potential, 0 kPa**. Dissolving any solute lowers it, so every solution has a **negative** water potential, and the more concentrated the solution, the more negative it is.

Osmosis is the net movement of water molecules from a region of **higher water potential** (less negative) to a region of **lower water potential** (more negative), through a **partially permeable membrane**. Water molecules cross in both directions all the time; osmosis is the **net** flow. When the water potentials are equal, the flows are equal and there is no net movement.

For example, water moves from a cell at -120 kPa to one at -300 kPa, and from that one to a cell at -750 kPa.

Animal cells and plant cells in solutions

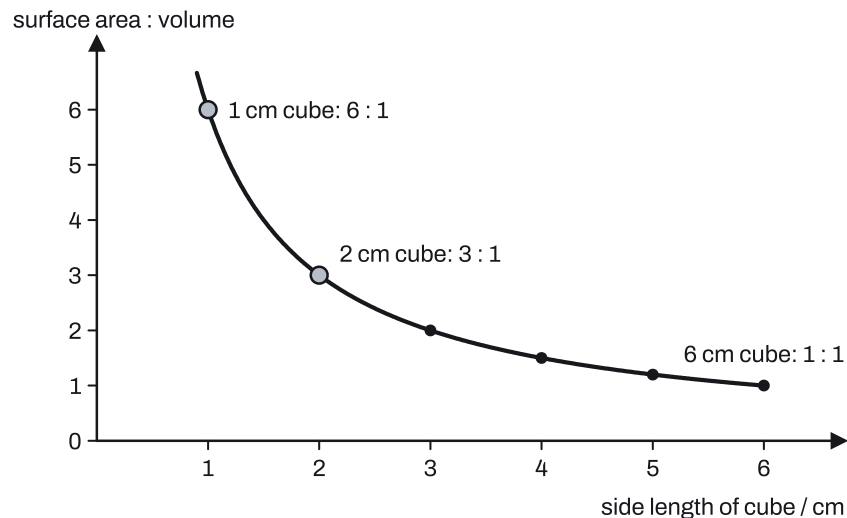


- **Animal cells have no cell wall.** In a solution with a higher water potential than the cytoplasm (such as pure water), water enters by osmosis, the cell swells and the membrane **bursts** (for red blood cells this is **haemolysis**). In a solution with a lower water potential, water leaves and the cell **shrinks** (red blood cells become crinkled, or **crenated**). This is why animal cells and organelles are kept in a solution with the **same** water potential: tissue fluid and blood plasma in the body, a salt solution when cells are grown in the lab, or an isotonic sucrose solution when organelles such as mitochondria are extracted.
- **Plant cells have a strong cell wall.** In a higher water potential, water enters the vacuole, the cell swells and presses on the wall, and the wall stops it bursting: the cell is **turgid**. In a lower water potential, water leaves the vacuole and cytoplasm, and the protoplast shrinks until the cell surface membrane **pulls away from the wall**: the cell is **plasmolysed**. The cell wall is **fully permeable**, so the gap between the wall and the membrane fills with the **outside solution**. The point where the membrane is just starting to pull away is **incipient plasmolysis**; at that point the cell's water potential equals that of the solution.

Surface area to volume ratio

Everything a cell needs (oxygen, glucose) and everything it gets rid of (carbon dioxide, waste) crosses its surface, but the demand comes from its whole volume. The **surface area to volume ratio (SA:V)** compares the two, written as $n : 1$.

For a cube of side 1 cm: surface area = $6 \times 1^2 = 6 \text{ cm}^2$, volume = $1^3 = 1 \text{ cm}^3$, SA:V = $6 : 1$. For a 2 cm cube: 24 cm^2 and 8 cm^3 , so $3 : 1$. For a 4 cm cube: 96 cm^2 and 64 cm^3 , so $1.5 : 1$.



Because area grows with the side squared but volume with the side cubed, **the bigger the object, the smaller its SA:V**. Doubling the side **halves** the ratio. Changing the shape matters too: 8 cm^3 as a 2 cm cube has SA:V 3 : 1, but as an $8 \times 1 \times 1\text{ cm}$ strip it has $34 : 8 = 4.25 : 1$. Flat or long thin shapes have a large SA:V and a short distance to the middle. This is why small organisms can rely on diffusion alone, while large ones need gas exchange surfaces and transport systems, and why cells stay small.

