

Cell membranes and transport: summary notes

These notes cover Topic 4, Cell membranes and transport, of the Cambridge International AS & A Level Biology syllabus (9700). They cover the fluid mosaic model of membrane structure, the roles of each membrane component, cell signalling in outline, and how substances move into and out of cells: diffusion, facilitated diffusion, osmosis, active transport, endocytosis and exocytosis. They also cover surface area to volume ratio, the standard practicals using agar blocks and plant tissue, and what happens to plant and animal cells in solutions of different water potential. Worked examples show every step, and the quick-check questions at the end use exam command words.

1. The fluid mosaic model of membranes

All cell membranes have the same basic structure. This includes the cell surface membrane and the membranes around organelles. Each membrane is about 7 nm thick and is described by the **fluid mosaic model**.

- **Fluid** means that the phospholipid molecules, and many of the proteins, can move sideways (laterally) within their layer, so the membrane is flexible and can change shape.
- **Mosaic** means that protein molecules are scattered through the phospholipid bilayer in an irregular pattern, like tiles in a mosaic.

Picture a cross-section of the membrane as follows. There are two rows of phospholipids. Their hydrophilic phosphate heads face outwards, towards the watery tissue fluid on one side and the cytoplasm on the other. Their hydrophobic fatty acid tails point inwards and meet in the middle. Cholesterol molecules sit between the tails. Some proteins span the whole bilayer (**intrinsic** or transmembrane proteins). Others sit on one surface only (**extrinsic** or peripheral proteins). Short branched carbohydrate chains are attached to some proteins and lipids, on the outer surface only.

Why a bilayer forms: phospholipids are amphipathic. They have a hydrophilic head that is attracted to water and hydrophobic tails that are repelled by water. In a watery environment they arrange themselves so that the heads face the water and the tails are hidden from it. This makes a bilayer.

Roles of the membrane components

Component	Structure and position	Role in the membrane
Phospholipids	Form the bilayer; heads face outwards, tails face inwards	Form a barrier to water-soluble (polar) molecules and ions, because these cannot easily pass through the hydrophobic core. Small non-polar molecules (O_2 , CO_2) and lipid-soluble molecules can pass through. The bilayer's fluidity lets the membrane bend, fuse with vesicles and self-seal.

Cholesterol	Lipid molecules sitting between the fatty acid tails (mainly in animal cell membranes)	Controls fluidity. At higher temperatures it restricts the movement of phospholipids, which makes the membrane less fluid. At lower temperatures it stops the tails packing closely together, so the membrane does not become too rigid. It also gives mechanical stability and further reduces the passage of ions and polar molecules.
Glycolipids	Lipids with a carbohydrate chain attached, facing outwards	Cell recognition (they can act as antigens, e.g. the ABO blood group markers); cell adhesion to neighbouring cells; can act as receptors
Glycoproteins	Proteins with carbohydrate chains attached, facing outwards	Receptors for signalling molecules such as hormones; cell recognition (self and non-self); cell adhesion. The hydrophilic sugar chains interact with the surrounding water, which helps to hold the membrane's structure steady.
Channel proteins	Intrinsic proteins with a water-filled, hydrophilic pore	Let specific ions or polar molecules pass through by facilitated diffusion. Some are gated and open or close in response to a signal. Aquaporins are channels for water.
Carrier proteins	Intrinsic proteins with a specific binding site	Bind a specific molecule or ion and change shape to move it across. This happens in facilitated diffusion (passive) and in active transport (which uses ATP).
Other proteins	Intrinsic or extrinsic	Enzymes (e.g. on the surface of cells lining the small intestine), receptors, electron carriers in the membranes of mitochondria and chloroplasts, and attachment points for the cytoskeleton

The carbohydrate chains of glycolipids and glycoproteins together make up the glycocalyx, a sugary coat on the outer surface of the cell.

