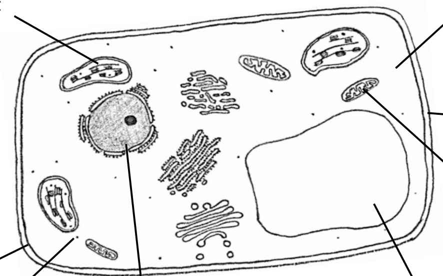
CELL STRUCTURE AND SPECIALISATION

Eukaryotic cells

Eukaryotic cells (including those of plants, animals and algae) contain many subcellular structures that each perform specific functions.

Eukaryotic cell:



Chloroplast (plant cells only)
Contains chlorophyll, a green pigment which absorbs light for photosynthesis

Cell membrane
Partially permeable barrier controlling the transport of substances into and out of the cell (e.g. glucose and O_2 in, CO_2 and urea out)

Ribosome
Where proteins are made

Nucleus
The control centre of the cell – contains DNA for making proteins, and controls reactions in the cell

Vacuole (plant cells only)
A sac of sap that stores salts and sugars and keeps cells rigid

Cytoplasm
Gel-like substance that contains the subcellular structures

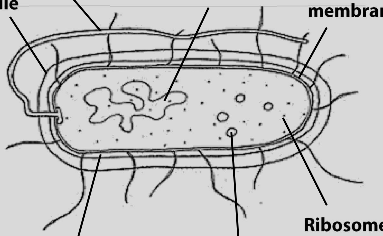
Cell wall (plant cells only):
Rigid outer layer made of cellulose that strengthens plant cells

Mitochondrion
The site of aerobic respiration, releasing energy to drive processes in the body

Prokaryotic cells

Prokaryotes include bacteria, like the one illustrated below. Prokaryotes are smaller than eukaryotes, and have different subcellular structures.

Prokaryotic cell:



Flagellum

Capsule

Single DNA loop
Genetic material is not contained in a nucleus

Cell membrane

Ribosome

Cell wall
Does not contain cellulose as in plant cells

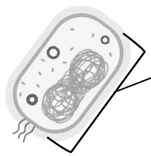
Plasmid
Small ring of DNA, coding for traits such as antibiotic resistance

Scale and size

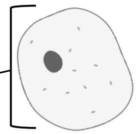
Animal cells can have a diameter of around 10–30 micrometres (µm), whereas plant cells can be up to 100 µm. Prokaryotes are much smaller at 0.1–5 µm.

Orders of magnitude

Orders of magnitude work in **powers of 10**. If something is 10 times bigger than something else, it is one order of magnitude bigger. If it is 100 times bigger than something, it is two orders of magnitude bigger.



This bacterial cell is around 2 µm, or 2×10^{-3} mm, long.



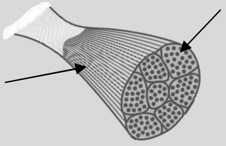
This animal cell is around 20 µm, or 2×10^{-2} mm, long.

The animal cell is 10 times, or one order of magnitude, bigger than the bacterium.

Animal cell specialisation

Cell **differentiation** is the formation of different cell types from stem cells. It involves the development of special **structures within the cell** that are essential in allowing different cell types to become **specialised** to perform a huge **variety of functions**.

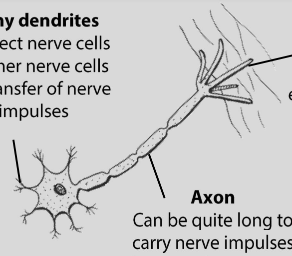
Muscle cells: contracting and relaxing



Sliding protein filaments
Enable muscle fibres to contract and relax

Cells contain lots of mitochondria
To transfer plenty of energy for contraction and relaxation

Neurons: transmitting nervous impulses



Many dendrites
Connect nerve cells to other nerve cells for transfer of nerve impulses

Axon
Can be quite long to carry nerve impulses between locations in the body

Nerve endings
Contain many mitochondria to supply energy for neurochemical production, used to transmit nerve impulses across synapses

Sperm cells: carrying genetic information to the egg

Nucleus
Contains DNA to be passed on

Tail
Moves rapidly to propel the sperm towards the egg cell

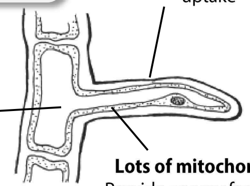
Acrosome
Contains digestive enzymes to break down outer layer of egg cell

Midpiece
Full of mitochondria to provide energy for sperm movement

Plant cell specialisation

In most **animals**, differentiation occurs **early** on in development, and cell division later on in life is just for repairing or replacing cells. However, many **plant** cells can differentiate at **any life stage**!

