

AQA GCSE Biology — Biology

Topic 1

Cell biology

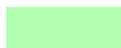
Specification 8461 · AQA

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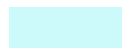
Revision notes for one topic, free to download.

These are the summary notes only. The full edition of this booklet also carries the worked examples, the required practicals and the formula sheets, with every topic in one place.

Colour Codes



Definitions



Diagrams



Notes and warnings



Sub-topic headings

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Define Eukaryotic cell

- a cell whose genetic material is enclosed in a nucleus (plant, animal, fungal cells).

Define Plasmid

- a small ring of DNA in a bacterial cell, separate from the main DNA loop.

Define Differentiation

- the process by which a cell changes to become specialised for its job.

Define Binary fission BIOLOGY ONLY

- simple cell division by which bacteria multiply, as often as once every 20 minutes.

Define Chromosome

- a DNA molecule in the nucleus carrying a large number of genes; found in pairs in body cells.

Define Mitosis

- the stage of the cell cycle in which one set of chromosomes is pulled to each end of the cell and the nucleus divides.

Define Meristem

- plant tissue at the growing tips of shoots and roots that can differentiate into any type of plant cell throughout the plant's life.

Define 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.

Define Prokaryotic cell

- a much smaller cell with no nucleus; the genetic material is a single DNA loop, sometimes with plasmids (bacteria).

Define Specialised cell

- a cell whose structure is adapted to carry out a particular function.

Define Magnification

- how many times bigger the image is than the real object.

Define Resolution (resolving power)

- the ability to distinguish two separate points as separate; higher resolution means finer detail.

Define Aseptic technique BIOLOGY ONLY

- a set of methods used to prepare an uncontaminated culture of microorganisms.

Define Cell cycle

- the series of stages in which a cell grows, copies its DNA, and divides by mitosis.

Define Stem cell

- an undifferentiated cell of an organism which is capable of giving rise to many more cells of the same type, and from which certain other cells can arise from differentiation.

Define Therapeutic cloning

- producing an embryo with the same genes as the patient so that stem cells taken from it are not rejected.

Define Osmosis

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

Define Active transport

- the movement of substances from a more dilute solution to a more concentrated solution (against a concentration gradient), requiring energy from respiration.

Define Surface area to volume ratio

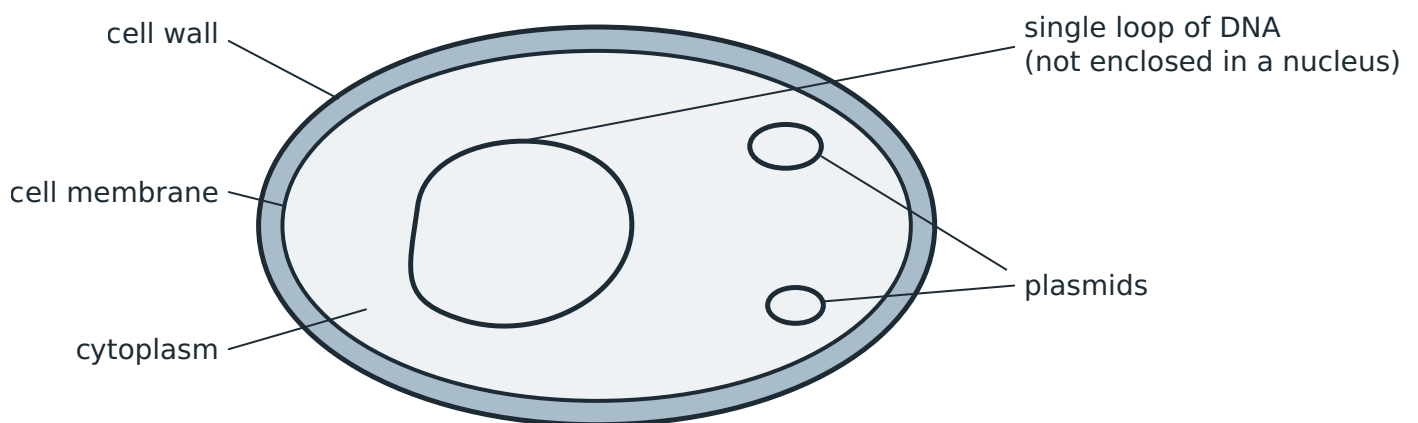
- the surface area of an organism divided by its volume; small organisms have a relatively large ratio.

