Heinemann Biology 3rd Edition

Preliminary



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Heinemann Biology 3rd Edition Preliminary



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- explicit focus on the syllabus dot points
- separate skills and verbs units
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- stunning online support for both teachers and students.

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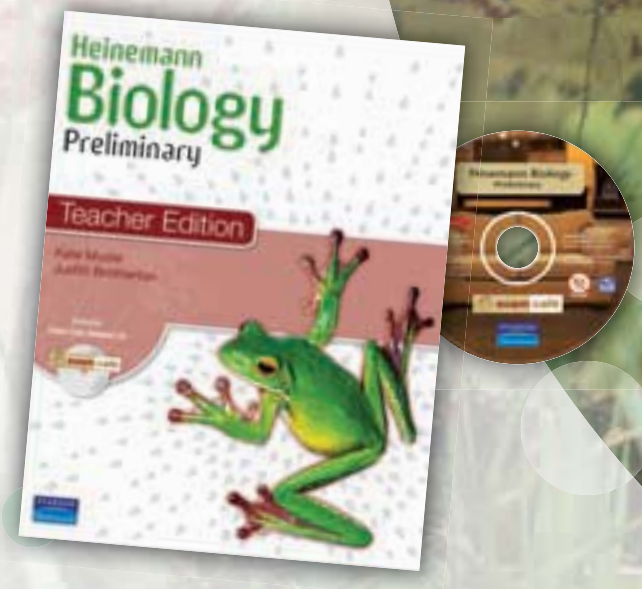
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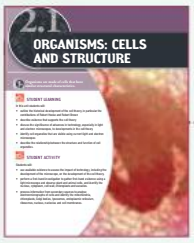
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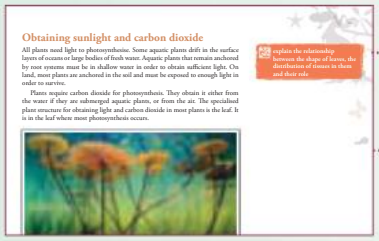
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Each chapter corresponds to a syllabus module. The chapter opener section includes syllabus outcomes and assumed knowledge.



Each chapter is divided into self-contained units. Syllabus dot points addressed by the unit are listed at the beginning.

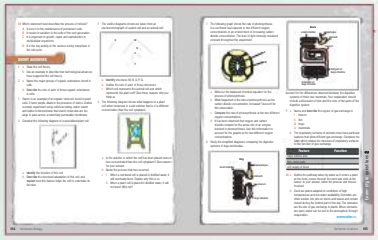


Syllabus dot points are highlighted when and where covered.

Each unit is broken up into accessible sections. Outstanding full-colour photos and illustrations enhance learning and interest.



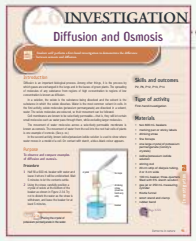
Each unit concludes with a unit review that includes a summary and questions. Questions are Board of Studies (BOS)-style with verbs clearly highlighted.



Each chapter concludes with a spread of exam-style questions. All questions are BOS-style with verbs clearly highlighted.



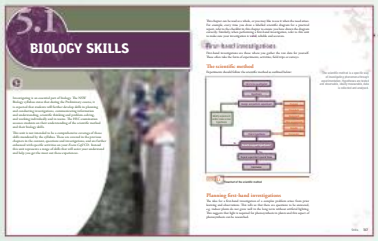
Extra material that is of an applied or historical nature is clearly indicated.



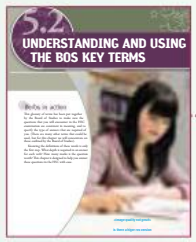
All mandatory investigations are included and appear where they should be addressed.



The Skills chapter is a new addition and is conveniently located on *Exam Café* CD in PDF format. It contains two units, Biology Skills and Understanding and using BOS key terms.



5.1 Biology skills covers the skills and techniques required to address the practical aspects of the syllabus effectively. It is designed to be accessed where and when required. To assist with this, clear links are made from the chapters and investigations where relevant skills are required.



5.2 Understanding and using BOS key terms addresses the verbs of the syllabus. Definitions and expansions are provided, along with examples of questions and answers using the different verbs.

Other features:

- **Summary points** and **definitions** are included in the margin.
- **BioFacts** are snippets of information to provide interest.
- **Key terms** are highlighted in bold when first encountered.
- A comprehensive **glossary** and **index**.



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- interactive quiz items assist students by testing their understanding and enhancing learning
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Outcomes correlation grid

Heinemann Biology Third Edition Preliminary covers all the course outcomes required for the New South Wales Board of Studies Preliminary course. Each chapter covers relevant content outcomes and the questions at the end of each chapter further develop outcomes 13, 14 and 16. Investigations within each chapter have the relevant skills outcomes listed separately for each activity. The skills chapter supports the investigations within the text. Below is a correlation grid showing where the outcomes are covered.

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16
Chapter 1		●		●	●	●	●	●			●	●	●	●	●	●
Chapter 2	●	●	●	●	●	●	●	●	●			●	●	●	●	
Chapter 3	●	●	●	●	●	●	●	●		●	●	●	●	●	●	
Chapter 4	●	●	●		●	●	●		●	●	●	●	●	●	●	●
Chapter 5	●	●			●						●	●	●	●	●	●

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CHAPTER 1

A LOCAL ECOSYSTEM

PFA: This chapter increases students' understanding of the nature, practice and applications of biology.



