Chapter: 3 Movement into and out of cells
Book/PDF: Chapter-3.pdf
Pages: 1–47
Exam level: Cambridge IGCSE (0610)

1) Big-picture overview

This chapter explains how vital substances like oxygen, water, and nutrients get into cells, and how waste products like carbon dioxide get out. It covers the three main ways this movement happens: **diffusion**, **osmosis**, and **active transport**. You'll learn that diffusion is the simple spreading out of particles, while osmosis is a special type of diffusion just for water moving across a membrane. Active transport is different because it uses energy to move substances against their natural flow, like pushing something uphill. Understanding these processes is crucial because they are fundamental to almost everything an organism does, from breathing and feeding to getting support (in plants) and removing waste.

2) Syllabus mapping

Outcome code (unofficial)	Outcome description	Where covered (page)
3.1.1	Define diffusion as the net movement of particles from a region of higher concentration to a region of lower concentration.	2
3.1.2	Explain the importance of diffusion for gas exchange in organisms.	3, 4
3.1.3	Investigate and describe the factors that influence the rate of diffusion (surface area, temperature, concentration gradient, distance).	5–8
3.2.1	Define osmosis as 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.	27

Outcome code (unofficial)	Outcome description	Where covered (page)
3.2.2	Describe the effects of osmosis on plant and animal cells, explaining the importance of water potential.	16–18, 30, 32
3.2.3	Explain the terms turgid, turgor pressure, flaccid, and plasmolysis in relation to plant cells.	30
3.3.1	Define active transport as the movement of particles against a concentration gradient using energy from respiration.	40
3.3.2	Explain the importance of active transport, giving examples like ion uptake by root hairs and glucose uptake by intestinal villi.	40, 41
3.3.3	Describe the role of protein carriers in active transport.	41

3) Key terms and definitions

Term	One-sentence definition	First appears (page)	Example/application
Diffusion	The net movement of particles from a region of their higher concentration to a region of their lower concentration down a concentration gradient.	2	Oxygen moving from the lungs into the blood. (p. 3)
Concentration gradient	The difference in the concentration of a substance between two regions.	8	The difference in oxygen levels inside and outside a respiring cell creates a gradient for diffusion. (p. 8)

Term	One-sentence definition	First appears (page)	Example/application
Partially permeable membrane	A membrane that allows small molecules like water to pass through but not larger solute molecules.	15	The cell membrane controls what enters and leaves a cell. (p. 16)
Osmosis	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.	27	Plant root hairs absorbing water from the soil. (p. 30)
Water potential	A measure of the concentration of free water molecules; pure water has the highest water potential.	29	A dilute solution has a higher water potential than a concentrated solution. (p. 29)
Turgid	A state where a plant cell is swollen and firm due to taking up the maximum amount of water.	30	A well-watered plant stands upright because its cells are turgid. (p. 30)
Turgor pressure	The pressure exerted by the cell contents pushing the cell membrane against the cell wall in a plant cell.	30	This pressure provides support to non-woody plants. (p. 30)
Flaccid	A state where a plant cell is limp because it has lost water and turgor pressure is low.	30	A wilting plant has flaccid cells. (p. 30)
Plasmolysis	The process where the cytoplasm and vacuole shrink away from the cell wall as a plant cell loses water by osmosis.	30	Occurs when a plant cell is placed in a concentrated salt or sugar solution. (p. 30)

Term	One-sentence definition	First appears (page)	Example/application
Active transport	The movement of particles through a cell membrane from a region of lower concentration to a region of higher concentration, using energy from respiration.	40	Mineral ions are absorbed from dilute soil water into root hair cells. (p. 41)

4) Core concepts explained

Diffusion (p. 2)

- [cite_start]Diffusion is a **passive process**, meaning it does not require energy from the cell[cite: 15]. [cite_start]The energy comes from the natural random movement (kinetic energy) of particles[cite: 74].
- [cite_start]It results in the **net movement** of particles down a **concentration gradient**—from an area of high concentration to an area of low concentration[cite: 28].
- [cite_start]This process continues until the particles are evenly distributed[cite: 29].
- [cite_start]In living organisms, diffusion is vital for moving small, non-polar molecules across the cell membrane, such as oxygen for respiration and carbon dioxide removal[cite: 38, 43].