2. Cell signalling (outline)

In cell signalling, one cell releases a chemical that changes the activity of another cell. In outline:

1. A cell releases a **signalling molecule** (a ligand), e.g. a hormone. Other cells may also be close enough to receive it.
2. The ligand travels to the target cell. It may diffuse over a short distance or be carried in the blood.
3. The ligand binds to a specific **receptor** on the cell surface membrane of the target cell. The receptor is usually a glycoprotein, and its binding site has a shape complementary to the ligand. Only cells with that receptor respond.
4. Binding changes the shape of the receptor. This passes the signal across the membrane without the ligand entering the cell (**signal transduction**).
5. This brings about a specific **response** inside the cell, e.g. activating enzymes or changing gene expression. Extension (beyond the AS outline): the receptor often activates an enzyme that makes a second messenger, such as cyclic AMP, which sets off a cascade of reactions that amplifies the signal.

Some ligands are lipid-soluble, such as steroid hormones. These can diffuse straight through the

phospholipid bilayer and bind to receptors inside the cell.

3. Diffusion and facilitated 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: it does not use energy from ATP.

Small non-polar molecules, such as oxygen and carbon dioxide, and lipid-soluble molecules diffuse straight through the phospholipid bilayer. This is **simple diffusion**.

Facilitated diffusion is the diffusion of molecules or ions across a membrane through channel proteins or carrier proteins, down their concentration gradient. It is passive.

Ions (e.g. Cl^- , Na^+) and larger polar molecules (e.g. glucose, amino acids) cannot easily cross the hydrophobic core, so they need these proteins. Because each protein is specific, the membrane controls which of these substances can cross. Once all the transport proteins are in use, the rate of facilitated diffusion levels off, even if the concentration gradient gets steeper.

Factors affecting the rate of diffusion across a membrane

Factor	Effect on rate
Steepness of concentration gradient	Steeper gradient → faster net diffusion
Temperature	Higher temperature → more kinetic energy → faster diffusion
Surface area	Larger area → more molecules cross per unit time
Diffusion distance	Thinner barrier → faster diffusion
Size and nature of molecule	Small, non-polar or lipid-soluble molecules cross the bilayer faster; ions and polar molecules need proteins
Number of channel or carrier proteins	More proteins → faster facilitated diffusion

4. Osmosis and water potential

Water potential (ψ) is a measure of the tendency of water molecules to move out of a system. It is measured in kilopascals (kPa). Pure water at atmospheric pressure has a water potential of 0 kPa. Adding solutes lowers the water potential, so any solution at atmospheric pressure has a negative water potential.

Osmosis is the net movement of water molecules from a region of higher water potential to a region of lower water potential, through a partially permeable membrane.

Key points about water potential:

- A **less negative** value means a **higher** water potential. For example, -200 kPa is higher than -900 kPa .
- Water always moves **down** a water potential gradient.
- More solute molecules $\rightarrow$ lower (more negative) water potential. Solute molecules attract water molecules, so fewer water molecules are free to move.
- In a plant cell, the cell wall pushes back on the expanding protoplast. This pressure **raises** the water potential of the cell, which is why a turgid cell stops taking in water even though its contents contain solutes.
- In exam answers, use the terms "higher/lower water potential". Do not say "water moves from a weak to a strong solution".

Worked example 1: direction of water movement

Cell P has $\psi = -450 \text{ kPa}$. The neighbouring cell Q has $\psi = -780 \text{ kPa}$. Which way does water move?

Step 1: Compare the values. -450 kPa is less negative than -780 kPa , so P has the higher water potential.

Step 2: Water moves by osmosis from higher to lower water potential.

Step 3: So there is a net movement of water from P to Q, through the partially permeable cell surface membranes.

5. Active transport

Active transport is the movement of molecules or ions across a membrane against their concentration gradient, through carrier proteins, using energy from ATP made in respiration.

