Contents

Getting the best from the book

Welcome to Collins *Cambridge IGCSE Biology*.

This textbook has been designed to help you understand all of the requirements needed to succeed in the Cambridge IGCSE Biology course. Just as there are twenty one sections in the Cambridge syllabus, there are twenty one sections in the textbook.

Each section is split into topics. Each topic in the textbook covers the essential knowledge and skills you need. The textbook also has some very useful features which have been designed to really help you understand all the aspects of Biology which you will need to know for this syllabus.

SAFETY IN THE SCIENCE LESSON

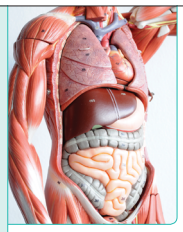
This book is a textbook, not a laboratory or practical manual. As such, you should not interpret any information in this book that related to practical work as including comprehensive safety instructions. Your teachers will provide full guidance for practical work and cover rules that are specific to your school.

A brief introduction to the section to give context to the science covered in the section.

The section contents shows the separate topics to be studied matching the syllabus order.

Knowledge check shows the ideas you should have already encountered in previous work before starting the topic.

Learning objectives cover what you need to learn in this topic.



Δ Fig 2.1 The human body is made up of several systems of grouped organs, including the digestive system, the nervous system, the muscle/skeletal system and the respiratory system.

Organisation and maintenance of the organism

INTRODUCTION

Bringing together similar activities that have the same purpose can make things much more efficient. For example, bringing teachers and students together in a school helps more students to learn more quickly than if each teacher travelled to each student's home for lessons. The same is true in the body. Having groups of similar cells in the same place as a tissue, and grouping tissues into organs, helps the body carry out all the life processes much more efficiently and so stay alive.

KNOWLEDGE CHECK

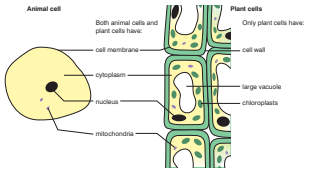
- ✓ State that organisms are formed from many cells.
- ✓ Describe how cells may be specialised in different ways to carry out different functions.
- ✓ Define the terms *tissue*, *organ* and *organ system*.
- ✓ Describe how the organisation of the body systems contributes to the seven life processes.
- ✓ State that a microscope can be used to magnify specimens so we can see more detail.

LEARNING OBJECTIVES

- ✓ Describe and compare the structures in plant and animal cells.
- ✓ Describe the function of each type of cell structure seen under the light microscope.
- ✓ EXTENDED Identify mitochondria and rough endoplasmic reticulum in cells, and describe the function of mitochondria and ribosomes.
- ✓ EXTENDED Know that the cytoplasm of all cells contain ribosomes on rough endoplasmic reticulum and vesicles.
- ✓ EXTENDED Know that almost all cells have mitochondria on rough endoplasmic reticulum.
- ✓ State that aerobic respiration occurs in mitochondria and that cells with high rates of respiration have many mitochondria to provide sufficient energy.
- ✓ Relate structure to function in a range of specialised cells.
- ✓ Define tissues as groups of similar cells with a similar function.
- ✓ Define organs as groups of tissues that work together for a particular function.
- ✓ Define organ systems as groups of organs that work together for a particular function.
- ✓ Give examples of tissues, organs and organ systems.
- ✓ Describe how to calculate the magnification of biological specimens seen under a microscope.
- ✓ Calculate the size of biological specimens using millimetres as units.
- ✓ Identify the different levels of organisation in images of familiar material.
- ✓ EXTENDED Identify the different levels of organisation in images of unfamiliar material.
- ✓ Calculate the size of biological specimens using millimetres as units.
- ✓ EXTENDED Calculate the size of biological specimens using micrometres as units.

CELL STRUCTURE AND ORGANISATION

The diagrams below show a typical animal cell and typical plant cells. These cells all have a nucleus and cytoplasm.

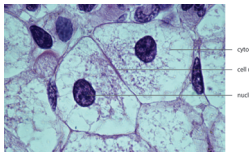


Δ Fig 2.2 The basic structures of an animal cell (e.g. liver cell) and plant cells (e.g. palisade mesophyll cells).

All living organisms are made of cells. Some, such as bacteria, protoctists and some fungi, are formed from a single cell; others, such as the majority of plants and animals, are **multicellular**, with a body made of many cells. All animal and plant cells have certain features in common:

- a **cell membrane** surrounds the cell
- **cytoplasm** inside the cell, in which all the other structures are found
- a large **nucleus**.

A typical animal cell is a human liver cell.



Δ Fig 2.3 Structures in animal cells seen using a light microscope. Note these cells have been stained to make some structures easier to see.

particularly carbohydrates but also fats and proteins, can contribute to the energy our bodies need. If we eat food that supplies more energy than we use, the extra will be deposited as energy stores of fat. This can lead to **obesity**, which is related to many health problems, such as heart disease and diabetes. Controlling the portion size at each meal, keeping between-meal snacks to a minimum, and increasing levels of exercise can help to reduce the risk of becoming overweight.

Energy requirements depend on body size, stage of development and level of exercise, as shown in Table 7.2.

	Energy used in a day (kJ)	
	Male	Female
6-year-old child	7 500	7 500
12–15-year-old teenager	12 500	9 700
adult manual worker	15 000	12 500
adult office worker	11 000	9 800
pregnant woman		10 000
breastfeeding		11 000

Δ Table 7.2 Daily energy requirements for different people.

Malnutrition

The term **malnutrition** literally means 'bad nutrition' and applies to any diet that will lead to health problems. A diet that is too high in energy content, and leads to obesity, is one form of malnutrition, because obesity increases the risk of several diseases.

Malnutrition can occur if one or more nutrients is in too high a proportion in the diet. For example, a high proportion of saturated fats in the diet can lead to deposits of cholesterol forming on the inside of arteries, increasing blood pressure and also increasing the risk of coronary heart disease (see Topic 9).

Malnutrition also occurs if any of the substances needed for a healthy body are in too low a proportion in the diet. For example, a lack of a vitamin or a mineral can cause deficiency diseases, as shown in Table 7.1. Too little fibre in the diet can lead to **constipation**, in which food moves too slowly through the **alimentary canal**, increasing the risk of diseases such as diverticulitis and bowel cancer.

Δ Fig 7.6 Starvation is most commonly seen in places where crops have failed due to drought (**famine**) or people are displaced as a result of war. However, it can also happen in people who choose to starve themselves, in crash diets or as a result of conditions such as anorexia.

Developing investigative skills

Examples of investigations are included with questions matched to the investigative skills you will need to learn.

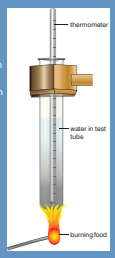
Combustion (burning) of foods releases heat energy. The word equation for combustion is:

food + oxygen → carbon dioxide + water (+ heat energy)

This reaction is similar to respiration inside cells, so we can use a combustion experiment to model the energy that is released from foods during respiration.

A crisp/potato chip and a plant leaf were tested in an investigation to see which released the most energy by combustion. Here are the results.

	Sample	
	Crisp	Leaf
mass of sample in grams	22	12
temperature of water after burning in °C	27	16
temperature of water before burning in °C	15	15
temperature rise in °C	12	1
energy released by the sample in joules	1260	105



Δ Fig 7.7 Apparatus for burning food.

Demonstrate and describe techniques

❶ **a)** Look at the diagram and describe what happens during the experiment.

b) Identify any areas of safety that should have been considered and suggest how risks could be controlled.

Analyse and interpret data

❷ **a)** Use the results to calculate the energy released per gram of each sample.

b) Explain why you need to do this.

❸ Which part of the sample released the most energy per gram?

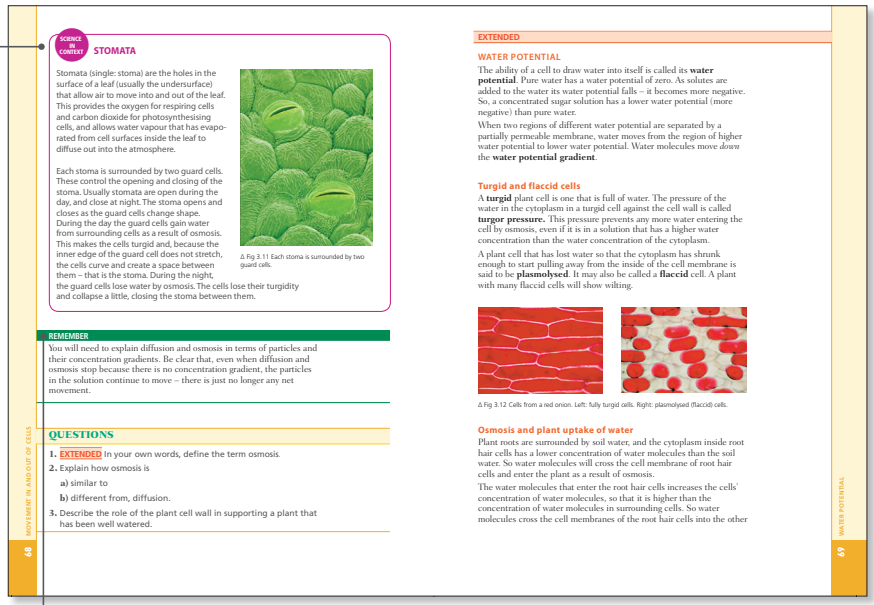
❹ A plant seed contains a similar amount of energy as a crisp. Suggest why some animals that eat the leaves of plants for most of the year change to eating seeds (nuts) when they are available.

Evaluate data and methods

❺ The apparatus shown does not give accurate results for the amount of energy in the burning material. Explain why, and suggest a method that would increase the accuracy of the results.

Getting the best from the book *continued*

Science in context boxes put the ideas you are learning into real-life context. It is not necessary for you to learn the content of these boxes as they do not form part of the syllabus. However, they do provide interesting examples of scientific application that are designed to enhance your understanding.