An ecosystem is any environment containing living organisms that interact with each other and with the non-living parts of the environment.

Ecosystems are largely self-sustaining, because materials and energy are exchanged between the organisms and their environment. Energy from sunlight enters the system through photosynthesis in plants, and then flows through other living organisms via food webs. Materials such as carbon, nitrogen, oxygen and water cycle through an ecosystem, and can also pass from one ecosystem to another.

The size of a population of organisms does not remain constant in an ecosystem. Populations can increase or decline dramatically. The contributing factors for this variation include disease, predation, competition, availability of resources, and increasing human activity and interference. Humans often disturb natural ecosystems to meet their own needs. The clearing of vast areas of forests and woodlands for agriculture is one example.

The interactions between organisms and their environment are often complex and not immediately obvious. The study of ecology enables us to understand these interactions. Studying a local ecosystem can give an insight into how other ecosystems function.

What is your local ecosystem? Carefully analysing the biotic and abiotic factors operating in your local area will allow you to identify and understand important biological concepts. You are encouraged to analyse and report on aspects of the local environment that have been affected by people, and suggest solutions to the problems that exist.

Assumed knowledge

Refer to the Board of Studies NSW Science Years 7–10 Syllabus.

- Distinguish between biotic and abiotic features of the local environment (5.10a).
- Describe the importance of cycles of materials in ecosystems (5.10b).
- Describe some impact of human activities on ecosystems (5.10c).
- Relate pollution to contamination by unwanted substances (5.11.2a).
- Discuss strategies used to balance human activities and needs in ecosystems with conserving, protecting and maintaining the quality and sustainability of the environment (5.11.2c).

Preliminary Course Outcomes

Prescribed focus areas

P2 Applies the processes that are used to test and validate models, theories and laws of science, with particular emphasis on first-hand investigations in biology.

P4 Describes applications of biology which affect society or the environment.

P5 Describes the scientific principles employed in particular areas of biological research.

Domain knowledge

P6 Explains how cell ultrastructure and the coordinated activities of cells, tissues and organs contribute to macroscopic processes in organisms.

P7 Describes the range of organisms in terms of specialisation for a habitat.

P8 Analyses the interrelationships of organisms within the ecosystem.

Domain skills

P11 Identifies and implements improvements to investigation plans.

P12 Discusses the validity and reliability of data gathered from first-hand investigations and secondary sources.

P13 Identifies appropriate terminology and reporting styles to communicate information and understanding in biology.

P14 Draws valid conclusions from gathered data and information.

P15 Implements strategies to work effectively as an individual and as a team member.

Values and attitudes

P16 Demonstrates positive values about and attitudes towards both the living and non-living components of the environment, ethical behaviour and a desire for a critical evaluation of the consequences of the applications of science.

UNIT 1.1

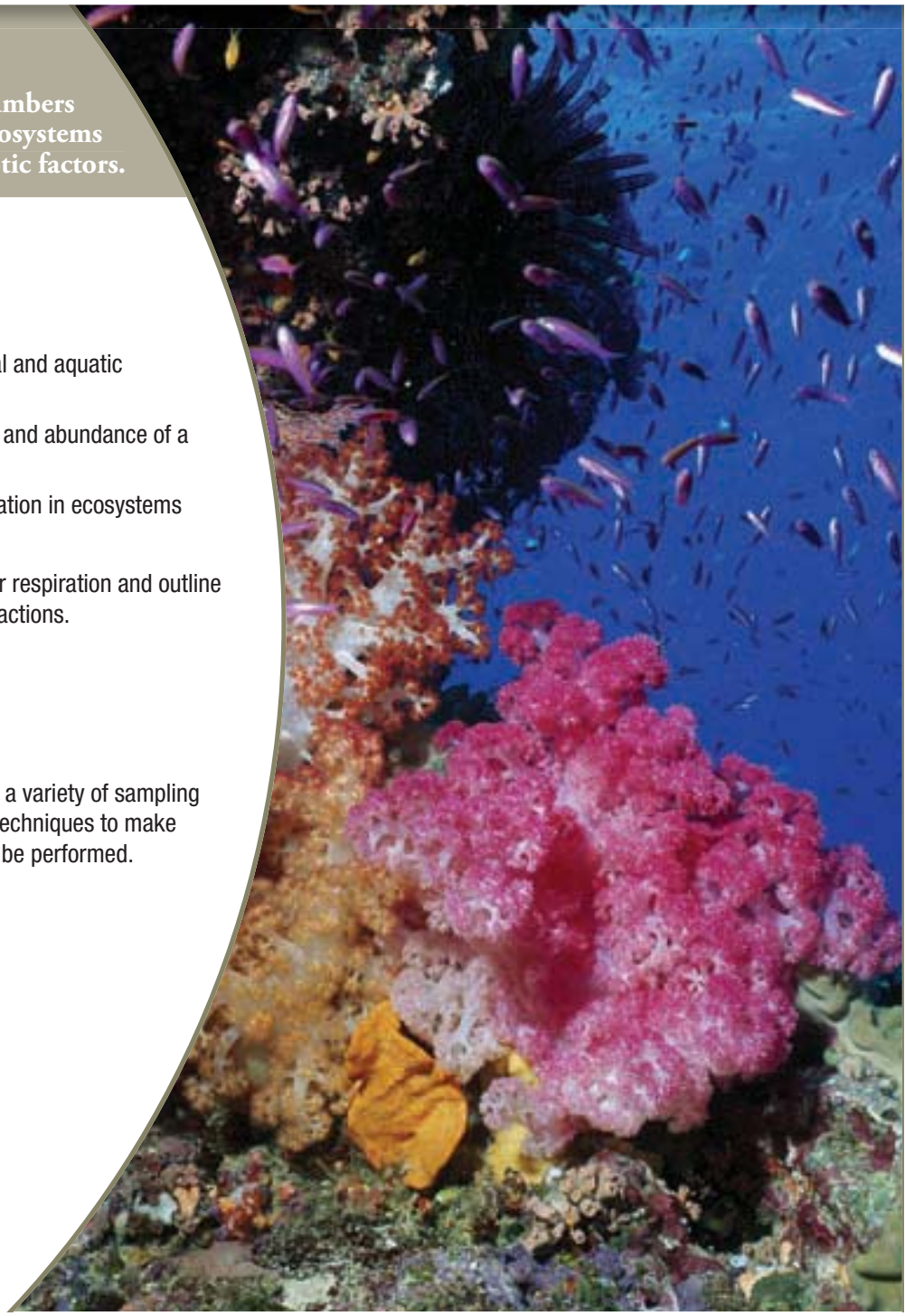
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Distribution and abundance 9
Population estimates 14
Photosynthesis and respiration 19
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Unit review 22
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UNIT 1.2

