Cambridge OL

Biology

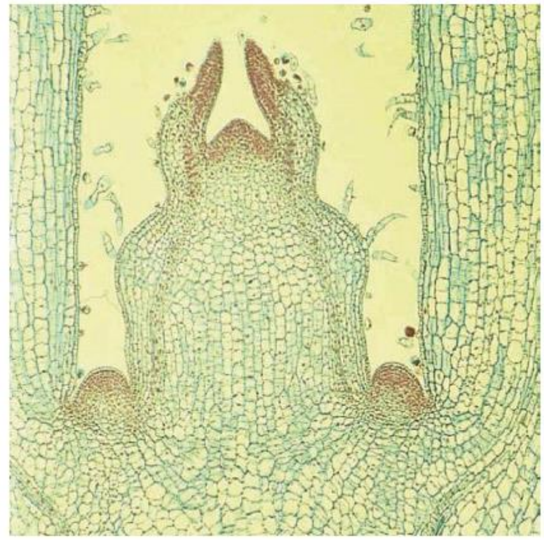
CODE: (5090)

Chapter 01

Cells

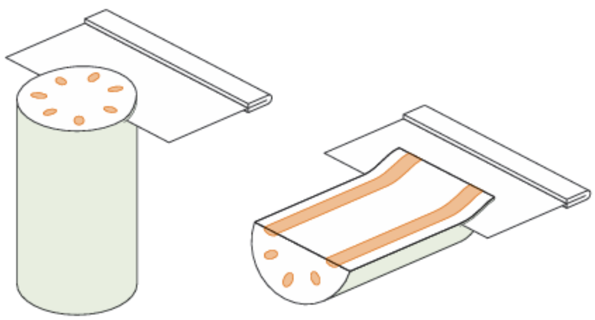
Cell structure and organization

Cell structure



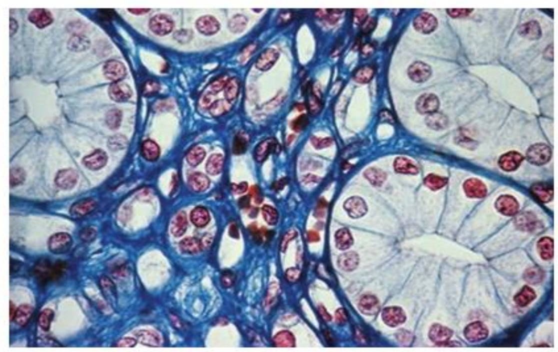
If a very thin slice of a plant stem is cut and studied under a microscope, the stem appears to consist of thousands of tiny, box-like structures. These structures are called **cells**. Figure 1.1 is a thin slice taken from the tip of a plant **shoot** and photographed through a microscope.

When sections of animal structures are examined under the microscope, they too are seen to be made up of cells, but they are much smaller than plant cells and need to be magnified more. The photomicrograph of kidney **tissue** in Figure 1.3 has been magnified 700 times to show the cells clearly.



(a) transverse section **(b)** longitudinal section

▲ **Figure 1.2** Cutting sections of a plant stem

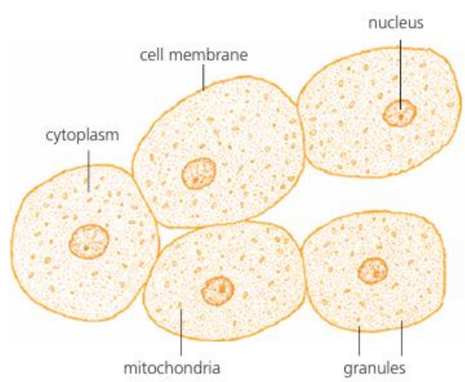


▲ **Figure 1.3** Transverse section through a kidney tubule (×700). A section through a tube will look like a ring (see Figure 1.7(b)). In this case, each 'ring' consists of about 12 cells

There is no such thing as a typical plant or animal cell because cells vary a lot in their size and shape depending on their function. However, it is possible to make a drawing, like that in Figure 1.4, to show the features that are present in most cells. All cells have a **cell membrane**, which is a thin boundary enclosing the **cytoplasm**. Most cells have a **nucleus**.

Cytoplasm

Cytoplasm, a thick liquid with particles like oil droplets or **starch** granules, is responsible for large chemical reactions in plant cells. It contains lipids and **proteins**, which are used to build cell structures like membranes. **Enzymes**, some of which are attached to the cell's membrane systems, control the rate and type of chemical reactions. These enzymes play a crucial role in maintaining cell life.



