

Transport in cells

Revision notes • Diffusion, surface area to volume ratio, exchange surfaces, osmosis and active transport, and how they differ.

For AQA GCSE Biology 8461 and Combined Science: Trilogy 8464. **Triple only** is not in Combined Science. **Higher tier** is only on the Higher paper.

Transport in cells Spec 4.1.3

Diffusion Spec 4.1.3.1

Substances may move into and out of cells across the cell membranes via **diffusion**.

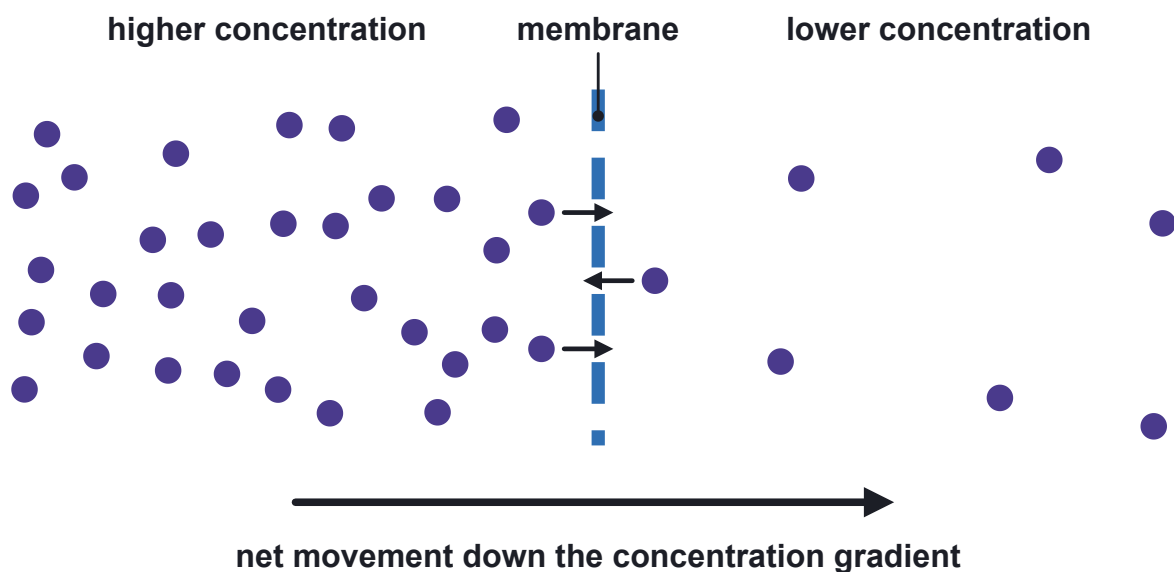
Diffusion

The spreading out of the particles of any substance in solution, or particles of a gas, resulting in a net movement from an area of higher concentration to an area of lower concentration.

Some of the substances transported in and out of cells by diffusion are **oxygen** and **carbon dioxide** in gas exchange, and the waste product **urea** from cells into the blood plasma for excretion in the kidney.

Factors affecting the rate of diffusion

Factor	Effect on the rate of diffusion
Difference in concentrations (concentration gradient)	A bigger difference means a faster rate, because more particles move down the gradient in the same time
Temperature	A higher temperature means a faster rate, because the particles have more energy and move faster
Surface area of the membrane	A larger surface area means a faster rate, because more particles can cross at once



Particles move both ways, but there is a **net movement** from higher to lower concentration.

Exam tip: Always say 'net movement' and 'down a concentration gradient'. Particles move in both directions, but more move from the high concentration side.

Surface area to volume ratio Spec 4.1.3.1

A single-celled organism has a relatively large **surface area to volume ratio**. This allows sufficient transport of molecules into and out of the cell to meet the needs of the organism.

As an organism gets bigger, its volume increases faster than its surface area, so its surface area to volume ratio becomes smaller. A multicellular organism cannot get enough molecules in and out of every cell by diffusion across its outer surface alone.

surface area to volume ratio = surface area ÷ volume

Cubes of different sizes

Side length	Surface area ($6 \times \text{side}^2$)	Volume (side^3)	Surface area : volume
1 cm	6 cm ²	1 cm ³	6 : 1
2 cm	24 cm ²	8 cm ³	3 : 1
3 cm	54 cm ²	27 cm ³	2 : 1

Comparing surface area to volume ratios

Calculate the surface area to volume ratio of a cube with sides of 4 cm. Is it larger or smaller than for a 2 cm cube?

