



# Life under a microscope

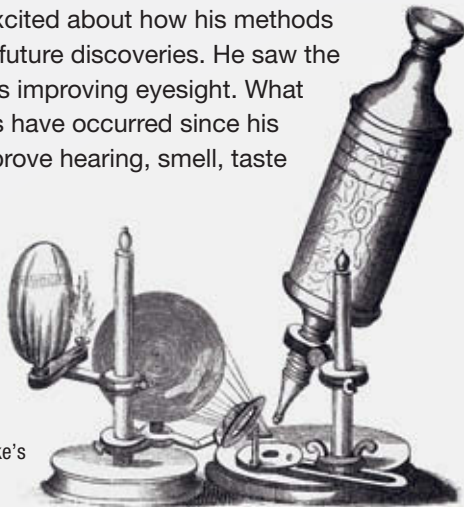


## How do we know about cells?

*It is the great prerogative of Mankind above other Creatures, that we are not only able to behold the works of Nature, or barely to sustain our lives by them, but we have also the power of considering, comparing, altering, assisting, and improving them to various uses ... By the means of Telescopes, there is nothing so far distant but may be represented to our view; and by the help of Microscopes, there is nothing so small as to escape our inquiry; hence there is a new visible World discovered to the understanding.*

The paragraph above is a section from Robert Hooke's *Micrographia*. He was the first man to discover and describe cells in 1665.

- 1 Why do you think it was such a big deal to have seen microscopic structures?
- 2 Hooke was excited about how his methods could lead to future discoveries. He saw the microscope as improving eyesight. What developments have occurred since his lifetime to improve hearing, smell, taste and touch?



→ Fig 1.1 Robert Hooke's microscope.



## What do we know about cells?



Living things are all around us. We can see them grow and change, get sick and die, or even reproduce. Scientists have made many observations of living things over many thousands of years. They can identify what has gone in and what has come out. They can see big changes and predict future changes. However, it was not until the development of the microscope that scientists fully appreciated the tiny building blocks that make up living things. In fact, the microscope opened their eyes to a new world of miniature life forms.



The human body is made up of approximately 200 different types of cells, each with a different job. However, humans start off life as a single cell, which becomes a ball of similar cells. Eventually, the cells are ‘given’ their special jobs and they change to suit these jobs. Cells that haven’t become specialised yet are called **stem cells**. Different types of stem cells differ in their ability to change into other types of cells. Scientists have discovered so much about cells since the days of Robert Hooke that they are now looking at ways to manipulate stem cells. Imagine being able to grow skin cells in a Petri dish—scientists are already doing this! What a fabulous development for burns victims!

- 1 If a stem cell is a cell without a job, describe an analogy (similar situation) using people instead of cells.
- 2 Do you think a part of your body that is constantly making new cells would have more or less stem cells? Explain.
- 3 Some stem cells are found only in embryos. What issues might arise from this?

→ Fig 1.2 Skin being grown in a Petri dish.

## 1.3

### How do cells work together?

Your body is incredibly complicated. It is made of so many parts performing so many functions that learning about it can be a little overwhelming. Sometimes it helps to relate complicated things to something you are already familiar with; that is, to create an *analogy*.

Think of the human body as a big city. It has lots going on: different structures, people working in different jobs, communication and transport systems for connecting different areas, products being imported and made, wastes being created and disposed of and, all the time, it needs to respond to what is happening in the rest of the world.

- 1 From what you know about your body, do you think a city is a good analogy?
- 2 What would happen if people didn’t ever work together in a city?
- 3 Think of five jobs your body undertakes. What would they be similar to in the city analogy?

→ Fig 1.3 Melbourne skyline.





# How do we know about cells?



Scientists haven't always known that living things were made up of cells. Until recently, scientists were trying to understand the behaviour of the different types of matter in our bodies. Some theories, such as that of Hippocrates around 400 BCE, involved a balance of different types of matter making us normal, crazy, intelligent or even dead!

It was the invention of the microscope in the mid-17th century that finally helped scientists work out a reliable way of telling a living thing from a non-living one. The microscope allowed us to see the building blocks of life—the tiny units that form every living thing, from the smallest microscopic bacteria to the tallest eucalypt tree. Microscopes showed that each and every living thing is made up of **cells**.

## ◀DISCOVERING IDEAS▶

### Under the microscope

Use the stereomicroscopes that have been set up by your teacher to look at a drop of water from a pond.

- What do you think you are likely to see?
- Does it look like there's anything in the water?
- If you see something, draw it and try to explain what it may be.
- Share your discoveries with the class.





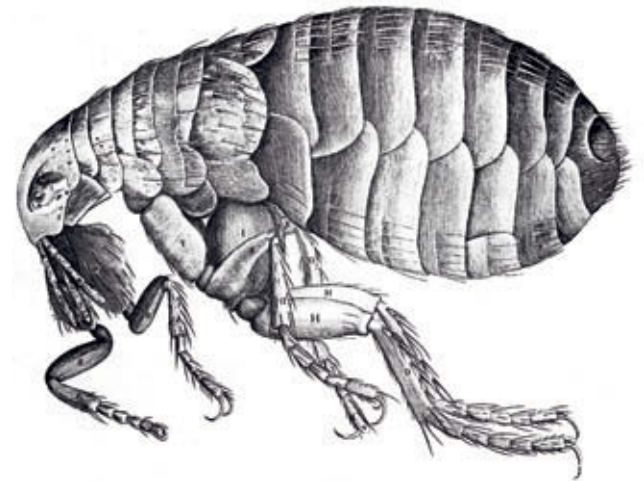
# Discovering cells

When Robert Hooke published his book *Micrographia* in 1665 it became a best seller. Hooke had made one of the first microscopes. With it, he observed many types of living things and made accurate drawings of what he saw, as his detailed picture of the flea shows (Figure 1.4).

Hooke's most famous achievement, as far as science was concerned, was his diagram of very thin slices of cork (Figure 1.5). He was surprised to see that, under the microscope, the cork looked like a piece of honeycomb. He described the 'holes' and their boundaries in the 'honeycomb' as cells because they reminded him of the rooms in a monastery. Hooke had discovered plant cells.

Although some called *Micrographia* 'the most ingenious book ever', others ridiculed Hooke for spending so much time and money on 'trifling pursuits'. Thankfully for us, and for the whole science of microbiology, which developed from this discovery of cells, Hooke ignored the taunts and kept experimenting with microscopes.

It was because of Hooke's important contribution to microbiology that other scientists went on to develop a further understanding of cells.



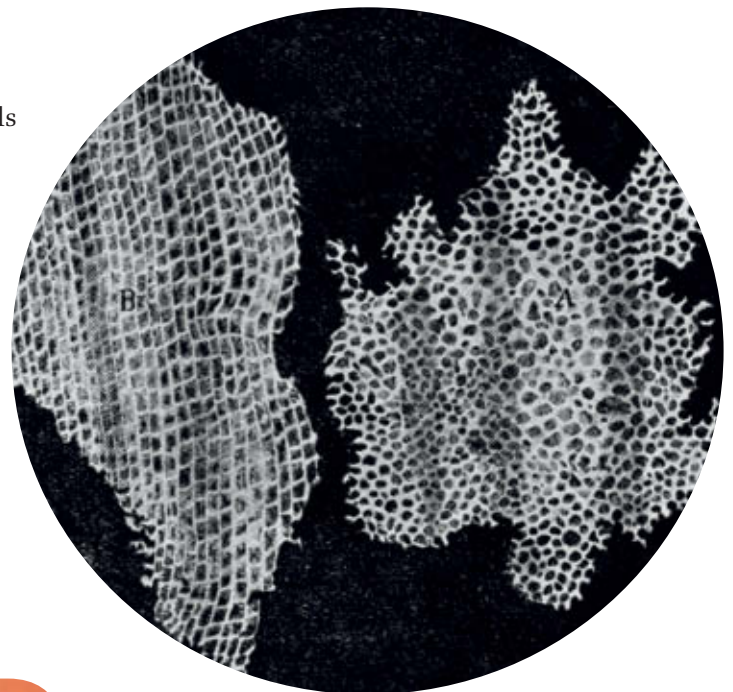
→ Fig 1.4 Robert Hooke's drawing of a flea.

## Cell theory

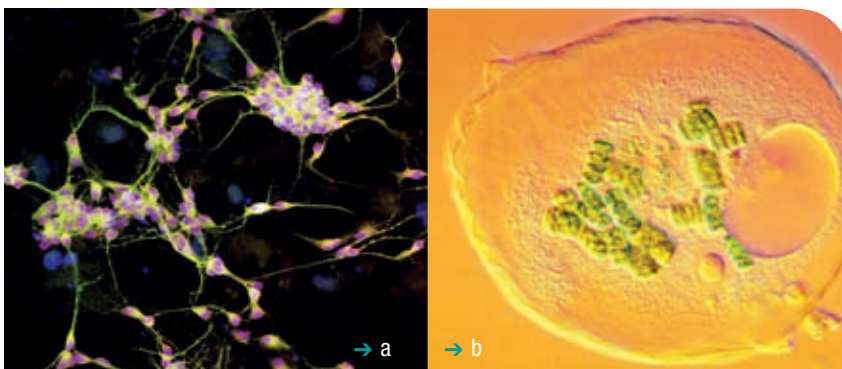
**Cell theory** describes the main ideas about the importance of cells and their role in living things. It was first proposed in 1839 by two German biologists, Theodor Schwann and Matthias Schleiden. In 1858, Rudolf Virchow concluded the final part of the classic cell theory. The combined cell theory included the following three principles:

- all organisms are composed of one or more cells
- cells are the basic unit of life and structure
- new cells are created from existing cells.

Any living thing that has more than one cell is referred to as multicellular, but there are many living things, such as bacteria, that consist of only one cell! These are called single-celled or unicellular organisms. Micro-organisms are often referred to as microbes.



→ Fig 1.5 Robert Hooke's drawing of cork.



→ Fig 1.6 (a) Human nerve cells make up multicellular humans, but (b) the amoeba survives as a unicellular organism.

## Looking at different cells

Several stations are set up around the laboratory with microscopes adjusted to show different kinds of cells.

Do not attempt to adjust any of the microscopes! Ask your teacher or laboratory technician to adjust the microscope if you think it has been bumped or has gone out of focus.

- 1 Look carefully at each specimen. Write down its name and a sentence that describes what you see.
- 2 Make a very simple pencil sketch of a part of the cells you see. For example, if there are many layers or rows of cells, just draw three or four layers.
- 3 If you can see anything inside a cell (it may only be a dark dot), mark this on your sketch.
  - Which cells, in your opinion, were the most unusual?
  - Which cells had very obvious walls around them?
  - Which cells were the smallest?
  - Which cells were the largest?
  - How did your view through the microscope compare with the images of the cells in Figure 1.6?
  - Describe some of the difficulties of drawing cells seen through a microscope.

## What do you know about discovering cells?

- 1 Can cells be seen without a microscope?
- 2 Who invented the first microscope?
- 3 Why are cells called 'cells'?
- 4 Name an organism that is made up of just one cell.
- 5 What does *multicellular* mean?
- 6 Name five multicellular organisms.
- 7 Why was the invention of the microscope important to our understanding of living things?
- 8 What are the three principles of the combined cell theory?

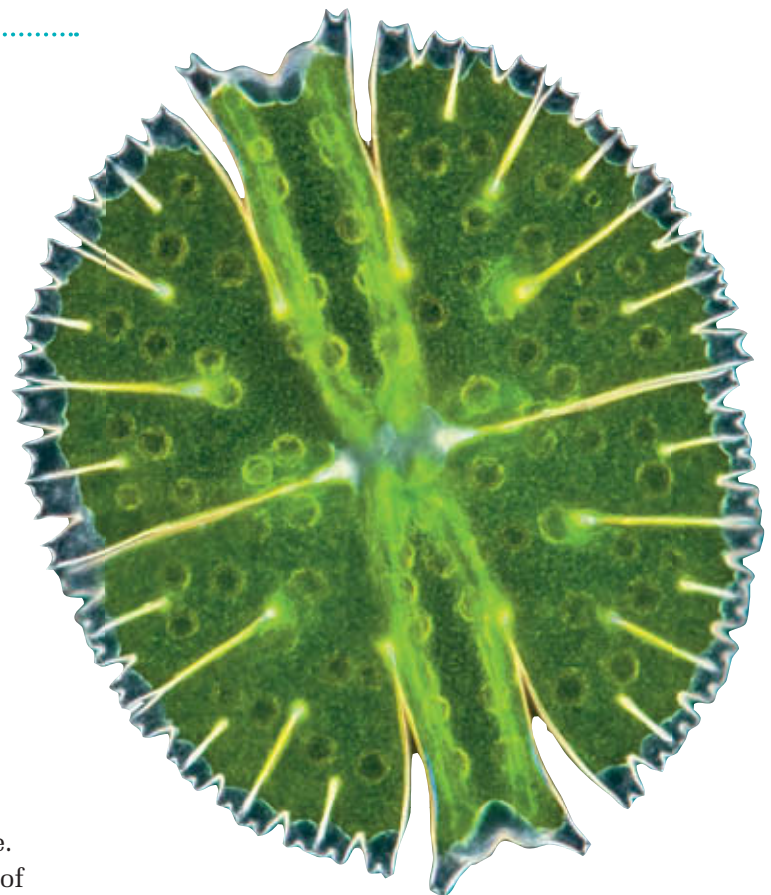
## Limitations to cell size

Have you ever considered why single-celled organisms are so small? A single cell must meet all the requirements of a unicellular organism. The cell's skin or membrane is particularly important because it provides a barrier between the inside of the cell and the external environment. The materials required for cell functioning and the waste products produced by these processes are all transported across the cell membrane. It is essential that the cell membrane provides a large surface area for the transport of so many molecules into and out of the cell.

## Why are cells so small?

The surface of a cell is its cell membrane. Substances inside and outside the cell move across the membrane covering the cell. Cells need to maximise their surface area to make sure they maximise their ability to exchange substances with their environment.

The total space inside the cell is referred to as the cell's volume. As a cell increases in size, its volume increases. A comparison of these two values as a fraction—the **surface area to volume ratio**—reveals exactly why cells are limited in size.



→ Fig 1.7 The irregular shape of unicellular desmids maximises their surface area to volume ratio.



## Calculating the surface area to volume ratio

To calculate the surface area of an object, calculate the surface area of each side and then add the values for all sides together.

The surface area of one side of the green cube shown in Figure 1.8 is:

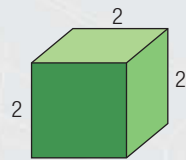
$$2 \times 2 = 4 \text{ cm}^2$$

There are six equal sides, so the total surface area is:

$$4 \times 6 = 24 \text{ cm}^2$$

### Example

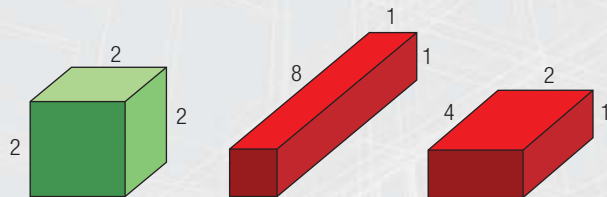
→ Fig 1.8



### Your turn

- 1 Volume = height × width × length. Calculate the volume for all three shapes shown in Figure 1.9. Is the volume the same for the three shapes?
- 2 What is the surface area for each shape?
- 3 Which shape has the greatest surface area to volume ratio?

→ Fig 1.9



### Answers

- 1  $8 \text{ cm}^3$ ,  $8 \text{ cm}^3$ ,  $8 \text{ cm}^3$     2  $24 \text{ cm}^2$ ,  $34 \text{ cm}^2$ ,  $28 \text{ cm}^2$     3  $8:24$ ,  $8:34$ ,  $8:28$

## What do you know about limitations to cell size?

- 1 What is the surface area of a cell?
- 2 How does the surface area:volume ratio limit cell size?
- 3 Would a cell with a bigger surface area:volume ratio be able to meet its requirements for nutrients more effectively? Why or why not?

