Cambridge IGCSE · Biology 0610 · Notes

Movement into and out of cells

Read online at **pastopic.com/cambridge/biology-0610/notes/movement-into-and-out-of-cells**

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Read first: **Organisation of the organism**

What you need to know

This topic is about the three ways substances get into and out of cells: **diffusion**, **osmosis** and **active transport**. The parts marked **Extended only** are tested on Papers 2 and 4 only. By the end of it you should be able to:

Diffusion

1. **Describe diffusion** as the net movement of particles from where they are more concentrated to where they are less concentrated (down a concentration gradient), caused by their random movement.
2. **State that the energy for diffusion** comes from the kinetic energy of the particles' random movement.
3. **State that some substances enter and leave cells by diffusion** through the cell membrane.
4. **Describe why diffusion of gases and dissolved substances matters** to living things.
5. **Investigate the factors that change the rate of diffusion**: surface area, temperature, concentration gradient and distance.

Osmosis

6. **Describe the role of water as a solvent** in digestion, excretion and transport.
7. **State that water diffuses through partially permeable membranes** by osmosis, and that water moves into and out of cells by osmosis through the cell membrane.
8. **Investigate osmosis** with materials such as dialysis tubing.
9. **Investigate and describe what happens to plant tissue** put into solutions of different concentrations.
10. **State that plants are supported** by the pressure of water inside their cells pushing outwards on the cell wall.
11. **Extended only:** describe osmosis as the net movement of water molecules from a region of higher water potential (a dilute solution) to a region of lower water potential (a concentrated solution), through a partially permeable membrane.
12. **Extended only:** explain what happens to plant cells in solutions of different concentrations using the words **turgid**, **turgor pressure**, **plasmolysis** and **flaccid**.
13. **Extended only:** explain why water potential and osmosis matter when organisms take up and lose water.

Active transport

14. **Describe active transport** as the movement of particles through a cell membrane from a lower to a higher concentration (against a concentration gradient), using energy from respiration.
15. **Extended only:** explain why active transport matters for moving molecules or ions across membranes, including ion uptake by root hairs.
16. **Extended only:** state that **protein carriers** move the molecules or ions across the membrane during active transport.

Understand it

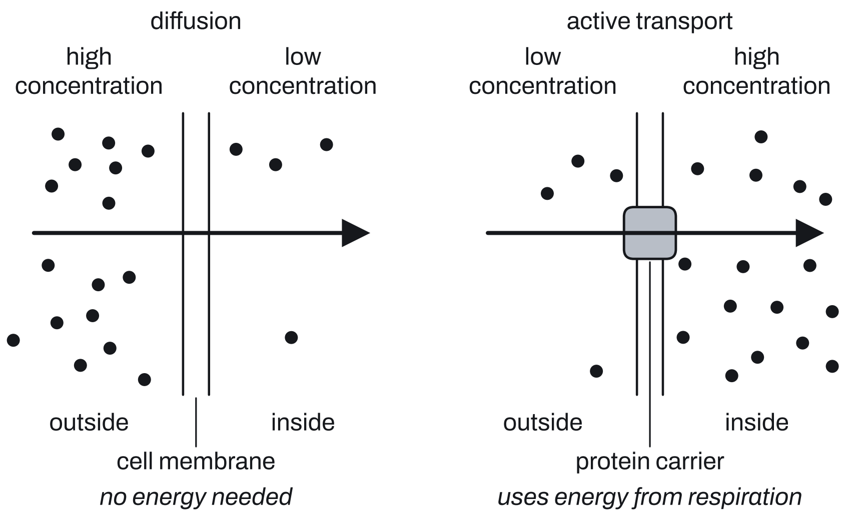
Particles are always moving

Particles of a gas or of anything dissolved (molecules and ions) move all the time, in random directions, because they have **kinetic energy**. Where there are more of them, more wander out than wander in, so they spread out until evenly mixed.

Diffusion

Diffusion is the **net** movement of particles from a region of their **higher concentration** to a region of their **lower concentration**, that is **down a concentration gradient**, as a result of their **random movement**.

- "**Net**" matters: particles still move both ways, but more go from high to low than from low to high.
- The **energy** comes from the particles' own **kinetic energy**. The cell spends **no energy from respiration** on it. That is why diffusion is called **passive**.
- A **concentration gradient** is a difference in concentration between two places. The bigger the difference, the steeper the gradient.
- Diffusion does **not** need a membrane. A scent spreading through a room, or ink spreading through jelly, is diffusion. But many substances enter and leave cells by diffusing **through the cell membrane**.
- Each substance diffuses down **its own** gradient. Oxygen can diffuse into a cell while carbon dioxide diffuses out at the same time.