1. Surface area = $6 \times 4 \times 4 = 96 \text{ cm}^2$.
2. Volume = $4 \times 4 \times 4 = 64 \text{ cm}^3$.
3. Ratio = $96 : 64 = 1.5 : 1$. The 2 cm cube has 3 : 1.

Answer: 1.5 : 1, which is smaller than the ratio of 3 : 1 for the 2 cm cube.

You should be able to explain the need for exchange surfaces and a transport system in multicellular organisms in terms of surface area to volume ratio. Their surface area to volume ratio is small, so they cannot rely on diffusion across the outside of the body to supply all of their cells. They need specialised **exchange surfaces** and a **transport system** to move substances to and from cells deep inside the body.

Maths skill: Divide both numbers by the volume so the ratio is written as 'something : 1'. This makes it easy to compare two ratios.

Exchange surfaces Spec 4.1.3.1

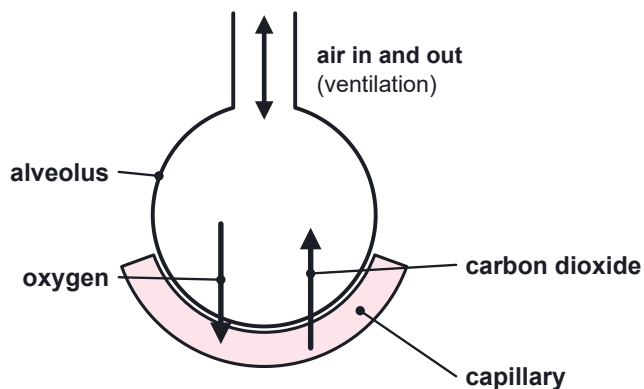
In multicellular organisms, surfaces and organ systems are specialised for exchanging materials. This is to allow sufficient molecules to be transported into and out of cells for the organism's needs. The effectiveness of an exchange surface is increased by:

- having a large surface area
- a membrane that is thin, to provide a short diffusion path
- (in animals) having an efficient blood supply
- (in animals, for gaseous exchange) being ventilated.

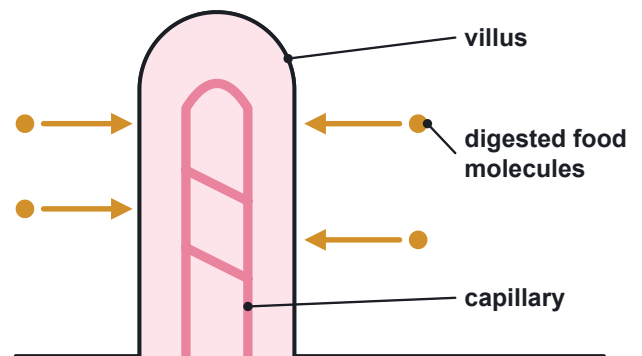
Adaptations of exchange surfaces

Exchange surface	Substances exchanged	Adaptations
Small intestine (mammals)	Digested food molecules into the blood	Villi give a large surface area; thin lining gives a short diffusion path; good blood supply carries absorbed molecules away
Lungs (mammals)	Oxygen into the blood, carbon dioxide out	Many alveoli give a large surface area; thin walls; good blood supply; ventilated by breathing
Gills (fish)	Oxygen from the water into the blood, carbon dioxide out	Many gill filaments covered in folds called lamellae give a large surface area; thin; good blood supply; ventilated as water flows over them
Roots (plants)	Water and mineral ions into the plant	Root hair cells give a large surface area; thin cell walls give a short diffusion path
Leaves (plants)	Carbon dioxide into the leaf, oxygen and water vapour out	Flat shape and air spaces inside give a large surface area; thin leaf gives a short diffusion path; stomata let gases in and out

