STUDY AND REVISION GUIDE

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Cambridge IGCSE™

Biology

Third Edition

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Boost

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Contents

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1 Characteristics and classification of living organisms

Key objectives

The objectives for this chapter are to revise:

- definitions of the key terms
- characteristics of living organisms
- classification of organisms into groups using shared features
- species and the binomial system of naming them
- features of the cells of all living organisms
- features used to place animals and plants into the appropriate kingdoms
- classification of vertebrates and arthropods
- construction and use of simple dichotomous keys

- how classification systems aim to reflect evolutionary relationships
- how the sequences of bases in DNA are used as a means of classification
- how similarities and differences in base sequences of DNA show how closely related groups of organisms are
- the features of the five kingdoms
- classification of ferns and flowering plants
- the features of viruses

Key terms

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Term	Definition
Binomial system	An internationally agreed system in which the scientific name of an organism is made up of two parts, showing the genus and the species
Excretion	Removal of waste products of metabolism and substances in excess of requirements
Growth	A permanent increase in size and dry mass
Movement	An action by an organism or part of an organism causing a change of position or place
Nutrition	The taking in of materials for energy, growth and development
Reproduction	The processes that make more of the same kind of organism
Respiration	The chemical reactions in cells that break down nutrient molecules and release energy for metabolism
Sensitivity	The ability to detect and respond to changes in the internal or external environment
Species	A group of organisms that can reproduce to produce fertile offspring

Characteristics of living organisms

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There are seven characteristics shown by all living things, including plants and other organisms. These are **movement**, **respiration**, **sensitivity**, **growth**, **reproduction**, **excretion** and **nutrition**. You need to be able to recall and describe these.

You may be given a picture of an organism to study and then asked to identify which characteristics you could observe by watching it for a few minutes. Some of the seven would not be suitable answers, for example growth, respiration and reproduction (these are not likely to be visible or observable in a short timespan). Some non-living things, such as cars, may appear to show some of the characteristics, but not all of them.

Do not confuse respiration (chemical reactions in cells that break down nutrient molecules and release energy for metabolism) with breathing. Also, do not use faeces or defecation as an example of excretion. Faeces are undigested food and are not formed through metabolic processes.

Revision activity

Create a mnemonic (a sentence using the first letter of each word) to help you remember the seven characteristics of living organisms, such as MRS GREN. It can be more memorable if you have made it up yourself.

Sample question

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Name three characteristics of living things that you would expect an organism to show, other than irritability. [3]

Student's answer

Movement ✓, reproduction ✓ and sensitivity ✗

Teacher's comments

The first two answers are fine. However, the term sensitivity means the same as irritability, which has already been given in the question, so it did not earn a mark. Other possible answers are respiration, growth, excretion and nutrition.

Classification systems

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Classification makes the identification of living organisms easier – there are more than one million different **species** already identified. It involves sorting organisms into groups according to the features they have in common. The biggest group is called a kingdom. Each kingdom is divided into smaller groups, which include genus and species. Organisms can exist in only one group at each level of classification. For example, an organism can belong to only one kingdom or one genus.

When learning details about the classification of an organism, remember to identify what features are adaptations to its environment.

Binomial nomenclature

The **binomial system** is a worldwide system used by scientists. The scientific name of an organism is made up of two parts – genus and species – which are in Latin. The genus always has a capital letter – for example, *Panthera leo* is the binomial name for lion.

Dichotomous keys

Keys are often used by biologists in the process of identifying organisms. You need to be able to construct and use a dichotomous key, i.e. a key that branches into two at each stage, requiring you to choose between alternatives.

When completing a question involving a dichotomous key, make sure you work through the key properly to select your answer, rather than jumping to a statement that appears to fit the organism.

Skills

Construction of dichotomous keys

You need to be able to develop the skill of constructing simple dichotomous keys, based on easily identifiable features. If you know the main characteristics of a group, it is possible to draw up a systematic plan for identifying an unfamiliar organism. The first question should be based on a feature that will split the group into two.

The question is going to generate a 'yes' or 'no' answer. For each of the two subgroups formed, a further question based on the features of some of that subgroup should then be developed. This questioning can be continued until every member of the group has been separated and identified.

Classification and evolutionary relationships

By classifying organisms, it is also possible to understand evolutionary relationships. Classification is traditionally based on studies of **morphology** (the study of the form, or outward appearance, of organisms) and **anatomy** (the study of their internal structure, as revealed by dissection). Vertebrates all have a vertebral column, a skull protecting a brain and a pair of jaws (usually with teeth). By studying the anatomy of different groups of vertebrates, it is possible to gain an insight into their evolution.

Use of DNA sequencing in classification

The sequences of DNA and of amino acids in proteins are used as a more accurate means of classification than studying morphology and anatomy. Eukaryotic organisms contain chromosomes, made up of strings of genes. Genes are made of DNA, which is composed of a sequence of bases (see Chapter 4). Each species has a distinct number of chromosomes and a unique sequence of bases in its DNA, making it identifiable and distinguishable from other species.

The process of biological classification involves organisms being grouped together according to whether or not they have one or more unique characteristics in common derived from the group's last common ancestor, which are not present in more distant ancestors. Organisms that share a more recent ancestor (and are more closely related) have DNA base sequences that are more similar than those that share only a distant ancestor.

Features of organisms

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The cells of all living organisms contain cytoplasm, a cell membrane and DNA as genetic material. Two kingdoms are the plant and animal kingdoms.

Plants are made up of many cells – they are multicellular. Plant cells have an outside wall made of cellulose. Many of the cells in plant leaves and stems contain chloroplasts with photosynthetic pigments, such as chlorophyll. Plants make their food through photosynthesis.