## Structures matter

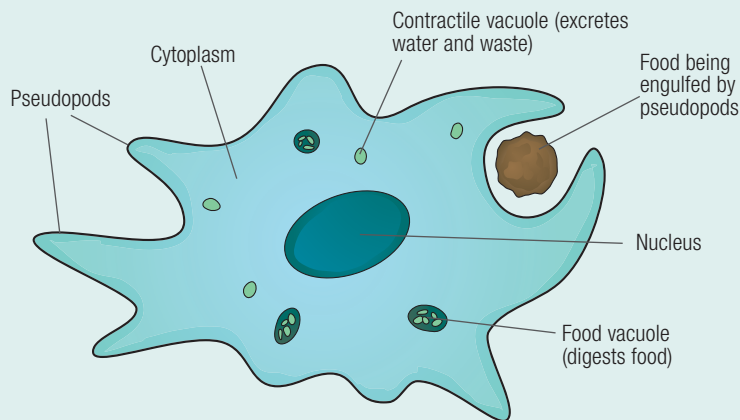
### Form and function

Protists are an extremely diverse group of organisms that are mostly unicellular. Many live in water, some are photosynthetic (i.e. make their own food, like plants), some are herbivores and some are parasites. Depending on the lifestyle and food source of the organism, the form or structure of its cell will have evolved to suit.

The following protists have structures particular to their lifestyles.

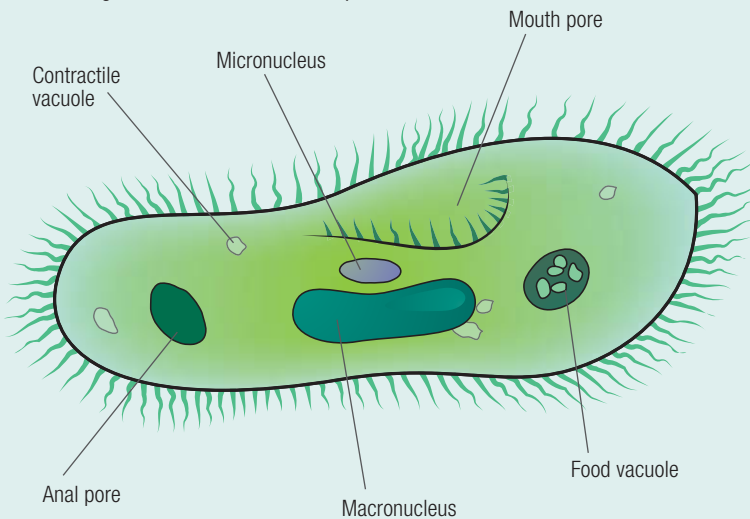
- 1 An *amoeba* can change the shape of its blobby body, creating foot shapes for movement and mouth shapes for swallowing food.

→ Fig 1.10 General structure of an amoeba.



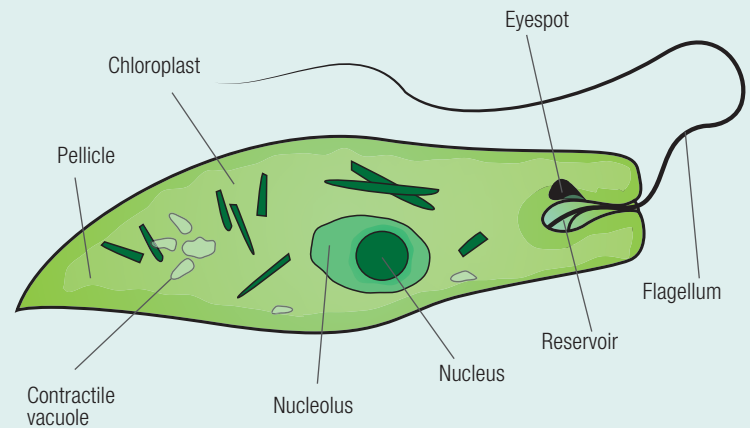
- 2 The *paramecium* plods along slowly with lots of tiny hairs called cilia that act like miniature oars.

→ Fig 1.11 General structure of a paramecium.



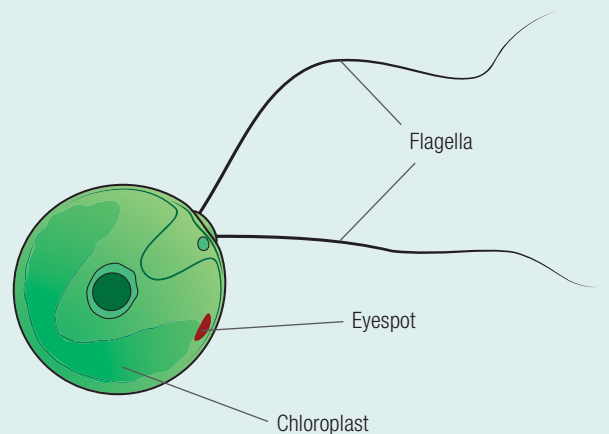
- 3 *Euglena* moves really quickly when it needs to, with a bullet-shaped body and a long tail called a flagellum to whip it into action.

→ Fig 1.12 General structure of euglena.



- 4 *Chlamydomonas* has an eye spot that can detect light for photosynthesis and two flagella that help it swim along in a breaststroke-like motion.

→ Fig 1.13 General structure of chlamydomonas.





# Microscopy

You probably know people who wear glasses to help them read. The glass or plastic lenses magnify the size of the text. In the same way, **microscopes** magnify the size of the object placed under them.

The first microscopes were very basic. However, over time their magnifying ability has improved. Scientists can now look at images that have been magnified thousands of times using various systems of lenses. This makes it possible to study the structure of cells.

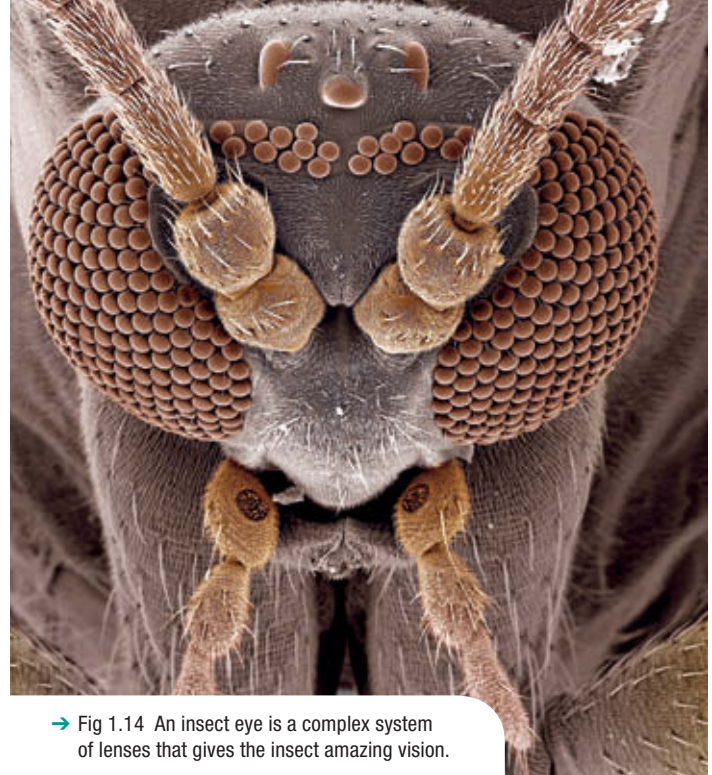
## Types of microscopes

As a science student, you will probably use two types of light microscope: the stereomicroscope and the compound light microscope.

The stereomicroscope is used for viewing larger objects, such as insects (Figure 1.15). It can magnify up to 200 times and shows a three-dimensional view of small things.

The compound light microscope (Figure 1.16) is used to observe thin slices of specimens, such as blood cells. It can magnify up to 1500 times. Its view is flat—that is, two dimensional. The specimen must be thin enough to allow light to pass through it.

The stereomicroscope has two **eyepieces** to look through, whereas the compound light microscope can have one or two eyepieces. The word *monocular* is used to describe a microscope with one eyepiece (mono = one). Microscopes with two lenses are called binocular (bi = two). The compound light microscope uses the



→ Fig 1.14 An insect eye is a complex system of lenses that gives the insect amazing vision.

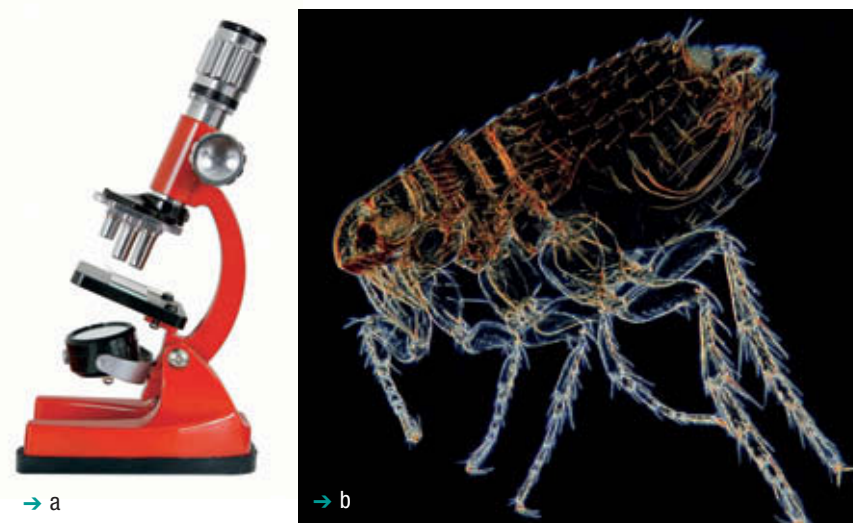
effect of two lenses (one in the eyepieces and one further down the column called the **objective lens**) combined with light to give a greater magnification. It can be used to observe much smaller things than those seen under a stereomicroscope.

## Looking at cells

To look at cells clearly through a compound light microscope, very thin layers of a sample must be used. The light has to be able to get through or all you will see is a dark shadow—a bit like a leadlight window. Most cells are clear in colour, so a **stain**, like iodine, is used to help make them more visible by providing contrast.



→ Fig 1.15 (a) A stereomicroscope. (b) An insect, as seen under a stereomicroscope.



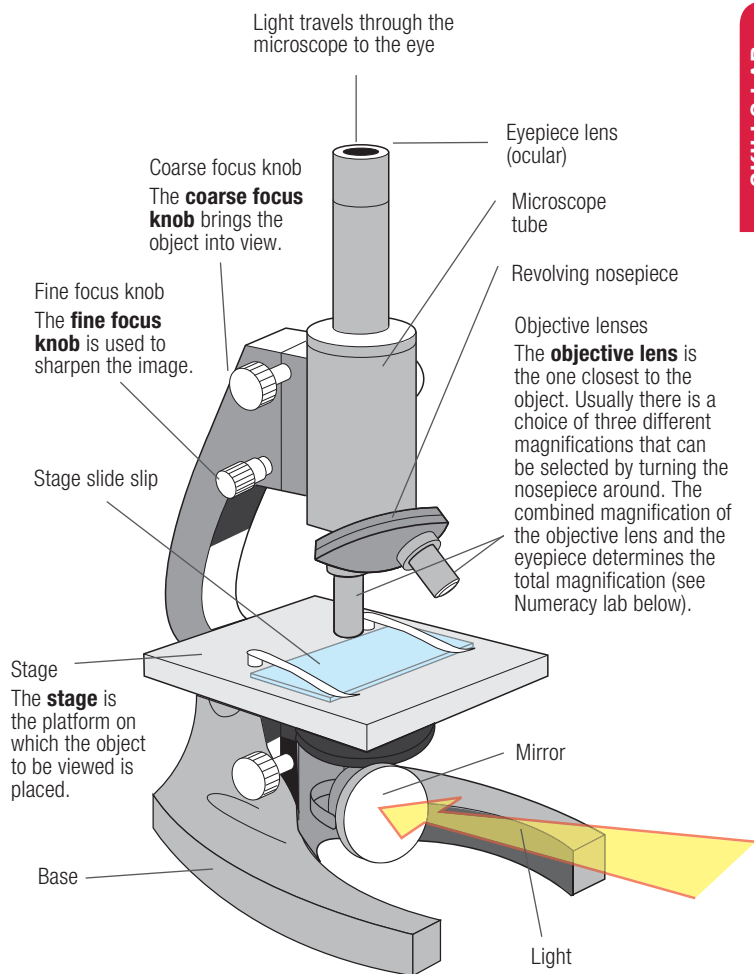
→ Fig 1.16 (a) A compound light microscope. (b) A flea, as seen under a compound light microscope.



## Ten tips for using a microscope

Microscopes are expensive, fragile instruments. They need to be handled carefully and used properly if they are going to help you see the microscopic world.

- 1 Always use two hands to carry a microscope—one hand should be around the main part of the instrument and the other underneath it.
- 2 Some microscopes have a built-in lamp. Others have separate lamps that need to be set up so they shine onto the mirror. Adjust the mirror to project the light through the stage onto the specimen. Do not allow sunlight to shine directly up the column.
- 3 Place the slide on the stage then select the objective lens with the lowest magnification first.
- 4 Look from the side and adjust the coarse focus knob so that the objective lens is *just above*—and *not touching*—the slide. Check which way you must turn the knob to move the objective lens away from the slide.
- 5 Use the coarse focus knob to bring the specimen into view. Then use the fine focus knob to help you see it more clearly.
- 6 If you want a higher magnification, rotate the objective lens to a higher magnification.
- 7 Draw what you see (as a record) using a pencil.
- 8 Work out the total magnification.
- 9 Write the magnification next to your sketch.
- 10 Label and date the sketch.



→ Fig 1.17 Parts of a compound light microscope. This example is monocular because it has only one eyepiece.

## Working out magnification

To calculate the total magnification of a compound light microscope, multiply the magnification of the eyepiece lens by the magnification of the objective lens. These figures are marked on each lens.

### Example

Eyepiece magnification	Objective lens magnification	Total magnification
×5	×10	×50
×10	×20	×200

### Your turn

- 1 You need a magnification of ×100. What magnification should you use for your objective lens if your eyepiece magnification is ×5?
- 2 A photo of a slide under a microscope says it has been taken at a magnification of ×200. What combination of eyepiece and objective lens magnifications was used?
- 3 To view a slide at a magnification of ×100, what combinations of lenses are possible?

Answers 1 ×20 and ×10 2 ×5 and ×20; ×10 and ×10 3 ×5 and ×20



EXPERIMENT 1.1

# Getting to know your microscope

## Aim

To experiment with a compound light microscope.

## Materials

Compound light microscope  
 Microscope slide  
 Coverslip  
 Small piece of newspaper  
 Small piece of tissue paper  
 Hair (use your own)  
 1 cm sticky tape (transparent)  
 Eyedropper  
 Small beaker of water

## Method

- 1 Cut out two small words from a piece of newspaper.
- 2 Place the cut out newspaper on the microscope slide and add two drops of water to help it 'stick' to the slide. Place a coverslip on top. This is called a **wet mount**.
- 3 Follow the instructions for using a microscope on page 10. On the lowest magnification, find one letter from the newsprint to focus on.
- 4 Move the slide slightly towards your body and observe what happens.
- 5 Move the slide slightly to the left and observe what happens.
- 6 Change the magnification and observe what happens.
- 7 Draw a diagram of the newspaper letter.

Take the newspaper out and prepare another slide using the tissue paper. Make sure the drop of water is added and the coverslip is placed over the top carefully.

- 9 Sketch what you see.

- 10 Repeat with sticky tape and then a hair from your head.

## Results

Include your diagrams here.

## Discussion

- 1 Describe what the newspaper letter looks like through the microscope. What does this mean for all things you see through this type of microscope?

### Cause

What did you do to cause the change you observed?



### Effect

What effect did it have?

→ Fig 1.18 Cause-and-effect graphic organiser.

- 2 What features could you see on the tissue paper and sticky tape that you could not see with the naked eye?
- 3 Use a series of cause-and-effect graphic organisers, similar to that shown in Figure 1.18, to record the results of your experiment when you moved the slide different ways. For example, the cause link may be 'move the slide to the left'. Then write what happened in the effect link.