1.1 Cell structure

1.1.1 Eukaryotes and prokaryotes

- Plant and animal cells are eukaryotic:** they have a cell membrane, cytoplasm and genetic material enclosed in a **nucleus**.
- Bacterial cells are prokaryotic** and are much smaller in comparison. They have cytoplasm and a cell membrane surrounded by a **cell wall**. The genetic material is **not enclosed in a nucleus** — it is a single **DNA loop**, and there may be one or more small rings of DNA called **plasmids**.
- You must have a feel for the scale and size of cells and be able to make **order of magnitude** calculations, using **standard form** where appropriate.

The structure of a bacterial (prokaryotic) cell



A bacterial cell is about 10× smaller across than an animal cell, so about 1000× smaller in volume. It is drawn here much larger than scale.

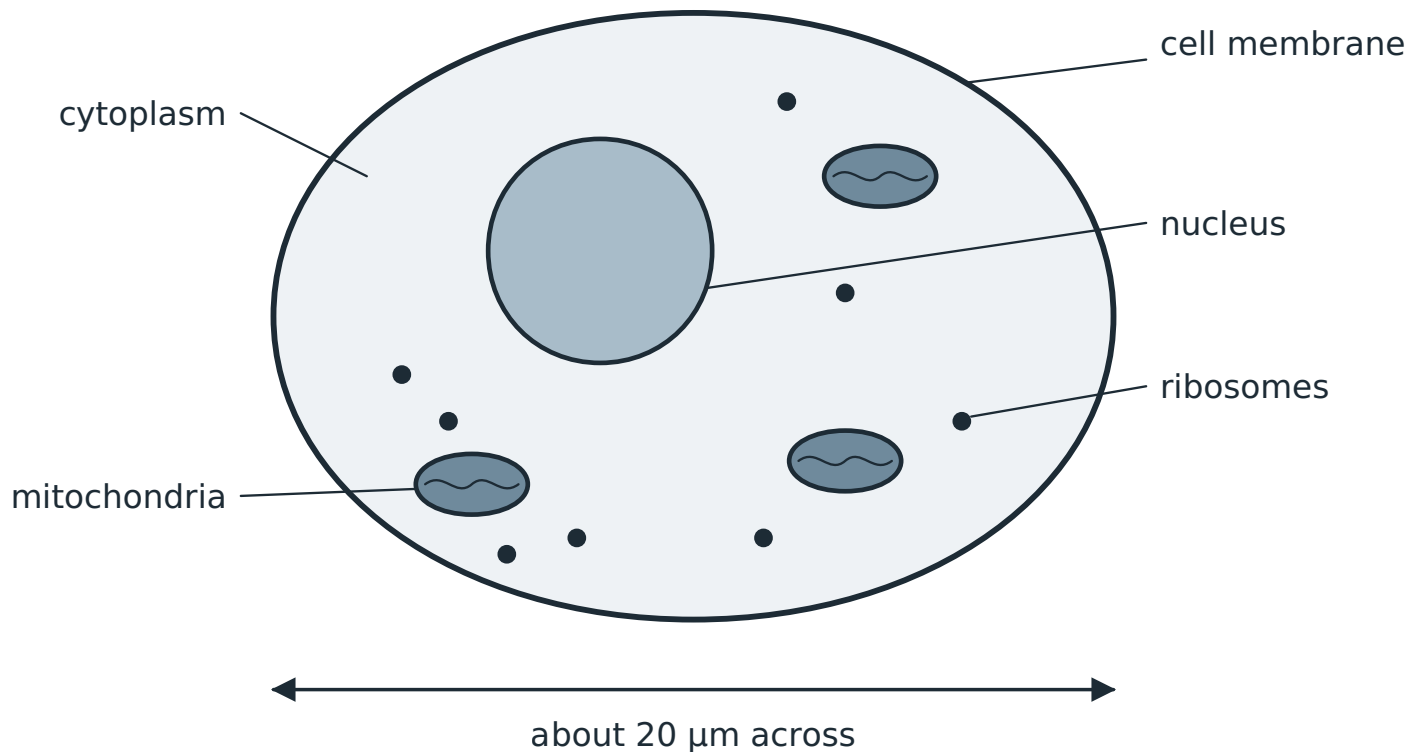
Prefix	Prefix symbol	Meaning	Applied to metres
centi	c	one hundredth	$1\text{ cm} = 1 \times 10^{-2}\text{ m}$
milli	m	one thousandth	$1\text{ mm} = 1 \times 10^{-3}\text{ m}$
micro	μ	one millionth	$1\text{ }\mu\text{m} = 1 \times 10^{-6}\text{ m}$
nano	n	one thousand-millionth	$1\text{ nm} = 1 \times 10^{-9}\text{ m}$