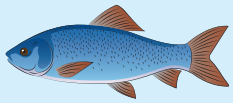
Animals are multicellular organisms whose cells have no cell walls or chloroplasts. Most animals ingest solid food and digest it internally.

For the core syllabus, you only need to learn the main groups of vertebrates and arthropods.

Classification of vertebrates

Vertebrates are animals with backbones (part of an internal skeleton). Vertebrates are divided into five groups called classes. Details of each group are given in Table 1.1. You only need to be able to describe visible external features, but other details can be helpful (see the 'Other details' column).

▼ **Table 1.1 Classification of vertebrates**

Vertebrate class	Body covering	Movement	Reproduction	Sense organs	Other details	Examples
Fish 	Scales	Fins (also used for balance)	Usually produces jelly-covered eggs in water	Eyes but no ears; lateral line along body for detecting vibrations in water	Cold blooded; gills for breathing	Herring, rohu, shark
Amphibians 	Moist skin	Four limbs; back feet often webbed to make swimming more efficient	Produces jelly-covered eggs in water	Eyes and ears	Cold blooded; lungs and skin for breathing	Frog, toad, salamander
Reptiles 	Dry, with scales	Four legs (apart from snakes)	Eggs with rubbery, waterproof shell; eggs are laid on land	Eyes and ears	Cold blooded; lungs for breathing	Crocodile, python
Birds 	Feathers, scales on legs	Wings; two legs	Eggs with hard shell	Eyes and ears	Warm blooded; lungs for breathing; beak	Flamingo, kestrel, pigeon
Mammals 	Fur	Four limbs	Live young	Eyes, ears with pinna (external flap)	Warm blooded; lungs for breathing; females have mammary glands to produce milk to feed young; four types of teeth	Elephant, mouse

Sample question

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Animals A, B and C are vertebrates:

- A has a scaly skin, four legs and lungs.
- B has hair, four legs and mammary glands.
- C has a scaly skin, fins and gills.

Create a table to show the group of organisms that each of the animals belongs to. [3]

Student's answer

Animal	Vertebrate group
A	Reptile ✓
B	Mammel ✓
C	Fish ✓

Teacher's comments

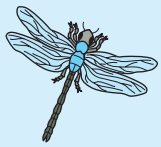
This answer has gained all three marks. The teacher allowed the second answer, although the spelling of mammal was not correct. Try to make sure that your spellings are correct – poor spelling can result in a mark not being awarded, especially if the word is similar to another biological word, for example meiosis and mitosis.

Classification of arthropods

Special features of arthropods:

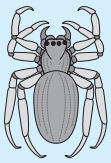
- They are invertebrates – they have no backbone.
- They have an exoskeleton that is waterproof. This makes arthropods an extremely successful group, because they can exist in very dry places and are not confined to water or moist places like most other invertebrates.
- Their bodies are segmented.
- They have jointed limbs (the exoskeleton would otherwise prevent movement).

There are more arthropods than any other group of animals, so they are divided into classes. Figure 1.1 shows the differences between the four classes – insects, arachnids, crustaceans and myriapods. You only need to know about their external features.



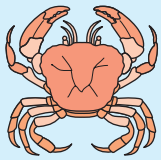
Insects, e.g. dragonfly, locust

Key features:
- three pairs of legs
- usually have two pairs of wings
- one pair of antennae
- body divided into head, thorax and abdomen
- a pair of compound eyes



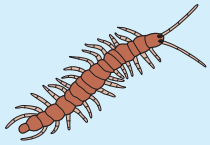
Arachnids, e.g. spider, tick

Key features:
- four pairs of legs
- body divided into cephalothorax and abdomen
- several pairs of simple eyes
- chelicerae for biting and poisoning prey



Crustaceans, e.g. crab, woodlouse

Key features:
- five or more pairs of legs
- two pairs of antennae
- body divided into cephalothorax and abdomen
- exoskeleton often calcified to form a carapace (hard)
- compound eyes



Myriapods, e.g. centipede, millipede

Key features:
- ten or more pairs of legs (usually one pair per segment)
- one pair of antennae
- body not obviously divided into thorax and abdomen
- simple eyes

▲ **Figure 1.1 Classification of arthropods**

Be careful with when answering questions about the different numbers of legs in insects, arachnids and crustaceans. Students often state that insects have three legs instead of three pairs of legs, losing the mark through carelessness or haste.

Five kingdoms

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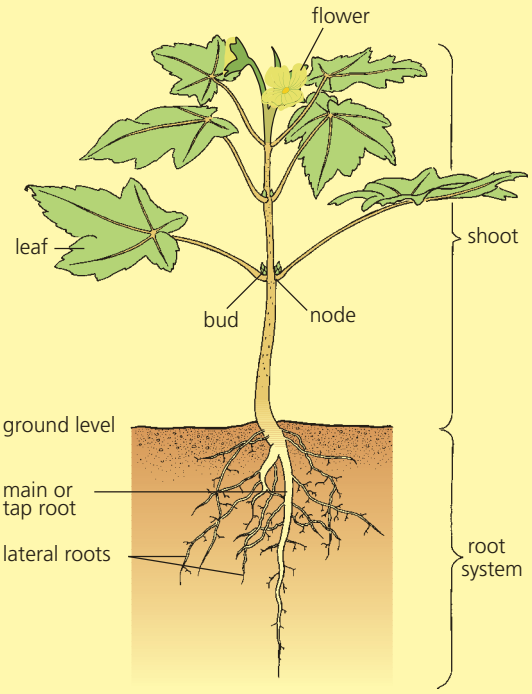
In the classification of living organisms, there are five kingdoms, each with its own special and obvious features. The kingdoms are as follows:

- Animals – multicellular organisms that have to obtain their food. Their cells do not have walls.
- Plants – multicellular organisms with the ability to make their own food through photosynthesis because of the presence of chlorophyll. Their cells have walls (containing cellulose).
- Fungi – many are made of hyphae, with nuclei and cell walls (containing chitin) but no chloroplasts.
- Prokaryotes (bacteria) – very small and single celled, with cell walls but no nucleus.
- Protoctists – single celled with a nucleus. Some have chloroplasts.

