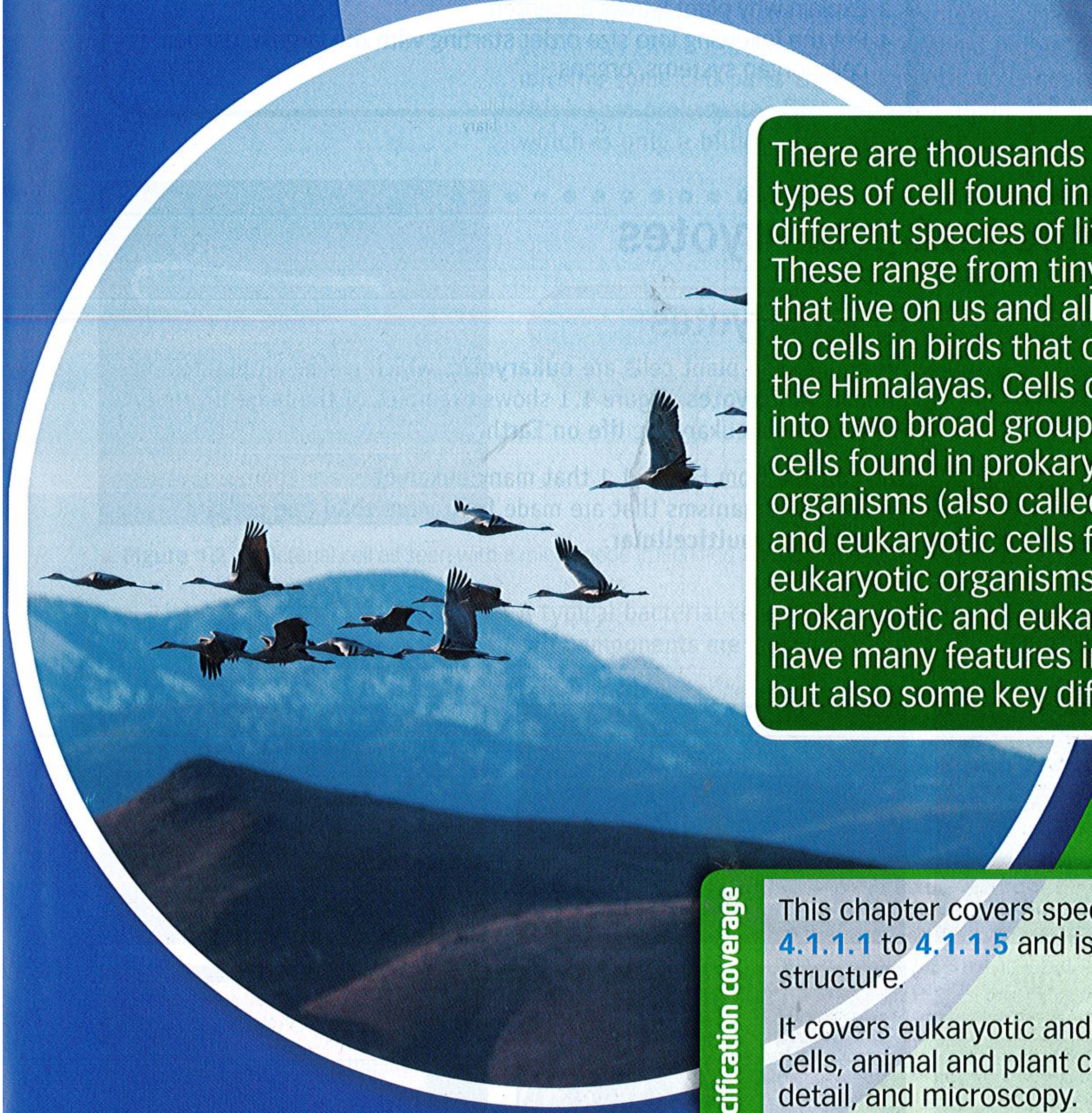
1 Cell structure



There are thousands of different types of cell found in millions of different species of life on Earth. These range from tiny bacteria that live on us and all around us to cells in birds that can fly over the Himalayas. Cells can be put into two broad groups: prokaryotic cells found in prokaryotic organisms (also called prokaryotes) and eukaryotic cells found in eukaryotic organisms (eukaryotes). Prokaryotic and eukaryotic cells have many features in common but also some key differences.

Specification coverage

This chapter covers specification points 4.1.1.1 to 4.1.1.5 and is called Cell structure.

It covers eukaryotic and prokaryotic cells, animal and plant cells in more detail, and microscopy.

Prior knowledge

Previously you could have learnt:

- that cells are the basic unit of living organisms
- about the functions of some cell parts
- about the similarities and differences between plant and animal cells
- about the adaptations of some unicellular organisms
- about the organisation of multicellular organisms: from cells to organisms.

Test yourself on prior knowledge

1. What are the functions of plant cell walls?
2. Describe a difference between plant and animal cells.
3. Explain why plant leaves are green.
4. Put the following into size order starting with the largest: tissues, cells, organ systems, organs.

Eukaryotes and prokaryotes

KEY TERMS

Eukaryotic cells Describes cells that contain a nucleus.