Why diffusion matters

Living things depend on diffusion to move gases and dissolved substances (solutes) over short distances:

Where	What diffuses, and which way
Alveoli in the lungs	oxygen from the air in the alveolus **into the blood**; carbon dioxide from the blood **into the alveolus**
Body cells and capillaries	oxygen and glucose from the blood **into cells**; carbon dioxide and urea from cells **into the blood**
Leaves	in daylight, carbon dioxide from the air spaces **into mesophyll cells** for photosynthesis, and oxygen **out** through the stomata; water vapour **out** through the stomata
Root hairs	oxygen from the air in the soil **into root cells**, for respiration
Placenta	oxygen and nutrients from the mother's blood **into the fetus's blood**; carbon dioxide and urea from the fetus **to the mother**
Small intestine	some digested food molecules from the gut **into the blood** in the villi
Plant shoots and roots	the plant hormone auxin spreads **away from the tip**

What changes the rate of diffusion

Factor	Change that makes diffusion **faster**	Why
Surface area	larger	more particles can cross at once (alveoli, villi and root hairs all give a large surface area)
Temperature	higher	particles have more kinetic energy, so they move faster
Concentration gradient	steeper (bigger difference)	many more particles move one way than the other
Distance (thickness of the surface)	shorter (thinner)	particles have less far to travel (alveolus and capillary walls are one cell thick)

The opposite change in each factor makes diffusion **slower**.

The agar-block investigation. Blocks of agar are coloured with an indicator that changes colour when acid (or alkali) diffuses in. Put the blocks in acid and time how long it takes for them to change colour right through. Cutting the same volume of agar into more, smaller blocks gives a **larger total surface area**, and the colour change is quicker. For example, a 2 cm cube has a surface area of $6 \times 2 \times 2 = 24$ cm²; cutting it into eight 1 cm cubes gives $8 \times 6 = 48$ cm² with the same volume. Keep the other factors the same (the acid's concentration, its temperature, the volume of agar).

Water as a solvent

Water **dissolves** many substances, and that is why living things need it:

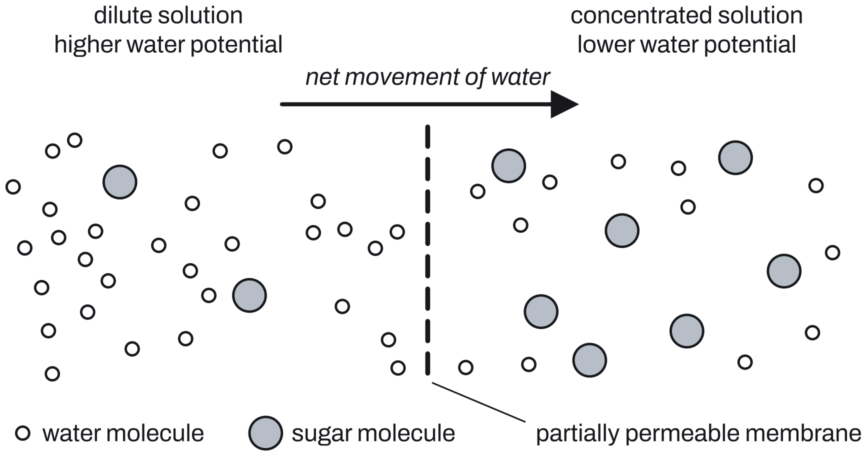
- **Digestion:** enzymes work in solution, and the small molecules made (such as glucose and amino acids) are dissolved so they can be absorbed.
- **Excretion:** urea and excess salts are removed dissolved in water, as urine.
- **Transport:** substances travel dissolved in water, in blood plasma in animals and in xylem and phloem in plants.

Water is the **solvent**; the substances dissolved in it are **solutes**; together they make a **solution**.

Osmosis

A **partially permeable membrane** lets small molecules, such as water, through but stops larger ones, such as sucrose or starch. The **cell membrane** is partially permeable. The **cell wall is not**: it is **fully permeable**, so water and dissolved substances pass straight through it.

Osmosis is the diffusion of **water** through a **partially permeable membrane**. Only the water moves; the solute molecules on each side cannot cross.



In the diagram, the dilute solution has more free water molecules than the concentrated one. More water molecules hit the membrane from the dilute side, so more cross from left to right than from right to left. The net movement of water is from the **dilute** solution to the **concentrated** solution.

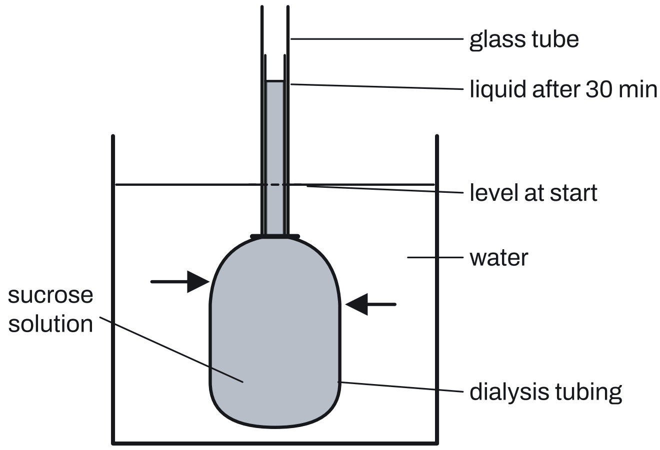
Extended only: biologists describe this with **water potential**, how freely water can move out of a solution.

