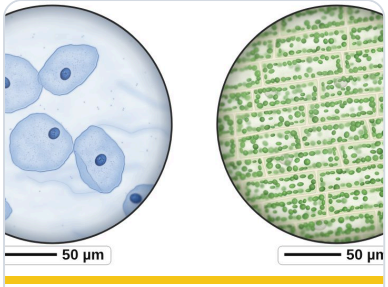
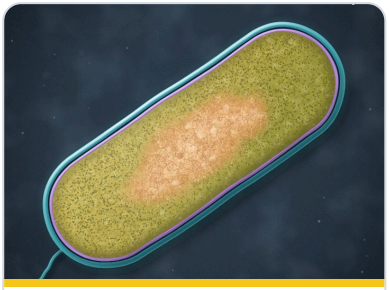
AQA GCSE COMBINED SCIENCE TRILOGY 8464 · BIOLOGY PAPER 1

B1 Cell biology

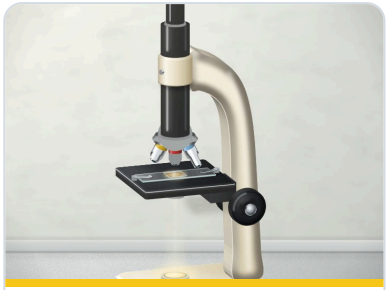
Revision notes for all 10 lessons. Each lesson has 4 pages. The pictures are paintings, not photos.



B1 L1
Animal and plant cells
page 2



B1 L2
Bacterial cells
page 6



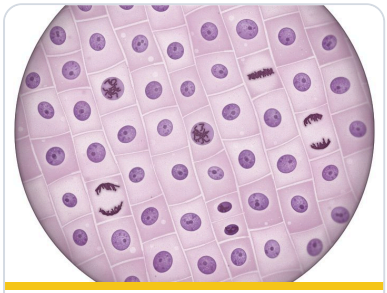
B1 L3
Using a microscope
page 10



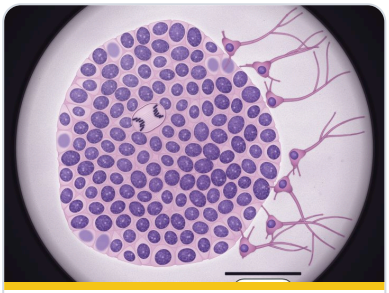
B1 L4
Magnification and cell size
page 14



B1 L5
Specialised cells
page 18



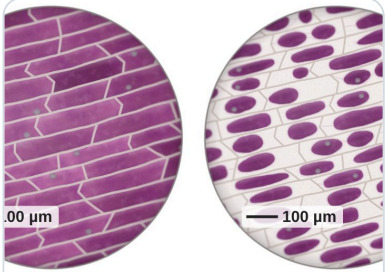
B1 L6
Cell division: mitosis
page 22



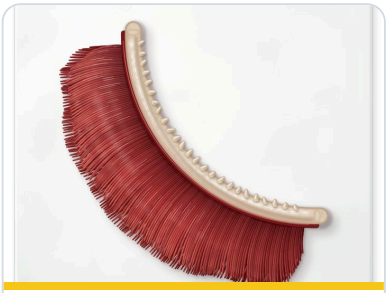
B1 L7
Stem cells
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B1 L1 Revision notes 1 of 4

Animal and plant cells

Cells, eukaryotic cells and the animal cell

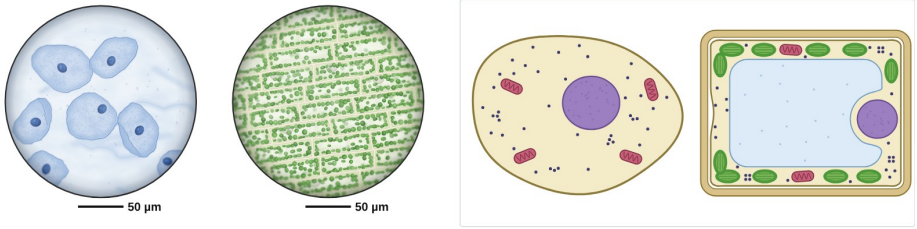
1. Cells: the building blocks

All living things are made of **cells**. A cell is the basic building block of all living things.

Most cells are far too small to see without a microscope. A typical animal cell is about 10 to 30 µm across, and a plant cell about 10 to 100 µm (1 mm = 1000 µm).

Inside each cell are smaller parts, called **sub-cellular structures**. Each one has a particular job. Together they keep the cell alive.

2. Real cells and cell diagrams



Real cells (painting) **Cell diagrams**

Stains colour the cells: the blue is a dye. The green chloroplasts are their real colour.

A picture of cells seen through a light microscope is a **light micrograph**. Real cells are almost colourless, so animal cells such as cheek cells are often **stained**: a blue dye shows up the nucleus. Pondweed leaf cells need no stain: their chloroplasts are really green.

Exam pictures of cells are usually **diagrams**. A diagram is simplified on purpose:

- It draws mitochondria and ribosomes. In a light micrograph, mitochondria are too small to see clearly, and ribosomes cannot be seen at all.
- It shows one neat cell. Real plant cells are packed together in rows and share their walls.
- It colours the permanent vacuole. In real cells it is clear and hard to see.
- It draws the cell membrane as a separate line. In a real plant cell it is pressed against the cell wall.
- It always shows the nucleus clearly. In real plant cells it is often hidden behind chloroplasts.

Watch out: the colours in a diagram are not real. Only the green of the chloroplasts is a real colour. The blue of stained cheek cells is a dye.

3. Eukaryotic cells

Animal and plant cells are **eukaryotic cells**. Every eukaryotic cell has:

- a **cell membrane** around the cytoplasm (in plant cells, just inside the cell wall)
- **cytoplasm** inside
- **genetic material** (DNA) enclosed in a **nucleus**.

"Eu-" means true: a eukaryotic cell has a true nucleus. Bacterial cells are prokaryotic: their genetic material is not in a nucleus (B1 L2 Bacterial cells).

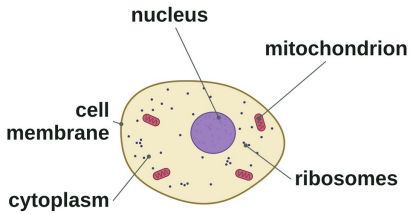
4. Inside an animal cell

Most animal cells have five parts. You need to know each one and its job.

Part	Job
nucleus	contains genetic material, which controls the activities of the cell
cytoplasm	a jelly-like substance where most of the chemical reactions in the cell happen; enzymes control the reactions
cell membrane	controls the movement of substances into and out of the cell
mitochondria	where aerobic respiration happens, releasing energy for the cell
ribosomes	protein synthesis: proteins are made there

Notes on the parts:

- The genetic material in the nucleus is **DNA**. It carries the instructions for making the cell's proteins (more in B1 L6 Cell division: mitosis).
- One **mitochondrion**, many **mitochondria**. Cells that need a lot of energy, such as muscle cells, have a lot of them.
- Ribosomes are tiny: about 25 nm across. They make proteins such as **enzymes** (B2 L3 Enzymes and digestion).



A diagram is simplified.

Watch out: mitochondria **release** energy by respiration. Never write that energy is "made" or "produced".

B1 L1 Revision notes 2 of 4

Animal and plant cells

Plant cells, and animal and plant cells compared

5. Inside a plant cell

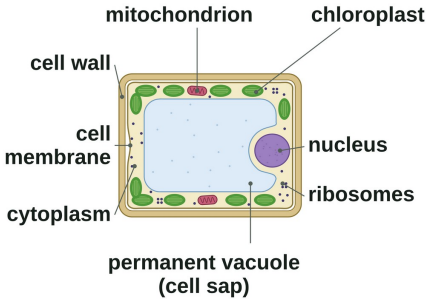
Plant cells have the same five parts as animal cells. They often have three more:

Part	What it is like	Job
cell wall	made of cellulose; outside the cell membrane	strengthens the cell
permanent vacuole	a space filled with cell sap, a weak solution of sugars and salts	helps to keep the cell firm
chloroplasts	green: they contain chlorophyll	absorb light to make food by photosynthesis

Algal cells, such as the cells of seaweeds and pond algae, also have a cell wall made of **cellulose**, and chloroplasts.

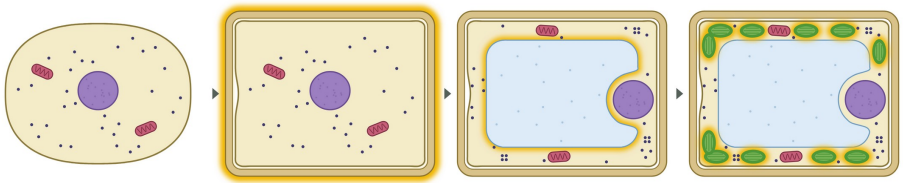
A full permanent vacuole pushes the cytoplasm out against the cell wall. This keeps the cell firm and helps the plant to stand up (more in B1 L9 Osmosis).

Watch out: the cell wall is not the cell membrane. Plant cells have both. The cell wall strengthens the cell. The cell membrane, just inside it, controls what goes in and out.



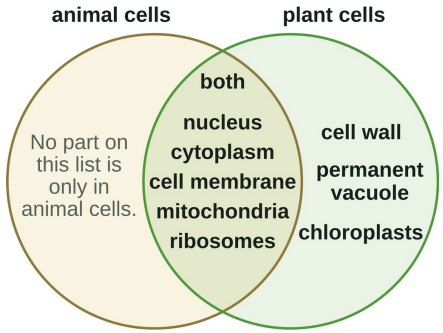
A diagram is simplified. Only the chloroplasts' green is a real colour.

Building a plant cell. Start with the five shared parts. Add a cell wall round the outside, a permanent vacuole in the middle, and chloroplasts in the cytoplasm: that is a plant cell.



6. Animal and plant cells compared

Part	Animal	Plant
nucleus	yes	yes
cytoplasm	yes	yes
cell membrane	yes	yes
mitochondria	yes	yes
ribosomes	yes	yes
cell wall	no	yes
permanent vacuole	no	often
chloroplasts	no	often



Plant cells have every part that animal cells have, and more. No part on the AQA list is only in animal cells.

Watch out: plant cells have mitochondria too. They respire all the time, day and night (section 9).

Watch out: animal cells have no cell wall and no permanent vacuole. The outside layer of an animal cell is the cell membrane.

Watch out: not every plant cell has chloroplasts. Onion bulb cells and root hair cells grow in the dark and have none.

7. Which cell is it?

- Look for the **cell wall** first. A cell wall and a permanent vacuole: a plant cell.
- No cell wall and no permanent vacuole: an animal cell.
- A cell wall made of cellulose and chloroplasts, living on its own in a pond: an algal cell.
- No chloroplasts does not mean an animal cell. Lots of mitochondria do not mean a plant cell.

B1 L1 Revision notes 3 of 4

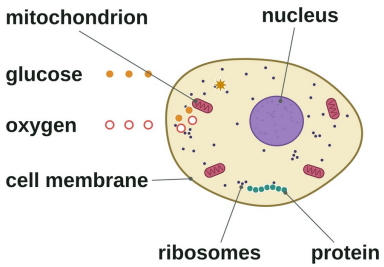
Animal and plant cells

Parts working together, day and night, and sizes

8. The parts work together

No part of a cell works alone. Follow glucose and oxygen into an animal cell:

- The **cell membrane** lets glucose and oxygen into the cell.
- In the **mitochondria**, aerobic respiration releases energy from glucose.
- The **nucleus** holds the instructions for making proteins.

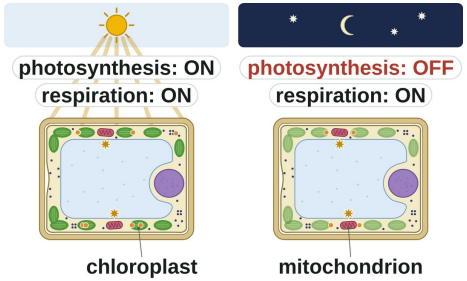


- At the **ribosomes**, proteins are made, using energy from the mitochondria.
- Most chemical reactions happen in the **cytoplasm**, controlled by enzymes. Waste carbon dioxide passes out through the cell membrane.

How substances get into cells is B1 L8 Diffusion.

9. Plant cells respire day and night

	Light	Dark
chloroplasts: photosynthesis	yes	no
mitochondria: aerobic respiration	yes	yes



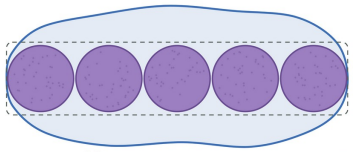
Chloroplasts absorb light to make food (glucose) by **photosynthesis**. This can only happen in the light.

Mitochondria release energy by **aerobic respiration**. Plant cells need energy all the time, so they respire all the time, day and night. At night they use food made in the day.

Watch out: plant cells respire as well as photosynthesise. Chloroplasts do not make energy: they absorb light to make food. Mitochondria release energy from the food.

10. How big are the parts?

Part	About how big
plant cell	10 to 100 µm
animal cell	10 to 30 µm (a cheek cell about 50 µm)
nucleus	5 to 10 µm
chloroplast	about 5 µm
mitochondrion	about 1 µm
ribosome	about 25 nm (0.025 µm)



50 µm ÷ 10 µm = 5 nuclei

1 mm = 1000 µm
1 µm = 1000 nm

An **estimate** is a rough value worked out quickly with simple numbers. Use estimates to compare the sizes of the parts, and to check that an answer is sensible. Cells vary in size, so always say "about".

To estimate how many copies of a part would fit across a cell:

number that fit = width of the cell ÷ width of the part

Worked example: a plant cell is about 80 µm long. Its nucleus is about 10 µm across. Estimate how many nuclei would fit along the cell.

Step 1: check both sizes are in the same unit: 80 µm and 10 µm.

Step 2: divide: 80 ÷ 10 = 8.

Answer: about **8 nuclei**. Check: 8 × 10 µm = 80 µm.

A ribosome (about 25 nm) is 400 times narrower than a 10 µm nucleus: far too small to see with a light microscope. Electron microscopes show ribosomes (B1 L3 Using a microscope).

Watch out: divide the size of the cell by the size of the part. Change both sizes into the same unit first (more in B1 L4 Magnification and cell size).

11. Answering "explain" questions about cells

Name the part, then give its job, then link the job to the question.

- Model answer: "A leaf cell has chloroplasts because they absorb light to make food by photosynthesis. A root cell has none because it is underground, in the dark."
- "The mitochondria make energy" scores nothing: write "the mitochondria release energy by aerobic respiration".

B1 L1 Revision notes 4 of 4

Animal and plant cells

Key words, exam tips and check yourself

Key words

Aerobic respiration: respiration that uses oxygen.

Cell: the basic building block of all living things.

Cell membrane: a thin layer around the cell that controls the movement of substances into and out of the cell.

Cell sap: a weak solution of sugars and salts that fills the permanent vacuole.

Cell wall: a layer outside the cell membrane that strengthens the cell; in plant and algal cells it is made of cellulose.

Cellulose: the tough substance that plant and algal cell walls are made of.

Chlorophyll: the green substance in chloroplasts that absorbs light.

Chloroplasts: green structures in some plant cells that absorb light to make food by photosynthesis.

Cytoplasm: a jelly-like substance where most of the chemical reactions in the cell happen.

Eukaryotic cell: a cell whose genetic material is enclosed in a nucleus, such as an animal or plant cell.

Mitochondria (one mitochondrion): the structures in the cytoplasm where aerobic respiration happens, releasing energy for the cell.

Nucleus: the part of a cell that contains the genetic material, which controls the activities of the cell.

Permanent vacuole: a space in a plant cell, filled with cell sap, that helps to keep the cell firm.

Photosynthesis: the process in which plants and algae use light to make glucose from carbon dioxide and water.

Ribosomes: tiny structures in the cytoplasm where proteins are made.

Sub-cellular structure: a part inside a cell that has a particular job, such as the nucleus or a mitochondrion.

Exam tips

- Learn the five parts that animal and plant cells share, and the three extra parts of plant cells.
- Learn a job for every part, in the exact words: "controls the activities of the cell", "controls the movement of substances into and out of the cell".
- Write "cell membrane" and "cell wall" in full. Write "permanent vacuole", not just "vacuole".
- Energy is **released** by respiration. Never write that energy is "made".
- In a light micrograph you cannot see mitochondria clearly, and you cannot see ribosomes at all. Look for the cell wall and the chloroplasts.
- In an estimate, show the division and give the unit.

Check yourself

Cover the answers, then check.

1. Name the five sub-cellular structures found in most animal cells.
2. Name three structures that plant cells often have but animal cells do not.
3. Name the sub-cellular structure where protein synthesis happens.
4. What is a plant cell wall made of, and what does it do?
5. Why do plant cells need mitochondria?
6. Give two reasons why a cell diagram looks different from a light micrograph of the same cells.
7. What does chlorophyll do?
8. A cell is about 45 µm wide. Its nucleus is about 9 µm wide. About how many nuclei would fit across the cell?

Answers

1. Nucleus, cytoplasm, cell membrane, mitochondria and ribosomes.
2. A cell wall, a permanent vacuole and chloroplasts.
3. The ribosomes.
4. Cellulose. It strengthens the cell.
5. To release energy by aerobic respiration, which they do all the time, day and night.
6. Any two: the diagram uses false colours; it draws mitochondria and ribosomes, which are too small to see clearly with a light microscope; it shows one neat cell, not cells packed together; it colours the clear permanent vacuole; it draws the cell membrane apart from the cell wall; it always shows the nucleus clearly.
7. It absorbs light (for photosynthesis).
8. 45 ÷ 9 = about 5 nuclei.

Common mistakes

- **Wrong:** "Plant cells do not have mitochondria." **Right:** they do, and they respire all the time.
- **Wrong:** "The cell wall controls what goes in and out." **Right:** the cell membrane does.
- **Wrong:** "Mitochondria make energy." **Right:** they release energy.
- **Wrong:** "Every plant cell has chloroplasts." **Right:** cells in the dark have none.