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1.1 TERRESTRIAL AND AQUATIC ENVIRONMENTS

The distribution, diversity and numbers of plants and animals found in ecosystems are determined by biotic and abiotic factors.



STUDENT LEARNING

In this unit students will:

- compare the abiotic characteristics of terrestrial and aquatic environments
- identify the factors determining the distribution and abundance of a species in each environment
- describe the roles of photosynthesis and respiration in ecosystems
- identify uses of energy by living organisms
- identify the general equation for aerobic cellular respiration and outline this as a summary of a chain of biochemical reactions.

STUDENT ACTIVITY

Students will:

- process and analyse information obtained from a variety of sampling studies to justify the use of different sampling techniques to make population estimates when total counts cannot be performed.

The **environment** of an organism is its surroundings—everything around it, both living and non-living, that affects it. An **ecosystem** is any environment containing living organisms interacting with each other and with the non-living parts of that environment. An ecosystem can be any size, from a drop of rainwater to the whole Earth. It can be a pond, a forest, a desert or a small area you are studying in a piece of bushland. The term 'ecosystem' tells us that it is being studied as a system. This system involves the exchange of materials and energy between organisms and their environment. Ecosystems are largely self-sustaining.

Environments have **abiotic** and **biotic** factors. Abiotic means non-living; biotic means living. Abiotic factors include physical and chemical factors, such as the temperature, rainfall, type of soil and the salinity of the water. Biotic factors include all the living organisms, how many types there are, their numbers, **distribution** and interactions.

The **habitat** of an organism is the place where it lives. The organisms that are found living together in a particular place form a **community**. The study of the relationships living organisms have with each other and with their environment is called **ecology**.

The environment of an organism is its surroundings—everything around it, both living and non-living, that affects it.

An ecosystem is any environment containing living organisms interacting with each other and with the non-living parts of that environment.

The habitat of an organism is the place where it lives.

Australian environments

Terrestrial environments are environments on land. Land covers about 35% of the Earth's surface. Differences in the climate, the topography of the land, the availability of water, and human actions have produced many different terrestrial environments. They include rainforests, open forests, mountain tops, deserts, grasslands, heathlands, farms and cities. Some terrestrial environments in Australia are shown in Figure 1.1.