Factors affecting the rate of diffusion (p. 5)

- [cite_start]**Surface area:** A larger surface area allows more particles to cross at the same time, increasing the rate[cite: 82, 83]. [cite_start]Example: Microvilli on intestinal cells increase the surface area for absorbing nutrients[cite: 84, 85].
- [cite_start]**Temperature:** Higher temperatures give particles more kinetic energy, so they move and diffuse faster[cite: 115, 116].
- [cite_start]**Concentration gradient:** A steeper gradient (bigger difference in concentration) results in a faster net movement of particles[cite: 118].
- **Distance:** Diffusion is fastest over short distances. [cite_start]The thicker the barrier, the slower the rate of diffusion[cite: 126, 128].

Osmosis (p. 14, 27)

- [cite_start]Osmosis is a special case of diffusion specifically for **water molecules**[cite: 248, 249].
- [cite_start]It requires a **partially permeable membrane** that allows water to pass through but restricts larger solute molecules[cite: 248].
- [cite_start]The net movement of water is from a region of higher water potential (e.g., a dilute solution or pure water) to a region of lower water potential (a more concentrated solution)[cite: 451].
- [cite_start]Dissolving solutes (like sugar or salt) in water lowers its water potential because water molecules are attracted to the solute molecules and are less "free" to move[cite: 453, 454].

Effects of osmosis on cells (p. 16-18)

Feature	Animal Cell (e.g., Red Blood Cell)	Plant Cell	Exam Note
In dilute solution (high water potential)	[cite_start]Water enters, cell swells and may **burst** (lysis) because it has no cell wall[cite: 277].	Water enters, vacuole swells, pushing against the cell wall. The cell becomes firm and **turgid**. [cite_start]The strong cell wall prevents bursting[cite: 288, 289].	The term "burst" is specific to animal cells.
In concentrated solution (low water potential)	[cite_start]Water leaves, cell shrinks and becomes **crenated** or **plasmolysed**[cite: 278, 528].	Water leaves, vacuole and cytoplasm shrink away from the cell wall (**plasmolysis**). [cite_start]The cell becomes **flaccid**[cite: 494, 495].	Plasmolysis is reversible if the cell is returned to water quickly.
In isotonic solution (same water potential)	No net water movement. [cite_start]Cell shape remains normal[cite: 280].	No net water movement. [cite_start]Cell is **flaccid** (not fully turgid)[cite: 496].	Plant cells need to be in a solution with a higher water potential than their cytoplasm to be fully turgid and provide support.

Active transport (p. 40)

- [cite_start]Active transport moves substances **against a concentration gradient** (from low to high concentration)[cite: 632].
- [cite_start]This process requires **energy**, which is supplied by cellular **respiration**[cite: 632, 644].
- It involves specific **protein carrier molecules** embedded in the cell membrane. [cite_start]These proteins bind to the substance and change shape to transport it across the membrane[cite: 646, 647].
- [cite_start]It allows cells to accumulate essential substances (like mineral ions in plant roots) or remove unwanted ones, even when diffusion would move them in the opposite direction[cite: 635, 636, 653].

5) Diagrams and micrographs (figures)

