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David Martindill , Joanna Haywood , Sheila Tarpey , With Mary Jones , Geoff Jones , Richard Harwood , Ian Lodge , Chris Millington , David Sang ,

B1

Cells and organisms

All learners study some content in this chapter

IN THIS CHAPTER YOU WILL:

- learn about the seven characteristics of living organisms
- find out about the structure of the cells of bacteria, plants and animals
- learn about the functions of each of the cells of bacteria, plants and animals
- identify cell structures in diagrams
- describe how the structures of some specialised cells are related to their functions
- state that new cells are produced by division of existing cells
- describe the meaning of the terms cell, tissue, organ, organ system and organism
- practise using the magnification equation
- convert measurements between millimetres (mm) and micrometres (μm).

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BEFORE YOU START

Different types of organisms have different kinds of cells. With a partner, think about the answers to these questions:

1 The list below contains some features of living organisms. With a partner, discuss which of these features are found in all living organisms.

breathing excretion a blood system a nervous system sensitivity
growth reproduction movement nutrition respiration

2 If you have a microscope, how can you distinguish between a cell from a plant, and a cell from an animal?

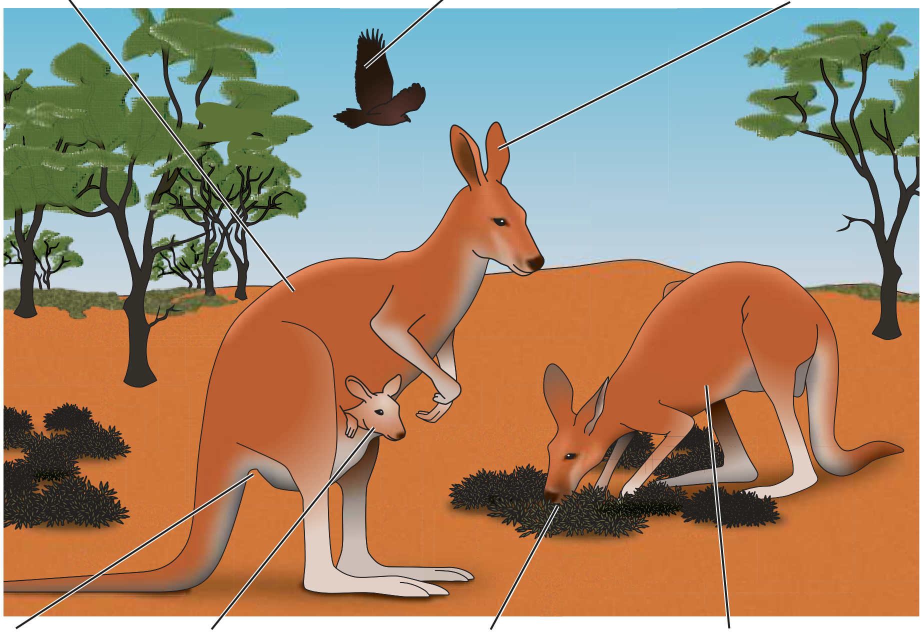
B1.01 Characteristics of living organisms

Biology is the study of organisms. An **organism** is a complete living thing – such as yourself, a platypus, a bacterium or a mango tree. There are very many different kinds of organism on Earth, but all of them share seven characteristics (Figure B1.01). Some non-living things have some of these characteristics, but no non-living thing has all of them.

Growth: All organisms begin small and get larger, by the growth of their cells and by adding new cells to their bodies. Growth can be defined as a permanent increase in size or dry mass. Measuring dry mass involves killing and drying the organism (so this method is more often used for plants than for animals). The mass of its body without any water is then found.

Movement: All organisms are able to move to some extent. Most animals can move their whole body from place to place, and plants can slowly move parts of themselves.

Sensitivity: All organisms pick up information about changes in their environment, and react to the changes. These changes may be in the internal environment (such as the temperature of the blood) or the external environment (such as the intensity of sunlight).



Excretion: All organisms produce unwanted or toxic waste products as a result of their metabolic reactions, and these must be removed from the body.

Reproduction: Organisms are able to make new organisms of the same species as themselves.

Nutrition: Organisms take substances from their environment and use them to provide energy or materials to make new cells.

Respiration: All organisms break down glucose and other substances inside their cells, to release energy that they can use. Organisms use the energy that they obtain from respiration to make other chemical reactions in their cells happen. All of these chemical reactions together – including respiration – are called metabolism.