Root hair cells: uptake of water and mineral ions

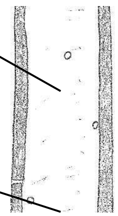


Long and thin
Increases surface area for water uptake

Large vacuole
Increases rate of water uptake by osmosis into the cell because it is concentrated with salts/sugars

Lots of mitochondria
Provide energy for active transport of mineral ions into the cell

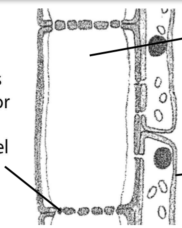
Xylem cells: transport of water and mineral ions



Dead cells
Form a continuous, **hollow** tube with plenty of space for water and mineral ions

No end walls
Water and mineral ions can travel easily up the stem to the leaves

Phloem cells: transport of sugars



Sieve plates
End walls of cells that have pores for sap to move through the vessel

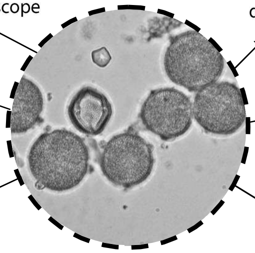
Long, live cells
Live, elongated cells form tubes

Companion cells
Provide energy for phloem cells, which have few organelles to leave room for sap

MICROSCOPY

Development of microscopes

Light microscope



An image of pollen from a light microscope

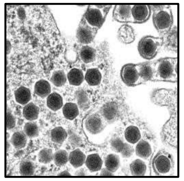
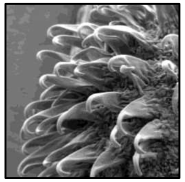
- Developed before electron microscope
- Produces an image by directing light at an object
- Can produce images of live organisms, unlike electron microscope
- More widely available than electron microscope
- Most have a magnification of several hundred times, but some can have a magnification of up to 2000×
- Cheap compared to electron microscope

Electron microscope

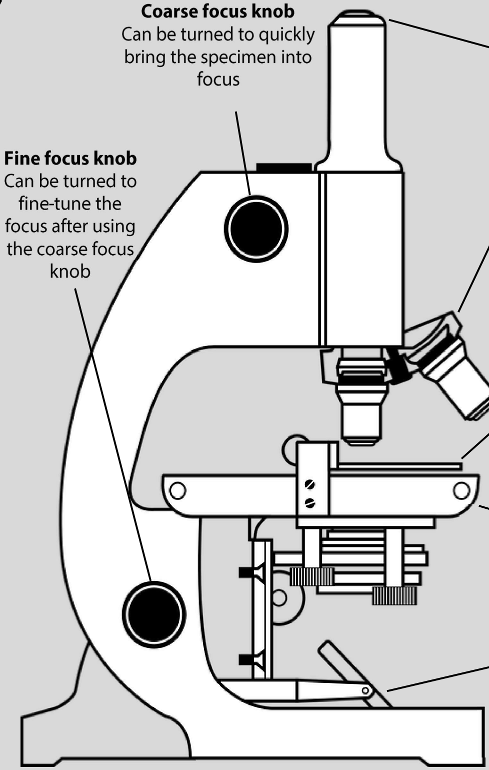
Features of an electron microscope

- Produces an image by firing electrons at an object
- Developed after light microscope
- Can have a magnification of up to 2,000,000×, allowing scientists to improve understanding of many subcellular structures that are not visible using a light microscope
- Expensive
- Larger than light microscope
- Fragile – must be kept at specific temperature, pressure and humidity levels

Types of electron microscope

Feature	Transmission electron microscope (TEM)	Scanning electron microscope (SEM)
Magnification	Higher magnification than SEM	Lower magnification than TEM
Resolution	Higher – about 0.2 nm	Lower – about 10 nm
Images produced	2D	3D
Example image		

Light microscope structure



Coarse focus knob
Can be turned to quickly bring the specimen into focus

Fine focus knob
Can be turned to fine-tune the focus after using the coarse focus knob

Eyepiece
For looking at the specimen

Objective lens
Forms the image

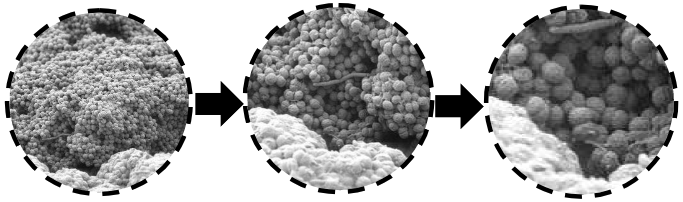
Slide
The sample is placed on a slide and covered with a coverslip (to protect it) for viewing

