IGCSE BIOLOGY 0610 · CHAPTER 3 NOTES · ~12 MIN READ

Movement into & out of cells

How substances get across cell membranes: diffusion, osmosis (with water potential) and active transport — including surface area to volume, turgor and plasmolysis, and the potato practical.

Diffusion | Osmosis | Water potential | Turgor | Active transport

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No tag = **Core** (everyone) EXTENDED Extended only highlight = comes up again and again

Test yourself at the end

IN 30 SECONDS

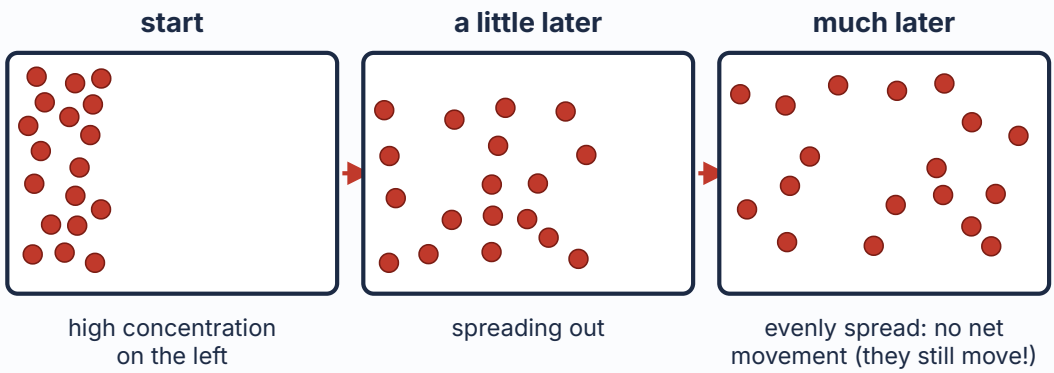
- **Diffusion**: net movement of particles from a **high** to a **low** concentration, down a concentration gradient. No energy needed from the cell.
- **Osmosis**: net movement of **water** through a **partially permeable membrane** from a region of **higher** water potential to **lower** water potential.
- **Active transport**: movement of particles **against** the concentration gradient, using **energy from respiration**.

BY THE END YOU CAN

- Define diffusion, osmosis and active transport and give an example of each.
- Describe the factors that affect the rate of diffusion.
- Explain what happens to animal and plant cells in different solutions.
- Describe and interpret the potato-cylinder investigation.
- Define water potential, and use the terms turgid, flaccid and plasmolysis. EXT
- Explain how carrier proteins use energy in active transport. EXT

1 Diffusion

What is diffusion?



Passive: no energy needed. Particles move randomly (kinetic energy).

Rate depends on the concentration gradient, temperature, surface area and distance.

Diffusion spreads particles out until they are evenly mixed. Individual particles keep moving after that, but there is no net movement.

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

- Particles in gases and liquids are always moving. More particles leave a crowded region than arrive, so there is a **net movement** to the less crowded region.
- The **energy for diffusion comes from the kinetic energy** of the particles. The cell does **not** use energy. Diffusion is a **passive** process.
- Diffusion works well for **small molecules** that can pass through the cell membrane: **oxygen, carbon dioxide, water, urea, glucose** (in some cases).

Where	What diffuses
alveoli in the lungs	oxygen into the blood, carbon dioxide out
leaf	carbon dioxide into the leaf cells, oxygen out
small intestine	digested food (partly by diffusion) into the blood
body cells	oxygen in, carbon dioxide and urea out