- **Fig 3.2 (p. 3):** Shows molecules entering a cell by diffusion. In (a), there's a higher concentration outside, so molecules move in. In (b), the concentration is equal inside and outside.
- **Fig 3.3 (p. 6):** Shows **microvilli**, which are tiny folds on the cell surface that increase the surface area for faster absorption.
- **Fig 3.10 (p. 16):** Illustrates osmosis. Water moves across a partially permeable membrane from a dilute solution to a concentrated solution, causing the level of the concentrated solution to rise.
- **Fig 3.11 (p. 17):** Shows osmosis in an animal cell. When placed in pure water (higher water potential), water enters and the cell swells up.
- **Fig 3.12 (p. 18):** Shows osmosis in a plant cell. Water enters the vacuole, which swells and pushes the cytoplasm against the strong cell wall, making the cell turgid.
- **Fig 3.13 (p. 19):** A photo showing a wilting plant (flaccid cells) and a recovered, turgid plant after watering.
- **Fig 3.21 (p. 33):** A micrograph of plasmolysed (shrunken) red blood cells, which can happen during dehydration.
- **Fig 3.24 & 3.25 (p. 37-38):** A micrograph and diagram showing **plasmolysis** in rhubarb cells. When placed in a concentrated solution, the vacuole loses water, shrinks, and pulls the cytoplasm away from the cell wall.
- **Fig 3.26 (p. 41):** A model for active transport. A substance binds to a carrier protein, which uses energy from respiration to change shape and release the substance on the other side of the membrane against the concentration gradient.

6) Processes and cycles

Process: Diffusion across a cell membrane

1. A substance (e.g., oxygen) is at a higher concentration outside the cell than inside.
2. The particles of the substance move randomly in all directions.
3. Because there are more particles outside, more will randomly move into the cell than out of it.
4. This results in a **net movement** of the substance into the cell, down the concentration gradient.
5. The process is **passive** and continues until the concentrations are equal or the substance is used up by the cell (maintaining the gradient).

Process: Osmosis in a plant cell (causing turgor)

1. The plant cell is placed in a solution with a higher water potential (e.g., pure water) than its cell sap.
2. Water molecules move by osmosis across the partially permeable cell membrane and vacuole membrane (tonoplast) into the vacuole.
3. The vacuole swells and pushes the cytoplasm against the cell wall.
4. The strong, inelastic cell wall pushes back, creating **turgor pressure**.
5. The cell becomes firm or **turgid**, providing support to the plant.

Process: Active transport

1. A substance (e.g., a mineral ion) needs to be moved into a cell where its concentration is already high (i.e., against the concentration gradient).
2. The substance binds to a specific **carrier protein** on the outer surface of the cell membrane.
3. **Energy from respiration** (in the form of ATP) causes the carrier protein to change shape.
4. The change in shape carries the substance through the membrane and releases it into the cytoplasm.
5. The carrier protein then returns to its original shape, ready to transport another particle.

7) Formulae and calculations

Quantity	Formula	Units	Typical values	Worked example (from p. 25)
Percentage change in		%	Positive (gain),	A potato cylinder starts at 2.5 g and ends at 2.3 g. Change = 2.3 -

Quantity	Formula	Units	Typical values	Worked example (from p. 25)
mass			negative (loss)	2.5 = -0.2 g. % change = (-0.2 / 2.5) x 100 = **-8%**

8) Required practicals / experiments

Experiment 7: Effect of sucrose concentration on potato tissue (p. 25)

- **Aim:** To investigate the effect of different concentrations of sucrose solution on potato cylinders and to find the concentration isotonic to potato cells.
- [cite_start]**Apparatus:** Large potato, cork borer, ruler/scalpel, balance, test tubes, test-tube rack, measuring cylinder, sucrose solutions of different concentrations (e.g., 0.0, 0.2, 0.4, 0.6, 0.8, 1.0 mol dm^{-3}), paper towels [cite: 397-403].
- **Method:**
    i. Use a cork borer to cut several cylinders of potato tissue. [cite_start]Trim them to the same length (e.g., 50 mm)[cite: 397, 400].
    ii. [cite_start]Blot each cylinder dry and measure its initial mass[cite: 404].
    iii. [cite_start]Place one cylinder into a test tube containing a known concentration of sucrose solution[cite: 404, 405].
    iv. [cite_start]Repeat for all other concentrations[cite: 405].
    v. [cite_start]Leave the cylinders for a set time (e.g., 30 minutes or longer)[cite: 406].
    vi. [cite_start]Remove each cylinder, blot it dry, and measure its final mass[cite: 407].
    vii. [cite_start]Calculate the change in mass and the percentage change in mass for each cylinder[cite: 409].
- **Variables:**
    - **Independent Variable (IV):** Concentration of sucrose solution.
    - **Dependent Variable (DV):** Percentage change in mass of the potato cylinder.
    - **Control Variables:** Length/surface area of potato cylinders, temperature, time in solution, volume of solution, source of potato.
- **Safety:** Wear eye protection. [cite_start]Take care when using a knife or cork borer[cite: 321, 370].
- **Sources of error:** Inaccurate measurement of mass/length, insufficient blotting of cylinders, evaporation of solutions.
- **Improvements:** Use a top-pan balance for accurate mass readings, repeat the experiment for each concentration and calculate a mean to improve reliability.