Typical sizes: animal cell $\approx 20\text{ }\mu\text{m}$; plant cell $\approx 100\text{ }\mu\text{m}$; bacterium $\approx 2\text{ }\mu\text{m}$; ribosome $\approx 20\text{ nm}$. An animal cell is therefore about $10\times$ bigger than a bacterium — one order of magnitude — and a bacterium is about $100\times$ bigger than a ribosome (two orders of magnitude).

1.1.2 Animal and plant cells

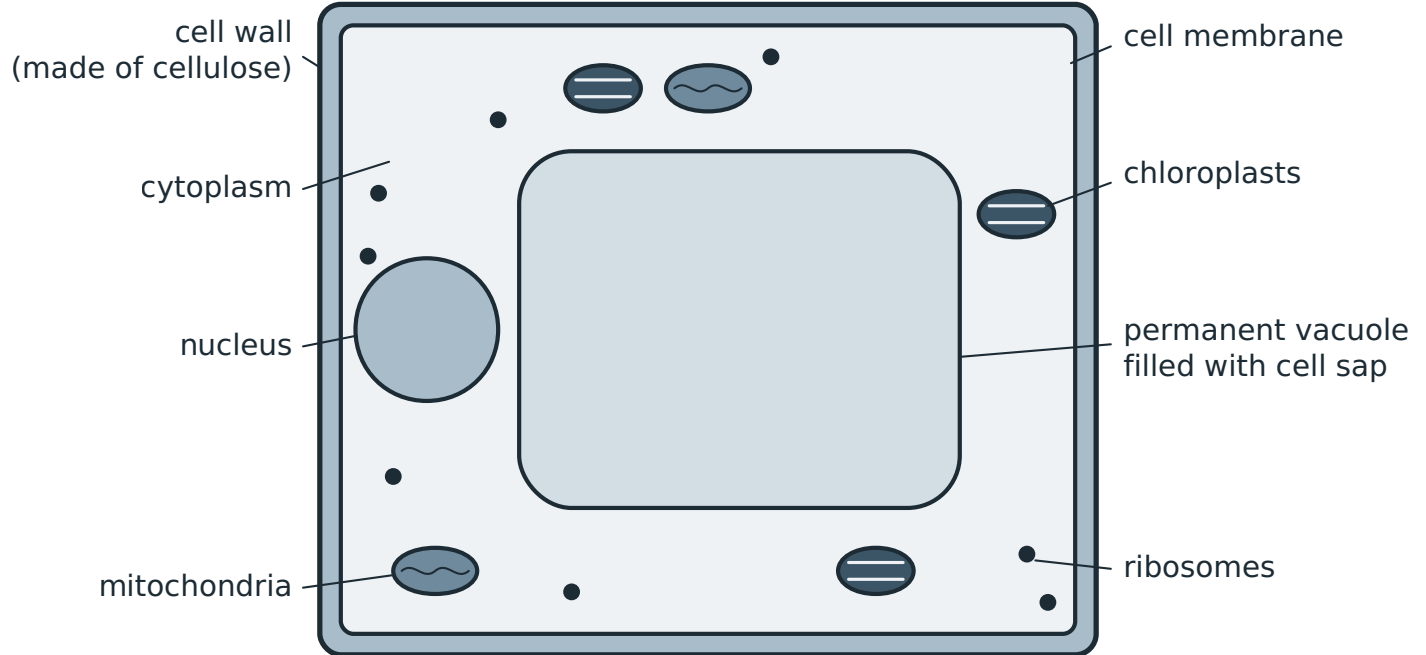
Most **animal cells** have: a **nucleus** (contains the genetic material that controls the cell's activities), **cytoplasm** (where most chemical reactions happen), a **cell membrane** (controls what enters and leaves), **mitochondria** (where aerobic respiration happens, releasing energy) and **ribosomes** (where protein synthesis happens).

A typical animal cell



In addition to the parts found in animal cells, **plant cells** often have **chloroplasts** (contain chlorophyll and absorb light for photosynthesis) and a **permanent vacuole** filled with cell sap (keeps the cell rigid). Plant and **algal** cells also have a **cell wall made of cellulose**, which strengthens the cell.