SCIENCE IN CONTEXT

STOMATA

Stomata (single: stoma) are the holes in the surface of a leaf (usually the undersurface) that allow air to move into and out of the leaf. This provides the oxygen for respiring cells and carbon dioxide for photosynthesising cells, and allows water vapour that has evaporated from cell surfaces inside the leaf to diffuse out into the atmosphere.

Each stoma is surrounded by two guard cells. These control the opening and closing of the stoma. Usually stomata are open during the day, and close at night. The stoma opens and closes as the guard cells change shape. During the day the guard cells gain water from surrounding cells as a result of osmosis. This makes the cells turgid and, because the inner edge of the guard cell does not stretch, the cells curve and create a space between them – that is the stoma. During the night, the guard cells lose water by osmosis. The cells lose their turgidity and collapse a little, closing the stoma between them.

Δ Fig 3.11 Each stoma is surrounded by two guard cells.

REMEMBER

You will need to explain diffusion and osmosis in terms of particles and their concentration gradients. Be clear that, even when diffusion and osmosis stop because there is no concentration gradient, the particles in the solution continue to move – there is just no longer any net movement.

QUESTIONS

1. EXTENDED In your own words, define the term osmosis.
2. Explain how osmosis is
   a) similar to
   b) different from, diffusion.
3. Describe the role of the plant cell wall in supporting a plant that has been well watered.

MOVEMENT IN AND OUT OF CELLS 68

EXTENDED

WATER POTENTIAL

The ability of a cell to draw water into itself is called its **water potential**. Pure water has a water potential of zero. As solutes are added to the water its water potential falls – it becomes more negative. So, a concentrated sugar solution has a lower water potential (more negative) than pure water.

When two regions of different water potential are separated by a partially permeable membrane, water moves from the region of higher water potential to lower water potential. Water molecules move *down* the **water potential gradient**.

Turgid and flaccid cells

A **turgid** plant cell is one that is full of water. The pressure of the water in the cytoplasm in a turgid cell against the cell wall is called **turgor pressure.** This pressure prevents any more water entering the cell by osmosis, even if it is in a solution that has a higher water concentration than the water concentration of the cytoplasm.

A plant cell that has lost water so that the cytoplasm has shrunk enough to start pulling away from the inside of the cell membrane is said to be **plasmolysed**. It may also be called a **flaccid** cell. A plant with many flaccid cells will show wilting.

Δ Fig 3.12 Cells from a red onion. Left: fully turgid cells. Right: plasmolysed (flaccid) cells.

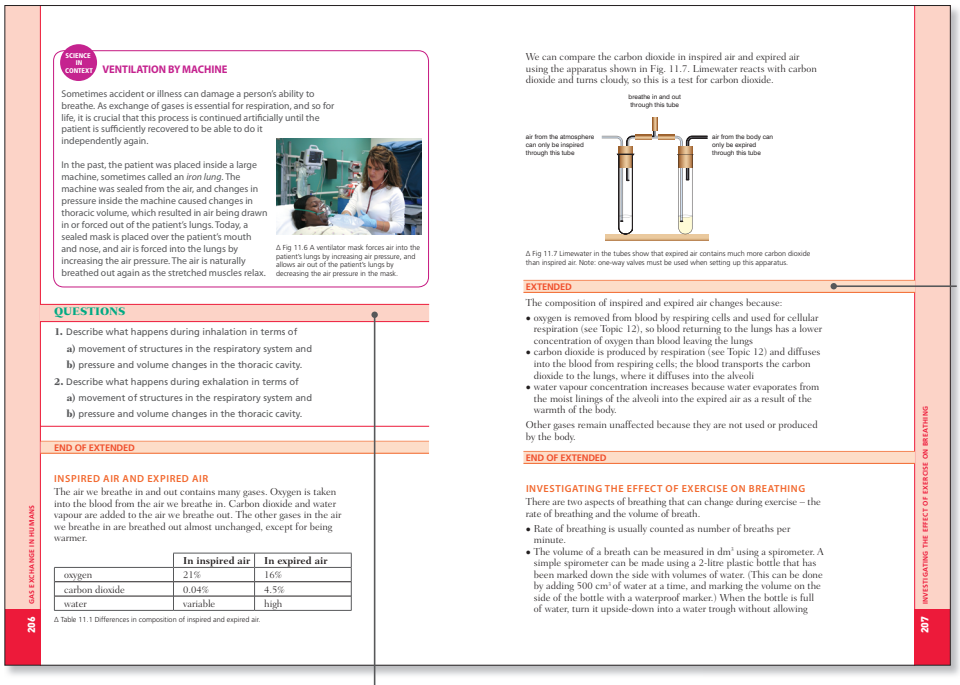
Osmosis and plant uptake of water

Plant roots are surrounded by soil water, and the cytoplasm inside root hair cells has a lower concentration of water molecules than the soil water. So water molecules will cross the cell membrane of root hair cells and enter the plant as a result of osmosis.

The water molecules that enter the root hair cells increases the cells' concentration of water molecules, so that it is higher than the concentration of water molecules in surrounding cells. So water molecules cross the cell membranes of the root hair cells into the other

WATER POTENTIAL 69

Remember boxes provide tips and guidance to help you during your course and to prepare for examination.



SCIENCE IN CONTEXT

VENTILATION BY MACHINE

Sometimes accident or illness can damage a person's ability to breathe. As exchange of gases is essential for respiration, and so for life, it is crucial that this process is continued artificially until the patient is sufficiently recovered to be able to do it independently again.

In the past, the patient was placed inside a large machine, sometimes called an *iron lung*. The machine was sealed from the air, and changes in pressure inside the machine caused changes in thoracic volume, which resulted in air being drawn in or forced out of the patient's lungs. Today, a sealed mask is placed over the patient's mouth and nose, and air is forced into the lungs by increasing the air pressure. The air is naturally breathed out again as the stretched muscles relax.

Δ Fig 11.6 A ventilator mask forces air into the patient's lungs by increasing air pressure, and allows air out of the patient's lungs by decreasing the air pressure in the mask.

QUESTIONS

1. Describe what happens during inhalation in terms of
   a) movement of structures in the respiratory system and
   b) pressure and volume changes in the thoracic cavity.
2. Describe what happens during exhalation in terms of
   a) movement of structures in the respiratory system and
   b) pressure and volume changes in the thoracic cavity.

END OF EXTENDED

INSPIRED AIR AND EXPIRED AIR

The air we breathe in and out contains many gases. Oxygen is taken into the blood from the air we breathe in. Carbon dioxide and water vapour are added to the air we breathe out. The other gases in the air we breathe in are breathed out almost unchanged, except for being warmer.

	In inspired air	In expired air
oxygen	21%	16%
carbon dioxide	0.04%	4.5%
water	variable	high

Δ Table 11.1 Differences in composition of inspired and expired air.

GAS EXCHANGE IN HUMANS 206

We can compare the carbon dioxide in inspired air and expired air using the apparatus shown in Fig. 11.7. Limewater reacts with carbon dioxide and turns cloudy, so this is a test for carbon dioxide.

Δ Fig 11.7 Limewater in the tubes show that expired air contains much more carbon dioxide than inspired air. *Note:* one-way valves must be used when setting up this apparatus.

EXTENDED

The composition of inspired and expired air changes because:

- oxygen is removed from blood by respiring cells and used for cellular respiration (see Topic 12), so blood returning to the lungs has a lower concentration of oxygen than blood leaving the lungs
- carbon dioxide is produced by respiration (see Topic 12) and diffuses into the blood from respiring cells; the blood transports the carbon dioxide to the lungs, where it diffuses into the alveoli
- water vapour concentration increases because water evaporates from the moist linings of the alveoli into the expired air as a result of the warmth of the body.

Other gases remain unaffected because they are not used or produced by the body.

END OF EXTENDED

INVESTIGATING THE EFFECT OF EXERCISE ON BREATHING

There are two aspects of breathing that can change during exercise – the rate of breathing and the volume of breath.

- Rate of breathing is usually counted as number of breaths per minute.
- The volume of a breath can be measured in dm^3 using a spirometer. A simple spirometer can be made using a 2-litre plastic bottle that has been marked down the side with volumes of water. (This can be done by adding 500 cm^3 of water at a time, and marking the volume on the side of the bottle with a waterproof marker.) When the bottle is full of water, turn it upside-down into a water trough without allowing

INVESTIGATING THE EFFECT OF EXERCISE ON BREATHING 207

Clearly differentiated Extended material.

Questions to check your understanding.

End of topic questions allow you to apply the knowledge and understanding you have learned in the topic to answer the questions.

A full checklist of all the information you need to cover the complete syllabus requirements for each topic.

End of topic checklist

Key words

alveoli, bronchus, bronchiole, cilia, diaphragm, gas exchange, intercostal muscles, larynx, lungs, mucus, trachea, ventilation

During your study of this topic you should have learned:

- ❍ That humans exchange gases with the environment by diffusion, so the lungs need a large surface area, a short distance for diffusion to the blood, and continual ventilation of the inside of the lungs.
- ❍ To describe ventilation as the breathing in and out of air to the lungs, through the larynx, where sound may be produced, down the trachea to the two bronchi, and through the bronchioles to the alveoli, where the gases are exchanged with the many capillaries that lie next to the alveoli.
- ❍ EXTENDED How to state the function of cartilage in the trachea
- ❍ EXTENDED Breathing in is caused by the diaphragm moving down and the intercostal muscles contracting to lift the ribcage up and out, causing an increase in volume and decrease in pressure inside the thoracic cavity, which draws air into the lungs.
- ❍ EXTENDED Breathing out is caused by the diaphragm relaxing and pushing up, and the intercostal muscles relaxing so the ribcage falls and moves in again. This reduces the volume and increases the pressure inside the thoracic cavity, so pushing air out of the lungs.
- ❍ Expired air contains more carbon dioxide, less oxygen and more water vapour than inspired air.
- ❍ EXTENDED The differences in gas concentration in inspired air and expired air are the result of respiration in cells using oxygen and producing carbon dioxide, and the evaporation of water vapour from surfaces inside the lungs.
- ❍ An increased level of activity increases the rate and depth of breathing.
- ❍ EXTENDED The increased rate of depth of breathing during activity removes the increased amount of carbon dioxide produced by respiration and so stops the pH of body tissues and blood falling.
- ❍ Goblet cells in the linings of the lungs secrete mucus that trap pathogens and particles. The mucus is swept out of the lungs by cilia, which protects the lungs from damage and infection.