## Conclusion

What do you know about compound light microscopes?



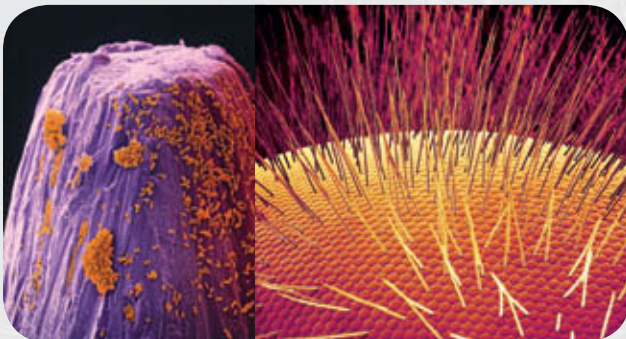


# Bigger and better microscopes

Although light microscopes, like the compound light microscope and stereomicroscope, had served scientists well for more than 300 years, the explosion of new technology in the 20th century led to the invention of more complex microscopes, such as electron microscopes.

An electron microscope uses electrons (tiny negatively charged particles) to create images. The first electron microscope, the transmission electron microscope (TEM), was invented in 1933 to help study the structure of metals. The scanning electron microscope (SEM), developed later, uses a beam of electrons to scan across a specimen and to recreate the image, showing details of its surface.

Electron microscopes can magnify up to a million times! Using this technology, many more details of the cell that were formerly invisible to scientists are now beginning to be understood.



→ Fig 1.19 These images were taken through an electron microscope. Can you guess what they are?



→ Fig 1.20 Using an electron microscope.

## The synchrotron

The development of the synchrotron is one of the biggest changes to microscopes. Synchrotrons are 'microscopes' that are about the size of a football field and cost a fortune to build.

The synchrotron provides even more magnification than an electron microscope and can 'see' down to the level of the molecules (particles) that make up substances. There are currently forty-three synchrotrons across the world. Australia's synchrotron opened in 2007 and is located near Monash University, in Melbourne. There are many beneficial applications of synchrotron science. For example, researchers can use the synchrotron to invent ways to tackle diseases, make plants more productive and metals more resilient.

## Questions

- 1 What extra magnification can be gained by using an electron microscope compared with a light microscope?
- 2 Compare the two photographs taken through a light microscope and an electron microscope (Figure 1.21). Describe what the electron microscope adds to the view of a normal light microscope.
- 3 Where is Australia's only synchrotron?
- 4 Find out more about one of the research projects currently being assisted by the Australian synchrotron.



→ Fig 1.21 (a) Flea cells seen through a compound light microscope. (b) The same flea cells seen through a transmission electron microscope.



# Different microscopes, different images

Images from microscopes will vary quite dramatically. Different microscopes produce different types of images because of the magnification, the way a specimen must be prepared, the way the specimen is treated by the microscope and the materials used in the process of viewing the specimen.



→ Fig 1.22 Stereomicroscope (SM).



→ Fig 1.23 Compound light microscope (LM).



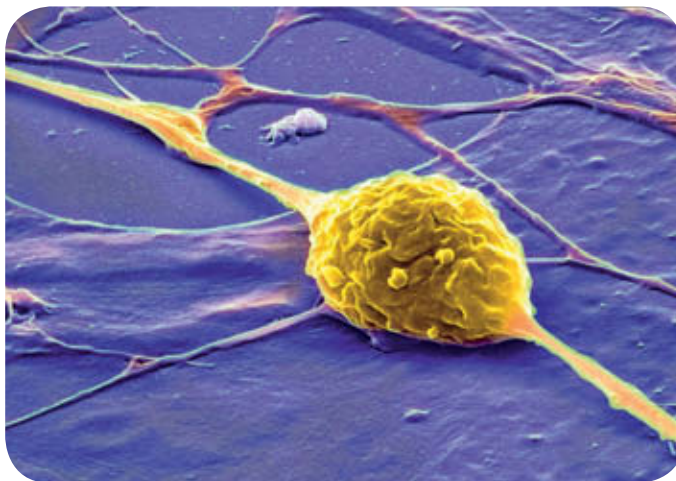
→ Fig 1.24 Scanning transmission electron microscope (STEM).



→ Fig 1.25 Scanning electron microscope (SEM).



→ Fig 1.26 SM image of a wasp.



→ Fig 1.27 SEM image of a nerve cell.



→ Fig 1.28 LM image of a hair root.

## Plant and animal cells

By looking at different characteristics of plants and animals, it's fairly easy to see that they are different types of organisms. It's not hard to tell an apple from an elephant! However, once microscopes started to become more powerful, suddenly scientists could see that there were differences between plant and animal cells (Figure 1.29). This made sense. If cells are the building blocks and the basic units differ, then the final living things will show different characteristics.



→ a



→ b

→ Fig 1.29 Typical (a) plant and (b) animal cells.



### EXPERIMENT 1.2

## Plant and animal cells

### Aim

To compare plant and animal cells.

### Materials

Light microscope  
Microscope slide  
Coverslip  
Iodine in dropper bottle  
Brown onion  
Prepared slide of animal cells

### Method

- 1 Peel off a very thin piece of brown onion skin so that it looks a bit like cling film.



→ Fig 1.30

- 2 Place the skin on the microscope slide and add a tiny drop of iodine. This stains parts of the cells to make them easier to see.



→ Fig 1.31

- 3 Place one edge of the cover slip onto the slide and carefully lower it so that no air bubbles get trapped underneath.
- 4 Place the slide on the stage.



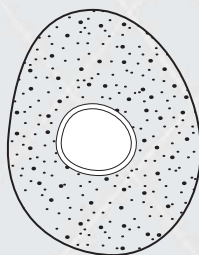
→ Fig 1.32



# Specimen diagrams

What you see through a microscope is not always easy to represent in a sketch. Compare the diagram of an animal cell (Figure 1.33) with the image shown in Figure 1.29.

The diagram is, in many ways, like a summary or a simplification of what you see through the microscope. It is impossible to draw all the cells you see, so select those that seem to be typical and try to show how they fit together.



→ Fig 1.33 Diagram of an animal cell.

## Tips for specimen diagrams

- 1 Always use a sharp lead pencil so you can erase and modify your diagram. Never colour or shade areas; if absolutely necessary, use dots or lines instead.
- 2 All diagrams should be large enough to view the details. Try to use about a quarter of a page for each diagram.
- 3 Draw a circle to represent your viewing area.
- 4 Use clear labels and appropriate scientific language.
- 5 Write the specimen name, date and magnification outside the circle.

## 5 Focus the microscope.



→ Fig 1.34

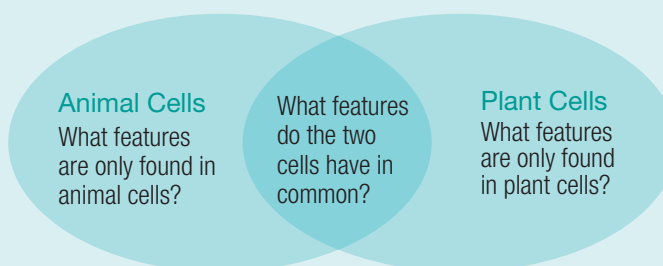
- 6 Draw the cells you observe. Don't forget to label your diagram and write down the total magnification.
- 7 Remove the slide and place the prepared slide of animal cells under the microscope. Focus the microscope.
- 8 Draw the cells you observe.
- 9 Write down the total magnification and label the diagram.

## Results

Include your cell diagrams here.

## Discussion

- 1 What is the purpose of staining the onion skin cells?
- 2 What kind of living thing did the onion skin come from?
- 3 Compare the two sketches you have prepared with the images of plant and animal cells in Figure 1.29. List any differences and similarities.
- 4 Use the Venn diagram in Figure 1.35 to show how plant and animal cells are similar and how they are different.



→ Fig 1.35

## Conclusion

What do you know about plant and animal cells?



## What do you know about using microscopes?

- 1 What type or types of microscope have you used in your science class?
- 2 Write a short description of each type of microscope you have used, including whether it is monocular or binocular, its maximum magnification and what it is used to view.
- 3 Why do you look from the side when you adjust the coarse focus knob?
- 4 What is a wet mount? How is one prepared?
- 5 Explain why it is important to label and date your specimen drawings. Give three different reasons.
- 6 Why must very thin samples be used under a light microscope?
- 7 What is *microbiology*?
- 8 Complete the following magnification table for a compound light microscope by working out the missing values:

Eyepiece	Objective lens magnification	Total magnification
×5		×100
	×20	×300
×10	×50	
×30		×450
×5	×100	

- 9 Prepare a microscope safety postcard that you could mail to a science student at another school.
- 10 Complete Venn diagrams similar to Figure 1.35 on page 15, for stereomicroscopes and compound light microscopes.



## 1.1

## How do we know about cells?



### Remember and understand

- 1 Who was the first to describe cells?
- 2 What type of cells were the first cells to be drawn?
- 3 What is the cell theory?
- 4 When would you use a stereomicroscope instead of a compound light microscope?
- 5 Why does a specimen need to be really thin to be viewed under a light microscope?

### Apply

- 6 What are the different lenses on a compound light microscope? Why are there different lenses?

### Analyse and evaluate

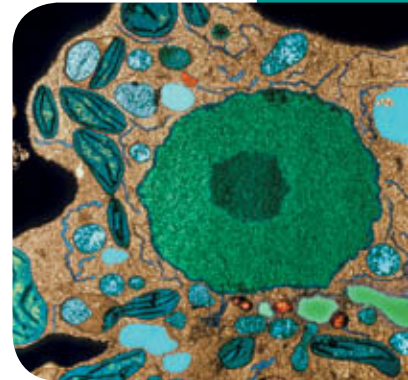
- 7 Make up a table that compares the similarities and differences between light microscopes and electron microscopes.
- 8 Explain why unicellular organisms are always tiny and multicellular organisms are made up of so many cells.
- 9 Investigate why the image you see through a compound light microscope, but not a stereomicroscope, is upside down and back to front.
- 10 Light microscopes allow you to view living cells. Electron microscopes view either dead cells or cells that have been killed in the process of viewing them. In what situations might light microscopes be preferable to electron microscopes? Explain.

- 11 Identify the microscope most likely to have created the images in Figure 1.36.

→ a



→ b



→ c



→ d



→ Fig 1.36

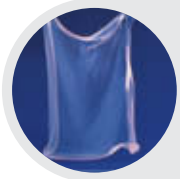
### Critical and creative thinking

- 12 Use the lenses from an old pair of reading glasses to create a model of a light microscope. Describe how your model is similar and different to Hooke's microscope and modern compound light microscopes.

## <<CONNECTING IDEAS>> Structure and function

- 13 a How has our understanding of how living things function changed with the development of the microscope?  
b Is living matter different from non-living matter? Explain?





# What do we know about cells?

One of the characteristics of an organism (living thing) is that it is composed of one or more cells. A cell is the basic unit of life. It is called this because it is the smallest unit of an organism that is considered living. But just as the basic unit of length—the metre—can be broken down into smaller parts (e.g. centimetres, millimetres, micrometres and even nanometres), the cell is made up of smaller parts too. Cells are made up of **organelles** (mini-organs), cytoplasm, DNA, nutrients, wastes and other substances. In scientific terms, a cell is actually quite big and it is made up of a lot of smaller parts that help it do its job.



## ◀DISCOVERING IDEAS▶

### Under the microscope

Working in small groups, brainstorm the different jobs that a living organism would undertake to stay alive and be successful.

- Do you think the jobs you've listed apply to all organisms?
- Do you think the jobs of a cell will be similar or different to your list for an organism? Explain.
- Share your thoughts with the rest of the class.

### Cell structures

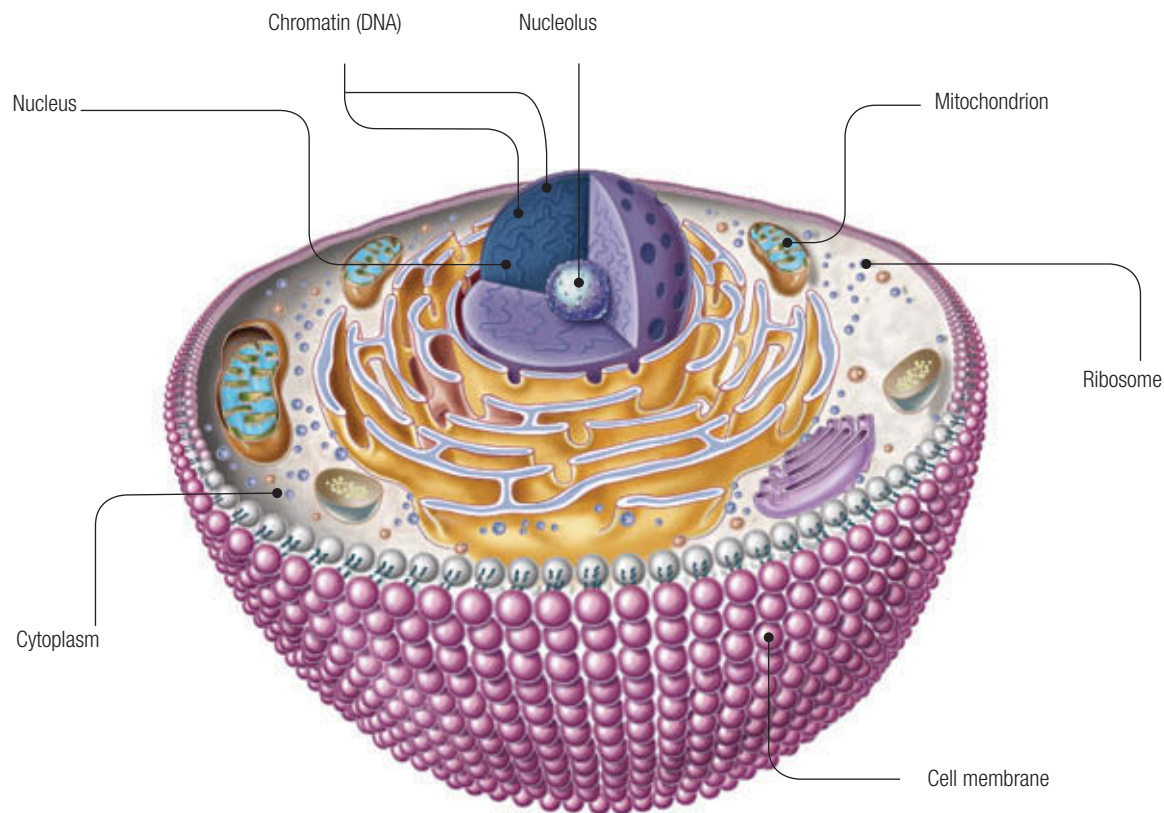
All cells, regardless of which type of organism they are found in, share the same basic structure. This basic structure includes three key features:

- **Cell membrane**—this acts like the 'skin' of a cell, forming a barrier around the cell. It controls the entry and exit of things into and out of the cell.
- **Cytoplasm**—this is the 'jelly-like' fluid inside the cell membrane that surrounds everything inside the cell. It helps provide structure to the cell and contains many dissolved nutrients and waste products.
- **DNA** (deoxyribonucleic acid)—this contains the instructions for every job your cells need to do and is passed from one generation to the next. The code for half your DNA came from your mother, whereas the other half came from your father. The same complete set of DNA is found in every one of your cells.

The main parts of cells and their functions are listed in Table 1.1. A diagram of an animal cell is shown in Figure 1.37.