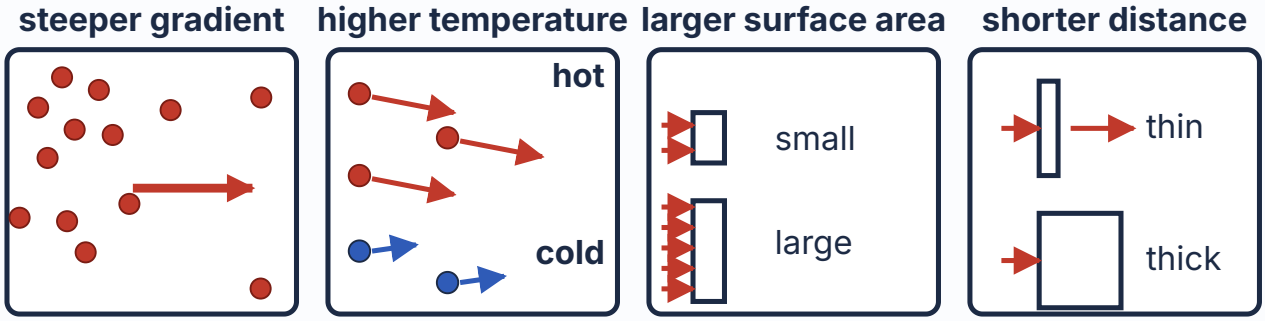
COMMON MISTAKE

"Diffusion needs energy." The **particles' own energy** (kinetic energy) drives it. The cell supplies **no** energy.

COMMON MISTAKE

"Diffusion stops when the concentrations are equal." Particles **keep moving**. There is just **no net movement**.

What affects the rate of diffusion?



All four make diffusion FASTER

(red arrows = diffusion; shorter arrow = slower movement)

Four factors that make diffusion faster.

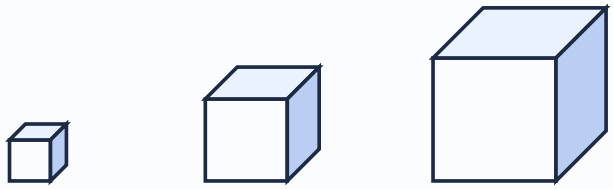
- **Concentration gradient** — the **steeper** (bigger difference), the faster.
- **Temperature** — particles gain kinetic energy, move faster, collide more: the **higher**, the faster.
- **Surface area** — a **larger** exchange surface gives more room for particles to cross.
- **Distance** — the **shorter** the distance, the faster. This is why exchange surfaces are **thin**.

EXAM TIP

Exam trick: for "explain how X is adapted for diffusion", use these four: **large surface area, thin, steep gradient (blood supply / ventilation)**.

Surface area to volume ratio

Bigger object → smaller surface area : volume ratio



1 cm cube | 2 cm cube | 3 cm cube

	1 cm cube	2 cm cube	3 cm cube
Surface area	6 cm²	24 cm²	54 cm²
Volume	1 cm³	8 cm³	27 cm³
SA : V	**6 : 1**	**3 : 1**	**2 : 1**

small cells exchange faster; big organisms need exchange surfaces

As a cube gets bigger, its volume grows faster than its surface area. Large objects have a small SA:V.

- A cube with side **1 cm** has surface area 6 × 1² = **6 cm²** and volume 1³ = **1 cm³**. SA:V = **6 : 1**.
- A cube with side **2 cm** has surface area 6 × 2² = **24 cm²** and volume 2³ = **8 cm³**. SA:V = **3 : 1**.
- A cube with side **3 cm** has surface area 6 × 3² = **54 cm²** and volume 3³ = **27 cm³**. SA:V = **2 : 1**.
- **Small cells** have a **large SA:V**, so substances can diffuse in and out fast enough. **Large organisms** have a **small SA:V**. They need special **exchange surfaces** (lungs, villi, root hairs) and **transport systems** (the circulatory system).

WORKED EXAMPLE

Calculate the surface area to volume ratio of a cube of side 4 cm.

