

# Cell biology revision notes

Cells are the basic unit of all forms of life. This topic covers how cells are built and how their structure relates to their function, how cells divide by mitosis, how stem cells can be used in medicine, and how substances move into and out of cells.

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.

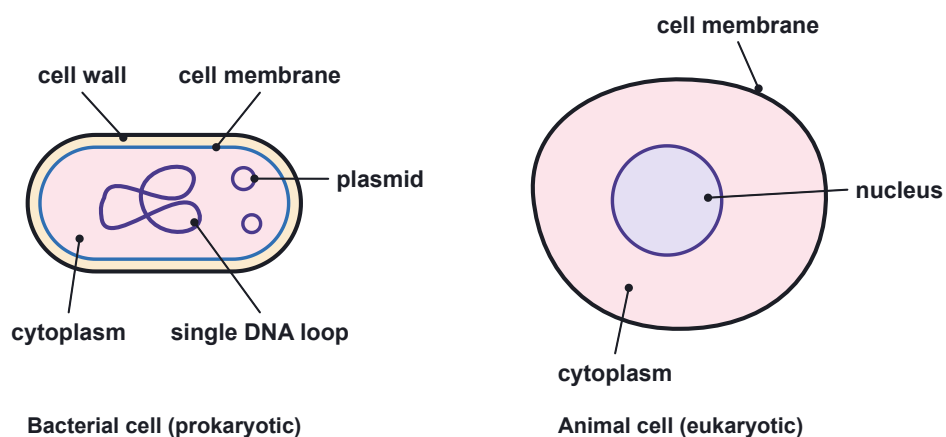
## 1 Cell structure Spec 4.1.1

### Eukaryotes and prokaryotes Spec 4.1.1.1

Plant and animal cells are **eukaryotic cells**. They have a cell membrane, cytoplasm and genetic material enclosed in a nucleus.

Bacterial cells are **prokaryotic cells**. They 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**.

| Eukaryotic and prokaryotic cells compared |                                                             |                                            |
|-------------------------------------------|-------------------------------------------------------------|--------------------------------------------|
|                                           | Eukaryotic cell (plant, animal)                             | Prokaryotic cell (bacterium)               |
| <b>Size</b>                               | Larger                                                      | Much smaller                               |
| <b>Genetic material</b>                   | Enclosed in a nucleus                                       | Single DNA loop, not enclosed in a nucleus |
| <b>Plasmids</b>                           | No                                                          | One or more may be present                 |
| <b>Cell membrane and cytoplasm</b>        | Yes                                                         | Yes                                        |
| <b>Cell wall</b>                          | Plant and algal cells (made of cellulose); not animal cells | Yes                                        |



A bacterial (prokaryotic) cell has a **single DNA loop** and plasmids, but **no nucleus**. Not to scale: bacteria are much smaller.

**Common mistake: Bacteria do have genetic material. Write that it is not enclosed in a nucleus, never that bacteria have no DNA.**

## Scale and size of cells

You need to understand the scale and size of cells and be able to make **order of magnitude** calculations. An order of magnitude is a power of ten. A cell that is 100 times wider than another is two orders of magnitude bigger, because  $100 = 10^2$ .

| Prefixes and units of length |        |                                   |                         |
|------------------------------|--------|-----------------------------------|-------------------------|
| Prefix                       | Symbol | Standard form (compared with 1 m) | Example                 |
| centi                        | c      | $\times 10^{-2}$                  | 1 cm = 0.01 m           |
| milli                        | m      | $\times 10^{-3}$                  | 1 mm = 0.001 m          |
| micro                        | $\mu$  | $\times 10^{-6}$                  | 1 $\mu$ m = 0.000 001 m |
| nano                         | n      | $\times 10^{-9}$                  | 1 nm = 0.000 000 001 m  |

To change units: 1 mm = 1000  $\mu$ m and 1  $\mu$ m = 1000 nm. **Standard form** is a number between 1 and 10 multiplied by a power of ten, for example  $0.000\ 004\ \text{m} = 4 \times 10^{-6}\ \text{m}$ .

### Order of magnitude

A plant cell is 100  $\mu$ m long. A bacterium is 1  $\mu$ m long. How many orders of magnitude longer is the plant cell?

1. Divide the larger length by the smaller:  $100 \div 1 = 100$ .
2. Write the answer as a power of ten:  $100 = 10^2$ .

**Answer:** The plant cell is  $10^2$  (100) times longer, which is two orders of magnitude.

### Standard form

A cell is 0.000 025 m wide. Write this in standard form, then in  $\mu$ m.

1. Move the decimal point to give a number between 1 and 10: 2.5.
2. Count the places moved: 5. Because the number is small, the power is negative:  $2.5 \times 10^{-5}\ \text{m}$ .
3. To convert to  $\mu$ m, multiply metres by 1 000 000:  $0.000\ 025 \times 1\ 000\ 000 = 25$ .