Part of cell	Function
Cell membrane	The cell membrane controls the entry and exit of things into and out of the cell and is covered in substances that help cells identify each other.
Cell wall	The cell wall is a layer surrounding the cell membrane that provides strength and structure to the cell. Animal cells do not have a cell wall. Cell walls are very important structures in plant cells, especially small plants that don't have a woody stem.
Nucleus	The nucleus is the control centre of the cell. It is surrounded by a nuclear membrane to separate the contents of the nucleus from the rest of the cell. The nucleus contains codes and instructions in the form of deoxyribonucleic acid (DNA).
Cytoplasm	The cytoplasm is the fluid-like part of the cell inside the cell membrane but outside the nucleus. It contains the cell's mini-organs, or organelles, and many dissolved substances that may be involved in chemical reactions or as food storage for the cell.
Vacuoles	Vacuoles are separate storage compartments within the cytoplasm that contain a watery fluid. They are very important in plant cells because they help provide support and structure to the cell, which assists the plants in growing upright and displaying their leaves to the Sun.
Ribosomes	Ribosomes are the site of protein production in the cell. Proteins are small molecules with many different roles. There are many different types of proteins. For example, some proteins are structural proteins (e.g. hair and nails), others are globular proteins (e.g. haemoglobin, which is found in red blood cells and helps transport oxygen through the bloodstream) and others still are involved in chemical reactions and the cell's own structure.
Mitochondria	Mitochondria are the 'powerhouse' of the cell, supplying the cell with energy through a process called cellular respiration.
Chloroplasts	Chloroplasts are found in plant cells and in some microorganisms. Their pigments are able to absorb the energy from the Sun to form chemical energy, which can be used by the plant and any animals that eat that plant. Solar energy is reacted with carbon dioxide and water to form glucose (chemical energy) and oxygen. This process is called photosynthesis.



→ Fig 1.37 Some key parts (organelles) of an animal cell.



## EXPERIMENT 1.3

# Looking at organelles

## Aim

To prepare slides to view the organelles in the cells of a brown onion and an *Elodea* plant. You may wish to review Experiment 1.2 Plant and animal cells on page 14 for slide and microscope use.

## Materials

Onion wedge  
Leaf from an *Elodea* plant  
Light microscope  
Three glass slides  
Three glass coverslips  
Blotting paper  
Methylene blue stain or iodine  
Water

## Method

### Onion skin cell—unstained

Light microscopes depend on the light being able to pass through the specimen. When preparing a slide, it is important that the specimen is as thin as possible.

- 1 Between the fleshy layers of an onion there are some thin, transparent layers. These layers are one cell thick. Peel off a layer of this skin and put it onto a microscope slide.
- 2 Add one drop of water and then gently lower the coverslip so that no air bubbles are trapped.
- 3 Draw and label what you see. Try to identify the nucleus, which contains the DNA, and the cell membrane and cytoplasm.
- 4 Keep this slide for use in the next part of the experiment.

### Onion skin cells—stained

Stains are often used on specimens because they add contrast to the image. Some highlight a particular feature of the cell.

- 5 Use another thin layer of onion skin to prepare a second slide as above.
- 6 Add a drop of methylene blue stain or iodine instead of the water before lowering the coverslip carefully so that no air bubbles are trapped. Be careful not to get the stain on your skin or clothes because it is very hard to remove.

- 7 Draw and label what you see. How does the use of the methylene blue stain or iodine change the appearance of the onion cells?

### *Elodea* cells

- 8 Pick a small green *Elodea* leaf and put it onto a microscope slide.
- 9 Add one drop of water and then gently lower the coverslip so that no air bubbles are trapped.
- 10 Draw and label what you see. Try to identify the cell membrane and cytoplasm.
- 11 What other organelle is clearly visible in these cells?



## Results

Include your labelled diagrams in this section.

## Discussion

- 1 How does the use of a stain change the image of the onion cells?
- 2 Both types of cells viewed are from plants. Suggest why there are differences between each of the cell types. (Hint: Consider which part of the plant the cells come from.)
- 3 It is often difficult to identify the nucleus in the *Elodea* cells. Can you suggest why?
- 4 The *Elodea* cells contain another structure that is very prominent. What could be the role of this structure within the cell?
- 5 Can you suggest why it is not necessary to stain the *Elodea* cells?

## Conclusion

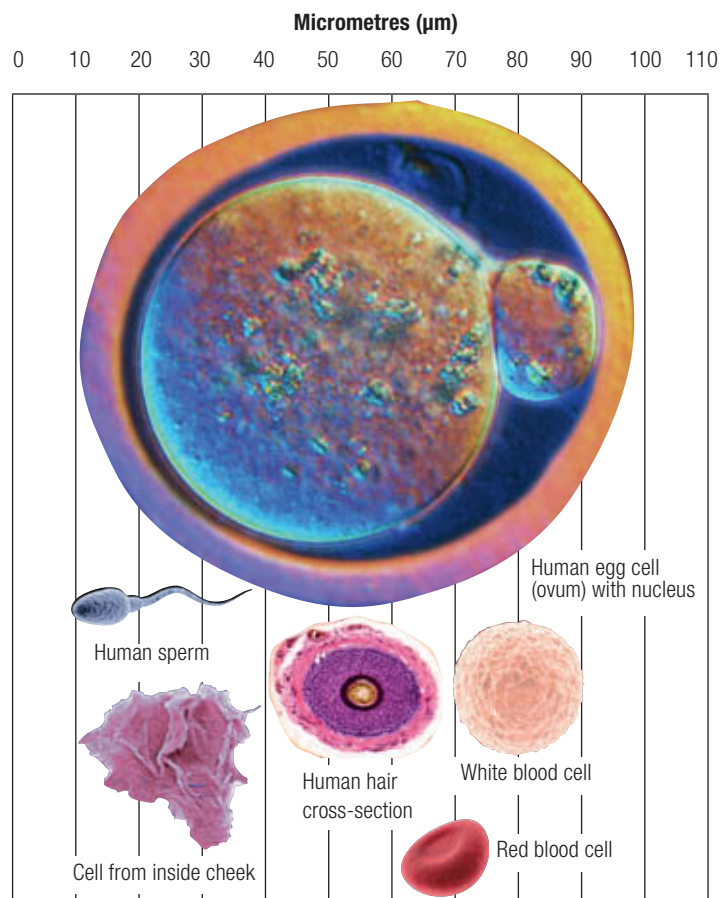
What do you know about the organelles in onion cells and *Elodea* cells?

## Measuring cells and their parts

If you were to measure the length of your bedroom, you would probably use metres as a unit of measurement. If you were measuring the distance between two houses in neighbouring suburbs, you would select kilometres as a unit of measurement. Selecting appropriate units of measurement means that you do not need to deal with numbers that are really large or really small. Can you imagine measuring the distance between Melbourne and Sydney in millimetres? Because cells are microscopic in size, an appropriate unit of measurement is needed to measure them and their parts.

Look at 1 millimetre on your ruler. Now imagine that this 1 millimetre is divided into a thousand parts. One of those tiny parts is equal to 1 **micrometre** ( $\mu\text{m}$ ). Cells and their parts are measured in micrometres. Cells vary in size depending on their function (Figure 1.38). A bacterial cell usually measures approximately  $1\ \mu\text{m}$ , whereas a plant cell may be up to  $100\ \mu\text{m}$  in size (equivalent to one-tenth of a millimetre).

→ Fig 1.38 A comparison of cell sizes.



## PRACTIVITY 1.2

## Comparing the size of cells and their parts

### What you need

Sheet of poster paper      Pencil  
30-cm ruler                      Eraser

### What to do

#### Part A

- Using the scale of  $1\ \text{cm} = 1\ \mu\text{m}$ , draw a series of circles to represent the average size of various cells and microbes according to the measurements given in Table 1.2.

→ Table 1.2

Cell type	Average diameter ( $\mu\text{m}$ )
Human cheek cell	30
Human red blood cell	7
Human white blood cell	25
Epidermal plant cell	50
Staphylococcus bacterium (spherical)	1
Escherichia coli bacterium (rod shaped)	3

- Rank the cells and microbes from smallest to largest.

#### Part B

Organelles vary in size. Some organelles, such as chloroplasts, are large enough to be visible under the light microscope. Others, such as mitochondria, are usually too small to be visible.

- Use the measurements given in Table 1.3 to add a chloroplast and mitochondrion (singular) to your set of diagrams.

→ Table 1.3

Cell organelle	Average size ( $\mu\text{m}$ )
Chloroplast	$5\ \mu\text{m}$ long $\times$ $1.5\ \mu\text{m}$ wide
Mitochondrion	$2\ \mu\text{m}$ long $\times$ $1\ \mu\text{m}$ wide

- Which of the cell organelles in Table 1.1 (page 19) are not visible under the light microscope?
- Viruses are much smaller than even bacterial cells. For example, the influenza virus, which causes the flu, is  $0.1\ \mu\text{m}$  in diameter. Add the influenza virus to your diagrams.





EXPERIMENT 1.4

# Measuring cells

## Aim

To measure the size of various plant and animal cells using a mini-grid.

## Materials

Onion cell slide (prepared in Experiment 1.2)  
Other various prepared slides, such as human blood, nerve cells, leaf epidermis  
Light microscope  
Mini-grid slide

## Method

- 1 Focus the onion cells under the light microscope.
- 2 Once in focus, estimate the average length and width of one cell in relation to the field of view.
- 3 Gently remove the slide and insert the slide containing the mini-grid.
- 4 Determine the length of the field of view and use this to calculate the average length and width of one onion cell.
- 5 Repeat this process for each of the other prepared slides.

## Results

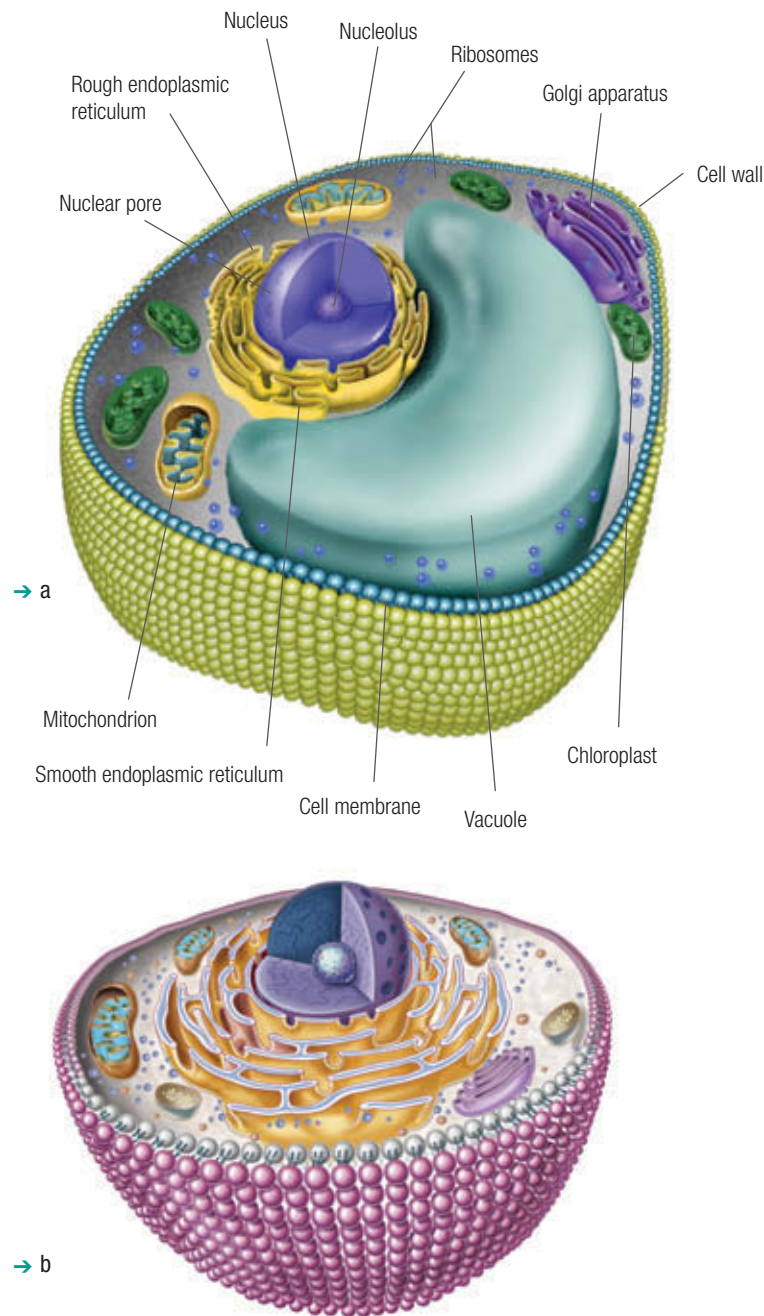
Rank the cells viewed in size from smallest to largest.

## Discussion

Does your ranking match Table 1.2 from Practivity 1.2?

## Conclusion

What do you know about the relative sizes of plant and animal cells?



→ Fig 1.39 Scientists know so much about the structures of (a) plant and (b) animal cells that they are able to create very detailed models and images.

## What do you know about cell structures?

- 1 Name the unit used to measure the size of cells.
- 2 What is the function of the cell membrane?
- 3 Why do plant cells and fungi cells have a cell wall but animal cells do not?
- 4 In which organelle does cellular respiration occur?
- 5 What features of cells mean they are classified as living things? Remember MRNGREWW from Year 7?
- 6 Have a close look at the diagram of the cell and all its parts. You will notice that the cell membrane is represented by two layers of 'balls with double tails'. These shapes represent the particles making up the membrane. Are the other parts of the cell also made of smaller particles? Why aren't they represented by their particles in the diagram?

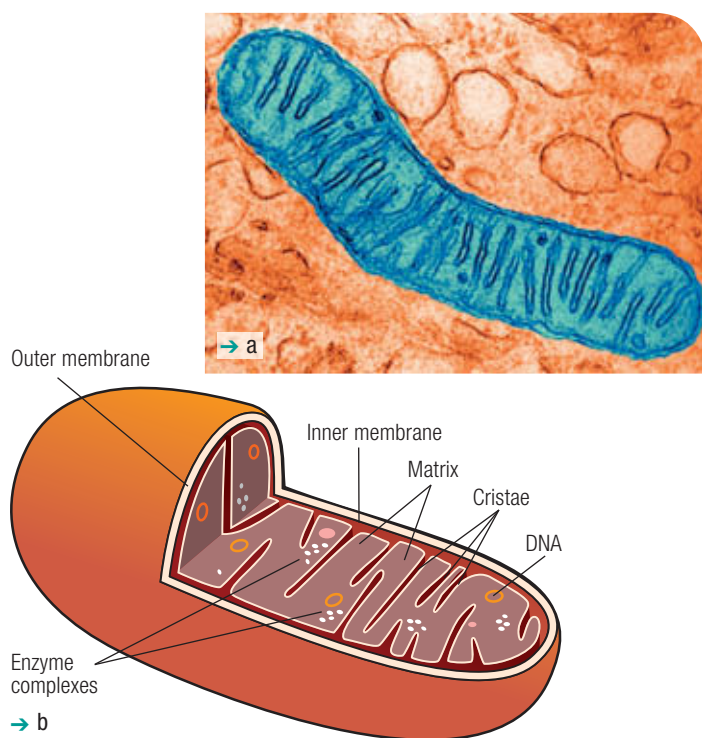
## A closer look at organelles

As described in Table 1.1 (page 19), the different organelles in cells all have specific functions. These functions are necessary for the cell to survive. Some organelles, such as ribosomes, are part of the cytoplasm, whereas other organelles are separated from the cytoplasm by a membrane much like the cell membrane. These organelles, such as the nucleus and chloroplast, are called membrane-bound organelles. Different cell functions happen inside each of a cell's membrane-bound organelles, so the membrane keeps these functions separate from those in other membrane-bound organelles. This means that these functions can happen efficiently without interfering with other events taking place in the cell.

Let's take a closer look at three very important membrane-bound organelles in the cell—the mitochondria, ribosomes and chloroplasts.

### Mitochondria

**Mitochondria** (*singular* mitochondrion) are the powerhouse of the cell, being the site of energy production in the cell. There may be several thousand mitochondria in a cell depending on what the cell does. For example, skeletal muscle cells contain a lot of mitochondria to make sure we have enough energy to run and jump when we need to.