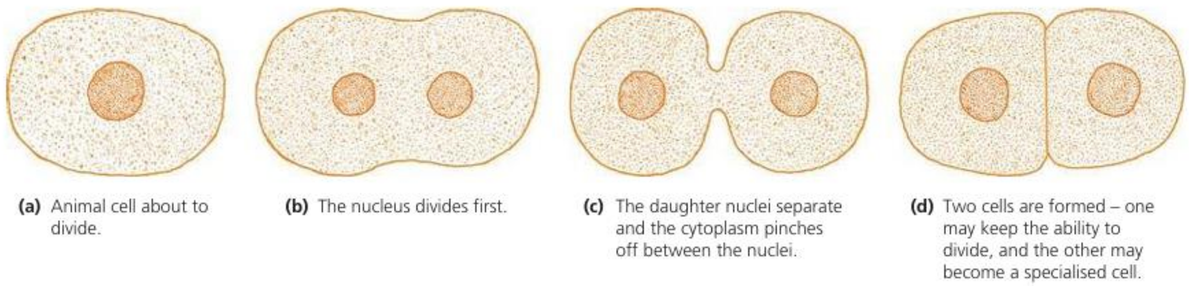
▲ **Figure 1.4** A group of liver cells. These cells have all the characteristics of animal cells

Cell membrane

In general, oxygen, food and water are allowed to enter; waste **products** are allowed to leave; and harmful substances are kept out. In this way the cell membrane maintains the structure and chemical reactions of the cytoplasm.

Nucleus (plural: nuclei)

The nucleus, a rounded structure in cells, controls the type and quantity of enzymes produced by the cytoplasm, regulating chemical changes in the cell. It determines the cell's type, such as blood, liver, muscle, or nerve. **Chromosomes**, thread-like structures inside the nucleus, are crucial for cell division, and a cell without a nucleus cannot reproduce.



▲ **Figure 1.5** Cell division in an animal cell

Plant cells

Plant cells differ from animal cells in several ways because they have extra structures: a cell wall, **chloroplasts** and sap **vacuoles**.

Cell wall

The cell wall, which is outside the membrane, contains **cellulose** and other compounds. It is nonliving and allows water and dissolved substances to pass through it.

Plant cells, visible under the microscope, are distinguished by their cell walls and nuclei. Each cell has its own, but side-by-side boundaries are not always clear, indicating cell sharing.

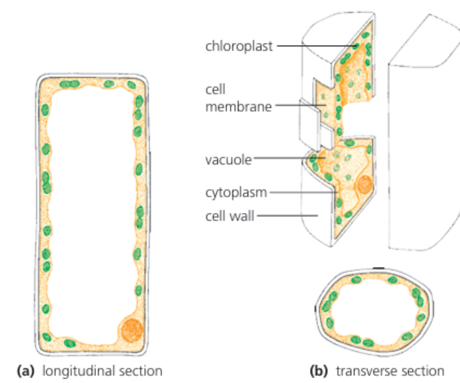
Vacuole

Most mature plant cells have a large, fluid-filled space called a vacuole. The vacuole contains cell **sap**, a watery solution of sugars, salts and sometimes pigments. A central vacuole pushes cytoplasm outward, creating a thin lining inside cell walls, making plant cells and tissues firm. Animal cells may have small vacuoles for special functions.

Chloroplasts

Chloroplasts are organelles that contain the green substance **chlorophyll**.
The shape of a cell when seen in a transverse section may be quite different from when the same cell is seen in a longitudinal section, and Figure 1.7 shows why this is so. Figures 7.8(b) and 7.8(c) show the appearance of cells in a stem **vein** as seen in transverse and longitudinal sections.

When studied at much higher **magnifications** with the electron microscope, the cytoplasm of animal and plant cells no longer looks like a structureless jelly.

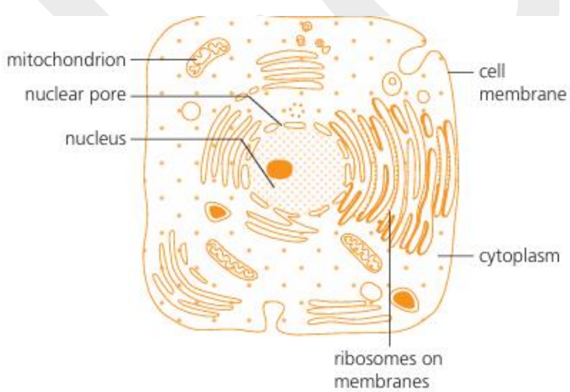


▲ **Figure 1.7** Structure of a **palisade mesophyll** cell. It is important to remember that, although cells look flat in sections or in thin strips of tissue, they are three-dimensional and may seem to have different shapes depending on the direction in which the section is cut. If the cell is cut across it will look like (b); if cut longitudinally it will look like (a)