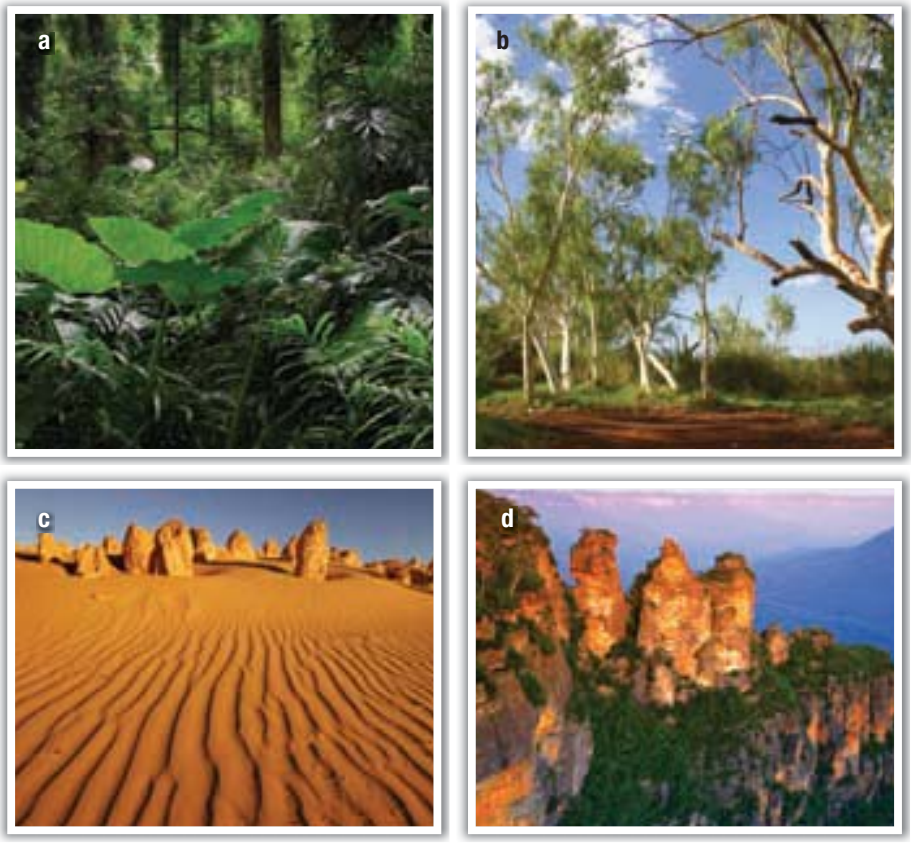
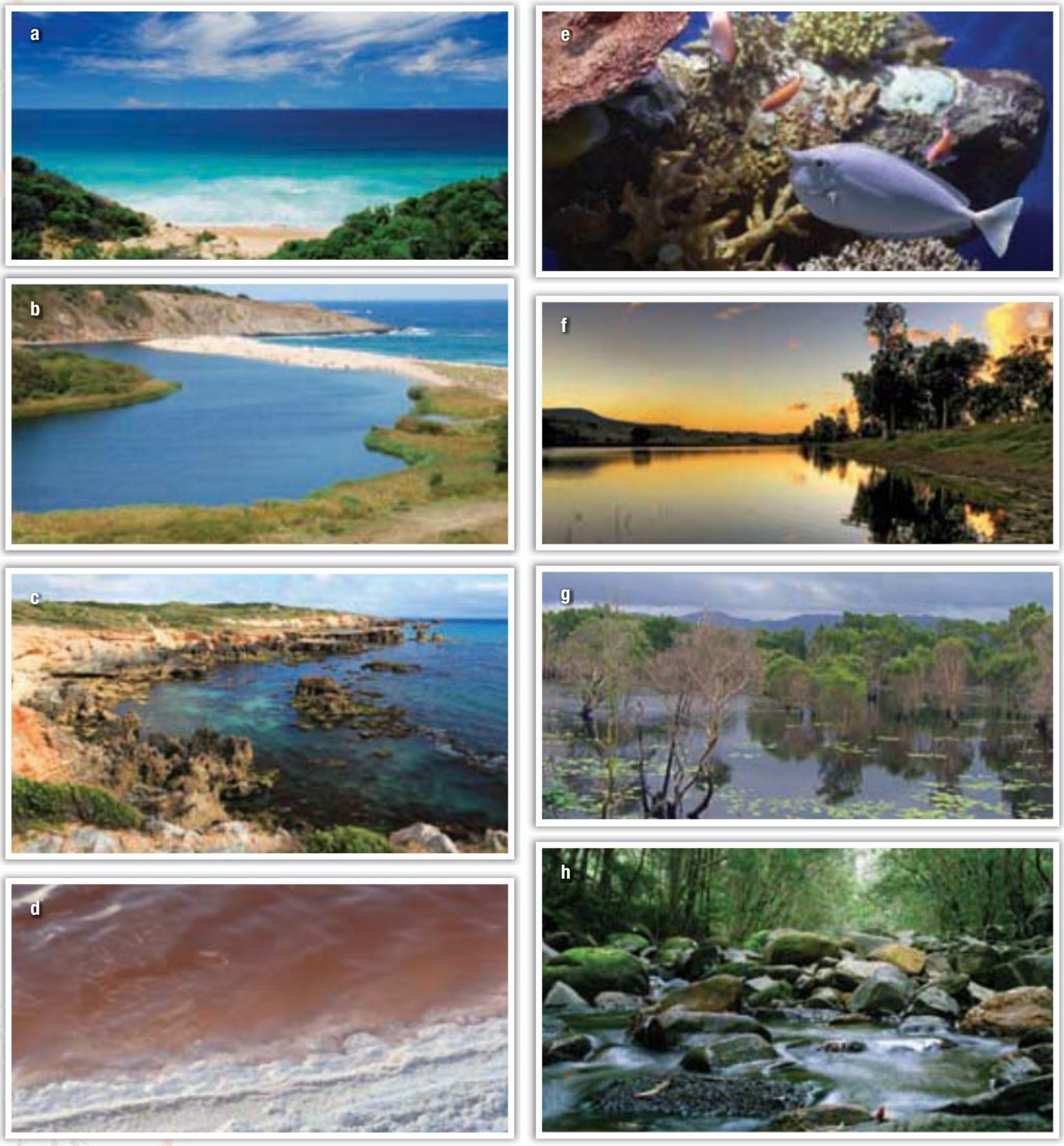


Figure 1.1 Some Australian terrestrial environments: (a) rainforest, (b) open forest, (c) desert, (d) mountain top, (e) grassland, (f) city, (g) farm.

Figure 1.2 Some Australian aquatic ecosystems: (a) open sea, (b) estuary, (c) rocky shore, (d) saltwater lake, (e) coral reef, (f) freshwater lake, (g) swamp, (h) river.