Features of the plant kingdom

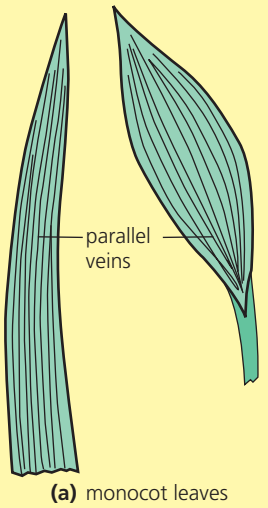
You only need to learn the features of flowering plants and ferns.

Flowering plants (Figure 1.2) are all multicellular organisms. Their cells have cellulose cell walls and sap vacuoles. Some of the cells contain chloroplasts. They have roots, stems and leaves. Reproduction can be by producing seeds, although asexual reproduction is also possible.

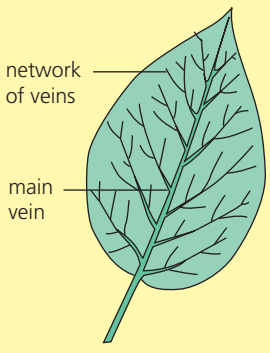


▲ **Figure 1.2 Structure of a typical flowering plant**

There are two groups – monocotyledons and dicotyledons. The term cotyledon means 'seed leaf'. The main differences between the two groups are shown in Figure 1.3 and listed in Table 1.2.



(a) monocot leaves



(b) a dicot leaf

▲ **Figure 1.3 Leaf types in flowering plants**

▼ **Table 1.2 Features of monocotyledons and dicotyledons**

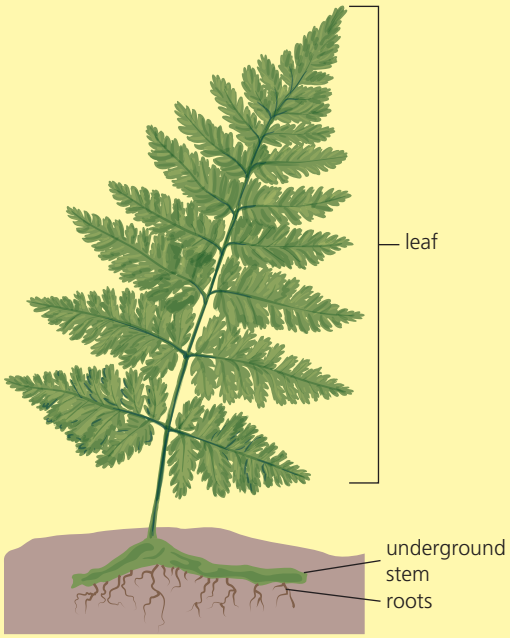
Feature	Monocotyledon	Dicotyledon
Leaf shape	Long and narrow	Broad
Leaf veins	Parallel	Branching
Cotyledons	One	Two
Grouping of flower parts, such as petals, sepals and carpels	In threes	In fives

Ferns (Figure 1.4) are land plants. Their stems, leaves and roots are very similar to those of the flowering plants. The stem is usually entirely below ground. The stem and leaves have sieve tubes and water-conducting cells. Ferns also have multicellular roots with vascular tissue. The leaves are several cells thick. Most of these have an upper and lower epidermis, a layer of palisade cells and a spongy mesophyll.

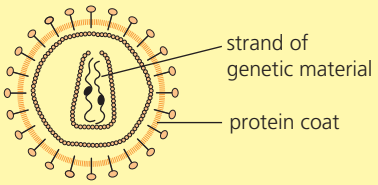
Ferns do not form buds. The midrib and leaflets of the young leaf are tightly coiled and unwind as it grows. Ferns produce gametes but no seeds. The zygote gives rise to the fern plant, which then produces single-celled spores from numerous **sporangia** (spore capsules) on its leaves. The sporangia are formed on the lower side of the leaf.

Features of viruses

Viruses are very small (one-hundredth the size of bacteria), and they do not have a typical cell structure (Figure 1.5). The only life process they show is reproduction (inside host cells). They contain a strand of genetic material (DNA or RNA) and are surrounded by a protein coat.



▲ **Figure 1.4 Structure of a fern**



▲ **Figure 1.5 Structure of a virus**

Revision activity

Make your own mnemonic for the five kingdoms, using the letters P, P, F, P, A.