B1 L2 Revision notes 1 of 4

Bacterial cells

Bacteria: one cell, one whole organism, and the parts of a bacterial cell

1. What is a bacterium?

A **bacterium** (plural **bacteria**) is a **single-celled organism** with a **prokaryotic cell**. Its one cell is the whole living thing: it takes in substances, releases energy, makes proteins and, in some bacteria, moves.

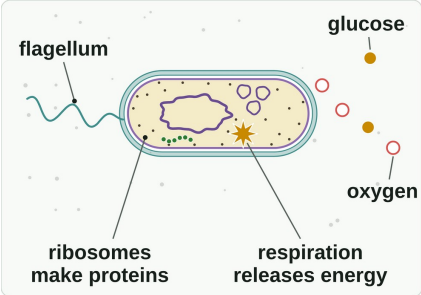
Bacteria are **microorganisms**: living things too small to see without a microscope. Most bacteria are about 1 to 5 µm long (1 mm = 1000 µm). They live almost everywhere: in soil, in water, on your skin and in your gut.

Bacterial cells are **prokaryotic**: their genetic material is not enclosed in a nucleus. Animal and plant cells are **eukaryotic**: their genetic material is enclosed in a nucleus (B1 L1 Animal and plant cells).

2. One cell, one whole organism

A bacterium is a **single-celled organism**: one cell does everything to stay alive.

- **Taking in:** substances such as glucose and oxygen pass through the cell wall and the cell membrane into the cytoplasm.
- **Releasing energy:** bacteria have no mitochondria, but they still **respire**. The reactions happen in the cytoplasm and on the cell membrane. Respiration releases energy.

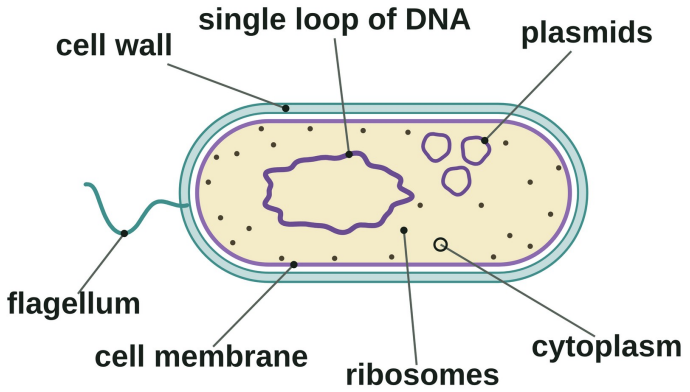


- **Making proteins:** the ribosomes make the proteins the cell needs.
- **Moving:** some bacteria swim by turning a **flagellum**.

Most bacteria are harmless or useful: they break down dead material in soil, help to make yoghurt and cheese, and help to break down some foods in your gut. A few are **pathogens**: microorganisms that cause infectious disease (B3 Infection and response). Bacteria are not viruses: viruses are not cells at all (B3).

Watch out: no mitochondria does not mean no respiration. Energy is released by respiration: never write that energy is "made".

3. The parts of a bacterial cell



A diagram is simplified. The colours help you tell the parts apart.

Part	Its job
cell wall	strengthens the cell and helps it keep its shape; not made of cellulose
cell membrane	controls the movement of substances into and out of the cell
cytoplasm	a jelly-like substance where most of the chemical reactions happen
ribosomes	tiny structures where proteins are made
single loop of DNA	carries the genetic instructions; free in the cytoplasm, not in a nucleus
plasmids (some bacteria)	small rings of DNA that carry a few extra genes
flagellum (some bacteria)	a long, whip-like tail used to move

A bacterial cell has **no nucleus**, **no mitochondria** and **no chloroplasts**.

Watch out: the bacterial cell wall is not made of cellulose. Only some bacteria have plasmids or a flagellum.

B1 L2 Revision notes 2 of 4

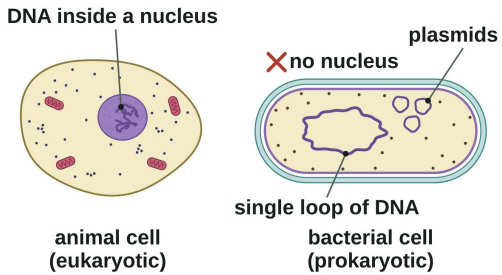
Bacterial cells

DNA with no nucleus, plasmids, and prokaryotic and eukaryotic cells

4. DNA, but no nucleus

Bacteria, animal cells and plant cells all have **DNA**: the chemical that carries the genetic instructions for a cell.

- In animal and plant cells, the DNA is enclosed in a **nucleus**.
- A bacterial cell has **no nucleus**. Its main DNA is a **single loop**, free in the cytoplasm.



A diagram is simplified. Not to scale.

The loop is very long, so it is folded into a tangle. In a micrograph it shows as a pale area in the middle of the cell. Because they have no nucleus, bacteria do not divide by mitosis (B1 L6 Cell division: mitosis).

Watch out: no nucleus does not mean no DNA. Write: "the DNA is a single loop, free in the cytoplasm".

5. Plasmids

Plasmids are small rings of DNA found in some bacterial cells, separate from the main loop of DNA.

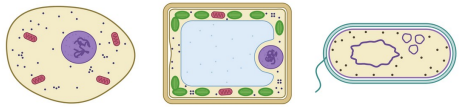
- The main loop carries most of the genes the bacterium needs to live.
- A plasmid carries a few **extra genes**. For example, some plasmids carry a gene that helps the bacterium survive an antibiotic (B6 Inheritance, variation and evolution).
- A bacterium may have no plasmids, one or several. It can live without them.
- Scientists can put useful genes, such as the human insulin gene, into bacteria, so the bacteria make that protein (B6).

Watch out: plasmids are extras. The main DNA is the single loop, and not every bacterium has plasmids.

6. Prokaryotic and eukaryotic cells

Structure	Animal cell	Plant cell	Bacterial cell
nucleus	✔	✔	✖
DNA	✔ in the nucleus	✔ in the nucleus	✔ a single loop
cell membrane	✔	✔	✔
cytoplasm	✔	✔	✔
ribosomes	✔	✔	✔
mitochondria	✔	✔	✖
chloroplasts	✖	✔ (some)	✖
permanent vacuole	✖	✔	✖
cell wall	✖	✔ cellulose	✔ not cellulose
plasmids	✖	✖	✔ (some)
typical size	about 20 µm	up to about 100 µm	about 1 to 5 µm

- **Eukaryotic cell:** a cell whose genetic material is enclosed in a nucleus, such as an animal or plant cell.
- **Prokaryotic cell:** a cell whose genetic material is not enclosed in a nucleus, such as a bacterial cell.



A diagram is simplified. Not to scale.

- Word clues: "pro-" means before and "karyon" means nucleus. "Eu-" means true: a true nucleus.
- All three kinds of cell have a cell membrane, cytoplasm, ribosomes and DNA.

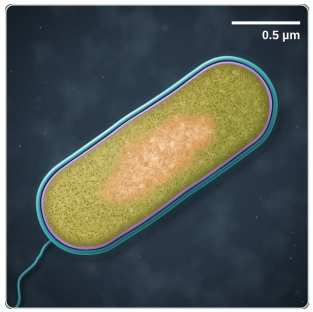
Watch out: single-celled does not mean prokaryotic. Yeast is a single-celled fungus with a nucleus, so its cell is eukaryotic.

B1 L2 Revision notes 3 of 4

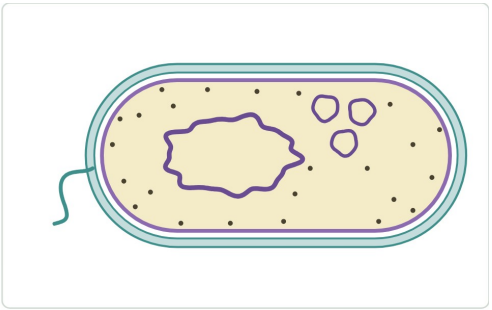
Bacterial cells

A real bacterium and a diagram, how small bacteria are, and answering compare questions

7. A real bacterium and a diagram



A real bacterium (painting)



A diagram (simplified)

Electron micrographs are black and white: the colours are added. Real bacteria are almost colourless.

Bacteria are so small that the clearest pictures of them come from an **electron microscope** (B1 L3 Using a microscope). A picture taken with one is an **electron micrograph**. The painting is based on a coloured electron micrograph of a bacterium cut lengthways. Exam pictures are usually **diagrams**, simplified on purpose:

- **DNA:** in the micrograph, the DNA is a pale, tangled mass in the middle, with no membrane round it. The diagram draws one neat loop.
- **Plasmids:** too small to pick out in the micrograph. The diagram draws them as clear small rings.
- **Ribosomes:** thousands of tiny dots make real cytoplasm look grainy. The diagram draws only a few.
- **Colour:** electron micrographs are black and white; the colours are added. Real bacteria are almost colourless.
- **Wall and membrane:** in the micrograph, two thin layers pressed close together. The diagram draws two clear lines with a gap.

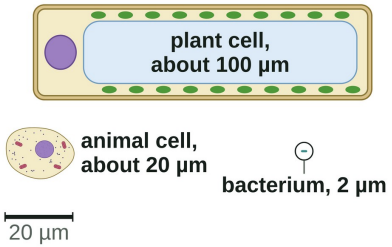
Both show a cell wall, a cell membrane, cytoplasm and DNA with no nucleus round it.

Watch out: the colours in a coloured electron micrograph are not real. They are added to make the parts easier to see.

8. How small are bacteria?

Cells are measured in **micrometres** (µm). A micrometre is one thousandth of a millimetre: 1 mm = 1000 µm.

- Most bacteria: about 1 to 5 µm long (a typical rod about 2 µm).
- An animal cell: about 20 µm across.
- A plant cell: up to about 100 µm long (most are 10 to 100 µm).



how many times bigger = bigger size ÷ smaller size (both in the same unit)

Worked example: a cheek cell is 0.05 mm across. A bacterium is 2.5 µm long. How many times bigger is the cheek cell?

Step 1: change mm into µm: 0.05 × 1000 = 50 µm.

Step 2: divide: 50 ÷ 2.5 = 20.

Answer: **20 times** bigger. Check: 20 × 2.5 µm = 50 µm.

An **order of magnitude** is a factor of 10: one order of magnitude bigger means about 10 times bigger. A bacterium is about one order of magnitude smaller than an animal cell. (Calculations with orders of magnitude and standard form: B1 L4 Magnification and cell size.)

Watch out: to find how many times bigger, divide. Do not subtract: 50 − 2.5 is not the answer. Change both sizes into the same unit first.

9. Answering "compare" questions

A compare question wants similarities **and** differences, with both cells named in each point. Use "both" for a similarity, and "but" or "whereas" for a difference.

- Model answer to "Compare the DNA in a bacterial cell with the DNA in an animal cell": "Both cells have DNA. An animal cell's DNA is enclosed in a nucleus, but a bacterial cell has no nucleus: its main DNA is a single loop, free in the cytoplasm. A bacterial cell may also have plasmids, small rings of DNA, whereas an animal cell has none."
- "A bacterium has no nucleus" on its own is only half a comparison: say what the other cell has.

B1 L2 Revision notes 4 of 4

Bacterial cells

Key words, exam tips and check yourself

Key words

Bacterium (plural bacteria): a single-celled organism with a prokaryotic cell.

Cell membrane: a thin layer around the cell that controls the movement of substances into and out of the cell.

Cell wall: a layer outside the cell membrane that strengthens the cell; in plant and algal cells it is made of cellulose.

Cytoplasm: a jelly-like substance where most of the chemical reactions in the cell happen.

DNA: the chemical that carries the genetic instructions for a cell.

Electron micrograph: a picture of something seen through an electron microscope.

Eukaryotic cell: a cell whose genetic material is enclosed in a nucleus, such as an animal or plant cell.

Flagellum (plural flagella): a long, whip-like tail that some bacteria use to move.

Micrometre (µm): one thousandth of a millimetre (1 mm = 1000 µm).

Microorganism: a living thing that is too small to see without a microscope, such as a bacterium.

Order of magnitude: a factor of 10; one order of magnitude bigger means about 10 times bigger.

Pathogen: a microorganism that causes infectious disease.

Plasmids: small rings of DNA found in some bacterial cells, separate from the main loop of DNA.

Prokaryotic cell: a cell whose genetic material is not enclosed in a nucleus, such as a bacterial cell.

Ribosomes: tiny structures in the cytoplasm where proteins are made.

Single-celled organism: an organism made of only one cell, such as a bacterium.

Common mistakes

- **Wrong:** "Bacteria have no DNA." **Right:** their DNA is a single loop, free in the cytoplasm.
- **Wrong:** "Plasmids are the main DNA." **Right:** plasmids are small extra rings.
- **Wrong:** "The bacterial cell wall is made of cellulose." **Right:** it is not made of cellulose.
- **Wrong:** "No mitochondria, so no respiration." **Right:** bacteria still respire.
- **Wrong:** subtracting to find how many times bigger. **Right:** divide.

Check yourself

Cover the answers, then check.

1. What does prokaryotic mean?
2. Name four structures found in every bacterial cell.
3. Describe the main DNA of a bacterial cell.
4. What are plasmids, and do all bacteria have them?
5. Give two structures that plant cells have but bacterial cells do not.
6. Name two structures that a bacterial cell and a plant cell both have.
7. Why does a coloured electron micrograph not show the real colours of a bacterium?
8. A plant cell is 40 µm long and a bacterium is 5 µm long. How many times longer is the plant cell?

Answers

1. The cell's genetic material is not enclosed in a nucleus.
2. Any four: cell wall, cell membrane, cytoplasm, ribosomes, a single loop of DNA.
3. It is a single loop, free in the cytoplasm (not in a nucleus).
4. Small rings of DNA, separate from the main loop. No: only some bacteria have them.
5. Any two: a nucleus, chloroplasts, mitochondria, a permanent vacuole.
6. Any two: a cell wall, a cell membrane, cytoplasm, ribosomes, DNA.
7. Electron micrographs are black and white: the colours are added. Real bacteria are almost colourless.
8. 40 ÷ 5 = 8 times.

Exam tips

- Prokaryotic = no nucleus (bacteria). Eukaryotic = the genetic material is in a nucleus (animal and plant cells).
- Never write that bacteria have no DNA. Write "the DNA is a single loop, free in the cytoplasm".
- Plasmids are small extra rings of DNA. Do not call them the main DNA.
- For bacteria, say "the cell wall is not made of cellulose".
- In "how many times bigger" questions, put both sizes in the same unit, divide, and show your working.
- In "compare" questions, give similarities and differences, and say which cell has which feature.

B1 L3 Revision notes 1 of 4

Using a microscope

The light microscope: its parts, a real microscope and a diagram, total magnification

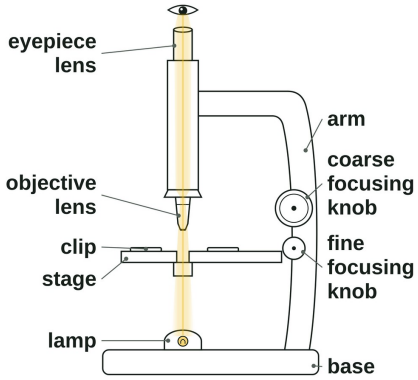
1. What a light microscope does

A **light microscope** uses light and lenses to make a magnified image. Light from the **lamp** shines up through the **specimen**, the thing you are looking at. Then two lenses magnify it: the **objective lens** and the **eyepiece lens**.

- The specimen sits on a **microscope slide**, a thin, flat piece of glass.
- The specimen must be **thin**, so that light can pass through it. A thick piece blocks the light.
- A picture of something seen through a light microscope is a **light micrograph**.

2. The parts and their jobs

Part	Job
Eyepiece lens	the lens you look through; it magnifies the image (often × 10)
Objective lens	magnifies the image; there are usually three (such as × 4, × 10 and × 40) on a turning nosepiece
Stage and clips	the stage holds the slide; the clips keep it still
Lamp	shines light up through the specimen (older microscopes use a mirror)
Coarse focusing knob	the larger knob: moves the lens and the slide a long way, to find the image
Fine focusing knob	the smaller knob: moves them a tiny distance, to make the image sharp
Arm and base	hold the microscope steady; carry it by the arm, with a hand under the base



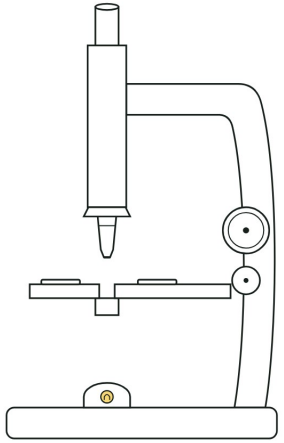
3. A real microscope and a diagram

- A real school microscope has **three objective lenses** on a turning nosepiece. A diagram usually shows one.
- On a real microscope the fine knob often sits inside the coarse knob, on both sides. A diagram draws two separate knobs.
- The parts are always in the same places, so you can name them on any microscope.

A diagram is simplified: it shows only the parts you need to name.



A real microscope



An exam diagram

4. Total magnification

total magnification = eyepiece lens magnification × objective lens magnification

Worked example: the eyepiece lens is × 10 and the objective lens is × 40.

- Numbers in: 10 × 40 = 400, so the total magnification is **× 400**. It has no unit.
- Check: the answer is bigger than either lens on its own.

The higher the magnification, the smaller the **field of view**. With a × 10 eyepiece lens:

Objective lens	Total magnification	Field of view	Onion cells across
× 4	× 40	about 4.0 mm	about 20
× 10	× 100	about 1.6 mm	about 8
× 40	× 400	about 0.4 mm	about 2

Watch out: multiply, never add. × 10 and × 40 give × 400, not × 50.