End of topic questions

Note: The marks awarded for these questions indicate the level of detail required in the answers. In the examination, the number of marks awarded to questions like these may be different.

1. a) Define the terms *diffusion* and *gas exchange* (2 marks)

b) Describe the role of diffusion in gas exchange in humans. (2 marks)

c) EXTENDED Explain how the tissues and organs of the lungs are adapted to maximise the rate of gas exchange. (4 marks)

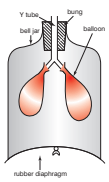
2. EXTENDED Fig. 11.8 shows a model that can be used to demonstrate the role of the diaphragm in breathing.

a) Describe and explain what will happen to the balloon 'lungs' when the rubber diaphragm is:

i) pulled down (4 marks)

ii) pushed up. (4 marks)

b) Which parts of the body that can be involved in breathing are not included in this model? Explain their role in breathing. (5 marks)



Δ Fig 11.8 Model for demonstrating breathing.

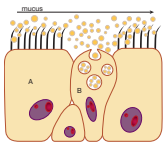
3. EXTENDED Fig. 11.9 shows a few cells of the epithelium lining the trachea.

a) State where the trachea is found and explain its role in the body. (2 marks)

b) Name the type of cell shown by cell A and describe its function. (2 marks)

c) Name the type of cell shown by cell B and describe its function. (2 marks)

d) Explain the role of these cells in protecting the body. (3 marks)



Δ Fig 11.9. Cells of the trachea epithelium

Exam-style questions help you prepare for your exam in a focussed way and get the best results.

Exam-style questions continued

The concentration of nitrous oxide has shown a little fluctuation from 0 to around 1800, ranging from 265–275 ppb. ✓ 1

But there has been a steep increase to around 320 ppb in 2005. ✓ 1

The concentration of methane has shown a very slow, slight upward trend from 0 to around 1750, ranging from 255 ppb to around 260 ppb. ✗

But then a steep increase to around 390 ppb in 2005. ✗

iii) How has human activity contributed to the change in the concentration of carbon dioxide in the air? (2)

Carbon dioxide production has increased from the burning of fossil fuels in transport, heating and cooling, and in manufacture. ✓ 1

iii) The student has written a good answer for the contribution of the burning of fossil fuels to the increase in carbon dioxide. These all refer to the burning of fossil fuels, however, and the student could have picked up the second mark by referring to deforestation.

b) The table gives information on several greenhouse gases.

Gas	Chemical formula	Lifetime (years)	Global Warming Potential*
Carbon dioxide	CO_2	Variable	1
Methane	CH_4	12	21
Nitrous oxide	N_2O	114	310
CFC-11	CCl_3F	45	3 800
CFC-12	CCl_2F_2	100	8 100
Sulfur hexafluoride	SF_6	3 200	23 900

*The **Global Warming Potential (GWP)** is a measure of how much heat a greenhouse gas traps in the atmosphere relative to that trapped by the same mass of carbon dioxide. A GWP is calculated over a time interval. The values in the table are for a 100-year time scale.

From: IPCC/TEAP (2005) *Special Report on Safeguarding the Ozone Layer and the Global Climate System: Issues Related to Hydrofluorocarbons and Perfluorocarbons* [Metz, B., et al. (eds.)]. Cambridge University Press.

ii) This is a good answer, but the student has not mentioned the enhanced greenhouse effect. The final marking point could have been extended:

'But increases in greenhouse gases as a result in human activity is leading to the enhanced greenhouse effect.'

'This is leading to a significant warming of the Earth called global warming.'

i) Which greenhouse gas contributes most to global warming? Explain your answer. (3)

Sulfur hexafluoride ✓ 1

It has the highest GWP. ✓ 1

ii) Explain how greenhouse gases result in the greenhouse effect and global warming. (6)

Shortwave radiation from the Sun passes through the Earth's atmosphere and warms the ground. ✓ 1

The warmed Earth gives off longer wave radiation that is prevented from leaving the earth by greenhouse gases in the atmosphere. ✓ 1

The trapping of the radiation leads to the Earth warming up, which is called the greenhouse effect. ✓ 1

The greenhouse effect is important, because without it, the temperature on the Earth would be 33°C lower – the Earth would be uninhabitable. ✓ 1

But increases in greenhouse gases as a result in human activity is leading to a significant warming of the Earth called global warming. ✓ 1

(Total 18 marks)

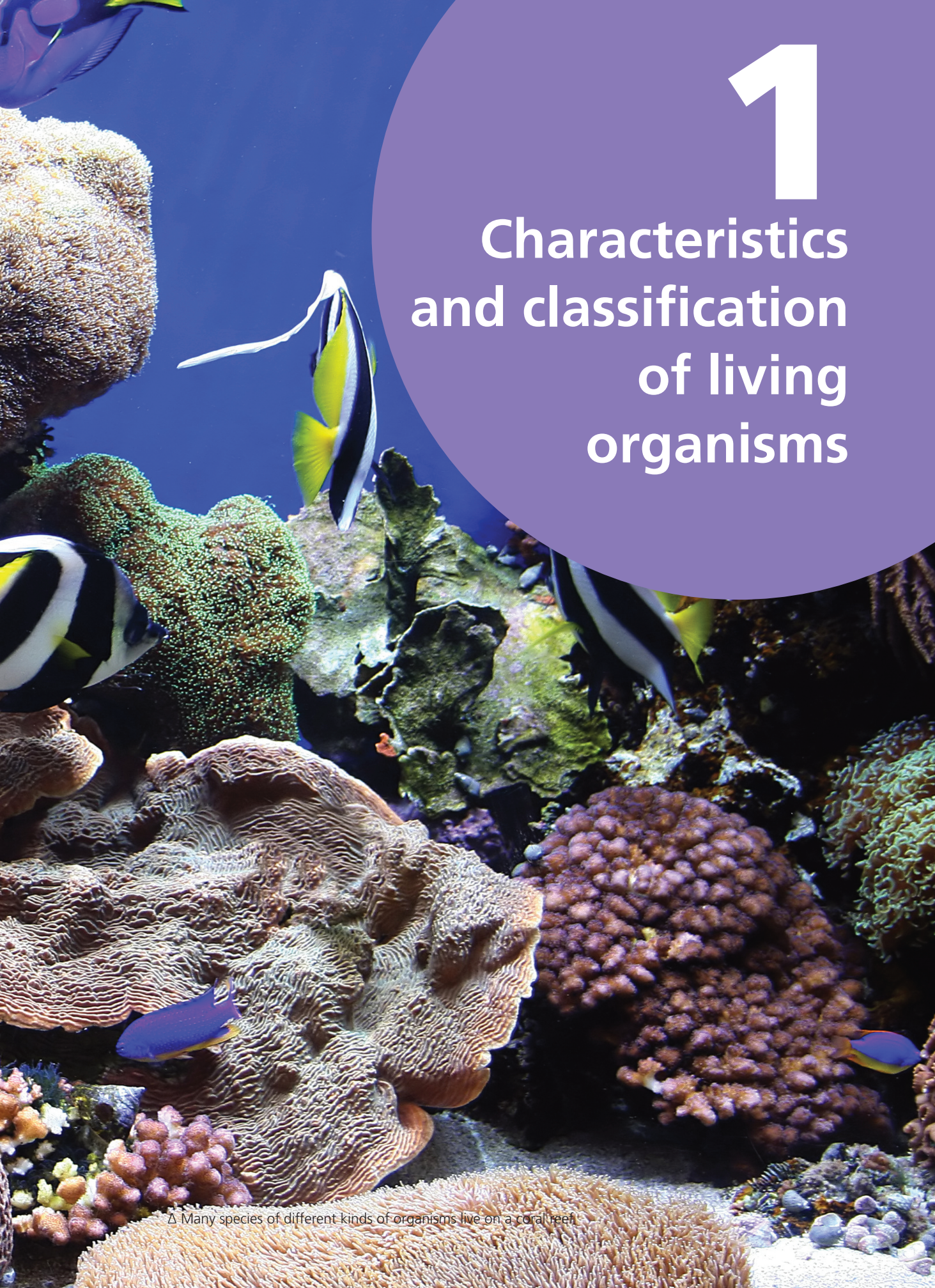
13/18

Student sample with teacher's comments to show best practice.

Around 1.74 million living species have been identified on Earth, not including bacteria. Over 320 000 of these species are classified as plants and around 1.36 million species are classified as animals. Over 62 000 of the animal species are vertebrates (animals with bony skeletons) and the rest are invertebrates (animals without backbones), of which the majority (around 1 million species) are insects.

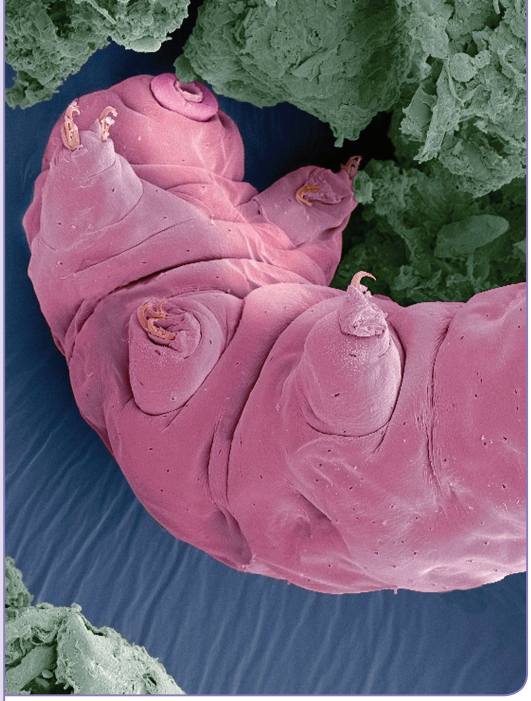
It is difficult to know how many species are still to be discovered, although it is thought that about 15 000 new species are discovered around the world every year. The smaller the organism, the greater the chance that there are species we don't yet know about. So, although around 4000 species of bacteria have been identified, there could be many more species of bacteria than of all the other kinds of organisms put together.