**Answer:**  $2.5 \times 10^{-5}\ \text{m}$ , which is 25  $\mu$ m.

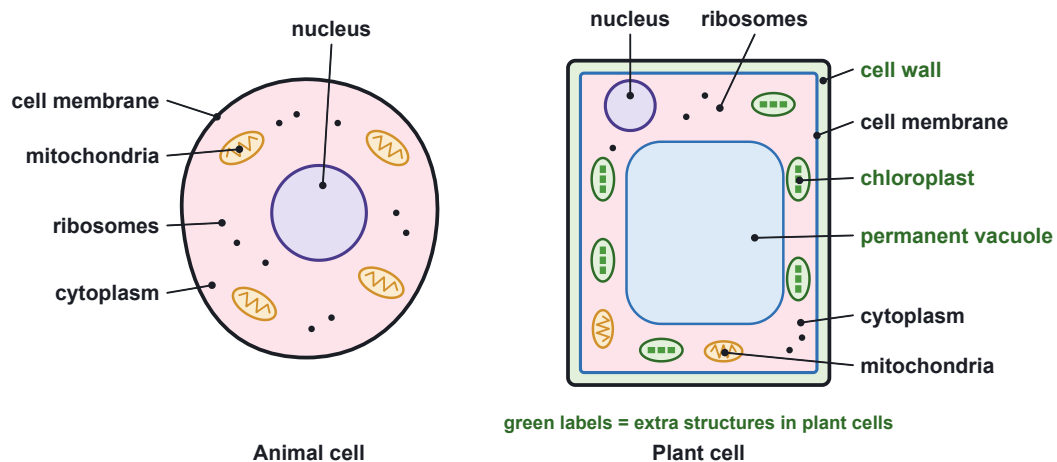
*Maths skill: A negative power of ten means a number smaller than 1. Check the sign of your power by asking whether the number you started with was big or small.*

## Animal and plant cells Spec 4.1.1.2

Most animal cells have: a nucleus, cytoplasm, a cell membrane, mitochondria and ribosomes. In addition, plant cells often have: chloroplasts and a **permanent vacuole** filled with **cell sap**. Plant and algal cells also have a **cell wall made of cellulose**, which strengthens the cell.

## Sub-cellular structures and their functions

| Structure                | Function                                                                    | Animal cell | Plant cell  | Bacterial cell      |
|--------------------------|-----------------------------------------------------------------------------|-------------|-------------|---------------------|
| <b>Nucleus</b>           | Contains the genetic material (DNA) and controls the activities of the cell | Yes         | Yes         | No                  |
| <b>Cytoplasm</b>         | Where most chemical reactions happen                                        | Yes         | Yes         | Yes                 |
| <b>Cell membrane</b>     | Controls the movement of substances into and out of the cell                | Yes         | Yes         | Yes                 |
| <b>Mitochondria</b>      | Where aerobic respiration takes place, releasing energy for the cell        | Yes         | Yes         | No                  |
| <b>Ribosomes</b>         | Where proteins are made (protein synthesis)                                 | Yes         | Yes         | Yes                 |
| <b>Cell wall</b>         | Strengthens the cell; made of cellulose in plant and algal cells            | No          | Yes         | Yes (not cellulose) |
| <b>Chloroplasts</b>      | Contain chlorophyll, which absorbs light energy for photosynthesis          | No          | Yes (often) | No                  |
| <b>Permanent vacuole</b> | Filled with cell sap; helps keep the cell firm                              | No          | Yes         | No                  |
| <b>Plasmid</b>           | Small ring of extra DNA                                                     | No          | No          | Possibly            |



Plant cells have the same structures as animal cells, plus a **cell wall**, **chloroplasts** and a **permanent vacuole**.

**Exam tip:** When asked to explain how a structure is related to its function, name the structure, state what it does, then link that to the job of the cell. Chloroplasts absorb light for photosynthesis, so they are found in cells that make food.

## Estimating size and area

You should be able to use **estimations** to judge the relative size or area of sub-cellular structures. Round the measurements to easy numbers and compare them. Use an estimate when you only need to know roughly how much bigger one structure is than another, or to check that a calculated answer is sensible.

### Estimating relative size

In a micrograph, a cell is 62 mm across and its nucleus is 19 mm across. Estimate how many times wider the cell is than the nucleus.