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Using a microscope

Required practical 1 (Combined Science and Biology): preparing a slide, focusing and working safely

5. Required practical 1 (Combined Science and Biology)

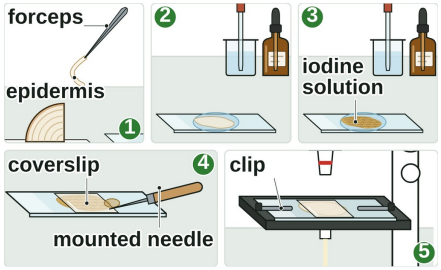
Aim: to use a light microscope to observe, draw and label plant and animal cells, with a magnification scale.

Apparatus: a light microscope, microscope slides, coverslips, an onion, forceps, a dropping pipette, water, iodine solution, a mounted needle, a paper towel, eye protection (and, for cheek cells, a clean cotton bud and methylene blue).

This practical is a skill, so it has no independent or dependent variable. To compare magnifications, you could change the objective lens (independent variable) and measure the diameter of the field of view (dependent variable), using the same slide (control variable).

6. Preparing a slide of onion cells

1. Peel a thin layer of **epidermis** (skin) from the inside of an onion layer, using **forceps**.
2. Put a drop of water on a clean **microscope slide**. Lay the epidermis flat in it, with no folds.
3. Add a drop of **iodine solution**. It is a **stain** that makes the cells, and parts such as the nucleus, easier to see. It stains the cells yellow-brown.
4. Lower a **coverslip** at an angle with a **mounted needle**, so no air bubbles are trapped. The coverslip keeps the specimen flat and stops it drying out.
5. Blot off any extra liquid with a paper towel. Clip the slide onto the stage, with the specimen over the hole.

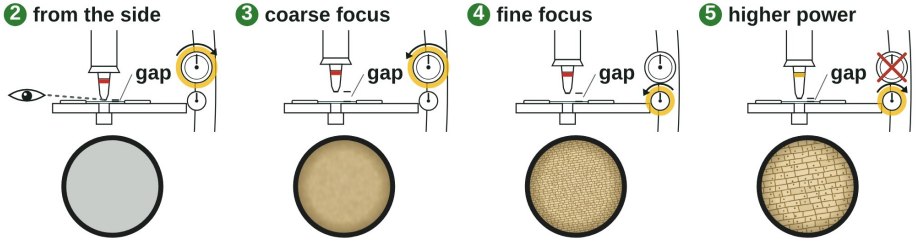


Watch out: a stain makes cells easier to see. It does not make them bigger: only the lenses magnify.

7. Animal cells: cheek cells

Gently wipe the inside of your own cheek with a clean cotton bud. Smear it on a slide, add a drop of **methylene blue** and lower a coverslip. Methylene blue stains the cells blue and the nucleus dark blue. Put used cotton buds straight into disinfectant. Many schools use a prepared slide of cheek cells instead.

8. Focusing step by step



1. Start with the **lowest-power objective lens**. Its wide field of view makes the cells easy to find.
2. Watching from the side, turn the **coarse focusing knob** to bring the lens close to the slide, without touching it.
3. Look through the eyepiece lens. Turn the coarse knob to move the lens and the slide apart until the cells appear.
4. Turn the **fine focusing knob** until the image is sharp.
5. For a higher magnification, turn the nosepiece to a higher-power objective lens and refocus with the **fine knob only**.

Watch out: never use the coarse knob at high power: the lens could crack the slide.

Watch out: focusing changes the sharpness, not the size.

9. Safety

Hazard	Risk	Precaution
Iodine solution, methylene blue	irritate the eyes; stain skin and clothes	wear eye protection; use a dropper; wipe up spills
Mounted needle, glass slides and coverslips	cuts	handle with care; tell the teacher about broken glass
Cheek cells	spreading infection	use only your own cheek and a clean cotton bud; used buds into disinfectant
The microscope	dropping it; a mirror pointed at the Sun can damage your eyes	carry it with one hand on the arm and the other under the base; never point a mirror at the Sun

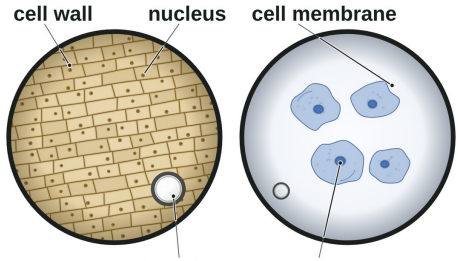
B1 L3 Revision notes 3 of 4

Using a microscope

Results, biological drawings, magnification and resolution, what can go wrong

10. What you see

- **Onion cells** (iodine solution): brick-shaped cells in rows, about 0.2 mm long. You can see the **cell wall**, the **cytoplasm** and a **nucleus**. The cell membrane is pressed against the wall, so you cannot see it on its own. There are **no chloroplasts**: an onion bulb grows underground.
- **Cheek cells** (methylene blue): flat, uneven cells, about 50 µm across, with a dark blue **nucleus**, a **cell membrane** and **no cell wall**.
- You cannot see **mitochondria** clearly with a school light microscope. **Ribosomes** are far too small to see at all.



onion cells, × 100
iodine solution

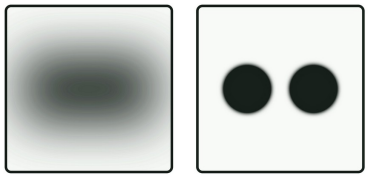
cheek cells, × 400
methylene blue

Watch out: an air bubble is round, with a thick dark edge. It is not a cell. Do not draw it.

11. Magnification and resolution

- **Magnification**: how many times bigger the image is than the real object.
- **Resolution** (resolving power): the ability to see two points that are close together as two separate points.

A light microscope can resolve points about **200 nm** (0.2 µm) apart. Points closer than that blur into one, however much you magnify them.

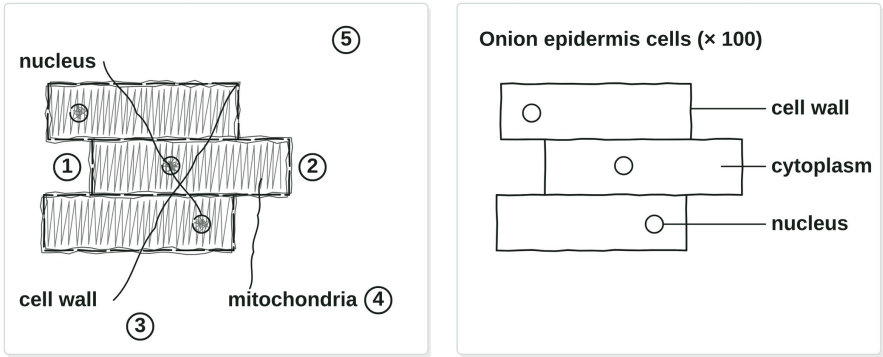


low resolution: one blur

high resolution: two points

Watch out: magnifying a blurry image only gives a bigger blur. More detail needs a higher resolution.

12. A biological drawing



Draw large: two or three cells, not the whole field of view. Keep the sizes of the parts in proportion. The numbers match the mistakes in the poor drawing.

1. Use a **sharp pencil** and clear, single lines.
2. **No shading.**
3. Draw **label lines with a ruler**. Each line touches its part, and no two lines cross.
4. **Label only what you can see.**
5. Add a **title** and the **magnification** (eyepiece × objective, such as "× 100"), or a scale bar.

Watch out: draw what you see, not a textbook cell: no mitochondria if you cannot see them.

13. What can go wrong

Problem	Likely cause	Fix
Dark image, cells on top of each other	the layer is too thick or folded	peel a thinner layer; lay it flat
Everything dark brown	too much iodine solution	add one drop only
Only a bright circle	out of focus, or the specimen is not over the hole	move the slide; refocus on low power

B1 L3 Revision notes 4 of 4

Using a microscope

Key words, exam tips and check yourself

Key words

Coarse focusing knob: the larger knob, which moves the lens and the slide a long way apart or together to find the image.

Coverslip: a very thin square of glass laid over the specimen to keep it flat and stop it drying out.

Electron microscope: a microscope that uses a beam of electrons instead of light, giving a much higher magnification and resolution.

Eyepiece lens: the lens at the top of a microscope that you look through.

Field of view: the circle you can see when you look down a microscope.

Fine focusing knob: the smaller knob, which moves the lens and the slide a tiny distance to make the image sharp.

Light microscope: a microscope that uses light and lenses to make a magnified image.

Magnification: how many times bigger the image is than the real object.

Methylene blue: a blue stain used to make the nuclei of animal cells, such as cheek cells, easier to see.

Objective lens: a lens just above the specimen; a microscope has several, each with a different magnification.

Resolution (resolving power): the ability to see two points that are close together as two separate points.

Specimen: the thing you look at under a microscope.

Stage: the flat platform that holds the microscope slide.

Stain: a dye that colours cells, or parts of cells, so they are easier to see.

Total magnification: the magnification of the eyepiece lens multiplied by the magnification of the objective lens.

Exam tips

- Use the exam names: eyepiece lens, objective lens, stage, coarse focusing knob, fine focusing knob.
- Total magnification: multiply, never add. Write it as “× 400”. It has no unit.
- Focusing: lowest power first; coarse knob, then fine knob; fine knob only at high power.
- A stain makes cells easier to see. It does not make them bigger.
- Drawings: sharp pencil, single lines, no shading, ruled label lines, a title and the magnification.
- Magnification makes the image bigger. Resolution decides how much detail you can see.

Check yourself

Cover the answers, then check.

1. What two things does a light microscope use to make a magnified image?
2. What is the job of the stage?
3. An eyepiece lens of × 5 is used with an objective lens of × 10. What is the total magnification?
4. Why is iodine solution added to onion cells on a slide?
5. Which focusing knob do you use first, to find the image?
6. On your slide you see a round shape with a thick, dark edge. What is it?
7. What is meant by resolution?
8. Name one structure you can see with an electron microscope but not with a light microscope.

Answers

1. Light and lenses.
2. It holds the microscope slide.
3. × 50 (5 × 10 = 50).
4. To make the cells, and parts such as the nucleus, easier to see. It is a stain.
5. The coarse focusing knob.
6. An air bubble, not a cell.
7. The ability to see two points that are close together as two separate points.
8. Ribosomes (allow the inside of a mitochondrion).

14. Light and electron microscopes

	Light microscope	Electron microscope
Uses	light	a beam of electrons
Magnification	up to about × 1500	up to about × 2 000 000
Resolution	about 200 nm	about 0.2 nm
You can see	cells, nuclei, chloroplasts	ribosomes, the inside of mitochondria

An **electron microscope** has a much higher magnification and resolution, so biologists can see many more **sub-cellular structures**. **1665**: Robert Hooke names cells. **1930s**: the first electron microscopes. **1950s**: ribosomes are seen for the first time.

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Magnification and cell size

How small cells are, units, and the view down a microscope

1. How small are cells?

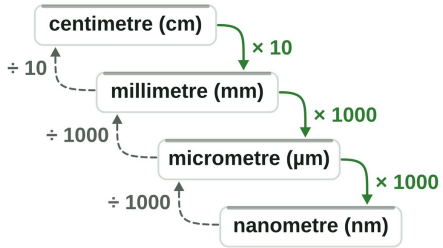
Most cells are far too small to see with your eyes alone. You need a microscope to see them, and very small units to measure them. Sizes vary, so these are typical values:

Thing	About how big
the width of a human hair	0.1 mm (100 µm)
an onion epidermis cell	0.2 mm (200 µm) long
a cheek cell	50 µm across
a chloroplast	5 µm
a bacterium	2 µm long
a mitochondrion	1 µm
a virus	100 nm
a ribosome	25 nm

2. Units for tiny things

- 1 cm = 10 mm
- 1 mm = 1000 µm (**micrometres**)
- 1 µm = 1000 nm (**nanometres**)

The prefix tells you the size: **centi** means one hundredth, **milli** one thousandth, **micro** one millionth and **nano** one billionth of a metre.



- To change to a **smaller** unit (down the staircase), **multiply**: 0.2 mm × 1000 = 200 µm.
- To change to a **bigger** unit (up the staircase), **divide**: 25 nm ÷ 1000 = 0.025 µm.

Watch out: to change µm into mm, divide by 1000. The number of mm is always smaller than the number of µm.

3. The view down a microscope

At × 100 (a × 10 eyepiece lens and a × 10 objective lens: B1 L3 Using a microscope) you see a round **field of view**, about 1.6 mm across. A slide of a thin layer of onion epidermis (skin), stained with iodine solution, shows:

- rows of brick-shaped cells, stained yellow-brown;
- a cell wall round each cell;
- a darker nucleus in most cells;
- sometimes an **air bubble**: a round shape with a thick dark edge. It is air trapped under the coverslip, not a cell.

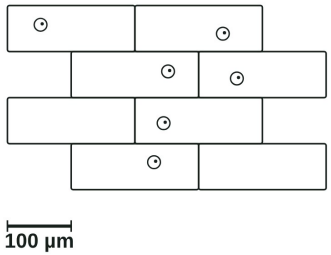
4. A real view and a biological drawing

Both show rows of brick-shaped cells with cell walls, and a nucleus in most cells.

Iodine stains the cells yellow-brown. The drawing adds a scale bar, so you can work out real sizes.



The view at × 100 (painting)



A drawing

Exam pictures of cells are usually **biological drawings**. A drawing is simplified on purpose:

- It has a **scale bar**, so you can work out real sizes. The view down the microscope has none.
- It shows only whole cells. Down the microscope, cells are cut off at the edge of the field of view.
- It tidies the cells into neat bricks. Real cells vary in size and shape.
- It leaves out air bubbles: they are not cells.
- It uses clear pencil lines, with no colour and no shading. The real cells are stained yellow-brown.

Watch out: an air bubble is not a cell. Leave air bubbles out of a biological drawing.

B1 L4 Revision notes 2 of 4

Magnification and cell size

Magnification, the magnification equation and scale bars

5. What magnification means

Magnification is how many times bigger the image is than the real object. "× 400" means the image is 400 times bigger than the real object.

- Magnification has **no unit**. Write it with a times sign: × 400.
- A light microscope magnifies up to about × 1500. An electron microscope magnifies up to about × 2 000 000 (B1 L3).
- The total magnification of a light microscope is the eyepiece lens magnification × the objective lens magnification (B1 L3).

The equation below works for any image: a micrograph, a drawing, or a picture on a screen.

Watch out: magnification has no unit. Never write 400 mm or 400 µm for a magnification.

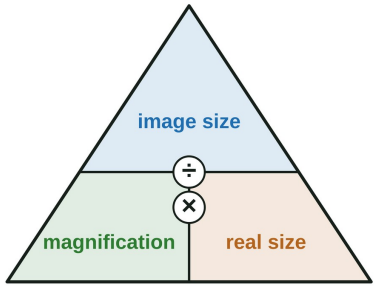
6. The magnification equation

magnification = size of image ÷ size of real object

Rearranged:

- **real size** = **image size** ÷ **magnification**
- **image size** = **real size** × **magnification**

Image size means the size of the image (measured with a ruler). Real size means the size of the real object.



How to answer a calculation:

1. Write the equation you need.
2. Put both sizes in the same unit (usually µm).
3. Put the numbers in and work it out. Type only the numbers into the calculator.
4. Give a unit (mm, µm or nm) for a size. Give no unit for a magnification.
5. Check: the real size must be smaller than the image.

7. Worked examples

Example 1: finding the magnification. An electron micrograph shows a mitochondrion. Its image is 30 mm long. The real mitochondrion is 1.5 µm long. Calculate the magnification.

Step 1: same unit: 30 mm = 30 × 1000 = 30 000 µm.

Step 2: magnification = size of image ÷ size of real object = 30 000 ÷ 1.5 = 20 000.

Answer: **× 20 000**. (Too high for a light microscope, as you would expect for an electron micrograph.)

Example 2: finding the real size. A drawing of a pollen grain is 45 mm wide. The magnification is × 1500. Calculate the real width in µm.

Step 1: real size = image size ÷ magnification = 45 ÷ 1500 = 0.03 mm.

Step 2: in µm: 0.03 × 1000 = **30 µm**.

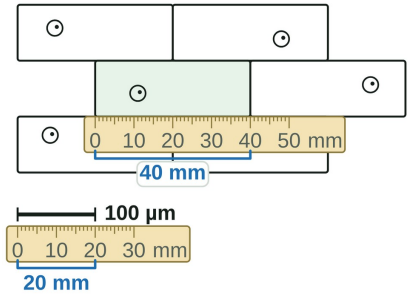
Check: 30 µm × 1500 = 45 000 µm = 45 mm, the size of the drawing.

8. Using a scale bar

A **scale bar** is a line on a picture that shows a real length, such as 10 µm.

1. Measure the scale bar with a ruler, in mm.
2. Measure the object, in mm.
3. real size = size on the picture ÷ length of the scale bar × value of the scale bar.

Example: in a drawing of onion cells, the 100 µm scale bar is 20 mm long and a cell is 40 mm long. 40 ÷ 20 × 100 = **200 µm**.



A scale bar is printed as part of the picture, so it stays right when the picture is printed bigger or smaller. A written magnification, such as × 200, is only right at the original size.

You can also find the magnification from a scale bar: 20 mm = 20 000 µm, and 20 000 ÷ 100 = × 200.

Watch out: measure the scale bar with a ruler. Do not use its label (100 µm) as its length.

B1 L4 Revision notes 3 of 4

Magnification and cell size

Getting it right, the field of view, standard form and orders of magnitude

9. Getting it right

Watch out: change both sizes into the same unit before you divide. mm → µm: multiply by 1000. If you forget, your answer is 1000 times too small or too big.

Watch out: the real size is smaller than the image. If your answer is bigger, the equation is upside down: divide, do not multiply.

Watch out: do not type the × sign into your calculator. For × 1500, type 1500.