Aquatic environments are water environments. They may be saltwater or freshwater. Saltwater environments include the open seas, estuaries and saltwater lakes. Oceans cover about 65% of the Earth's surface. Tides, waves, currents and winds continuously move the water in the surface layers. Freshwater environments include still water such as lakes, ponds and swamps, and moving water such as springs, creeks and rivers. Some aquatic environments in Australia are shown in Figure 1.2.



Abiotic characteristics

compare the abiotic characteristics of aquatic and terrestrial environments

Terrestrial and aquatic environments have very different abiotic characteristics. These differences mean that, in order to survive, animals and plants living in an aquatic environment will be very different from the animals and plants living in a terrestrial environment. These differences are summarised in Table 1.1.

TABLE 1.1 A comparison of the abiotic characteristics of aquatic and terrestrial environments

Characteristic	In aquatic environments	In terrestrial environments
Viscosity Viscosity is a measure of how hard it is to move through a gas or a liquid (fluid).	Water has a high viscosity. This makes it more difficult for organisms to move through it.	Air has a low viscosity. This makes it easier for organisms to move through it.
Buoyancy Buoyancy is the amount of support experienced by an object immersed in a liquid or gas. It is equal to the weight of the liquid or gas displaced (Figure 1.3).	The buoyancy of water offers support to both animals and plants. It may help them to maintain their shape, and enables some organisms to function at different depths.	Animals and plants do not experience much buoyancy from air. They need to be able to support themselves.
Temperature variation The main source of heat is from the Sun's radiation. The radiation intensity depends on latitude. It is greater at the equator than at the poles. Animals and plants can survive only within a certain temperature range.	Water heats up more slowly than air. Temperatures in the surface ocean layers vary from 30°C at the equator to freezing point in arctic regions. However, the temperature in a particular region varies only a little from year to year. Deep waters everywhere are cold (Figure 1.5). Small bodies of water may show considerable daily and seasonal variation.	Surface temperatures on land vary far more than in water. The highest recorded is 60°C, and the lowest is less than –80°C. Daily and seasonal variations may be very great. Temperatures beneath the ground do not vary so much. The ability to avoid or tolerate heat gain and loss is important in land organisms.
Pressure variation The Earth's gravitational field (the pull of gravity) gives rise to pressure differences between the upper and lower layers in both air and water. At any one level pressure is constant.	Pressure in water increases rapidly with depth. At a depth of 10 metres the pressure is twice that on the surface. Very few organisms live at great depths. Changing depth rapidly may be difficult for many organisms.	Atmospheric pressure decreases with height above sea level and also fluctuates over time. It may affect breathing by animals and flight.
Availability of gases Oxygen (O_2) and carbon dioxide (CO_2) are important gases for living organisms.	Gas availability in water is low and depends on the temperature. Diffusion is slower. More gases can be dissolved at lower temperatures. Oxygen concentration also decreases with depth. Oxygen availability affects the number and distribution of aquatic organisms, and also their body structure. Carbon dioxide dissolves in water to form carbonate and bicarbonate ions.	Gases are freely available in air and diffusion is rapid. Air contains about 20% oxygen and 0.03% carbon dioxide. The remainder is mostly nitrogen. Gas availability is not usually a limiting factor for land organisms, except at high altitudes.
Availability of water	Water availability is rarely a problem in aquatic environments, but the osmotic effects of fresh and salt water are important to organisms.	Water availability varies. The amount of rainfall and when it falls particularly affect plants. Obtaining water and preventing its loss may be a problem for all land organisms, especially in arid environments.
Availability of ions	Saltwater (marine) environments contain 3.5% dissolved salts—mostly sodium and chloride ions. Freshwater environments have a low ion concentration. Organisms need to be able to cope with any osmotic differences between their cells and the external environment.	Ions are available in the soil. The type and amount depend on the composition of the soil. Soil type and pH influence the type and amount of plant growth.

TABLE 1.1 (cont.)

Characteristic	In aquatic environments	In terrestrial environments
Light penetration Light is received from the Sun's radiation. The light intensity is greater at the equator than at the poles.	Light falling on water may be reflected, scattered or absorbed. Light penetration in water decreases rapidly with depth (see Figure 1.4). Light availability affects the distribution of organisms in water.	Light can pass freely through air. Plenty of light is available to land organisms. Dense plant growth or topography may affect light penetration to some areas. The amount of light received is important for plant growth.
Availability and type of substrates There are many different types of rocks, soils, sands and other material formed from rock. They vary in their mineral and nutrient status.	Bottom-dwellers are affected by the type and amount of substrate available. Free-swimming and surface-level aquatic organisms are less affected, although the amount of sediment (turbidity) in water is important.	The amount and type of soil, the amount of rock and the gradient of the land all influence plant growth and the availability of habitats for ground-dwellers and animals that live underground.
Strength of natural forces	Tides, currents and waves vary in strength according to the season and the weather. Some organisms cannot survive in moving water, while others cannot survive in still water.	Winds and rain vary in strength and duration according to the season and the climate. Many organisms cannot survive exposure to these factors in open environments.
Availability of shelter	Not all aquatic organisms require shelter. The substrate, rocks, vegetation and coral reefs may provide for those that do.	Most animals require shelter. Some plants will grow only in sheltered environments.
Availability of space	This can be a limiting factor in some aquatic environments, especially for animals requiring territory.	This can be a limiting factor on land for both plants and animals, particularly those requiring territory, shelter or nesting sites.