1. The ion or molecule binds to a specific site on the carrier protein, on one side of the membrane.
2. ATP is hydrolysed. The energy released causes a change in the shape (conformation) of the carrier.
3. The carrier releases the ion or molecule on the other side of the membrane.
4. The carrier returns to its original shape.

Example: the sodium–potassium pump in animal cells moves Na^+ out of the cell and K^+ into it, using ATP. (Extension: it moves 3 Na^+ out and 2 K^+ in for each ATP hydrolysed.) Root hair cells use active transport to take up mineral ions such as nitrate from soil water, where these ions are at a lower concentration than in the cell.

Cells that carry out a lot of active transport usually have many mitochondria. Anything that stops respiration (e.g. lack of oxygen, a respiratory poison such as cyanide, or low temperature) slows or stops active transport. It does not stop simple diffusion.

6. Endocytosis and exocytosis (bulk transport)

Some materials are too large to pass through transport proteins, such as whole bacteria, large proteins

or droplets of fluid. These are moved in bulk inside vesicles. Bulk transport needs ATP, both to move the membrane and to move vesicles along the cytoskeleton.

Feature	Endocytosis	Exocytosis
Direction	Into the cell	Out of the cell
What happens to the membrane	The cell surface membrane folds inwards around the material and pinches off to form a vesicle	A vesicle moves to the cell surface membrane and fuses with it, releasing its contents outside
Types or examples	Phagocytosis ("cell eating") takes in solid material, e.g. a neutrophil engulfing a bacterium. Pinocytosis ("cell drinking") takes in liquid, e.g. small droplets of fluid containing dissolved molecules.	Secretion of digestive enzymes by pancreatic cells; release of hormones such as insulin; release of mucus from goblet cells. The vesicles often come from the Golgi body.
Energy	Requires ATP	Requires ATP
Effect on membrane area	Removes some membrane from the cell surface	Adds membrane to the cell surface

Summary: comparing the transport processes

Process	Direction relative to gradient	ATP needed?	Proteins involved?
Simple diffusion	Down	No	No
Facilitated diffusion	Down	No	Channel or carrier
Osmosis	Down the water potential gradient	No	Water crosses the bilayer and aquaporins
Active transport	Against	Yes	Carrier
Endocytosis / exocytosis	Not applicable (bulk movement)	Yes	Vesicles; no transport protein needed

7. Surface area to volume ratio

An organism, or a cell, exchanges substances across its surface. Its needs depend on its volume. As an object gets larger, its volume increases faster than its surface area, so its **surface area to volume ratio (SA:V) decreases**. A large cell or organism therefore has less surface per unit volume, and diffusion takes longer to reach its centre. This is why:

- cells are small, and cells with a high rate of absorption have folds or microvilli that increase their surface area;
- large multicellular organisms need specialised exchange surfaces (e.g. alveoli) and mass transport systems (e.g. blood).

For a cube of side length l : surface area = $6l^2$ and volume = l^3 . For a cuboid with sides a , b and c : surface area = $2(ab + bc + ac)$ and volume = abc .

Worked example 2: calculating SA:V

Calculate the SA:V for agar cubes of side 1 cm, 2 cm and 4 cm, and for a cuboid measuring 2 cm × 1 cm × 0.5 cm.

Block	Surface area / cm ²	Volume / cm ³	SA:V
1 cm cube	$6 \times 1^2 = 6$	$1^3 = 1$	$6 \div 1 = 6 : 1$
2 cm cube	$6 \times 2^2 = 24$	$2^3 = 8$	$24 \div 8 = 3 : 1$
4 cm cube	$6 \times 4^2 = 96$	$4^3 = 64$	$96 \div 64 = 1.5 : 1$
2 × 1 × 0.5 cm cuboid	$2 \times [(2 \times 1) + (1 \times 0.5) + (2 \times 0.5)] = 2 \times 3.5 = 7$	$2 \times 1 \times 0.5 = 1$	$7 \div 1 = 7 : 1$

Conclusion: doubling the side of a cube halves its SA:V. The flattened cuboid has the same volume as the 1 cm cube but a larger SA:V. This is why thin, flat shapes (e.g. a leaf, or a flatworm) help diffusion.