▼ **Table 1.1** Summary: the parts of a cell

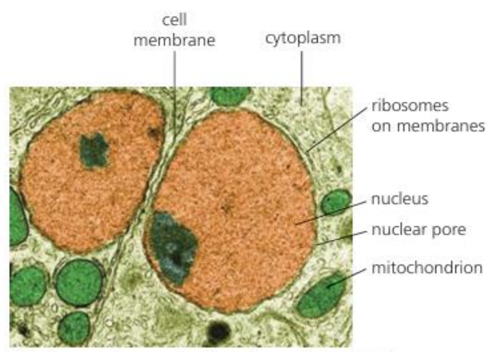
	Name of part	Description	Where found	Function
Animal and plant cells	cytoplasm	jelly-like with particles and organelles in	enclosed by the cell membrane	contains the cell organelles, e.g. **mitochondria** and nucleus site of chemical reactions
	cell membrane	a **partially permeable** layer that forms a boundary around the cytoplasm	around the cytoplasm	prevents cell contents from escaping controls what substances enter and leave the cell
	nucleus	a circular or oval structure containing **DNA** in the form of chromosomes	inside the cytoplasm	controls cell division controls cell development controls cell activities
	mitochondria	circular, oval or slipper-shaped organelles	inside the cytoplasm	responsible for aerobic **respiration**
	ribosomes	small, circular structures attached to membranes or lying free	inside the cytoplasm	protein **synthesis**
Plant cells only	cell wall	a tough, non-living layer made of cellulose surrounding the cell membrane	around the outside of plant cells	prevents plant cells from bursting allows water and salts to pass through (freely **permeable**)
	vacuole	a fluid-filled space surrounded by a membrane	inside the cytoplasm of plant cells	contains salts and sugars helps to keep plant cells firm
	chloroplast	an organelle containing chlorophyll	inside the cytoplasm of some plant cells	traps light energy for **photosynthesis**

Mitochondria are tiny organelles with a spherical, rod-like, or extended outer and inner membranes. They are common in regions of rapid chemical activity and release energy from food substances through aerobic respiration. Other organelles include chloroplasts and a cell wall, as well as other structures like animal cells and liver cells.

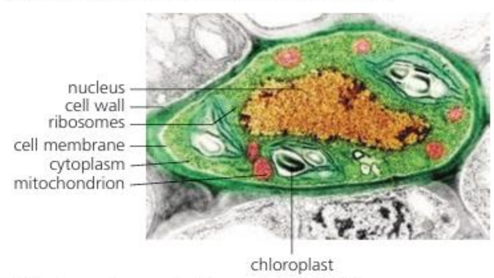


(a) diagram of a liver cell (×10 000)

▲ **Figure 1.8** Cells at high magnification



(b) electron micrograph of two liver cells (×10 000)



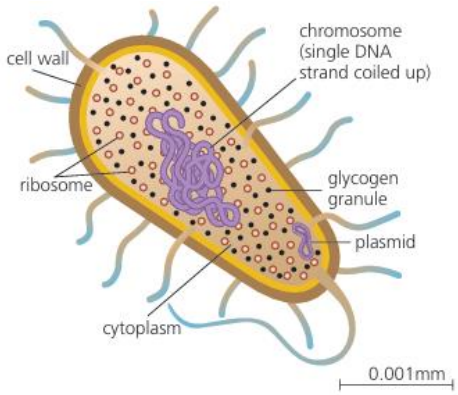
(c) electron micrograph of a plant cell (×6 000)

▲ **Figure 1.8** Cells at high magnification (continued)

Bacterial cell structure

Bacteria (singular: **bacterium**) are very small **organisms** that are single cells not often more than 0.01 mm in length. They can be seen only at high magnification under a microscope.

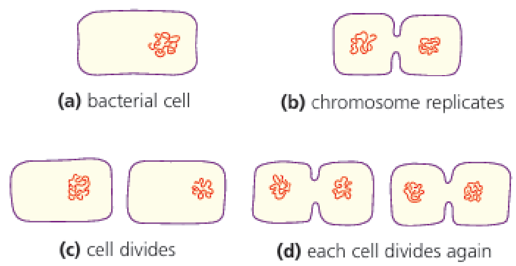
Plant cells have a complex cell wall composed of proteins, sugars, and lipids, with a cytoplasm containing **glycogen**, lipid, and food reserves. Large ribosomes, smaller than plant and animal cells, perform protein synthesis.



▲ **Figure 1.9** Generalised diagram of a bacterium

▲ **Figure 1.10** Longitudinal section through a bacterium (×27 000). The light areas are coiled DNA strands. There are three of them because the bacterium is about to divide twice (see Figure 1.11)

Plasmids, small circular structures made of DNA, are used in **genetic modification** by scientists due to their ease of inserting genetic material into them. Bacteria can be spherical, rod-shaped, or spiral, and contain a single chromosome.



▲ **Figure 1.11** Bacterium reproducing. This is asexual reproduction by cell division (see 'Asexual reproduction' and 'Mitosis' in Chapter 16)

▼ **Table 1.2** Summary: the parts of a bacterial cell

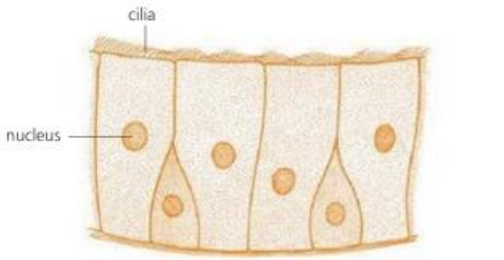
Name of part	Description	Where found	Function
cytoplasm	jelly-like, contains particles and organelles	surrounded by the cell membrane	contains cell structures, e.g. ribosomes, circular DNA, plasmids
cell membrane	a partially permeable layer that surrounds the cytoplasm	around the cytoplasm	prevents cell contents from escaping controls what substances enter and leave the cell
circular DNA	a single circular chromosome	inside the cytoplasm	controls cell division controls cell development controls cell activities
plasmids	small, circular pieces of DNA	inside the cytoplasm	contain **genes** that carry genetic information to help the process of the survival and **reproduction** of the bacterium
ribosomes	small, circular structures	inside the cytoplasm	protein synthesis
cell wall	a tough, non-living layer (not made of cellulose) that surrounds the cell membrane	around the outside of the bacterial cell	prevents the cell from bursting, allows water and salts to pass through (freely permeable)