1. Round the numbers: 62 mm is about 60 mm and 19 mm is about 20 mm.
2. Divide:  $60 \div 20 = 3$ .

**Answer:** The cell is roughly 3 times wider than the nucleus.

### Required practical 1: using a light microscope Spec 4.1.1.2

*Required practical: Use a light microscope to observe, draw and label a selection of plant and animal cells. A magnification scale must be included.*

1. Place a thin piece of tissue (for example onion epidermis, or cheek cells) on a clean microscope slide. Add a drop of water or a stain such as iodine solution.
2. Lower a cover slip onto the specimen at an angle, using a mounting needle, so that no air bubbles are trapped.
3. Clip the slide onto the stage. Select the lowest-power objective lens and turn the coarse focusing knob until the specimen is roughly in focus.
4. Use the fine focusing knob to get a sharp image. Then switch to a higher-power objective lens and refocus with the fine focusing knob only.
5. Draw what you see using a sharp pencil. Use clear, unbroken lines, no shading, and make the drawing large. Draw only a few cells accurately rather than many badly.
6. Label the sub-cellular structures with straight label lines that do not cross. Add a title and the magnification.

To find the total magnification of a light microscope, multiply the magnification of the eyepiece lens by the magnification of the objective lens. The magnification of your drawing is found with the equation  $\text{magnification} = \text{size of image} \div \text{size of real object}$ , using the width of your drawing and the real width of the cell.

**Safety:** carry the microscope with two hands, handle glass slides and cover slips carefully, and take care with the stain, which can mark skin and clothes. Start with the lowest-power lens so that the objective lens does not hit the slide.

*Exam tip: A scale or magnification must be included on a drawing. Always write the magnification next to the title, for example 'Onion cells,  $\times 400$ '.*

### Cell specialisation Spec 4.1.1.3

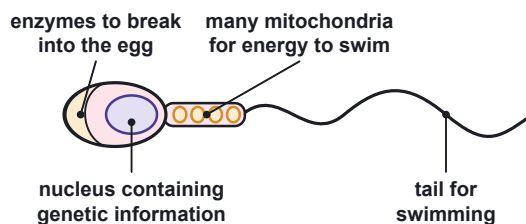
Cells may be specialised to carry out a particular function. You should be able to explain how the structure of different types of cell relate to their function in a tissue, an organ or organ system, or the whole organism, when you are given appropriate information.

## Specialised cells in animals and plants

| Cell                  | Function                                        | How its structure helps                                                                                                                                                        |
|-----------------------|-------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Sperm cell</b>     | Carries the male genetic information to the egg | Tail for swimming; many mitochondria to release the energy needed to swim; streamlined head; enzymes in the head to break into the egg; nucleus containing genetic information |
| <b>Nerve cell</b>     | Carries electrical impulses around the body     | Long (extended) so it can carry impulses over long distances; branched connections at the ends to connect with other nerve cells and organs                                    |
| <b>Muscle cell</b>    | Contracts (shortens) to cause movement          | Contains protein fibres that can slide to make the cell shorten; many mitochondria to release energy for contraction; may store glycogen as an energy source                   |
| <b>Root hair cell</b> | Absorbs water and mineral ions from the soil    | Long hair-like projection gives a large surface area; thin cell wall; many mitochondria to release energy for active transport of mineral ions                                 |
| <b>Xylem cell</b>     | Carries water and mineral ions up the plant     | Joined end to end to form a hollow tube with no end walls and no cytoplasm; walls strengthened (by lignin)                                                                     |
| <b>Phloem cell</b>    | Carries dissolved sugars around the plant       | Elongated cells joined end to end to form tubes; pores in the end walls let cell sap containing dissolved sugars move from one phloem cell to the next                         |