8. Investigating diffusion using agar blocks

A typical method uses agar made with a pH indicator. For example, agar containing dilute sodium hydroxide and phenolphthalein is pink. When it is placed in dilute hydrochloric acid, the acid diffuses in and neutralises the alkali, and the agar turns colourless.

1. Cut cubes of different sizes from the coloured agar, using a sharp scalpel and a ruler.
2. Put each cube into the same volume of acid, at the same concentration and temperature.
3. Record the time taken for each cube to lose its colour completely. Or, after a fixed time, cut each block in half and measure how far the colourless zone has spread.
4. Repeat for each size and calculate a mean.

Variables: the independent variable is block size (and therefore SA:V). The dependent variable is the time to decolourise, or the proportion of the block decolourised. Control the concentration and volume of acid, the temperature, the agar recipe and whether the solution is stirred. Safety: wear eye protection, because both the acid and the alkali are irritants.

Visking (dialysis) tubing can also be used as a model of a partially permeable membrane. For example, fill the tubing with a mixture of starch and glucose and stand it in water. Then test the water for glucose and starch at intervals: glucose diffuses out, but starch molecules are too large to pass through.

Worked example 3: fraction of each block reached by diffusion in a fixed time

Acid diffuses 0.5 cm into agar from every face in 10 minutes. What percentage of each cube's volume has lost its colour after 10 minutes?

1 cm cube: acid enters 0.5 cm from each side, and $0.5 + 0.5 = 1$ cm, so it reaches the centre. 100% is decolourised.

2 cm cube: the uncoloured layer is 0.5 cm deep on every face. The pink core has side $2 - (2 \times 0.5) = 1$ cm, so its volume is $1^3 = 1 \text{ cm}^3$. Total volume = 8 cm^3 . Decolourised volume = $8 - 1 = 7 \text{ cm}^3$. Percentage = $(7 \div 8) \times 100 = 87.5\%$.

4 cm cube: the pink core has side $4 - 1 = 3$ cm and volume 27 cm^3 . Total volume = 64 cm^3 . Decolourised volume = $64 - 27 = 37 \text{ cm}^3$. Percentage = $(37 \div 64) \times 100 = 57.8\%$ (3 s.f.).

Conclusion: the acid diffuses the same distance into every block. But the smaller the SA:V, the smaller the fraction of the volume it reaches in a given time.

9. Investigating osmosis using plant tissue

The standard method uses cylinders or strips of potato (or another plant tissue) placed in a range of sucrose solutions. Water moves in or out of the tissue by osmosis, which changes its mass.

1. Prepare a range of sucrose solutions by simple (proportional) dilution of a 1.0 mol dm^{-3} stock solution with distilled water, e.g. 0.0, 0.2, 0.4, 0.6, 0.8 and 1.0 mol dm^{-3} (see the volumes table below).
2. Use a cork borer to cut cylinders from the same potato. Trim them all to the same length and remove any peel.
3. Blot each cylinder dry, weigh it, and put it into a labelled tube containing one of the solutions.
4. Leave the tubes at the same temperature for the same time, e.g. 60 minutes.
5. Take the cylinders out, blot them dry in the same way, and weigh them again.
6. Calculate the percentage change in mass. Use three or more replicates per concentration and find the mean.

Final concentration / mol dm^{-3}	Volume of 1.0 mol dm^{-3} stock / cm^3	Volume of distilled water / cm^3
0.0	0	10
0.2	2	8
0.4	4	6
0.6	6	4
0.8	8	2
1.0	10	0

Do not confuse this with serial dilution, which divides the concentration by the same factor each time and gives a series such as 1.0, 0.5, 0.25... mol dm^{-3} . Practical papers treat these as two different techniques.