1. surface area = 6 × 4 × 4 = 96 cm²
2. volume = 4 × 4 × 4 = 64 cm³
3. **ratio = 96 : 64 = 1.5 : 1**

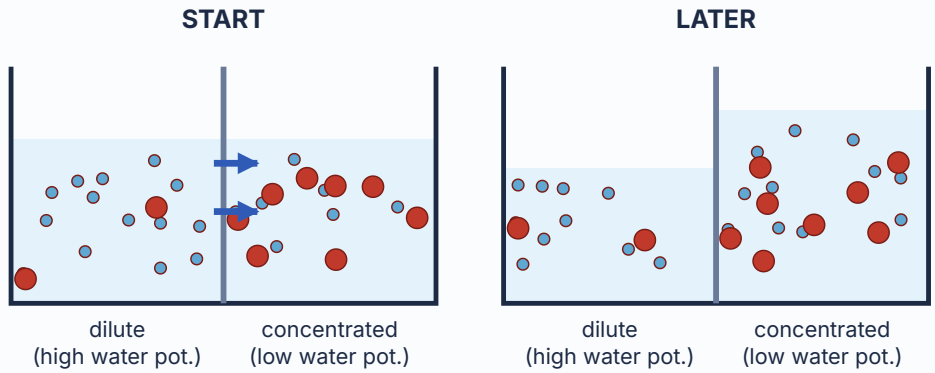
Investigating diffusion

- Cut **agar jelly** containing **phenolphthalein indicator and a little alkali** (it is pink) into cubes of different sizes.
- Put the cubes in **dilute acid**. As acid diffuses in, the pink colour **disappears**.
- Measure the **time to go colourless**. The **small cube** goes colourless **fastest** because it has the **largest SA:V**.
- Keep the same acid concentration and temperature, so only **one variable** (cube size) changes.

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2 Osmosis

What is osmosis?



water solute (too big to pass)

LATER: more water on the concentrated side, so its level rises

Water moves from HIGH to LOW water potential through a partially permeable membrane

Water moves across the membrane towards the more concentrated solution. Solute particles are too big to pass.

Osmosis — the **diffusion of water molecules** from a region of **higher water potential** to a region of **lower water potential**, through a **partially permeable membrane**.

- Water is the **solvent** in cells. A **dilute solution** has a **high** proportion of water. A **concentrated solution** has a **low** proportion of water.
- A **partially permeable membrane** lets small molecules like **water** through but stops larger solute molecules.
- **Dialysis (Visking) tubing** acts as a partially permeable membrane. A bag of sugar solution in a beaker of water **gains mass** as water enters by osmosis.

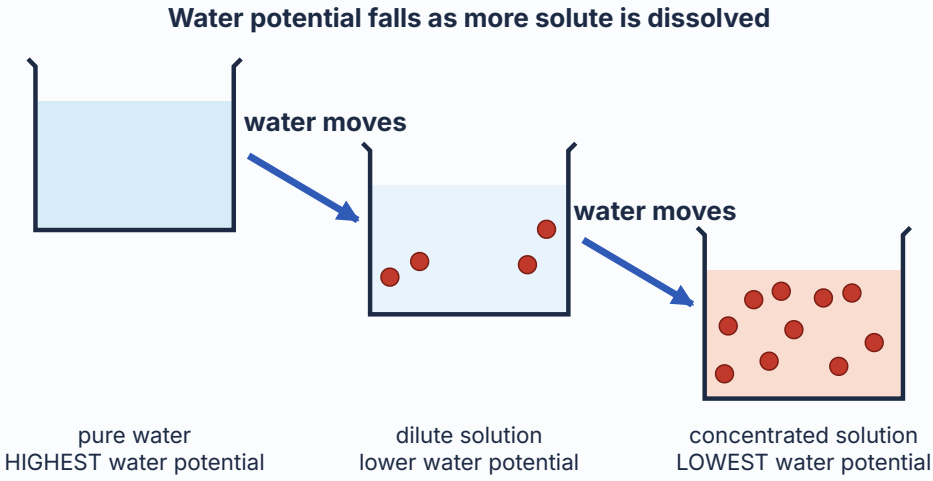
PICTURE IT

Water behaves like a crowd leaving a packed room through a door that only small people fit through: they move to where there are **fewer** of them.