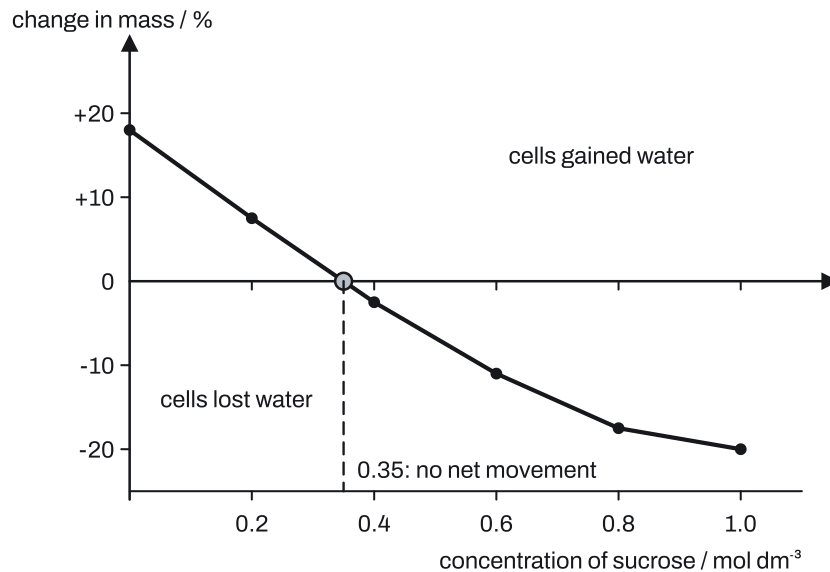
The agar block practical. Agar is mixed with an indicator (for example cresol red or phenolphthalein) and cut into cubes of different sizes. The blocks go into acid (or alkali), which diffuses in and changes the colour from the outside inwards. The **smallest** block, with the **largest SA:V** and the **shortest distance to its centre**, changes colour completely first. Keep the same volume of acid, concentration and temperature, and time each block.

Investigating diffusion and osmosis

- **Visking (dialysis) tubing** is a non-living partially permeable membrane with tiny pores. Water and small molecules (glucose, iodine, ions) pass through; large molecules (starch, proteins) do not. Fill a bag with, say, starch and glucose, stand it in water, and test the water: Benedict's test turns positive but the iodine test doesn't, so only glucose left the bag. To show osmosis, fill tubing with a solution, attach a capillary tube or measure the level, and put it in water or a different solution: the level rises if water moves in and falls if it moves out.
- **Plant tissue.** Cut equal cylinders of potato (or discs of beetroot, or strips of onion epidermis), blot and weigh them, and leave them in a range of sucrose concentrations. Weigh again and work out the **percentage change in mass**, so that pieces with different starting masses can be compared:

$$\text{percentage change} = \frac{\text{final mass} - \text{initial mass}}{\text{initial mass}} \times 100$$

Plot it against concentration. Where the line **crosses zero**, there was no net movement of water, so the solution there has the **same water potential as the tissue**. Using onion epidermis instead, count the percentage of cells that are plasmolysed; where 50% are plasmolysed (incipient plasmolysis on average), the solution's water potential equals the cells'.



Key facts and formulas

None of these are in the syllabus's list of mathematical formulae, so they are all "Learn it". Questions usually print the cylinder formulas when they use a cylinder.

Formula	Status
Cube of side L : surface area = $6L^2$, volume = L^3	Learn it
Cuboid $a \times b \times c$: surface area = $2(ab + ac + bc)$, volume = abc	Learn it
Cylinder of radius r , length h : surface area = $2\pi r^2 + 2\pi rh$, volume = $\pi r^2 h$	Learn it
SA:V = $\frac{\text{surface area}}{\text{volume}}$, written as $n : 1$	Learn it
Percentage change = $\frac{\text{final} - \text{initial}}{\text{initial}} \times 100$	Learn it
Rate of diffusion $\propto \frac{\text{surface area} \times \text{concentration difference}}{\text{thickness}}$	Learn it
Pure water has $\psi = 0$ kPa; solutions have negative ψ ; water moves from higher (less negative) to lower (more negative) ψ	Learn it
Membrane thickness about 7–10 nm	Learn it

Which process needs what:

Process	Direction	Membrane protein?	ATP?
Simple diffusion	Down the gradient	No	No
Facilitated diffusion	Down the gradient	Yes: channel or carrier	No
Osmosis (water)	Higher to lower ψ	No (water also passes through channel proteins)	No
Active transport	Against the gradient	Yes: carrier (pump)	Yes
Endocytosis, exocytosis	In (endocytosis) or out (exocytosis); not down a gradient	No (vesicles)	Yes

How to do it

We have tagged 162 questions on this topic from 2021–2025: 125 multiple choice on Paper 1 and 37 structured questions on Paper 2. 12 of them mix types, so the counts add up to 179.