- **Pure water** has the **highest** water potential.
- Adding solute **lowers** the water potential: a **dilute** solution has a **high** water potential, a **concentrated** solution a **low** one.
- **Osmosis** is the net movement of water molecules from a region of **higher water potential** (dilute solution) to a region of **lower water potential** (concentrated solution), through a **partially permeable membrane**.
- In kPa, the **more negative** the number, the **lower** the water potential.

Water moves **into and out of cells by osmosis through the cell membrane**, whichever side has the higher water potential.

Investigating osmosis with dialysis tubing

Dialysis tubing (Visking tubing) is a partially permeable membrane, so a bag made from it is a **model cell**: the tubing stands for the **cell membrane**, and the solution inside for the cytoplasm.



water enters the bag by osmosis, so the liquid rises

- Sucrose solution inside and water outside: water moves **into** the bag, so the bag swells and gets heavier, and the liquid **rises** up the glass tube.
- Water inside and a concentrated solution outside: water moves **out**, so the bag gets smaller and lighter.
- Starch and glucose inside and water outside: **glucose** molecules are small, so they diffuse **out** through the tubing and can be detected in the water; **starch** molecules are too **large** to pass, so they stay inside.

Plant tissue in solutions

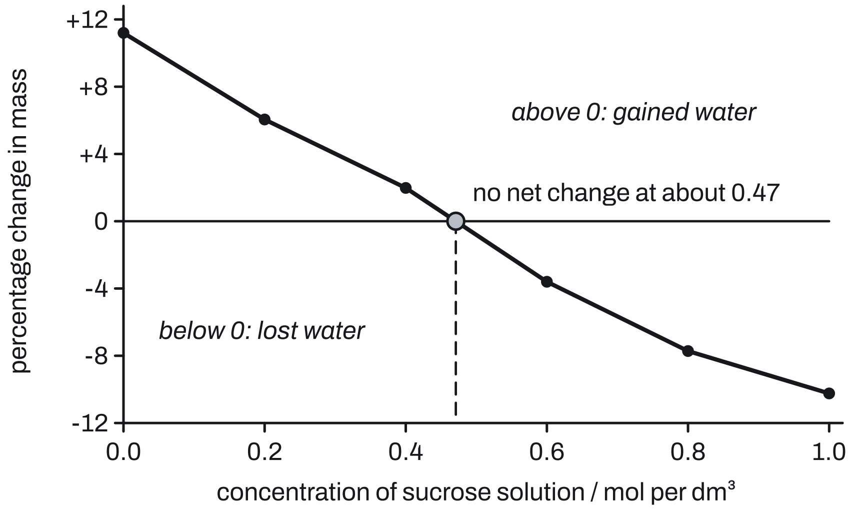
The classic experiment uses cylinders or cubes of potato. Measure the mass (or length) of each piece, leave them in sugar or salt solutions of different concentrations, then measure again.

- In **water** or a **dilute** solution, the potato cells take in water by osmosis: the pieces get **heavier**, **longer** and **firm**.
- In a **concentrated** solution, the cells lose water by osmosis: the pieces get **lighter**, **shorter**, **soft** and bendy.
- At one concentration there is **no net change**: the solution has the same concentration (the same water potential) as the potato cells, so water enters and leaves at the same rate.

Pieces start with different masses, so compare **percentage change in mass**:

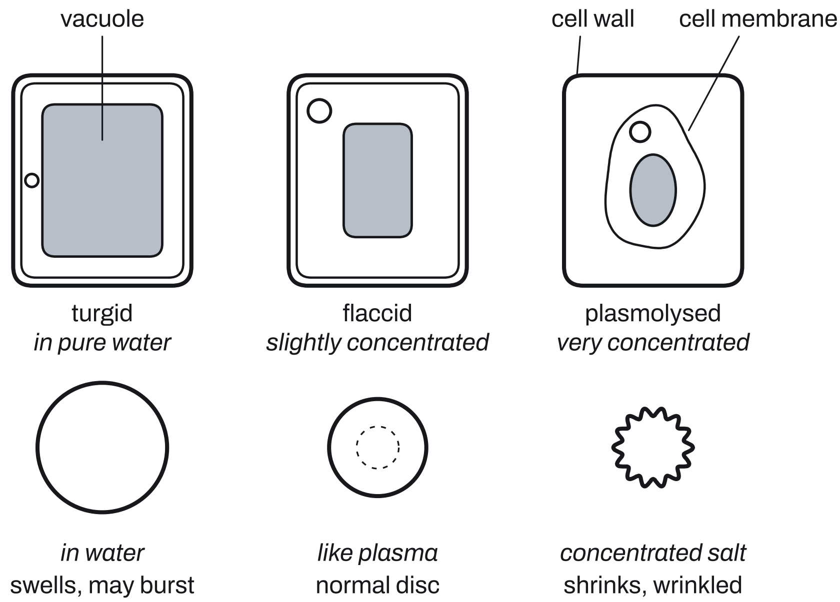
$$\text{percentage change} = \frac{\text{final mass} - \text{starting mass}}{\text{starting mass}} \times 100$$

A gain is positive; a loss is negative. For example, 5.00 g falling to 4.60 g is $\frac{-0.40}{5.00} \times 100 = -8.00\%$.