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Water potential

EXTENDED



Osmosis: water moves DOWN the water-potential gradient

(high → low) through a partially permeable membrane

Pure water has the highest water potential. Dissolving more solute lowers it. Water moves down the water-potential gradient.

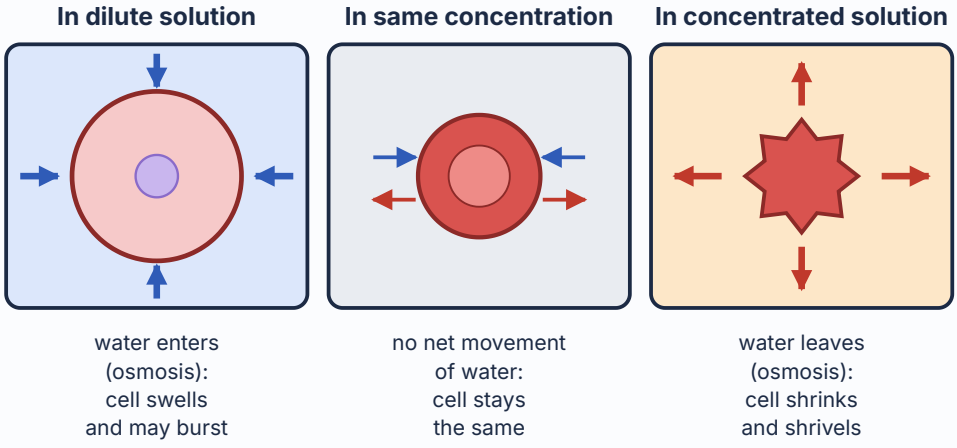
Water potential — the **tendency of water molecules to move** from one region to another. Pure water has the **highest** water potential. Adding solute **lowers** it.

- Water moves **from a higher water potential** (dilute) **to a lower water potential** (concentrated).
- So "osmosis" and "diffusion of water down a water-potential gradient" mean the same thing.

COMMON MISTAKE

Mixing up "high water potential" with "concentrated". A **concentrated** solution has a **low** water potential, because it has **less free water**.

Osmosis in animal cells



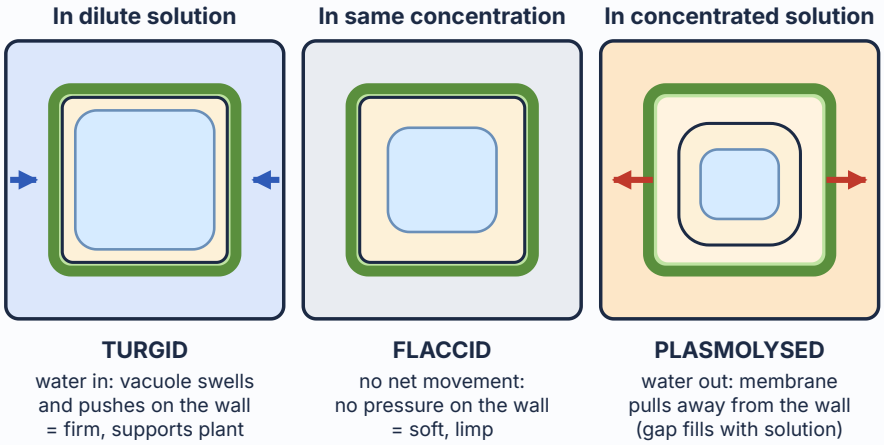
Animal cells have NO cell wall, so they cannot resist swelling

(blue arrows = water in · red arrows = water out)

An animal cell has no cell wall, so it bursts or shrinks depending on the solution.

- In a **dilute solution** (higher water potential than the cell), water **enters** by osmosis. The cell **swells** and may **burst**.
- In a solution with the **same concentration**, there is **no net movement** of water.
- In a **concentrated solution** (lower water potential than the cell), water **leaves** by osmosis. The cell **shrinks** and shrivels.