Question type	Questions
Identify, compare and explain transport mechanisms	36
Identify membrane components, their arrangement and roles	30
Calculate SA:V and predict diffusion time	27
Predict and explain water movement by water potential	19
Interpret plant-tissue osmosis investigations	16
Explain factors affecting fluidity and permeability	13
Describe, identify or sequence endocytosis and exocytosis	12
Outline the stages of cell signalling	11
Interpret Visking tubing or model-cell experiments	7
Deduce the transport mechanism from data	4
Draw and label a membrane diagram	4

1. Identify, compare and explain transport mechanisms (36 questions)

- Decide what the substance is like.** Small and non-polar or lipid-soluble (O_2 , CO_2 , steroids): simple diffusion through the bilayer. Ions or polar molecules (Na^+ , K^+ , Cl^- , glucose, amino acids): they need a channel or carrier protein. Very large molecules or particles (proteins, bacteria): vesicles.
- Decide the direction.** Down the gradient with no ATP: diffusion (simple or facilitated). Against the gradient: active transport.
- Name the protein** if there is one, and say whether ATP is used.

Comparing facilitated diffusion and active transport (a common 3-mark part):

- Similarity: both use **specific transport proteins** in the membrane; both can move ions and polar molecules.
- Differences: facilitated diffusion goes **down** the gradient, active transport **against** it; facilitated diffusion is **passive** (no ATP), active transport **uses ATP**; facilitated diffusion can use **channels or carriers**, active transport uses **carriers only**.

Variations you will meet:

- **"Which processes use ATP?"** Active transport, endocytosis (including phagocytosis) and exocytosis. **Never** facilitated diffusion or osmosis.
- **Completing a table** of letters A–D on a diagram: type of movement, the part of the membrane used, and an example substance, reading the numbers of particles on each side to see the direction.
- **Why an ion can't cross by simple diffusion:** it is charged, so it is repelled by (can't dissolve in) the hydrophobic fatty acid tails of the bilayer.
- **A poison that stops respiration** (cyanide, a mitochondrial inhibitor) stops active transport, endocytosis and exocytosis, but not diffusion.
- **Cotransport:** one substance moves down its gradient through a carrier and takes another with it against its gradient.

2. Identify membrane components, their arrangement and roles (30 questions)

1. **Name the part from its shape and position:** bilayer of phospholipids (heads out, tails in); proteins spanning the bilayer (channel, carrier) or on one surface (extrinsic); small molecule among the tails with an OH by the heads (cholesterol); protein or lipid with a branching chain on the **outside** (glycoprotein, glycolipid).
2. **Give the role** from the table in "Understand it", using the syllabus words: stability, fluidity, permeability, transport, cell signalling (receptors), cell recognition (antigens).

Variations you will meet:

- **Polar or non-polar?** Phosphate heads are polar and face outwards; fatty acid tails are non-polar and face inwards.
- **Why cholesterol sits the way it does:** its OH group is polar, so it lies next to the polar heads; the rest is non-polar, so it lies among the tails.
- **Where the carbohydrate chains are:** on the outer surface only, for both glycoproteins and glycolipids.
- **Evidence that proteins move:** the fused-cell experiment, where two dyes mix over time.
- **R groups of a transmembrane protein:** hydrophobic in the section inside the bilayer, hydrophilic in the sections outside it.
- **Other membranes:** the bacterial cell surface membrane is also a phospholipid bilayer. A Gram-negative bacterium's outer membrane has lipopolysaccharide in its outer layer and lacks cholesterol, glycoproteins and glycolipids.

3. Calculate SA:V and predict diffusion time (27 questions)

1. **Find the surface area:** add up the area of every face. For a cuboid $2(ab + ac + bc)$; use the given formula for a cylinder.
2. **Find the volume.**
3. **Divide** surface area by volume and write it as $n : 1$. Keep the units the same (all mm or all cm).
4. **Predict:** the block with the largest SA:V (smallest block, or thinnest shape) takes the shortest time to change colour all the way through.