A typical plant cell



In bacteria, plasmids carry extra genes (such as antibiotic resistance) that can be passed between bacteria.

1.1.3 Cell specialisation

Cells may be **specialised** to carry out a particular function. Given information about any cell, you should be able to link its structure to its function in a tissue, organ, organ system or whole organism.

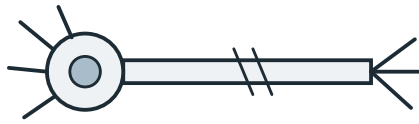
Cell	Adaptation	Function
Sperm cell	tail (flagellum), many mitochondria, enzymes in the head, streamlined	swims to the egg and fertilises it
Nerve cell	long axon, branched endings, insulating sheath	carries electrical impulses around the body
Muscle cell	contains protein fibres that shorten, many mitochondria	contracts to allow movement
Root hair cell	long thin projection giving a large surface area, no chloroplasts, many mitochondria	absorbs water by osmosis and mineral ions by active transport
Xylem cell	hollow dead tubes strengthened by lignin, no end walls	transports water and mineral ions up the plant
Phloem cell	elongated cells with pores in the end walls, few sub- cellular structures	transports dissolved sugars (translocation)

Specialised cells and their adaptations



Sperm cell

tail to swim; many mitochondria for energy; enzymes in the head to digest into the egg



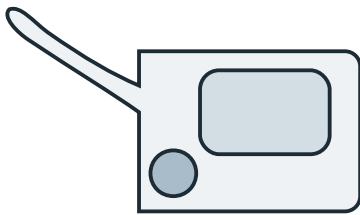
Nerve cell

long and thin to carry electrical impulses a long way; branched ends join other cells



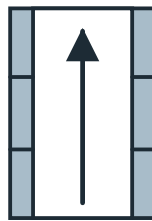
Muscle cell

contracts and relaxes; many mitochondria to release the energy needed to contract



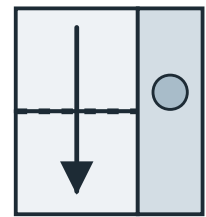
Root hair cell

long, thin hair gives a large surface area to absorb water and mineral ions from the soil



Xylem vessel

hollow dead cells joined end to end, no end walls — carries water; lignin strengthens walls



Phloem cell

sieve plates with pores let cell sap flow; companion cells supply the energy needed

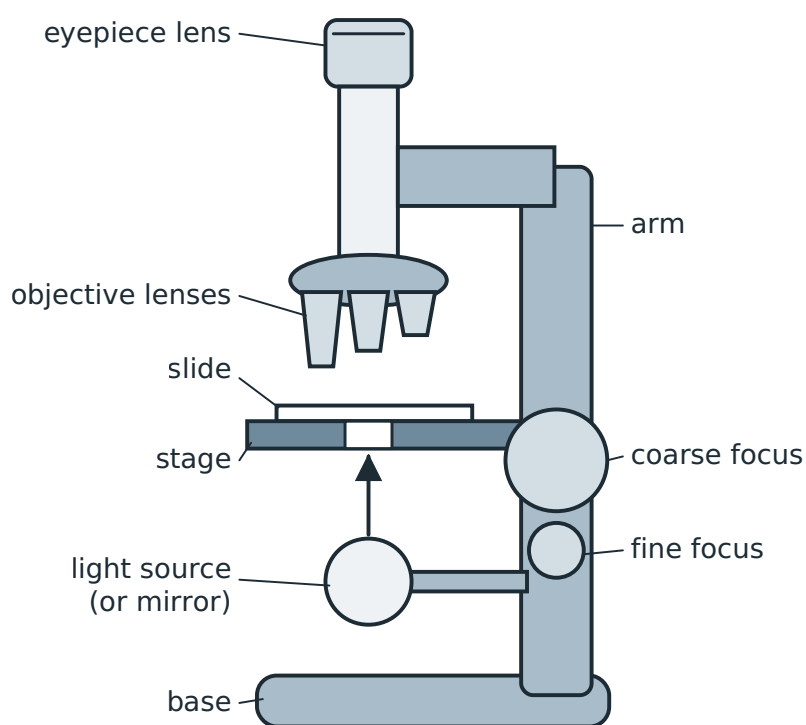
1.1.4 Cell differentiation

- As an organism develops, cells **differentiate** to form different types of cell. As a cell differentiates it acquires different sub-cellular structures to enable it to carry out a certain function — it has become a **specialised cell**.
- Most types of **animal** cell differentiate at an **early stage**. In mature animals, cell division is mainly restricted to **repair and replacement**.
- Many types of **plant** cell retain the ability to differentiate throughout life.