- **Expected results:** Potato cylinders in dilute solutions (or pure water) will gain mass (positive % change). Cylinders in concentrated solutions will lose mass (negative % change). A graph of % change vs. concentration can be plotted.

9) Data handling and graphing

- **Graphing for the Potato Experiment:**
  - Plot the **concentration of sucrose solution (mol dm^{-3})** on the **x-axis** (the independent variable).
  - Plot the **percentage change in mass (%)** on the **y-axis** (the dependent variable).
  - [cite_start]The y-axis must include both positive and negative values[cite: 415].
- **Interpreting the graph:**
  - [cite_start]Where the line crosses the x-axis (i.e., where the percentage change in mass is zero), the external solution has the same water potential as the potato cells[cite: 623]. This is the **isotonic point**.
  - Points above the x-axis show a net gain of water by osmosis.
  - Points below the x-axis show a net loss of water by osmosis.
  - The trend should show that as the sucrose concentration increases, the percentage change in mass decreases (becomes more negative).

10) Common misconceptions and exam tips

- **Misconception:** "Osmosis is the movement of water from high concentration to low concentration."
  - **Correct understanding:** This is too vague. Osmosis is the movement of water molecules from a region of *higher water potential* to a region of *lower water potential* through a *partially permeable membrane*. Always include all three parts in your definition.
  - **Quick tip:** Remember **H**igh **W**ater **P**otential to **L**ow **W**ater **P**otential (**HWP** → **LWP**).
- **Misconception:** "Strong solutions suck water out of cells."
  - **Correct understanding:** Avoid using non-scientific terms like "suck". Water moves passively down a water potential gradient due to the random motion of water molecules.
  - **Quick tip:** Describe osmosis in terms of water potential gradients and net movement.
- **Misconception:** "Active transport is just faster diffusion."
  - **Correct understanding:** They are completely different. Diffusion is passive and moves down a concentration gradient. Active transport requires energy and moves substances against a

concentration gradient.
  - **Quick tip:** "Active" means it needs energy from respiration. "Passive" (diffusion/osmosis) does not.

11) Exam-style practice

Multiple Choice Questions (MCQs)

1. Which process requires energy from respiration?
   A. Diffusion
   B. Osmosis
   C. Active transport
   D. Plasmolysis
   (Answer: C. Active transport is the only process listed that moves substances against a concentration gradient, requiring cellular energy)
2. A plant cell is placed in pure water. Which of the following correctly describes the cell's final state?
   A. Plasmolysed
   B. Flaccid
   C. Turgid
   D. Burst
   (Answer: C. The cell will take in water until the cell wall prevents further expansion, making it turgid.)
3. Which factor would *decrease* the rate of diffusion of oxygen into a cell?
   A. Increasing the temperature
   B. Increasing the concentration of oxygen outside the cell
   C. Increasing the thickness of the cell wall
   D. Increasing the surface area of the cell
   (Answer: C. A greater distance for diffusion slows down the rate.)
4. The definition of osmosis requires which of the following?
   A. A concentration gradient for solutes
   B. A partially permeable membrane
   C. Energy from respiration
   D. Carrier proteins
   (Answer: B. Osmosis is specifically the movement of water across a partially permeable membrane.)