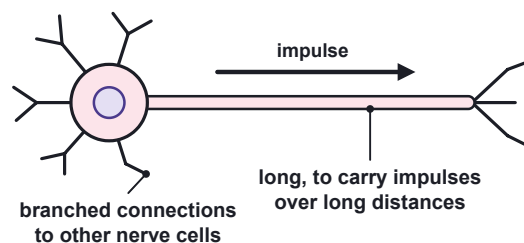
### Sperm cell

Carries the male genetic information to the egg



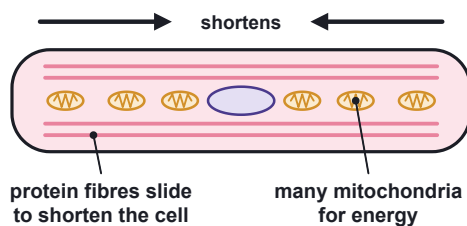
### Nerve cell

Carries electrical impulses around the body



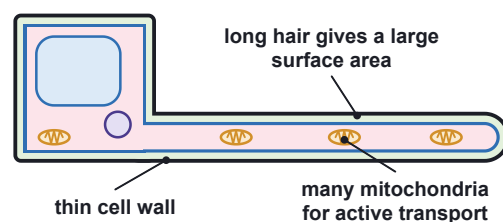
### Muscle cell

Contracts (shortens) to cause movement



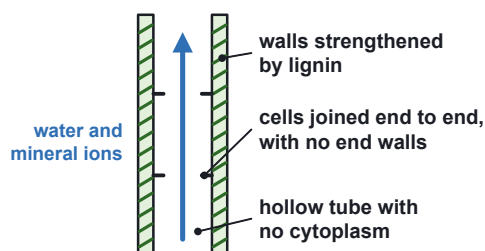
### Root hair cell

Absorbs water and mineral ions from the soil



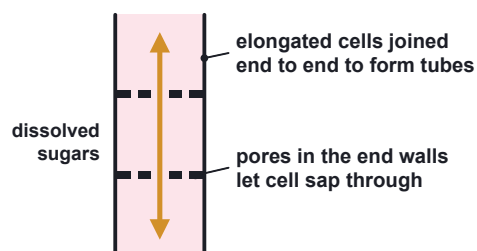
### Xylem cell

Carries water and mineral ions up the plant



### Phloem cell

Carries dissolved sugars around the plant



Each specialised cell has features that suit its **function**.

*Exam tip: For an unfamiliar cell, pick out each feature in the information, say what it does and link it to the cell's function. 'Many mitochondria' means more energy released by respiration.*

## Cell differentiation Spec 4.1.1.4

As an organism develops, cells **differentiate** to form different types of cells. 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.
- Many types of plant cell retain the ability to differentiate throughout life.
- In mature animals, cell division is mainly restricted to repair and replacement.

Differentiation is important because it allows cells to become specialised, with the sub-cellular structures they need for a particular job. A multicellular organism made of specialised cells can carry out many different functions efficiently, as the specialised cells work together in tissues, organs and organ systems.

*Exam tip: To explain the importance of differentiation, say that cells gain different sub-cellular structures so that they can carry out specific functions. Do not just say that cells 'change'.*

## Microscopy Spec 4.1.1.5

Microscopy techniques have developed over time. The first microscopes used light and lenses to magnify a specimen, and these **light microscopes** were improved with better lenses and the use of stains. Later, **electron microscopes** were developed. These use electrons instead of light.

An electron microscope has much higher **magnification** and **resolving power** than a light microscope. This means that it can be used to study cells in much finer detail. This has enabled biologists to see and understand many more sub-cellular structures.

| Light and electron microscopes      |                                                              |                                                                                                     |
|-------------------------------------|--------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|
|                                     | Light microscope                                             | Electron microscope                                                                                 |
| <b>Magnification</b>                | Lower                                                        | Much higher                                                                                         |
| <b>Resolving power (resolution)</b> | Lower                                                        | Much higher                                                                                         |
| <b>Detail seen</b>                  | Cells and larger sub-cellular structures such as the nucleus | Much finer detail, including the internal structure of mitochondria and chloroplasts, and ribosomes |

|                        |                                                                                                                                                        |
|------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Magnification</b>   | How many times larger the image is than the real object.                                                                                               |
| <b>Resolving power</b> | The ability to distinguish between two points that are close together as separate points. Higher resolving power gives a sharper, more detailed image. |

*Common mistake: Magnification and resolution are not the same: making an image bigger does not add detail. Electron microscopes show more because their resolving power is higher.*

## Magnification calculations

**magnification = size of image ÷ size of real object**

Rearranged: real size = image size  $\div$  magnification, and image size = real size  $\times$  magnification. Make sure the image and real object are in the same units before you divide, then convert at the end. Give the answer in **standard form** if appropriate.

### Calculating magnification

A drawing of a cell is 45 mm wide. The real cell is 0.15 mm wide. Calculate the magnification.

1. Both sizes are in mm, so no conversion is needed.
2. magnification =  $45 \div 0.15 = 300$ .

**Answer:**  $\times 300$

### Calculating real size

A cell appears 12 mm wide in an image magnified  $\times 400$ . Calculate the real width in  $\mu\text{m}$ .

1. real size = image size  $\div$  magnification =  $12 \div 400 = 0.03$  mm.
2. Convert to  $\mu\text{m}$ :  $0.03 \times 1000 = 30$   $\mu\text{m}$ .

**Answer:** 30  $\mu\text{m}$

*Maths skill: Use the triangle trick: put image size on top, and real size and magnification below. Cover the one you want and you can see the calculation.*

## Culturing microorganisms Spec 4.1.1.6 Triple only

Bacteria multiply by simple cell division called **binary fission**, as often as once every 20 minutes if they have enough nutrients and a suitable temperature.

Bacteria can be grown in a **nutrient broth solution** or as colonies on an **agar gel plate**. **Uncontaminated cultures** of microorganisms are required for investigating the action of disinfectants and antibiotics, so that the only microorganisms present are the ones being tested.

### Preparing an uncontaminated culture using aseptic technique

1. Sterilise the Petri dish and the agar culture medium before use (for example by heating), to kill any unwanted microorganisms.
2. Sterilise the inoculating loop by passing it through a flame.
3. Use the sterile loop to transfer the microorganisms to the agar. Keep the lid of the Petri dish open for as short a time as possible.
4. Secure the lid of the Petri dish with adhesive tape and store it upside down.
5. Incubate the plate at 25 °C.