1.1.5 Microscopy

- Light microscopes** use light and lenses; **electron microscopes** use a beam of electrons.
- An electron microscope has much **higher magnification and resolving power** than a light microscope, so it can be used to study cells in much **finer detail**. This has enabled biologists to see and understand many more sub-cellular structures (for example ribosomes and the internal structure of mitochondria, which cannot be resolved with a light microscope).
- Microscopy techniques have developed over time: as magnification and resolution improved, our model of the cell became more detailed.

The light microscope and how total magnification is worked out



Magnification

$$\text{magnification} = \frac{\text{size of image}}{\text{size of real object}}$$

$$\text{so: real size} = \frac{\text{size of image}}{\text{magnification}}$$

$$1 \text{ mm} = 1000 \mu\text{m}; 1 \mu\text{m} = 1000 \text{ nm}$$

Electron microscope

has much higher magnification and resolving power than a light microscope, so far more detail of sub-cellular structures can be seen.

WATCH OUT

Magnification has **no units**. Writing "× 500 mm" loses the mark. Also, a bigger magnification is useless without **resolution** — enlarging a blurred light-microscope image does not reveal new detail.

1.1.6 Culturing microorganisms **BIOLOGY ONLY**

- **BIOLOGY ONLY** Bacteria multiply by simple cell division (**binary fission**) as often as **once every 20 minutes** if they have enough **nutrients** and a **suitable temperature**.
- **BIOLOGY ONLY** Bacteria can be grown in a **nutrient broth solution** or as **colonies on an agar gel plate**. **BIOLOGY ONLY** **Uncontaminated cultures** of microorganisms are required for investigating the action of **disinfectants and antibiotics**.

BIOLOGY ONLY **Aseptic technique** — and the reason for each step

Step	Why
Petri dishes and culture media are sterilised before use (e.g. autoclaved)	kills unwanted microorganisms that would contaminate the culture
Inoculating loops are sterilised by passing them through a flame	kills microorganisms on the loop before and after transferring the culture
The lid is secured with adhesive tape (not sealed all round)	stops airborne microorganisms getting in and the culture escaping, while still letting oxygen in so harmful anaerobic bacteria do not grow
The dish is stored upside down	condensation collects in the lid instead of dripping onto the agar and spreading the colonies
In school laboratories cultures are generally incubated at 25 °C	higher temperatures (e.g. 37 °C) are more likely to allow growth of pathogens harmful to humans

1.2 Cell division

1.2.1 Chromosomes

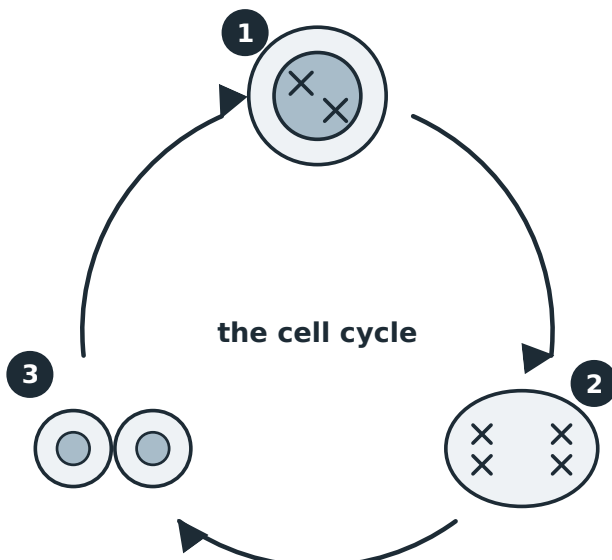
- The **nucleus** of a cell contains **chromosomes** made of **DNA molecules**. Each chromosome carries a **large number of genes**.
- In **body cells** the chromosomes are normally found in **pairs** (humans have 23 pairs).