Stage
Where the slide is placed

Light source / mirror
Illuminates the specimen so that it can be viewed

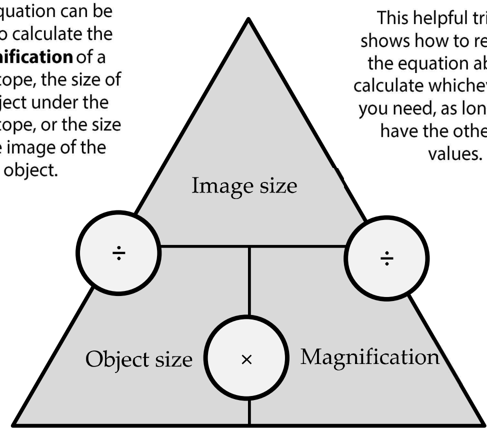
Magnification calculations

Increasing the **magnification** of a microscope makes the image bigger.



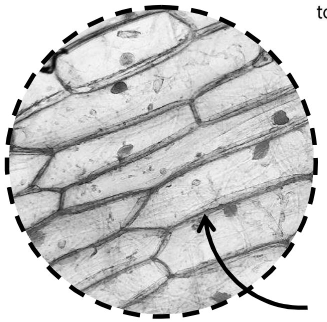
$$magnification = \frac{image\ size}{object\ size}$$

This equation can be used to calculate the **magnification** of a microscope, the size of an object under the microscope, or the size of the image of the object.

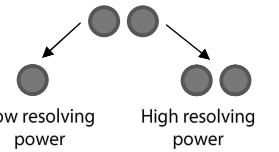


This helpful triangle shows how to rearrange the equation above to calculate whichever value you need, as long as you have the other two values.

Resolving power



The **resolution** of a microscope is its ability to distinguish between two separate points that are close together.



High **resolving power** enables a microscope to produce detailed images of specimens, like this image of onion cells

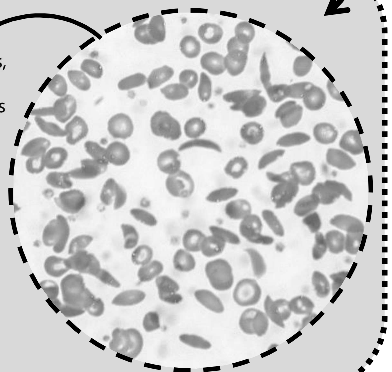
Worked example: magnification

In this image of red blood cells, a cell is around 4 mm across and the actual size of the cell is 10 micrometres (µm):

4 mm = 4000 µm

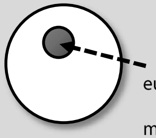
4000/10 = 400×

The magnification is 400×



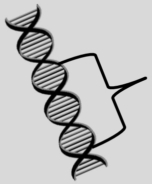
CELL DIVISION AND STEM CELLS

Chromosomes



Nucleus
A subcellular structure in eukaryotic cells that contains genetic material in the form of **chromosomes**.

Chromosomes
Thread-like structures usually found in pairs. Made of DNA containing many **genes**.

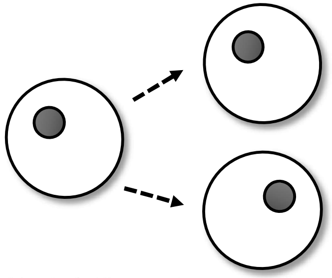


Gene
A small section on a chromosome that codes for a particular protein.

The cell cycle

What is the cell cycle?

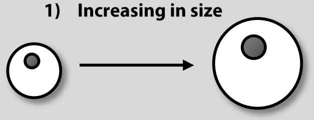
Cell division involves several stages, known as the **cell cycle**.
Division of a cell by **mitosis** results in two new cells with the exact same genetic material as the original cell.



Division is vital for growth and development of an organism.
It also allows the body to repair tissues (for example, if you cut your finger) and replace cells (for example, red blood cells need replacing around every four months).

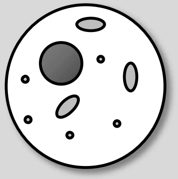
Stage 1
The cell must prepare for division:

1) **Increasing in size**

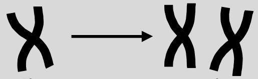


2) **Increasing the number of subcellular structures**

e.g. ribosomes, mitochondria and chloroplasts (in plant cells)