Figure B1.01: Characteristics of living organisms.

SCIENCE IN CONTEXT B1.01

How many cells in a human body?

In some organisms, it is possible to count the number of cells in their bodies. In organisms such as humans, we can only estimate numbers. It would be impossible to count them all. Cells differ in their volume, mass and how closely or loosely they are packed together.

Scientists recently calculated the numbers of different cells and cell types in different organs and added them up.

This latest estimate suggests that the body of an adult human contains around 37 trillion cells – that is 37 000 000 000 000.

Discussion question

1 Can you think of any advantages for larger organisms of consisting of multiple cells, rather than just one larger cell?

KEY WORD

organism: a living thing.

ACTIVITY B1.01

Matching the characteristics of living things with their descriptions

Work in a group of four or five for this activity.

You will need:

- 14 pieces of blank card, all exactly the same.

1 Write the seven characteristics of living things on seven of the pieces of card.
2 Write descriptions of each of the seven characteristics on the other seven cards.
3 Shuffle each set of cards. Place them face down in two rows of seven.
4 One person then selects a card from each row and turns them face up. If the name and description match, this person keeps the two cards. If they do not match, they place them face down again in the same positions.
5 Now the next person does the same.
6 Keep taking turns until all the cards have been taken by someone. The winner is the person with most cards at the end.

Questions

B1.01 A student claimed that plants show fewer of the characteristics of living things than animals. Explain why this claim is wrong.

B1.02 Consider *two* organisms. For each, identify:

a the characteristics of living things that the organism carries out all the time

b the characteristics of living things that only happen at certain times.

B1.02 Cell structure

All organisms are made of **cells**. Cells are very small, so large organisms contain millions of cells. They are multicellular. Some organisms are unicellular, which means that they are made of just a single cell. Bacteria and yeast are examples of single-celled organisms.

All cells are made from existing cells. New cells are formed when a fully grown cell divides. You can read about how cells divide in Chapter B12.

KEY WORD

cells: the smallest units from which all organisms are made.

Microscopes

To see cells clearly, you need to use a microscope (Figure B1.02). The kind of microscope used in a school laboratory is called a light microscope. This is because it shines light through the piece of animal or plant you are looking at. It uses glass lenses to magnify and focus the image. A very good light microscope can magnify about 1500 times, so that all the structures in Figures B1.03 and B1.04 can be seen.

A photograph taken using a light microscope is called a photomicrograph. Figure B1.05 is a photomicrograph of some animal cells, and Figure B1.06 is a photomicrograph of some plant cells.

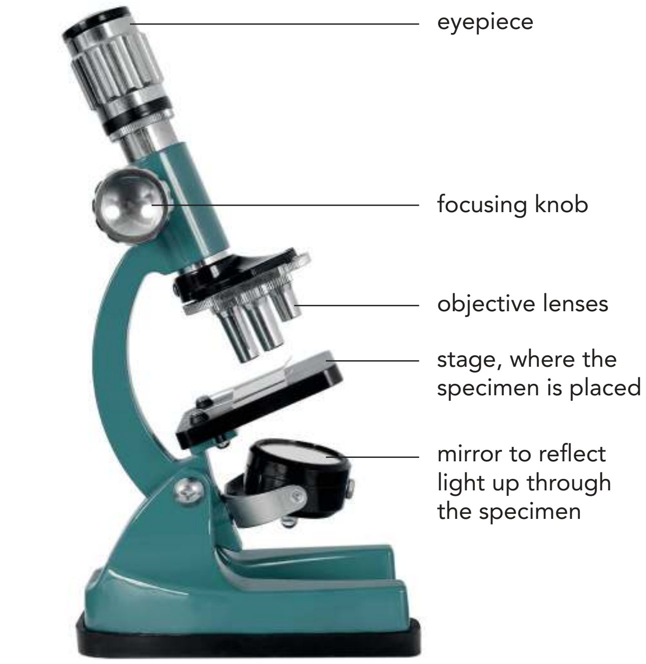


Figure B1.02: A light microscope.