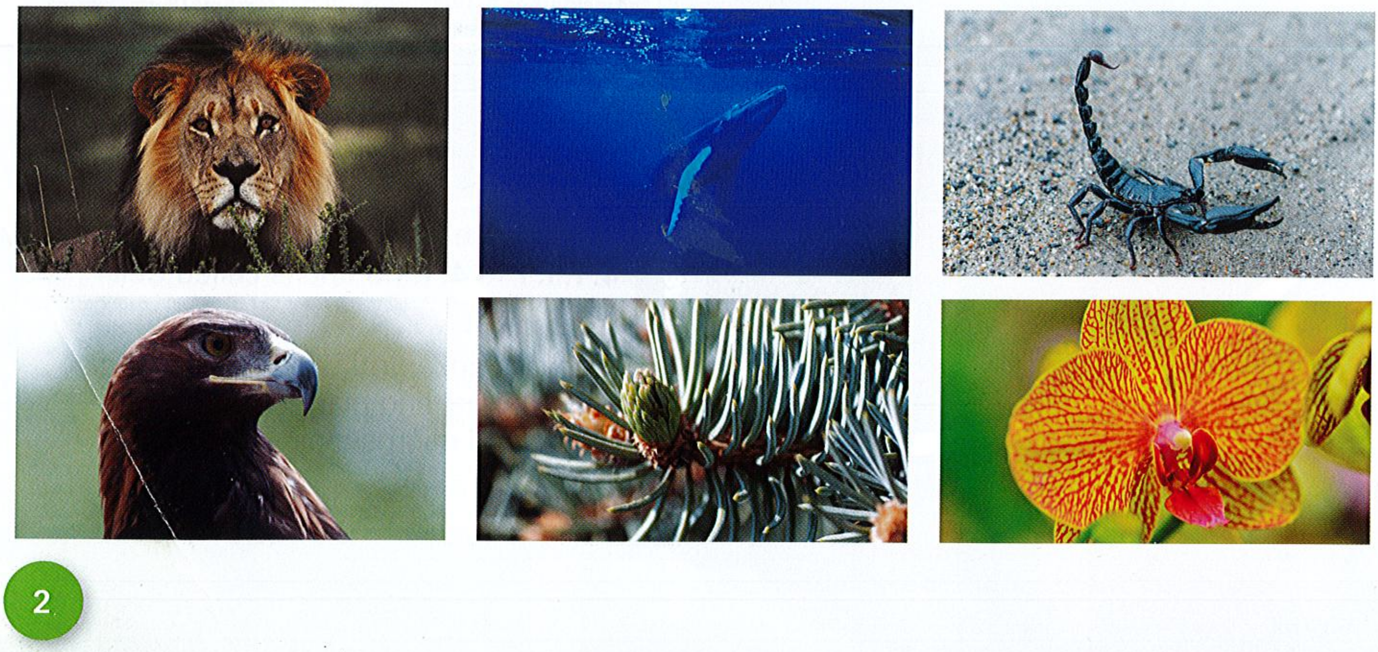
Eukaryote An organism that is made of eukaryotic cells (those that contain a nucleus).

Eukaryotes

All animal and plant cells are **eukaryotic**, which makes all plants and animals **eukaryotes**. Figure 1.1 shows examples of the huge diversity we can see in eukaryotic life on Earth.

You can see from Figure 1.1 that many eukaryotes are complex organisms. Organisms that are made from more than one cell are described as **multicellular**.

▼ **Figure 1.1** A range of different eukaryotic organisms.



KEY TERMS

Prokaryotic cells Describes single-celled organisms that do not contain a nucleus.

Prokaryotes Prokaryotic organisms (bacteria).

DNA (deoxyribonucleic acid) The genetic information found in all living organisms.

TIP

It is important that you develop a sense of scale and know which type of cell is largest.

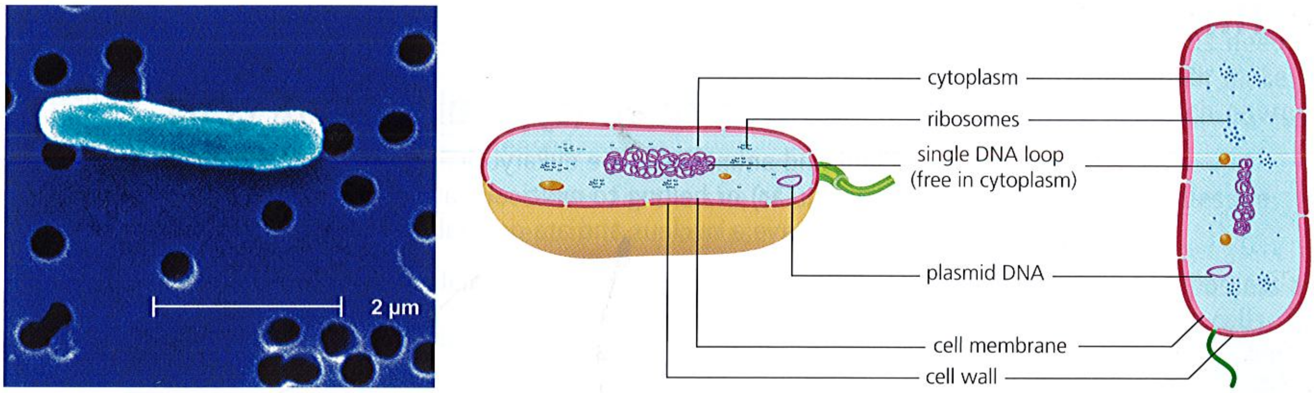
Prokaryotes (bacteria)

All bacterial cells are **prokaryotic**, which means that all bacteria are **prokaryotes**.

Prokaryotes:

- are **single celled**
- do **not have a nucleus** containing their genetic material (**DNA**)
- are **smaller** than eukaryotic cells
- may also have small rings of DNA called **plasmids**.

Individual bacterial cells are usually between 1 µm and 10 µm in length. One million micrometres (µm) make up one metre (m) and one thousand make up one millimetre (mm). This means that between 100 and 1000 bacteria will fit in a straight line in a space of 1 mm. Groups of bacterial cells are called colonies. Many, but not all, scientists think that prokaryotes evolved before eukaryotes and so are missing some cell parts that eukaryotic cells contain. These scientists think that prokaryotes first appeared about 3.5 billion years ago, which is only a billion years after the Earth's crust formed.



▲ **Figure 1.2** A bacterial cell as seen with a microscope (magnified ×20000) and as three- and two-dimensional diagrams.

A typical bacterial cell is shown in Figure 1.2. The functions of bacterial cell components are shown in Table 1.1.

Table 1.1 The components of bacterial cells and their functions.

Component	Structure and function
Cytoplasm	This fluid is part of the cell inside the cell membrane. It is mainly water and it holds other components such as **ribosomes**. Here most of the chemical reactions in the cell happen (such as the making of proteins in ribosomes).
Cell wall	Like those of plants and fungi, bacterial cells have a cell wall to provide support. However, unlike plant cell walls this is not made of cellulose. The cell membrane is found on the inside surface of the cell wall.
Single DNA loop (DNA not in chromosomes)	DNA in prokaryotes is not arranged in complex chromosomes as in eukaryotic cells. It is not held within a nucleus.
Plasmids	These are small, circular sections of DNA. They provide genetic variation for bacteria.
Cell membrane	This controls what substances go in and out of a cell. It also has internal extensions that have enzymes attached to them. **Respiration** occurs in these enzymes.
Ribosome	Proteins are made by ribosomes, which are present in the cytoplasm.

KEY TERMS

Ribosome A small cell organelle in the cytoplasm in which proteins are made.

Respiration The release of energy from glucose.

TIPS

It is important that you can explain what a chromosome is.

Copy out the headings in the first row and column of Table 1.1 and test yourself by filling in the rest of the table from memory. This will help you remember the details.

▲ **Figure 1.3** Prokaryotic bacterial cells seen on a pinhead.

Figure 1.3 shows how small bacterial cells are. Typical eukaryotic cells are much larger than this. However, even eukaryotic cells are microscopic. This means you can't see a single cell without using a microscope.