## Explaining the steps

| Step                                             | Reason                                                                                                                              |
|--------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|
| <b>Sterilise Petri dishes and culture media</b>  | Kills unwanted microorganisms that could contaminate the culture                                                                    |
| <b>Pass the inoculating loop through a flame</b> | Kills microorganisms already on the loop, so that only the intended microorganisms are transferred                                  |
| <b>Secure the lid with adhesive tape</b>         | Stops microorganisms from the air getting in, and stops the cultured microorganisms escaping                                        |
| <b>Store the dish upside down</b>                | Condensation drips onto the lid rather than onto the agar surface                                                                   |
| <b>Incubate at 25 °C in school laboratories</b>  | Reduces the chance of growing pathogens that are harmful to humans, which grow best at higher temperatures such as body temperature |

*Exam tip: Answers on aseptic technique must say what the step prevents. 'To keep it sterile' earns less than 'to stop microorganisms from the air contaminating the culture'.*

## Culture calculations Spec 4.1.1.6 Triple only

### Number of bacteria after a certain time

You should be able to calculate the number of bacteria in a population after a certain time if you are given the mean division time. Each division doubles the population.

1. Work out the number of divisions: total time  $\div$  mean division time (use the same units).
2. Number of bacteria = starting number  $\times 2$  to the power of the number of divisions.

### Bacterial population

A single bacterium divides every 20 minutes. How many bacteria are there after 2 hours?

1. 2 hours = 120 minutes. Number of divisions =  $120 \div 20 = 6$ .
2. Number of bacteria =  $1 \times 2^6 = 64$ .

**Answer:** 64 bacteria

### Higher tier

#### Standard form

A single bacterium divides every 20 minutes. How many bacteria are there after 8 hours? Give your answer in standard form to 2 significant figures.

1. 8 hours = 480 minutes. Number of divisions =  $480 \div 20 = 24$ .
2. Number of bacteria =  $2^{24} = 16\,777\,216$ .
3. Move the decimal point 7 places:  $1.6777216 \times 10^7$ . To 2 significant figures:  $1.7 \times 10^7$ .

**Answer:**  $1.7 \times 10^7$  bacteria

### Areas of colonies and clear areas

You should be able to calculate the cross-sectional area of colonies, or of clear areas around colonies, using  $\pi r^2$ . The radius is half of the diameter.

$$\text{area} = \pi \times r^2$$

### Area of a clear zone

The clear zone around an antibiotic disc has a diameter of 14 mm. Calculate its cross-sectional area. Use  $\pi = 3.14$ .

1. Radius =  $14 \div 2 = 7$  mm.
2. Area =  $\pi \times r^2 = 3.14 \times 7 \times 7 = 3.14 \times 49 = 153.86 \text{ mm}^2$ .

**Answer:** About  $154 \text{ mm}^2$

*Common mistake: Using the diameter as the radius is the most common error. Halve the diameter first, then square the radius.*

## Required practical 2: antiseptics and antibiotics Spec 4.1.1.6 Triple only

*Required practical: Investigate the effect of antiseptics or antibiotics on bacterial growth using agar plates and measuring zones of inhibition.*

1. Using aseptic technique, spread a sample of bacteria evenly over the surface of a sterile agar plate to make a bacterial 'lawn'.
2. Using sterile forceps, place sterile paper discs soaked in different antiseptics or antibiotics (or different concentrations of one) onto the agar. Include a control disc soaked in sterile water.
3. Secure the lid with adhesive tape, label the base, store the plate upside down and incubate at  $25^\circ\text{C}$  for about two days.
4. Measure the diameter of the clear area (zone of inhibition) around each disc and calculate its area using  $\pi r^2$ .

Where the antiseptic or antibiotic has killed or stopped the growth of the bacteria, there is a clear zone around the disc. The **larger the zone of inhibition**, the more effective the substance is against that bacterium. The control disc should have no clear zone, which shows that the water itself does not kill the bacteria.

- Independent variable: the type or concentration of antiseptic or antibiotic.
- Dependent variable: the size (diameter or area) of the zone of inhibition.
- Control variables: type and amount of bacteria, type and depth of agar, size of disc, volume of solution on the disc, temperature, incubation time.

Safety: the cultures may contain harmful microorganisms. Use aseptic technique, wash hands, keep the plate taped shut, never open it after incubation, and disinfect the work area and dispose of plates safely.