For example, a $4 \times 2 \times 1$ cm block has surface area $2(8 + 4 + 2) = 28 \text{ cm}^2$ and volume 8 cm^3 , so SA:V = $3.5 : 1$.

Variations you will meet:

- **Doubling each side** halves SA:V; halving each side doubles it.
- **Same volume, different shapes:** the flatter or longer and thinner the block, the larger its SA:V.
- **Distance to the centre:** the dye has to travel from the nearest surface to the centre, half the smallest dimension.
- **A cell drawn with dimensions in μm :** work in μm^2 and μm^3 ; the ratio has no units.
- **A graph of surface area and volume against side length:** volume overtakes surface area once the cube's side is more than 6 units (at $L = 6$ both equal 216).
- **Rate** of diffusion into a block: distance or volume divided by time.

4. Predict and explain water movement by water potential (19 questions)

1. **Compare the water potentials.** The less negative one is higher. Pure water (0 kPa) is the highest possible.
2. **Water moves by osmosis from higher to lower water potential**, through the partially permeable membrane.
3. **Say what happens to the cell:** animal cells burst or shrink; plant cells become turgid or plasmolysed; nothing changes when the water potentials are equal.

Variations you will meet:

- **Several cells with given ψ values:** draw arrows from each cell to every neighbour with a more negative ψ .
- **Why red blood cells burst in water** but plant cells don't: no cell wall to resist the swelling.
- **Why organelles or cells are kept in a salt or sucrose solution:** the same water potential as the cytoplasm stops them swelling and bursting, or shrinking.
- **"More water enters than leaves":** correct wording for net movement; water never moves only one way.
- **A poison that lets ions leave cells** raises the water potential inside (fewer solutes) and lowers it outside, so water leaves the cells.
- **Single-celled organisms in fresh water** constantly gain water by osmosis and must pump it out (with a contractile vacuole, using ATP).

5. Interpret plant-tissue osmosis investigations (16 questions)

1. **Read the graph of percentage change in mass against concentration.** Gain means the solution had a higher ψ than the tissue; loss means a lower ψ .
2. **Find where the line crosses zero** (read carefully from the graph, or interpolate between the two points either side). That concentration has the **same water potential as the tissue**.
3. If a table converts concentration to ψ , read or interpolate the water potential.

Variations you will meet:

- **Matching cell drawings to solutions:** turgid (most dilute), incipient plasmolysis, plasmolysed (most concentrated).
- **What fills the gap** in a plasmolysed cell: the outside solution, because the wall is fully permeable.
- **Tissues stored for different times** or from different plants: a tissue that gains mass in a given solution has a lower (more negative) water potential than the solution.
- **Why percentage change:** the pieces started with different masses.
- **Curling strips** (such as a hollow stalk cut in half): thin-walled cells take in (or lose) more water and swell (or shrink) more than thick-walled cells, so the strip bends. In the highest water potential the thin-walled side swells most and ends up on the outside of the curve.
- **Improving the estimate:** repeat with a narrower range of concentrations around the zero point.

6. Explain factors affecting fluidity and permeability (13 questions)

1. **Say which way fluidity changes.**
2. **Explain with the tails:** double bonds give kinks; kinks and short chains stop the phospholipids packing closely; the hydrophobic interactions between tails are weaker; the phospholipids move more.
3. **Link to permeability** if asked: a more fluid membrane lets more polar molecules and ions through, and fuses more easily with other membranes.

Variations you will meet:

- **Cholesterol** reduces fluidity at high temperatures and increases it (prevents stiffening) at low temperatures.
- **Less cholesterol** in a membrane (for example a lysosome membrane) makes it more fluid, so it fuses more easily with vesicles.
- **Beetroot pigment leakage:** more leakage at high temperature (proteins denatured, phospholipids moving more) and in ethanol (lipids dissolved).

7. Describe, identify or sequence endocytosis and exocytosis (12 questions)

1. **In or out?** Into the cell is endocytosis (phagocytosis for solids, pinocytosis for liquids); out is exocytosis.

2. **Put the stages in order** for exocytosis: the protein is made on ribosomes of the rough ER, modified in the Golgi body, packed into a vesicle that buds off, the vesicle moves to the cell surface (along microtubules), it fuses with the cell surface membrane, and the contents are released.
3. **Say that ATP is used**, and that it does not depend on a concentration gradient.