To find the concentration with no net change, read where the line crosses 0 on a graph like this one. Here it is about 0.47 mol per dm³, so the potato cells' contents are about as concentrated as a 0.47 mol per dm³ sucrose solution.

What happens to cells



Plant cells have a strong cell wall:

- In **water**, water enters by osmosis. The vacuole and cytoplasm swell and push the cell membrane against the wall. The wall stops the cell **bursting**.
- In a **concentrated** solution, water leaves by osmosis. The vacuole and cytoplasm shrink, and the membrane can pull away from the wall.

Plants are supported by the **pressure of water inside the cells pressing outwards on the cell wall**. When cells lose water this pressure falls and the plant **wilts**.

Extended only: the words to use:

- **Turgid:** a cell that has taken in water until it is swollen and firm, with its membrane pressed hard against the wall.
- **Turgor pressure:** the outward pressure of the swollen cell contents on the cell wall. The wall pushes back, so no more water can enter and the cell cannot burst. Turgor pressure in many cells makes stems and leaves rigid.
- **Flaccid:** a cell that has lost water so it is soft and limp, with little or no turgor pressure. Flaccid cells make a plant wilt.
- **Plasmolysis:** a cell that loses a lot of water shrinks so much that the **cell membrane pulls away from the cell wall**. The cell is **plasmolysed**. The gap between wall and membrane fills with the outside solution, because the wall is fully permeable.

Animal cells have **no cell wall**. A red blood cell in **water** takes in water by osmosis, swells and can **burst**. In a solution with the **same concentration as blood plasma** it keeps its normal shape. In a **concentrated** salt solution it loses water, **shrinks** and its edge becomes wrinkled.

Extended only: water potential and osmosis matter for every organism that takes in or loses water:

- **Root hair cells** take in water by osmosis because the soil water has a **higher water potential** than the cell's cytoplasm. Active uptake of ions into the root lowers the root cells' water potential further, so more water follows.
- If the soil or the surrounding solution has a **lower** water potential than the cells, water **leaves** them and the plant wilts. This is why plants can die in very salty soil.
- In animals, the water potential of the blood must be kept steady so that body cells neither swell nor shrink. Cells can move water by pumping ions: moving ions out of a cell lowers the water potential outside, so water follows by osmosis.

Active transport

Sometimes a cell needs to take in a substance that is already **more concentrated inside** the cell than outside. Diffusion would move it the wrong way. Instead the cell uses **active transport**:

- the movement of particles **through a cell membrane**,
- from a region of **lower** concentration to a region of **higher** concentration (**against** the concentration gradient),
- using **energy from respiration**.

Because it needs energy, active transport needs **respiration**: cells that do a lot of it have many **mitochondria**, and anything that stops respiration (no oxygen, no glucose, a poison such as cyanide) stops active transport too.

Extended only: protein carriers in the cell membrane do the moving. A molecule or ion binds to a carrier on one side; energy from respiration changes the carrier's shape, and the particle is released on the other side. Each carrier moves particular molecules or ions, so fewer carriers means slower uptake.

Extended only: why active transport matters:

- **Ion uptake by root hairs.** Mineral ions such as **nitrate** and **magnesium** are usually **more concentrated inside** root hair cells than in the soil water, so the root must take them in against the gradient. (Water, by contrast, enters by osmosis.)
- **Glucose uptake** from the small intestine into the epithelial cells of the villi, and **reabsorption** of glucose from the kidney tubules back into the blood: active transport lets the body take in all of it, even when there is less outside the cell than inside.

Comparing the three processes

Feature	Diffusion	Osmosis	Active transport
What moves	any particles (gases, solutes)	**water only**	particles (molecules, ions)
Direction	high → low concentration (down the gradient)	high → low water potential (dilute → concentrated)	low → high concentration (**against** the gradient)
Energy from respiration needed?	no	no	**yes**
Needs a membrane?	no (but can cross one)	**yes, partially permeable**	**yes, cell membrane**
Protein carriers?	no	no	**yes**
Particles move randomly?	yes	yes (osmosis is a kind of diffusion)	no, they are carried
Happens in all living cells?	yes	yes	not in every cell

Key facts and formulas

There is no formula list in the IGCSE Biology exam. Everything below must be learnt.