Specialisation of cells

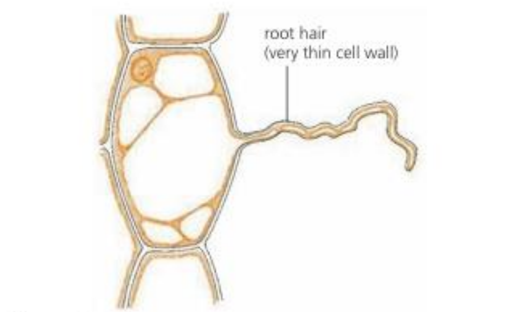
When cells have finished dividing and growing, most become specialised and have specific functions. When cells are specialised:

» They do one special job
» They develop a distinct shape
» Special kinds of chemical changes take place in their cytoplasm.

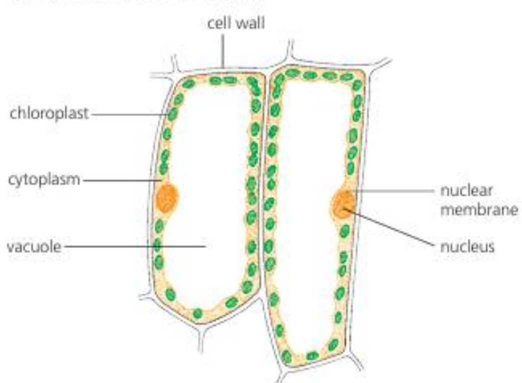
The changes in shape and the chemical reactions enable the cell to carry out its special function. Red blood cells and **root hair** cells are just two examples of specialised cells.



(a) ciliated cells
These cells form the lining of the nose and windpipe, and the tiny cytoplasmic 'hairs', called cilia, are in a continual flicking movement, which creates a stream of fluid (mucus) that carries dust and bacteria through the bronchi and trachea, away from the lungs.

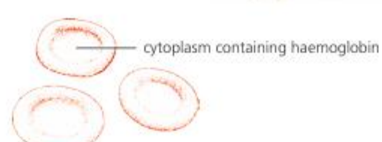


(b) root hair cell
These cells absorb water and mineral salts from the soil. The hair-like projection on each cell penetrates between the soil particles and offers a large absorbing surface. The cell membrane is able to control which dissolved substances enter the cell.



(c) palisade mesophyll cells
These are found underneath the upper epidermis of plant leaves. They are columnar (quite long) and packed with chloroplasts to trap light energy. Their function is to make food for the plant by photosynthesis using carbon dioxide, water and light energy.

(d) nerve cells
These cells are specialised for conducting electrical impulses along the fibre, to and from the brain and spinal cord. The fibres are often very long and connect distant parts of the body to the CNS, e.g. the foot and the spinal column. Chemical reactions cause the impulses to travel along the fibre.



(e) red blood cells
These cells are distinctive because they have no nucleus when mature. They are tiny disc-like cells that contain a red pigment called haemoglobin. This readily combines with oxygen and their function is the transportation of oxygen around the body.

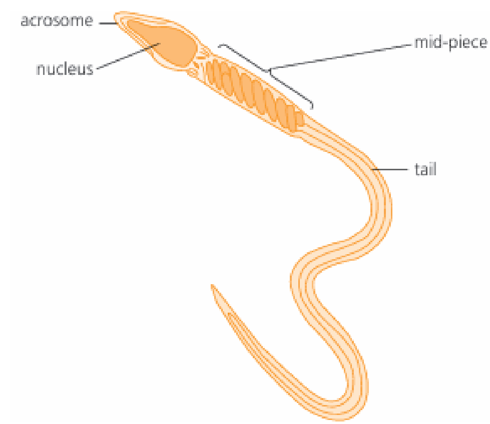
▲ **Figure 1.16** Specialised cells (not to scale)

Tissues, organs, Organ system and the organisms

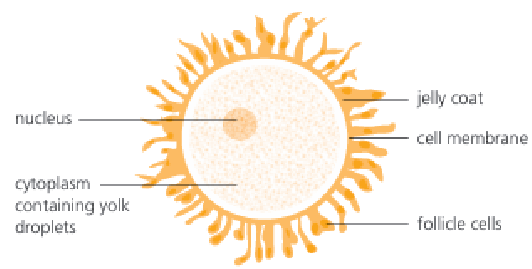
Tissues

A tissue, like bone, nerve or muscle in animals, and **epidermis**, **xylem** or pith in plants, is made up of large numbers of cells. These are often just a single type. Figure 1.17 shows how some cells are arranged to form simple tissues. Some forms of tissues are **epithelium**, tubes, sheets and **glands**.