Variation: "Name the process by which the enzymes (or mucus, collagen, hormone) are released": exocytosis.

8. Outline the stages of cell signalling (11 questions)

1. **Secretion** of the ligand by the signalling cell.
2. **Transport** of the ligand (for example in the blood) to the target cells.
3. **Binding** to a **specific receptor** with a **complementary** shape on the target cell's cell surface membrane.
4. **Response:** the receptor changes shape and sets off events inside the cell (signal transduction, often an enzyme cascade), leading to a specific response.

Always name the actual signal in the question (for example "the hormone is carried in the blood to the pancreas"). **Variations:** "why only some cells respond" (only they have the complementary receptor); "why one ligand causes different responses" (different events inside different cells); a lipid-soluble ligand that binds a receptor inside the cell.

9. Interpret Visking tubing or model-cell experiments (7 questions)

1. **List what can cross:** water and small molecules (glucose, iodine, ions) cross; large molecules (starch, proteins) do not. The question tells you whether sucrose can cross.
2. **Predict each movement:** each solute that can cross diffuses down its own concentration gradient; water moves from higher to lower water potential.
3. **Predict the tests or level changes:** iodine turns blue-black where starch meets it; Benedict's shows where glucose ended up; the liquid level inside rises if water moved in.

For example, if tubing containing a solution **more** concentrated than the outside is put in the beaker, water enters and the level rises; if it contains a **less** concentrated one, water leaves and the level falls; at the same concentration it stays the same.

10. Deduce the transport mechanism from data (4 questions)

1. **Compare the concentrations inside and outside.** If the cell keeps an ion at a higher concentration than outside (against the gradient), it must use **active transport**.
2. **Movement down a gradient** through proteins is facilitated diffusion.
3. **Rate graphs:** if the rate of uptake levels off as concentration rises, the transport proteins are all in use (facilitated diffusion or active transport). If uptake stops when respiration is stopped, it is active transport.

11. Draw and label a membrane diagram (4 questions)

1. Draw **two rows of heads** (circles) with **tails** pointing inwards, facing each other.
2. Draw a **channel protein** as a protein spanning the bilayer with a pore through the middle, or a carrier as a solid protein spanning it.
3. **Label** with ruled label lines; for facilitated diffusion draw the arrow **through a protein** and in the direction given (from the higher concentration side).

Worked examples

The bold codes show where marks are earned, as in Cambridge mark schemes. The number is how many marks.

- **M1** method mark: for a correct method, even if the numbers slip.
- **A1** accuracy mark: for a correct answer; it needs the M mark before it.
- **B1** mark for a correct result on its own, with no method needed.

Example 1

(a) Describe how phospholipids are arranged in a cell surface membrane and explain why they form this arrangement. **[3]**

(b) Explain how cholesterol helps to keep the membrane stable when the temperature changes. **[2]**

(c) Fish living in very cold water have a higher proportion of unsaturated fatty acids in their membrane phospholipids than fish living in warm water. Explain the advantage of this. **[3]**

(a) Phospholipids form a **bilayer**. **B1** The hydrophilic phosphate heads face outwards, towards the watery tissue fluid and cytoplasm, and the hydrophobic fatty acid tails face inwards, away from the water. **B1** This is because the heads are polar and attracted to water, while the tails are non-polar and repelled by it. **B1**

(b) At high temperatures cholesterol **restricts the movement** of the phospholipids, so the membrane doesn't become too fluid. **B1** At low temperatures it **stops the phospholipids packing closely**, so the membrane doesn't become rigid. **B1**

(c) Unsaturated fatty acids have C=C double bonds, which put kinks in the tails. **B1** The phospholipids can't pack closely, so the hydrophobic interactions between them are weaker and the membrane stays fluid in the cold. **B1** So the membrane can still work: for example, transport proteins can still change shape and vesicles can still fuse with it. **B1**

Example 2

A student made agar blocks containing an indicator that changes colour in acid. The blocks were cubes of side 1 cm, 2 cm and 4 cm, and a cuboid measuring 4 cm × 1 cm × 1 cm.

(a) Calculate the surface area to volume ratio of each block. [3]

(b) The blocks were put into acid at the same time. Predict which cube changed colour completely first and explain your answer. [2]

(c) The cuboid changed colour completely in about the same time as the 1 cm cube, although its SA:V is smaller. Suggest why. [1]

(a)

Block	Surface area / cm ²	Volume / cm ³	SA:V
1 cm cube	6	1	6 : 1
2 cm cube	24	8	3 : 1
4 cm cube	96	64	1.5 : 1
4 × 1 × 1 cuboid	2(4 + 4 + 1) = 18	4	4.5 : 1

B1 for the surface areas, **B1** for the volumes, **B1** for the ratios as $n : 1$.