Osmosis in plant cells



Turgor pressure keeps stems firm; flaccid cells = a wilting plant

(blue arrows = water in · red arrows = water out)

A plant cell in a dilute solution becomes turgid. In a concentrated solution it becomes plasmolysed.

Turgid — a plant cell that is **full of water**, with the vacuole **pushing the cell membrane against the cell wall**.

Turgor pressure — the pressure of the cell contents pushing on the cell wall. It **supports** non-woody plants and keeps leaves firm.

Flaccid — a cell that has **lost water** and is no longer pressing on the wall: **soft and limp**. EXT

Plasmolysis — the **cell membrane pulls away from the cell wall** because water has left the cell by osmosis. EXT

- The strong **cellulose cell wall** stops a plant cell from bursting, so it stays **turgid** in water.
- When a plant does not get enough water, its cells lose turgor, become flaccid and the plant **wilts**.

EXAM TIP

Turgor is the reason **celery goes crisp in water** and **limp in salt solution**.

COMMON MISTAKE

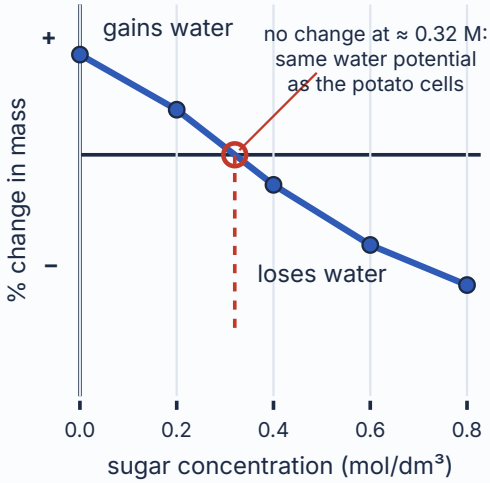
"Plant cells burst in pure water." The cell wall **stops** them bursting. They just become turgid.

Investigation: potato cylinders

Method

1 cut potato cylinders of the same size
2 blot dry, weigh each
3 soak 30 min in sugar solutions (0 → 0.8 M)
4 blot dry, weigh again

% change in mass = (final − start) ÷ start × 100



Potato cylinders gain mass in dilute solutions and lose mass in concentrated ones. Where the line crosses zero, the solution matches the potato.

- **Method:** cut potato into cylinders of the **same size**. Blot and **weigh** each. Put one in each sugar solution (for example 0, 0.2, 0.4, 0.6, 0.8 mol/dm³) for about **30 minutes**. Blot dry and **weigh again**.
- **Control variables:** same size and type of potato, same time, same volume of solution, same temperature.

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

positive = gained water, negative = lost water

WORKED EXAMPLE

A potato cylinder has a mass of 3.00 g. After soaking in 0.2 mol/dm³ sugar solution it weighs 3.27 g. Calculate the percentage change.

1. change = 3.27 − 3.00 = 0.27 g
2. 0.27 ÷ 3.00 = 0.09
3. **× 100 = +9.0% (it gained water)**

WORKED EXAMPLE

Another cylinder of 3.00 g weighs 2.46 g after soaking in 0.6 mol/dm³ sugar solution. Calculate the percentage change.

1. change = 2.46 − 3.00 = −0.54 g
2. −0.54 ÷ 3.00 = −0.18
3. **× 100 = −18% (it lost water)**

- The graph crosses **0% change** at about **0.32 mol/dm³**. At this concentration the sugar solution has the **same water potential** as the cell sap, so there is **no net movement** of water.