10. Estimating size from the field of view

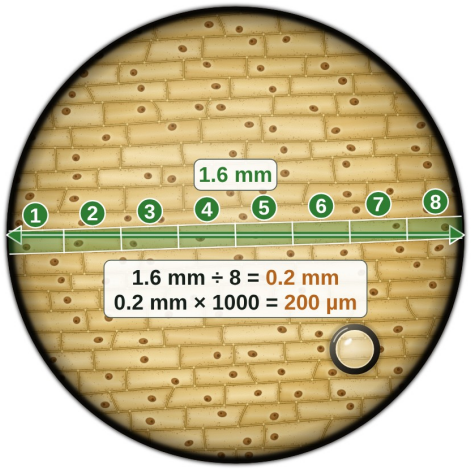
With a × 10 eyepiece lens:

Magnification	Width of the field of view
× 40	about 4.0 mm
× 100	about 1.6 mm
× 400	about 0.4 mm

size of one cell ≈ width of the field of view ÷ number of cells across

Example: at × 40, about 20 onion cells fit across the 4.0 mm field of view. 4.0 ÷ 20 = 0.2 mm = **200 µm**.

This is an **estimate**: cells vary in size, and cells at the edge are cut off. Use estimates to check that a calculated answer is sensible.



Which method? Three ways to find a real size

- **The magnification is given:** real size = image size ÷ magnification.
- **The picture has a scale bar:** real size = size on the picture ÷ length of the scale bar × value of the scale bar.
- **You can see the whole field of view:** size of one cell ≈ width of the field of view ÷ number of cells across. This is only an estimate.

11. Standard form

Standard form writes a very large or very small number as a number between 1 and 10 multiplied by a power of 10.

Length	In metres	Standard form
1 mm	0.001 m	1×10^{-3} m
1 µm	0.000 001 m	1×10^{-6} m
1 nm	0.000 000 001 m	1×10^{-9} m
an onion cell, 200 µm	0.0002 m	2×10^{-4} m
a bacterium, 2 µm	0.000 002 m	2×10^{-6} m

- Count how many places the decimal point moves to give a number between 1 and 10. That is the power.
- Small numbers (less than 1) have **negative** powers. Big numbers have positive powers: 2000 = 2×10^{3}.

Watch out: the first number must be between 1 and 10. 25 × 10^{-6} m is not standard form: write 2.5×10^{-5} m.

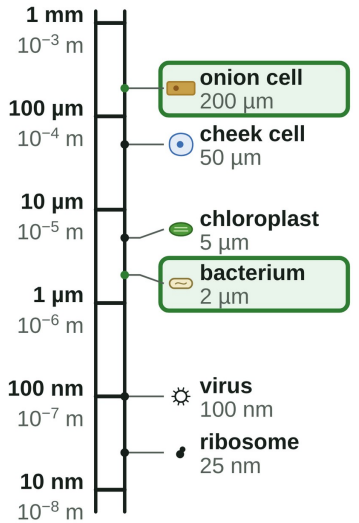
12. Orders of magnitude

An **order of magnitude** is a factor of 10. To compare two sizes:

1. Put them in the same unit.
2. Divide the bigger by the smaller.
3. Write the answer as a power of 10. The power is the number of orders of magnitude.

Example: a plant cell about 100 µm across and a bacterium about 1 µm long. 100 ÷ 1 = 100 = 10^{2}, so the plant cell is **2 orders of magnitude** bigger.

Watch out: two orders of magnitude is 10 × 10 = 100 times, not 20 times.



each rung is 10 times bigger

B1 L4 Revision notes 4 of 4

Magnification and cell size

Key words, exam tips and check yourself

Key words

Estimate: a rough value worked out quickly, using simple numbers.

Field of view: the circle you can see when you look down a microscope.

Image size: the size of an object in a picture or drawing, measured with a ruler.

Light micrograph: a picture of something seen through a light microscope.

Magnification: how many times bigger the image is than the real object.

Micrometre (µm): one thousandth of a millimetre (1 mm = 1000 µm).

Nanometre (nm): one thousandth of a micrometre (1 µm = 1000 nm).

Order of magnitude: a factor of 10; one order of magnitude bigger means about 10 times bigger.

Real size: the actual size of the object, before it was magnified.

Scale bar: a line on a picture that shows a real length, such as 10 µm.

Stain: a dye that colours cells, or parts of cells, so they are easier to see.

Standard form: a way of writing a very large or very small number as a number between 1 and 10 multiplied by a power of 10, such as 2×10^{-6}.

Exam tips

- Learn the equation word for word: magnification = size of image ÷ size of real object.
- Put both sizes in the same unit before you divide, and show your working.
- Magnification has no unit: write × 400. A size always needs a unit: mm, µm or nm.
- Check your answer: the real size is smaller than the image, and a cell is usually 1 to 200 µm.
- With a scale bar, measure the bar and the object with a ruler, in mm.
- In standard form, the first number is between 1 and 10, and a small number has a negative power.

Common mistakes

- **Wrong:** 20 mm ÷ 2 µm, with two different units. **Right:** change both into µm first: 20 000 ÷ 2.
- **Wrong:** real size = image size × magnification. **Right:** real size = image size ÷ magnification.
- **Wrong:** using the label (100 µm) as the length of the scale bar. **Right:** measure the bar with a ruler.
- **Wrong:** 25×10^{-6} m. **Right:** 2.5×10^{-5} m: the first number is between 1 and 10.
- **Wrong:** two orders of magnitude is 20 times. **Right:** it is 10 × 10 = 100 times.

Check yourself

Cover the answers, then check.

1. Change 2.5 mm into µm.
2. Change 750 nm into µm.
3. What does a magnification of × 250 mean?
4. Write the equation for the real size of an object.
5. An image is 18 mm long. The real object is 0.09 mm long. Calculate the magnification.
6. A 5 µm scale bar is 10 mm long. A chloroplast in the same picture is 12 mm long. How long is the real chloroplast?
7. Write 0.0003 m in standard form.
8. One object is 10 000 times bigger than another. How many orders of magnitude bigger is it?

Answers

1. 2.5 × 1000 = 2500 µm.
2. 750 ÷ 1000 = 0.75 µm.
3. The image is 250 times bigger than the real object.
4. real size = image size ÷ magnification.
5. 18 ÷ 0.09 = × 200.
6. 12 ÷ 10 × 5 = 6 µm.
7. 3×10^{-4} m.
8. $10\,000 = 10^4$, so 4 orders of magnitude.

A worked answer: set out every step

A drawing of a cheek cell is 25 mm wide. The magnification is × 500. Find its real width.

1. **real size** = **image size** ÷ **magnification**
2. = 25 ÷ 500 = 0.05 mm
3. 0.05 mm × 1000 = **50 µm**

Check: 50 µm × 500 = 25 000 µm = 25 mm, the size of the drawing.

In the exam, each step can earn a mark, so write every step and give the unit.

B1 L5 Revision notes 1 of 4

Specialised cells and root hair cells

1. What is a specialised cell?

A large organism, such as you or an oak tree, is made of many cells. The cells do not all do the same job. A **specialised cell** is a cell with a structure that suits it to one job. Its shape, and the sub-cellular structures inside it, help it to do that job. A feature that suits a cell to its job is an **adaptation**.

To explain an adaptation, use three parts:

feature → how it helps → job

- **Example:** a root hair cell has a long, thin extension (feature), which gives it a large surface area (how it helps), so it can take in more water and mineral ions from the soil (job).

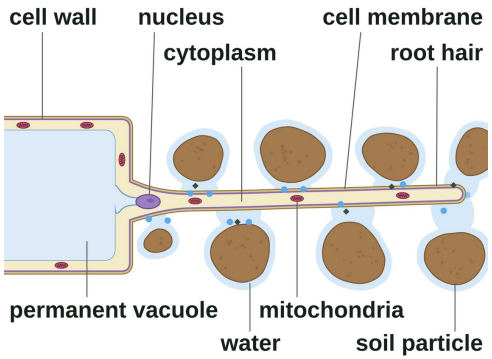
The six specialised cells you need to know, and their jobs, are in the table on page 2 (section 4).

Watch out: a list of features scores few marks. For each feature, say how it helps the cell do its job.

2. Root hair cells

A **root hair cell** is a cell on the surface of a root. Its job is to take in water and mineral ions from the soil.

- A **long, thin extension** (the root hair) reaches out between the soil particles. It gives the cell a large surface area touching the water in the soil, so it takes in more water and mineral ions.
- It has **no chloroplasts**. It grows underground, where there is no light, so it cannot photosynthesise.
- It has **many mitochondria**. They release energy, which the cell uses to take in mineral ions by active transport (B1 L10 Active transport and exchange surfaces).
- Water moves into the root hair cell by **osmosis** (B1 L9 Osmosis).



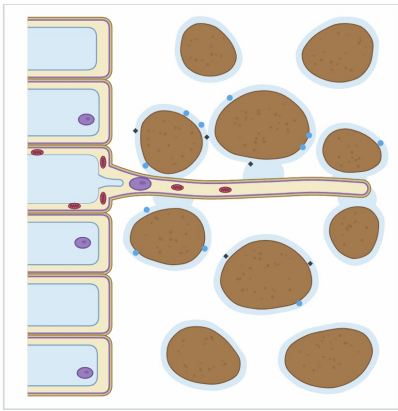
Blue dots = water. Grey diamonds = mineral ions. A diagram is simplified.

Watch out: not every plant cell is green. Root hair cells have no chloroplasts.

3. A real root and a diagram



A real root (painting)



A diagram

Each white hair is part of one root hair cell. Root hair cells have no chloroplasts.

If you look at the root of a young seedling through a hand lens, you see a white fuzz. The fuzz is thousands of **root hairs**. Each root hair is the long, thin extension of one root hair cell. Near the root tip there are no root hairs yet: the new cells there have not become root hair cells.

Exam pictures of a root hair cell are usually **diagrams**. A diagram is simplified on purpose:

- It shows one root hair cell. A real root has thousands of root hairs.
- It shows the whole cell, with its nucleus and vacuole. In the real root, each white hair is only part of one cell.
- It adds colours to show the parts. Real root hairs are white because they have no chloroplasts.
- It draws the cell much bigger than real life. A real root hair is up to about 1 mm long and far thinner than a hair on your head.
- It shows the hair between soil particles. The painted seedling grew on damp paper, so its hairs are easy to see.

Both show the long, thin extension that gives a large surface area for taking in water and mineral ions.

Watch out: a root hair is not a separate hair, and not a whole root. It is part of one root hair cell.

B1 L5 Revision notes 2 of 4

Specialised cells

Sperm, nerve and muscle cells, and the sizes of cells

4. The six specialised cells you need to know

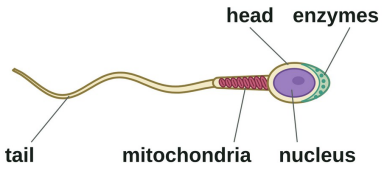
Animal cell	Job
sperm cell	swims to an egg cell and fertilises it
nerve cell	carries electrical impulses from one part of the body to another
muscle cell	contracts (gets shorter) to cause movement

Plant cell	Job
root hair cell	takes in water and mineral ions from the soil
xylem cells	carry water and mineral ions up the plant
phloem cells	carry dissolved sugars up and down the plant

5. Sperm cells

A **sperm cell** is the male sex cell. Its job is to swim to an egg cell and fertilise it.

- A long **tail** lashes from side to side, so the sperm cell can swim to the egg cell.
- **Many mitochondria**, packed just behind the head, release energy for swimming.
- **Enzymes** in the head digest a way through the outer layer of the egg cell.
- The **nucleus** carries half the genetic material of a body cell. It joins with the egg cell's nucleus at fertilisation (B6).

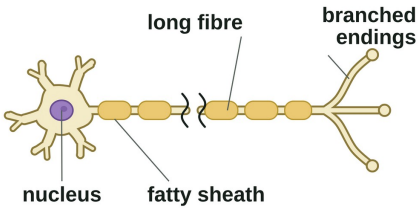


Watch out: mitochondria release energy. Never write that they make or produce energy.

6. Nerve cells

A **nerve cell** is a long cell that carries electrical impulses from one part of the body to another.

- It is **long**, so it can carry impulses a long way.
- **Branched endings** connect with many other cells, so impulses can pass to them.
- A **fatty sheath** insulates the long fibre, so impulses travel quickly.



Nerve cells are also called neurones. How impulses control the body is B5 Homeostasis and response.

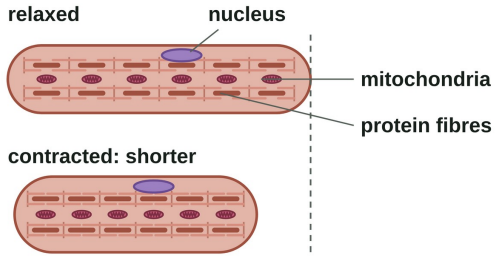
Watch out: nerve cells carry electrical impulses, not blood.

7. Muscle cells

A **muscle cell** is a cell that can contract (get shorter) to cause movement.

- It contains **protein fibres** that slide over each other, so the cell gets shorter.
- It has **many mitochondria**, which release the energy needed to contract.

Many muscle cells working together make muscular tissue (B2 L1 Cells, tissues and organs).



8. Comparing the sizes of cells

Cell	About how big
sperm cell	50 µm long
egg cell	0.1 mm (100 µm) across
root hair	up to 1 mm (1000 µm) long
nerve cell (the longest)	1 m long, from the bottom of the spine to the toes

To compare two sizes, change them into the **same unit** first: 1 mm = 1000 µm.

Worked example: how many times longer is a root hair 0.5 mm long than a sperm cell 50 µm long?

Step 1: change mm into µm: 0.5 × 1000 = 500 µm.

Step 2: divide: 500 ÷ 50 = 10.

Answer: **10 times** longer. Check: 10 × 50 µm = 500 µm = 0.5 mm.

Watch out: change both sizes into the same unit before you divide. mm → µm: multiply by 1000.

B1 L5 Revision notes 3 of 4

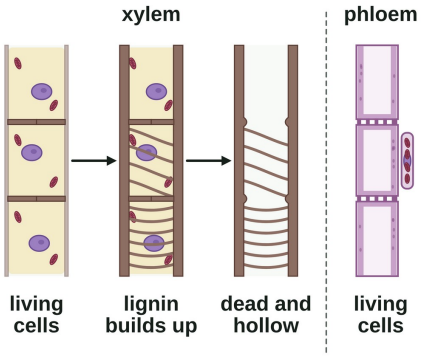
Specialised cells

Xylem and phloem cells, differentiation, and cells you have not met

9. Xylem cells

Xylem carries water and mineral ions from the roots up to the stem and leaves.

- Young xylem cells are living cells joined end to end.
- **Lignin** builds up in their walls, in rings and spirals. It strengthens the walls and helps to support the plant.
- Then the cells **die**. Their cytoplasm, nucleus and end walls break down.
- This leaves long, **hollow tubes** with no end walls, so water and mineral ions flow through with nothing in the way.



In the diagram, brown = xylem and purple = phloem. Real xylem and phloem are pale.

10. Phloem cells

Phloem carries dissolved sugars from the leaves to the rest of the plant, up and down.

- Phloem cells are **living** cells joined end to end in tubes.
- **Pores in the end walls** let cell sap, carrying dissolved sugars, move from one cell to the next.
- They have few sub-cellular structures. Small cells beside them supply the energy they need.

	Xylem cells	Phloem cells
living or dead?	dead	living
end walls	none: hollow tubes	end walls with pores
walls	strengthened with lignin	thin
carry	water and mineral ions	dissolved sugars
which way	up	up and down

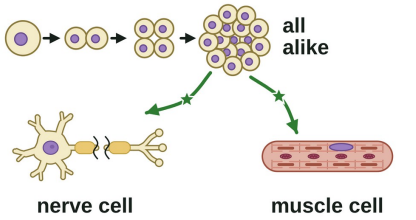
Watch out: the 'cell sap' in phloem is not a vacuole's cell sap (B1 L1 Animal and plant cells).

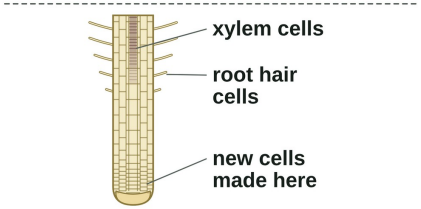
How the whole plant transports water and sugars is B2 L13 Plant transport: xylem and phloem.

11. Differentiation

Differentiation is the process by which a cell becomes specialised, gaining the sub-cellular structures it needs for its job.

- As an organism develops, its cells differentiate into different types of cell.
- **Most animal cells** differentiate at an **early stage**.
- In adult animals, cell division is mainly for **repair and replacement**, such as replacing skin cells.
- **Many plant cells** keep the ability to differentiate **throughout life**. That is why a plant can keep growing new roots, shoots and leaves.





Why it matters: a multicellular organism needs many types of cell to do different jobs. Specialised cells then work together in tissues (B2 L1 Cells, tissues and organs). Stem cells: B1 L7 Stem cells.

Watch out: differentiation is not division. A cell divides by mitosis (B1 L6 Cell division: mitosis) and becomes specialised by differentiating.

12. Answering "Explain how this cell is adapted"

In the exam you may meet a cell you have not studied. You will be given information about it.

Step 1: read the cell's job.

Step 2: find each feature in the picture or the text.

Step 3: for each feature, write feature → how it helps → job.

Model answer (a ciliated cell, which moves mucus away from the lungs): "The cell has tiny hairs called cilia, which beat together to sweep the mucus along, so it is moved away from the lungs. The cell has many mitochondria, which release energy for the cilia to keep beating."

B1 L5 Revision notes 4 of 4

Specialised cells

Key words, exam tips and check yourself

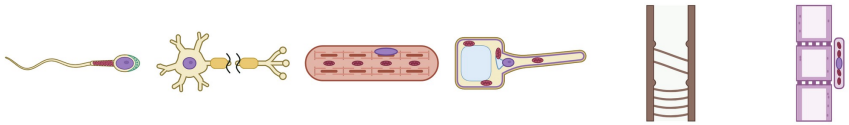
Key words

Adaptation: a feature that suits a cell or an organism to its job or to where it lives.
Differentiation: the process by which a cell becomes specialised, gaining the sub-cellular structures it needs for its job.
Lignin: a tough substance that strengthens the walls of xylem tubes.
Micrometre (µm): one thousandth of a millimetre (1 mm = 1000 µm).
Mineral ions: substances from the soil, such as nitrate, that a plant needs to stay healthy.
Mitochondria (one mitochondrion): the structures in the cytoplasm where aerobic respiration happens, releasing energy for the cell.
Muscle cell: a cell that can contract (get shorter) to cause movement.
Nerve cell: a long cell that carries electrical impulses from one part of the body to another.
Phloem: a plant tissue of tubes of elongated living cells that carries dissolved sugars from the leaves to the rest of the plant.
Root hair cell: a cell on the surface of a root, with a long, thin extension that gives a large surface area for taking in water and mineral ions.
Specialised cell: a cell with a structure that suits it to one job.
Sperm cell: the male sex cell, which swims to an egg cell and fertilises it.
Xylem: a plant tissue of hollow tubes strengthened by lignin that carries water and mineral ions from the roots to the stem and leaves.