Test yourself

1 Name the type of DNA structure only present in prokaryotes.
2 Which organisms have a single loop of DNA?
3 Describe the main difference between eukaryotic and prokaryotic cells.
4 Describe the function of ribosomes.

Show you can...

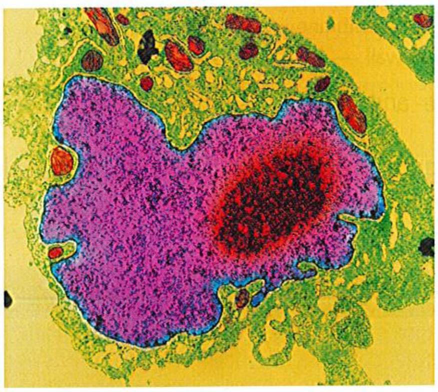
Explain why some scientists think that prokaryotic cells evolved first.

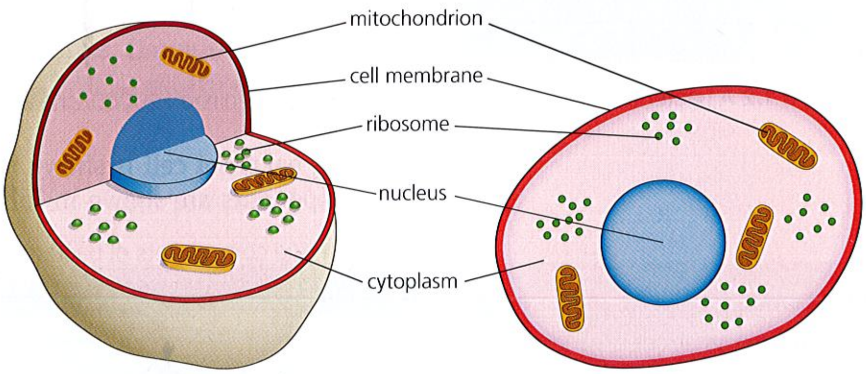
Animal and plant cells

○ Generalised (typical) animal cells

Plant and animal cells are eukaryotic. They can be single-celled (unicellular) or belong to multicellular organisms. Eukaryotic cells almost always have a nucleus and are generally larger than prokaryotic cells.

The structure of a generalised animal cell is shown in Figure 1.4.





▲ **Figure 1.4** A generalised animal cell as seen with a microscope (magnified ×4800) and as three- and two-dimensional diagrams.

Components of animal cells

In the previous section we looked at bacterial cells. Animal cells, including human cells, have many components in common with these. The cytoplasm of animal cells is also mainly water and it holds other components such as ribosomes. In the cytoplasm most of the chemical reactions in the cell happen (such as the making of proteins using ribosomes).

The cell membrane of animal cells also surrounds the cell. There are no cell walls in animal cells and so the membrane is on the outside of these cells. The membrane controls what substances go in and out of the cell. Many of your cells need glucose and oxygen for respiration, and these substances move by **diffusion** or are transported into the cells from the blood, where they are found at a higher concentration. Carbon dioxide moves back into the blood capillaries through the membrane.

KEY TERMS

Diffusion The net movement of particles from an area of high concentration to an area of lower concentration.

Organelle A part of a cell with a specific function.

Chromosome Structure containing DNA, found in the nucleus of eukaryotic cells.

Mitochondrion A small cell organelle, in which respiration occurs, found in the cytoplasm of eukaryotic cells.

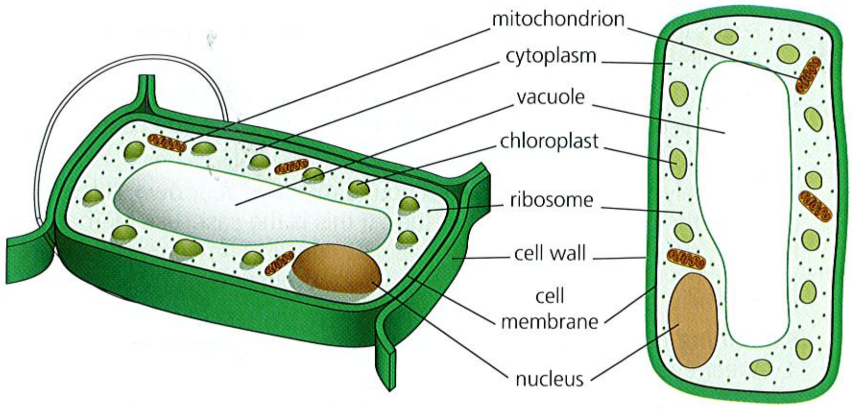
Mitochondria are small **organelles** found in the cytoplasm and are only present in eukaryotic cells. They are the site of most of a cell's respiration. Here the energy stored in glucose is released for the cell to complete the seven life processes. Without this energy all cells die. More active cells, such as those in muscles or sperm cells, usually have more mitochondria because these cells need more energy. Mitochondria have many folds inside them, which make their surface area very large to increase the rate at which energy is released.

Ribosomes are the site of protein synthesis. These organelles are present in the cytoplasm of animal cells.

Animal cells are unlike bacterial cells in that they usually possess a nucleus. This component is present in almost all eukaryotic cells. It is found in the cytoplasm and is surrounded by its own membrane. The cell's genetic material (DNA) is enclosed within it, arranged into **chromosomes**. The nucleus controls the activities of the cell.

○ Generalised (typical) plant cells

Like animal cells, plant cells are eukaryotic. They have a nucleus and they are generally larger than prokaryotic (bacterial) cells.



▲ **Figure 1.5** A generalised plant cell as three- and two-dimensional diagrams.

Components of plant cells

Plant cells have many components in common with animal cells, including a nucleus in which the organism's genetic material (DNA) is found. As in animal cells, the DNA is packaged into chromosomes. Plant cells also have ribosomes for protein synthesis and mitochondria for respiration in their cytoplasm.

Plant cells have some components not present in animal cells. Chloroplasts are small organelles, full of a green pigment called chlorophyll, which absorb the light necessary for **photosynthesis** to occur. This reaction uses the light energy from the Sun to convert carbon dioxide and water into glucose and oxygen and so provides an energy source for the plant. It is the green chlorophyll in plants that gives some of their parts their green colour. Most roots are hidden from the Sun and so cannot photosynthesise. They do not have chloroplasts and so are often white, not green.

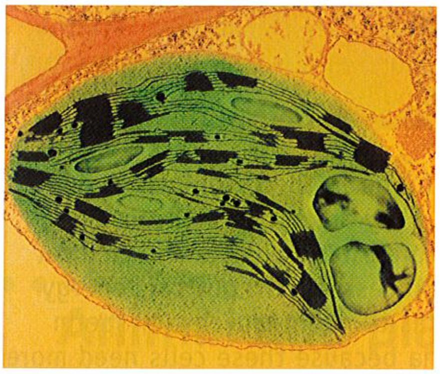
There are huge numbers of chloroplasts in leaf cells. There are often well over half a million per square millimetre of leaf.