CONTENTS



1 Characteristics and classification of living organisms

Δ Many species of different kinds of organisms live on a coral reef



Δ Fig 1.1 Tiny tardigrades (about 1 mm long) are the toughest organisms known. They can survive temperatures below –200 °C, 10 days in the vacuum of space and over 10 years without water!

Characteristics and classification of living organisms

INTRODUCTION

Sometimes it is easy to tell when something dies – an animal will stop moving around, a plant may wilt and all the green parts collapse. But does a tree die in winter, when its leaves have dropped off? Are animals 'dead' when they hibernate underground for months? As technology gets increasingly sophisticated, and we can create machines with 'brains' and new organisms from basic molecules, distinguishing between living and dead could get even more difficult. We need a set of 'rules' that work for most organisms, most of the time.

KNOWLEDGE CHECK

- ✓ Living organisms show a range of characteristics that distinguish them from dead or non-living material.
- ✓ The life processes are supported by the cells, tissues, organs and systems of the body.
- ✓ Living organisms show great variety.
- ✓ Organisms can be classified according to their characteristics.
- ✓ Living organisms can be grouped into species using their physical features.

LEARNING OBJECTIVES

- ✓ **EXTENDED** Define the seven characteristics of living organisms.
- ✓ Describe each of the characteristics of living organisms.
- ✓ Explain that not all living organisms show every characteristic all of the time.
- ✓ Define the term *species*.
- ✓ Describe how the binomial system is used to name and classify organisms.
- ✓ **EXTENDED** Explain why it is important to classify organisms.
- ✓ **EXTENDED** Explain that classification is usually based on similarities of morphology and anatomy.
- ✓ **EXTENDED** Describe the use of DNA in classification.
- ✓ **EXTENDED** State that organisms which are closely related have DNA that is more similar than organisms which are more distantly related.
- ✓ List the features shared by all living organisms.
- ✓ Identify the main features of plants and animals.
- ✓ Describe the main features of groups within the animal kingdom.
- ✓ **EXTENDED** Describe the main features of the five kingdoms of organisms.

✓ **EXTENDED** Describe the main features of groups within the plant kingdom.

✓ **EXTENDED** Describe the features of viruses.

✓ Use and construct simple dichotomous keys to identify organisms.

CHARACTERISTICS OF LIVING ORGANISMS

There are seven life processes that most living organisms will show at some time during their life.

- **Movement**: Animals may move their entire body so that it changes position or place.

EXTENDED

Organisms may also move parts of their body. For example, plants may move body parts in response to external stimuli such as light, while structures in the cytoplasm of all living cells move.

END OF EXTENDED

- **Respiration**: This is a series of chemical reactions inside living cells that break down nutrient molecules and release energy.

EXTENDED

The energy released from respiration is used for all the chemical reactions that help to keep the body alive. Together, these reactions are known as **metabolism**.

END OF EXTENDED

- **Sensitivity**: Living organisms are able to detect (or sense) and respond to changes in the environment around them. For example, we see, hear and respond to touch.

EXTENDED

Living organisms can also detect and respond appropriately to changes inside their bodies (the internal environment).

END OF EXTENDED

- **Growth**: This is the permanent increase in size of an organism.

EXTENDED

Gowth is often defined as an increase in dry mass (mass without water content) of cells or the whole body of an organism. This is because total mass can vary, depending on how much the organism eats and drinks. Dry mass only measures the amount by which the body

Δ Fig 1.2 Sunflowers respond to light by tracking the Sun across the sky during the day.

increases in size when nutrients are taken into the cells and used to increase their number and size.

END OF EXTENDED

- **Reproduction**: This includes the processes that result in making more individuals of that kind of organism, such as making gametes and the fertilisation of those gametes.
- **Excretion**: This is the removal from the body of substances that are toxic (poisonous) and may damage cells if they stay in the body. Organisms also excrete substances that are in **excess**, where there is more in the body than is needed.

EXTENDED

Living cells produce many products from the metabolic reactions that take place inside them. Some of these are waste products – materials that the body does not use; for example, animals cannot use the carbon dioxide produced during respiration. These waste products may be toxic, so they must also be removed from the body by excretion.

END OF EXTENDED

- **Nutrition**: This is the absorption of nutrients into the body. The nutrients are the raw materials needed by the cells to release energy and to make more cells for growth, development and repair.

EXTENDED

Plant nutrition requires light, carbon dioxide, water and mineral ions, such as iron and magnesium. Animal nutrition requires organic compounds such as carbohydrates and proteins, mineral ions such as iron and sodium, and usually water.

END OF EXTENDED

All these characteristics will be described in greater detail in later Topics in this book.

Δ Fig 1.3 Growth of a child can be measured by recording their change in height over time.

QUESTIONS

1. For each of the seven characteristics, give one example for:
   - **a)** a human
   - **b)** an animal of your choice
   - **c)** a plant.
2. For each of the seven characteristics, explain why they are essential to a living organism.

An easy way to remember all seven processes is to take the first letter from each process. This spells Mrs Gren. Alternatively you may wish to make up a sentence in which each word begins with same letter as one of the processes, for example: My Revision System Gets Really Entertaining Now.

CONCEPT AND USE OF A CLASSIFICATORY SYSTEM

Classification means 'grouping things'. When we classify organisms we group them according to how similar their features are. For example, zebras are horse-like mammals that are striped.

The main classification group is the **species**. We define a species as organisms that share many features. They can also interbreed to produce **fertile** offspring. This means that the offspring are able to reproduce when they are adult. Some species, like the horse and donkey, can be bred together but they produce offspring called mules that are not fertile.

EXTENDED

The definition of species in terms of breeding to produce fertile offspring is not always true. Plains zebras and mountain zebras don't live in the same habitat, so they don't normally try to interbreed. However, in captivity they have been bred together, although the chance of a pregnancy failing is high.

END OF EXTENDED

Plains zebras and mountain zebras are so alike that we group these species together in the same **genus** (plural: genera). There are other species in this genus that also share many characteristics, including the domesticated horse and donkey.

- Genera that share many features are grouped into a **family**, so horses, donkeys and zebras are grouped in the horse family.
- Families that share key features are grouped together in an **order**. So the horse family is grouped in the perissodactyl order together with other mammals that have an odd number of toes, such as the rhinoceros family.
- Orders that share key features are grouped together in a **class**. So the odd-toed perissodactyls, even-toed ungulates and apes (including humans) are grouped in the mammal class because they all produce milk for their young.
- Classes that share key features are grouped together in a **phylum** (plural: phyla). So the mammals, birds and other organisms with a bony backbone are grouped as chordates.

Δ Fig 1.4 These zebra look very similar, and can all interbreed, so they are classified in the same species – the plains zebra.

Δ Fig 1.5 This is a different species of zebra, called a mountain zebra. It differs from plains zebras in a few characteristics, such as having a white belly and narrow white stripes. Plains zebras and mountain zebras do not normally interbreed.

- Phyla that share key features are grouped into a **kingdom**. So the chordates are grouped with all the other animals in the animal kingdom. There are five kingdoms, as you will see later in this topic.

The full classification for the plains zebra is shown below. Note that the names for the groups are not English words. This is because this classificatory system was started when Latin was the language used to describe science.

Kingdom	Animalia
Phylum	Chordata
Class	Mammalia
Order	Perissodactyla
Family	Equidae
Genus	*Equus*
Species	*quagga*

REMEMBER

You do not need to remember examples of each classificatory group, but you should remember the structure of the classificatory system.

Note that the genus and species names are written in italics. When we refer to a species using its Latin name we use both of these. So the plains zebra is called *Equus quagga*, whereas the mountain zebra is called *Equus zebra*.

This use of two names to identify a species is called the **binomial system**. (*Bi-* means 'two', and *nomial* relates to 'names', so *binomial* literally means 'two names'.) The binomial system is an internationally agreed system that gives a different binomial name to every species. Anyone who wants to be very clear about the species they are referring to uses the agreed binomial name.

EXTENDED

The value of classification

Classifying organisms in the way described above is called a hierarchical classification. This can be useful in helping us to understand the evolutionary relationships between organisms. Organisms within a classificatory group are usually more closely related than organisms in different groups. So we could guess that the plains zebra and mountain zebra became separate species relatively recently in evolution, but that zebras and rhinoceroses are more distantly related because they belong to a larger group – the same order rather than the same genus.

Using the binomial name helps to prevent confusion – so for example, if someone is describing zebras that they have seen, they can be much clearer about the species if they refer to *Equus quagga* or *Equus zebra*. This can be very important in **conservation** – the protection of species

and habitats. For example, there are thousands of plains zebra in Africa, although most of them live in game reserves. However, the mountain zebra is considered vulnerable to extinction, as there are less than 3000 in the wild. This means that zoos and animal parks around the world are putting more effort into breeding *Equus zebra* than *Equus quagga*, to help protect the mountain zebra species.

END OF EXTENDED

QUESTIONS

1. Define the term *species*.
2. Describe how features are used to classify organisms.
3. Using an example, explain what is meant by the *binomial system* of naming organisms.
4. EXTENDED Give two reasons why classification of species is useful.

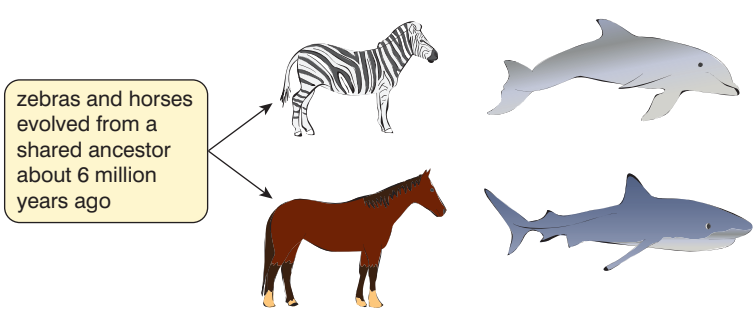
EXTENDED

METHODS OF CLASSIFICATION

In the past, scientists used the physical features of organisms to identify how similar they were and therefore decide how to classify them. These features included:

- **morphology** – the study of what organisms look like
- **anatomy** – the study of the body structure of organisms.