> **Key definitions**
> A **tissue** is a group of cells with similar structures working together to perform a shared function.



(f) sperm cell
Sperm cells are male sex cells. The front of the cell is oval shaped and contains a nucleus which carries genetic information. There is a tip, called an **acrosome**, which secretes enzymes to digest the cells around an egg and the egg membrane. Behind this is a mid-piece which is packed with mitochondria to provide energy for **movement.** The tail moves with a whip-like action, enabling the sperm to swim. Their function is reproduction, achieved by fertilising an **egg cell.**



(g) egg cell
Egg cells are larger than sperm cells and are spherical. They have a large amount of cytoplasm, containing yolk droplets made up of protein and fat. The nucleus carries genetic information. The function of the egg cell is reproduction.

▲ **Figure 1.16** Specialised cells (not to scale) (continued)

Organs

Organs are made of several tissues grouped together to make a structure with a special job.

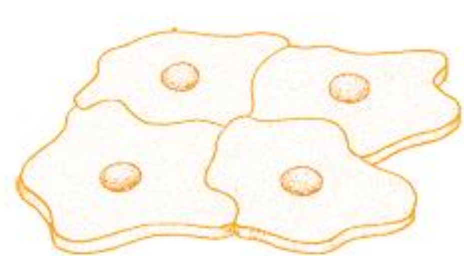
The heart, **lungs**, intestines, brain and eyes are further examples of organs in animals. In flowering plants, the root, stem and leaves are the organs. Some of the tissues of the leaf are epidermis, palisade tissue, spongy tissue, xylem and **phloem**.

> **Key definitions**
> An **organ** is a structure made up of a group of tissues working together to perform a specific function.

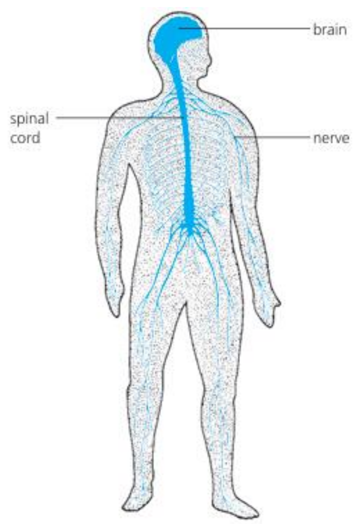
Organ systems

An **organ system** usually describes a group of organs with closely related functions. For example, the heart and blood vessels make up the **circulatory system**; the brain, spinal cord and nerves make up the **nervous system** (Figure 1.18). In a flowering plant, the stem, leaves and buds make up a system called the shoot.

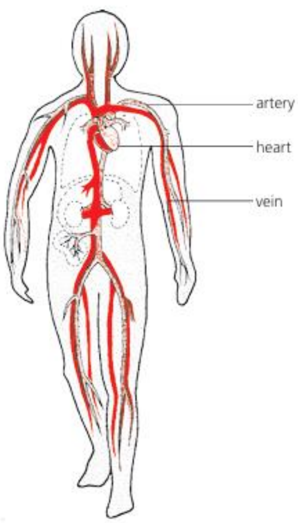
> **Key definitions**
> An **organ system** is a group of organs with related functions working together to perform a body function.



(a) cells forming an epithelium
A thin layer of tissue, e.g. the lining of the mouth cavity. Different types of epithelium form the internal lining of the windpipe, air passages, food canal, etc., and protect these organs from physical or chemical damage.

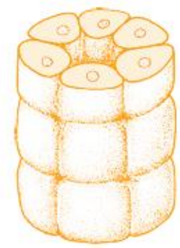


(a) nervous system

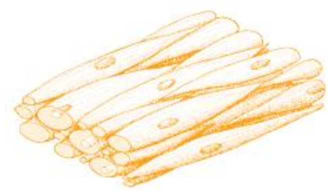


(b) circulatory system

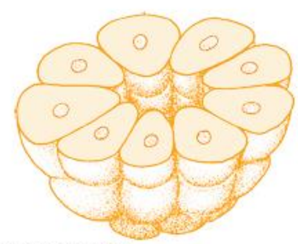
▲ **Figure 1.18** Two examples of systems in the human body



(b) cells forming a small tube
E.g. a kidney tubule (see page 210). Tubules such as this carry liquids from one part of an organ to another.



(c) one kind of muscle cell
Forms a sheet of muscle tissue. Blood vessels, nerve fibres and connective tissues will also be present. Contractions of this kind of muscle help to move food along the food canal or close down small blood vessels.