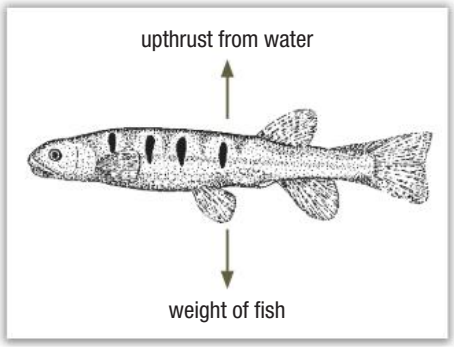


Figure 1.3 Buoyancy in water. The fish's body is supported by buoyancy. If the upthrust is greater than the fish's weight, the fish rises. If it is less, the fish sinks.

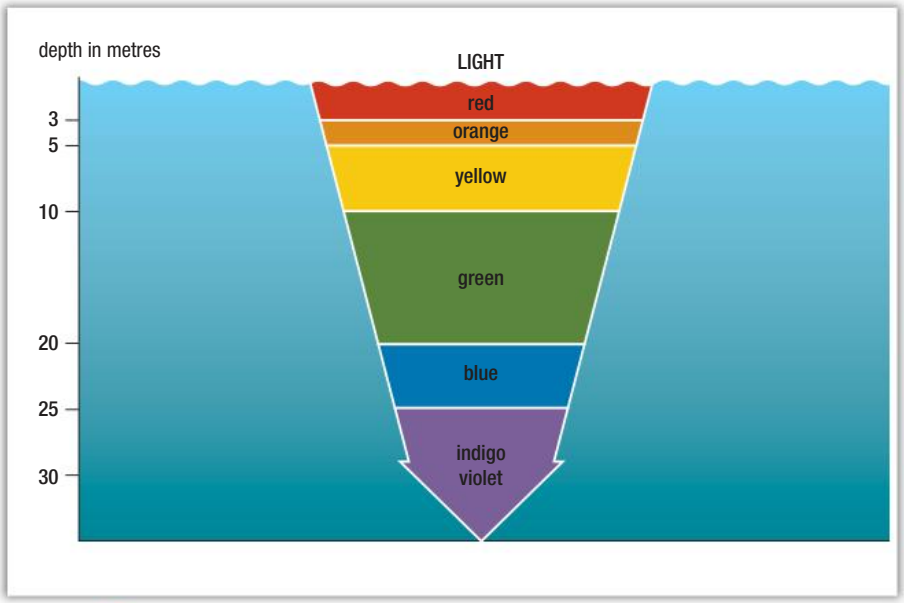


Figure 1.4 Light penetration in water. When light enters water, the different wavelengths are absorbed at different depths. Red, orange and yellow are absorbed first. The green, blue and violet wavelengths are absorbed with increasing depth. This is why the underwater world is dominated by blues and greens. Almost no light penetrates below a depth of about 30 metres.

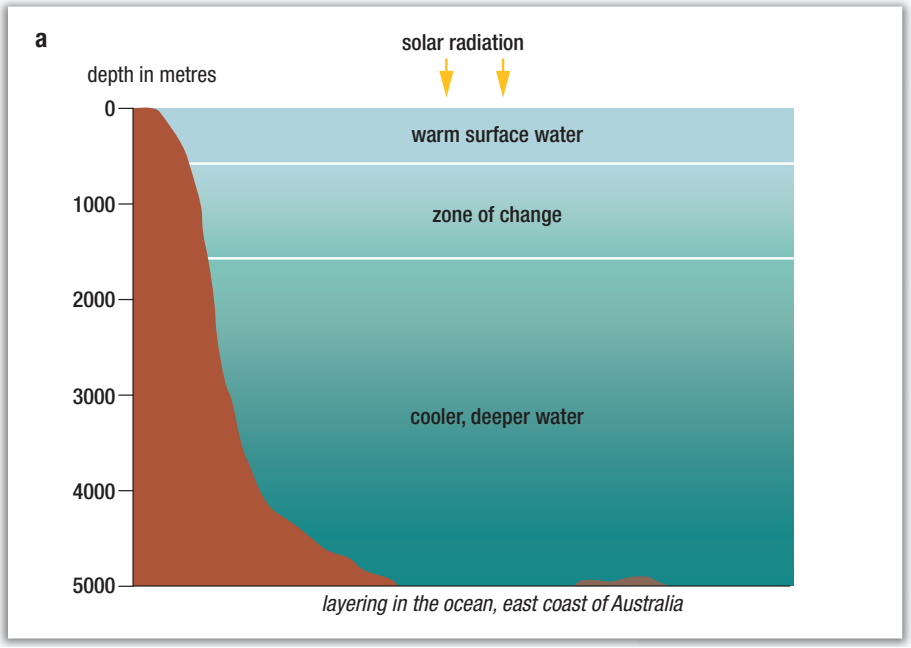




Figure 1.5 (a) In large bodies of water, the surface layers of water warm up in spring and summer. In calm conditions two layers form: a warmer surface layer and a colder layer below. In autumn and winter, when air temperatures are colder and there is more turbulence at the surface, this layered effect disappears. (b) In very cold regions, a layer of ice forms on the surface of water in winter. This insulates the water below, allowing aquatic organisms to survive.