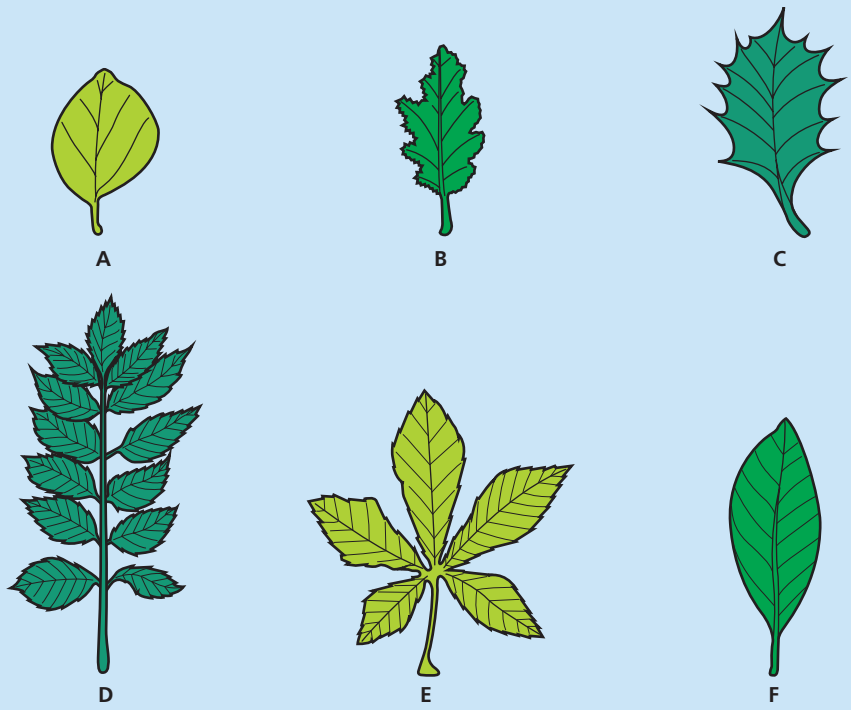
Exam-style questions

1 Complete the following sentences about the characteristics of living organisms using only words from the list below. [4]

excretion growth movement nutrition
respiration sensitivity

A living organism can be compared to a machine such as a car. The supply of petrol for the car is similar to _____, and the release of energy when the petrol is burned resembles _____ in a living organism. This can bring about the _____ of the wheels. _____ in living organisms is similar to the release of exhaust fumes by the car.

2 Figure 1.6 shows single leaves from six different trees.



▲ **Figure 1.6**

Use the key below to identify which tree each leaf comes from. Make a table similar to the one below and put a tick in the correct box to show how you identified each leaf. Give the name of the tree. Leaf A has been identified for you as an example. [5]

1	**a**	Leaf with smooth outline	*go to 2*
	b	Leaf with jagged outline	*go to 3*
2	**a**	Leaf about the same length as width	*Cydonia*
	b	Leaf about twice as long as it is wide	*Magnolia*
3	**a**	Leaf divided into more than two distinct parts	*go to 4*
	b	Leaf not divided into more than two distinct parts	*go to 5*
4	**a**	Leaf divided into five parts	*Aesculus*
	b	Leaf divided into ten or more parts	*Fraxinus*
5	**a**	Leaf with pointed spines along its edge	*Ilex*
	b	Leaf with rounded lobes along its edge	*Quercus*

Leaf	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b	Name of tree
A	✓		✓								*Cydonia*
B											

3 Figure 1.7 shows some invertebrates found in a compost heap.

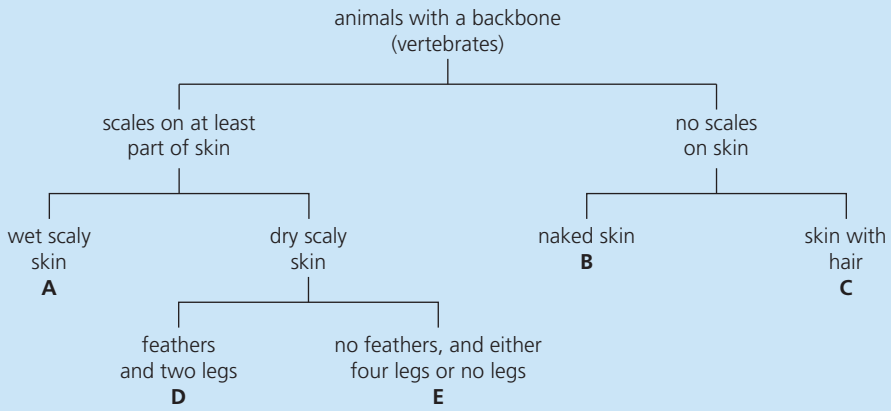
▲ **Figure 1.7**

Use the key to identify each animal and state the items in the key used in each identification. One has been done for you. [6]

1	Has legs	*2*
	No legs	*5*
2	More than six legs	*3*
	Six legs	*4*
3	Short, flattened grey body	*Oniscus asellus*
	Long brown/yellow body	*Lithobius forficatus*
4	Pincers on last segment	*Forficula auricularia*
	Hard wing covers	*Coccinella septempunctata*
5	Body segmented	*Lumbricus terrestris*
	Body not segmented	*6*
6	Has a shell	*Helix aspersa*
	No shell	*Arion ater*

Animal	Name of animal	Items used in the key
A	*Helix aspersa*	1, 5, 6
B		
C		
D		

4 Figure 1.8 can be used to identify the main classes of vertebrate. Use the key to identify the main classes represented by the letters A–E. [5]



▲ **Figure 1.8**

5 **a** Copy the diagrams of the insect, crustacean and arachnid in Figure 1.1 (p. 5) and label the key features that you can see. [4]

b Copy the myriapod diagram in Figure 1.1 and label the features that are common to all arthropods. [3]

2 Organisation of the organism

Key objectives

The objectives for this chapter are to revise:

- definitions of the key terms
- structures of plant, animal and bacterial cells and the functions of cell structures
- tissues, organs and organ systems
- calculating the magnification and size of biological specimens
- how to convert measurements between millimetres (mm) and micrometres (μm)

Key terms

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Term	Definition
Cell	The smallest basic unit of an animal or plant; it is microscopic and acts as a building block
Magnification	The observed size of an image divided by the actual size of the image
Organ	A structure made up of a group of tissues working together to perform a specific function
Organ system	A group of organs with related functions working together to perform a body function
Organism	A living thing that has an organised structure, can react to stimuli, reproduce, grow, adapt, and maintain homeostasis
Tissue	A group of cells with similar structures working together to perform a shared function

Cell structure and organisation

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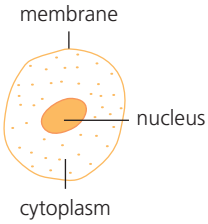
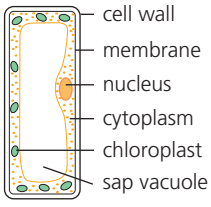
Most living things are made of **cells** – microscopic units that act as building blocks. Multicellular **organisms** are made up of many cells. Cell shape varies depending on its function (what job it does). Plant and animal cells differ in size, shape and structure (Figure 2.1). Plant cells are usually larger than animal cells.