Common mistakes

- **Wrong:** "Root hairs are tiny hairs on a root." **Right:** each root hair is part of one root hair cell.
- **Wrong:** "Mitochondria make energy." **Right:** they release energy.
- **Wrong:** "Xylem carries sugars." **Right:** xylem carries water and mineral ions; phloem carries dissolved sugars.
- **Wrong:** "Differentiation is when a cell divides." **Right:** it is when a cell becomes specialised.

The six cells at a glance



sperm cell: swims to an egg
nerve cell: carries impulses
muscle cell: contracts
root hair cell: takes in water
xylem: carries water up
phloem: carries sugars

Check yourself

Cover the answers, then check.

1. Give the job of a phloem cell.
2. How is a root hair cell adapted to take in water?
3. Name three ways a sperm cell is adapted to its job.
4. How does a fatty sheath help a nerve cell?
5. Why do muscle cells need many mitochondria?
6. Why are xylem cells hollow?
7. Describe what happens to a cell when it differentiates.
8. A root hair is 0.5 mm long. How long is it in micrometres?

Answers

1. It carries dissolved sugars up and down the plant.
2. It has a long, thin extension, which gives a large surface area, so it takes in more water.
3. A tail to swim; many mitochondria to release energy for swimming; enzymes in the head to digest a way into the egg cell.
4. It insulates the cell, so impulses travel quickly.
5. To release the energy the cell needs to contract.
6. The cells are dead, and their cytoplasm, nucleus and end walls have broken down, so water and mineral ions flow through with nothing in the way.
7. It becomes specialised: it gains the sub-cellular structures it needs for its job.
8. 0.5 × 1000 = 500 µm.

Exam tips

- Learn the job of each of the six cells and two or three features of each.
- For "explain how this cell is adapted", write feature → how it helps → job for each feature.
- With a cell you have not met, use the information given. Many mitochondria means energy is released for something: say what.
- Energy is **released** by respiration in mitochondria. Never write that energy is "made".
- Xylem: dead, hollow, lignin, water and mineral ions. Phloem: living, pores in end walls, dissolved sugars.
- In size questions, change both sizes into the same unit first, show your working and give the unit.

B1 L6 Revision notes 1 of 4

Cell division: mitosis

Why cells divide, chromosomes, DNA and genes, and a real root tip

1. Why cells divide

A **multicellular organism**, such as a human or a tree, is made of many cells. You started as one cell. To grow, an organism needs more cells, so its cells divide to make new cells. New body cells are made by mitosis.

Cells divide for:

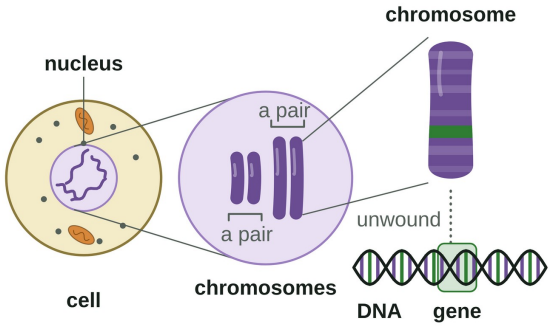
- **growth and development**: making a bigger organism, such as a root growing longer;
- **repair**: mending damage, such as a cut in the skin;
- **replacement**: replacing cells that wear out, such as skin cells that rub off.

Before a cell divides, it copies its genetic material, so that each new cell gets a full set (section 6).

2. Chromosomes, DNA and genes

The **nucleus** of a cell contains **chromosomes**. A chromosome is made of one very long, coiled molecule of **DNA**, the chemical that carries the genetic instructions for a cell. Each chromosome carries a large number of **genes**. A gene is a small section of DNA on a chromosome.

In body cells, chromosomes are normally found in **pairs**.



A diagram is simplified: this model cell has only 4 chromosomes. A human body cell has 46.

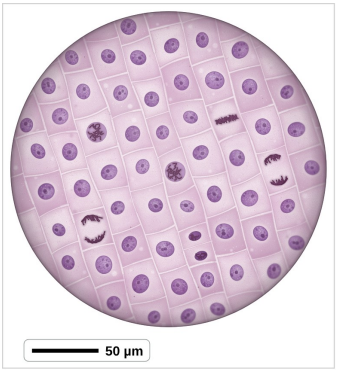
Cell	Chromosomes	Pairs
a human body cell	46	23
an onion cell	16	8
the model cell in diagrams	4	2

Watch out: a gene is not a whole chromosome. It is a small section of the DNA in a chromosome. From smallest to largest: gene, chromosome, nucleus, cell.

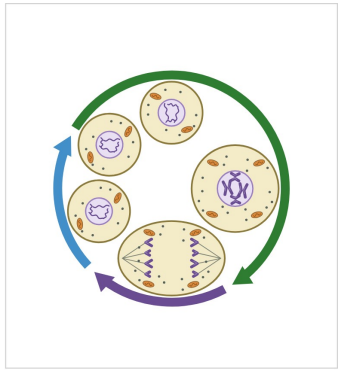
3. A real root tip and a diagram

A painting based on a light micrograph. Stains colour the chromosomes; most cells are not dividing.

Both show cells with one round nucleus, and dividing cells with one set of chromosomes pulled to each end.



A real root tip (painting)



A diagram

Roots grow at their tips, so this is where cells divide. To see them, a thin root tip is squashed on a slide and **stained**, then looked at with a light microscope (B1 L3 Using a microscope). A picture of what you see is a **light micrograph**.

Exam pictures of the cell cycle are usually **diagrams**. A diagram is simplified on purpose:

- Most real cells are not dividing: many are growing and copying their DNA, ready to divide. The diagram gives every stage its own picture.
- In real cells, chromosomes show as separate threads only when a cell divides. The diagram draws them in every cell.
- A real onion cell has 16 chromosomes. The diagram cell has only 4 (2 pairs), so they are easy to count.
- The purple is a stain: real chromosomes are colourless. The diagram colours them so you can see them.
- Real cells are packed together in rows, sharing their walls. The diagram draws one cell on its own.

Watch out: chromosomes are in the nucleus all the time. Between divisions they are long, thin threads, so you cannot see them one by one. When a cell divides, they coil up, short and thick, and show up.

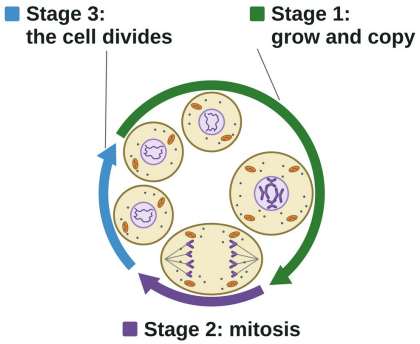
B1 L6 Revision notes 2 of 4

Cell division: mitosis

The cell cycle, mitosis and two identical cells

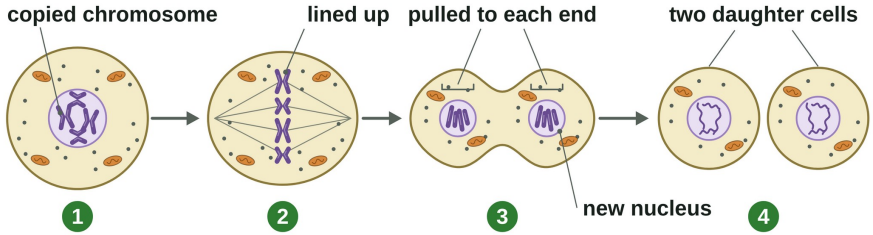
4. The cell cycle

Stage	What happens
Stage 1: grow and copy	The cell grows and makes more sub-cellular structures, such as ribosomes and mitochondria. The DNA replicates to form two copies of each chromosome.
Stage 2: mitosis	One set of chromosomes is pulled to each end of the cell, and the nucleus divides.
Stage 3: the cell divides	The cytoplasm and cell membrane divide to form two identical cells.



Cells divide in a series of stages called the **cell cycle**. A human cell cycle takes about 24 hours. Mitosis takes only about 1 hour of it: most of the time, a cell is growing and copying its DNA.

5. Mitosis step by step



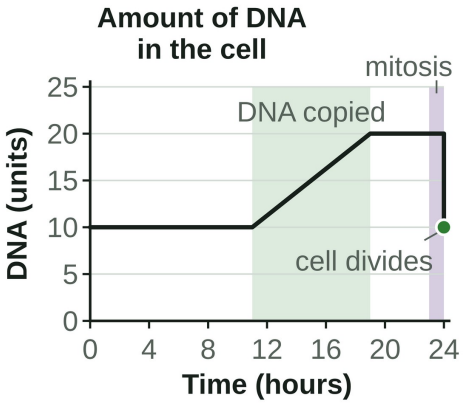
1. Each chromosome has been copied. The two copies are joined together.
2. The chromosomes line up across the middle of the cell.
3. The copies are pulled apart: one set of chromosomes goes to each end of the cell. A new nucleus forms round each set, so the nucleus has divided.
4. The cytoplasm and cell membrane divide. There are now two daughter cells.

You do not need the names of the phases of mitosis. Describe what the chromosomes do.

6. Two genetically identical cells

During the cell cycle the genetic material is **doubled** and then **divided** into two identical cells:

- In stage 1, the DNA is copied, so the amount of DNA in the cell doubles.
- In mitosis, one copy of every chromosome goes to each end of the cell.
- When the cell divides, each daughter cell has the starting amount of DNA again.



So the two **daughter cells** are **genetically identical**: they have exactly the same genetic material as each other and as the parent cell. They have the same number of chromosomes as the parent cell. A human body cell with 46 chromosomes makes two daughter cells with 46 each.

Watch out: mitosis is only stage 2, when the nucleus divides. The DNA is copied before mitosis, in stage 1, while the cell grows.

Watch out: mitosis makes two cells, not four. Each new cell has 46 chromosomes, not 23. Halving the number happens only when sex cells are made, by a different division, meiosis (B6 Inheritance, variation and evolution).

Watch out: a pair is two matching chromosomes of the same size (why they come in pairs is B6). The two copies made when the DNA is copied are not a pair: they are exact copies, and mitosis shares them out, one to each new cell.

B1 L6 Revision notes 3 of 4

Cell division: mitosis

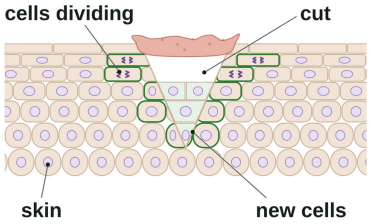
Growth, repair and replacement, and the maths

7. Where does mitosis happen?

Cell division by mitosis is important in the **growth and development** of multicellular organisms. It is also used for **repair** and **replacement**.

In adult animals, most mitosis is for repair and replacement. Plants keep growing at their root and shoot tips all their lives.

Not mitosis: making sex cells (sperm and egg cells are made by meiosis, B6); a bacterium splitting into two (it has no nucleus, B1 L2 Bacterial cells).



Job	Example	Which cells divide
growth and development	a root growing longer; a young tree growing taller; one cell growing into a ball of cells	cells at the root and shoot tips; every cell in the ball
repair	a cut in the skin healing; a lizard regrowing its tail	cells beside the cut; cells at the end of the tail
replacement	replacing skin cells that rub off	cells deep in the skin

Some organisms reproduce using mitosis: asexual reproduction (B6). Cells that divide to make new cells for growth and repair: B1 L7 Stem cells. Changes in cells that lead to uncontrolled division can cause a tumour (B2 L11 Health, risk factors and cancer).

Spot it: in a question, look for an organism that is growing, repairing damage or replacing cells. That is where mitosis is happening.

8. Doubling

If every cell divides once in each round, the number of cells doubles: 1 → 2 → 4 → 8 → 16.

after n rounds, number of cells = 2^n

Rounds	0	1	2	3	4	5	10
Cells	1	2	4	8	16	32	1024

Worked example: a cell divides by mitosis every 24 hours, and every new cell does the same. How many cells are there after 10 days, starting from one cell?

Step 1: 10 days = 10 rounds of division.

Step 2: $2^{10} = 2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2 = 1024$.

Answer: **1024 cells**, about 1×10^3 in standard form (B1 L4 Magnification and cell size).

9. Counting dividing cells

Scientists count the dividing cells in a stained root tip to find where the root grows fastest. Close to the tip, many cells are dividing; further back, cells stop dividing, get longer and become specialised.

percentage of cells dividing = cells dividing ÷ total cells × 100

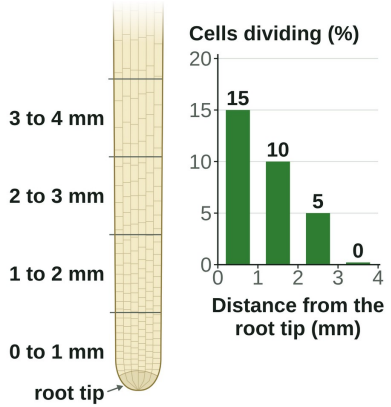
Worked example: 9 of 180 cells in a root tip are dividing. What percentage of the cells are dividing?

Step 1: 9 ÷ 180 = 0.05.

Step 2: 0.05 × 100 = 5 %.

Answer: **5 %**.

Check: 5 % of 180 = 180 ÷ 100 × 5 = 9. ✓



Watch out: divide the number of cells dividing by the total, not the other way round, and multiply by 100. A percentage of cells can never be more than 100 %.

Time in a stage (stretch): the more cells you see in a stage, the longer that stage lasts.

time in mitosis = (cells in mitosis ÷ total cells) × time for one cell cycle

For example, 10 of 240 cells are in mitosis, and the cycle takes 24 hours: 10 ÷ 240 × 24 = 1 hour.

10. Answering cell cycle questions

Give the stages in order, and use the key words: grows, sub-cellular structures, the DNA replicates (is copied), one set of chromosomes pulled to each end, the nucleus divides, the cytoplasm and cell membrane divide, two genetically identical cells.

- Question: "Explain why a cell must copy its DNA before it divides."
- Model answer: "So that each daughter cell gets a full set of chromosomes. The DNA replicates to form two copies of each chromosome. In mitosis, one copy of each chromosome goes to each end of the cell. If the DNA were not copied, each new cell would get only some of the chromosomes."
- "The chromosomes split" or "the cell splits into four" scores nothing: say one set of chromosomes is pulled to each end, and two cells are made.

B1 L6 Revision notes 4 of 4

Cell division: mitosis

Key words, exam tips and check yourself

Key words

Cell cycle: the series of stages in which a cell grows, copies its DNA and divides into two identical cells.

Chromosome: a structure in the nucleus, made of DNA, that carries a large number of genes.

Daughter cells: the two new cells made when a cell divides.

DNA: the chemical that carries the genetic instructions for a cell.

Gene: a small section of DNA on a chromosome.

Genetically identical: having exactly the same genetic material.

Light micrograph: a picture of something seen through a light microscope.

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.

Multicellular organism: an organism made of many cells, such as a human or a tree.

Nucleus: the part of a cell that contains the genetic material, which controls the activities of the cell.

Stain: a dye that colours cells, or parts of cells, so they are easier to see.

Sub-cellular structure: a part inside a cell that has a particular job, such as the nucleus or a mitochondrion.

Exam tips

- Learn the three stages in order: grow and copy the DNA; mitosis; the cytoplasm and cell membrane divide.
- Mitosis is the stage when one set of chromosomes is pulled to each end and the nucleus divides.
- Say "two genetically identical cells", and give the chromosome number: 46 → 46.
- Do not use the phase names: describe what the chromosomes do.
- In percentage questions, write the formula, show your working and check the answer is sensible.
- Energy is **released** by respiration in mitochondria. Never write that energy is "made".

Check yourself

Cover the answers, then check.

1. What is a chromosome made of, and what does it carry?
2. How many chromosomes are in a human body cell, and how are they arranged?
3. Name the three stages of the cell cycle.
4. What happens to the number of sub-cellular structures in stage 1?
5. Describe what happens in mitosis.
6. Why are the two daughter cells genetically identical?
7. Give three reasons why cells divide by mitosis.
8. One cell divides by mitosis. In each round, every cell divides once. How many cells are there after 6 rounds?

Answers

1. DNA. It carries a large number of genes.
2. 46, in 23 pairs.
3. Stage 1: the cell grows and copies its DNA. Stage 2: mitosis. Stage 3: the cytoplasm and cell membrane divide.
4. It increases: the cell makes more of them, such as ribosomes and mitochondria.
5. One set of chromosomes is pulled to each end of the cell, and the nucleus divides.
6. The DNA is copied, and each daughter cell gets one copy of every chromosome.
7. Growth (and development), repair and replacement.
8. $2^6 = 64$ cells.

Common mistakes

- **Wrong:** "Mitosis makes four cells." **Right:** mitosis makes two cells.
- **Wrong:** "Each new cell has 23 chromosomes." **Right:** it has 46, the same as the parent cell.
- **Wrong:** "The DNA is copied during mitosis." **Right:** it is copied before, in stage 1.
- **Wrong:** "Chromosomes appear when a cell divides." **Right:** they are there all the time; they only show up then.