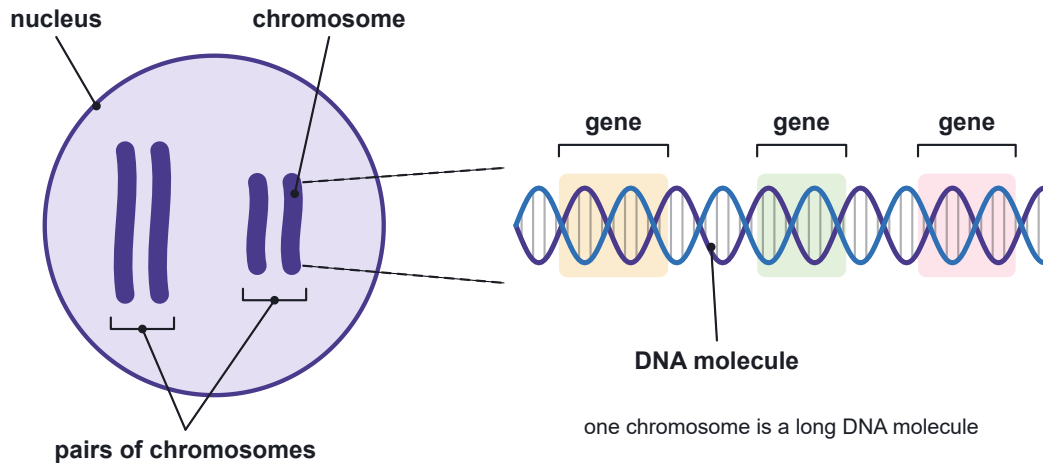
### Quick check

1. How is the genetic material of a bacterial cell arranged?
2. Which sub-cellular structure is the site of aerobic respiration?
3. What is the formula for magnification?
4. Why does an electron microscope show more detail than a light microscope?
5. Triple only: why are inoculating loops passed through a flame?

## 2 Cell division Spec 4.1.2

### Chromosomes Spec 4.1.2.1

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**.



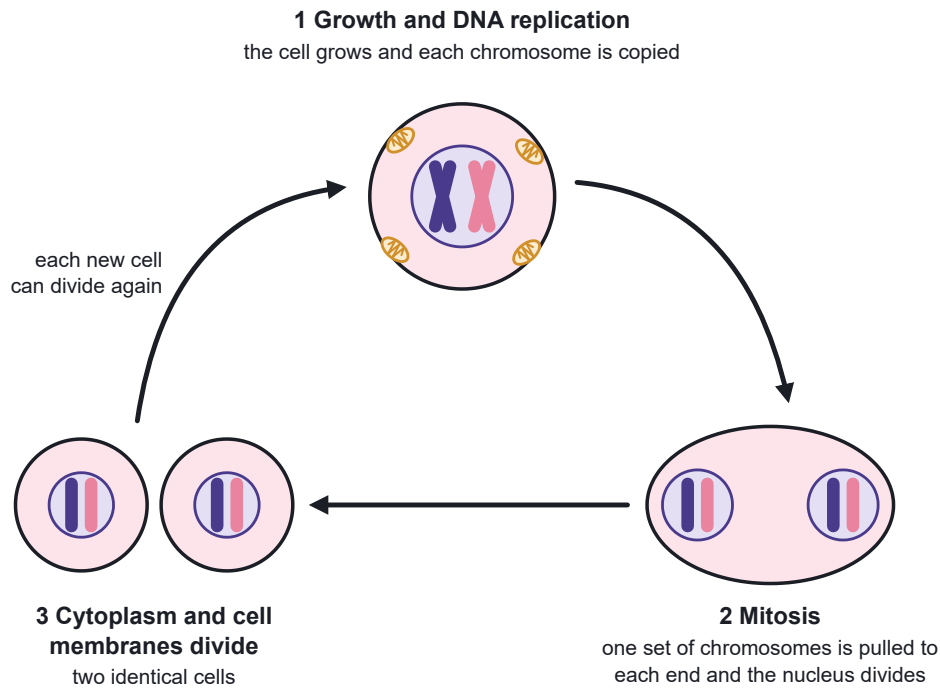
A nucleus contains **chromosomes** in pairs. Each chromosome is a long DNA molecule carrying many **genes**.

**Exam tip: Keep the order straight: a nucleus contains chromosomes, a chromosome is a long DNA molecule, and a chromosome carries many genes.**

### Mitosis and the cell cycle Spec 4.1.2.2

Cells divide in a series of stages called the **cell cycle**. During the cell cycle the genetic material is doubled and then divided into two identical cells. There are three overall stages.

1. Growth and DNA replication. Before a cell can divide it needs to grow and increase 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. Cytoplasm and cell membranes divide. Finally the cytoplasm and cell membranes divide to form two identical cells.



The cell cycle: the DNA is copied, mitosis divides the nucleus, then the cell splits into **two identical cells**.

You need to understand the three overall stages but you do not need to know the different phases of the mitosis stage.

Cell division by mitosis is important in the **growth and development** of multicellular organisms. In mature animals, cell division is mainly restricted to repair and replacement.

### Recognising mitosis in context

You should be able to recognise and describe situations in given contexts where mitosis is occurring. Look for the production of new, genetically identical cells.