Animal cell



This is a liver cell. It is a very active cell. The cytoplasm contains many mitochondria, which provide energy for the cell's activities.

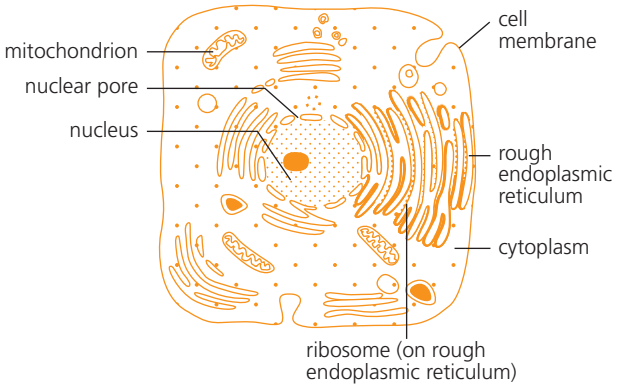
Plant cell



This is a palisade cell. It is found below the upper epidermis of leaves. Its role is in photosynthesis – trapping sunlight and converting it into chemical energy.

▲ **Figure 2.1 Comparison of animal and plant cells**

When viewed under an electron microscope, other organelles become visible. These include ribosomes and mitochondria (Figure 2.2).



▲ **Figure 2.2 Liver cell**

Remember:

- Animal cells contain only three main parts: membrane, nucleus and cytoplasm.
- Animal cells never have a cell wall, chloroplasts or sap vacuoles (although they may have temporary vacuoles where food is stored).
- Not all cells have all cell parts when mature – for example, red blood cells do not have a nucleus and xylem cells do not have a nucleus or cytoplasm.
- It is not true that all plant cells contain chloroplasts – for example, epidermis cells and root cells do not.
- Chloroplasts (structures or organelles) are different from chlorophyll (the chemical found in them).

Revision activity

Make a mnemonic to help you remember the three main parts of animal cells (membrane, nucleus, cytoplasm) – for example, Mice Nibble Cheese.

Parts of a cell

Structures found in animal and plant cells are summarised in Table 2.1.

▼ **Table 2.1 Structures in animal and plant cells, and their functions**

	Part	Description	Where found	Function
Animal and plant cells	Cytoplasm	Jelly-like, containing particles and organelles	Enclosed by a cell membrane	Contains cell organelles, e.g. mitochondria, nucleus Chemical reactions take place here
	Membrane	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	Round or oval structure containing DNA in the form of chromosomes	Inside the cytoplasm	Controls cell division Controls cell development Controls cell activities
	Ribosomes	Tiny particles floating freely or attached to membranes called rough endoplasmic reticulum	Inside the cytoplasm	Responsible for synthesis of proteins from amino acids
	Mitochondria (singular: mitochondrion)	Circular, oval or slipper-shaped organelle	Inside the cytoplasm	Responsible for aerobic respiration Cells with high rates of metabolism, e.g. liver cells, require large numbers of mitochondria to provide sufficient energy

	Part	Description	Where found	Function
Plant cells only	Cell wall	Tough, non-living layer made of cellulose; it surrounds the membrane	Around the outside of plant cells	Prevents plant cells from bursting Freely permeable (allows water and mineral ions to pass through)
	Sap vacuole	Fluid-filled space surrounded by a membrane	Inside the cytoplasm of plant cells	Contains mineral ions and sugars Helps keep plant cells firm
	Chloroplasts	Organelles containing chlorophyll	Inside the cytoplasm of some plant cells	Trap light energy for photosynthesis

Sample question

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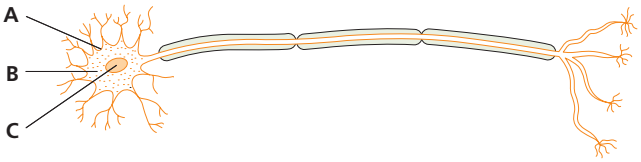
Figure 2.3 shows a nerve cell. State the names of the cell parts A, B and C. [3]



▲ **Figure 2.3**

Student's answer

A: *cell wall* ✗; B: *cytoplasm* ✓; C: *nucleus* ✓

Teacher's comments

The first answer is wrong – a nerve cell is an animal cell, so it does not have a cell wall. The correct answer for part A is cell membrane.

Revision activity

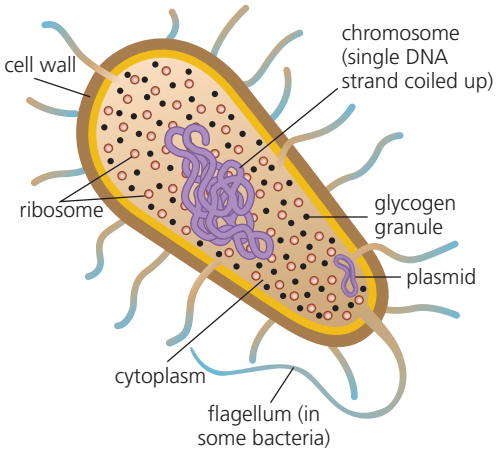
Trace, copy or sketch the cells shown in Figure 2.1 (p. 10). Practise labelling both cells. Then do the same with other types of animal and plant cells.