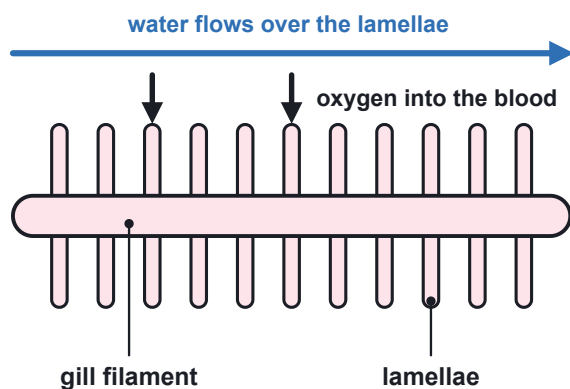
Lungs: alveolus and capillary



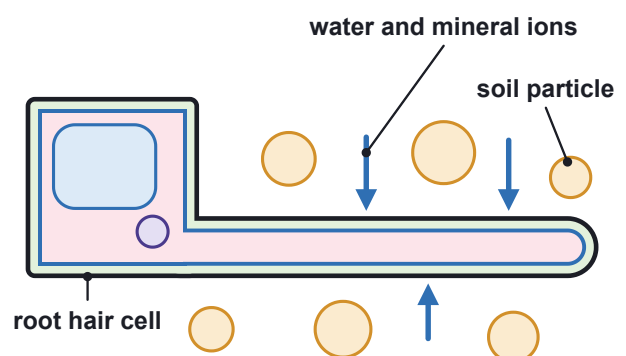
Small intestine: villus



Fish gills: gill filament



Roots: root hair cell



Exchange surfaces have a **large surface area**, a short diffusion path and (in animals) a good blood supply.

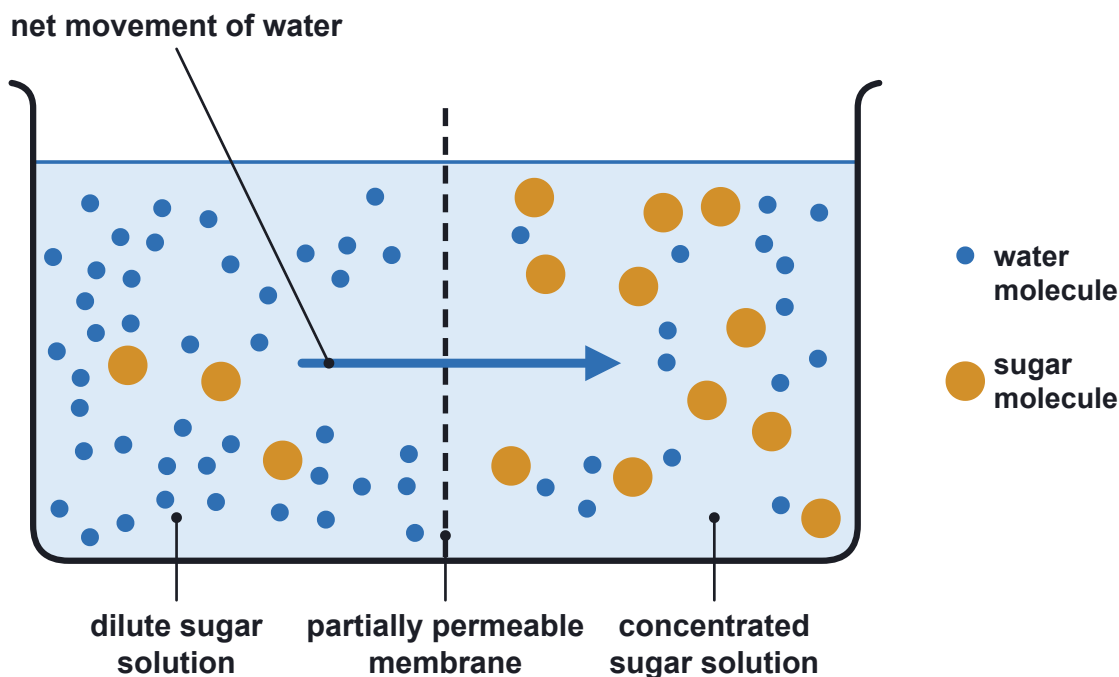
Exam tip: A maintained concentration gradient comes from the blood supply (in animals) and from ventilation. Say that both keep the concentration gradient steep so diffusion stays fast.

Osmosis Spec 4.1.3.2

Water may move across cell membranes via **osmosis**.

Osmosis

The diffusion of water from a dilute solution to a concentrated solution through a partially permeable membrane.



In osmosis, water moves from the **dilute** solution to the **concentrated** solution through a **partially permeable membrane**.