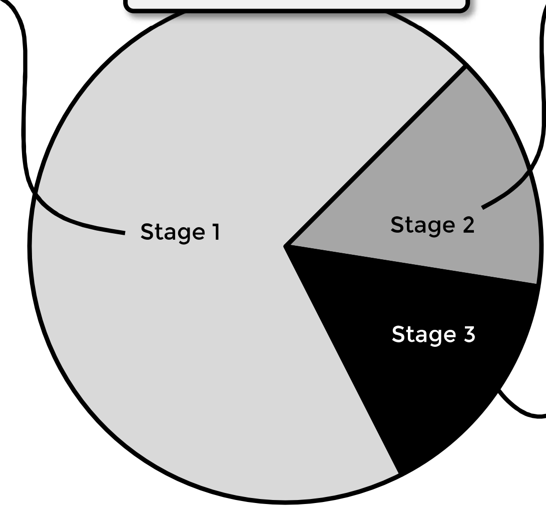


3) **Doubling the genetic material**

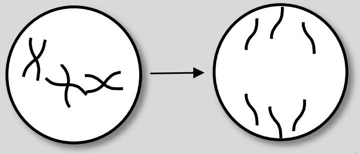


Chromosomes are copied by DNA replication

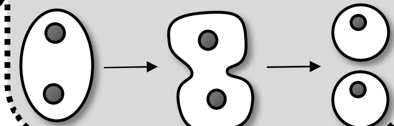
Cell cycle stages



Stage 2
This stage involves **mitosis**.
Pairs of chromosomes separate and are pulled to opposite ends of the cell, and the nucleus divides.



Stage 3
Division of the cytoplasm and cell membranes to form two new cells. Each new cell contains a nucleus with identical genetic material to the original cell.

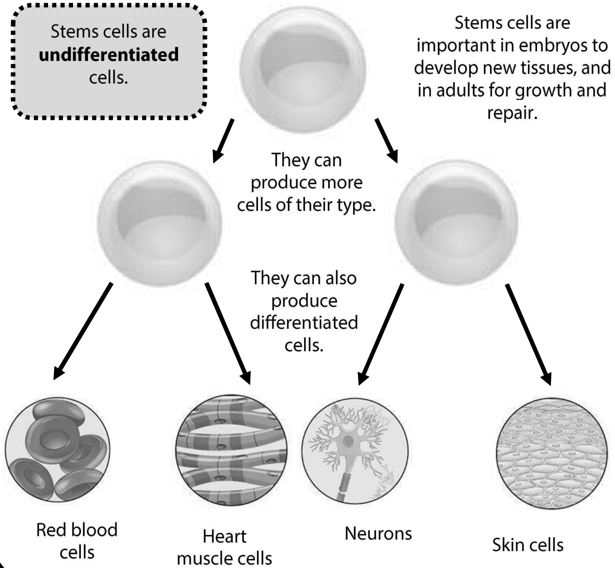


Stem cells

What is a stem cell?

Stems cells are **undifferentiated** cells.

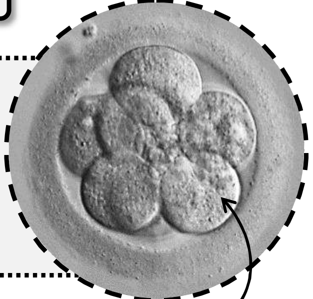
Stems cells are important in embryos to develop new tissues, and in adults for growth and repair.



Importance

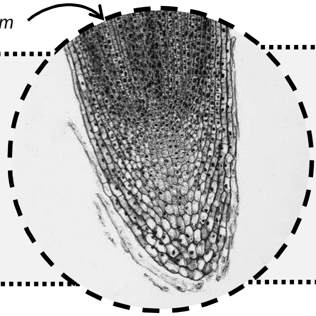
Bone marrow of adult animals contains stem cells that are able to differentiate into several types of cell (e.g. red blood cells).

Scientists can clone stem cells from **human embryos** and produce many types of human cells from them.



A human embryo

A plant meristem



In plants, **meristem tissues** (usually at root and shoot tips) can produce any type of plant cell at any point in a plant's life.

We can use stem cells from plant meristems to clone rare plant species for conservation, and to clone crop plants with desirable features (such as disease resistance).

Therapeutic cloning

Therapeutic cloning involves producing an **embryo** by **cloning a body cell** taken from a **patient**. Stem cells taken from this embryo can then be used in **medical treatments**.

Benefits	Risks / Ethical Issues
Embryonic stem cells have potential for **treating many serious conditions** such as stroke, diabetes and paralysis caused by spinal cord injury.	The embryo is destroyed following the removal of stem cells. Some people see this as **immoral** because the embryo is a potential human life.
	Some people fear that using such cloning techniques could lead to **cloning of human beings.**
Stem cells from the patient **will not be rejected** by the patient's immune system.	The method is **time-consuming** and **expensive.**
	There is a risk of **viral infections** being passed to patients from stem cells.