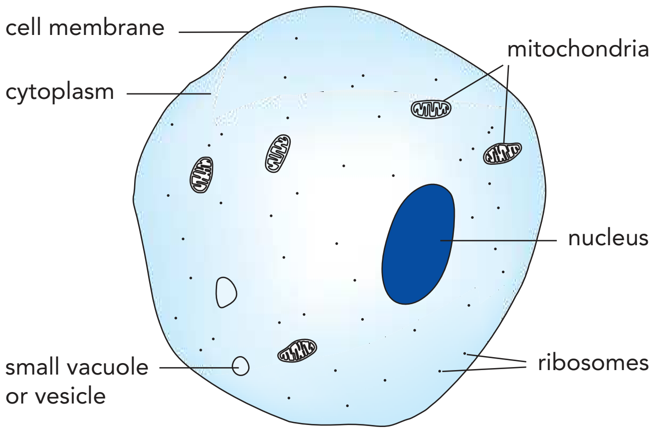


Figure B1.03: An animal cell as it appears through a light microscope.

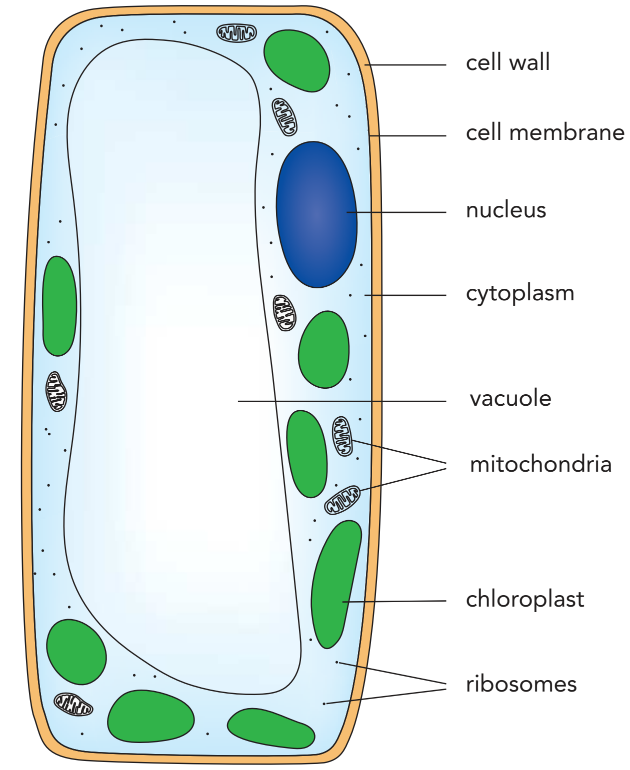


Figure B1.04: A plant cell as it appears through a light microscope.

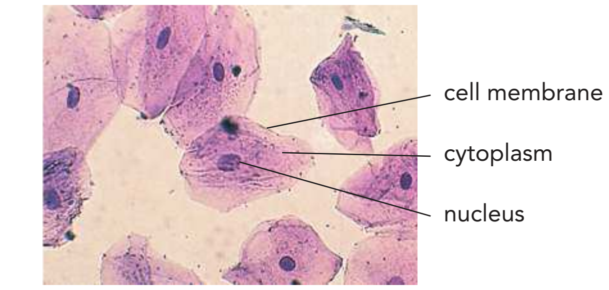


Figure B1.05: These are cells from the trachea (windpipe) of a mammal. They have been stained (coloured) with a dye that makes the nucleus look darker than the cytoplasm.

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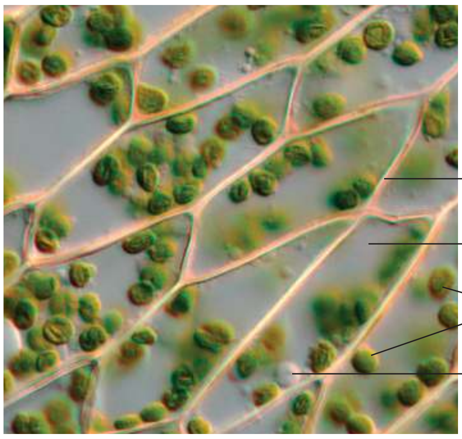

Figure B1.06: These are cells from a moss plant. You cannot see the cell membranes because they are pressed tightly against the inside of the cell walls.

Questions

B1.03 Explain the difference between a unicellular organism and a multicellular organism, giving *one* example of each.

B1.04 Look at the micrographs in Figures B1.05 and B1.06. Suggest why a stain has been added to the animal cells, but we can easily see the plant cells without using a stain.