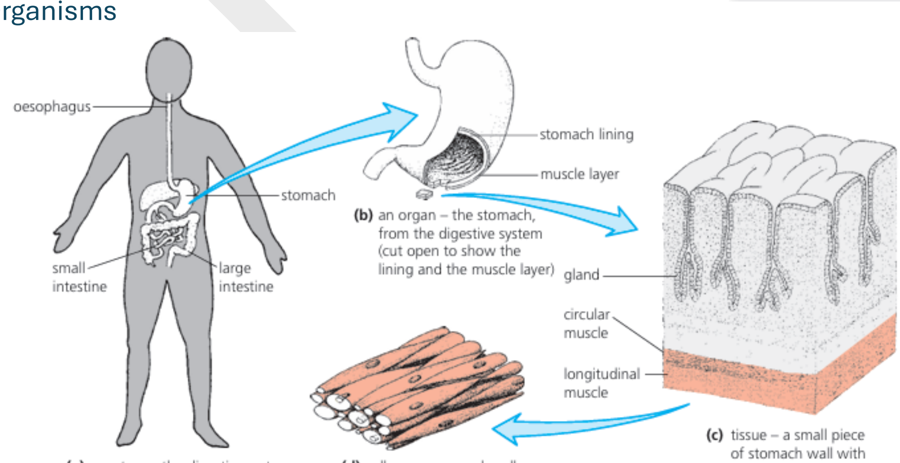


(d) cells forming part of a gland
The cells make chemicals, which are released into the central space and carried away by a tubule such as that shown in **(b)**. Hundreds of cell groups like this would form a gland like the salivary gland.

▲ **Figure 1.17** How cells form tissues

> **Key definitions**
> An **organism** is an individual animal or plant, formed by all the organs and systems working together to produce an independent living thing.

Organisms



(a) a system – the digestive system of the human organism

(b) an organ – the stomach, from the digestive system (cut open to show the lining and the muscle layer)

(c) tissue – a small piece of stomach wall with muscle tissue and gland tissue

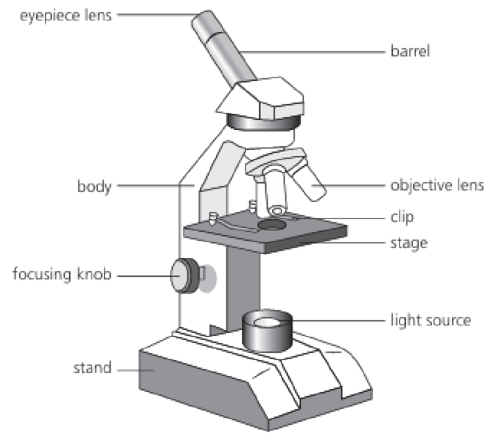
(d) cells – some muscle cells from the muscle tissue

▲ **Figure 1.19** An example of how cells, tissue and organs are related

Size of specimens

The light microscope

You cannot see most cells with the naked eye. A hand lens has a **magnification** of up to ×20, but this is not enough to see the detail in cells. Cells cannot be seen with the naked eye, but light microscopes can magnify up to ×1 500. Eyepiece lenses are usually ×10, and objective lenses are ×4, ×10, and ×40. Light is projected through the specimen, magnifying the image. Coarse and fine focus knobs can be used to make the image clearer. Microscope slides can be temporary or permanent, with temporary slides drying out quickly. Permanent slides are usually dehydrated and fixed in a special resin, storing well for a long time.



▲ **Figure 1.20** A light microscope

Calculating magnification

A lens is usually marked with its magnifying power. This tells you how much larger the image will be compared to the specimen's actual size.

Key definitions

Magnification is the observed size of an image divided by the actual size of the specimen.

When you draw the image, your drawing is usually much larger than the image, so the total magnification of the specimen is even bigger.

$$\text{Magnification} = \frac{\text{image size}}{\text{actual size of the specimen}}$$

For example, if the actual size is in **millimetres** and the **image size** is in centimetres, convert the centimetres to millimetres. (There are 10 millimetres in a centimetre.)

In questions, you may be asked to calculate the actual size of a specimen, given a drawing or photomicrograph and a magnification.

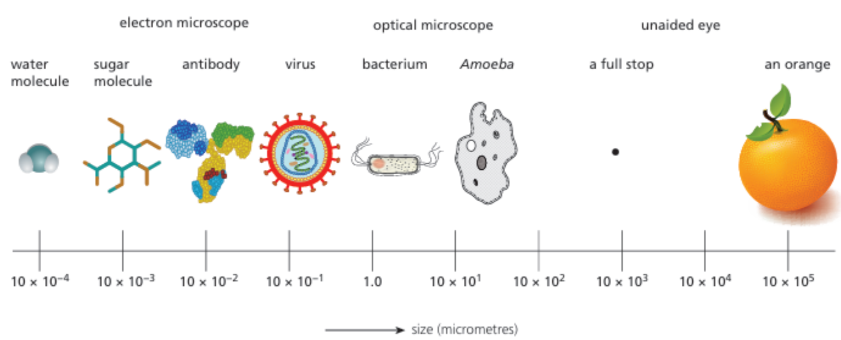
$$\text{Actual size of the specimen} = \frac{\text{image size}}{\text{magnification}}$$

Converting measurements

Organelles in cells are too small to be measured in millimetres. A smaller unit, called the **micrometre** (micron or µm), is used. Figure 1.21 shows a comparison of the sizes of a range of objects.

There are:

» 1 000 000 micrometres in a metre
» 10 000 micrometres in a centimetre
» 1 000 micrometres in a millimetre



▲ **Figure 1.21** Comparing the sizes of a range of objects

Revision questions

1)

Fig. 1 is a diagram of an animal cell.