Plant cells also have a cell wall, unlike animal cells. This is made from cellulose and provides structure for the cell. Plants would not be able to stand upright to catch light energy from the Sun without cell walls. The cell membrane is found inside the cell wall.

Many plant cells also contain a permanent vacuole. This is filled with cell sap (water in which dissolved sugars and mineral ions are found). The pressure in the vacuole presses the cytoplasm against the wall to keep the cell **turgid**.

KEY TERM

Photosynthesis A chemical reaction that occurs in the chloroplasts of plants and algae and stores energy in glucose.



▲ **Figure 1.6** The structure of a chloroplast (magnification about ×15 000).

KEY TERM

Turgid Describes swollen cells.

Required practical 1

Use a light microscope to observe, draw and label a selection of plant and animal cells

In this practical you will examine the structure and features of different animal and plant cells.

Your teacher may provide you with slides showing a range of cells from plants and animals. If this is the case, use Method 1 below.

Method 1

1. Place your slide on a microscope stage and observe using the lowest power objective lens.
2. Focus in on the image and then increase the magnification until you can clearly observe the cell's structure.
3. Make a drawing of what you observe, labelling any structures you recognise. Ensure that you record the magnification you used when making your observations.

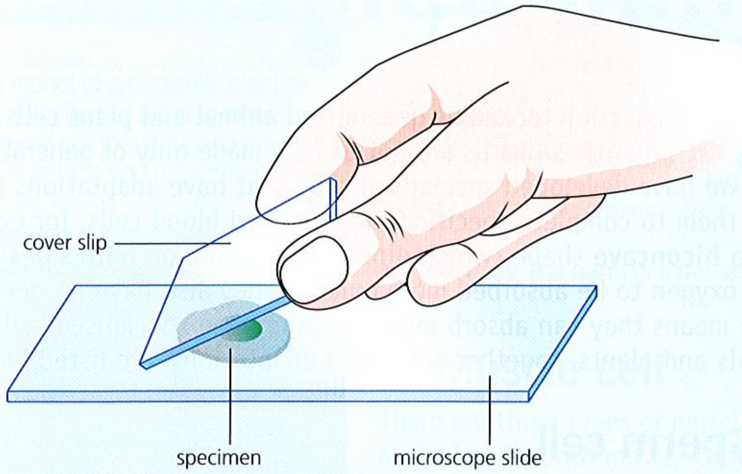
Alternatively, your teacher may ask you to make up your own slides to examine the cells in a range of tissues. If this is the case, use Method 2 below.

Method 2

Examining plant cells

1. Wear eye protection.
2. Use tweezers to remove a thin sheet of cells (epidermal tissue) from the inner part of an onion layer.

3 Place this flat on a microscope slide, being careful not to fold it.
4 Place a drop of iodine onto the onion tissue.
5 Carefully lower a cover slip on top of the tissue, ensuring no air bubbles form (Figure 1.7).
6 Follow the steps in Method 1 above to examine and draw the cells present.



▲ **Figure 1.7** How to make a light microscope slide.

7 Repeat this process using a leaf from a piece of pond weed (*Elodea*), but add a drop of water rather than iodine.

Examining animal cells

1 Wear eye protection.
2 Using an interdental stick or flossing brush from a freshly opened pack, gently scrape the inside of your cheek.
3 Smear the cotton swab on the centre of the microscope slide in small circles.
4 Add a drop of methylene blue solution to the centre of the slide. This is an irritant and can be harmful, so avoid contact with the skin and wear eye protection.
5 Carefully lower a cover slip on top and remove any excess stain by allowing a paper towel to touch one side of the cover slip.
6 Follow the steps in Method 1 above to examine and draw the cells present.
7 Repeat this process using a single hair from your head. Place the base of the hair on a microscope slide and then stain and observe the cells using the microscope.
8 Put all slides in a solution of 1% Virkon.

Questions

1 Compare and contrast the structure of the cells you observed. Were any features missing from the animal cells you observed that were present in the plant cells?
2 Can you relate any of the structures or features of the cells you observed to their functions or position in the organisms they came from?
3 Order the cells you observed, from smallest to largest.

TIP

It is important that you can explain how the main components of animal and plant cells are linked to their structure.

Show you can...

Describe the function of mitochondria.

Test yourself

5 Name two structures present only in plant cells.
6 In which types of cell would you find mitochondria?
7 Describe the function of the cytoplasm.

Cell specialisation

KEY TERM

Biconcave Describes a shape with a dip that curves inwards on both sides.

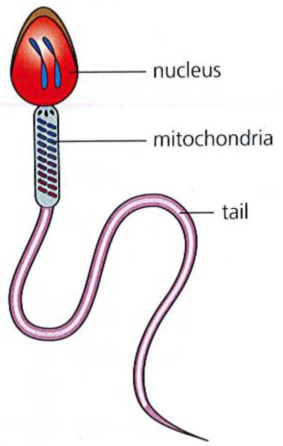
Ova (singular ovum) Eggs.

TIP

If you are asked to explain how a cell is adapted to its function, don't forget to use a connecting phrase like 'so that it can' or 'to allow it to'.

The previous section looked at generalised animal and plant cells. Eukaryotic organisms like us are not usually made only of generalised cells. We have developed specialised cells that have adaptations to allow them to complete specific functions. Red blood cells, for example, have a **biconcave** shape (which dips in the middle on both sides) to allow oxygen to be absorbed more quickly. They also have no nucleus, which means they can absorb more oxygen. Some specialised cells in animals and plants, together with their adaptations, are listed below.

Sperm cell



▲ **Figure 1.8** The parts of a sperm cell.

In humans, about a teaspoon of semen is ejaculated during a male orgasm. In the semen are tens of millions of sperm cells, which must swim through the female reproductive system. Here one cell may fertilise an **ovum** (egg cell). Sperm cells have a tail to help them swim towards the ovum (Figure 1.8). They have a relatively large number of mitochondria to release the energy from glucose during respiration. This is needed to keep them swimming. The nucleus of a human sperm contains the genetic material (DNA) of the father. This will make up half of the DNA of the baby.

TIP

You should remember that sperm cells, nerve cells and muscle cells are only found in animals.