Formula	Status
percentage change $= \dfrac{\text{final} - \text{starting}}{\text{starting}} \times 100$ (a loss is negative)	Learn it
mean $= \dfrac{\text{sum of the readings}}{\text{number of readings}}$	Learn it
Surface area of a cube of side x: $6x^2$; volume x^3	Learn it
Faster diffusion: larger surface area, higher temperature, steeper gradient, shorter distance	Learn it

Formula	Status
Extended: water moves from higher to lower water potential; pure water has the highest; more negative kPa = lower	Learn it
Plant cell that gains water: swollen, membrane pressed against the wall; loses water: membrane pulls away from the wall; the wall stops it bursting. Extended: turgid, flaccid, plasmolysed	Learn it

Learn the three definitions and the comparison table from "Understand it" as well.

How to do it

In the questions we have tagged for this topic (174 questions, 2021–2025, on Papers 1–4), the types came up this often. 24 of the 174 questions mix types, so the counts add up to more than 174.

Question type	Questions
Define or recognise active transport (direction, energy, carriers, examples)	49
Define or name diffusion and give examples of it	39
Define osmosis and identify the partially permeable membrane	25
Predict or interpret plant tissue (potato) changes in solutions, including percentage change	19
Describe plant cells in solutions: turgid, flaccid, plasmolysed	17
State how factors change the rate of diffusion	16
Predict the net direction of diffusion from concentrations	12
Compare diffusion, osmosis and active transport	9
Explain turgor pressure, plant support and why plant cells don't burst	8
Explain model-cell experiments with dialysis tubing	7
Explain why water matters (solvent, transport)	7
Use water potential to predict water movement (Extended)	6
Explain red blood cells in solutions of different concentration	4

Most are one-mark multiple choice on Papers 1 and 2. On Papers 3 and 4 the topic comes as short structured parts, often inside a longer question about roots, leaves, blood or digestion.

1. Define or recognise active transport (49 questions)

1. **Check the three features**: it moves particles **through a cell membrane**, from **low to high** concentration (**against** the gradient), using **energy from respiration**.
2. **In a table of rows**, cross out any row that says "down the gradient", "no energy", "energy from photosynthesis", "no membrane" or "moves water".

3. **To name the process**, ask: is the substance already more concentrated where it is going? If yes, it is active transport.

Variations you will meet:

- **Examples to recognise:** mineral ions (nitrate, magnesium, sodium) into root hair cells from the soil; glucose into villi epithelial cells or back into the blood from kidney tubules. Gases entering or leaving cells are **never** active transport.
- **Written definition** (Paper 3, 2–3 marks): "movement of particles through a cell membrane from a lower to a higher concentration, against a concentration gradient, using energy from respiration".
- **Extended, "explain how nitrate ions are taken into the root hair cell"** (about 4 marks): active transport; from a low concentration in the soil to a high concentration in the cell (against the gradient); across the cell membrane; using **protein carriers**; using **energy from respiration**.
- **Extended, applied:** a poison that stops respiration (cyanide), or no oxygen, stops active transport; more mitochondria or more carriers make it faster.
- **A graph of glucose uptake with and without oxygen:** the uptake that still happens with no oxygen is diffusion; the extra uptake with oxygen is active transport (it needs aerobic respiration), so both processes happen.

2. Define or name diffusion and give examples of it (39 questions)

1. **Give the definition** from "Understand it", with every key word: net, higher to lower, down the gradient, random movement; the energy is the particles' kinetic energy.
2. **To name the process**, ask: is it a gas or solute moving from high to low concentration, with no energy from the cell? Then it is diffusion.

Variations you will meet:

- **Gap-fills**: "higher ... lower ... down", "gradient", "kinetic", "random". Watch the order of words: high **to** low.
- **Examples**: oxygen from an alveolus into the blood; oxygen out of a leaf; carbon dioxide into a mesophyll cell; ink spreading in jelly; a scent or a gas spreading through air (in **all** directions, not just upwards); auxin moving down a root.
- **"State the name of the part of all cells that substances pass through"**: the **cell membrane**.

3. Define osmosis and identify the partially permeable membrane (25 questions)

1. **Osmosis** is water only, through a partially permeable membrane, from the dilute side to the concentrated side; no respiration energy, no cell wall needed.
2. **Which part is partially permeable?** The **cell membrane**: in a plasmolysed cell drawing, the line that has pulled away from the wall.

Variations you will meet:

- **Name the process** that moves water into a root hair cell or out of potato cells: osmosis. Ions entering the same cell use active transport.

- **"State two structures water passes through to reach the cytoplasm"** of a plant cell: the cell wall, then the cell membrane.
- **Two liquids either side of a membrane**: water moves towards the side with more solute molecules.

4. Predict or interpret plant tissue (potato) changes in solutions (19 questions)

1. **Decide which way water moves** (see "Plant tissue in solutions"), and calculate percentage change to the decimal places asked.
2. **Describe the trend**: as the concentration increases, the gain gets smaller, then becomes a loss that gets bigger.
3. **Find "no net change"** where the graph crosses 0 (or a length ratio of 1): that solution matches the cells' concentration.