Cell membrane

Every cell has a **cell membrane** around the outside. The cell membrane is a very thin layer of protein and fat. It is very important to the cell because it controls what goes in and out of it. It is **partially permeable**. This means that it will let some substances through but not others. The cell membrane separates the contents of the cell from its environment (surroundings).

It is difficult to see the cell membrane in a plant cell, because it is pressed tightly against the inside of the **cell wall**.

KEY WORDS

cell membrane: a very thin layer surrounding the cytoplasm of every cell; it controls what enters and leaves the cell.

partially permeable: allows some molecules and ions to pass through, but not others.

cell wall: a tough layer outside the cell membrane; found in the cells of plants, fungi and bacteria.

Cell wall

All plant cells are surrounded by a cell wall made mainly of cellulose. Animal cells never have cell walls.

Cellulose belongs to a group of substances called polysaccharides, which are described in Chapter B3. Cellulose forms fibres which criss-cross over one another to form a very strong covering to the cell (Figure B1.07). This helps to protect and support the cell. If the cell absorbs a lot of water and swells, the cell wall prevents it from bursting.

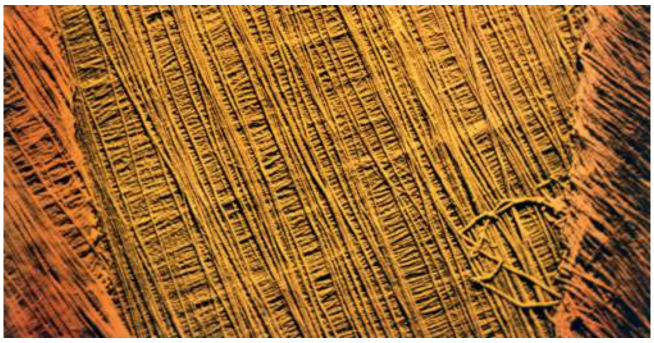

Figure B1.07: This photograph shows surfaces in three dimensions. You can see how the fibres of cellulose criss-cross over one another.

Because of the spaces between fibres, even very large molecules are able to go through the cellulose cell wall. It is **fully permeable**.

Cytoplasm

Cytoplasm is a clear jelly. It is nearly all water. It contains many substances dissolved in it, especially proteins. Many different **metabolic reactions** (the chemical reactions of life) take place in the cytoplasm.

KEY WORDS

fully permeable: allows all molecules and ions to pass through it.

cytoplasm: the jelly-like material that fills a cell.

metabolic reactions: chemical reactions that take place in living organisms.

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Vacuole

A **vacuole** is a fluid-filled space inside a cell which is surrounded by its own membrane. Plant cells have very large, permanent vacuoles, which contain a solution of sugars and other substances called **cell sap**. When the vacuole is full, it presses outwards on the rest of the cell, and helps it to keep its shape. Animal cells have much smaller vacuoles, called **vesicles**, which also contain solutions.

KEY WORDS

vacuole: a fluid-filled space inside a cell, separated from the cytoplasm by a membrane.

cell sap: the fluid that fills the large vacuoles in plant cells.

vesicle: a very small vacuole.

Nucleus

The **nucleus** (plural: nuclei) is where the genetic information is stored. The information is kept on the **chromosomes**, which are inherited from the organism's parents (Figure B1.08). The chromosomes are made of **DNA**. The information carried on the DNA determines the kinds of proteins that are made in the cell.

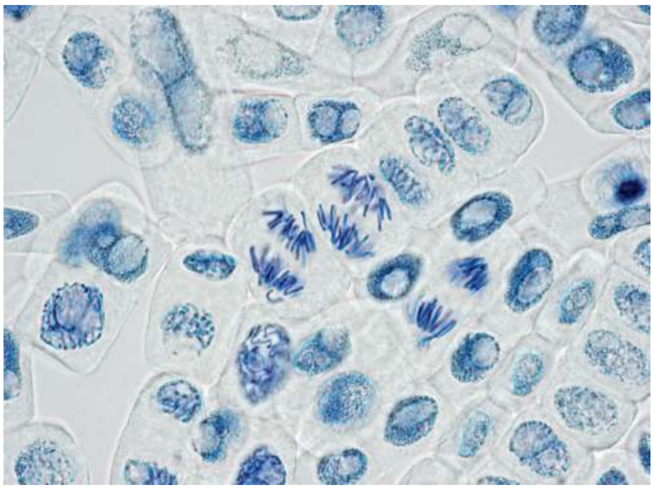

Figure B1.08: This photomicrograph shows some plant cells dividing. The nuclei of the cells have been coloured with a blue stain. The things that look like spider legs are chromosomes. We can normally only see chromosomes when a cell is dividing.