This works well when organisms share similar features because they evolved from a shared **ancestor**. It fails when organisms share features that are adaptations to a particular habitat.



Horses and zebras look similar because they share a recent ancestor.

Dolphins (mammals) and sharks (fish) are not closely related. They have a similar morphology because they are both active predators in the sea.

Δ Fig 1.6 Similar features may be the result of inheritance or the result of adaptation to the same environment.

END OF EXTENDED

SCIENCE IN CONTEXT

DUCK-BILLED PLATYPUS

Grouping organisms by features can cause problems because you have to use the right features to get a good classification. For example, a duck-billed platypus has a beak, webbed feet and lays eggs, which are all characteristics more commonly associated with birds. However, the platypus is not a bird but a mammal, because it has fur and the mother produces milk from mammary glands to feed her young. These two characteristics are unique to mammals. The beak and feet are adaptations to the environment, and the platypus lays eggs because it belongs to the oldest group of mammals.

Δ Fig 1.7 The duck-billed platypus can be difficult to classify from its features.

EXTENDED

New techniques for comparing organisms include **DNA analysis** (sequencing of bases in DNA, Topic 4), and **protein analysis** (sequencing of amino acids in proteins, Topic 4). Offspring inherit copies of their parent's DNA, but a few changes may occur during the copying. This not only changes the DNA base sequence, but may also change the amino acid sequence in the proteins made from the DNA. More changes happen each time the DNA is copied. So the more different the DNA or protein in two organisms, the less related they are, and also the longer the time since they shared a common ancestor.

Sometimes the DNA and protein results are virtually identical to those produced from morphology and anatomy, but occasionally they are very different. For example, there are mole species on almost every continent, and they all look very alike. However, DNA and protein analysis shows that on each continent the moles evolved from other larger species and so are not closely related to moles on other continents. This helps to confirm that the new techniques are more accurate for classification than the older ones.

END OF EXTENDED

QUESTIONS

1. EXTENDED Define the terms *morphology* and *anatomy*.
2. EXTENDED Describe the advantages and disadvantages of using morphology and anatomy to classify organisms.
3. EXTENDED Explain how evidence from DNA and proteins is being used to classify organisms.

FEATURES OF ORGANISMS

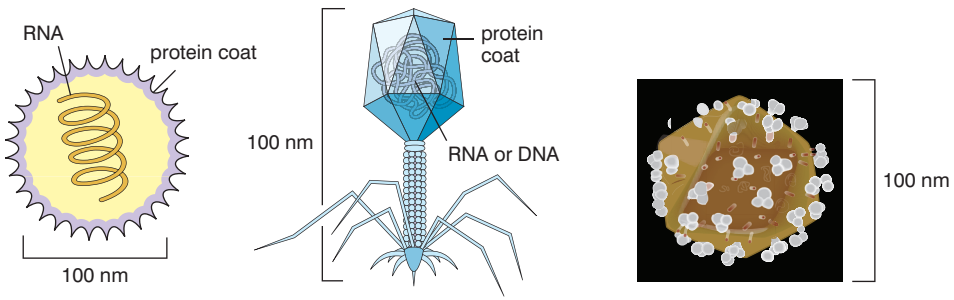
All living organisms are formed from cells. Each cell is surrounded by a **cell membrane**, which controls what enters and leaves the cell. Within each cell is the jelly-like **cytoplasm**. This is where many reactions take place. Each cell also contains genetic material in the form of **DNA** (deoxyribonucleic acid). DNA makes it possible for cells to divide and reproduce. It also controls the processes that go on in the cell.

EXTENDED

All cells need to make proteins and they do this in a process called **protein synthesis**. Some kinds of proteins are used as parts of structures in the cell, such as the cell membrane. One particular group of proteins are the **enzymes**. Their role in the cell is to control reactions (see Topic 5), such as the reactions in the process of **respiration**. Protein synthesis is carried out on particular structures in the cell called **ribosomes**. Ribosomes are too small to be seen with a standard light microscope, but there may be millions of them within a cell.

Viruses

Viruses are very simple structures, consisting of an outer protein coat that protects the genetic material inside. They have no cell structures or cytoplasm, so they do not respire or sense their surroundings. They also do not take in substances to build more cells, or excrete anything. In many ways they behave like simple crystalline chemicals. However, when viruses infect a cell, such as a bacterial, plant or animal cell, they cause that cell to produce many copies of the virus. So they do reproduce. Not everyone agrees on whether viruses can be called *living* organisms.



Δ Fig 1.8 Three kinds of virus. One thousand virus particles would fit across the width of one human hair.

END OF EXTENDED

SCIENCE IN CONTEXT

HIV AND AIDS

The HIV virus is one of a group of viruses that attack and destroy cells in the body's immune system. This leaves the body open to infection by other **pathogens** (disease-causing organisms). In the case of HIV, this results in the disease called AIDS. Many AIDS patients die not from the HIV virus, but from other diseases such as tuberculosis, which is caused by a bacterium.

The HIV virus does not survive well in the environment and is mainly transmitted from one person to another through body fluids. The most common route of transmission is sexual intercourse. However, transmission in blood is also possible, such as through blood transfusion, or the sharing of injection needles between drug users. An infected mother can pass the HIV virus to a fetus in her uterus through the placenta, or to the baby through breast milk after birth.

QUESTIONS

1. Identify three key features shared by all living organisms.
2. EXTENDED Describe the function of ribosomes in living organisms.
3. EXTENDED Name the energy-releasing process inside cells that is controlled by enzymes.
4. EXTENDED Which features of viruses are similar to cells of other kinds of organism, and which are different?

The kingdoms of life

Most of the organisms that you see around you belong to one of two kingdoms, the animals and the plants.

Plants

Plants vary greatly in size and shape, from tall rainforest trees to tiny flowers such as violets. Plants are multicellular organisms, which means they are made up of more than one cell (usually thousands or millions of cells).

Plant cells have features that are not found in animal cells. For example, plant cells may contain **chloroplasts**. These

Δ Fig 1.9 The green leaves of a plant show that it is able to make its own food.

are green structures inside cells, in which the plant is able to make its own food. (You will learn more about cell structure in Topic 2.) Making their own food distinguishes plants from animals, which have to eat their food.

Plants are not usually able to move about, as animals can do. However, parts of plants may move, such as when leaves track the Sun's movements across the sky, or when seeds are spread by wind or with help from animals.

Animals

The variety of animals is huge, from enormous whales and elephants to tiny ants. Animals are also multicellular organisms. Animals differ from plants in having to find food to eat. Many animals move about to do this.

Δ Fig 1.10 Animals can usually move more freely than plants.

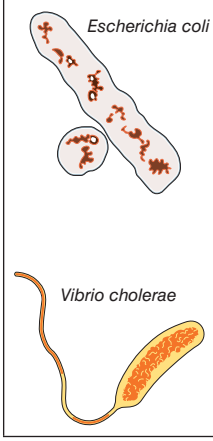
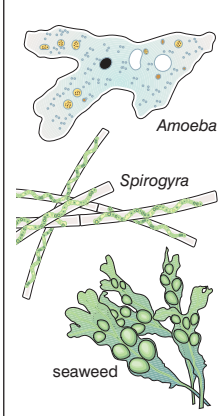
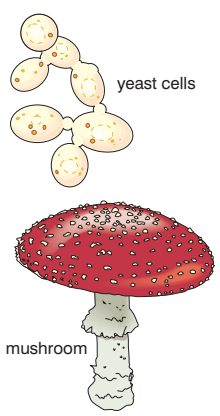
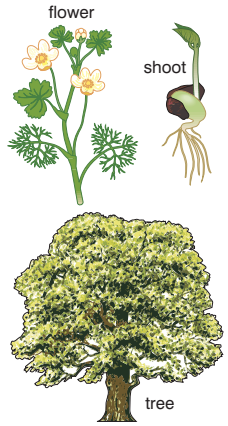
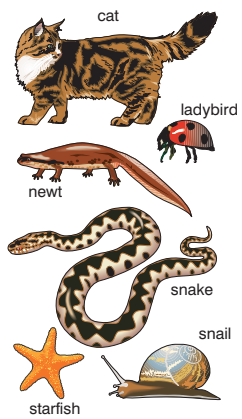
QUESTIONS

1. Describe one difference between plant and animal cells.
2. Describe one other difference between plants and animals.
3. A new organism has been discovered. Some of its cells contain chloroplasts. Should the organism be classified as a plant or as an animal? Explain your answer.

EXTENDED

The five kingdoms of life

Living organisms can be classified into one of the five kingdoms shown in. The organisms in each kingdom have particular features that distinguish them from other kingdoms.

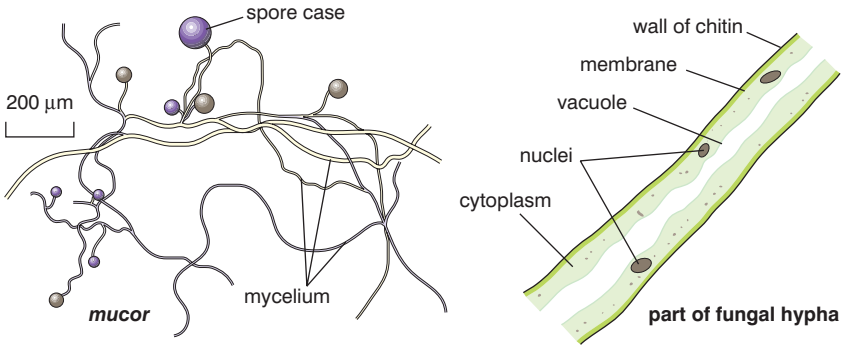
Prokaryote kingdom	Protoctist kingdom	Fungus kingdom	Plant kingdom	Animal kingdom
				

Δ Fig 1.11 The five kingdoms of living organisms.