Percentage change in mass = $(\text{final mass} - \text{initial mass}) \div \text{initial mass} \times 100$

A positive value means the tissue gained water. A negative value means it lost water. Percentage change is used, not the actual change, because the cylinders do not all start with exactly the same mass. It lets you compare them fairly.

Worked example 4: percentage change in mass

A potato cylinder has a mass of 2.40 g before it is placed in a sucrose solution and 2.16 g afterwards.

Step 1: Change in mass = $2.16 - 2.40 = -0.24$ g

Step 2: Divide by the initial mass: $-0.24 \div 2.40 = -0.10$

Step 3: Multiply by 100: $-0.10 \times 100 = -10.0\%$

Interpretation: the tissue lost mass, so the solution had a lower water potential than the tissue. Water left the cells by osmosis.

Finding the water potential of the tissue from a graph

Plot percentage change in mass (y-axis) against sucrose concentration (x-axis), and draw a line or curve of best fit. The point where the line crosses the x-axis (0% change) is the concentration at which there is **no net movement of water**. At that concentration, the water potential of the solution **equals** the water potential of the tissue. You can then convert the concentration to a water potential using a table or calibration graph of known values. Alternatively, convert each concentration to its water potential first, plot percentage change in mass against water potential, and read the water potential directly from the x-axis intercept.

Worked example 5: water potential of potato tissue

A student obtained these mean results:

Sucrose concentration / mol dm ⁻³	Mean percentage change in mass / %
0.0	+18
0.2	+9
0.4	+2
0.6	-6
0.8	-13
1.0	-17

The question also gives this conversion table:

Sucrose concentration / mol dm ⁻³	Water potential / kPa
0.3	-860
0.4	-1120
0.5	-1450
0.6	-1800

Plot the results and read off the x-axis intercept. The calculation below checks the reading.

Step 1: Find where the change in mass is 0%. It changes sign between 0.4 mol dm⁻³ (+2%) and 0.6 mol dm⁻³ (-6%).

Step 2: Assume a straight line between these two points. Over 0.2 mol dm^{-3} the value falls by $2 - (-6) = 8$ percentage points. To fall by 2 (from +2 to 0), the concentration must increase by $(2 \div 8) \times 0.2 = 0.05 \text{ mol dm}^{-3}$.

Step 3: Concentration at 0% change = $0.4 + 0.05 = 0.45 \text{ mol dm}^{-3}$. On a well-drawn graph you would read this value from the x-axis intercept.

Step 4: Convert to water potential. 0.45 mol dm^{-3} lies halfway between 0.4 (-1120 kPa) and 0.5 (-1450 kPa). $-1120 + 0.5 \times (-1450 - (-1120)) = -1120 + 0.5 \times (-330) = -1120 - 165 = -1285 \text{ kPa}$.

Answer: the water potential of the potato tissue is about -1290 kPa (3 s.f.).

Linear interpolation is an approximation, because neither the mass change nor the concentration–water potential relationship is exactly linear. Values read from a well-drawn graph are accepted.

Always use the conversion values given in the question. Published values vary slightly with temperature and source.

10. Effects of solutions of different water potential on cells

External solution	Animal cell (e.g. red blood cell)	Plant cell
Higher ψ than cell contents (e.g. pure water)	Water enters by osmosis. The cell swells and, because it has no cell wall, the membrane bursts. This is lysis ; for red blood cells it is called haemolysis.	Water enters by osmosis and the protoplast (the cell membrane and its contents) swells and pushes against the cell wall. The strong wall resists expansion, and the wall pressure raises the water potential of the cell until it equals the water potential of the solution, so there is no further net uptake of water. The cell becomes turgid but does not burst.
Same ψ as cell contents	No net movement of water; the cell keeps its normal shape	No net movement of water; the cell stays the same size and its appearance does not change. If the solution's ψ equals the ψ of the cell at incipient plasmolysis, the membrane just begins to pull away from the wall.
Lower ψ than cell contents (concentrated solution)	Water leaves by osmosis. The cell shrinks and the membrane puckers. The cell becomes crenated .	Water leaves by osmosis, mainly from the vacuole. The protoplast shrinks and the cell becomes flaccid . Then the membrane pulls away from the wall: this is plasmolysis . The cell wall is freely permeable, so external solution fills the space between wall and membrane.