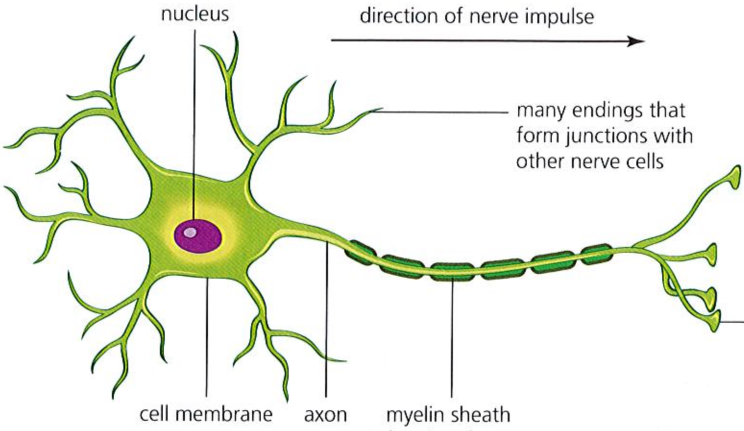
Nerve cell

KEY TERMS

Axon The extension of a nerve cell along which electrical impulses travel.

Myelin sheath The insulating cover along an axon, which speeds up the electrical impulse.

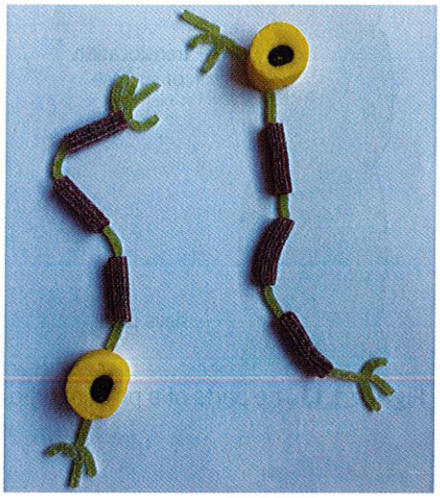
Our nervous system controls and coordinates all our actions. These can be either voluntary actions (such as picking up the television remote control) or involuntary actions (such as our heart beating faster when we exercise). There are two main parts to our nervous system. The first is our central nervous system (CNS), which is made up of our brain and spinal cord. The other is our peripheral nervous system (PNS), which is all the other nerve cells that connect to the CNS but then spread out across our bodies. To control our actions, signals must be sent and received. Nerve impulses are electrical signals that travel along nerve cells. To keep these impulses moving quickly, some of our nerve cells are the longest cells in our body. Their long extensions are called **axons** and these have a **myelin sheath** surrounding much of their length (Figure 1.9). This acts like the plastic coating on an electrical wire and insulates the electrical impulse. The cell body of the nerve cell also has smaller extensions, which allow it to pick up signals from neighbouring cells.



▲ **Figure 1.9** The parts of a nerve cell.

TIP

Make a model of a bacterial, plant or animal cell (Figure 1.10) and label it with the cell components and their functions to help you remember them.

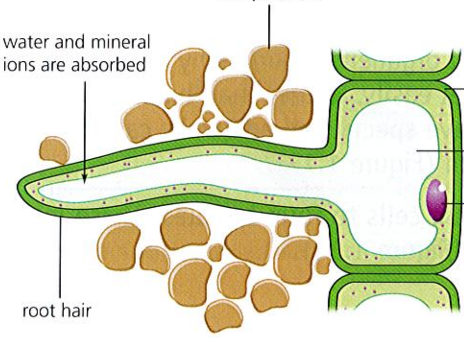


▲ **Figure 1.10** A model of nerve cells made from sweets.

○ Muscle cell

There are three types of muscle in our bodies, all of which can contract and relax. Smooth muscle contracts and relaxes automatically and is found in places such as the linings of the vessels that make up our circulatory system and the iris of our eyes. Cardiac muscle also contracts and relaxes automatically and is found in our heart. The third type is skeletal muscle, which is usually found attached to our bones. We control the contractions of this type of muscle, so its movements are not automatic.

All three types of muscle are made from muscle cells. These are specialised cells that can contract and so move parts of the body. Muscle cells contain large numbers of mitochondria, as muscular contraction requires a lot of energy.



▲ **Figure 1.11** The parts of a root hair cell.

○ Root hair cell

Root hair cells in plants have a small thin extension, which pokes out into the soil (Figure 1.11). Many plants have roots with such high numbers of long root hairs that they can look like a spider's web. The purpose of these hairs is to increase the surface area of the root that is in contact with the soil. This allows the plant to absorb more water and minerals from the soil. For example, a single rye plant has billions of root hairs, which have a total length of hundreds of miles! Without these it is likely that the adult plant would not be able to absorb enough water to survive.

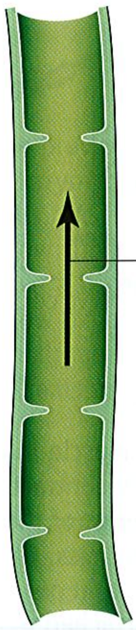
KEY TERMS

Xylem Dead plant cells joined together into long tubes through which water flows during transpiration.

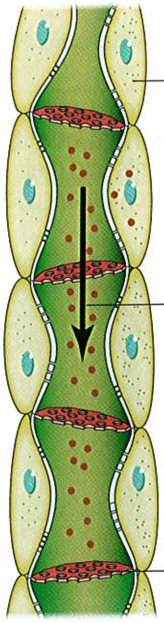
Transpiration The gradual release of water vapour from leaves to continue the 'pull' of water up to them from the soil.

○ Xylem cell

Xylem cells form long tubes running along the roots and stems of plants. They carry water and some dissolved minerals from the roots upwards to other parts of the plant. This water evaporates and is lost from leaves as water vapour during the continual process of **transpiration**. Xylem cells also carry water to the green parts of plants for photosynthesis during the day. Xylem tubes are made from lots of individual cells that have died and have no end walls and no contents, leaving a hollow tube like a pipe (Figure 1.12). They have reinforced side walls to support the weight of the plant. The side walls are strengthened by a substance called lignin.



▲ **Figure 1.12** The parts of a xylem tube.

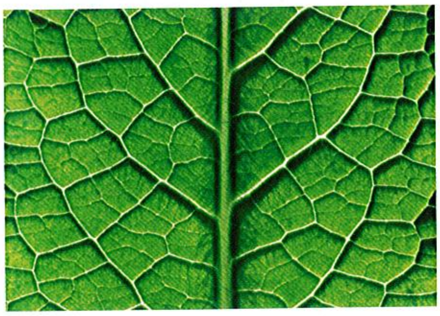


▲ **Figure 1.13** The parts of a phloem tube.

KEY TERMS

Phloem Living cells that carry sugars made in photosynthesis to all cells of a plant.

Translocation The movement of sugars made in photosynthesis from the leaves of plants.