Fungi

Some fungi (such as yeast) are single celled, but most have a structure consisting of fine threads known as **hyphae**. Several hyphae together form a **mycelium**. Many fungi can be seen without a microscope. Their cells do not contain chlorophyll, so they cannot carry out **photosynthesis**. To obtain nutrients they secrete digestive enzymes outside the cells onto living or dead animal or plant material, and absorb the digested nutrients (**saprotrophic nutrition**).

Examples of fungi include yeast, a single-celled fungus used by humans in baking and brewing, and *Mucor*, a fungus with the typical hyphal structure. *Mucor* is often seen as a mould growing on spoiled foods.



Δ Fig 1.12 Left: the mycelium and spore cases of *Mucor*, a mould. Right: detail of a hypha of *Mucor*.

SCIENCE IN CONTEXT

MUSHROOMS AND TOADSTOOLS

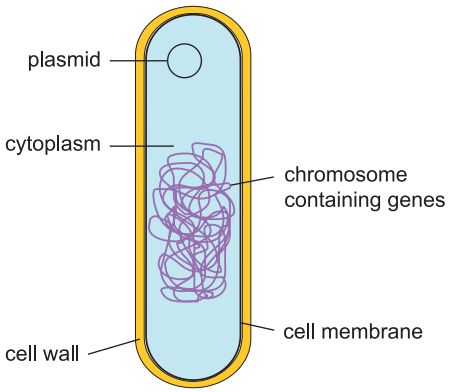
We normally think of a mushroom or toadstool as the whole of a fungus, because this is usually all we can see. However, these are only the reproductive organs, in which spores are produced. The mycelium of the fungus is usually hidden below ground or within rotting materials, where it is moist and where the hyphae can digest the surrounding tissue and absorb the nutrients that are released. The reproductive structures have to be large enough so that the wind can carry the spores away to other places, and tough enough to survive the drying conditions of the air until the spores have been dispersed.

Δ Fig 1.13 The fruiting body is often the only visible evidence of a fungus.

Prokaryotes

Prokaryotes are single-celled microscopic organisms. Their cells are much smaller than those of plants and animals.

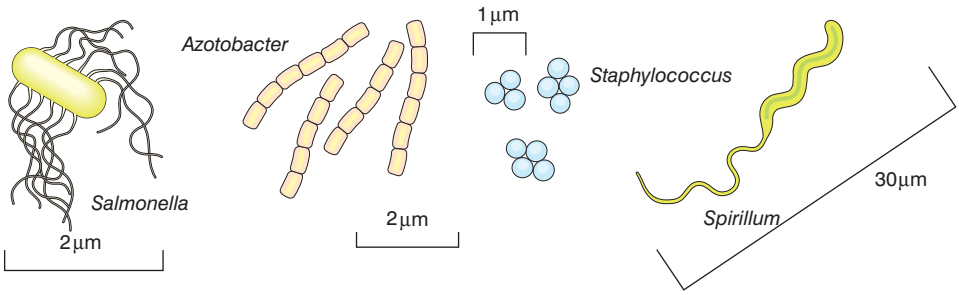
Prokaryote cells also differ from the cells of plants and animals in that they have no **nucleus**, so their genetic material (DNA) lies free in the cytoplasm inside the cell. This feature gives the group their name: *pro* means 'before' and *karyon* is Greek for 'nucleus'. Animals, plants, fungi and protoctists are eukaryotes, from *eu* meaning 'true' and *karyon* because the DNA in their cells is within a nucleus. Many bacteria have additional circles of genetic material, called **plasmids**.



Δ Fig 1.14 Generalised structure of a bacterial cell.

Prokaryotic cells are surrounded by a cell membrane. Some bacterial cells also have a **cell wall**, although in different groups of bacteria the cell wall is made of different chemicals.

The kingdom includes bacteria such as *Salmonella*, which causes food poisoning, and *Mycobacterium*, which causes a disease called tuberculosis.



Δ Fig 1.15 Different bacteria can be recognised from their shape and structure.

SCIENCE IN CONTEXT

BACTERIAL PLASMIDS

Bacterial plasmids have become very useful to us in genetic engineering, where they are used as vectors (see Topic 20). Not all bacteria have plasmids, but those that do transfer these small circles of genetic material to other bacteria quite easily. Plasmids may even be transferred between bacteria of different species. This is not true reproduction, as the transfer is not of the main chromosome and may not lead to production of new individuals. However, this kind of transfer may be important in the spread of antibiotic resistance between bacterial species, because some of the genes for antibiotic resistance are found in the plasmids.

Protoctists

Protoctists are also single-celled microscopic organisms, but they are usually much larger than bacteria. Their cells contain a nucleus, so they are eukaryotes, and many have features of animal cells or plant cells.

One example is *Amoeba*, which looks like an animal cell, is found in ponds and feeds on other microscopic organisms. Other protoctists, such as *Chlorella*, look more like plant cells because they contain chloroplasts and so can photosynthesise. A few protoctists are pathogens, such as *Plasmodium*, the organism that causes the disease malaria in humans.

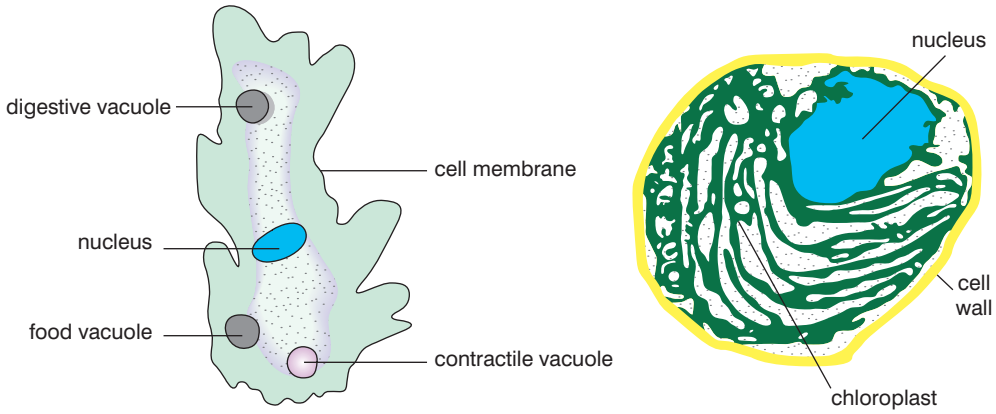


Fig 1.16 *Amoeba* (left) and *Chlorella* (right) are both protoctists because they are single celled and contain a nucleus.

SCIENCE IN CONTEXT

MALARIA

Malaria is one of the greatest causes of death through infectious illness in the world today. Around 0.75 million people die of the disease each year, mostly young children and mostly in sub-Saharan Africa. The disease is caused by the protoctist *Plasmodium*, which has a clever way of getting from one person to the next: it hitches a lift in the alimentary canal of an *Anopheles* mosquito. The female mosquitoes suck blood from humans to get the nutrients they need to lay eggs. As a mosquito pierces into a blood vessel, it inserts a little liquid to prevent the blood from clotting. If the mosquito has fed recently on a person infected with *Plasmodium*, this liquid will contain some of the parasites and so infect the new person. This protects the protoctist from the harsh conditions of the environment.

QUESTIONS

1. Name the five kingdoms of living organisms and give an example of each kingdom.
2. Describe one key difference between a bacterial cell and an animal cell.
3. Which characteristics do fungi share with
   a) plants
   b) animals?
4. Explain why some protoctists were once classified as plants and others as animals.

END OF EXTENDED

Features of the animal kingdom

The animal kingdom can be divided into two large groups:

- **invertebrates**, which have no backbone
- **vertebrates**, which have a backbone.

The vertebrates are placed in the phylum Chordata. This phylum includes five orders:

- mammals.
- birds
- reptiles
- amphibians
- fish (including bony fish)

There are many groups of invertebrates, but some of the largest and most important groups are the insects, crustaceans, arachnids and myriapods. These groups are classified together as arthropods, which all have a tough outer shell called an **exoskeleton**.

The following sections describe the main features of these groups.

Mammals

Mammals live on land and in the water. Examples include humans, elephants, mice and whales.

- All mammals have hair or fur on their body, which can be important as insulation. Hairs can also provide sensitivity, as in whiskers.

Δ Fig 1.17 Even aquatic (water-living) mammals have some hair. In the walrus, the hairs are very sensitive to touch, which helps them to find their food.

- Mammals maintain a constant internal body temperature, which is usually above that of the environment.
- Mammals have entirely internal fertilisation, with the penis of the male being inserted into the vagina of the female.
- A few mammal species lay eggs, although most give birth to live young. In the largest group of mammals the young develop inside the mother's body, supported by the placenta.
- After birth the young are fed on milk produced by mammary glands.
- In some species extensive parental behaviour also helps to protect and raise the young.

Birds

Birds exist in almost every environment and across every continent. Examples include swans, penguins and ostriches. Most birds feature:

- feathers and wings that allow them to fly and that provide good insulation against transfer of heat to the surroundings
- a well-developed circulatory system to supply oxygen to the powerful flight muscles
- a constant body temperature that is often much higher than that of the surrounding air
- bones that are modified to be strong but light
- internal fertilisation
- a reproductive process that involves producing and laying hard-shelled eggs in which the young develop outside the parent's body
- often significant parental behaviour to protect the eggs and raise the young.

Δ Fig 1.18 Most birds are well adapted to flight.

Reptiles

Reptiles are found living in a wide range of environments from marine and freshwater, through to dry deserts. They include snakes, lizards, turtles and crocodiles.

- Some reptiles have legs (never more than four), whereas snakes have none.
- Reptiles have a thick scaly skin that protects them from water loss.
- Their body temperature generally varies with the temperature of the environment, although they may bask in the early morning sun to help raise body temperature quickly.
- Fertilisation is internal and occurs when the openings of the male and female reproductive tracts are brought together. This means that reptiles do not have to find water for reproduction, as amphibians do.
- Reptiles lay their eggs, which are protected by thick leathery shells, on land.

Δ Fig 1.19 Snakes are legless reptiles that lay eggs on land.

Amphibians

Amphibians include frogs and toads, newts and salamanders.