B1 L7 Revision notes 1 of 4

Stem cells

What stem cells are: real stem cells and a diagram, divide and differentiate

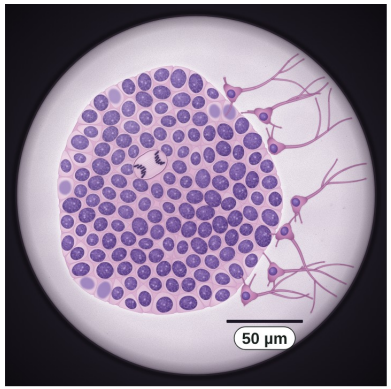
1. What is a stem cell?

A **stem cell** is an undifferentiated cell that can divide to make many more cells of the same type, and can differentiate into certain other types of cell.

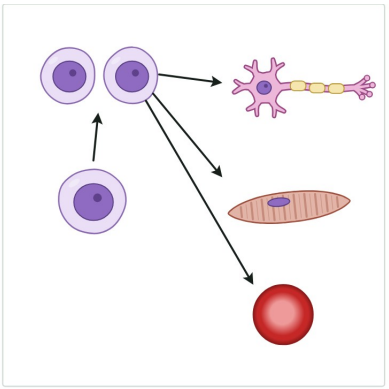
- **Undifferentiated** means not yet specialised for a particular job.
- **Differentiation** is the process by which a cell becomes specialised, gaining the sub-cellular structures it needs for its job.

Watch out: a stem cell is not a "special" cell. It is the opposite: it has not specialised yet.

2. Real stem cells and a diagram



Stem cells in a dish (a painting)



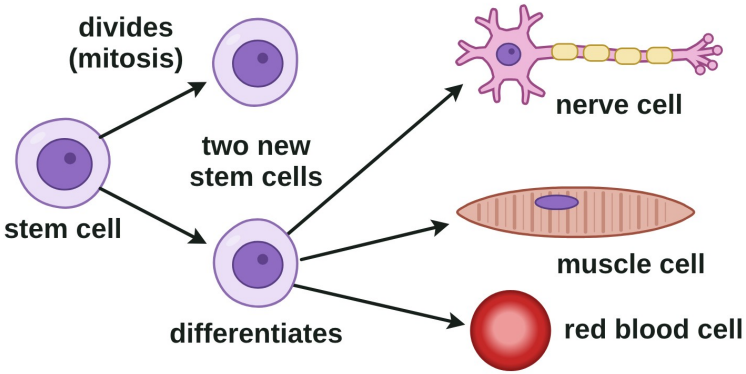
A diagram

A painting based on a light micrograph. Stains colour the cells.

- Real stem cells look plain and alike, and they grow packed together in a colony.
- They are tiny: about 10 µm across.
- The painting's colours are stains. In a diagram, colours only show the types of cell.

Stem cells look plain: they have not yet developed the structures of a specialised cell.

3. Divide and differentiate



- A stem cell divides by **mitosis** to make two genetically identical stem cells.
- Some new cells stay as stem cells, so there is always a supply.
- Others differentiate into specialised cells, such as nerve cells, muscle cells and red blood cells.

Watch out: division makes more cells; differentiation changes what a cell can do. A stem cell does not "divide into a nerve cell".

4. Stem cells in a growing organism

- In an **embryo**, stem cells make all the cells of the body as it grows.
- In an **adult**, stem cells repair the body and replace cells that wear out.
- In a **plant**, stem cells in the meristems make new cells so the plant can grow all through its life.

Most animal cells lose the ability to differentiate early. Many plant cells keep it.

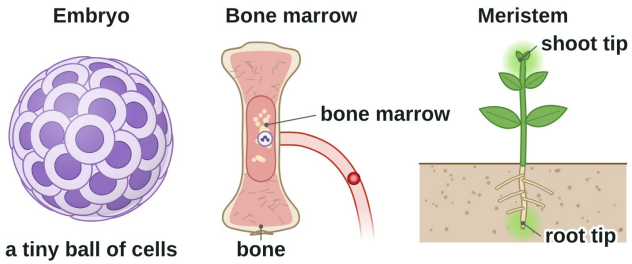
B1 L7 Revision notes 2 of 4

Stem cells

Where stem cells come from: embryos, bone marrow and meristems; cloning plants

5. Three sources of stem cells

Stem cells from embryos can be cloned (grown into many identical cells) and made to differentiate into most types of human cell.



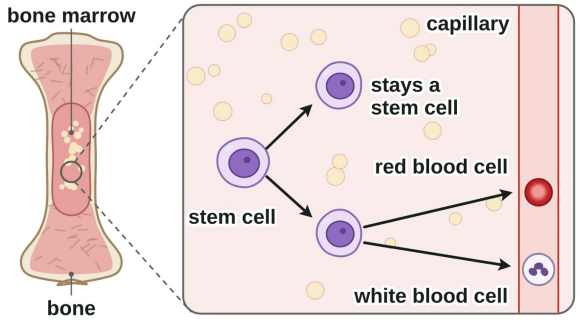
Source	Where	What the stem cells can become
Embryo	an early embryo: a tiny ball of cells	**most** types of human cell
Adult bone marrow	the soft tissue inside some bones	**many** types of cell, including blood cells
Plant meristem	the tips of roots and shoots	**any** type of plant cell, throughout the life of the plant

Watch out: most (embryo), many (adult bone marrow), any (meristem). Adult stem cells form fewer types of cell than embryonic stem cells.

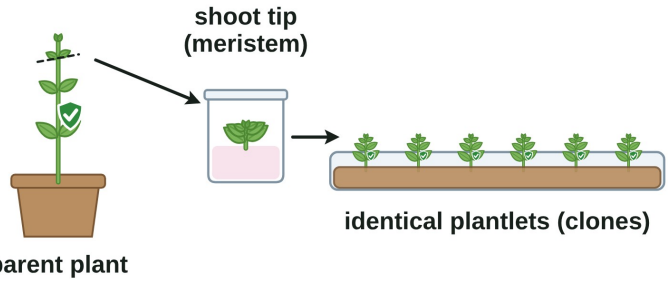
6. Bone marrow makes new blood cells

Stem cells in the **bone marrow** divide all the time. Some new cells become red blood cells or white blood cells.

A bone marrow transplant from a donor already helps people with some blood disorders, such as leukaemia.



7. Cloning plants from meristems



A **clone** is a genetically identical copy of a cell or an organism. Meristem cells can be used to clone plants quickly and economically.

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

Watch out: clones have no variation. If a new disease can attack one plant, it can attack them all.

8. Maths: percentages from a table

percentage = number with the feature ÷ total number × 100

Worked example: 400 plants are grown from seed. 200 have a useful feature. 200 ÷ 400 × 100 = **50 %**.

Clones from a plant with the feature: all of them have it (100 %).

B1 L7 Revision notes 3 of 4

Stem cells

Using stem cells: medicine, therapeutic cloning, risks, and ethical and religious issues

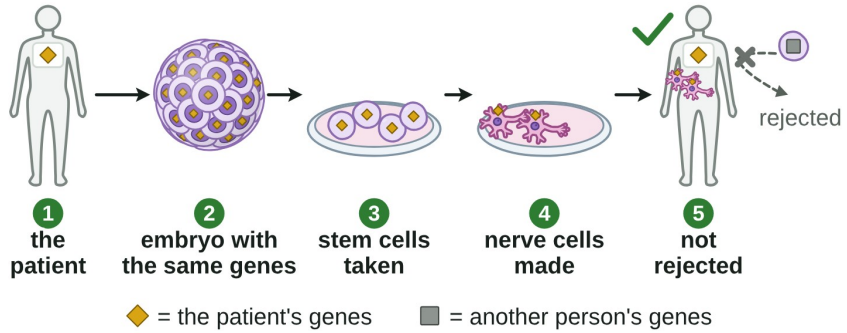
9. Stem cells in medicine

Condition	How stem cells might help	Now?
Blood disorders, such as leukaemia	new blood cells from donated bone marrow stem cells	**used now**
Diabetes	new cells that make insulin	being researched
Paralysis	new nerve cells to repair damaged nerves	being researched

Watch out: write "may be able to help". Most stem cell treatments are not yet cures.

10. Therapeutic cloning

Therapeutic cloning is producing an embryo with the same genes as the patient, so that its stem cells are not rejected by the patient's body.



The stem cells are made to differentiate into the cells the patient needs.

Watch out: the embryo is grown only for its stem cells, never to make a baby. The cells are not rejected because they have the same genes as the patient, not because they are stem cells.

11. Risks

- A virus (viral infection) could be passed on with the cells.
- The cells might divide out of control and form a tumour.
- The treatments are new, so long-term effects are not yet known.

12. Ethical and religious issues

An **ethical issue** is a question about whether something is morally right or wrong.

- Taking stem cells from an embryo destroys the embryo.
- Some people, including some religious groups, believe an early embryo should have the same right to life as a person.
- Others think helping patients matters more, especially when spare embryos from fertility treatment would not be used anyway.
- In the UK, research embryos are usually spare embryos from fertility treatment, given with consent; the law allows research only up to 14 days.

13. How to evaluate

1. Give the **benefits**: for example, stem cells may help people with diabetes or paralysis, and cells made by therapeutic cloning are not rejected.
2. Give the **risks**.
3. Give the **ethical issues**, both sides.
4. Then give your own **conclusion** with a reason.

There is no single right answer. People reach different views. In an exam, give both sides, then your own reasoned view.

Watch out: a risk is something that could go wrong, such as a virus being passed on. An ethical issue is about right and wrong, such as destroying an embryo. Do not give one as the other.

Questions or worries about anything here? Talk to a trusted adult. The NHS website has reliable information about stem cells and donating bone marrow.

B1 L7 Revision notes 4 of 4

Stem cells

Key words, exam tips and check yourself

Key words

Adult stem cell: a stem cell found in adult tissue, such as bone marrow, which can form many types of cell, including blood cells.

Bone marrow: the soft tissue inside some bones, where blood cells are made.

Clone: a genetically identical copy of a cell or an organism.

Differentiation: the process by which a cell becomes specialised, gaining the sub-cellular structures it needs for its job.

Embryo: an organism at its earliest stage of development; an early human embryo is a tiny ball of cells.

Embryonic stem cell: a stem cell from an early embryo, which can differentiate into most types of human cell.

Ethical issue: a question about whether something is morally right or wrong.

Genetically identical: having exactly the same genetic material.

Meristem: tissue at the growing tips of shoots and roots, where cells divide to make new cells.

Specialised cell: a cell with a structure that suits it to one job.

Stem cell: an undifferentiated cell that can divide to make many more cells of the same type, and can differentiate into certain other types of cell.

Therapeutic cloning: producing an embryo with the same genes as the patient, so that its stem cells are not rejected by the patient's body.

Undifferentiated: not yet specialised for a particular job.

Exam tips

- Learn the definition: a stem cell is undifferentiated, and it can divide and differentiate.
- Most, many, any: embryonic stem cells, most types of human cell; adult bone marrow stem cells, many types, including blood cells; meristem cells, any type of plant cell, all through the plant's life.
- Write "may be able to help", not "cures". Bone marrow transplants are the treatment used now.
- Therapeutic cloning: write both parts: same genes as the patient, so not rejected.
- "Evaluate" means benefits, risks and ethical issues (both sides), then a conclusion with a reason.
- For a percentage, write number ÷ total × 100, and show your working.

Check yourself

Cover the answers, then check.

1. What does "undifferentiated" mean?
2. Name the two processes that turn one stem cell into many specialised cells.
3. Name two sources of human stem cells.
4. Meristem cells can differentiate into which types of plant cell, and for how long?
5. Give two conditions that stem cells may be able to help.
6. In therapeutic cloning, how do the embryo's genes compare with the patient's genes?
7. Give one ethical or religious objection to using embryonic stem cells.
8. In a group of 300 plants grown from seed, 45 have a useful feature. Calculate the percentage.

Answers

1. Not yet specialised for a particular job.
2. Division (by mitosis) and differentiation.
3. Early embryos and adult bone marrow.
4. Any type of plant cell, throughout the life of the plant.
5. Diabetes and paralysis.
6. They are the same.
7. Taking the stem cells destroys the embryo; some people believe an early embryo should have the same right to life as a person.
8. 45 ÷ 300 × 100 = 15 %.

B1 L8 Revision notes 1 of 4

Diffusion

Diffusion, a real beaker and a particle diagram, random movement

1. What diffusion is

Drop a crystal of purple **potassium manganate(VII)** into a beaker of **still water**. It dissolves, and the purple slowly spreads out through the water on its own. Nobody stirs it.

The purple colour shows where the purple **particles** are. Where the colour is dark, there are lots of particles in a small volume: a **high concentration**. **Concentration** is the amount of a substance in a given volume.

Diffusion is the net movement of particles from an area of higher concentration to an area of lower concentration.

- Diffusion happens in **solutions** (a substance dissolved in a liquid) and in **gases**. A smell spreading across a room is diffusion in a gas.
- Diffusion does not need energy from respiration. The particles move on their own.
- Substances move into and out of cells across the **cell membrane** by diffusion (B1 L1: the cell membrane controls the movement of substances into and out of the cell).

Watch out: diffusion happens in gases **and** in solutions. Water crossing a cell membrane is a special case of diffusion, called **osmosis** (B1 L9 Osmosis).

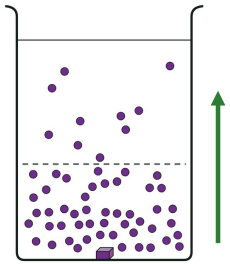
2. A real beaker and a particle diagram

Exam questions use **particle diagrams**. A particle diagram is a model, simplified on purpose:

- **Particles:** real particles are far too small to see, even with a light microscope. The diagram draws each one as a dot.
- **No line:** in the beaker the colour fades gradually. The diagram may draw a dashed line to split the water into two areas. The line is not a barrier.
- **How many:** a beaker holds billions of billions of particles. A diagram draws a few dozen.



A real beaker



A particle diagram

Particles are far too small to see: the dots in the diagram are a model. The purple colour shows where the particles are.

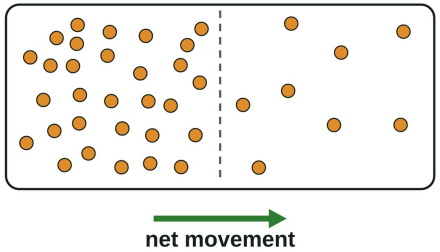
- **Movement:** each real particle moves at random. The arrow in a diagram shows only the net movement.
- **3D:** the real colour spreads in every direction. A diagram is flat.

Both show the same science: a higher concentration at the bottom and a net movement upwards.

3. Particles move at random

- Particles in a liquid or a gas are always moving, at **random**, in all directions.
- They cross from one area to the other **both ways**.
- There are more particles in the crowded area, so more of them move out of it than move into it.
- **Net movement** is the overall movement in one direction, after taking away the movement the other way.

Worked example: in one second, 30 particles cross from the left to the right and 8 cross back. The net movement is 30 − 8 = **22 particles to the right**.



Each dot is a particle. Real particles are far too small to see.

A **concentration gradient** is the difference in concentration between two areas. A bigger, or steeper, concentration gradient (a bigger difference in concentration) gives a faster net movement.

Watch out: particles do not "want" to spread out, and they do not all move one way. They move at random. Diffusion is a **net** movement.

4. Evenly spread: no net movement

As the particles spread out, the difference in concentration gets smaller, so the net movement slows down.

When the particles are **evenly spread**, they **keep moving**. The same number cross each way, so the concentration stays the same everywhere. There is **no net movement**.

This is why the purple beaker ends up an even pale purple, not clear.

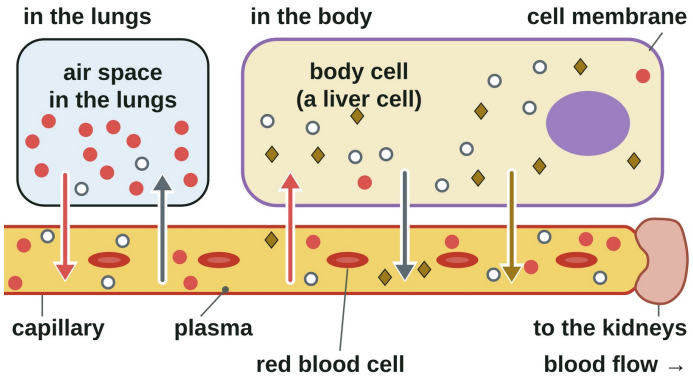
Watch out: evenly spread particles do **not** stop moving. Only the net movement stops.

B1 L8 Revision notes 2 of 4

Diffusion

Diffusion in the body, urea, keeping the gradient steep

5. Diffusion into and out of cells



(the blood goes through the heart: B2 L6 The heart and circulation)

● oxygen ○ carbon dioxide ◆ urea. A diagram is simplified. Real particles are far too small to see.

Substance	Diffuses from	Diffuses to	Why
oxygen	the air in the lungs	the blood	there is more oxygen in the air
oxygen	the blood	respiring body cells	cells use oxygen in respiration
carbon dioxide	respiring body cells	the blood (then out in the lungs)	cells make carbon dioxide in respiration
urea	cells (mostly liver cells)	the blood plasma	cells make urea as a waste product

Each substance diffuses from where **its** concentration is higher to where it is lower. Several substances can diffuse across the same membrane at the same time, in different directions.

Respiration is a chemical reaction in every living cell that releases energy. It uses oxygen and makes carbon dioxide (B4 Bioenergetics).

Watch out: water crossing a partially permeable membrane, such as a cell membrane, is a special case of diffusion called **osmosis** (B1 L9 Osmosis).

6. Urea and excretion

Urea is a waste product that diffuses from cells into the blood plasma and is removed from the body by the kidneys. Most urea is made in liver cells.

- **Plasma** is the pale yellow liquid part of the blood, which carries blood cells and dissolved substances.
- The blood carries the urea to the **kidneys**. The kidneys remove it from the blood, in **urine**.
- **Excretion** is the removal of waste products made in the body.