(b) The **1 cm cube**. **B1** It has the largest surface area to volume ratio, so acid can diffuse in over more surface for each unit of volume, and it has the shortest distance (0.5 cm) to the centre. **B1**

(c) The acid only has to diffuse 0.5 cm to reach the centre of the cuboid, the same distance as for the 1 cm cube. **B1**

Example 3

Cylinders of potato were blotted, weighed and left in sucrose solutions for 2 hours, then blotted and weighed again.

Sucrose / mol dm ⁻³	0.0	0.2	0.4	0.6	0.8	1.0
Initial mass / g	2.50	2.40	2.80	3.00	2.40	2.50
Final mass / g	2.95	2.58	2.73	2.67	1.98	2.00

(a) Calculate the percentage change in mass in each solution. [2]

(b) Estimate the sucrose concentration that has the same water potential as the potato tissue. [2]

(c) A 0.30 mol dm⁻³ sucrose solution has a water potential of -820 kPa and a 0.40 mol dm⁻³ solution -1120 kPa. Estimate the water potential of the potato cells. [1]

(d) Explain the result in 0.8 mol dm⁻³ sucrose. [3]

(a) For 0.0: $\frac{2.95-2.50}{2.50} \times 100 = +18.0\%$. **M1** In order: +18.0, +7.5, -2.5, -11.0, -17.5, -20.0%. **A1**

(b) The change is zero between 0.2 (+7.5%) and 0.4 (-2.5%). **M1** Reading the graph (the last diagram in "Understand it") or interpolating: $0.2 + 0.2 \times \frac{7.5}{7.5+2.5} = 0.35 \text{ mol dm}^{-3}$. **A1**

(c) 0.35 is halfway between 0.30 and 0.40, so $\psi \approx -970 \text{ kPa}$. **B1**

(d) The solution had a **lower (more negative) water potential** than the potato cells. **B1** So water left the cells **by osmosis**, through their partially permeable cell surface membranes. **B1** The cells lost water from their vacuoles and cytoplasm, so the cylinder lost mass (and many cells became plasmolysed). **B1**

Example 4

The table shows the concentrations of potassium ions and sodium ions in human red blood cells and in blood plasma.

Ion	Inside red blood cells / mmol dm ⁻³	Blood plasma / mmol dm ⁻³
K ⁺	140	4
Na ⁺	12	145

(a) Calculate how many times greater the K⁺ concentration is inside the cells than in the plasma. **[1]**

(b) Name the process that keeps the K⁺ concentration high inside the cells and explain how it works. **[3]**

(c) Blood was kept in a cold, airless bag, which stops the cells' respiration. After several days, the K⁺ concentration in the cells had fallen and the Na⁺ concentration had risen. Explain these results. **[2]**

(d) Na⁺ can enter the cells through channel proteins. Name this process and explain why a protein is needed. **[2]**

(a) $140 \div 4 = 35$ times. **B1**

(b) **Active transport**. **B1** K⁺ binds to a specific **carrier protein** (the sodium–potassium pump), which moves it into the cell **against its concentration gradient**. **B1** It uses energy from **ATP**, which makes the carrier change shape. **B1**

(c) With no respiration there is no ATP, so active transport stops. **B1** K⁺ then diffuses out and Na⁺ diffuses in, down their concentration gradients (Na⁺ is about 12.1 times more concentrated outside). **B1**

(d) **Facilitated diffusion**. **B1** Na⁺ is charged, so it can't pass through the hydrophobic core of the bilayer; the channel has a hydrophilic pore it can pass through. **B1**

Common mistakes

- **Saying facilitated diffusion uses ATP.** In one report two fifths of all candidates thought it did. Facilitated diffusion is passive; only active transport, endocytosis and exocytosis use ATP.