- An embryo or seedling growing in size.
- The tip of a root or shoot lengthening.
- A cut healing, as new skin cells replace the damaged ones.
- Worn out cells being replaced.

**Common mistake:** Mitosis makes two cells that are genetically identical to each other and to the parent cell. Do not say 'different' or 'half the chromosomes'.

### Stem cells Spec 4.1.2.3

#### 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.

You should be able to describe the function of stem cells in embryos, in adult animals and in the meristems in plants.

| Where                    | What the stem cells can do                                                                      |
|--------------------------|-------------------------------------------------------------------------------------------------|
| <b>Human embryos</b>     | Can be cloned and made to differentiate into most different types of human cell                 |
| <b>Adult bone marrow</b> | Can form many types of cell, including blood cells                                              |
| <b>Plant meristems</b>   | Meristem tissue can differentiate into any type of plant cell, throughout the life of the plant |

Knowledge and understanding of stem cell techniques are not required.

### Medical uses

Treatment with stem cells may be able to help conditions such as **diabetes** and **paralysis**.

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

- There are potential risks, such as transfer of viral infection.
- Some people have ethical or religious objections to the use of stem cells from embryos.

*Exam tip: In evaluation questions, give at least one benefit and one risk or objection, then reach a conclusion. Compare the medical benefit to patients with the ethical concerns of others.*

### Plant stem cells

Stem cells from meristems in plants can be used to produce clones of plants quickly and economically.

- Rare species can be cloned to protect them from extinction.
- Crop plants with special features such as disease resistance can be cloned to produce large numbers of identical plants for farmers.

#### Quick check

1. What are chromosomes made of, and where are they found?
2. Name the three overall stages of the cell cycle.
3. What does mitosis produce?
4. Why are stem cells from therapeutic cloning not rejected?
5. Where are stem cells found in plants?

### 3 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**.

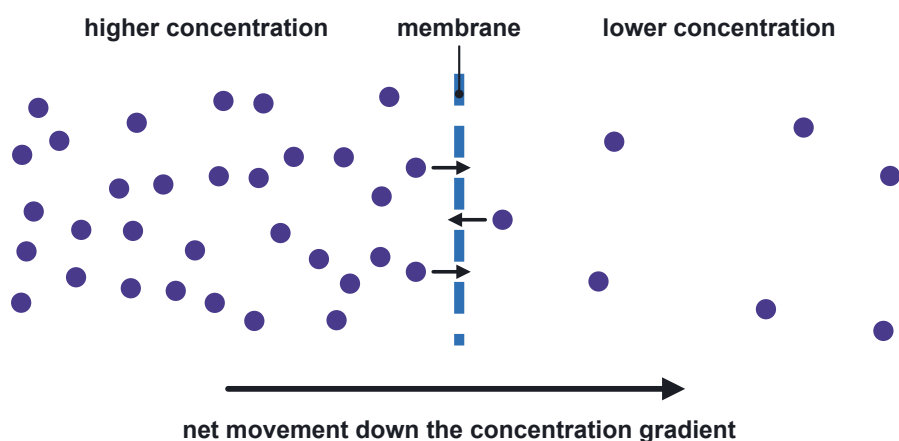
##### Diffusion

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                                                                         |
|--------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|
| <b>Difference in concentrations (concentration gradient)</b> | A bigger difference means a faster rate, because more particles move down the gradient in the same time |
| <b>Temperature</b>                                           | A higher temperature means a faster rate, because the particles have more energy and move faster        |
| <b>Surface area of the membrane</b>                          | 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.

$$\text{surface area to volume ratio} = \text{surface area} \div \text{volume}$$

### Cubes of different sizes

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

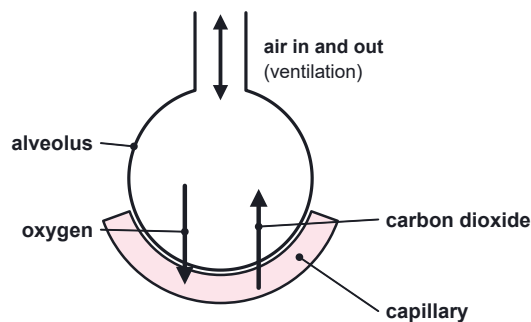
In multicellular organisms, surfaces and organ systems are specialised for exchanging materials. This is to allow sufficient molecules to be transported into and out of cells for the organism's needs. The effectiveness of an exchange surface is increased by:

- 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.