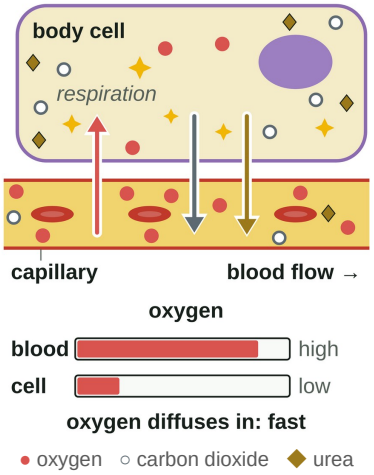
If the kidneys stopped removing urea, it would build up in the blood. The difference in concentration between the cells and the blood would get smaller, so urea would diffuse out of the cells more slowly.

7. Keeping the gradient steep

Diffusion stays fast only while the concentration gradient stays steep. In the body:

- Cells **use oxygen** in respiration all the time, so the oxygen concentration inside them stays low.
- **Flowing blood** keeps bringing oxygen, so the oxygen concentration in the blood stays high.
- Flowing blood **carries away** carbon dioxide and urea, so their concentration next to the cells stays low.
- The heart keeps the blood moving (B2 L6 The heart and circulation).

If the blood stopped flowing, the difference in concentration would shrink and diffusion would slow down.



Watch out: diffusion needs **no** energy from respiration. Respiration only keeps the gradient steep, by using oxygen. Energy is **released** by respiration; never write that it is "made".

B1 L8 Revision notes 3 of 4

Diffusion

The rate of diffusion

8. Four factors that affect the rate of diffusion

AQA lists three factors: the difference in concentration (concentration gradient), the temperature, the surface area of the membrane. The distance is a fourth. A bigger concentration gradient, a higher temperature, a larger surface area and a shorter distance each make diffusion faster.

Factor	Diffusion is faster when ...	Why
concentration gradient	the difference in concentration is bigger (a steeper gradient)	more particles move out of the crowded area than move back
temperature	the temperature is higher	the particles have more energy and move faster
surface area of the membrane	the surface area is larger	more particles can cross at the same time
distance	the distance is shorter (a thin membrane)	the particles have less far to go

Exchange surfaces in the body, such as the alveoli in the lungs, have a large surface area and a thin membrane: B1 L10 Active transport and exchange surfaces explains them.

Watch out: when they are heated, particles do **not** expand or get bigger. They have more energy and move faster.

9. Measuring the rate of diffusion

A coloured dye spreads into clear **agar jelly**. Jelly is still, so there are no currents: the dye moves only by diffusion.

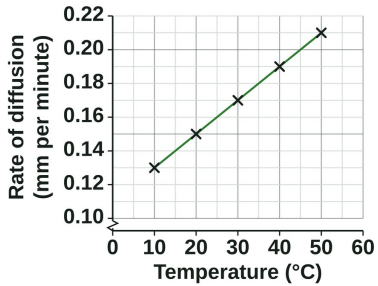
1. Half-fill five test tubes with agar jelly.
2. Stand them in water baths at 10, 20, 30, 40 and 50 °C.
3. Add the same volume of the same dye on top of each.
4. After 60 minutes, measure how far the colour has moved down, with a ruler (mm).

- **Independent variable:** the temperature. **Dependent variable:** the distance the dye moves (or the rate).
- **Control variables:** the same dye, the same concentration and volume of dye, the same jelly, the same size of tube, the same time.
- Safety: wear eye protection; take care with hot water.

10. Maths skills: the rate of diffusion

rate of diffusion = distance ÷ time

Temperature (°C)	Distance moved in 60 minutes (mm)	Rate of diffusion (mm/min)
10	7.8	0.13
20	9.0	0.15
30	10.2	0.17
40	11.4	0.19
50	12.6	0.21



Reading the graph: go up from 35 °C to the line, then across: the rate is about 0.18 mm per minute.

Worked example 1: a dye moves 8.4 mm in 35 minutes.

- Rate = 8.4 ÷ 35 = **0.24 mm per minute**. Check: 0.24 × 35 = 8.4 mm.

Worked example 2 (change the units first): a dye moves 1.1 cm in 1 hour 40 minutes.

- 1.1 cm = 11 mm (1 cm = 10 mm). 1 hour 40 minutes = 100 minutes (1 hour = 60 minutes).
- Rate = 11 ÷ 100 = **0.11 mm per minute**.

Always show your working and give the unit (mm per minute).

This is a **mean** (average) rate. The dye slows down as it spreads further, because the difference in concentration gets smaller.

11. Apply it: muscles during exercise

During exercise, muscle cells **respire faster**:

- They use oxygen faster, so the oxygen inside them falls lower. The oxygen gradient is steeper, so oxygen diffuses in faster.
- They make more carbon dioxide, so it builds up inside them. The carbon dioxide gradient is steeper, so it diffuses out faster.
- Working muscles get a little warmer (about 39 °C), so the particles move faster.

B1 L8 Revision notes 4 of 4

Diffusion

Key words, exam tips and check yourself

Key words

Cell membrane: a thin layer around the cell that controls the movement of substances into and out of the cell.

Concentration: the amount of a substance in a given volume.

Concentration gradient: the difference in concentration between two areas.

Diffusion: the net movement of particles from an area of higher concentration to an area of lower concentration.

Excretion: the removal of waste products made in the body.

Net movement: the overall movement in one direction, after taking away the movement the other way.

Particle: a tiny piece of a substance, far too small to see.

Plasma: the pale yellow liquid part of the blood, which carries blood cells and dissolved substances.

Rate of diffusion: how quickly diffusion happens, such as the distance a substance spreads in one minute.

Respiration: a chemical reaction in every living cell that releases energy.

Urea: a waste product that diffuses from cells into the blood plasma and is removed from the body by the kidneys.

Exam tips

- Write "net movement" and "from a higher concentration to a lower concentration": never just "from high to low".
- Say what moves and where: "oxygen diffuses from the blood into the cell".
- Particles move at random. Never write that they "want" to spread out. Diffusion needs no energy from respiration.
- Temperature: "the particles have more energy and move faster". Never "the particles expand".
- A steeper concentration gradient means a bigger difference in concentration.
- Rate = distance ÷ time. Change cm to mm and hours to minutes first, and give the unit.

Check yourself

Cover the answers, then check.

1. Write the definition of diffusion.
2. Diffusion happens in gases. Where else does it happen?
3. What is a concentration gradient?
4. Particles are evenly spread. Are they still moving? Is there a net movement?
5. Does diffusion need energy from respiration?
6. Name three substances that diffuse into or out of cells in the body.
7. Give the four factors that affect the rate of diffusion.
8. A dye moves 5.6 mm in 20 minutes. Calculate the rate of diffusion.

Answers

1. The net movement of particles from an area of higher concentration to an area of lower concentration.
2. In solutions (substances dissolved in a liquid).
3. The difference in concentration between two areas.
4. Yes, they keep moving. No, there is no net movement.
5. No. The particles move on their own, at random, using their own (kinetic) energy.
6. Oxygen, carbon dioxide and urea.
7. The difference in concentration (concentration gradient), the temperature, the surface area of the membrane, and the distance.
8. 5.6 ÷ 20 = 0.28 mm per minute.

B1 L9 Revision notes 1 of 4

Osmosis

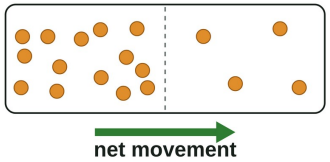
Osmosis, partially permeable membranes, and real cells beside a diagram

1. What osmosis is

In B1 L8 Diffusion you met **diffusion**: the net movement of particles from an area of higher concentration to an area of lower concentration.

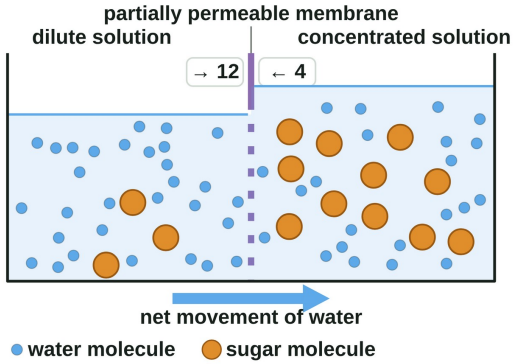
Osmosis is a special case of diffusion. It is the diffusion of **water** from a **dilute solution** to a **concentrated solution** through a **partially permeable membrane**.

Water moves into and out of every cell by osmosis, across the **cell membrane**.



2. Partially permeable membranes

- A **partially permeable membrane** lets small molecules, such as water, pass through, but not larger ones, such as sugar.
- The cell membrane is partially permeable. The **cell wall** is not: it lets water and dissolved substances through.
- Water molecules move all the time, in every direction. They cross the membrane **both ways**.
- More water molecules cross from the dilute side, because there are more of them there to hit the membrane. So there is a **net movement** of water into the more concentrated solution.
- Osmosis needs **no energy** from respiration. (Active transport does: B1 L10 Active transport and exchange surfaces.)



A model: blue dots = water molecules, orange dots = sugar molecules. Real molecules are far too small to see.

Watch out: only **water** moves by osmosis. Sugar and salt do not move by osmosis: the membrane stops them.

3. Dilute and concentrated solutions

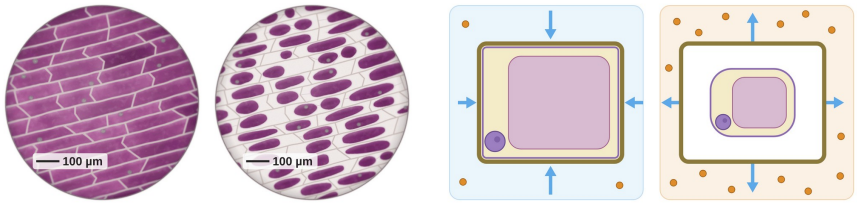
A **solution** is made when a **solute**, such as sugar or salt, dissolves in a liquid, such as water.

	Dilute solution	Concentrated solution
Solute	a little	a lot
Concentration of water	high	low
Water moves by osmosis (across a partially permeable membrane between them)	out of it	into it

Pure water has no solute, so it has the highest concentration of water.

Watch out: write “water moves from a **dilute** solution to a more **concentrated** solution”. If you write about high and low concentrations, say “of water” every time. A concentrated solution has **less** water, not more.

4. Real cells and a diagram



Real red onion cells (painting) — A diagram

A painting based on light micrographs. The purple is the cell sap's own colour: no stain.

Red onion cells have purple **cell sap** in their **permanent vacuole**, so you can see the vacuole without a stain.

- In **pure water** (left), each vacuole is full and presses against the cell wall.
- In strong **salt solution** (right), water leaves by osmosis. The vacuole shrinks and the cytoplasm pulls away from the wall.

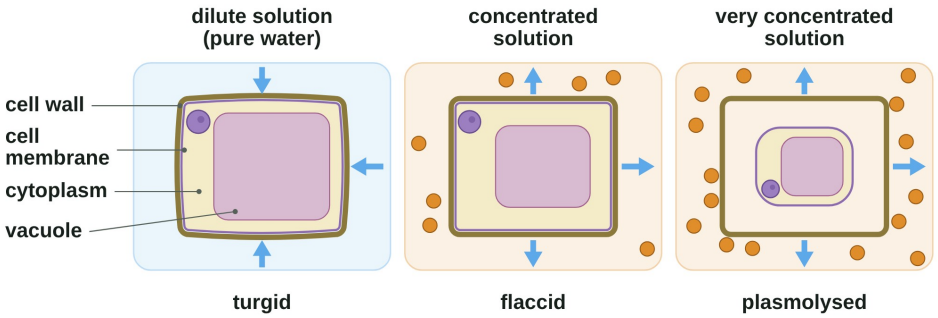
A diagram is simplified: it shows one neat cell in each solution, with arrows for the water. Real cells are packed together and share walls, they shrink unevenly, and you cannot see the water move. The clear gap in a shrunken cell is full of salt solution, not air.

B1 L9 Revision notes 2 of 4

Osmosis

Plant cells, animal cells and root hair cells

5. Plant cells



Blue arrows show which way water moves. You cannot see water move.

- **In a dilute solution** (such as pure water), the cell's contents are more concentrated than the solution. Water moves **in** by osmosis. The vacuole swells and pushes the cytoplasm against the cell wall. The cell is **turgid**: swollen and firm.
- The **cell wall** is strong. It pushes back, so the cell cannot take in more water. A plant cell **never bursts**.
- **In a concentrated solution**, water moves **out** by osmosis. The vacuole shrinks. The cell is **flaccid**: soft.
- If the cell loses more water, the cytoplasm and cell membrane pull away from the cell wall. This is **plasmolysis**. The wall keeps its shape, and the gap fills with the outside solution.

Watch out: plant cells do not burst in water. The cell wall stops them.

6. Why plants wilt

Turgid cells press against each other. This holds up the stems and leaves of plants that are not woody, and keeps leaves flat to the light.

When a plant is short of water, its cells lose water and become flaccid. They no longer hold the plant up, so it **wilts**. Water it, and water moves back into the cells by osmosis: they become turgid again. (Why leaves keep losing water is B2 L14 Transpiration and the potometer.)

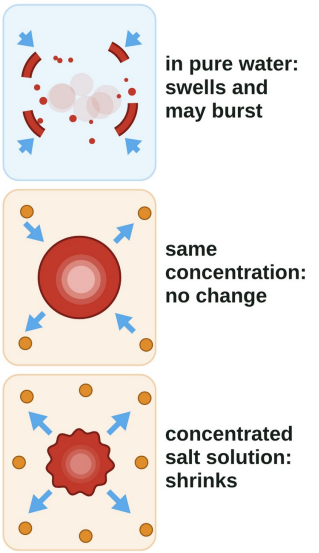
7. Animal cells

Animal cells, such as **red blood cells**, have a cell membrane but **no cell wall**.

- In **pure water**, water moves in by osmosis. Nothing stops the cell swelling, so it may **burst**.
- In a solution with the **same concentration** as the cell, there is no net movement of water.
- In a **concentrated** salt solution, water moves out by osmosis and the cell **shrinks**.

This is why a hospital drip is a salt solution about as concentrated as the inside of blood cells, and never pure water.

Watch out: an animal cell may burst in pure water, but a plant cell never does. Use **turgid** for plant cells only.

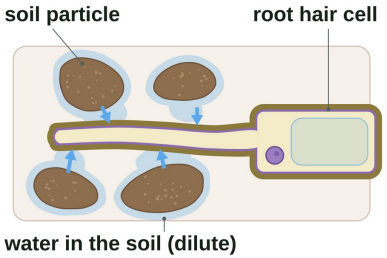


8. Root hair cells

Root hair cells take in water from the soil by osmosis. The water in the soil is more dilute than the inside of the root hair cell, so the net movement of water is into the cell.

The long, thin extension gives a large surface area, so more water is taken in (B1 L5 Specialised cells).

Mineral ions enter root hair cells a different way, by **active transport** (B1 L10 Active transport and exchange surfaces).



B1 L9 Revision notes 3 of 4

Osmosis

Required practical 2 (Combined Science) · 3 (Biology): potato cylinders

9. The method

Aim: find out how the concentration of a sugar (or salt) solution affects the mass of potato tissue.

1. Use a cork borer to cut potato cylinders. Trim them all to 3 cm with a scalpel on a tile. Take off any skin.
2. Put 10 cm³ of sugar solution into each of six labelled boiling tubes: 0.0, 0.2, 0.4, 0.6, 0.8 and 1.0 mol/dm³.
3. Blot each cylinder gently with a paper towel. Find its mass on a balance: the **starting mass**.
4. Put one cylinder into each tube. Leave them overnight at room temperature.
5. Take each cylinder out, blot it gently in the same way, and find its mass again: the **final mass**.
6. Calculate the percentage change in mass. Do three cylinders at each concentration and find the mean.

Safety: cut onto a tile, away from your fingers; take care with the cork borer and the scalpel; wipe up spills; do not eat the potato.

Variable	In this practical
Independent (you change it)	the concentration of the sugar (or salt) solution
Dependent (you measure it)	the percentage change in mass
Control (you keep it the same)	the same potato; the size of the cylinders; the volume of solution; the time; the temperature; blotting the same way

10. Percentage change in mass

percentage change in mass = (final mass − starting mass) ÷ starting mass × 100

Worked example: a cylinder in 0.6 mol/dm³ goes from 2.00 g to 1.70 g.

Change in mass = 1.70 − 2.00 = −0.30 g.

Percentage change = −0.30 ÷ 2.00 × 100 = **−15 %**.

Check: the solution is concentrated, so the cylinder should lose mass. It did: the answer is negative.

- A **gain** (+) means water moved **in**. A **loss** (−) means water moved **out**.
- Use a percentage because the cylinders start with different masses: it compares them fairly.

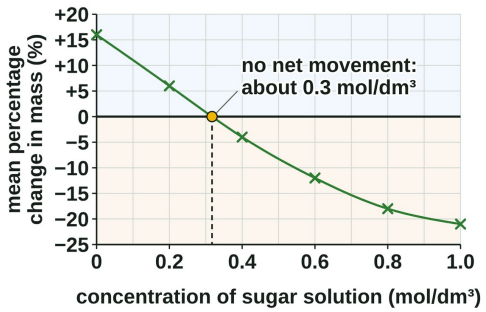
Rate of water uptake = gain in mass ÷ time. A cylinder that gains 0.30 g in 20 hours takes in water at 0.30 ÷ 20 = **0.015 g per hour**.

Watch out: divide by the **starting** mass, not the final mass. Keep the minus sign for a loss.

11. Results, the graph and the conclusion

Concentration (mol/dm³)	0.0	0.2	0.4	0.6	0.8	1.0
Cylinder 1 (%)	+12	+5	−4	−15	−18	−20
Cylinder 2 (%)	+17	+7	−3	−10	−19	−22
Cylinder 3 (%)	+19	+18 (anomaly)	−5	−11	−17	−21
Mean (%)	+16	+6	−4	−12	−18	−21

- At 0.2 mol/dm³, +18 % is an **anomaly**: it does not fit the pattern of the other results. Leave it out. Mean = (5 + 7) ÷ 2 = +6 %.
- Put the concentration along the bottom and the mean percentage change up the side.
- The y-axis must go **below zero**: some cylinders lost mass.
- Plot small crosses. Draw one smooth **line of best fit**, not dot to dot.
- **Conclusion.** Below about 0.3 mol/dm³ the potato **gains** mass: the solution is more dilute than the potato cells, so water moves in by osmosis.