5. Red blood cells were placed in a solution and they burst. What can be concluded about the solution?
   A. It had a higher water potential than the cytoplasm.
   B. It had a lower water potential than the cytoplasm.
   C. It was isotonic to the cytoplasm.
   D. It contained a respiratory poison.
   (Answer: A. A higher external water potential causes water to enter the cell rapidly by osmosis, causing an animal cell to burst.)
6. Root hair cells absorb nitrate ions from the soil. The concentration of nitrates is higher in the cell than in the soil. By what process do the ions enter the cell?
   A. Diffusion
   B. Osmosis
   C. Plasmolysis
   D. Active transport
   (Answer: D. Movement against a concentration gradient requires active transport.)
7. Which structures are adaptations to increase surface area for diffusion?
   A. Contractile vacuoles
   B. Cell walls
   C. Microvilli
   D. Mitochondria
   (Answer: C. Microvilli are foldings of the cell membrane that increase the surface area for absorption.)
8. What is a concentration gradient?
   A. The speed at which particles move
   B. The difference in concentration between two areas
   C. The energy used to move particles
   D. The total number of particles in a solution
   (Answer: B. A gradient refers to a difference across a distance.)
9. A wilted plant has cells that are...
   A. Turgid
   B. Burst
   C. Plasmolysed
   D. Flaccid
   (Answer: D. Wilting occurs when cells lose turgor and become limp, or flaccid.)
10. What is water potential a measure of?
   A. The pressure inside a plant cell
   B. The concentration of solutes in a solution
   C. The concentration of free water molecules

D. The amount of energy in water
(Answer: C. It measures the tendency of water molecules to move from one place to another.)

Short-answer questions

1. **Define** diffusion. [2]
   - *Model answer:* The net movement of particles [1] from a region of higher concentration to a region of lower concentration (down a concentration gradient) [1].
2. **Explain** why a plant that is not watered will wilt. Use the terms *water potential*, *osmosis*, and *flaccid* in your answer. [3]
   - *Model answer:* The soil will have a lower water potential than the root cells [1]. Water will move out of the plant cells by osmosis [1]. The cells will lose turgor and become flaccid, causing the plant to wilt [1].
3. **State two** ways in which active transport differs from diffusion. [2]
   - *Model answer:* Active transport moves substances against a concentration gradient, whereas diffusion is down a gradient [1]. Active transport requires energy from respiration, whereas diffusion is passive [1].
4. A student is investigating osmosis using potato cylinders. **Suggest one** variable they should control and **explain** why it is important. [2]
   - *Model answer:* Control variable: Temperature [1]. Explanation: Temperature affects the kinetic energy of water molecules, so it would affect the rate of osmosis and make the results invalid [1]. (Other valid answers: surface area of potato, time, etc.)
5. **Explain** the role of protein carriers in active transport. [2]
   - *Model answer:* Carrier proteins are specific to the substance being transported [1]. They bind to the substance and use energy to change shape, moving it across the membrane against the concentration gradient [1].

Structured questions

1. The graph shows the results of an experiment on the effect of sucrose concentration on the mass of potato tissue.
   a. **Describe** the trend shown in the graph. [2]
   b. From the graph, **estimate** the concentration of sucrose solution that is isotonic with the potato cells. **Explain** your reasoning. [2]
   c. **Explain**, in terms of water potential, why the potato tissue lost mass in the 1.0 mol dm^{-3} solution. [3]
   - *Marking points:*
     - a. As the sucrose concentration increases, the percentage change in mass decreases / becomes more negative [1]. There is a negative correlation [1].

- b. Approximately 0.3 mol dm^{-3} [1]. This is the point where the line crosses the x-axis, meaning there was no net change in mass, so no net movement of water by osmosis [1].
    - c. The 1.0 mol dm^{-3} sucrose solution has a lower water potential than the potato cell sap [1]. Therefore, water moved by osmosis [1] from a region of higher water potential (the potato cells) to a region of lower water potential (the sucrose solution) [1].