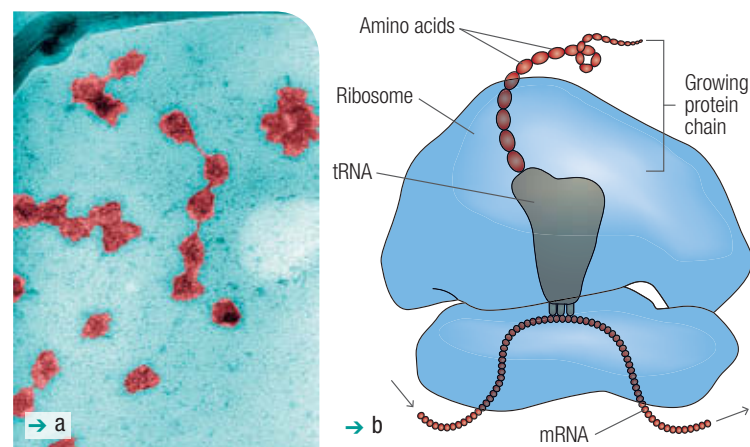
→ Fig 1.40 (a) Electron micrograph of a mitochondrion. (b) Schematic diagram showing the structure of a mitochondrion.

Mitochondria are like self-contained miniature power plants—they have their own DNA, make some of their own proteins and are able to grow and divide when a cell needs more of them.

Mitochondria are rod-shaped, membrane-bound organelles with an inner and outer membrane. The inner membrane is folded to increase the surface area of the membrane. The process of cellular respiration occurs inside the mitochondria. In this process, glucose (from the food we eat) and oxygen react to form water, carbon dioxide and energy. This energy is used by our bodies to help us function.

### Ribosomes

**Ribosomes** are the site of protein production in the cell. These organelles use the codes from the DNA (in the form of mRNA) to assemble amino acids floating in the cytoplasm into a wide variety of proteins. A bit like Lego pieces, **amino acids** can be assembled into lots of different shapes and sizes, each with a different function. These amino acids have either been made by the body or come from proteins in foods that have been broken down. Essential amino acids are called 'essential' because they cannot be made by the body and must come from food.



→ Fig 1.41 (a) Electron micrograph ribosomes. (b) Schematic diagram showing the structure of a ribosome.

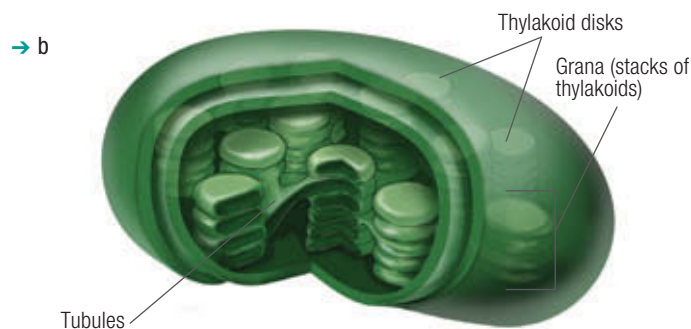
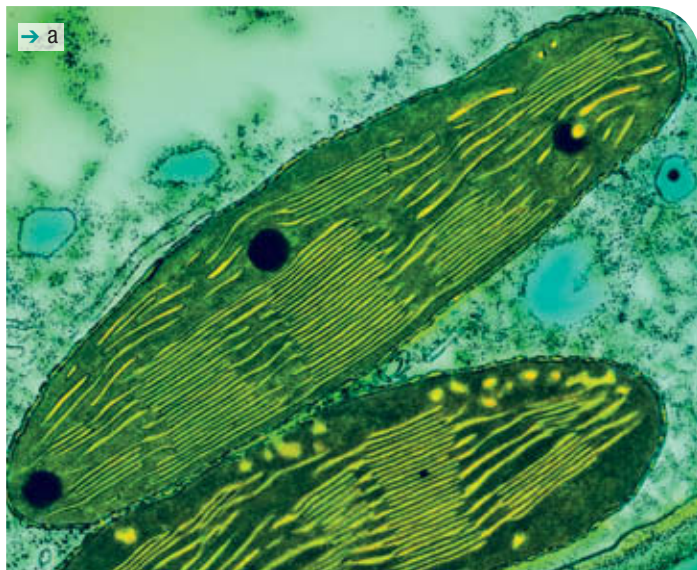
**Proteins** are grouped according to their structure and function. Structural proteins, as the name suggests, are important in the structure of cells, organelles and much larger organs, such as cartilage, hair and nails. Globular proteins are blob shaped and may be involved in taking messages around the body (hormones), helping chemical reactions occur (enzymes), fighting disease (immunoglobulins) or carrying substances (haemoglobin). These examples are just the start, so it's not surprising that there are scientists who focus solely on proteins!



## Chloroplasts

**Chloroplasts** are only found in plant cells and some unicellular organisms. These organelles are like microscopic solar panels that transform solar energy into chemical energy. In fact, the idea for solar panels came from studying how plants were able to harness energy from the Sun. Cells containing chloroplasts are mostly found on the tops of leaves.

The pigment in chloroplasts is usually green and called **chlorophyll**. You would have noticed that on hot days black, dull objects tend to heat up more than white, shiny objects—this is because different colours and materials react differently to heat and light energy.



→ Fig 1.42 (a) Electron micrograph of a chloroplast. (b) Schematic diagram showing the structure of a chloroplast.

Chlorophyll is perfectly suited to absorbing solar energy for a process called **photosynthesis**, which literally translates to ‘making with light’.

Solar energy allows the particles of carbon dioxide and water molecules to be rearranged to form glucose and oxygen. Glucose can then be used as an energy source for the plant and any animal that eats that plant.

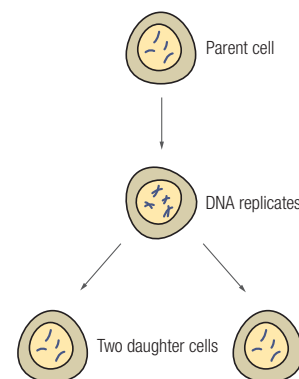
## What do you know about looking closer at organelles?

- 1 Name three membrane-bound organelles.
- 2 What are some of the roles of proteins in organisms?
- 3 How is DNA related to protein production?
- 4 Why are most organelles surrounded by a membrane?
- 5 Where would you be more likely to find large numbers of mitochondria, in a muscle cell or a bone cell? Explain.
- 6 Food chains always begin with a plant. Which organelle explains the position of plants in food chains?

## Making more cells

Cells, like organisms, need to carry out many functions for survival. They need to process many substances, harness energy and, ultimately, reproduce. The instructions for all these jobs are in the form of DNA—lengths of codes that can be ‘read’ when required to make sure jobs are done correctly. The DNA is stored in the **nucleus**, which is often referred to as the control centre or ‘brain’ of the cell.

When cells are ready to reproduce they simply split in half, but each new cell needs its own copy of the full set of DNA. The process of splitting in half needs to involve copying a new set of DNA and making sure one full set ends up in each of the new cells. The organelles are also roughly split into two groups. This process of cell division is called **mitosis**. New cells need to be made to replace old or damaged cells, help an organism grow or even carry out a specific job, such as in the case of red or white blood cells.

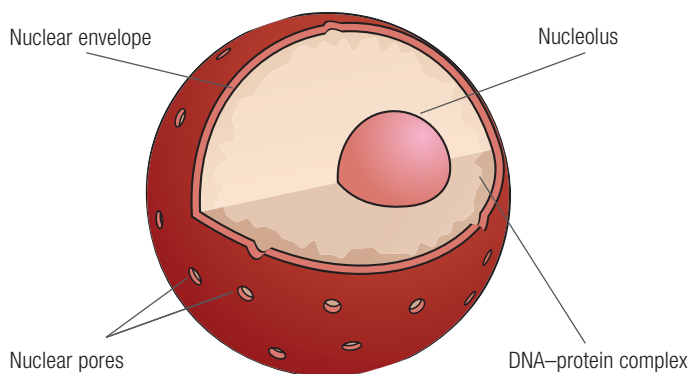


→ Fig 1.43 The process of mitosis.

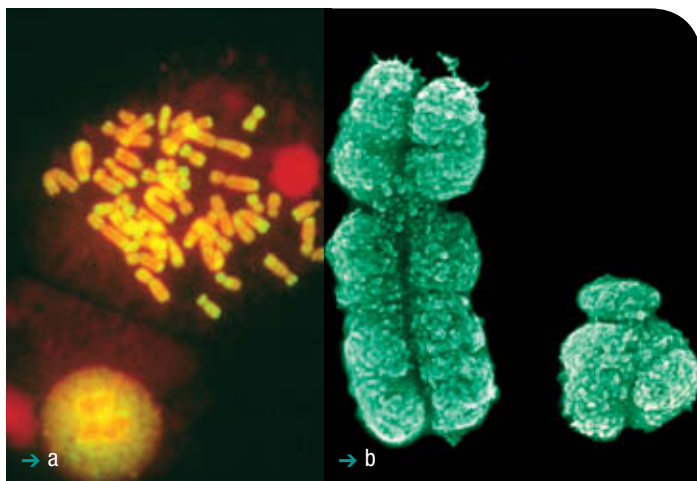
## The cell nucleus

The **nucleus** is a membrane-bound organelle that is separated from the rest of the cell by a double membrane called the nuclear envelope (Figure 1.44). The nucleus also contains one or more suborganelles called nucleoli (*singular nucleolus*), which are involved in the production of proteins. The nuclear envelope has nuclear pores that allow the movement of substances into and out of the nucleus.

Long molecules of DNA are found in the nucleus. When a cell is not dividing, the DNA is found in unravelled strands in the nucleus. When a cell is dividing, the DNA strands coil up to form **chromosomes**, which can be seen easily with a light microscope (Figure 1.45). Chromosomes are like packets of genetic material that carry several sets of instructions for our cells. The number of chromosomes in an organism's cells varies among different organisms. Human cells have forty-six chromosomes, with twenty-three chromosomes coming from the mother and twenty-three from the father.



→ Fig 1.44 Structure of the cell nucleus.



→ Fig 1.45 (a) Light microscope and (b) electron microscope images of human chromosomes.

ZOOMING IN

## Cancer: cell division out of control

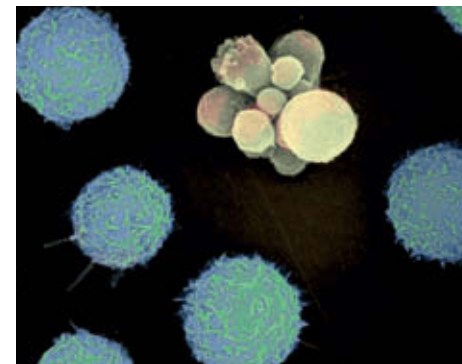
Cells do not survive indefinitely within an organism. They have a use-by date, after which they actually self-destruct. This ensures that cell division is controlled.

The term **cancer** describes a group of diseases that result from uncontrolled cell division. A cancer can form in any part of the body and affects humans and other animals. As an organism grows, cells reproduce to replace cells that are old or those that have died through injury. The process of a cell dying is a very normal and important part of the development and functioning of an organism. Programmed cell death is known as **apoptosis**. In fact, it was only through the programmed death of cells around your hands and feet that your fingers and toes formed during your early development.

If a cell experiences some kind of damage, the genetic material may also be damaged or altered. DNA may be damaged by a number of things, such as radiation, viruses or chemicals, called **mutagens**. Cancer-causing substances are called **carcinogens**. The change to the DNA results in a change in the instructions for the cell. Depending on this change, instructions may be lost or modified.

Damage to the genetic material may prevent a cell from self-destructing. When cell division gets out of control, a lot of cells grow. This is called a growth or tumour. The **tumour** is the cancer. The tumour may split off and spread throughout the body, causing secondary cancers. The secondary cancers can damage or destroy other organs.

There are two types of tumours: benign and malignant. Benign tumours do not spread and they are not normally fatal (causing death) unless they grow in a vital organ, such as the brain. In contrast, malignant tumours can spread to different parts of the body and can be fatal if their growth is not stopped.



→ Fig 1.46 The yellow cells are undergoing apoptosis, or programmed cell death.



## What do you know about making more cells?

- 1 List three reasons why new cells need to be made.
- 2 Use diagrams to describe the steps involved in mitosis.
- 3 What is the name of the substance that provides instructions for the cell and where is it found?
- 4 What would happen if there were no nuclear pores?
- 5 What is *apoptosis*? When does it occur?
- 6 What are *chromosomes*? How many chromosomes do humans have?
- 7 How might the formation of chromosomes help organise genetic information?

## Using cells to classify

A giraffe, worm and mushroom are all classified as living organisms, yet they have many differences. Although they all share cells as their basic building blocks, the structure and function of these cells are different. Single-celled or unicellular organisms, such as bacteria, are made of one cell only. Multicellular organisms, like us, are made of more than one cell and often many billions of cells. The different cells in a multicellular organism communicate and work together to produce a functioning organism.

## Similarities and differences between the kingdoms

An organism's cell type can also be used to classify it. Organisms are classified into one of five groups, called kingdoms. Table 1.5 outlines the main characteristics of a typical cell for organisms from each of the five kingdoms.

The cells of organisms from each kingdom have similarities in their basic structure. This knowledge assists in the classification of existing and newly discovered organisms. Because cells are the basic building blocks of life, understanding the structure of cells enables us to understand better how organisms function.

## Prokaryotes and eukaryotes

Cells are classified into two main groups—prokaryotic cells and eukaryotic cells. **Prokaryotic cells** are the most primitive cellular forms on Earth and are unicellular. They are much simpler in structure than eukaryotic cells and lack the membrane-bound organelles described in Table 1.2 (page 19); for example, they have no nucleus and the DNA is found free in the cytoplasm. Prokaryotes include the diverse range of bacteria.

**Eukaryotic cells** are more complex cells and are found in organisms from each of the other four kingdoms—animals, plants, fungi and protists. Eukaryotic cells contain a nucleus as well as other membrane-bound organelles. Organisms that contain eukaryotic cells are called eukaryotes. Most eukaryotes are multicellular.

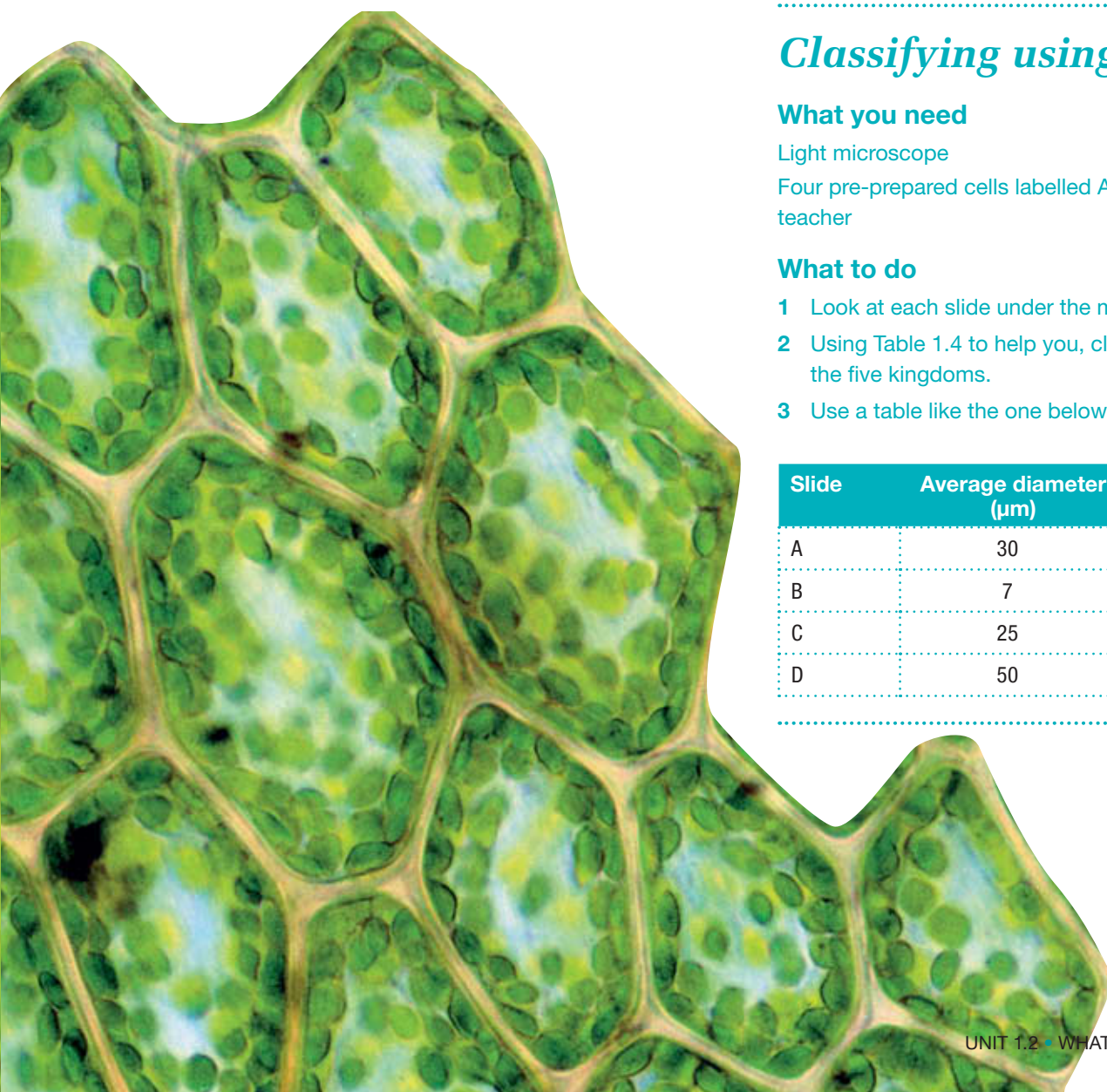
## Fungal cells

Fungi have often been considered as types of plants, but with the development of the microscope scientists were able to see that fungal cells are not the same as plant cells at all. For example, fungal cells don't have chloroplasts, so they cannot photosynthesise, they don't have large vacuoles filled with liquid and their cell wall is made of chitin instead of cellulose.