When labelling plant cells, start from the outside (the cell wall) and work inwards on this order: cell wall, membrane, cytoplasm, chloroplast, nucleus, sap vacuole. The chloroplasts and nucleus are both held inside the cytoplasm.

Cell walls are always drawn as a double line to show their thickness. Make sure that your cell wall label line touches the outer line. The membrane label line should touch the inner line of the cell wall (when plant cells are turgid – firm – the membrane is pressed against the cell wall).

Bacterial cell structure

Bacteria are very small organisms that are single cells. They have a cell wall surrounding the cytoplasm, which contains large numbers of free-floating ribosomes and granules. Bacteria do not have a nucleus: they have circular DNA, made of a single chromosome, and plasmids (Figure 2.4).



▲ **Figure 2.4 Generalised diagram of a bacterium**

▼ **Table 2.2 Structures in bacterial cells and their functions**

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 processes of 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 mineral ions to pass through (freely permeable)

Formation of new cells

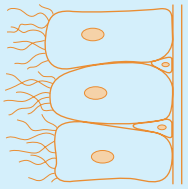
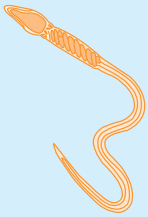
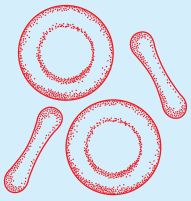
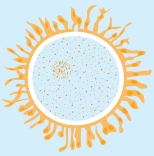
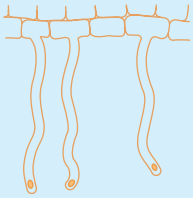
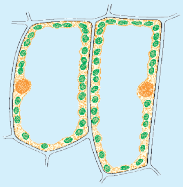
Cells have a limited lifespan; if they become damaged, they may not function properly. New cells are constantly being formed by the division of existing cells.

Plant and animal cells divide by a process called **mitosis** (Chapter 17). Gametes (sex cells) are formed by a different process called **meiosis**, which involves halving the chromosome number (Chapter 17).

Bacterial cells do not divide by mitosis because they do not have a nucleus. They divide in the process of asexual reproduction (Chapter 16).

Specialisation of cells

Figure 2.5 shows examples of cells and their functions in **tissues**.

Animal cells				
Ciliated cells – in respiratory tract  **Special features:** tiny hairs called cilia that can move mucus **Function:** waft mucus with bacteria and dust away from the lungs	**Sperm cells**  **Special features:** tail to enable the sperm to swim. Nucleus carries genetic information **Function:** reproduction, achieved by penetrating an egg cell	**Red blood cells**  **Special features:** no nucleus; contain haemoglobin **Function:** transport oxygen around the body	**Egg cells**  **Special features:** large amount of cytoplasm containing yolk droplets, made up of protein and fat. Nucleus carries genetic information **Function:** reproduction	**Neurones**  **Special features:** often very long and able to conduct electrical impulses. Some have a fatty sheath for insulation **Function:** carry electrical impulses to and from the brain and spinal cord
Plant cells				
Root hair cells  **Special features:** hair gives a large surface area **Function:** absorb water and mineral ions	**Palisade mesophyll cells**  **Special features:** column-shaped cells, packed with chloroplasts **Function:** trap sunlight to make food for the plant by photosynthesis			

▲ **Figure 2.5 Examples of specialised animal and plant cells**

Xylem and phloem tissues are often confused. Remember:

- Xylem carries water and mineral ions.
- Phloem transports sugars and amino acids.
- In a vascular bundle in a stem, phloem is on the outside and xylem is on the inside.

Sample question

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With reference to a suitable named example, define the term *tissue*. [3]

Student's answer

A tissue is a group of cells ✓ carrying out the same job ✓.

Teacher's comments

The answer needs three clear points to gain the 3 marks available. This student has not named a type of tissue (even though this was the first instruction in the question) and has given only two correct points. Always use the marks shown in the margin to show you how many points to give. Avoid giving more than three; this would waste time that you might need to answer other questions. Choose three statements to make before writing them down. The teacher will not select the best answers from a mixture of good and bad ones.

Organs and organ systems

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You need to be able to give examples of **organs** and **organ systems** in both plants and animals.

Organs are made of several tissues grouped together to make a structure with a special job. A leaf is an organ made up of a number of tissues, such as the upper epidermis and palisade mesophyll. Organ systems are groups of organs with closely related functions. Table 2.3 shows examples found in animals and plants.

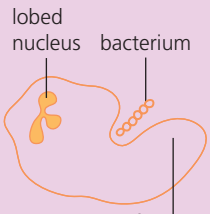
▼ **Table 2.3 Examples of organs and organ systems in animals and plants**

Organism	Examples of organs	Examples of organ systems
Animal	Heart, lungs, intestine, eye, brain	Circulatory system, nervous system, digestive system
Plant	Leaf, stem, flower	Shoot, reproductive system

Revision activity

It is important that you can identify the different levels of organisation in drawings, diagrams and images of plant and animal material. Practise this by looking at examples in textbooks or on the internet.

Annotating (adding a description to a labelled part of a diagram or drawing) these diagrams and drawings is also a useful revision tool, and may help you gain extra marks in an exam answer. Figure 2.6 shows the action of a phagocyte, for example.



cytoplasm forms pseudopodia to surround and engulf bacteria – enzymes are released to digest and kill bacteria

▲ **Figure 2.6 A phagocyte engulfing a bacterium**

Size of specimens

REVISED

A microscope makes a specimen appear larger than it really is (it magnifies the specimen). You need to be able to calculate the **magnification** and also the actual size of the specimen.

If dealing with a very large number, it may be better to display it in standard form.

Skills

Standard form

Standard form is a way of writing down very large or very small numbers more easily. It uses the powers of 10 to show how big or how small the number is.