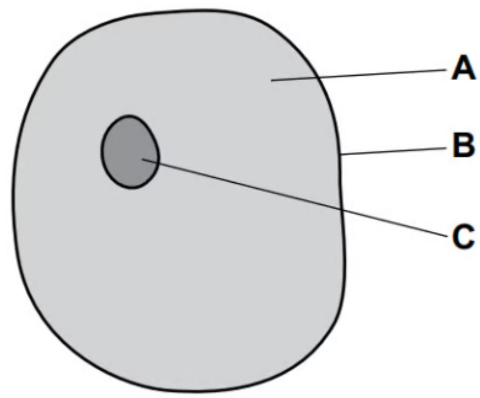


Fig. 1

(i) Identify the parts labelled **A, B** and **C** in Fig. 1

[3]

(ii) State the names of **two** structures in plant cells that are absent in animal cells.

[2]

(iii) State the name of **one** structure that is present in bacterial cells and in plant cells but

2) Fig. 1 shows a bacterial cell.

Identify the structures labelled A - F.

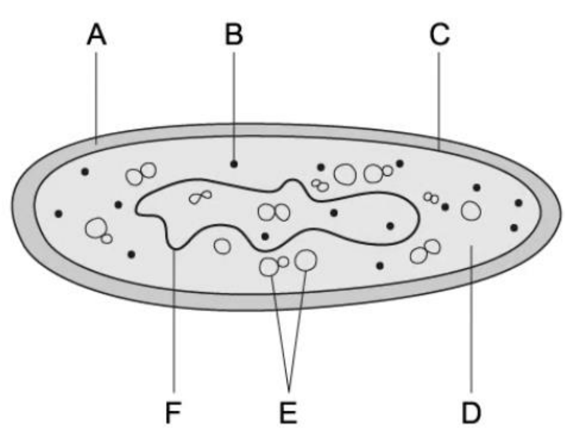


Fig. 1

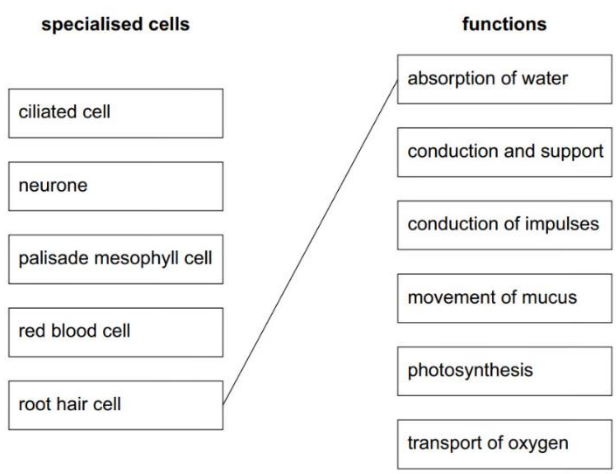
3) Some cells are specialised to perform a particular function.

The boxes on the left show the names of some specialised cells.

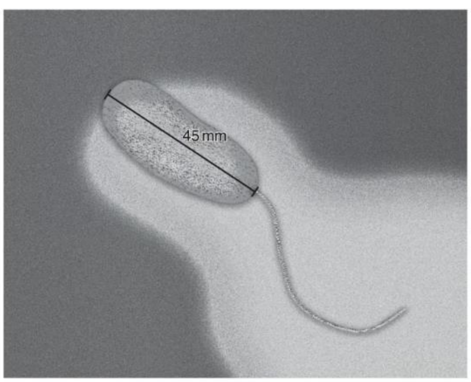
The functions of some specialised cells are in the boxes on the right.

Draw **four** lines to link each specialised cell with its function.

One line has been drawn for you. Draw four additional lines.



4) Fig. 1 is a photomicrograph of *Vibrio cholerae*, the bacterium that causes cholera.



magnification ×17300

Fig. 1

(i) Write the formula that would be used to calculate the actual length of the bacterium (not including the flagellum) in Fig. 1.

[1]

(ii) The actual length of the bacterium shown in Fig. 1 is 0.0026 mm.

Convert this value to micrometres (μm).

[1]

5) Which of the following orders would be correct showing the size of structures from biggest to smallest?

A. chromosome → red blood cell → stomach → gene → nucleus

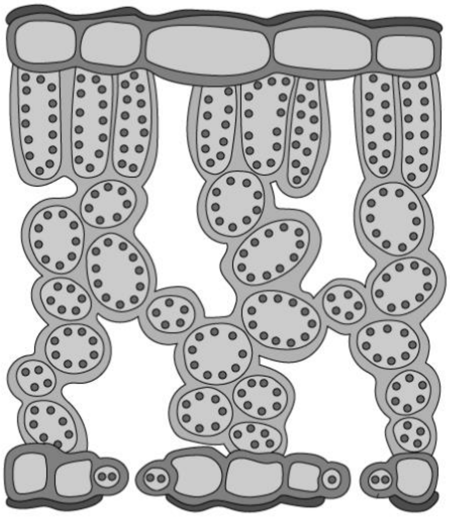
B. stomach → red blood cell → gene → chromosome

C. stomach → red blood cell → nucleus → chromosome → gene

D. gene → chromosome → red blood cell → stomach

6) A student looks at an image of a cross-section of a leaf in his Biology textbook.