1.2.2 Mitosis and the cell cycle

Cells divide in a series of stages called the **cell cycle**. There are three overall stages:

1. **Growth and DNA replication.** The cell grows and increases the number of sub-cellular structures such as **ribosomes and mitochondria**. The DNA replicates to form **two copies of each chromosome**.
 2. **Mitosis.** One set of chromosomes is pulled to each end of the cell and the **nucleus divides**.
 3. **Cytokinesis.** Finally the **cytoplasm and cell membranes divide** to form **two identical cells**.
- Cell division by mitosis is important in the **growth and development** of multicellular organisms, and in **repair and replacement** of cells.
 - You need the three overall stages only — the named phases within mitosis are **not required**.

The three stages of the cell cycle



1 Cell grows and DNA replicates

The cell grows and the number of sub-cellular structures such as ribosomes and mitochondria increases. The DNA replicates to form two copies of each chromosome.

2 Mitosis

One set of chromosomes is pulled to each end of the cell and the nucleus divides.

3 Cell divides in two

The cytoplasm and cell membranes divide to form two identical daughter cells.

The cell cycle produces two genetically identical cells. Cell division by mitosis is important in the growth and development of multicellular organisms.

WATCH OUT

Mitosis is only one stage *within* the cell cycle, not the whole thing. Most of the cycle is spent growing and copying DNA.

1.2.3 Stem cells

- A **stem cell** is an undifferentiated cell capable of giving rise to many more cells of the same type, and from which certain other cells can arise by differentiation.
- **Embryonic stem cells** can be cloned and made to differentiate into **most different types of human cell**.
- **Adult stem cells** from **bone marrow** can form many types of cell **including blood cells**.
- **Meristem tissue** in plants can differentiate into any type of plant cell, throughout the life of the plant.
- Treatment with stem cells may be able to help conditions such as **diabetes** (making insulin-producing cells) and **paralysis** (making new nerve cells).
- In **therapeutic cloning**, an embryo is produced with the **same genes as the patient**. Stem cells from the embryo are **not rejected** by the patient's body, so they may be used for medical treatment.
- Risks and objections: potential **transfer of viral infection**; some people have **ethical or religious objections**, often because the embryo is destroyed and cannot give consent.
- Plant meristem stem cells can produce **clones of plants quickly and economically**: **rare species** can be cloned to protect them from extinction, and **crop plants with special features** such as disease resistance can be cloned to give farmers large numbers of identical plants.
- Knowledge of stem cell **techniques** is not required.

1.3 Transport in cells

1.3.1 Diffusion

- Substances may move into and out of cells across the cell membranes via **diffusion**: the spreading out of particles of a substance in solution, or particles of a gas, giving a net movement from an area of higher concentration to an area of lower concentration (down the concentration gradient). It is a **passive** process — no energy is needed.
- Substances transported by diffusion include oxygen and carbon dioxide in gas exchange, and the waste product **urea** from cells into the blood plasma for excretion by the kidney.
- Factors that affect the **rate of diffusion**: the **difference in concentrations (concentration gradient)** — steeper is faster; the **temperature** — higher temperature means particles have more kinetic energy so move faster; the **surface area of the membrane** — larger area, faster diffusion.

ANALOGY

Diffusion is like the smell of toast spreading through a house. No one pushes the particles — they move randomly, but because there are far more of them near the toaster, the *net* movement is outwards until the smell is even everywhere.

How the surface area : volume ratio falls as an organism gets bigger

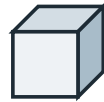
Working it out

surface area = $6 \times \text{side} \times \text{side}$

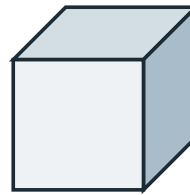
volume = $\text{side} \times \text{side} \times \text{side}$

ratio = surface area $\div$ volume,

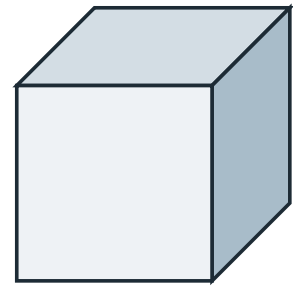
written in the form $n : 1$



side 1 cm



side 2 cm



side 3 cm

surface area (cm ²)	$6 \times 1 \times 1 = 6$	$6 \times 2 \times 2 = 24$	$6 \times 3 \times 3 = 54$
volume (cm ³)	$1 \times 1 \times 1 = 1$	$2 \times 2 \times 2 = 8$	$3 \times 3 \times 3 = 27$
surface area : volume	$6 : 1$	$24 : 8 = 3 : 1$	$54 : 27 = 2 : 1$

As an organism gets bigger, its surface area : volume ratio falls, so diffusion alone is too slow — it needs specialised exchange surfaces and a transport system.