Variations you will meet:

- **"Tick the correct conclusions"**: check each against the numbers. The biggest change is the biggest number, positive or negative.
- **A length ratio** above 1 means water gained; below 1, water lost. The piece that lost most was in the most concentrated solution; a cube in pure water always gains.
- **Appearance**: soft and bendy after a concentrated solution; firm after water.
- **Extended, explain two results**: compare each solution's water potential with the cells' (as in Example 3(d)).
- **Why percentage change?** The pieces started at different masses. Keep size, time, temperature and the potato the same.

5. Describe plant cells in solutions: turgid, flaccid, plasmolysed (17 questions)

1. **Work out whether the cell gains or loses water**, then describe it using the diagram in "What happens to cells". **Extended:** name the state: turgid, flaccid or plasmolysed.

Variations you will meet:

- **Multiple-choice pairs**: gains water goes with turgid; loses water with flaccid or plasmolysed.
- **Extended, a wilted plant's cells**: flaccid, little turgor pressure, smaller vacuole, possibly plasmolysed, because they lost water and have a low water potential.

6. State how factors change the rate of diffusion (16 questions)

1. **Use the factors table**: larger area, higher temperature, steeper gradient and shorter distance are faster. In rows of changes, find the row where every change speeds diffusion up.

Variations you will meet:

- **"Name two factors, other than concentration"**: temperature and surface area (distance also scores).

- **Agar blocks**: work out a mean (add the trials, divide by how many, round as asked); more blocks from the same volume means more surface area and a shorter time. Say "as surface area increases, the time taken decreases, so the rate of diffusion increases".
- **Adaptations**: many alveoli, villi, root hairs or gill filaments (area); one-cell-thick walls (distance); a blood supply (gradient). A thicker membrane is slower.

7. Predict the net direction of diffusion from concentrations (12 questions)

1. **Compare the same substance on the two sides.** Its net movement is from the side where there is more of it to the side where there is less.
2. **Draw or choose the arrow** that way, and explain: "there is a higher concentration of oxygen outside, so the net movement is into the cell, down the concentration gradient".

Variations you will meet:

- **Two gases at once**: judge each one separately. Oxygen can go in while carbon dioxide goes out. Don't compare oxygen on one side with carbon dioxide on the other.
- **Leaf, placenta, alveolus**: use the "Why diffusion matters" table. Oxygen goes towards the blood (which carries it away), carbon dioxide away from it.

8. Compare diffusion, osmosis and active transport (9 questions)

1. **Use the comparison table** in "Understand it", one row at a time; tick tables usually score one mark per row or column.
2. **For "how does X differ from Y"**, give **both** halves: "active transport moves particles against the gradient, **but** osmosis moves water down a water potential gradient". "How does osmosis differ from other diffusion?": only water moves, always through a partially permeable membrane.

9. Explain turgor pressure, plant support and why plant cells don't burst (8 questions)

1. **The cell wall** stops plant cells bursting; water inside presses **outwards** on it and supports the plant (not the pull in the xylem, not sugar movement).
2. **Extended, a firm stem** (about 3 marks): water enters by osmosis, the vacuole swells, turgor pressure pushes on the wall, the cells are turgid and the stem rigid. Losing water gives flaccid cells and wilting.

10. Explain model-cell experiments with dialysis tubing (7 questions)

1. **The tubing is the cell membrane** (not filter paper, which lets everything through).
2. **Water moves towards the more concentrated solution**; small molecules (glucose) pass, large ones (starch) don't. See "Investigating osmosis with dialysis tubing".

Variations you will meet:

- **Glucose but no starch outside** (2 marks): which one moves, and why (molecule size).

- **Predict which bag gains or loses mass** in a set of bags and solutions: compare the concentration inside with outside for each bag.
- **Say where the solution is**: "the sucrose solution inside the tubing", not just "the solution".

11. Explain why water matters (solvent, transport) (7 questions)

1. **Water is a solvent**; link it to digestion, excretion and transport as in "Water as a solvent".

Variations you will meet:

- **Circle or tick the uses**: "as a solvent" and "for transport" are right; "as an enzyme", "as genetic material" or "as a mineral" are wrong.
- **Paper 4 extensions**: water is needed for germination, for photosynthesis, to keep cells turgid, and to cool the body by sweating.

12. Use water potential to predict water movement (Extended, 6 questions)

1. **Find the highest and lowest water potential.** With kPa values, the **least negative** is the highest.
2. **Water moves from higher to lower water potential** by osmosis, between every pair of cells where there is a difference.

For example, cells P (-300 kPa), Q (-450 kPa) and R (-380 kPa): water moves from P to Q, from P to R, and from R to Q.

Variations you will meet:

- **Ions moved out of a cell** (for example, chloride ions pumped into a duct) lower the water potential outside, so water follows by osmosis. Ions pumped **into** root cells lower their water potential, so water enters from the soil.

13. Explain red blood cells in solutions of different concentration (4 questions)

1. **Match the shape to the solution** (diagram in "What happens to cells"), then order them: swollen (lowest salt concentration) → normal → shrunken (highest).
2. **Explain** with osmosis: water enters (or leaves) the cell by osmosis through the partially permeable membrane. Extended: say where the water potential is higher.