The actual thickness of this leaf is 450 µm, but the image in the textbook has a depth of 83 mm.



What would be the correct magnification of the image?

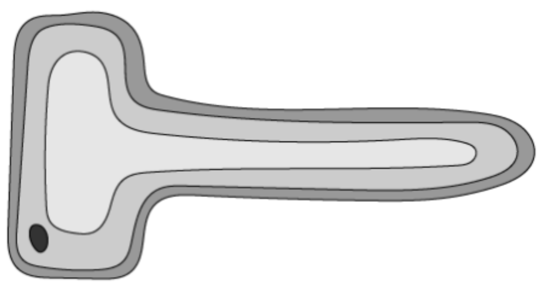
A. × 5

B. × 184

C. × 0.184

D. × 500

7) A student looks at the image below in a textbook.



The image is 43 mm wide and has been magnified 2500 times.

What is the actual width of the cell?

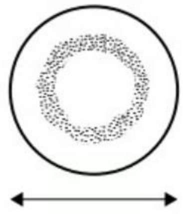
A. 0.0172 µm

B. 1.72 mm

C. 58.1 mm

D. 17.2 µm

8) A student draws a red blood cell. The drawing is 20mm in diameter.



This red blood cell is 0.008mm in diameter.

What is the magnification of the cell shown in the drawing?

A. ×40

B. ×250

C. ×2500

D. ×40000

9)
Which description of the liver below is correct?

A. The liver is a cell, containing several tissues, which forms part of the digestive system.

B. The liver is an organ, containing several systems, which forms part of the digestive tissue

C. The liver is an organ, containing several tissues, which forms part of the digestive system.

D. The liver is a cell, containing several systems, which forms part of the digestive system.

10)
Which row of the table below correctly matches a structure to its level of organisation within an organism?

	tissue	organ	system
A	phloem	small intestine	digestive
B	red blood cell	xylem	stomach
C	small intestine	sperm	digestive
D	root hair	leaf	heart

11) Which structures are present in plant cells but not in animal cells?

A. cell membrane, cytoplasm, chloroplasts

B. cell wall, chloroplasts, sap vacuole

C. cell wall, cell membrane, cytoplasm

D. cytoplasm, nucleus, chloroplasts

12) Which structures are found in animal cells and plant cells?

1 mitochondria
2 cell wall
3 ribosomes
4 sap vacuole

A. 1 and 3

B. 1 and 4

C. 2 and 3

D. 2 and 4

13)
Which row of the table below correctly matches functions to some of the components in a root hair cell?

	cell wall	cell membrane	mitochondria
A	support	active transport	energy release
B	energy release	active transport	nutrition
C	support	active transport	nutrition
D	active transport	support	energy release

14) The salivary glands contain cells which are responsible for producing salivary amylase, a digestive enzyme.

Which organelles would be present in large numbers in cells of the salivary glands?

A. mitochondria and nuclei

B. nuclei and ribosomes

C. mitochondria and vacuoles

D. mitochondria and ribosomes

15)

Which row of the table below correctly describes the structures present in a bacterial cell?

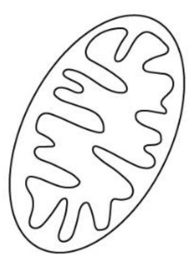
	cell membrane	cell wall	chromosome	nucleus
A	X	✓	X	X
B	✓	✓	✓	X
C	✓	✓	X	X
D	✓	X	X	✓

16)

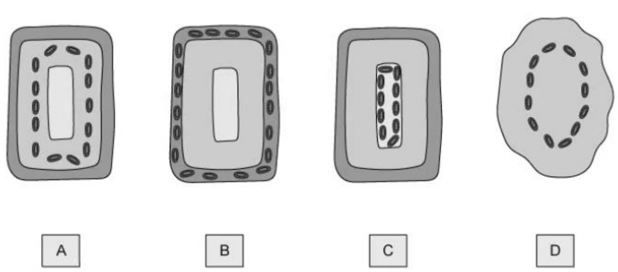
Which row of the table below correctly describes a spongy mesophyll cell?

	contains chloroplasts for photosynthesis	loses water by transpiration	ideal surface area for gas exchange
A	X	✓	✓
B	✓	✓	X
C	✓	✓	✓
D	✓	X	X

17) Eukaryotic cells contain mitochondria (a mitochondrion is shown below).



Which diagram below correctly shows the position of mitochondria in a plant cell?



18)

Which structures are present in plant cells but not in animal cells?

A. cell membrane, cytoplasm, chloroplasts

B. cell wall, chloroplasts, sap vacuole

C. cell wall, cell membrane, cytoplasm

D. cytoplasm, nucleus, chloroplasts

19)

Which structures are found in animal cells and plant cells?

1 mitochondria
2 cell wall
3 ribosomes
4 sap vacuole

A. 1 and 3

B. 1 and 4

C. 2 and 3

D. 2 and 4