You write it as $y \times 10^n$ where:

- y is always a number greater than or equal to 1, but less than 10
- n can be any positive or negative whole number

If answering an extended paper, remember that there are 1000 micrometres (μm) in a millimetre. Therefore:

- To change a measurement from micrometres to millimetres, you need to divide the figure by 1000.
- To change a measurement from millimetres to micrometres, you need to multiply the figure by 1000.

Skills

Magnification

To calculate the magnification of specimens that have been observed using a light microscope, memorise and use the following equation:

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

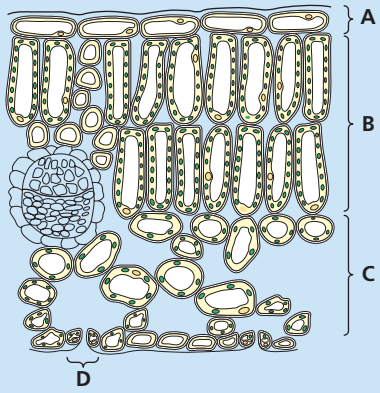
Make sure that the observed size and actual size have the same units.

Exam-style questions

1 **a** Describe how a bacterial cell is different from a plant cell such as a palisade cell. [3]

b Explain why bacterial cells do not divide by mitosis. [1]

2 Identify parts A, B, C and D shown in Figure 2.7, and describe their main features and functions. [12]



▲ **Figure 2.7**

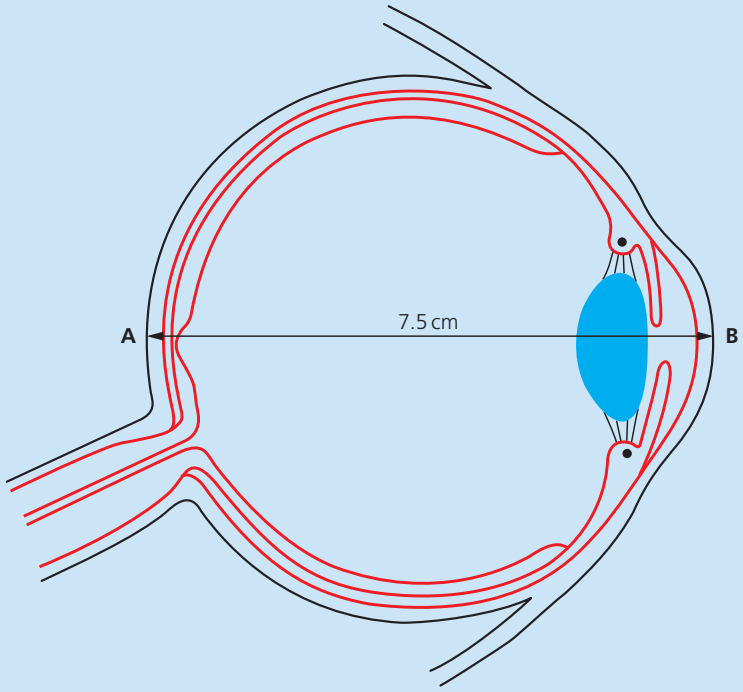
3 **a** Name one organ *not* given in Table 2.3 that is found in:

i animals [1]

ii plants [1]

b Name two tissues found in each of the organs you have named. [4]

4 The diagram of a cow's eye shown in Figure 2.8 is magnified ×2.5 (not drawn to scale). Calculate the actual width of the eye, as shown between points A and B. Show your working. [2]



▲ **Figure 2.8**

5 Display the sizes of the following organisms in standard form.

a The actual length of leaf D in Figure 1.6 (p. 8) (350 mm). [1]

b The diameter of a bacterial cell (0.002 mm). [1]

6 The actual length of leaf D in Figure 1.6 is 350 mm.

a Convert this figure into micrometres. [1]

b Display your answer in standard form. [1]

3 Movement into and out of cells

Key objectives

The objectives for this chapter are to revise:

- definitions of diffusion and active transport
- the source of energy for diffusion
- that some substances move into and out of cells by diffusion through the cell membrane
- the importance of diffusion of gases and solutes in living organisms
- the factors that influence diffusion
- the role of water as a solvent in organisms
- that water diffuses through partially permeable membranes, and into and out of cells through the cell membrane, by osmosis
- investigations into the effects on plant tissues of immersing them in solutions of different concentrations
- that plants are supported by the pressure of water inside the cells pressing outwards on the cell wall

- the definition of osmosis
- how to explain the effects of osmosis on plant cells
- how to use the terms associated with osmosis
- the importance of water potential and osmosis in the uptake and loss of water by organisms
- how to explain the importance of active transport as a process for movement of molecules or ions across membranes
- that protein carriers move molecules or ions across a membrane during active transport

Key terms

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Term	Definition
Active transport	The movement of particles through a cell membrane from a region of their lower concentration to a region of higher concentration (i.e. against a concentration gradient), using energy from respiration
Diffusion	The net movement of particles from a region of their higher concentration to a region of lower concentration (i.e. down a concentration gradient), as a result of their random movement
Osmosis	The net movement of water molecules from a region of higher water potential (dilute solution) to a region of lower water potential (concentrated solution) through a partially permeable membrane

Diffusion

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Diffusion is a really important process for living organisms because it helps to provide essential gases and solutes (materials in solution), and also helps to remove some substances that are potentially toxic (poisonous). These move into or out of the cell through the cell membrane. Table 3.1 gives some examples.