- A **single-celled organism** has a relatively **large surface area to volume ratio**, which allows sufficient transport of molecules into and out of the cell to meet the organism's needs by diffusion alone.
- **Multicellular organisms** have a small surface area to volume ratio and a longer diffusion path, so they need specialised exchange surfaces and a transport system.
- The effectiveness of an exchange surface is increased by: a **large surface area**; a thin membrane, to provide a short diffusion path; (in animals) an **efficient blood supply**; and (in animals, for gaseous exchange) **being ventilated**.

1.3.2 Osmosis

- **Osmosis** is the diffusion of **water** from a **dilute solution** to a **concentrated solution** through a **partially permeable membrane**. The membrane lets water molecules through but not the larger solute molecules.
- Net movement stops when the concentrations either side are equal.

Exchange surface	Adaptations
Small intestine	millions of villi (and microvilli) give a huge surface area; wall one cell thick; rich blood supply keeps the concentration gradient steep
Lungs	millions of alveoli give a large surface area; walls one cell thick; surrounded by a capillary network; ventilated by breathing
Gills in fish	many gill filaments and lamellae give a large surface area; thin; good blood supply; water is constantly pumped over them
Roots	root hair cells give a large surface area for absorbing water and mineral ions
Leaves	flattened shape and internal air spaces give a large surface area; thin, so a short diffusion path; stomata allow gases in and out

ANALOGY

Think of the partially permeable membrane as a nightclub door that only lets small guests (water) through. The room with fewer small guests keeps pulling them in until both rooms are equally crowded.

1.3.3 Active transport

- **Active transport** moves substances from a more dilute solution to a more concentrated solution (against a concentration gradient). This **requires energy from respiration**, so cells that carry out a lot of active transport have **many mitochondria**.
- It 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. The sugar molecules are used for **cell respiration**.

ANALOGY

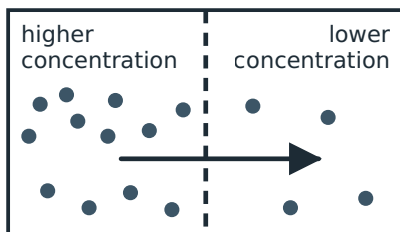
Diffusion and osmosis are like rolling a ball down a hill — it happens on its own. Active transport is like carrying the ball back up the hill: it goes the "wrong" way, so you have to spend energy from respiration to do it.

Comparing the three transport processes

	Diffusion	Osmosis	Active transport
What moves	any dissolved substance or gas	water only	dissolved substances/ions
Direction	high to low concentration	dilute to concentrated solution	low to high concentration (against the gradient)
Membrane needed?	not necessarily	partially permeable membrane required	carrier proteins in the membrane
Energy from respiration?	no (passive)	no (passive)	yes
Example	oxygen into cells; urea into plasma	water into root hair cells; water into/out of potato cells	mineral ions into root hairs; glucose from the gut into the blood

Diffusion, osmosis and active transport across a cell membrane

Diffusion



partially permeable membrane

Moves:

any substance in solution, or a gas — e.g. oxygen, carbon dioxide, urea

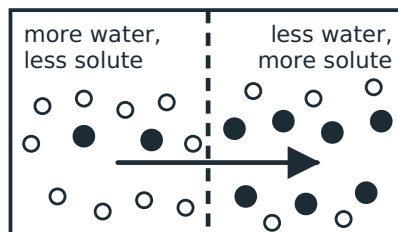
Direction:

down the concentration gradient, from a higher to a lower concentration

Energy from respiration:

not needed — it is passive

Osmosis



partially permeable membrane
○ = water ● = dissolved solute

Moves:

water only, through a partially permeable membrane

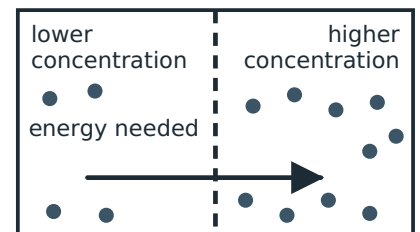
Direction:

from a dilute solution to a more concentrated solution

Energy from respiration:

not needed — it is passive

Active transport



partially permeable membrane

Moves:

dissolved substances — mineral ions into root hair cells, sugar from the gut into the blood

Direction:

against the concentration gradient, from a lower to a higher concentration

Energy from respiration:

yes — energy is needed