Common mistake: Osmosis is only about water. A partially permeable membrane lets small molecules such as water through but not larger solute molecules.

Required practical: Investigate the effect of a range of concentrations of salt or sugar solutions on the mass of plant tissue. (Required practical 3 in Triple and required practical 2 in Combined Science: Trilogy.)

1. Cut identical cylinders of plant tissue, for example potato, using a cork borer, and trim them to the same length.
 2. Blot each cylinder dry and measure its mass using a balance.
 3. Place each cylinder in a different concentration of sugar or salt solution, including one in pure water. Use the same volume of solution in each tube.
 4. Leave for the same length of time at the same temperature.
 5. Remove the cylinders, blot them dry in the same way and measure their mass again.
 6. Calculate the percentage change in mass for each cylinder.
- Independent variable: the concentration of the solution.
 - Dependent variable: the change in mass (as a percentage).
 - Control variables: type and size of plant tissue, volume of solution, temperature, time left in the solution, how the tissue is dried.

In dilute solutions, water moves into the plant cells by osmosis and the mass increases. In concentrated solutions, water moves out of the cells and the mass decreases. Where the mass does not change, there is no net movement of water, so the solution is the same concentration as the inside of the cells.

Safety: take care when using the cork borer and scalpel, cutting on a tile and away from your hand.

Calculations and graphs

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

A positive answer is a gain in mass and a negative answer is a loss in mass. You should be able to use simple compound measures of rate of water uptake, for example the change in mass or volume per minute (g/min or cm³/min).

Percentage change in mass

A potato cylinder has a mass of 4.0 g at the start and 3.4 g after 30 minutes in a salt solution. Calculate the percentage change in mass and the rate of mass change in g per minute.

1. Change in mass = $3.4 - 4.0 = -0.6$ g.
2. Percentage change = $-0.6 \div 4.0 \times 100 = -15\%$.
3. Rate = $-0.6 \div 30 = -0.02$ g per minute.

Answer: -15% (a 15% loss in mass), a rate of -0.02 g/min.

Plot the concentration of solution on the x-axis (the independent variable) and the percentage change in mass on the y-axis. Draw a smooth line or a line of best fit through the points. The point where the line crosses the x-axis shows the concentration with no change in mass.

Maths skill: Calculate percentage change using the initial mass, not the final mass, as the denominator. Show the sign: a loss is negative.

Active transport Spec 4.1.3.3

Active transport

Moves substances from a more dilute solution to a more concentrated solution (against a concentration gradient). This requires energy from respiration.

- Active transport allows **mineral ions** to be absorbed into plant root hairs from very dilute solutions in the soil. Plants require ions for healthy growth.
- It also allows **sugar molecules** to be absorbed from lower concentrations in the gut into the blood, which has a higher sugar concentration. Sugar molecules are used for cell respiration.

Because active transport needs energy from respiration, cells that carry it out (such as root hair cells) have many mitochondria.

Comparing the three processes

You should be able to describe how substances are transported into and out of cells by diffusion, osmosis and active transport, and explain the differences between the three processes.

Diffusion, osmosis and active transport

	Diffusion	Osmosis	Active transport
What moves	Particles of a gas or of a substance in solution	Water only	Substances such as mineral ions and sugar
Direction	From higher to lower concentration (down the gradient)	From a dilute solution to a concentrated solution	From a more dilute to a more concentrated solution (against the gradient)
Membrane	Across a membrane or not	Through a partially permeable membrane	Across the cell membrane
Energy from respiration needed?	No	No	Yes

Exam tip: For 'explain the differences' answers, compare on the same point each time: 'active transport needs energy from respiration, whereas diffusion does not'.

Quick check

1. Name three factors that affect the rate of diffusion.
2. Why do multicellular organisms need exchange surfaces and a transport system?
3. Define osmosis.
4. How is active transport different from diffusion?
5. Give an example of active transport in plants.

Quick check answers

Transport in cells

1. The concentration gradient, the temperature and the surface area of the membrane.
2. They have a small surface area to volume ratio, so diffusion across the outside alone cannot supply all of their cells.
3. The diffusion of water from a dilute solution to a concentrated solution through a partially permeable membrane.
4. It moves substances against a concentration gradient and needs energy from respiration.
5. Absorption of mineral ions into root hairs from very dilute solutions in the soil.