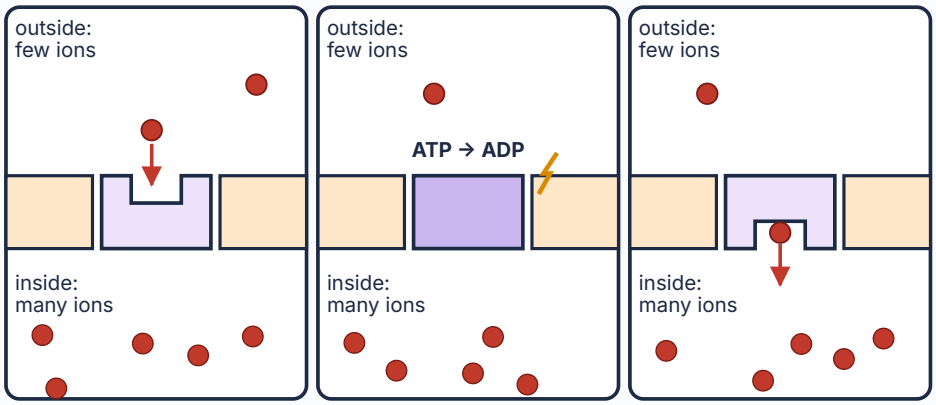
COMMON MISTAKE

Using the final mass only. Always calculate the **percentage change** so that the cylinders can be compared fairly.

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3 Active transport

What is active transport?



Moves ions AGAINST the concentration gradient (low → high): needs energy from respiration

A carrier protein in the membrane uses energy from respiration to pump ions across, against the concentration gradient.

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

- **Root hair cells** take up **mineral ions** (for example nitrate) from the soil, even though the soil water holds **less** of them than the cell. Active transport pulls them in.

- **Glucose** is absorbed in the small intestine and kidney by active transport when there is less in the gut than in the blood.
- EXT **Carrier proteins** in the membrane pick up a particle, change shape using **energy released by respiration**, and release the particle on the other side.
- Cells that do a lot of active transport have many **mitochondria**. If a cell is **poisoned** so it cannot respire, active transport **stops**.

Comparing the three processes

	Diffusion	Osmosis	Active transport
what moves	any small particles	water only	ions and molecules
direction	high → low concentration	high → low water potential	**low → high** concentration
energy from respiration?	no	no	**yes**
membrane protein needed?	no	no	yes (carriers) EXT

EXAM TIP

"**Against** the gradient" = active transport. "**Down** the gradient" = diffusion or osmosis.

4 Test yourself

Test yourself — cover the answers first

QUICK CHECK

1. Define diffusion.
2. Does diffusion need energy from respiration?
3. Name two factors that increase the rate of diffusion.
4. What type of membrane does osmosis need?
5. What happens to an animal cell placed in pure water?
6. What stops a plant cell bursting in water?
7. Name a substance taken up by root hair cells by active transport.
8. EXT What do you call a plant cell whose membrane has pulled away from the wall?

EXAM-STYLE

9. A cube has a side of 2 cm. Calculate its surface area to volume ratio. [3]
10. Explain why a large animal needs a transport system but a single-celled organism does not. [3]
11. Describe what happens to a plant cell placed in a concentrated sugar solution and explain why. [3]
12. Explain how a root hair cell takes up nitrate ions from soil that has a low nitrate concentration. [3]

Show answers

1. net movement of particles from higher to lower concentration, down a concentration gradient
2. no (passive)
3. larger surface area, higher temperature, steeper concentration gradient, shorter distance
4. partially permeable
5. water enters by osmosis; it swells and may burst
6. the cellulose cell wall
7. mineral ions (e.g. nitrate)
8. plasmolysed
9. surface area = 6 × 2 × 2 = 24 cm²
   volume = 8 cm³
   ratio = 3 : 1
10. large animals have a small surface area to volume ratio
    diffusion is too slow to supply all cells
    single-celled organisms have a large SA:V and a short diffusion distance
11. water leaves the cell by osmosis
    because the solution has a lower water potential than the cell
    the cell shrinks and the membrane pulls away from the wall (plasmolysis)
12. active transport
    using energy from respiration
    against the concentration gradient, with carrier proteins

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