- Most amphibians have two pairs of legs, although a few species have none.
- Many amphibians spend part of their life in water and part on land.
- When amphibians hatch from eggs (as tadpoles), they have gills rather like those of fish.
- As the tadpoles develop they lose their gills, the tail shortens, they develop legs and a simple lung. These changes are known as metamorphosis. Adult frogs exchange gases with the air mainly through their moist skin or lung.
- Fertilisation is external, with males shedding sperm over eggs released by the female directly into the water.

Δ Fig 1.20 Adult frogs usually have a short body, no tail and webbed fingers and toes to aid swimming.

Bony fish

Bony fish are well adapted for swimming.

Δ Fig 1.21 Bony fish have many features for survival in water.

- Their body shape is usually streamlined, to help them swim efficiently.
- Their bony fins and tail control the direction of their movements.
- They also have a structure called a swim bladder, which allows them to control their buoyancy and remain stationary in water.
- Their skin is protected with overlapping scales.
- Many have a flap-like structure, called an operculum, which covers the gills on either side of the body. Movement of the operculum draws water across the gills even when the fish is stationary in the water.
- Fertilisation is external, with the male shedding sperm over the eggs as the female sheds the eggs directly into the water. The young usually have to fend for themselves when they hatch from the eggs.

Myriapods

Myriapods means 'many legged ones' and this group includes centipedes and millipedes.

- Millipedes can have up to 200 pairs of legs on their body and range in size from microscopic to nearly 30 cm in length. They live in leaf litter and soil and generally eat plant debris.
- Centipedes have fewer legs and are predators.

Δ Fig 1.22 Myriapods can have up to 200 pairs of legs.

Insects

Insects are the most successful group on the planet in terms of numbers. Examples include bees, beetles, flies and butterflies.

- Insect bodies have three regions: the head, thorax and abdomen.
- They have six jointed legs and many insects have pairs of wings.
- The whole of the body is covered by a tough exoskeleton made of chitin.
- The head is well supplied with sense organs, including compound eyes. The antennae can detect vibrations, and some insects have extremely sensitive chemical detectors that can sense chemicals in tiny quantities in the air.
- Some insects (e.g. ants and bees) have a complex social structure with intricate behaviour patterns. These sorts of insects often live in large communities with a single individual (the queen) who produces most of the young.

Δ Fig 1.23 Bees work together to find food and care for the young in the colony.

Arachnids

The majority of arachnids are spiders, although the group also includes scorpions. Almost all arachnids live on land.

- The body plan of spiders has two main parts, with eight legs that arise from the front part. A pair of pedipalps at the front is used to manipulate food.
- Most spiders are carnivorous, catching flying insects in webs. Spider webs are made of a sticky protein that is said to be, weight for weight, stronger than steel.
- Scorpions have an elongated body. The venomous sting at the end of the tail is used for defence and to capture prey.
- Most scorpions are nocturnal and feed on a variety of smaller insects.

Δ Fig 1.24 A spider's body is made up of the prosoma (the head region) and the opisthosoma (the back section).

Crustaceans

Crustaceans are a mainly marine group, including crabs, lobsters, crayfish and woodlice. Woodlice are terrestrial but need to live in cool damp places to avoid drying out.

- Crustaceans have a standard body plan with head, thorax and abdomen, although the abdomen may be made of several segments.
- The head has two pairs of antennae.
- The number of legs varies in different groups of crustaceans. Real legs are attached to the thorax but some crustaceans, such as the shrimps, have additional 'swimming legs' attached to the abdomen.
- In some species, such as crabs, a pair of front legs has been highly modified into pincers, or chelipeds.
- Marine crustaceans grow in size by moulting their hard exoskeleton, growing rapidly and then hardening the new exoskeleton. This can occur a number of times during life.

Δ Fig 1.25 The front pincers of a crab may be modified for handling food or for signalling to other crabs.

QUESTIONS

1. Use the following headings to draw up a table: Group, Key body features, Fertilisation, Production of young. Use your table to compare the following groups of vertebrates: bony fish, birds, mammals, amphibians and reptiles.
2. A new animal species has been discovered. It has a backbone, scaly legs, lungs and feathers. How should it be classified? Give a reason for your answer.
3. Myriapods, insects, arachnids and crustaceans are all classified as arthropods. Explain why.
4. Compare the body plan of myriapods, insects, arachnids and crustaceans.

EXTENDED

Features of the plant kingdom

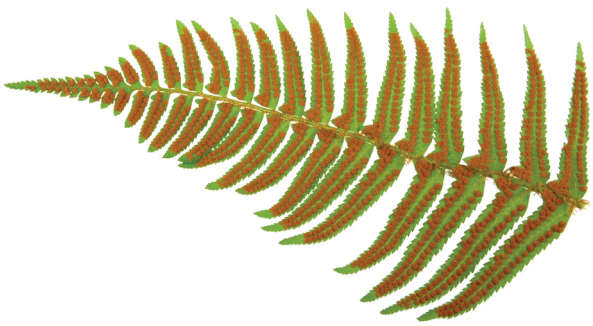
The plant kingdom also contains several groups. Two of these are the ferns and the flowering plants.

Ferns

Ferns usually have broad divided leaves called *fronds*. Most grow as clumps of fronds from the ground, though some produce long tough stalks that support the fronds above the ground. In some species the stalks, surrounded by the tough frond bases, form a thick trunk resulting in a tree. Roots at the base of the fern hold it firmly in the ground and absorb water and nutrients from the soil.

During the winter, the fronds die back so there is little to be seen above ground. In the spring the new fronds unfurl from the ground to the tip of the leaf.

Ferns do not have flowers or seeds. Instead they reproduce using spores that are released into the air from spore cases under the leaves.



Δ Fig 1.26 Fern spore cases (brown) on the underside of a fern frond release spores into the air when the conditions are right for new ferns to grow.

Flowering plants

The flowering plants are the most obvious group of the plant kingdom. Most of the trees, woody plants, herbaceous (soft leafy) plants and grasses that you see are flowering plants.

They generally have a central stem bearing side branches with leaves that tend to be smaller than the large fronds of ferns. Roots are generally well developed for supporting the plant and absorbing water and nutrients from the soil.

Reproduction in flowering plants depends on flowers. Male gametes in pollen are usually carried from the flower in which they are produced to flowers containing the female gametes. Fertilisation results in seeds. Flowering plants may also produce fruits around the seeds. The fruit may aid the seeds in their dispersal or help to protect them.

The flowering plant group is divided in two depending on seed structure. Cotyledons are food stores that are found in the seeds of flowering plants. **Monocotyledon** flowering plants include grasses and have a single cotyledon. **Dicotyledon** flowering plants have two cotyledons, and include most of the plants with visible flowers. The two groups of plants also differ in structure, as monocotyledons often have long strap-like leaves with parallel veins, whereas dicotyledons usually have broad leaves of many shapes with branching veins.

QUESTIONS

1. Summarise the similarities and differences between ferns and flowering plants.
2. List the features that distinguish dicotyledonous plants from monocotyledonous plants.

END OF EXTENDED

DICHOTOMOUS KEYS

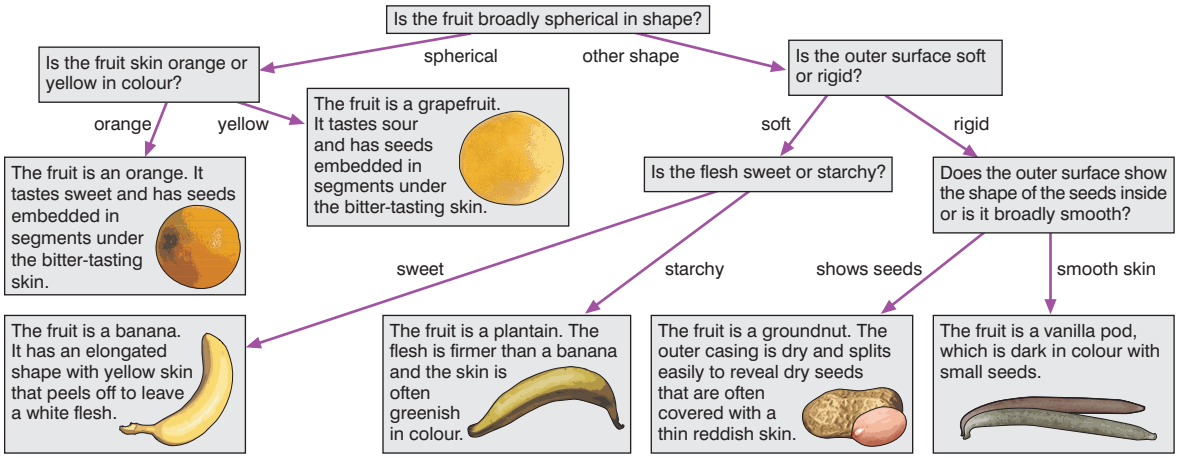
Identification keys consist of a series of questions that allow biologists to identify unknown organisms. The questions must have simple answers (usually yes or no) and be answerable by looking at the organism. A **dichotomous key** separates the choices into two groups each time (see Fig. 1.27). Each question results in smaller and smaller groups until the final group contains only one species. In this way an organism can be identified in the field without use of complicated equipment.

This type of key requires careful use. As well as being easily observed, the feature chosen for each question must always be present. So using flowers to identify plants can be a problem if the plant is not in flower when you find it.

Remember that living things are highly variable. Think how different one human being can be from another. It is often better to examine several examples of an organism rather than only one.

When using a key make sure you understand exactly which feature you are meant to be observing and always carefully consider both options given, especially where the answer is not a simple yes or no.

Many keys include a simple description of the organism along with its name to act as a quick check that the key has been used correctly. If, when using a key, you find that the organism you are examining does not fit this description, go back over all the questions and carefully consider your answers.



Δ Fig 1.27 A simple dichotomous key to identify some common fruits.

QUESTIONS

1. Explain what is meant by a *dichotomous key*.
2. Give two reasons why a dichotomous key may not always identify an organism.