Chloroplasts

Chloroplasts are never found in animal cells, but most of the cells in the green parts of plants have them. They contain the green colouring, or pigment, called chlorophyll.

Chlorophyll absorbs energy from sunlight, and this energy is then used in making food for the plant by photosynthesis (Chapter B5). Chloroplasts often contain **starch grains**, which have been made by photosynthesis (Figure B1.09). Animal cells never contain starch grains.

Figure B1.09: This image shows a chloroplast from a cell in a pea plant. The large blue structure inside the chloroplast is a starch grain. The black stripes inside the chloroplast are membranes where the chlorophyll is kept.

KEY WORDS

nucleus: a structure containing DNA in the form of chromosomes.

chromosome: a length of DNA, found in the nucleus of a cell; it contains genetic information in the form of many different genes.

DNA: a molecule that contains genetic information, in the form of genes, that controls the proteins that are made in the cell.

chloroplasts: small structures found inside some plant cells, inside which photosynthesis takes place.

starch grains: structures that consist of thousands of starch molecules, stored in some plant cells.

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Mitochondria

All the structures we have looked at so far – cell membrane, cell wall, cytoplasm, vacuoles, nucleus and chloroplasts – can be seen with a good light microscope. But there are some smaller structures inside cells that we cannot see clearly unless we use an electron microscope. These include mitochondria (singular: **mitochondrion**).

Mitochondria are found in almost all plant and animal cells. Figure B1.10 is an electron micrograph of a mitochondrion, and Figure B1.11 shows what one might look like if we could cut it open and see it in three dimensions.

Mitochondria are the parts of the cell where **aerobic respiration** happens. This is how energy is released from glucose. You can read about aerobic respiration in Chapter B9.

Aerobic respiration is the main way in which cells get the energy that they need to stay alive. The more energy a cell needs, the more mitochondria it has. Muscle cells, for example, are packed full of mitochondria.

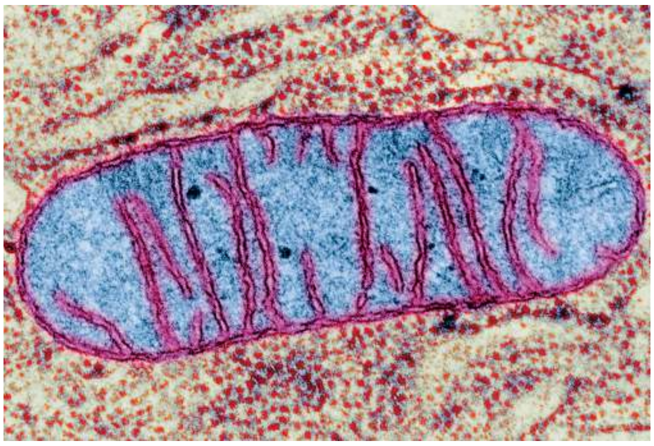

Figure B1.10: An electron micrograph of a mitochondrion. The pink lines are membranes, which separate the inside of the mitochondrion from the rest of the cell.

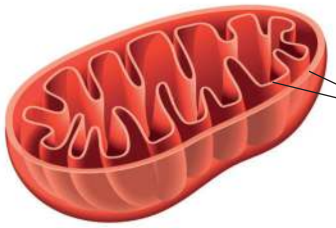

Figure B1.11: A drawing of a mitochondrion, cut open to show the membrane inside it.

Ribosomes

Ribosomes are tiny structures found in almost all animal cells and plant cells. They are so small that we can only see them with an electron microscope.

Ribosomes are where the cell makes proteins. The instructions on the DNA molecules are used to link together long chains of amino acids in a particular sequence. You can read more about protein molecules in Chapter B4, and more about how a cell makes them in Chapter B6.

Questions

B1.05 Name the part of a cell which has each of these functions:

- **a** makes proteins
- **b** contains the information for which proteins to make
- **c** photosynthesis
- **d** prevents the cell bursting when it takes up water
- **e** stores a solution of sugars and other solutes
- **f** controls what enters and leaves the cell.

B1.06 Which of the structures that you have named in Question B1.05 are found in both animal and plant cells?