Variations you will meet:

- **Percentage change in diameter**: a cell that grows from 7.4 μm to 8.0 μm has increased by $\frac{0.6}{7.4} \times 100 = 8.1\%$ (2 s.f.).
- **"Why did the cell not change?"**: the solution had the same water potential as the cytoplasm, so there was no net movement of water.

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 student cuts agar blocks containing an indicator. The indicator changes colour when acid diffuses into the agar. She places the blocks in acid and times how long they take to change colour completely.

(a) Complete the sentence. Diffusion is the net movement of particles from a region of their ______ concentration to a region of their ______ concentration, down a concentration ______. **[2]**

(b) State where the energy for diffusion comes from. **[1]**

(c) One block took 184 s, 176 s and 191 s in three trials. Calculate the mean time, to the nearest whole number. **[1]**

(d) A 2 cm cube of agar is cut into eight 1 cm cubes. Calculate the total surface area before and after cutting, and predict the effect on the time taken. **[3]**

(e) State **two** other factors that would change the rate of diffusion in this investigation. **[2]**

(a) higher, lower **B1**; gradient **B1**.

(b) The kinetic energy of the particles' random movement. **B1**

(c) $(184 + 176 + 191) \div 3 = 551 \div 3 = 183.67$, so 184 s. **B1**

(d) Before: $6 \times 2 \times 2 = 24$ cm². **B1** After: $8 \times 6 \times 1 \times 1 = 48$ cm². **B1** The surface area has doubled for the same volume, so the acid diffuses in faster and the time taken is **shorter**. **B1**

(e) Any two of: temperature (higher is faster), concentration of the acid (a steeper gradient is faster), the distance to the centre of the block. **B1 B1**

Example 2

A student fills a bag of dialysis tubing with 20% sucrose solution, ties it and places it in a beaker of distilled water. At the start the bag has a mass of 12.40 g. After 30 minutes it is 13.55 g.

(a) State what the dialysis tubing represents in a cell. **[1]**

(b) Calculate the percentage change in mass of the bag. Give your answer to two decimal places. **[2]**

(c) Explain the change in mass. **[3]**

(d) The experiment is repeated with the bag filled with a mixture of starch and glucose. After 30 minutes glucose is found in the water outside the bag, but starch is not. Explain this result. **[2]**

(a) The cell membrane (a partially permeable membrane). **B1**

(b) Change $= 13.55 - 12.40 = 1.15$ g. **M1** Percentage change $= \frac{1.15}{12.40} \times 100 = +9.27\%$. **A1**

(c) Water moved **into** the bag **B1** by osmosis **B1**, from the distilled water (dilute) into the more concentrated sucrose solution, through the partially permeable tubing; the sucrose molecules could not move out. **B1** (Extended: from a higher water potential outside to a lower water potential inside.)

(d) Glucose can pass out through the tubing but starch cannot **B1**, because glucose molecules are small and starch molecules are too large to pass through. **B1**

Example 3

Potato cylinders were weighed, left in sucrose solutions for 2 hours, dried and weighed again.

Concentration / mol per dm³	Starting mass / g	Final mass / g	Percentage change / %
0.0	2.50	2.78	+11.20
0.2	2.48	2.63	+6.05
0.4	2.52	2.57	
0.6	2.50	2.41	−3.60
0.8	2.46	2.27	−7.72
1.0	2.54	2.28	−10.24

(a) Calculate the percentage change in mass at 0.4 mol per dm³, to two decimal places. **[2]**

(b) Describe the trend in the results. **[2]**

(c) The results are plotted on a graph (the graph in "Understand it"). Estimate the concentration at which there is no net change in mass. **[1]**

(d) **Extended only:** explain the difference between the results at 0.2 and 0.8 mol per dm³. Use the term water potential. **[4]**

(e) **Extended only:** describe and explain the appearance of a cell from the cylinder in 1.0 mol per dm³. **[2]**

(a) $\frac{2.57-2.52}{2.52} \times 100$ **M1** $= +1.98\%$. **A1**

(b) As the concentration increases, the percentage gain in mass decreases **B1**; from 0.6 mol per dm³ the cylinders lose mass, and the loss increases with concentration. **B1**

(c) Where the line crosses 0: about 0.47 mol per dm³. **B1**

(d) At 0.2 mol per dm³ the solution has a **higher water potential** than the potato cells **B1**, so water **enters** the cells by osmosis and the mass increases. **B1** At 0.8 mol per dm³ the solution has a **lower water potential** than the cells **B1**, so water **leaves** by osmosis, through the partially permeable cell membranes, and the mass decreases. **B1**

(e) The cell is **plasmolysed** (flaccid) **B1**: it has lost so much water that the vacuole and cytoplasm have shrunk and the cell membrane has pulled away from the cell wall. **B1**

Example 4 (Extended)

(a) The concentration of magnesium ions is higher inside root hair cells than in the soil water. Explain how the root hair cells absorb magnesium ions. **[4]**

(b) The roots are placed in a solution without oxygen. Suggest and explain the effect on magnesium ion uptake. **[2]**