- **Writing "water concentration".** Examiners want **water potential** and "down a water potential gradient", from higher (less negative) to lower (more negative). Don't say water moves "from low to high concentration".
- **Thinking cholesterol only sits between the heads**, or that carbohydrate chains are on the inside. Cholesterol lies among the tails with its OH by the heads; the chains are on the outside only.
- **"Cholesterol maintains cell fluidity".** Say it regulates **membrane** fluidity, and say how: less fluid when hot, less rigid when cold.
- **Saying the ligand has "the same shape" as the receptor.** It has a **complementary** shape.
- **Leaving out stages of cell signalling.** Many answers describe only the binding. Include secretion, transport to the target cells, binding to a specific receptor, and the response inside the cell.
- **Not naming the process.** When a question is about crossing a membrane, name it (facilitated diffusion, active transport, exocytosis) rather than just "moves across".
- **Describing the phospholipid instead of the role.** When asked for a role, give what it does (stability, fluidity, barrier to ions), not what it is made of.
- **Not showing the working** in SA:V calculations, and forgetting that the answer is a ratio ($n : 1$) with the same units for area and volume.
- **Mixing up which block changes colour first.** The smallest block, with the **largest** SA:V, is quickest.
- **Using mass change instead of percentage change** when the starting masses differ.

How to get the marks

- **Use the key words** the mark scheme looks for: phospholipid bilayer, hydrophilic, hydrophobic, channel protein, carrier protein, specific, concentration gradient, ATP, water potential, partially permeable membrane, osmosis, complementary receptor, ligand.
- **"Describe"** a result or graph: state the trend with figures, including units (for example "mass fell by 11.0% at 0.6 mol dm^{-3} "). **"Explain"**: give the reason, using water potential or the membrane structure.
- **"Compare"**: give a similarity and differences **point by point** ("facilitated diffusion is passive, **but** active transport uses ATP"), not two separate descriptions.
- **Osmosis answers** need three parts: which side has the higher water potential, that water moves by osmosis down the water potential gradient, and through a partially permeable membrane. Then the effect on the cell.
- **Calculations**: show the working, keep units consistent, and give ratios as $n : 1$. Round only at the end (to the number of decimal places asked, or to match the data).
- **"Suggest"** means apply what you know to a new situation (a lysosome membrane, a bacterium, a poison). Link each suggestion to membrane structure or a transport process.
- **Drawing**: sharp continuous lines, ruled label lines touching the part, and an arrow direction that matches the question.
- **Multiple choice**: check each numbered statement separately against the facts in this note before looking at the options.

Quick check

1. Calculate the surface area to volume ratio of a cube with sides of 5 mm.
2. A cell is a cuboid $20\ \mu\text{m} \times 10\ \mu\text{m} \times 5\ \mu\text{m}$. Calculate its surface area to volume ratio.
3. Cell X has a water potential of $-450\ \text{kPa}$ and neighbouring cell Y has $-800\ \text{kPa}$. In which direction does water move? What happens to both cells if they are put into a solution of $-1200\ \text{kPa}$?
4. A potato cylinder has a mass of 3.20 g. After an hour in a sucrose solution its mass is 2.88 g. Calculate the percentage change in mass and explain it.
5. State how each substance crosses a cell surface membrane: oxygen; glucose moving down its concentration gradient; K^+ moving into a cell against its concentration gradient; insulin leaving a pancreatic cell.

Answers

1. Surface area = $6 \times 5^2 = 150 \text{ mm}^2$, volume = $5^3 = 125 \text{ mm}^3$, so SA:V = $150 \div 125 = 1.2 : 1$.
2. Surface area = $2(200 + 100 + 50) = 700 \mu\text{m}^2$, volume = $1000 \mu\text{m}^3$, so SA:V = $0.7 : 1$.
3. From X to Y, because X's water potential is higher (less negative). In the -1200 kPa solution both cells lose water by osmosis, because the solution has a lower water potential than either.
4. $\frac{2.88-3.20}{3.20} \times 100 = -10.0\%$. The solution had a lower water potential than the potato cells, so water left the cells by osmosis.
5. Oxygen: simple diffusion through the bilayer. Glucose: facilitated diffusion through a carrier protein. K^+ : active transport by a carrier protein, using ATP. Insulin: exocytosis.

Past questions to try

- **9700/23/O/N/25 Q1**: transport types from a diagram of red blood cell membranes.
- **9700/22/F/M/24 Q1**: cholesterol's position, why ions can't diffuse through the bilayer, and comparing facilitated diffusion with active transport.
- **9700/22/M/J/21 Q4**: surface area to volume ratios in a table.
- **9700/21/M/J/21 Q3**: osmosis with Visking tubing, and red blood cells bursting in salt solutions.