KEY WORDS

mitochondrion: a small structure in a cell, where aerobic respiration releases energy from glucose.

aerobic respiration: chemical reactions that take place in mitochondria, which use oxygen to break down glucose and other nutrient molecules to release energy for the cell to use.

ribosome: very small structure in a cell that uses information on DNA to make protein molecules.

ACTIVITY B1.02

Comparing animal cells and plant cells

Work in a group of three or four for this activity.

You are going to make a display to compare the structures of animal cells and plant cells.

Decide how you will do this. You could perhaps use annotated drawings, construct a large comparison table, or make a presentation.

You can use the information in this chapter to make your comparison. You might also like to look for some more pictures on the internet.

Bacterial cells

Bacteria (singular: bacterium) are unicellular organisms. Bacterial cells are rather different from the cells of animals and plants. Figure B1.12 is a diagram of a bacterium.

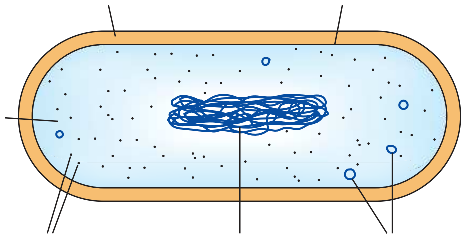

Figure B1.12: A bacterial cell.

Bacterial cells always have a cell wall. Unlike plant cells, this cell wall is not made of cellulose.

But the function is the same as in plant cells – the bacterial cell wall helps to support the cell, and prevents it from bursting if the cell takes up a lot of water.

A partially permeable cell membrane is pressed tightly against the inside of the bacterial cell wall.

As in plant and animal cells, the cell membrane controls what enters and leaves the cell.

Bacterial cells have cytoplasm and ribosomes.

These have the same functions as in animal and plant cells.

KEY WORD

bacteria: unicellular organisms whose cells do not contain a nucleus.

Bacterial cells do not have mitochondria or chloroplasts.

The most important difference between a bacterial cell and animal or plant cells is that bacteria do not have a nucleus. Bacterial cells are also known as **prokaryotic cells**. 'Pro' means 'before', and 'karyotic' means 'nucleus'. Prokaryotic cells appeared on Earth millions of years before cells with nuclei appeared.

Instead of chromosomes inside a nucleus, bacteria have a circle of DNA. This is sometimes called a bacterial chromosome.

The DNA has exactly the same function as in other cells – it provides instructions for making proteins.

Bacterial cells often have one or more smaller circles of DNA, called **plasmids**.

Scientists can use plasmids in the genetic modification of cells and organisms.

KEY WORDS

prokaryotic cells: cells with no nucleus; bacteria have prokaryotic cells.

plasmids: small, circular molecules of DNA, found in many prokaryotic cells in addition to the main, much larger circle of DNA.

Question

B1.07 Construct a table to compare the structure of a bacterial cell with animal and plant cells. Remember to include similarities as well as differences.

REFLECTION

How will you try to learn the names of the parts of animal, plant and bacterial cells, and their functions? Think about which of these ideas might work for you:

- looking at diagrams and reading about the structures
- practising drawing your own diagrams and labelling them
- getting a friend to test you by asking questions
- making some revision cards for yourself, with the name of a structure on one side and its function on the other side.

What other ideas might you try?

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B1.03 Specialised cells

Multicellular organisms, such as humans or plants, may contain vast numbers of cells. Not all of these cells are alike. For example, in a human body almost all of our cells have the same features that are found in most animal cells – a cell membrane, cytoplasm and a nucleus. But most of our cells have a particular function to perform, and their structure is modified to help them to carry out that function effectively. They are specialised. The same is true in a flowering plant, where all the cells have the basic characteristics of plant cells, but then have slightly different structures that relate to their specific functions.

You will meet many examples of specialised cells as you continue through your biology course. Table B1.01 lists seven of these (five from animals and two from plants) and indicates where you can find out more about each one.

Tissues

Often, cells that specialise in the same activity are found together. A group of cells like this is called a **tissue**. An example of a tissue is a layer of cells lining your stomach. These cells make enzymes to help to digest your food (Figure B1.13).

The stomach also contains other tissues. For example, there is a layer of muscle in the stomach wall, made of cells which can move. This muscle tissue makes the wall of the stomach move in and out, churning the food and mixing it up with enzymes.