(c) Three neighbouring leaf cells have water potentials $A = -250$ kPa, $B = -410$ kPa and $C = -330$ kPa. State the direction of water movement between each pair of cells. **[2]**

(d) A red blood cell with a diameter of 7.5 μm is placed in a dilute salt solution. Its diameter increases to 8.1 μm. Calculate the percentage increase, and explain why the cell swells. **[3]**

(a) By active transport **B1**, from a lower concentration in the soil to a higher concentration in the cell, against the concentration gradient **B1**, through the cell membrane using protein carriers **B1**, using energy released by respiration. **B1**

(b) Uptake decreases (or stops) **B1**, because without oxygen there is no aerobic respiration, so less energy is released for active transport. **B1**

(c) From A to B, from A to C, and from C to B. **B2** (water moves from the higher, less negative, water potential to the lower).

(d) $\frac{8.1-7.5}{7.5} \times 100 = 8.0\%$. **B1** The solution has a higher water potential than the cytoplasm **B1**, so water enters the cell by osmosis through the partially permeable cell membrane, and with no cell wall the cell swells. **B1**

Common mistakes

- **Leaving key words out of a definition.** Diffusion needs "net" and "random movement"; active transport needs "through a membrane" and "energy from respiration". Many candidates are unsure of active transport's direction: it is **low to high**.
- **Mixing up osmosis and diffusion.** Osmosis is only **water** crossing a partially permeable membrane. Oxygen entering the blood, auxin moving down a root and glucose leaving dialysis tubing are diffusion.

- **Saying salt or sugar enters the potato.** The mass changes because **water** moves; the solute stays outside.
- **"Water moves down a concentration gradient"** (Extended). Examiners want **water potential**, higher to lower, and which side is higher. A concentrated solution has a **low** water potential.
- **Confusing turgid and flaccid**, or saying a plant cell **bursts** in water. The wall stops it bursting. The water pressure presses **outwards** on the wall.
- **Calling the cell wall partially permeable.** It is fully permeable; the **cell membrane** is partially permeable.
- **Thinking a gas diffuses only upwards**, or comparing two different gases to decide a direction. Compare the **same** substance on each side.
- **Dividing by the final value** in a percentage change. Divide by the **starting** value and keep the minus sign for a loss.

How to get the marks

- **"Define" or "describe" a process**: each key word in the definitions scores; Extended active transport answers add protein carriers.
- **"State the name of the process"**: one word, spelled clearly: diffusion, osmosis or active transport.
- **"Explain" a water movement** (Extended): compare the water potentials of the two sides, name osmosis, name the partially permeable membrane, and say what happens as a result (mass increases, cell becomes turgid).
- **"Describe the appearance"**: what you would see; Extended answers add turgid, flaccid, plasmolysed.
- **"Describe the trend"** in a table: say what happens as the variable increases and quote a turning point (where gain becomes loss).
- **Calculations**: show the working; give the decimal places or significant figures asked, the sign for a loss and the unit.
- **Tick tables and multiple choice**: check one row or column at a time against the comparison table.

Quick check

1. State **three** differences between active transport and diffusion.
2. Name the process by which: (a) oxygen moves from an alveolus into the blood; (b) water enters a root hair cell; (c) nitrate ions enter a root hair cell.
3. A potato cube of mass 3.20 g is left in a concentrated salt solution. Its mass becomes 2.96 g. Calculate the percentage change in mass, to two decimal places, and explain the change.
4. In an agar-block experiment the times in four trials were 64 s, 58 s, 61 s and 57 s. Calculate the mean, then state the effect on the time of raising the temperature of the acid.
5. **Extended only:** cell X has a water potential of -520 kPa and cell Y of -280 kPa. State the direction of water movement and name the process.

Answers

1. Active transport moves particles against the concentration gradient (low to high), diffusion down it (high to low); active transport uses energy from respiration, diffusion uses the particles' kinetic energy; active transport must cross a membrane, using protein carriers, but diffusion needs no membrane.
2. (a) Diffusion. (b) Osmosis. (c) Active transport.
3. $\frac{2.96-3.20}{3.20} \times 100 = -7.50\%$. The salt solution has a lower water potential (is more concentrated) than the potato cells, so water leaves the cells by osmosis through their partially permeable membranes.
4. Mean $= (64 + 58 + 61 + 57) \div 4 = 240 \div 4 = 60$ s. A higher temperature gives the particles more kinetic energy, so diffusion is faster and the time is shorter.
5. From Y to X (from the higher, less negative, water potential to the lower), by osmosis.

Past questions to try

- **0610/41/M/J/23 Q2**: percentage change in potato mass, explained with water potential, and active transport compared with osmosis.
- **0610/31/M/J/24 Q3**: the agar-block investigation, a mean time and the diffusion gap-fill.
- **0610/43/M/J/23 Q1**: a tick table comparing diffusion and active transport.
- **0610/22/O/N/24 Q7**: water movement between three cells from their water potentials.