→ Table 1.4 Characteristics of eukaryotic and prokaryotic cells.

Characteristic	Kingdom				
	Eukaryotes				Prokaryotes
	Animals	Plants	Fungi	Protista	Monera
Number of cells	Multicellular	Multicellular	Multicellular, some unicellular (e.g. yeasts)	Multicellular or unicellular	Unicellular
Cell wall	Absent	Present (cellulose)	Present (chitin)	Present in some	Present (murein)
Genetic material	Present	Present	Present	Present	Present
Nucleus	Present	Present	Present	Present	Absent
Mitochondria	Present	Present	Present	Present	Absent
Chloroplasts	Absent	Present	Absent	Present in some	Absent
Large vacuoles	Absent	Present	Absent	Present in some	Absent
Ribosomes	Present	Present	Present	Present	Present



..... PRACTIVITY 1.3 .....

## Classifying using cells

### What you need

Light microscope

Four pre-prepared cells labelled A–D supplied by your teacher

### What to do

- 1 Look at each slide under the microscope.
- 2 Using Table 1.4 to help you, classify each slide into one of the five kingdoms.
- 3 Use a table like the one below to present your results.

Slide	Average diameter (µm)	Kingdom
A	30	
B	7	
C	25	
D	50	



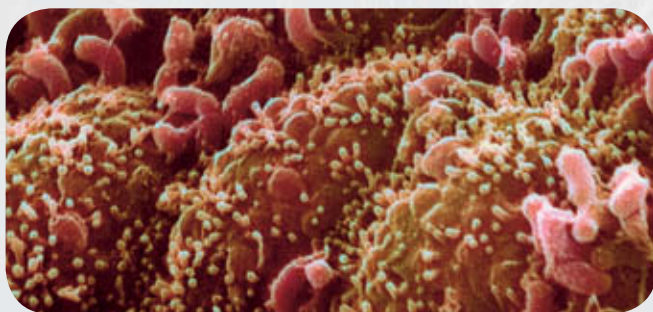
## Using similes

Scientists use models to explain complicated concepts or abstract ideas like the particle model of matter.

Another useful tool for scientists is the use of similes. Similes are used to compare two things using the words 'like' or 'as'. Have you ever heard someone say that a sprinter moves as quick as lightning? Or that their little sister sticks to them like glue? These are both similes.

### Similes in science

Similes are often used in creative writing, but they are also very useful in science. If you don't have the right scientific terminology to explain a concept, it is useful to explain the concept by comparing it to something that you do understand. When learning about cells, similes can be very helpful because you're dealing with structures that are far too small to see. The same applies to learning about matter—matter can be unbelievably tiny, like water molecules, or unbelievably massive, like the solar system. Similes should not be used in formal science reports but are good to use in chapter summaries or homework tasks.



Here are some similes that relate to this chapter:

- Cells are like building blocks.
- The cells in your body are like bricks in a house.
- The nucleus is like a control centre.
- The mitochondrion is like a power station.
- Cytoplasm is like a jelly that holds a cell's organelles in place.
- Your body is like a zoo because it contains so many microbes.

### Simile challenge

Working in a small group, come up with a list of similes for animal and plant cell organelles (but don't copy the above ideas!). Present your similes to the class.

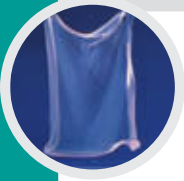
- 1 Were your similes the same or different from those of the other groups?
- 2 Why do you think using similes is useful?
- 3 Why shouldn't similes be used in formal reports?
- 4 In what other subjects could you use similes?
- 5 Did you find it difficult to come up with similes? Come up with a strategy for practising simile use.

## What do you know about using cells to classify?

- 1 Give an example of a unicellular organism and a multicellular organism.
- 2 Suggest why a unicellular organism cannot grow as large as a multicellular organism.
- 3 Describe the two main differences between eukaryotic and prokaryotic organisms.
- 4 Where is DNA found in a prokaryotic cell?
- 5 Suggest why ribosomes are found in cells from each of the five kingdoms.
- 6 Table 1.4 shows that plants cells contain chloroplasts. Although a typical plant cell contains chloroplasts, chloroplasts are not found in all plant cells.
  - a Suggest why some plant cells may lack chloroplasts.
  - b In which part of a plant would you expect cells to contain many chloroplasts?
- 7 Examine Table 1.4 on page 27; then suggest which kingdom is often referred to as 'the rest'.

## 1.2

## What do we know about cells?



### Remember and understand

- 1 Explain two key ideas presented in the cell theory.
- 2 Explain why programmed cell death is necessary.
- 3 What is the benefit of using a stain when viewing some specimens?
- 4 Explain at least one similarity and one difference between a mitochondrion and a chloroplast.

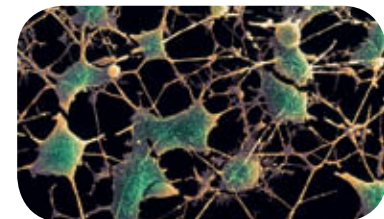
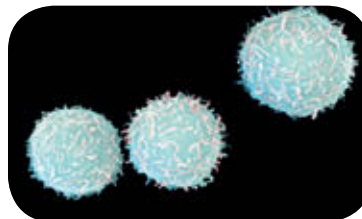
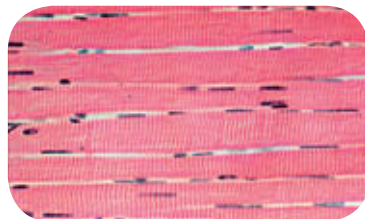
### Apply

- 5 A cell membrane is *partially permeable*. This means that only certain substances are able to cross the membrane. List some substances that would need to get into the cell and some that would need to get out.

### Analyse and evaluate

- 6 Figure 1.47 shows human nerve cells, white blood cells and a muscle cell. Identify each cell and explain how the shape and features of each cell enable it to perform a certain function within the human body.

- 7 Mutagens are substances that can potentially change the genetic material within cells and thus result in cancer. Find out about three substances that have been described as mutagens. Where are these substances found? How do scientists think they cause cancer? How can their effects be minimised?
- 8 Two students prepare slides from different sections of a spring onion under a light microscope in their school laboratory. James views a section of the green leafy part and observes many chloroplasts within each cell, but has difficulty identifying a nucleus in each cell. Emily views a section of the white stem part of the plant. She comments that a nucleus is clearly visible in most of the cells, but does not identify any chloroplasts.
  - a Suggest why James identified many chloroplasts within each cell when they appeared to be absent from the cells viewed by Emily.
  - b Emily commented that she could identify a nucleus in most cells. If a nucleus is not visible in a particular cell, does this mean that the cell does not contain a nucleus?



→ Fig 1.47

- 9 Research the role of stomata and guard cells in plants. Find out how the stomata open and close in response to changing environmental conditions. Under what type of conditions are the stomata likely to open? What are triggers for the stomata to close? How does the shape of the guard cells assist the opening and closing of the hole?

# How do cells work together?

Cells are often called the 'building blocks of life'. Think of the way bricks and other materials are used to build a house. Cells build living things in a similar way. However, there are often many more cells in living things than bricks in a house: an adult human body is made up of approximately ten trillion (10 000 000 000 000) cells. Elephants have even more.

Cells that make up unicellular organisms need to perform lots of functions, so they can be quite complex. Cells of multicellular organisms have different functions, so they come in different sizes and shapes to suit their functions. For example, your nerve cells are different from the cells that form your skin or muscles.

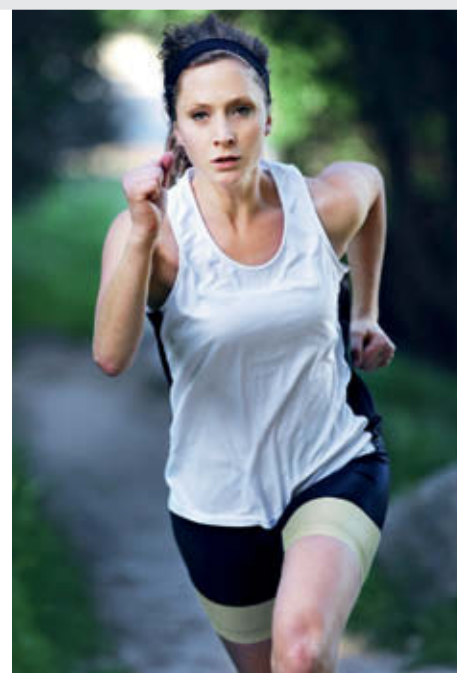
## DISCOVERING IDEAS

### Working together

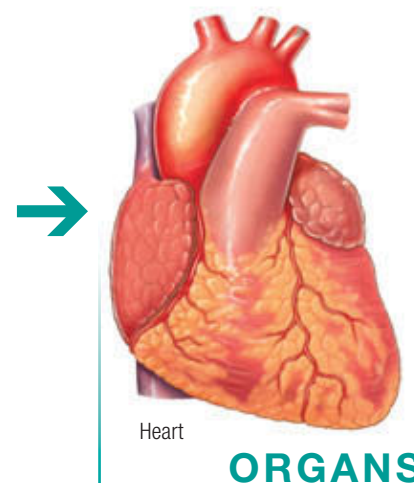
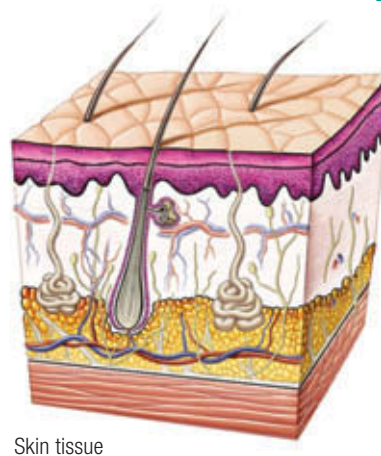
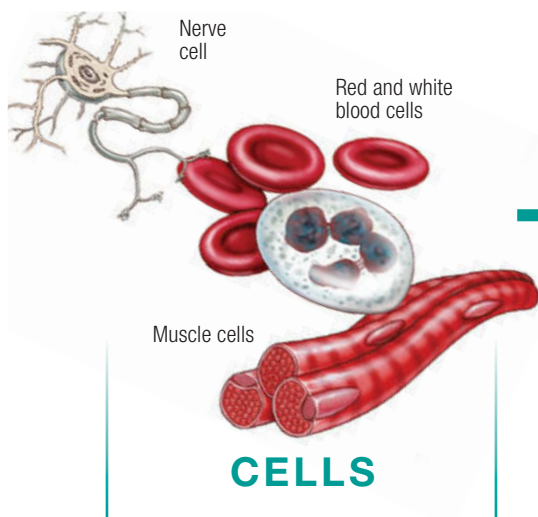
Working in small groups, brainstorm the different jobs that a living organism would undertake to stay alive and be successful.

What communications need to happen in your body? Have you ever had a 'dead leg'? This was an example of a part of your body not being able to communicate with the rest of the body.

- 1 With a partner, try to list as many 'communication partnerships' of body parts as you can. You might like to start with your toes and slowly work your way up your body, identifying all possible options as you go.
- 2 For each 'communication partnership', suggest whether the communication is fast, slow, essential or just a bit helpful.



→ Fig 1.49 The different levels of organisation in the body.



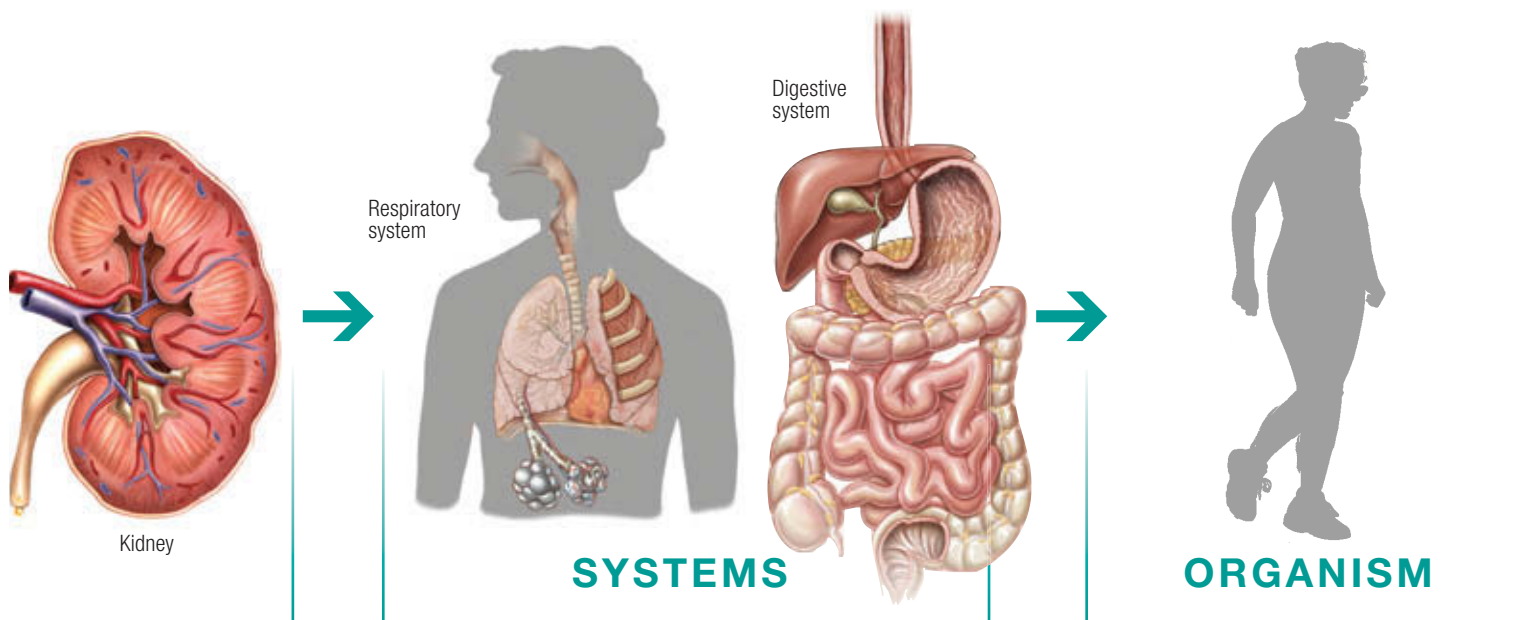
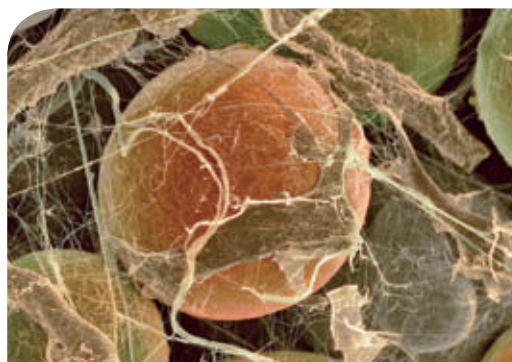
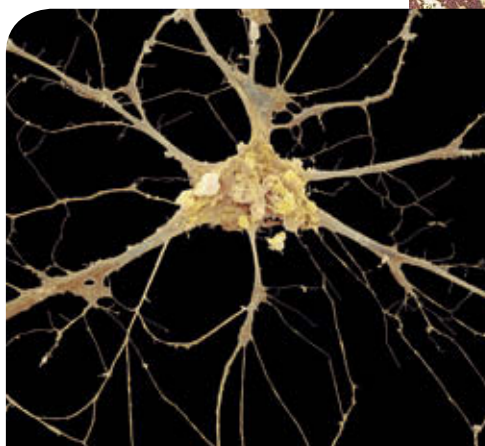
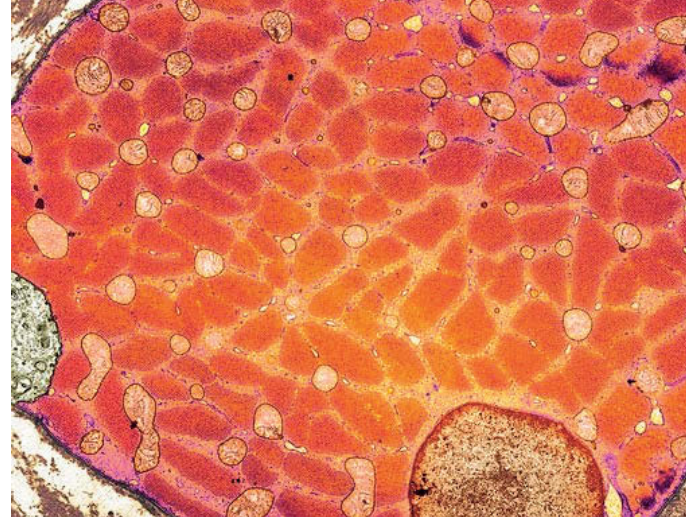
→ Fig 1.48 Any form of exercise or movement requires lots of body parts to communicate.