- Above about 0.3 mol/dm³ the potato **loses** mass: water moves out.
- Where the line crosses 0 %, at about **0.3 mol/dm³**, there is **no net movement** of water. The potato cells' contents are about as concentrated as this solution.

Watch out: at 0 % change, water still moves both ways. There is no **net** movement, not "no movement".

12. Evaluating

- **Blotting:** blotting harder or more gently changes the mass. Blot every cylinder the same way.
- **Drying:** a cylinder left out on the bench loses water to the air. Find the mass straight away.
- **The balance:** a balance that reads to 0.01 g has a better resolution than one that reads to 0.1 g: it shows smaller changes in mass.
- **Different pieces of potato** can behave differently. Use one potato, and do three cylinders at each concentration: if the results are close, they are **repeatable**.

B1 L9 Revision notes 4 of 4

Osmosis

Key words, exam tips and check yourself

Key words

Anomaly: a result that does not fit the pattern of the other results.

Concentrated solution: a solution with a lot of solute dissolved in it, so it has a low concentration of water.

Control variable: a variable that is kept the same, so the test is fair.

Cork borer: a metal tube with a sharp end, used to cut cylinders of tissue with the same diameter.

Dependent variable: the variable that you measure.

Diffusion: the net movement of particles from an area of higher concentration to an area of lower concentration.

Dilute solution: a solution with only a little solute dissolved in it, so it has a high concentration of water.

Flaccid: describes a plant cell that is soft because it has lost water.

Independent variable: the variable that you change.

Mean: the total of the results divided by the number of results.

Net movement: the overall movement in one direction, after taking away the movement the other way.

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

Partially permeable membrane: a membrane that lets small molecules, such as water, pass through, but not larger ones, such as sugar.

Percentage change in mass: the change in mass divided by the starting mass, multiplied by 100.

Plasmolysis: when a plant cell loses so much water that its cytoplasm and cell membrane pull away from the cell wall.

Solute: the substance that dissolves in a liquid, such as sugar or salt.

Solution: a mixture made when a solute dissolves in a liquid, such as water.

Turgid: describes a plant cell that is swollen and firm because its vacuole is full of water.

Check yourself

Cover the answers, then check.

1. Give the definition of osmosis.
2. What does a partially permeable membrane let through, and what does it stop?
3. Which has more water in it: a dilute solution or a concentrated solution?
4. A plant cell is put in pure water. Which way does water move, and what word describes the cell afterwards?
5. What is plasmolysis?
6. Why can a red blood cell burst in pure water when a plant cell cannot?
7. A potato cylinder goes from 1.60 g to 1.48 g. Calculate the percentage change in mass.
8. On the graph of the potato practical, what does the point where the line crosses 0 % show?

Answers

1. The diffusion of water from a dilute solution to a concentrated solution through a partially permeable membrane.
2. It lets small molecules such as water through, but stops larger ones such as sugar.
3. A dilute solution.
4. Into the cell, by osmosis. The cell becomes turgid.
5. When a plant cell loses so much water that its cytoplasm and cell membrane pull away from the cell wall.
6. A red blood cell has no cell wall. A plant cell's wall stops it bursting.
7. (1.48 − 1.60) ÷ 1.60 × 100 = −7.5 %.
8. No net movement of water: the solution is about as concentrated as the inside of the potato cells.

Exam tips

- Say **water** every time: osmosis is the movement of water, never of sugar or salt.
- Write “from a **dilute** solution to a more **concentrated** solution”. If you use “high” and “low”, add “of water”.
- Use the words **turgid**, **flaccid** and **plasmolysis** for plant cells. Animal cells **swell and may burst**, or **shrink**.
- Say why a plant cell does not burst: the **cell wall**.
- Percentage change = (final − starting) ÷ starting × 100. Keep the minus sign for a loss.
- At 0 % change there is **no net movement** of water, not “no movement”.

B1 L10 Revision notes 1 of 4

Active transport, exchange surfaces

Exchange surfaces, a real gill and a diagram, active transport, root hair cells

1. Getting substances in and out

Cells need substances such as oxygen, water, sugar (glucose) and mineral ions. Plants take in their water and mineral ions from the soil. Cells must get rid of waste, such as carbon dioxide. Substances move into and out of cells in three ways:

- **diffusion** (B1 L8 Diffusion)
- **osmosis**, for water only (B1 L9 Osmosis)
- **active transport** (this lesson).

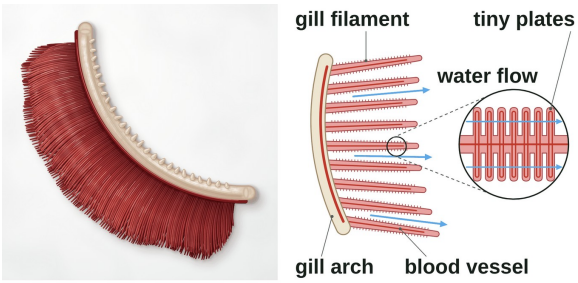
An **exchange surface** is a surface specialised for substances to move into or out of an organism, such as the alveoli or the gills.

A fish's **gills** are the organs it uses to take in oxygen from water and get rid of carbon dioxide. Each gill has a curved, bony **gill arch** that holds two rows of **gill filaments**: many thin, feathery strands, covered in tiny plates, which give a large surface area.

2. A real gill and a diagram

Exam pictures of gills are usually **diagrams**. A diagram is simplified on purpose:

- **Colour:** real gills are deep red all over, from the blood in their many capillaries. A diagram is pale, with thin red lines for the blood vessels.
- **Number:** a real gill has hundreds of filaments. A diagram shows a few.



A real gill — A diagram

Real gills are deep red because they are full of blood. The diagram is simplified.

- **Tiny plates:** these are too small to see without a microscope. A diagram draws them big, in an enlarged circle.
- **Two rows:** a real gill has two rows of filaments. A diagram usually shows one.
- **Water flow:** in a living fish, the gills sit under a bony flap, the gill cover, and water flows over them. A diagram shows the flow with arrows.

Both show a bony gill arch that supports many thin gill filaments.

3. Active transport

Active transport is the movement of substances from a more dilute solution to a more concentrated solution (against a concentration gradient), which requires energy from respiration.

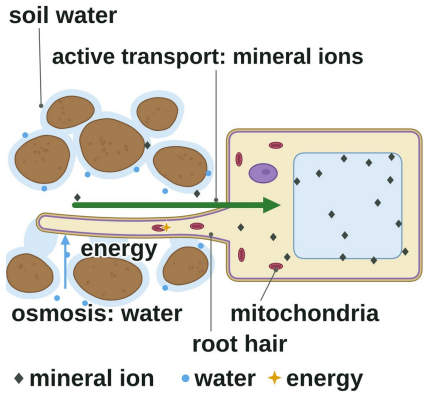
- It moves substances from a **lower** to a **higher** concentration.
- The energy is released by **respiration**, which happens in the **mitochondria**.
- Cells that do a lot of active transport have **many mitochondria**.

Watch out: only active transport goes against a concentration gradient. Diffusion and osmosis go the other way and need no energy from respiration.

4. Root hair cells

Plants need **mineral ions**, such as nitrate, to stay healthy. The water in the soil is a very dilute solution of mineral ions, so there are more ions inside a root hair cell than in the soil water.

- Diffusion would move the ions **out** of the cell. So the root hair cell uses **active transport** to move mineral ions in, against the concentration gradient.
- Root hair cells have many mitochondria to release the energy.
- Root hair cells take in water from the soil by osmosis (B1 L9 Osmosis). Osmosis needs no energy.
- The long, thin root hair gives a large surface area (B1 L5 Specialised cells).



Watch out: water enters root hair cells by osmosis; mineral ions enter by active transport. Not the other way round.

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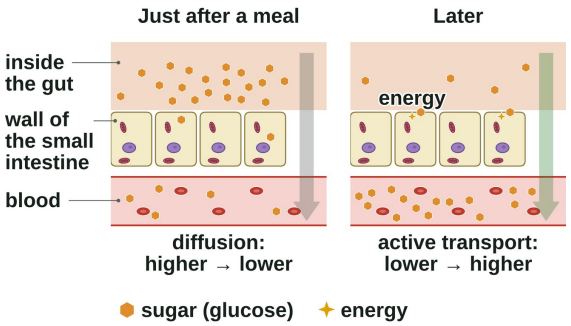
Active transport, exchange surfaces

The gut, comparing the three processes, surface area to volume ratio

5. Active transport in the gut

Digested food in the small intestine includes sugar (glucose). It is absorbed into the blood, which carries it to the body's cells for respiration.

- Just after a meal, there is more sugar in the gut than in the blood, so sugar **diffuses** into the blood.
- Later, the gut has less sugar than the blood. **Active transport** keeps moving sugar into the blood, against the gradient, so very little sugar is left in the gut. The gut wall cells have many mitochondria to release the energy.



The wall of the small intestine is folded into **villi** (B2 L2 The digestive system), which give a large surface area.

Watch out: sugar is absorbed by diffusion **and** by active transport. Active transport lets absorption carry on when the gut has less sugar than the blood.

6. Diffusion, osmosis and active transport

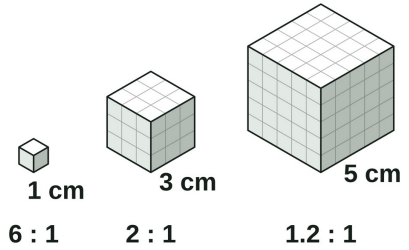
	Diffusion	Osmosis	Active transport
What moves	particles of a gas or a dissolved substance	water only	substances such as mineral ions and sugar
Which way	higher → lower concentration	dilute → more concentrated solution	lower → higher concentration
Energy from respiration?	no	no	yes
Membrane	not always needed (in cells: the cell membrane)	partially permeable	a cell membrane
Example	oxygen into the blood in the gills	water into a root hair cell	mineral ions into a root hair cell

Watch out (section 6): osmosis and active transport can both be described as "from a dilute solution to a more concentrated solution". In osmosis, **water** moves. In active transport, the **dissolved substance** (such as mineral ions) moves, from where there is less of it to where there is more.

7. Surface area to volume ratio

Surface area is the total area of the outside of an object (in cm²). **Volume** is the space inside it (in cm³).

The **surface area to volume ratio** is the surface area of an object compared with its volume, written as a ratio such as 6 : 1.



For a cube: surface area = 6 × side × side; volume = side × side × side

Side of cube	Surface area	Volume	Ratio
1 cm	6 cm²	1 cm³	6 : 1
3 cm	54 cm²	27 cm³	2 : 1
5 cm	150 cm²	125 cm³	1.2 : 1

Worked example: a cuboid, 5 cm × 2 cm × 1 cm.

It has 6 faces: two of 5 × 2, two of 5 × 1 and two of 2 × 1.

Surface area = 2 × (10 + 5 + 2) = **34 cm²**.

Volume = length × width × height = 5 × 2 × 1 = **10 cm³**.

Ratio = 34 : 10. Divide both numbers by 10: **3.4 : 1**. Check: 3.4 × 10 = 34 ✓

Watch out: a bigger cube has more surface area **in total**, but less surface area for each cm³ of volume. Put surface area first and simplify the ratio (54 : 27 = 2 : 1).

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Active transport, exchange surfaces

Size and exchange, the four features, gills, exchange surfaces in animals and plants

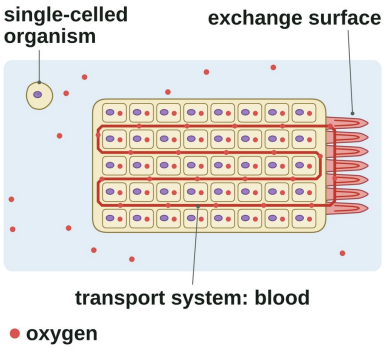
8. Why big organisms need exchange surfaces

A **single-celled organism** (an organism made of only one cell, such as a bacterium) has a large surface area to volume ratio. Every part of it is close to the surface, so diffusion across its surface meets its needs.

A **multicellular organism** (an organism made of many cells, such as a human or a tree) has a much smaller surface area to volume ratio, and most of its cells are far from the surface. Diffusion alone would be far too slow.

So multicellular organisms need:

- **exchange surfaces**, to take substances in and get rid of waste
- a **transport system**, to carry substances to and from every cell (in animals, the blood: B2 L6 The heart and circulation; in plants, the xylem and phloem: B2 L13 Plant transport: xylem and phloem).



9. Effective exchange surfaces

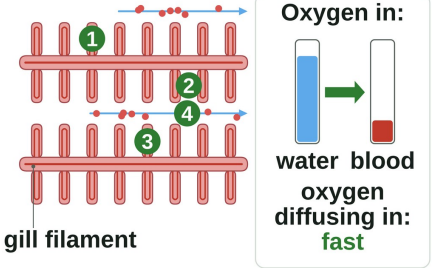
Feature	How it helps
1. A large surface area	More substances can move across at the same time.
2. A thin membrane	A short diffusion path, so substances cross quickly.
3. An efficient blood supply (animals)	Blood carries substances away, so the concentration gradient stays steep.
4. Ventilation (animals, for gas exchange)	Fresh air or water keeps the concentration gradient steep.

Watch out: "thin" means a short diffusion path, often only one cell thick. Do not just write "thin": say what it does.

10. Gills

Gills have all four features:

1. Many thin **gill filaments**, each covered in tiny plates, give a huge surface area.
2. The plates are very thin, so oxygen has a short diffusion path into the blood.
3. Each plate has a good blood supply. Flowing blood carries oxygen away, so the blood arriving always has less oxygen than the water.



4. The fish keeps water flowing over its gills, in through the mouth and out under the gill cover. This brings fresh oxygen and keeps the gradient steep.

Out of water, the filaments stick together. The surface area becomes much smaller, so the fish cannot take in enough oxygen.

11. Exchange surfaces in animals and plants

Exchange surface	What is exchanged	Adapted by
Gills (fish)	oxygen in, carbon dioxide out	many thin filaments with tiny plates; a good blood supply; water flowing over them
Lungs	oxygen in, carbon dioxide out	many alveoli with thin walls, capillaries and breathing (B2 L9 Lungs and gas exchange)
Small intestine	sugar and other food molecules in	villi: a large surface area, a thin wall and a good blood supply (B2 L2 The digestive system)
Roots	water and mineral ions in	root hair cells give a large surface area
Leaves	carbon dioxide in, oxygen out (in the light)	flat and thin; stomata; air spaces inside (B2 L12 Leaf tissues and stomata)

Watch out: plants have no blood. A leaf's features are being flat and thin, its stomata and its air spaces.

B1 L10 Revision notes 4 of 4

Active transport, exchange surfaces

Key words, exam tips and check yourself

Key words

Active transport: the movement of substances from a more dilute solution to a more concentrated solution (against a concentration gradient), which requires energy from respiration.

Concentration gradient: the difference in concentration between two areas.

Diffusion: the net movement of particles from an area of higher concentration to an area of lower concentration.

Exchange surface: a surface specialised for substances to move into or out of an organism, such as the alveoli or the gills.

Gill filaments: the many thin, feathery strands of a gill, covered in tiny plates, which give it a large surface area.

Gills: the organs a fish uses to take in oxygen from water and get rid of carbon dioxide.

Mineral ions: substances from the soil, such as nitrate, that a plant needs to stay healthy.

Mitochondria (one **mitochondrion**): the structures in the cytoplasm where aerobic respiration happens, releasing energy for the cell.

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

Respiration: a chemical reaction in every living cell that releases energy.

Stoma (plural **stomata**): a tiny hole (pore) in the surface of a leaf that lets gases diffuse in and out.

Surface area: the total area of the outside of an object.

Surface area to volume ratio: the surface area of an object compared with its volume, written as a ratio such as 6 : 1.

Villi (one **villus**): tiny finger-shaped parts that stick out from the inside wall of the small intestine and give it a large surface area.

Exam tips

- For active transport, say "against the concentration gradient" **and** "uses energy from respiration".
- Water enters root hair cells by osmosis; mineral ions enter by active transport.
- Energy is **released** by respiration. Never write that energy is "made".
- Ratios: surface area first, then volume. Simplify to "something : 1". Use cm^2 and cm^3 in your working.
- A bigger object has a **smaller** surface area to volume ratio.
- Link each feature of an exchange surface to its effect: "thin, so a short diffusion path".

Check yourself

Cover the answers, then check.

1. What is active transport?
2. Give two places where active transport happens.
3. Some hours after a meal, the gut has less sugar than the blood. Why can diffusion not absorb this sugar?
4. Give one way a diagram of a gill is different from a real gill.
5. Calculate the surface area to volume ratio of a cube with sides of 8 cm.
6. Explain why a large multicellular organism needs exchange surfaces and a transport system.
7. Give the four features of an effective exchange surface.
8. Give two ways a leaf is adapted for exchanging gases.

Answers

1. The movement of substances from a more dilute solution to a more concentrated solution (against a concentration gradient), which requires energy from respiration.
2. Root hair cells (taking in mineral ions) and the small intestine (absorbing sugar into the blood).
3. Diffusion only moves particles from a higher to a lower concentration. Here the blood has more sugar than the gut, so active transport is needed, using energy from respiration.
4. Any one: it is pale, not deep red; it shows a few filaments, not hundreds; it draws the tiny plates big; it shows one row of filaments, not two; it shows the water flow with arrows.
5. $6 \times 8 \times 8 = 384$ cm^2; $8 \times 8 \times 8 = 512$ cm^3; $384 : 512 = 0.75 : 1$.
6. It has a small surface area to volume ratio, and most of its cells are far from the surface, so diffusion across its outer surface would be too slow to supply them.
7. A large surface area; a thin membrane (a short diffusion path); an efficient blood supply (in animals); ventilation (in animals, for gas exchange).
8. Any two: it is flat and thin; it has stomata; it has air spaces inside.