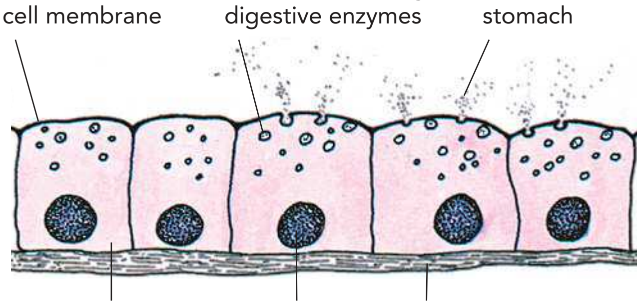

Figure B1.13: Cells lining the stomach – an example of a tissue.

Plants also have tissues. You may already have looked at some **epidermis** tissue from an onion bulb. Inside a leaf, a layer of cells makes up the palisade tissue. These cells are specialised to carry out photosynthesis.

KEY WORDS

tissue: a group of similar cells that work together to perform a particular function.

epidermis: the outer layer of tissue on a plant; also the outer layer of an animal's skin.

Specialised cell	Where it is found	Function	Where you can find out more
root hair cell	near the tips of the roots of flowering plants	absorption of water and mineral ions	Chapter B2
palisade mesophyll cell	in the leaves of flowering plants	photosynthesis	Chapter B5
red blood cell	in the blood of mammals	transporting oxygen	Chapter B7
ciliated cell	lining the trachea and bronchi of animals	cilia move mucus upwards	Chapter B9
neurone	in the nervous system of animals	conducting electrical impulses	Chapter B10
sperm cell	produced in the testes of mammals	the male gamete in sexual reproduction	Chapter B11
egg cell	produced in the ovaries of mammals	the female gamete in reproduction	Chapter B11

Table B1.01: Examples of specialised cells.

Organs

A group of different tissues that carry out a function together is called an **organ**. The stomach is an organ. Other organs include the heart, the kidneys and the lungs. In a plant, an onion bulb is an organ. A leaf is another example of a plant organ.

The stomach is only one of the organs which help in the **digestion** of food. The mouth, the intestines and the stomach are all part of an **organ system** called the digestive system. The heart is part of the circulatory system, and each kidney is part of the excretory system.

The way in which organisms are built up can be summarised like this: cells make up tissues, which make up organs, which make up organ systems, which make up organisms.

B1.04 Sizes of specimens

Many of the structures that biologists study are very small. Cells, for example, are so small that we cannot see them without a microscope. The photographs and diagrams of cells in this chapter are all much larger than actual cells.

We can tell someone how much bigger the image is than the actual object by giving its **magnification**. The magnification of an object is how many times larger it is than the real object.

KEY EQUATION

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

There are two very important things to remember when you are calculating a magnification:

- Make sure that all the numbers in your calculation have the same units. It is often a good idea to convert everything to millimetres, mm, before you do anything else.
- Magnification is always written with a multiplication sign in front of it, ×. Magnification does not have units.

Some of the objects that we study in biology are so small that even millimetres are not a suitable unit to use for measuring them. Instead, we use micrometres. The symbol for a micrometre is µm.

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

KEY WORDS

organ: a structure made up of a group of tissues, working together to perform specific functions.

digestion: the breakdown of food.

organ system: a group of organs with related functions, working together to perform body functions.

magnification: how many times larger an image is than an object.

Questions

B1.08 How many micrometres are there in 1 mm?

B1.09 The mitochondrion in Figure B1.10 is magnified 20 000 times.

- **a** Using a ruler, carefully measure the maximum length of the mitochondrion. Record your measurement in mm (millimetres).
- **b** Convert your answer to µm (micrometres).
- **c** Use this formula to calculate the real size of the mitochondrion in µm:

$$\text{Real size in } \mu\text{m} = \frac{\text{size of image in } \mu\text{m}}{\text{magnification}}$$

- **d** How many of these mitochondria could you line up end to end between two of the mm marks on your ruler?

ACTIVITY B1.03

Practising using the magnification equation

Work on your own for the first part of this activity, and then pair up with someone else for the second part.

You will need:

- several small objects that are easy to measure and draw – for example, an eraser, a paper clip, a button
- a ruler that can measure in mm
- some plain paper, a sharp pencil and an eraser.

Part 1

Work on your own for this.

1 Measure each object carefully and write down the measurements. Do not let anyone else see these measurements at this point.