Distribution and abundance

Distribution

The distribution of a species describes where it is found. No species is spread evenly through an entire natural ecosystem. Organisms occupy the areas where the biotic and abiotic factors of the environment suit them. They live where their chances of survival are high, where their requirements for survival are met, and where they are able to avoid predators.

The distribution of a species is all the places in which it is found.

Figure 1.6 is a **profile sketch** showing where three different plant species were found by an ecologist who walked in a straight line for 140 m across a slight dip between two ridges at Myall Lakes, New South Wales. The places where the plants were found are indicated by shading. As you can see, closely related species (the two banksias) can occur in different zones. The boundaries between different species are not always as distinct as this; these three species seem to have quite different requirements for survival.

Figure 1.7 is a **plan sketch** of the same area, giving us more information about the extent of the three species than the profile does.

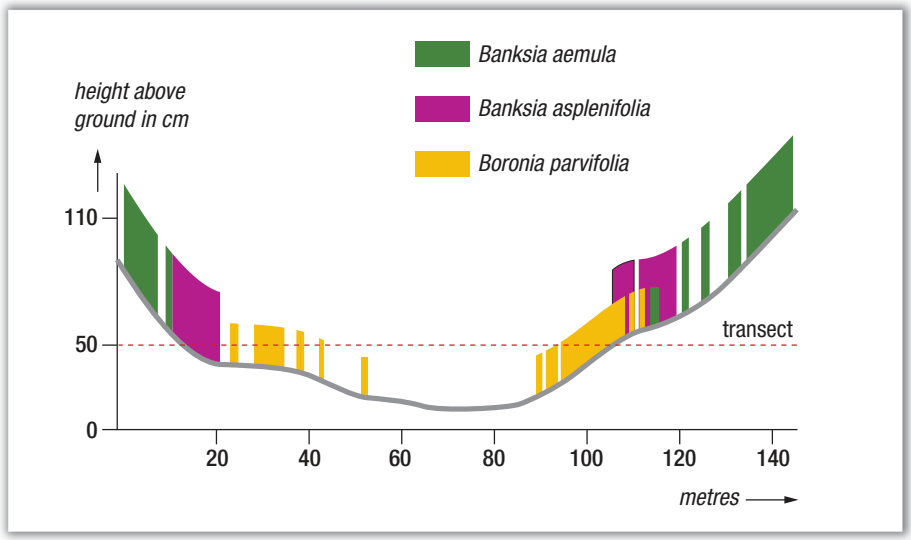


Figure 1.6 Profile sketch of the distribution of three species of plants in a sample area at Myall Lakes, New South Wales.

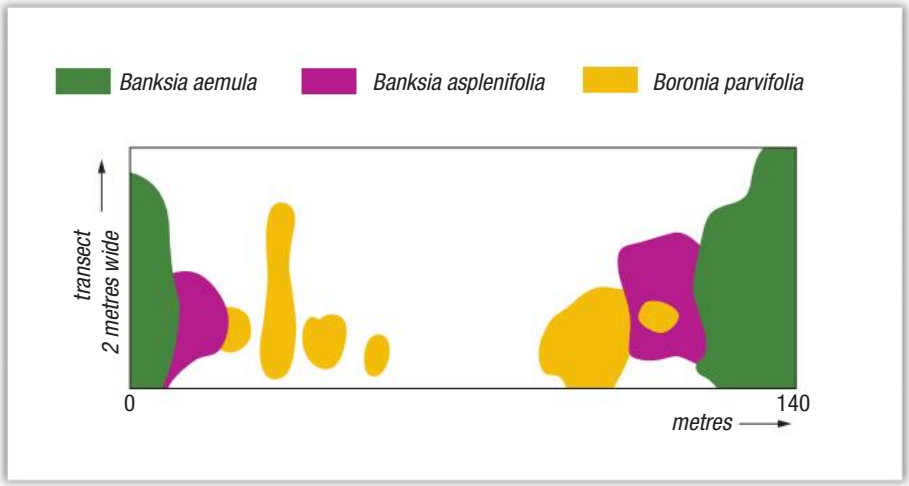


Figure 1.7 Plan sketch of the area covered in Figure 1.6. (For clarity, the length has been compressed in this sketch.)

Abundance

The **abundance** of a species means how many members of the species live throughout the ecosystem. Abundance is not the same throughout the area, and changes over time. A species will increase in abundance if the birth or germination rate exceeds the death rate; that is, if its resources are plentiful and there is not much predation or disease. Increases in the abundance of animals are caused by births and **immigrations**; decreases are due to deaths and **emigrations**. Plant abundances increase through the germination of seeds or spores, and decrease when plants die or are consumed. Change in abundance is often represented graphically (Figure 1.8).