Incipient plasmolysis is the point at which the cell membrane is just starting to pull away from the cell wall. At this point the wall exerts no pressure on the protoplast.

Animal cells are therefore kept in body fluids whose water potential closely matches their cytoplasm. The kidneys and other homeostatic mechanisms control the water potential of the blood.

Key terms

Term	Definition
Fluid mosaic model	Model of membrane structure: a phospholipid bilayer in which the molecules can move laterally, with proteins scattered through it in a mosaic pattern
Partially permeable	Lets some molecules through but not others, e.g. lets water through but restricts ions and large polar molecules
Glycoprotein	A protein with carbohydrate chains attached; acts in cell recognition, adhesion and as a receptor
Glycolipid	A lipid with a carbohydrate chain attached; acts in cell recognition and adhesion
Ligand	A signalling molecule that binds specifically to a receptor
Signal transduction	Passing a signal across the membrane: the ligand binds to a receptor and changes its shape, which causes a response inside the cell without the ligand entering
Channel protein	An intrinsic protein with a hydrophilic pore that lets specific ions or polar molecules diffuse through
Aquaporin	A channel protein that lets water molecules through
Carrier protein	An intrinsic protein that binds a specific molecule or ion and changes shape to move it across the membrane
Facilitated diffusion	Passive movement of a substance down its concentration gradient through channel or carrier proteins
Water potential (ψ)	The tendency of water to move out of a system, measured in kPa; pure water at atmospheric pressure = 0 kPa
Osmosis	Net movement of water molecules from higher to lower water potential through a partially permeable membrane
Active transport	Movement against a concentration gradient through carrier proteins, using ATP
Phagocytosis	Endocytosis of solid material
Pinocytosis	Endocytosis of liquid
Exocytosis	Release of materials from a cell when vesicles fuse with the cell surface membrane
Turgid	Describes a plant cell whose protoplast is pressing firmly against the cell wall
Flaccid	Describes a plant cell whose protoplast is not pressing on the cell wall
Incipient plasmolysis	The point at which the cell membrane is just starting to pull away from the cell wall; the wall exerts no pressure on the protoplast
Plasmolysis	Loss of water from a plant cell so that the cell membrane pulls away from the cell wall
Crenation	Shrinking and puckering of an animal cell that has lost water by osmosis

Quick check

1. State **two** roles of cholesterol in a cell surface membrane. [2]
2. Define *osmosis*. [2]
3. Name the process by which a neutrophil takes in a bacterium, and state whether it needs ATP.

[2]

4. Outline **one** similarity and **one** difference between channel proteins and carrier proteins. [2]
5. Calculate the surface area to volume ratio of a cube with sides of 3 cm. Show your working. [2]
6. Calculate the surface area to volume ratio of a cuboid measuring 4 mm × 2 mm × 1 mm. [2]
7. Explain why oxygen can cross a cell surface membrane by simple diffusion but glucose cannot. [3]
8. A potato cylinder had a mass of 3.20 g before and 3.52 g after 1 hour in a sucrose solution. Calculate the percentage change in mass and explain the result in terms of water potential. [3]
9. Describe and explain what happens to red blood cells placed in distilled water, and why onion epidermis cells placed in distilled water do not show the same effect. [4]
10. Explain how a glycoprotein receptor allows a hormone to affect only certain cells in the body. [3]
11. In another experiment, the mean percentage changes in mass of beetroot tissue were +8% in 0.1 mol dm⁻³, +3% in 0.2 mol dm⁻³, -2% in 0.3 mol dm⁻³ and -7% in 0.4 mol dm⁻³ sucrose. A 0.2 mol dm⁻³ solution has $\psi = -540$ kPa and a 0.3 mol dm⁻³ solution has $\psi = -860$ kPa. Calculate the water potential of the beetroot tissue. [4]
12. The uptake of potassium ions by root tissue was measured with and without a respiratory inhibitor. Uptake fell by over 90% when the inhibitor was added. Explain what these results suggest about how potassium ions enter the root cells. [3]