# Cells to systems

Because of the work scientists have undertaken using microscopes, we now know that the human body is home to a mixture of body systems all working separately and together to keep us alive. Similar to a business, our cells are like workers with different jobs: they work in teams to achieve different goals and keep the business successful. Like all living things, we are made of different types of cells. Groups of cells that do a similar task are called **tissues**. Groups of tissues that work together are called **organs**. The liver, heart, eyes, brain and intestines are all examples of organs. When groups of different organs work together, they are called a **body system**. Our mouth, oesophagus, stomach and intestines make up the digestive system. All the systems then connect to ensure the survival of the whole organism (us!).

→ Fig 1.50 Cells and tissues.





## How many systems?

The answer to this question is not as straightforward as you may think! There are many different body systems. All your body systems work together and sometimes organs are involved in more than one system. Some systems are so complex that we describe systems within systems!

## What do you know about cells to systems?

- 1 What is the difference between cells, tissues and organs?
  - a digestive system
  - b excretory system
  - c circulatory system
- 2 Name three:
  - a types of cells
  - b types of tissues
  - c organs
  - d systems
- 3 Name at least two organs that belong to the following body systems:
  - a digestive system
  - b excretory system
  - c circulatory system
- 4 Which system is responsible for:
  - a transporting substances around the body?
  - b processing wastes?
  - c protecting soft inner organs?
  - d removing wastes?

### Skeletal system

All bones, including spine, skull, pelvis and ribs

Gives body structure and supports and protects other organs; provides attachment for muscles

### Digestive system

Mouth, stomach, small intestine, large intestine, rectum, anus

Breaks down food into substances small enough to be absorbed into the bloodstream; separates some waste

### Respiratory system

Lungs, windpipe, diaphragm

Filters oxygen from the air and transfers it to the blood so that it is taken to all other parts of the body; removes carbon dioxide from cells via blood back to the lungs

### Excretory system

Kidneys, liver, bladder, urethra, skin, lungs

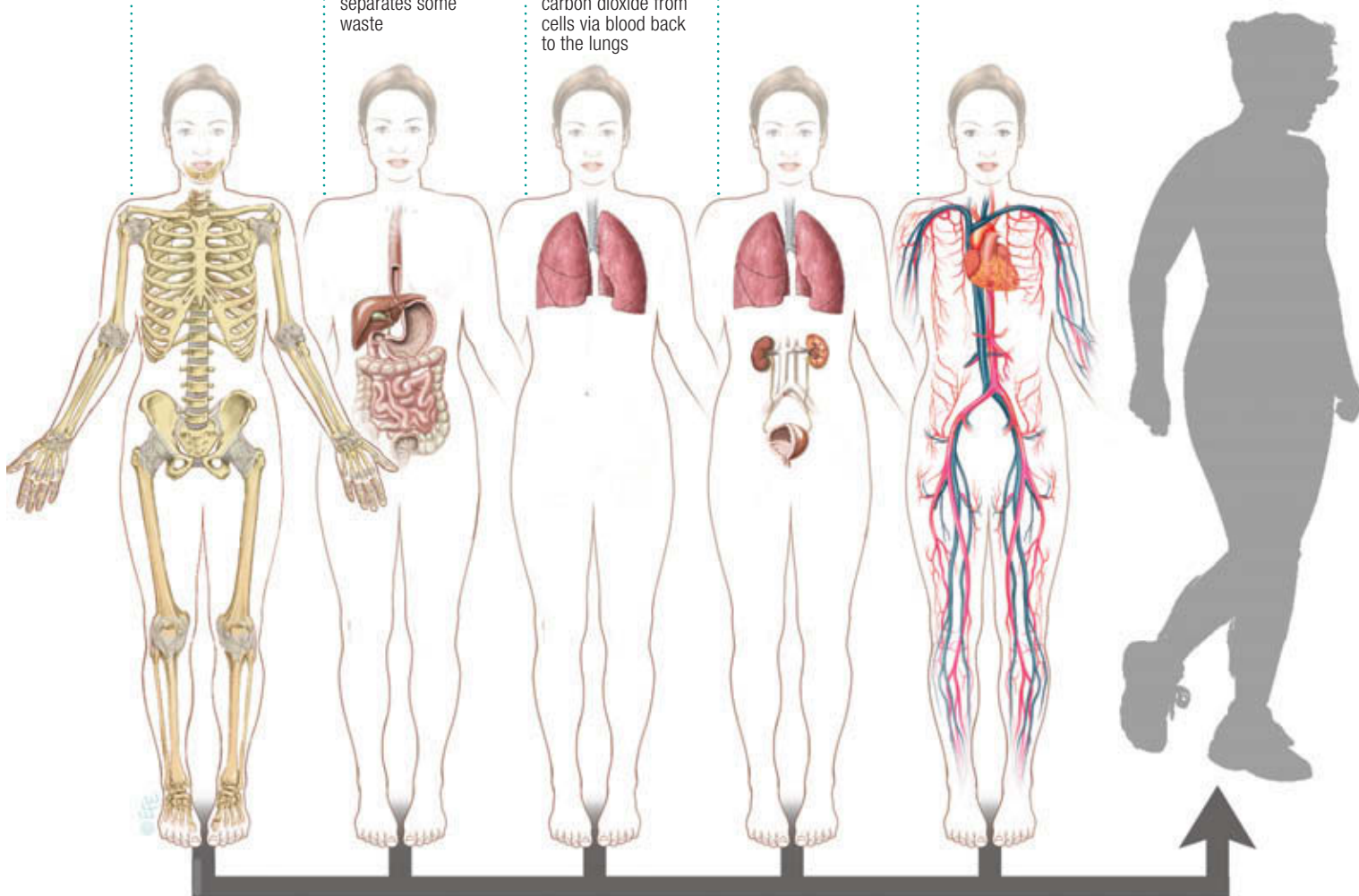
Processes and filters out wastes and controls the amount and content of body fluids

### Circulatory system

Heart, veins, arteries

Carries oxygen and nutrients to cells and waste materials away from cells via the blood

→ Fig 1.51 Our body systems work together.



## Foreign cells in our systems

Unicellular organisms, such as bacteria, are living in and around us all the time. The average adult human has 1 kilogram of non-human life inside their large intestine alone. This kilogram is made up of thousands of different types of microbes. Bacteria and other microbes are essential for keeping our body healthy and working correctly. Without the microbes in our gut we would not be able to digest food properly, get rid of wastes or make essential vitamins. This is just one example of how

microbes are essential for our survival. Other microbes, such as those that cause food poisoning, can be deadly.

The microbes that live happily in our bodies are referred to as **natural flora** and it's the balance between natural flora and the microbes in our environment that we need to keep an eye on. The right amount of natural flora will protect us from foreign invaders, whereas too much of the natural flora can actually make us ill.

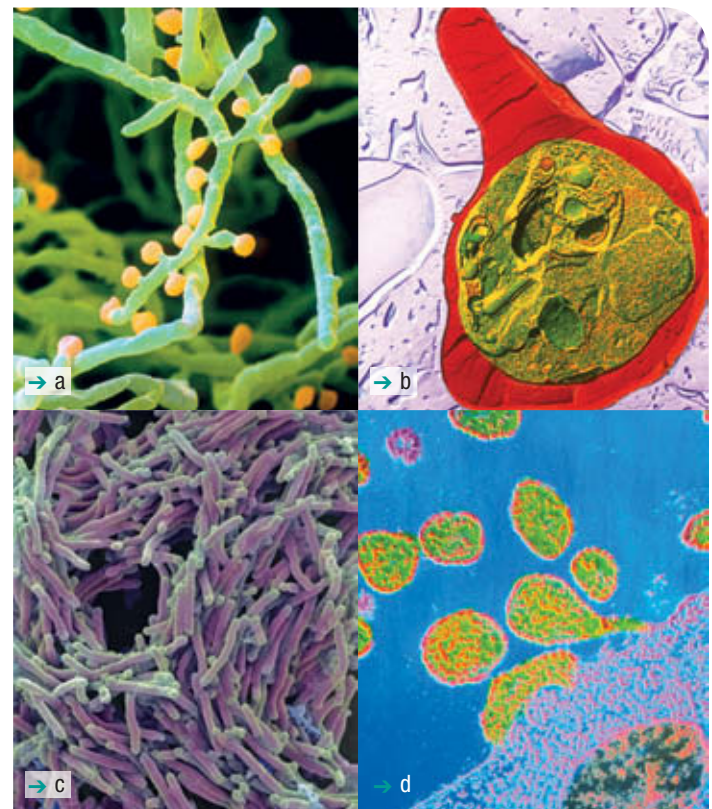


→ Fig 1.52 (a) *Staphylococcus epidermis*, (b) *Staphylococcus aureus* in the hair, (c) *Haemophilus influenza* in the nose, (d) *Chlamydia trachamates* in the eye, (e) *Esherichia coli* in the intestines.

## Microbes causing disease

We have all been sick at some stage in our lives and much sicker at some times than others. Some forms of sickness are caused by pathogens. A **pathogen** is a micro-organism that can potentially cause a disease. With **infectious diseases**, the pathogen may be passed from one organism to another. Such diseases are said to be contagious. The host is an organism, such as a human, animal or plant, on which another organism lives. You will be investigating pathogens in more detail in Year 9. The **symptoms** of a disease are the changes that occur to an individual as a consequence of the disease.

Harmful microbes may be bacteria, fungi, protists, viruses or prions. All these microbes can invade the body and cause disease. You will probably be familiar with some diseases caused by harmful microbes. Fungi can cause infections such as tinea, which is also known as athlete's foot, and ear infections. Protists can cause malaria and dysentery. Bacteria cause diseases such as tuberculosis (also known as TB), pneumonia, Legionnaires' disease and cholera. Viruses can cause diseases like the common cold and flu, measles and herpes.



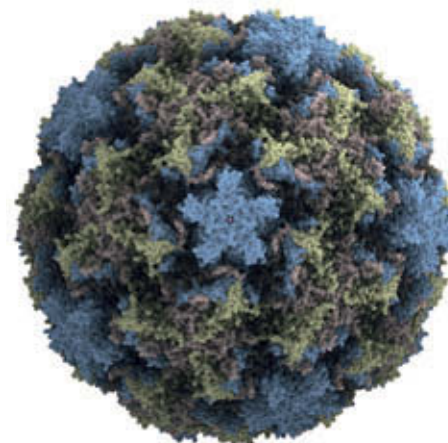
→ Fig 1.53 (a) *Trichophyton mentagrophtes*, cause of ringworm and tinea; (b) a red blood cell infected with malarial parasites; (c) tuberculosis bacteria; (d) Rubella virus.



# Viruses

Viruses and prions are actually considered by most scientists to be non-living pathogens. Viruses cannot survive and reproduce outside a host cell, and prions are actually just an infectious form of a naturally occurring protein.

Viruses are responsible for most of the common colds that we experience and cannot be controlled by antibiotics because they're hiding inside our cells. This also makes it much harder for our own immune cells to find and fight them, so our best defence is rest and to eat a healthy diet to let our bodies concentrate on getting rid of the viruses by themselves.



→ Fig 1.54 Human rhinovirus.

## ..... PRACTIVITY 1.4 .....

### Microbes all around

In this activity you will investigate the type of microbes found in the local environment. Most human pathogenic bacteria and fungi (those that are potentially harmful to humans) grow optimally at 37°C. For this reason, samples should be sealed with paraffin wax or tape and incubated at a maximum of 27°C. Do not reopen samples at any time and destroy them immediately after analysis.

#### What you need

Three Petri dishes (containing nutrient agar)

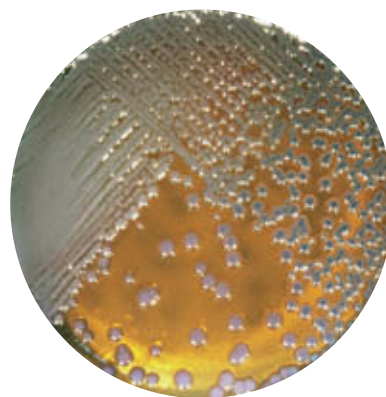
Two sterilised swabs

Paraffin wax strips or masking tape

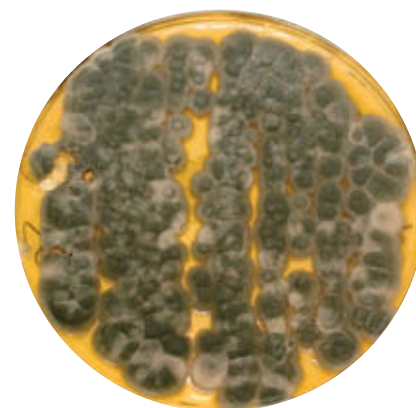
2 Incubators set to 20°C and 27°C

#### What to do

- Two agar plates are to be used for growing microbes and the third is the control plate. The control plate should not be opened at any stage of the activity, but must be incubated alongside the sample plates.
- Decide on a site around the school to be tested for microbes.
- Keep the swabs sterile (germ free) until you reach the site.
- Rub the swab over the site and then gently rub it across the surface of the agar in both directions. Take care not to damage the surface of the agar.
- Quickly place the lid on the plate, seal it with a wax strip or tape and then incubate it, along with the control plate, at 20°C for 4–7 days.
- Repeat for the second plate, but incubate this plate at 27°C for the same period of time.
- Observe any bacterial and fungal growth. Some charts showing common types of bacteria and fungi may assist your identification.
- At the end of the activity, dispose of the agar plates appropriately.