▲ **Figure 1.14** The veins of a leaf are made from xylem tubes transporting water to the leaf and phloem tubes transporting sugars away from it.

TIP

You should remember that root hair cells, xylem cells and phloem cells are only found in plants.

Phloem cell

Phloem cells carry the glucose (as sucrose) made in photosynthesis from the leaves of a plant to all other parts of the plant in cell sap. This process is called **translocation**. The sugar is used immediately in respiration to release energy for the plant or is stored as starch in cells or in structures such as the roots of vegetables. Unlike xylem, phloem cells are living. They have fewer cell organelles than many other types of cell, which allows the sugar to travel easily. Rather than having no end walls (as in xylem), phloem cells have specialised end walls called sieve plates that have small holes in them (Figure 1.13).

Phloem cells are arranged with xylem cells to form bundles. These make up the veins you can see in a leaf (Figure 1.14).

Cell differentiation

The previous two sections have looked at generalised and specialised animal and plant cells. After generalised cells are formed they become specialised as an organism develops. This process is called cell differentiation. Your cells did this while you were in your mother's uterus. Part of this process involves cells developing specific structures within them to allow them to function. For example, muscle cells need to release lots of energy during respiration and so require a high number of mitochondria. Unlike animal cells, most plant cells retain the ability to differentiate throughout their life. We would not be able to take plant cuttings without this.

Show you can...

Explain why animals and plants have specialised cells.

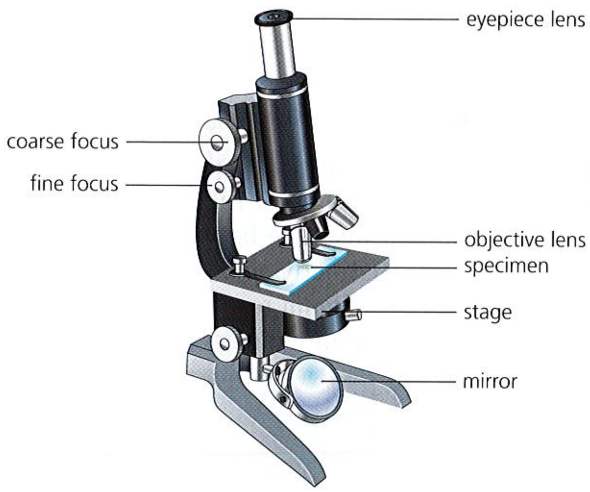
Test yourself

8 Give the function of nerve cells.
9 Name the components of nerve cells.
10 Describe how red blood cells are adapted for their function.
11 Describe how root hair cells are adapted for their function.

Microscopy

The invention of the microscope is likely to have occurred in the 1590s in the Netherlands by makers of eye glasses. Seventy-five years later, in 1665, English scientist Robert Hooke (1635–1703) published a book called *Micrographia*, which was full of impressive images including a drawing of the eyes of a fly, seen using a microscope. In this book he first used the word 'cell', because when he looked at plant cells using his microscope he was reminded of the cells in a honeycomb.

The microscopes used by Robert Hooke looked very different from those that you may use in your science lessons today. But the thing they have in common is that they all use magnifying lenses to enlarge images.



▲ **Figure 1.15** A labelled diagram of a light microscope.

Light microscopes

The parts of a light microscope and their functions are shown in Table 1.2.

Table 1.2 The functions of the parts of a light microscope.

Part	Function
Eyepiece lens	You look through this lens to see your sample. This is often ×10.
Objective lens	Usually there are three to choose from (often ×5, ×10 and ×25). The smallest will be the easiest to focus, so select this first. When you have focused this lens try a different one with a greater magnification.
Stage	This holds the sample securely, often using two metal clips.
Specimen	This is usually placed in a drop of water or stain on a microscope slide under a very thin glass cover slip.
Mirror	This reflects the light up through the sample, and then the objective and eyepiece lenses into your eyes. In more expensive/advanced microscopes the mirror is replaced by a light source.
Course focus	This quickly and easily moves the stage up and down to focus on the sample.
Fine focus	This sensitively and slowly moves the stage up and down to allow you to make your image very sharp.

TIP

Use the coarse focus at low magnification first to find your sample easily. Then increase the magnification lens by lens. Finally use the fine focus to make your image as sharp as possible.

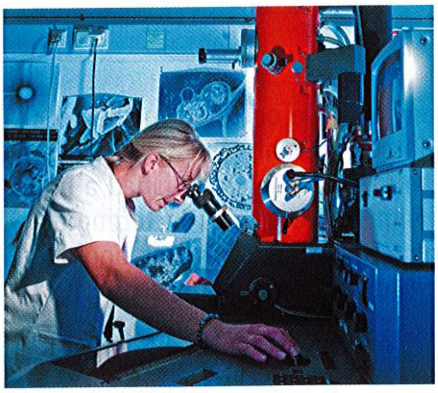
The total magnification of the image you are looking at is calculated by:

$$\text{total magnification} = \frac{\text{magnification of}}{\text{eyepiece lens}} \times \frac{\text{magnification of}}{\text{objective lens}}$$

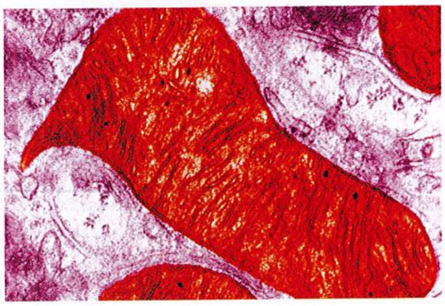
KEY TERMS

Electron microscope A microscope that uses electron beams in place of light to give higher magnification.

Electron Negatively charged, tiny subatomic particle that is found in shells surrounding the nucleus of an atom.



▲ **Figure 1.16** A scientist using a large modern electron microscope.



▲ **Figure 1.17** (a) A three-dimensional image of an ant's head taken with a scanning electron microscope. (b) A two-dimensional image of a mitochondrion taken using a transmission electron microscope. These have had colour added to them.

KEY TERM

Resolution The smallest distance between two separate points.

Electron microscopes

Electron microscopes use **electrons** in place of rays of light to make an image (Figure 1.16). The wavelength of electrons can be up to 100 000 times smaller than that of visible light. This means that electron microscopes can take images at significantly higher magnifications. The first electron microscope was made by German scientists Ernst Ruska (1906–1988) and Max Knoll (1897–1969) in 1931. This was a transmission electron microscope (TEM). Several years later, in 1937, German scientist Manfred von Ardenne (1907–1997) invented a second type called a scanning electron microscope (SEM).