Answers

1. Any two of: regulates membrane fluidity over a range of temperatures (1); gives mechanical stability (1); reduces the permeability of the membrane to ions and polar molecules (1). Max 2.
2. The net movement of water molecules from a region of higher water potential to a region of lower water potential (1), through a partially permeable membrane (1).
3. Phagocytosis (a type of endocytosis) (1); yes, it requires ATP (1).
4. Similarity (1): both are intrinsic proteins that are specific to particular ions or molecules / both can carry out facilitated diffusion. Difference (1): a channel protein has a water-filled pore that substances pass through, whereas a carrier protein binds the substance and changes shape / only carrier proteins can carry out active transport.
5. Surface area = $6 \times 3^2 = 54$ cm²; volume = $3^3 = 27$ cm³ (1). SA:V = $54 \div 27 = 2 : 1$ (1).
6. Surface area = $2 \times [(4 \times 2) + (2 \times 1) + (4 \times 1)] = 2 \times 14 = 28$ mm²; volume = $4 \times 2 \times 1 = 8$ mm³ (1). SA:V = $28 \div 8 = 3.5 : 1$ (1).
7. Oxygen is small and non-polar, so it can pass through the hydrophobic core of the phospholipid bilayer (1). Glucose is larger and polar (hydrophilic), so it is repelled by the hydrophobic fatty acid tails (1). It needs specific carrier proteins (facilitated diffusion, or active transport in some cells) (1).
8. Change = $3.52 - 3.20 = +0.32$ g; percentage change = $(0.32 \div 3.20) \times 100 = +10.0\%$ (1). The solution had a higher water potential than the potato cells (1), so water entered the tissue by osmosis (1).
9. Distilled water has a higher water potential than the cytoplasm of red blood cells, so water enters by osmosis (1). The cells swell and burst (haemolysis) because they have no cell

wall (1). Onion cells also take in water and swell (1), but the cellulose cell wall resists expansion. The wall pressure raises the water potential inside, so water stops entering. The cells become turgid rather than bursting (1).

10. The hormone (ligand) has a specific shape (1). Only target cells have receptors whose binding site is complementary to it (1). Binding changes the receptor's shape, which triggers a response inside the cell (1). Cells without the receptor do not respond (1). Max 3.
11. Identifies the zero crossing between 0.2 mol dm^{-3} (+3%) and 0.3 mol dm^{-3} (−2%) / reads the x-intercept from a graph (1). The fall across this interval is 5 percentage points and a fall of 3 is needed, so concentration = $0.2 + (3 \div 5) \times 0.1 = 0.26 \text{ mol dm}^{-3}$ (1). Interpolates ψ between −540 and −860 kPa: $\psi = -540 + 0.6 \times (-860 - (-540)) = -540 + 0.6 \times (-320)$ (1) = $-540 - 192 = -732 \text{ kPa} \approx -730 \text{ kPa}$ (1). Allow ECF from an incorrect concentration. Accept a correct value read from a graph.
12. Uptake depends on respiration / ATP, so potassium ions enter mainly by active transport (1). The inhibitor stops respiration, so less ATP is produced (1). Carrier proteins need ATP to change shape and move ions against their concentration gradient; the small remaining uptake could be by diffusion or facilitated diffusion (1).