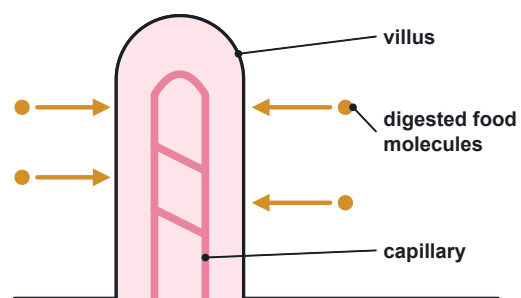
## Adaptations of exchange surfaces

| Exchange surface                 | Substances exchanged                                      | Adaptations                                                                                                                                  |
|----------------------------------|-----------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Small intestine (mammals)</b> | 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                 |
| <b>Lungs (mammals)</b>           | Oxygen into the blood, carbon dioxide out                 | Many alveoli give a large surface area; thin walls; good blood supply; ventilated by breathing                                               |
| <b>Gills (fish)</b>              | 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 |
| <b>Roots (plants)</b>            | Water and mineral ions into the plant                     | Root hair cells give a large surface area; thin cell walls give a short diffusion path                                                       |
| <b>Leaves (plants)</b>           | 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             |

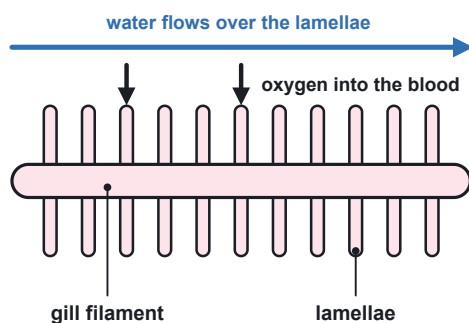
**Lungs: alveolus and capillary**



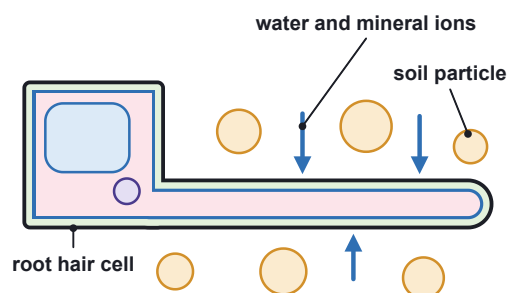
**Small intestine: villus**



**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.

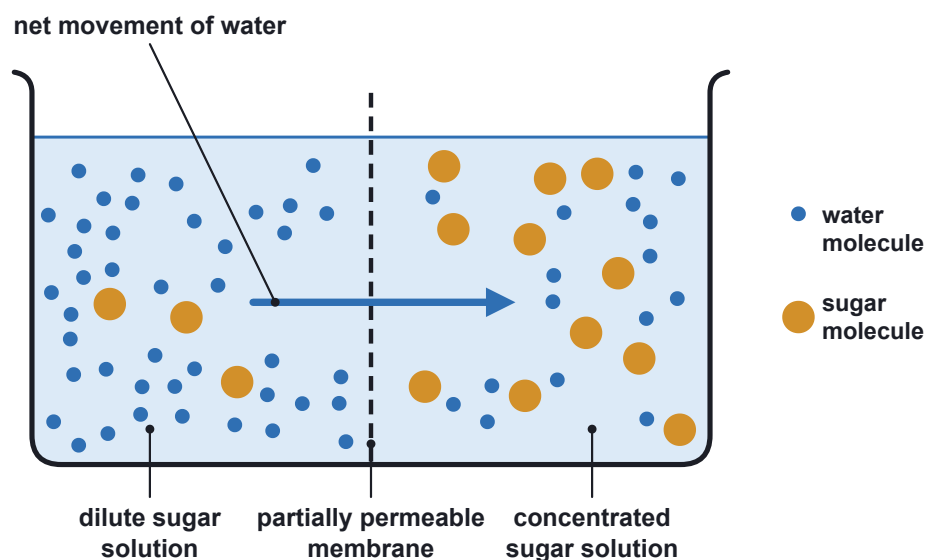
*Exam tip: A maintained concentration gradient comes from the blood supply (in animals) and from ventilation. Say that both keep the concentration gradient steep so diffusion stays fast.*

## 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 cm<sup>3</sup>/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                                                          |
|----------------------------------------|--------------------------------------------------------|---------------------------------------------------|---------------------------------------------------------------------------|
| <b>What moves</b>                      | Particles of a gas or of a substance in solution       | Water only                                        | Substances such as mineral ions and sugar                                 |
| <b>Direction</b>                       | 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) |
| <b>Membrane</b>                        | Across a membrane or not                               | Through a partially permeable membrane            | Across the cell membrane                                                  |
| <b>Energy from respiration needed?</b> | 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

### Cell structure

1. As a single DNA loop that is not enclosed in a nucleus. There may also be plasmids.
2. Mitochondria.
3. Magnification = size of image  $\div$  size of real object.
4. It has much higher magnification and resolving power.
5. To sterilise them and kill unwanted microorganisms.

### Cell division

1. DNA molecules, in the nucleus.
2. Growth and DNA replication; mitosis; division of the cytoplasm and cell membranes.
3. Two genetically identical cells.
4. The embryo has the same genes as the patient.
5. In meristems, throughout the life of the plant.

### 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.