▼ **Table 3.1 Examples of diffusion in living organisms**

Site of diffusion	Substance	Description
Alveoli of lungs	Oxygen	From the alveoli into the blood capillaries
Alveoli of lungs	Carbon dioxide	From blood capillaries into the alveoli
Stomata of leaf	Oxygen	From the air spaces, through stomata, into the atmosphere during photosynthesis

The energy for diffusion comes from the kinetic (movement) energy of the random movement of molecules and ions. From the organism's point of view, it is a 'free' process – no energy needs to be provided to make it happen.

Rates of diffusion

You need to be able to state the factors that help diffusion to be efficient. These are:

- distance (the shorter the better), for example the thin walls of alveoli and capillaries
- concentration gradient (the bigger the better); this can be maintained by removing the substance as it passes across the diffusion surface (think about oxygenated blood being carried away from the surface of alveoli)
- surface area for diffusion (the larger the better), for example there are millions of alveoli in a lung, giving a huge surface area for the diffusion of oxygen
- temperature (molecules have more kinetic energy at higher temperatures)

Do not confuse cell walls with capillary walls – animal cells do not have walls. Many students throw away marks by referring to 'the thin cell walls of capillaries'. What they mean is 'the *walls of capillaries* are thin because they are only one cell thick'.

Revision activity

Make a mnemonic to remember the factors that help diffusion to be efficient. The order of letters is not important; sort them so they make a memorable sentence. For example, Cold Dinosaurs Sip Tea (concentration gradient, distance, surface area, temperature). The sillier the better, as it helps make it more memorable.

Skills

Investigating how distance travelled affects the rate of diffusion

You may be asked how to investigate how the distance a material has to travel affects the rate of diffusion. This can be done using transparent blocks of agar or gelatine. They are cut into four cubes, all with length of side 3.0 cm, and placed in a beaker containing a dye, such as methylene blue.

After 15 minutes, the first cube is removed and cut in half. The depth to which the dye has diffused is measured. The other cubes are removed at intervals of 15 minutes, sectioned and measured in the same way. The rate of diffusion for each cube is calculated using the equation:

$$\text{rate} = \frac{\text{distance travelled}}{\text{time}}$$

Your results should lead you to the following conclusions:

1. The longer the cube is left in the dye, the greater the distance travelled by the dye.
2. The further the dye travels, the slower the rate of diffusion.

Osmosis

REVISED

Water is important to living things as a solvent – many substances (solutes) dissolve in it. Examples include glucose, mineral ions and amino acids. In animals, water is essential for the following processes:

- **Digestion** – water helps to break down and dissolve food molecules in the process of digestion.
- **Transport** – blood is made up of cells and a water-based liquid called plasma. The plasma is a way of transporting many dissolved substances, for example carbon dioxide, urea, glucose and hormones.
- **Excretion** – water is important in the process of excretion in animals because some of the excretory materials, for example urea, are toxic. Water dilutes these to make them less poisonous. Urine is a solution containing dissolved mineral ions, urea, used hormones and drugs.

Osmosis is a special form of diffusion. It always involves the movement of water across a partially permeable membrane. Plants rely on osmosis to obtain water through their roots. They use water as a transport medium to carry dissolved mineral ions, sucrose and amino acids around the plant through the xylem and phloem vessels, and to maintain the firmness of cells. When young plants lose more water than they gain, cells become limp and the plants wilt.

Fish living in salt water lose water by osmosis. They have very efficient kidneys to reduce water loss in urine.

If we get dehydrated, water is lost from our red blood cells by osmosis. As the cells shrink, they become less efficient at carrying oxygen.

Effects of osmosis on plant and animal tissues

- When placed in water, plant and animal cells will take in the water through their cell membranes by diffusion. The diffusion of water in this way is called osmosis.
- Plant cells become swollen, but do not burst because of their tough cell wall.
- Plants are supported by the pressure of water inside the cells pressing outwards on the cell wall, which is inelastic and prevents further net entry of water.
- Animal cells will burst because they have no cell wall.
- The reverse happens when plant and animal cells are placed in concentrated sugar or salt solutions – plant and animal cells become limp.

Remember that sugars and mineral ions do *not* move by osmosis. Cell membranes can prevent some substances entering or leaving the cell.

Sample question

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Some sugar solution was collected from the phloem of a plant stem. Plant cells were placed on a microscope slide and covered with this sugar solution.

Describe what changes would occur to each of the following three cell parts if the sugar solution was more concentrated than the sap in the cell vacuole: sap vacuole, cytoplasm, cell wall. [3]

Student's answer

Sap vacuole: this will get smaller ✓ because there is a higher concentration of water inside the cell, so the water will pass out of the vacuole by osmosis.

Cytoplasm: this will shrink because it is losing water. ✗

Cell wall: this will stop stretching and stop curving outwards. ✓

Correct answer

The sap vacuole will get smaller.

The cytoplasm will shrink and pull away from the cell wall.

The cell wall will stop stretching and stop curving outwards.

Teacher's comments

The first answer is correct, but this student has wasted time writing more than is needed – the question required a description, not an explanation. The second answer should give details about the way the cytoplasm comes away from the cell wall. In the third answer, details about the cell wall are not very well worded, but it is clear that the student understands what is happening.

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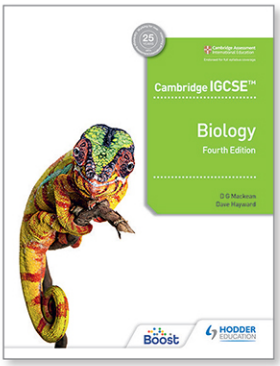

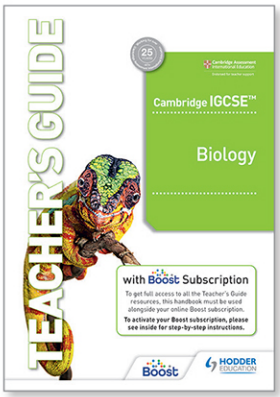

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