2. Gas exchange in the lungs and mineral uptake by roots both involve the movement of substances.
   a. **Describe** how oxygen moves from the alveoli in the lungs into the blood by diffusion. [3]
   b. Mineral ions are taken up by root hairs using active transport. **Explain** why this process is necessary. [2]
   c. **Suggest** why root hair cells have a large number of mitochondria. [2]
   - *Marking points:*
     - a. The concentration of oxygen is higher in the alveoli than in the blood [1]. This creates a concentration gradient [1]. Oxygen diffuses across the thin walls of the alveolus and capillary into the blood [1].
     - b. The concentration of mineral ions is often lower in the soil than inside the root hair cells [1]. Active transport is needed to move these ions against the concentration gradient [1].
     - c. Active transport requires energy [1]. This energy is released by aerobic respiration, which occurs in the mitochondria [1].

12) Quick revision checklist

- [ ] I can define diffusion and give an example in a living organism.
- [ ] I can list the four factors that affect the rate of diffusion.
- [ ] I can define osmosis, making sure to mention water potential and a partially permeable membrane.
- [ ] I can describe what happens to an animal cell in pure water and concentrated salt solution.
- [ ] I can describe what happens to a plant cell in pure water and concentrated salt solution.
- [ ] I can explain the meanings of turgid, flaccid, and plasmolysis.
- [ ] I know that turgor pressure provides support to plants.
- [ ] I can define active transport, mentioning energy and the concentration gradient.
- [ ] I can give an example of active transport in a plant and an animal.
- [ ] I understand that protein carriers and energy from respiration are needed for active transport.
- [ ] I can calculate percentage change in mass from experimental data.

- [ ] I can interpret a graph of percentage change in mass vs. solution concentration to find the isotonic point.

13) Flashcards (ready-to-use)

Q1: What is diffusion?
A1: The net movement of particles from a region of higher concentration to a region of lower concentration.

Q2: What are the 4 factors affecting the rate of diffusion?
A2: Surface area, temperature, concentration gradient, and distance.

Q3: What is osmosis?
A3: The net movement of water molecules from a region of higher water potential to one of lower water potential, through a partially permeable membrane.

Q4: What happens to an animal cell in pure water?
A4: It swells and bursts (lysis) because it has no cell wall.

Q5: What happens to a plant cell in pure water?
A5: It takes in water and becomes turgid (firm). It does not burst due to the strong cell wall.

Q6: What happens to a plant cell in a concentrated sugar solution?
A6: It loses water, and the cytoplasm pulls away from the cell wall. This is called plasmolysis and the cell is flaccid.

Q7: What does "turgid" mean?
A7: A plant cell that is swollen and rigid due to high water content and turgor pressure.

Q8: How do plants get support without a skeleton?
A8: From the turgor pressure in their cells pushing outwards on the cell walls.

Q9: What is active transport?
A9: The movement of particles against a concentration gradient, using energy from respiration.

Q10: Why does active transport need energy?
A10: To move substances from a low concentration to a high concentration ("uphill").

Q11: Give an example of active transport in plants.

A11: Uptake of mineral ions (e.g., nitrates) by root hair cells from the soil.

Q12: Give an example of active transport in animals.

A12: Uptake of glucose from the small intestine into the blood.

Q13: What is a partially permeable membrane?

A13: A membrane that allows small molecules (like water) to pass through but not larger ones (like sugar).

Q14: Which has a higher water potential: pure water or a sugar solution?

A14: Pure water. Adding solutes lowers the water potential.

Q15: What is the role of mitochondria in a root hair cell?

A15: To carry out respiration to release energy for the active transport of mineral ions.

14) 60-second recap

This chapter covers the three key ways substances move across cell membranes. **Diffusion** is the passive movement of particles down a concentration gradient, essential for gas exchange. Its rate is affected by surface area, temperature, the gradient, and distance. **Osmosis** is the specific diffusion of water across a partially permeable membrane, from a high to a low water potential. It makes plant cells turgid for support and can cause animal cells to burst. Finally, **active transport** uses energy from respiration to pump substances against their concentration gradient using carrier proteins, allowing cells to absorb vital minerals from dilute solutions.

15) References to pages

16) Excluded "Going further" sections (not summarized)

Section title	**Pages**
Nitrogen and divers	4
Artificial partially permeable membranes (leading to dialysis)	11, 12, 13
The physical and chemical properties of water	15
Controlled diffusion	42
Total excluded:	**4**