Transmission electron microscopes fire a large beam of electrons though a very thin slice of the specimen. All electrons are fired at the same time. Not all of the electrons pass though the specimen. The image is made from only those electrons that do.

Scanning electron microscopes also use a beam of electrons. This beam is much smaller and scans across the whole image but not all at the same time. Electrons scatter from the surface of the sample and are detected to make an image.

As a consequence of their different methods of working, the images that these two microscopes make are very different from each other. Images from transmission electron microscopes are flat and are usually taken in cross-section through a specimen. That is, they are frequently used to look at a section through a cell. Scanning electron microscopes don't need thin samples so can be used to make images that look more three-dimensional. All electron microscope images are black and white. On occasions scientists colour these images to make them look more striking (Figure 1.17).

Electron microscopes can magnify much more than light microscopes, but the key thing is that they have a much greater **resolution**. The resolution of microscopes is the shortest distance between two parts of a specimen that can be seen as two distinctly separate points. As a result of the wavelength of light the maximum resolution of light microscopes is 200 nm. (There are one million nanometres (nm) in a millimetre.) An electron microscope can resolve points up to 2000 times closer than a light microscope, at a separation of just 0.1 nm.

Test yourself

12 What is the range of magnification you might see in a light microscope?
13 Give the resolution of an electron microscope.
14 Describe why electron microscopes have greater magnification.
15 Describe a disadvantage of using an electron microscope.

Show you can...

Explain why scanning electron microscopes can take images that look three-dimensional.

Chapter review questions

1 Name two organelles that are only present in prokaryotic cells.

2 Name the substances present in a plant cell vacuole.

3 What substances move into leaf cells?

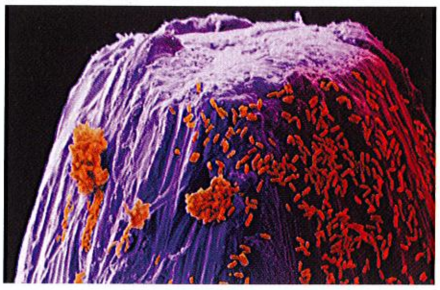
4 Explain why plant cells are often green.

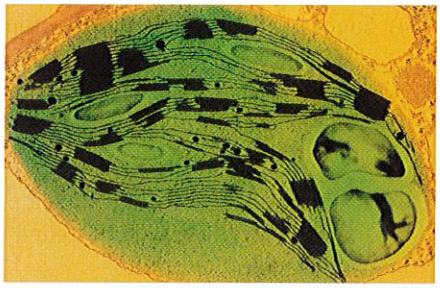
5 Describe how the structure of sperm cells helps their function.

6 Name the three types of muscle tissue.

7 Describe how you would make a microscope slide to look at an onion cell.

8 Describe the function of flagella.





9 a) These two images were taken using which types of microscope? Be specific in your answer.

b) Suggest one advantage and one disadvantage of using an electron microscope.

10 Describe three differences between prokaryotic and eukaryotic cells.

11 Give the function of cytoplasm and what it is made from.

12 What are the function of ribosomes?

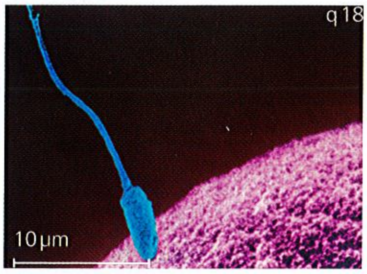
13 Describe three differences between plant and animal cells.

14 Give the function of a vacuole and in which organism's cells it is often found.

15 Describe how a nerve cell is adapted for its function.

16 Describe how the structure of red blood cells helps their function.

17 Define the term 'resolution'.



18 a) Name the two types of cell you can see in this photo (left, upper image).

b) Use the scale to estimate the length of the small cell.

c) Explain why the small cell might have relatively more mitochondria than the large cell.

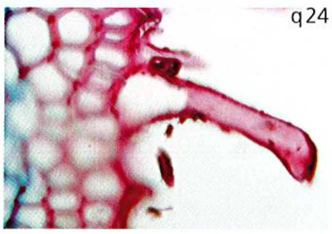
19 Explain why some cells have more mitochondria than other cells.

20 Define the term 'turgid'.

21 Explain which substances move out of animal cells.

22 Explain how xylem cells are adapted for their function.

23 How do many scientists think that prokaryotic and eukaryotic cells first evolved?



24 a) This cell (left, lower image) is 1.3 mm long. By how much has it been magnified?

b) Explain how this cell is adapted.

Practice questions

1 Orchids are often found growing high up on other plants. They are unusual plants in that some species have green roots.

a) Choose the name of the chemical substance that makes parts of plants green:

A chloroplast

B chlorophyll

C mitochondria

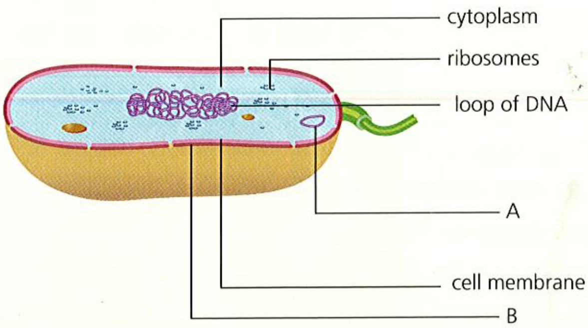
D ribosome [1 mark]

b) Suggest why orchids grow on other plants. [1 mark]

c) Suggest why some orchids have green roots. [3 marks]

d) Explain how root hair cells are adapted for their function. [3 marks]

2 Life exists on Earth as single-celled or multicellular organisms. Bacteria are single-celled organisms that grow in many places.



▲ Figure 1.18

a) Copy the diagram of a bacterial cell in Figure 1.18, and complete the missing labels. [2 marks]

b) Which of the following cell components is not found in prokaryotic organisms?

A cell wall

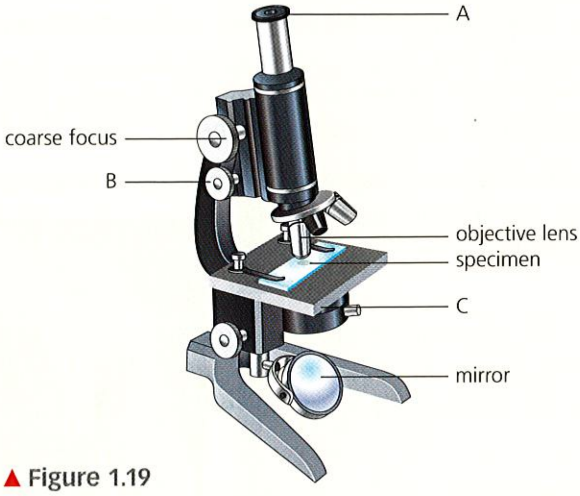
B DNA

C nucleus

D mitochondria [2 marks]

c) Name the process that keeps bacteria alive. [1 mark]

3 Microscopes have been around since the end of the 16th century. Their invention allowed us to see single-celled organisms for the first time and also understand that multicellular organisms are made up of many cells.