SCIENCE IN CONTEXT

IDENTIFICATION IN THE FIELD

Scientists working in the field can now take photos of organisms that they cannot identify and email them back to museums, where they are checked against keys of organisms. If the organism is new to science, the scientist can then take further pictures, or collect an individual, to take back to the lab for further study.

Constructing A Dichotomous Key

To construct a key, you start by looking carefully at the organisms to find simple differences between them that will help to produce the groups. It is important to choose features that are fairly constant in a species, or that are so different between species that the variation within the species is not a problem for distinguishing them. Colour, shape and markings can all be useful distinguishing features, but be sure that they are not too variable between individuals.

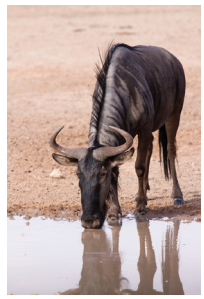
Size of species can be used as a distinguishing feature as long as you can compare it with something standard for each species. For example, if you were making a key for identifying the different herbivores on the African grasslands, you would see that some are larger than others. Just

saying one is a 'big animal' and another is a 'smaller animal' isn't helpful. So if you are about 1.5 m tall, you could use 'greater than 1.5 m tall to top of head' and 'less than 1.5 m tall to top of head', using your height to compare each species against.

Try to choose features that are present in all individuals of the species. For example, using shape of horns as a distinguishing feature for African herbivores will only work for species in which both males and females have horns of similar shape, or have no horns at all.

If you are starting with many organisms for your key, try to choose the first question or two to split the group almost equally. For example, a key for all the herbivores of the African grasslands might start: 'Does it look a bit like a horse?' This would separate out all the antelopes from animals such as the elephant, giraffe and rhinoceros.


kudu


wildebeest


zebra


Thomson's gazelle

Δ Fig 1.28 Some herbivores of the African savannah.

You can group the organisms in any way that is useful. So, for the animals shown in Fig. 1.28, we could group kudu, wildebeest and zebra with 'stripes across the back', leaving the gazelle out of the group.

This would give us this question for a key:

Does it have stripes across the back? yes – go to next question

no – **gazelle**

We would then need a question that separates out one of kudu, wildebeest or zebra from the other two. And so on, until the key has identified each species separately.

QUESTIONS

1. Explain why it is important to use easily identifiable features when constructing a key.
2. Using the photographs above, complete the key for these four animals.

End of topic checklist

Key terms

anatomy, binomial system, cell membrane, cell wall, chloroplast, classification, conservation, cytoplasm, dichotomous key, DNA analysis, enzyme, excretion, exoskeleton, genus, growth, kingdom, morphology, movement, photosynthesis, plasmid, prokaryote, protein analysis, protein synthesis, reproduction, respiration, ribosomes, species, vertebrate

During your study of this topic you should have learned:

- ❍ How to describe the seven characteristics of life: movement, respiration, sensitivity, growth, reproduction, excretion and nutrition.
- ❍ **EXTENDED** How to define the seven characteristics of life.
- ❍ That organisms are classified into groups by the features that they share.
- ❍ How to define a species a group of organisms with many similar features, and know that members of a species can breed with others of the same species to produce fertile offspring.
- ❍ How to describe the binomial system as giving organisms a genus and species name that distinguishes them from other species.
- ❍ **EXTENDED** That the classification of organisms helps us to identify evolutionary relationships between them.
- ❍ **EXTENDED** That the binomial system of naming organisms makes it easier for people working on the of species to be certain they are talking about the same species.
- ❍ **EXTENDED** That classification used to be based just on the visible features (morphology) and body structure (anatomy) of an organism.
- ❍ **EXTENDED** Scientists now also use the DNA sequence of organisms to help identify how closely related the organisms are.
- ❍ All living organisms have cells that are surrounded by a cell membrane. Inside the cell is jelly-like cytoplasm and genetic material in the form of DNA.
- ❍ Plants are multicellular organisms that make their own food in photosynthesis using light energy. Many of their cells contain chloroplasts, in which photosynthesis takes place. Their cells are surrounded by a cellulose cell wall.
- ❍ Animals are multicellular organisms that get their food by eating other organisms. They coordinate their movements using nerves, and most are able to move around.

End of topic checklist continued

- ❍ The definition of vertebrates as animals that have a backbone.
- ❍ The definition of arthropods as invertebrates that have jointed exoskeletons in three main parts.
- ❍ **EXTENDED** That all living cells contain ribosomes and to define these as the site of protein synthesis, including the formation of enzymes that control cell processes such as anaerobic respiration.
- ❍ **EXTENDED** To list the main features of viruses, including know that they are infective particles made of a protein coat surrounding nucleic acid, they do not have a true cell structure, can only reproduce when inside a cell of another organism and many people think they are not true living organisms.
- ❍ **EXTENDED** Living organisms can be divided into five kingdoms based on their features: animals, plants, fungi, protoctists and prokaryotes.
- ❍ **EXTENDED** The plant kingdom contains the ferns, which have frond leaves and produce spores during reproduction, and flowering plants that reproduce using flowers.
- ❍ **EXTENDED** Flowering plants are divided into monocotyledons, which have leaves with parallel veins and seeds containing one food store, and dicotyledons, which have leaves with branching veins and seeds containing two food stores.
- ❍ **EXTENDED** Bacteria are microscopic, single-celled organisms that have no nucleus; they have a circular chromosome and some have additional genetic material in plasmids. They have cell walls and some feed off other living organisms.
- ❍ **EXTENDED** Protoctists are single-celled microscopic organisms. They are eukaryotes because they have a nucleus in their cell.
- ❍ How to use and construct a dichotomous key to identify organisms from easily identifiable features.

End of topic questions

Note: The marks awarded for these questions indicate the level of detail required in the answers. In the examination, the number of marks awarded to questions like these may be different.

1. Name and describe the seven processes of life. **(7 marks)**

2. Name two life processes necessary for an organism to release energy. **(2 marks)**

3. Explain why dry mass is used to measure growth. **(2 marks)**

4. When you place a crystal of copper(II) sulfate in a saturated solution of the same compound, the crystal will increase in size. Does this mean that the crystal is alive? Explain your answer. **(2 marks)**

5. Plants cannot move about, as animals can. Does that mean animals are more alive than plants? Explain your answer. **(2 marks)**

6. During winter, an oak tree in the UK will lose its leaves and not grow. Is the tree still living during this time? Explain your answer using all the characteristics of life. **(4 marks)**

7. The binomial name of the lion is *Panthera leo*.

a) Which part of the name is unique to the lion? **(1 mark)**

b) What does the other part of the name indicate? Explain your answer. **(1 mark)**

8. A zoo has a male animal and a female animal that look very alike. They put them in the same enclosure to see if they will breed.

a) Suggest why the zoo think the animals may be of the same species. **(1 mark)**

b) Describe what the zoo would expect to happen if the animals were of the same species. **(1 mark)**

c) **EXTENDED** Describe another method that the zoo could use to check if the animals were of the same species. Explain your answer. **(2 marks)**

9. Imagine you discovered a new animal while on an expedition to a remote island in Indonesia. Explain how you would work out how to classify it. **(2 marks)**

10. **EXTENDED** In an exam question about classification, a student wrote:

A bat has wings, and birds have wings, so they should be classified in the same group.

Bats are actually classified in the class Mammalia (mammals) and birds are classified in the class Aves (birds). Mammals and birds are grouped in the phylum Chordata (organisms with a bony backbone).

End of topic questions continued

a) Identify the student's error and explain why it is a problem. **(2 marks)**

b) Explain why bats and birds are classified in different classes but in the same phylum. **(2 marks)**

11. **EXTENDED** DNA analysis has shown that humans share the following proportions of their genetic code with other animals: chimpanzee 96%, chicken c.60%, fly 60%, mouse c.75%.

a) Explain what this evidence suggests about all these animals. **(1 mark)**

b) Describe and explain the pattern of the results in relation to humans. **(2 marks)**

12. **a)** Describe three main features that are found in both plant cells and in animal cells. **(3 marks)**

b) Describe two main features that are found in plant cells but not in animal cells. **(2 marks)**

13. Explain why a large tree and a crop such as rice or maize are both classified as plants. **(2 marks)**

14. The blue whale is the largest animal on Earth. It is classified as a mammal, although it has no fur. Suggest which other features the whale has that means it belongs to the mammal group and not another group. **(2 marks)**

15. **a)** Separate the following animals into two groups based on a main feature:

crab dog shark bee **(2 marks)**

b) Describe the main feature you used to classify the animals. **(1 mark)**

16. **EXTENDED** Put the following organisms into size order, starting with the smallest:

bacteria protoctists viruses **(2 marks)**

17. **EXTENDED** Draw up a table to compare the features of the five kingdoms. Your table should include basic cell structure, and any feature that distinguishes the group from other kingdoms. **(5 marks)**

18. **EXTENDED** Fungi were once classified as plants.

a) Suggest which features were used to justify this classification. Explain your choice. **(2 marks)**

b) Explain why fungi are no longer classified in the same kingdom as plants. **(2 marks)**

19. EXTENDED Some people think viruses are living organisms, other people do not.

a) Which characteristic of living organisms do viruses have? **(1 mark)**

b) List the other characteristics of living organisms, and for each one describe what viruses can and cannot do. **(6 marks)**

c) Using what you know about viruses, prepare an argument for classifying them as living organisms. **(2 marks)**

d) Using what you know about viruses, prepare an argument for *not* classifying them as living organisms. **(2 marks)**

20. Look at the key of fruits shown in Fig 1.27. List the questions and answers that would lead to an identification of a banana. **(3 marks)**

21. a) Give two advantages for the sort of dichotomous key shown in Fig. 1.27. **(2 marks)**

b) Identify one problem you might have when using such a key. **(1 mark)**

22. Read the following questions carefully.

i) Does the specimen have wings?

ii) Does the specimen have feathers?

iii) Does the specimen lay eggs?

a) Which question do you think would be most useful for placing an organism in the bird group? **(1 mark)**

b) Explain your answer. **(1 mark)**

23. Look at the pictures of flowers. Construct a simple dichotomous key to identify each flower. **(2 marks)**

			
Daisy	Hibiscus	Poppy	Rose