→ a



→ b

→ Fig 1.55 (a) Bacterial colonies growing on an agar plate. (b) Fungus tends to have a dusty or fuzzy appearance.

## What do you know about foreign cells in our systems?

- 1 What type of micro-organism does our digestive system rely on? What does it rely on it for?
- 2 What is natural flora?
- 3 Can natural flora ever be harmful to our bodies?
- 4 What is a *pathogen*? What are the five main groups of pathogens?
- 5 Why is a virus not considered to be living?
- 6 How does a virus avoid being killed by our immune system?

### Questions to consider

- 1 Describe the growth on your sample plates after the incubation period. A labelled diagram may assist your description. Did you observe the growth of both bacteria and fungi? What were some of the differences between them?
- 2 If your sample plate showed evidence of bacterial growth, do you think that there was more than one type of bacteria present? Justify your response.
- 3 Suggest why the agar plates were incubated at 22°C and 37°C for a period of 4–7 days.
- 4 Describe how the growth on the two sample plates differed. How do you think the temperature influenced this growth?
- 5 Suggest why there may be some differences between the growth on your plates and those of other students.
- 6 Explain why it is important that both the swab and plate are sterile and only exposed to the environment for a short period while collecting the sample.
- 7 If the control plate was sterilised appropriately prior to the beginning of this activity and then incubated alongside the sample plate, it should have showed no bacterial or fungal growth. Explain the purpose of the control plate.
- 8 What do your results suggest about microbes in your local environment?

## Flushing out the truth

### Karl Kruszelnicki

Sometimes, if things are a bit rushed at work, we might grab a quick sandwich at our office desk. But you'd never be in such a hurry as to even dream of eating off the toilet seat because we all 'know' that toilets are really 'dirty' and loaded with germs. But, on average, per square centimetre your desk has fifty times more bacteria than your toilet seat!

This was discovered by Dr Charles Gerba, a microbiologist from the University of Arizona. He's Dr Germs ...

Dr Gerba has also studied germ counts in the house and, by doing so, discovered the right way to flush the toilet: you should flush with the lid down.

If you flush with the lid up, a polluted plume of bacteria and water vapour erupts out of the flushing toilet bowl. The polluted water particles float for a few hours around your bathroom before they all land. Some of them will land on your toothbrush.

Dr Gerba also found that, in the home, the kitchen sponge had the highest germ count, followed by the kitchen sink. The lowest bacteria count, out of fifteen household locations, was the toilet seat. He said (perhaps a little jokingly), 'If an alien came from space and

studied the bacterial counts, he probably would conclude he should wash his hands in your toilet'. Dr Gerba went on to say what the alien might do in your sink.



→ Fig 1.56 A bacterial plume rises from the toilet bowl when you flush.

So, if you flush with the lid up, you are probably brushing your teeth with toilet water. I guess that's one story to tell the males in your household so that they put the lid down, because if they put the lid down they have to put the seat down as well.

- 1 What conditions are needed for bacteria to multiply so quickly? Why would the kitchen sponge and the desktop provide these conditions?
- 2 What areas of your house would you consider the most germey? Why? Design an experiment to test your theory.

## 1.3

## How do cells work together?



### Remember and understand

- 1 What is a group of similar cells performing a similar function called?
- 2 Identify an organ that is involved in more than one system. Which systems does it play a part in?
- 3 What is the main function of the following systems:
  - a digestive
  - b circulatory
  - c respiratory
  - d muscular
- 4 What is the name given to a microorganism that causes disease?
- 5 Why is it important for the cells in multicellular organisms to work together?
- 6 How do the respiratory and circulatory systems rely on each other?
- 7 How do the muscular and skeletal systems rely on each other?

### Apply

- 8 How does the digestive system 'feed' all the other systems?
- 9 What is the best thing to do if you contract an infectious disease? Explain.

### Analyse and evaluate

- 10 If you were sick with a cold or flu, a doctor may prescribe antibiotics. But antibiotics are quite useless against viruses, the pathogens

responsible for colds and flu. So why would a doctor prescribe antibiotics?

- 11 Why are unicellular organisms more complex in the structures they contain, whereas multicellular organisms contain relatively simple cells?
- 12 Mad cow disease, a disease caused by prions, spread from cattle to humans in the United Kingdom. Why do you think it took so long for scientists to work out what was causing the disease? How large are prions compared with bacteria and other pathogens? Prions affect healthy proteins by simply coming in contact with them. This turns 'good' protein into prion proteins. What does this tell you about the similarities that exist between cattle and human proteins?

### Critical and creative thinking

- 13 Create a table that identifies the different groups of pathogens and common diseases they cause. In your table, provide information in separate rows or columns that compares and contrasts the features of each pathogen (e.g. how it is transmitted, the symptoms it causes etc.).
- 14 Write a very short creative story about a virus. Your story needs to be from the point of view of a cell. The first line of your story is: 'Once upon a time, a virus arrived for an uninvited visit.'

- 15 The connections between cells, tissues, organs, systems and organisms can be linked in a flow diagram. How are they connected? For each arrow in your flow diagram, write a short statement that connects the parts. Make reference to the structure and/or function of the parts.



## Research

### Linking big ideas

In this chapter three big questions were asked: How do we know about cells? What do we know about cells? How do cells work together? Think of a creative way to represent these questions and make links between them, using as many of the key words in the chapter as you can. You might use a concept map or mind map with each of the questions as major bubbles. You could choose to use diagrams only or perhaps draw a picture that shows all three aspects of the particles of life. The method of presentation that you select must enable you to share your ideas with others. Try to use similes to help you convey your ideas.

### Stem cells

Stem cells are cells in multicellular organisms that haven't become specialised yet—they're like blank canvases. Find out what scientists have learned about stem cells, where they find them and what they hope to be able to do with them.

### Organ transplants

Organ transplants are necessary when organs are diseased or damaged and fail to function effectively. Human organs are the best option for us because there is a greater chance of them 'communicating' with the rest of the body properly, but the availability of organs usually relies on someone dying. Some organs, like kidneys, can be donated leaving the donor with a single kidney that will filter their wastes. Find out about the options for organ transplants in Australia. What other animals are used as donors of organs and tissue? Are prosthetic (fake) organs possible? Which body parts can be replaced?

### Discovery of penicillin

Research the story of the discovery of penicillin. Write the story in the form of a newspaper article.

## Reflect

### Me

- 1 What new science laboratory skills have you learned in this chapter?
- 2 What was the most surprising thing you found out about cells?
- 3 What were the most difficult aspects of this topic?

### My world

- 4 Why is hot, soapy water usually just as effective as harsh cleaning chemicals for getting rid of microbes?
- 5 Why is it important not to take antibiotics unnecessarily?
- 6 Why is it best for you and others that you stay home and rest when you're unwell?

### My future

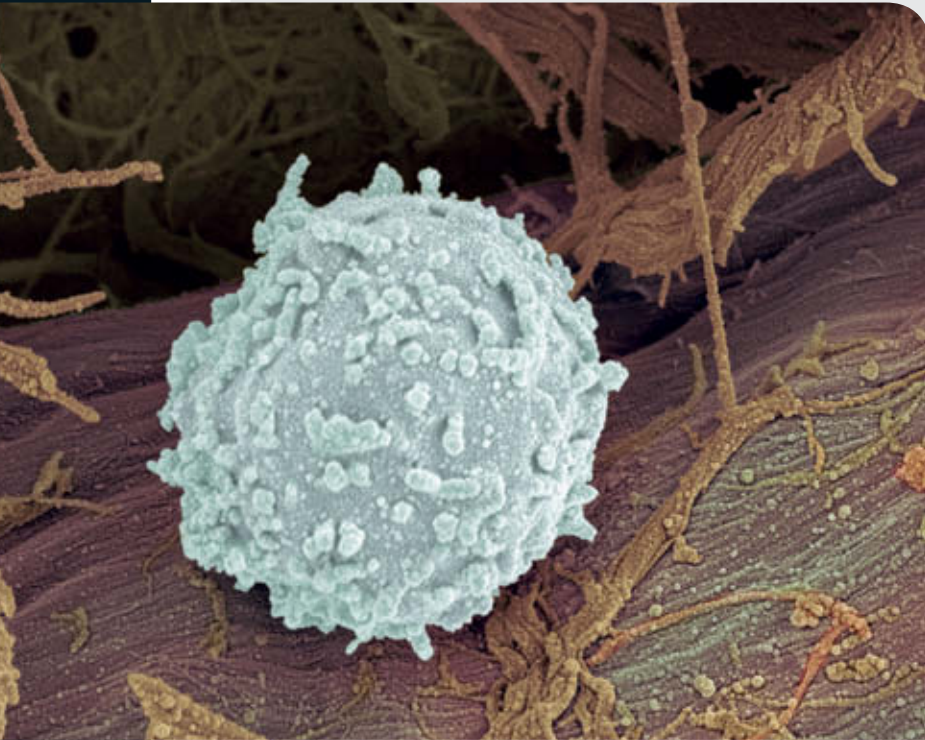
- 7 What sort of infectious diseases do you predict will present the greatest challenges to humans across this century?

## Review

### Key words

amino acid  
apoptosis  
body system  
cancer  
carcinogen  
cell  
cell membrane  
cell theory  
chlorophyll  
chloroplast  
chromosome  
cytoplasm  
deoxyribonucleic acid (DNA)  
eukaryotic cell  
eyepiece  
infectious disease  
micrometre  
microscope  
mitochondrion  
mitosis  
mutagen  
natural flora  
nucleus  
objective lens  
organ  
organelle  
pathogen  
photosynthesis  
prokaryotic cell  
protein  
respiration  
ribosome  
stain  
surface area to volume ratio  
symptom  
tissue  
tumour  
wet mount

## HIV/AIDS pandemic



→ Fig 1.57 A white blood cell.

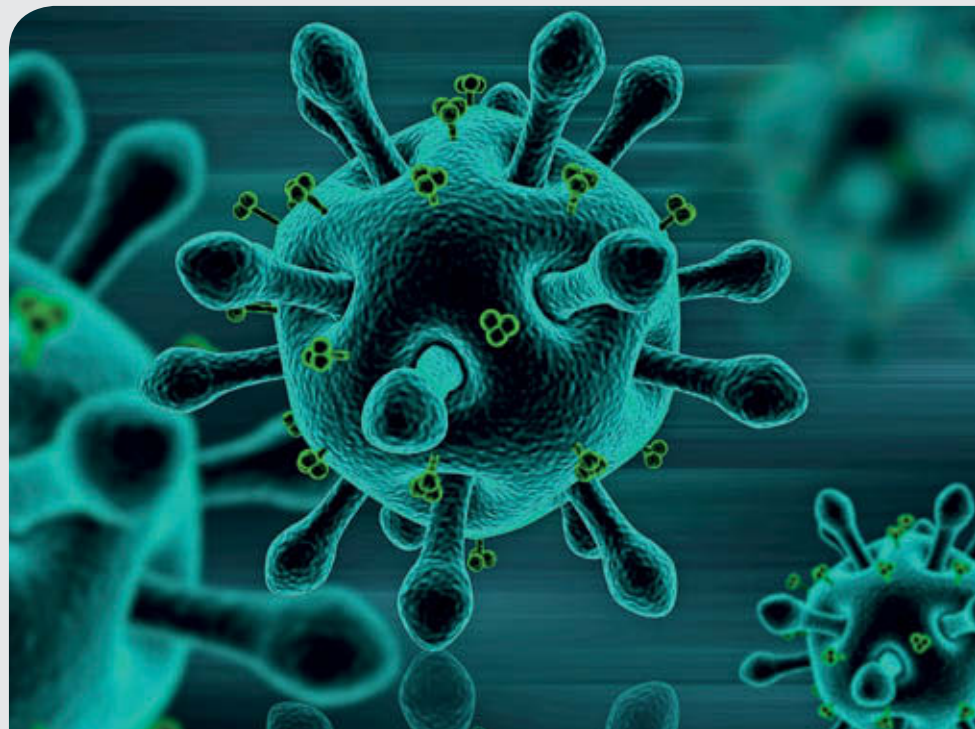
The main host cell for HIV is a particular type of white blood cell known as a CD4+ T cell. These T cells are part of our immune system and help us fight infection. Infection with HIV results in gradual destruction of the number of CD4+ T cells in the body. This causes a deficiency in an infected person's immune system because they are no longer able to fight other infections.

Once inside the host cell, the RNA of HIV is able to make a copy of itself as DNA and insert itself into the host cell's DNA. This means that when the host cell divides, it is making new copies of its own DNA and the HIV's DNA at the same time. The host cell is tricked into making more HIV viruses.

In 1981, public health officials in the United States documented the presence of a new disease. This disease became known as AIDS—acquired immunodeficiency syndrome. However, it was not until 1985 that the cause of AIDS was discovered—a tiny virus that was named HIV—human immunodeficiency virus. HIV infection is described as a pandemic, which means that it is a disease that occurs in people throughout the world. This pandemic is still on the increase. In 2007, 33.2 million people worldwide were living with HIV and 1.1 million people died of AIDS. Since the beginning of the pandemic, more than 60 million people have been infected with HIV and more than 20 million of those have died.

HIV is called a retrovirus. This is because it makes more copies of itself, or replicates, backwards compared with living organisms—that is, it goes from RNA to DNA instead of the usual DNA to RNA. RNA is very similar to DNA in its function.

→ Fig 1.58 The HIV virus.



Initial infection with HIV results in large amounts of virus in the blood because HIV replication occurs at a rapid rate. In fact, 108–109 new virus particles are made each day. People who are infected with HIV can pass it on to others within a few days of being infected themselves and are able to pass it on for the rest of their lives.

Screening tests are available to determine whether someone is infected, but these tests are not effective until 2 months after infection.

HIV can only be passed from person to person through contact with infected body fluids, such as blood, semen, vaginal secretions and breast milk. HIV is not spread through hugging, kissing, shaking hands, sharing eating utensils, toilet seats or attending school or work with someone who is infected with HIV. Nor is it transmitted through tears, saliva, urine, sputum, faeces or sweat.

Initial infection with HIV results in a flu-like syndrome with fevers, swollen glands, sore throat, headache, lethargy, nausea, muscle and joint pain, diarrhoea and/or a rash.

AIDS is actually an advanced stage of chronic HIV infection. AIDS is diagnosed, on average, approximately 11 years after the initial infection with HIV. A diagnosis of AIDS is made when the immune system is so severely reduced that lots of infections develop. These infections would not normally develop in a person with a healthy immune system and are known as *opportunistic infections* because they infect when there is a 'perfect opportunity'. Common opportunistic infections include infections with fungi, such as *Candida albicans*, other viruses, such as hepatitis and herpes, protists and bacteria, such as those that cause tuberculosis. Opportunistic cancers can also develop, such as Kaposi's sarcoma and various lymphomas. Weight loss of 10% or more can occur, as can AIDS dementia complex.

Antiretroviral drugs are available for the treatment of AIDS. However, most doctors prefer not to prescribe these drugs until patients have symptoms of AIDS or their blood tests indicate that their immune system has almost collapsed.

- 1 How is a retrovirus different from other viruses?
- 2 The letter 'I' in HIV stands for immunodeficiency. Why is this?
- 3 Viruses are often called parasites. How is the HIV virus a parasite?
- 4 Find out more about HIV and AIDS and present your findings to the class in an appropriate and interesting format. The AIDS Trust of Australia and World AIDS Day websites may provide good starting points. Alternatively, you might like to research another virus or pathogen of equal significance, such as hepatitis or syphilis.



→ Fig 1.59 Lesions of Kaposi's sarcoma can appear anywhere on the skin or on the internal organs of people with AIDS. This lesion has been outlined ready for removal with a ring of healthy tissue.



→ Fig 1.60 Azidothymidine (AZT), sold as Retrovir or Retrovis, is used to delay the onset of AIDS.