▲ Figure 1.19

a) Copy the diagram of a light microscope in Figure 1.19, and complete the missing labels. [3 marks]

b) Choose the part of the microscope that light first passes through:

A fine focus

B objective lens

C eyepiece lens

D slide [1 mark]

c) How is the total magnification of a light microscope calculated? [1 mark]

d) Describe two differences between a light microscope and an electron microscope. [4 marks]

4 Describe the similarities and differences between prokaryotic cells and eukaryotic plant and animal cells. [6 marks]

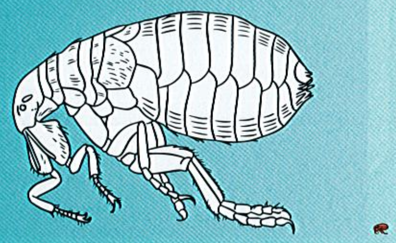
Working scientifically: Dealing with data

Microscopy and magnification

It is important that you can carry out calculations involving magnifications, real size and image size.

Magnification is a measure of how many times an object has been enlarged. If a sesame seed is actually 3 mm long, but in a diagram has been drawn to be 3 cm long, then it has been magnified 10 times. You can work out magnification using the formula:

$$\text{magnification} = \frac{\text{image size}}{\text{actual size}}$$



For example, this drawing of a flea is 40 mm long but the actual flea is 2 mm.

To work out the magnification the above formula is used:

$$\text{magnification} = \frac{40\text{ mm}}{2\text{ mm}} = \times 20$$

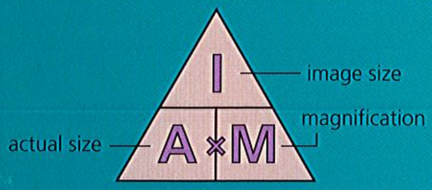
Sometimes you might want to know the actual size of an object if you know the magnification and size of the image. To work this out the formula for magnification can be rearranged:

$$\text{actual size} = \frac{\text{image size}}{\text{magnification}}$$

Also, you might need to work out what image size would be produced if you were given the actual size of the image and its magnification:

$$\text{image size} = \text{actual size} \times \frac{\text{magnification}}{\text{magnification}}$$

A formula triangle can be used to help you rearrange the equation.



TIP

It is really important to ensure that measurements are always in the same units. So if you have mixed units you will need to convert them all to the same format.

Questions

1 What is the magnification of this spider?
2 If a pinhead measures 1.8 mm and is magnified ×12.5, how large would the image be?
3 If an image of a snake's fang is 22.5 cm and it has been magnified ×7.5, how large is the actual fang?
4 What is the actual size of this frog's eye if the image has been magnified ×1.5?

TIP
Cell lengths are usually measured in μm (micrometres). Sub-cellular structures can be measured in mm or nm (nanometres), depending on their size.

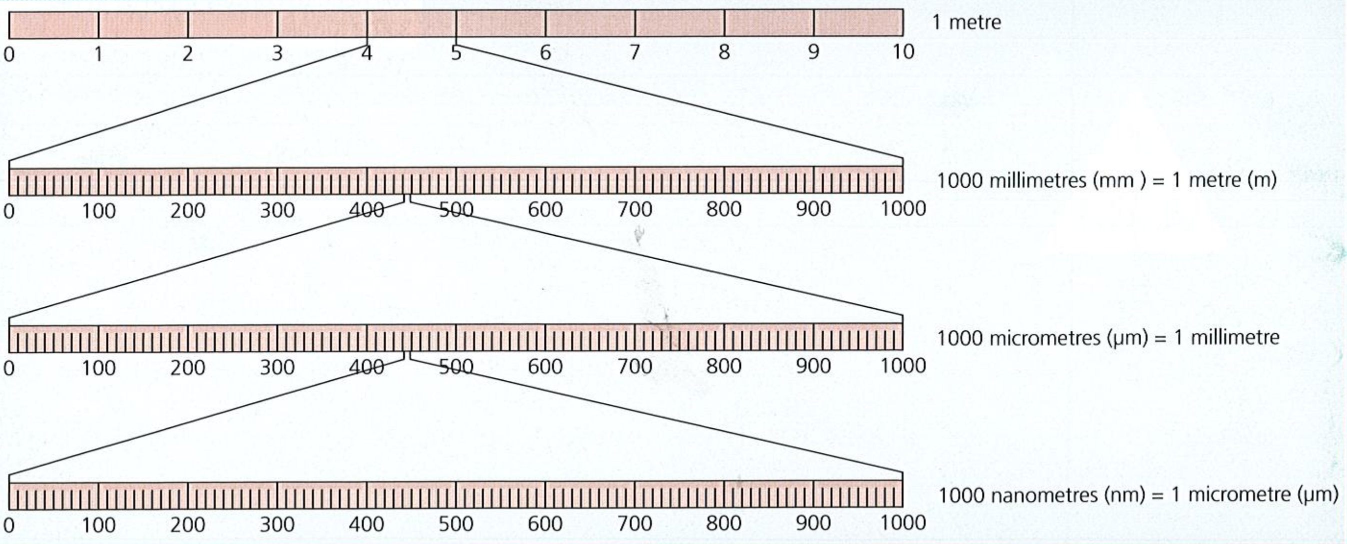
Extension

Often the actual object being studied is too small to be measured using a ruler, which means that a scale lower than a millimetre is needed. A micrometre (μm) is a thousandth of a millimetre and a millionth of a metre.

Using standard form, this can be written as:

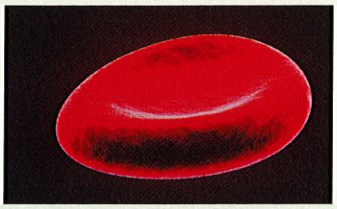
$1\,\mu m = 1 \times 10^{-3}$ mm and

$1\,\mu m = 1 \times 10^{-6}$ m.



Question

What is the actual size of this red blood cell if it has been magnified ×6000?



Example

If the actual size of this cheek cell is 60 µm, by how much has it been magnified?

- First measure the size of the cell in mm. In this micrograph, the cell is 45 mm wide.
- Then convert this to µm by multiplying by 1000.

  So 45 × 1000 = 45 000 µm
- To work out the magnification:

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

$$\text{magnification} = \frac{45\,000}{60}$$

$$\text{magnification} = \times 750$$