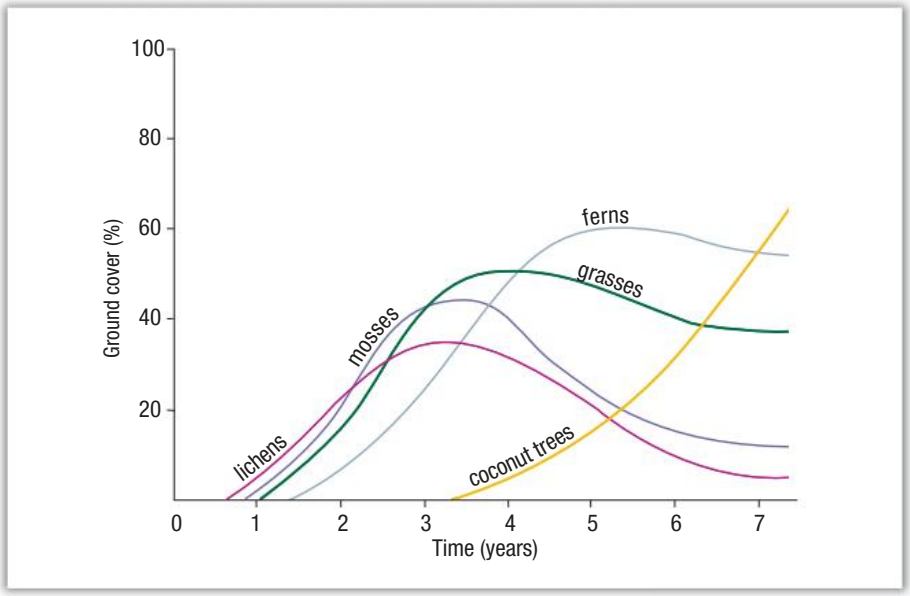


Figure 1.8 This graph shows the changes in abundance of various plants that became established on the island of Krakatoa after a volcanic eruption. Abundance is measured here by the amount of ground covered by each type of plant.

identify the factors determining the distribution and abundance of a species in each environment

Factors determining distribution and abundance

Now try to think of as many factors as possible to explain the distribution and abundance of species in aquatic and terrestrial environments.

- Why do they occupy certain areas and not others?
- Why aren't there more (or fewer) individuals of each species?

All organisms have their own requirements for successful survival and maximum growth and development. The word 'resources' is often used in reference to factors affecting distribution and abundance of organisms. Resources are anything in an environment that organisms use. Resources are usually limited; organisms that need the same resource will be in competition.

Plants need light and water for photosynthesis; their rate of growth depends on temperature and soil or water quality. The distribution and abundance of plants directly affect the distribution and abundance of animals. Animals depend on plants for food; they may also need shelter and nesting sites. Organisms are only found in areas that can supply their needs.

Resource competition refers to the competition for requirements for successful survival, growth and development of an organism.

Abiotic factors

The following abiotic factors can affect the ability of an organism to survive in an ecosystem:

- amount of light
- amount and strength of wind and rainfall
- temperature—daily and seasonal variations
- effect of topography, altitude and depth
- strength of tides, currents and waves
- water—amount, salinity, pH and availability
- type and availability of substrate
- availability of space and shelter
- availability of gases such as oxygen and carbon dioxide.

See Table 1.1 on pages 7 and 8 for details of these factors.

Biotic factors

The following biotic factors can affect the ability of an organism to survive in an ecosystem:

- seasonal availability and abundance of food for animals—suitable plants for herbivores and suitable prey for carnivores
- number of competitors—these can be from the same species or other species with similar requirements; the birth rate and death rate of a species may be important here
- number of mates available—animals need to find mates for the species to survive and reproduce in a given ecosystem
- number of predators
- number and variety of disease-causing organisms (pathogens).

In your field studies, you will have to measure some of these factors. Those which are significant for the organisms you are studying will depend on the ecosystem you are investigating and the types of organisms.

Distribution and abundance: case studies

Your practical work will include measuring the distribution and abundance of a named species in the field. The following examples show how a knowledge of the distribution and abundance of organisms can help us understand their requirements, contribute to our knowledge of the complex interactions of ecosystems, and even perhaps help us to prevent their extinction.

BIOFACT

When white clover and strawberry clover are planted together in the same field, the strawberry clover with its longer leaf stalks grows taller, overtopping the shorter white clover. Strawberry clover competes better for space and shades out the other species, eventually excluding it from the field.

BIOFACT

The conservation status of a species is decided by looking at factors influencing its current size, distribution and population trend.

A species that is common is one that is widespread and is often seen or trapped. Its status may be described as of least concern.

Under the Environmental Protection and Biodiversity Act 1999, species that are threatened may be listed as:

- extinct
- extinct in the wild
- critically endangered
- endangered
- vulnerable
- conservation dependent.

For more information, visit the website of the Department of the Environment, Water, Heritage and the Arts.

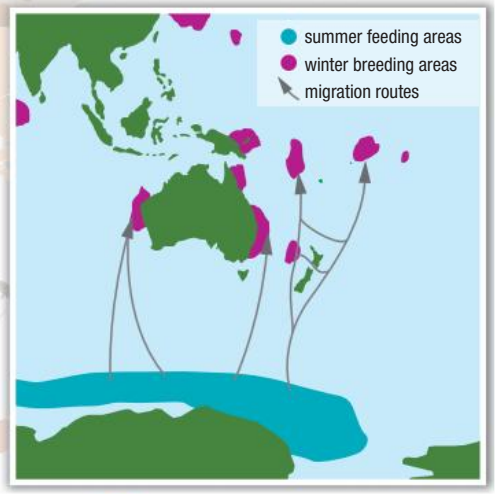


Figure 1.10 Humpback whale migration and distribution patterns in the Australasian region.

BIOFACT

The Australian government has a recovery plan for the humpback whale for 2005–2010, which details factors affecting distribution and abundance, threats and protective management. For more information, visit the website of the Department of the Environment, Water, Heritage and the Arts.

CASE STUDY 1. The humpback whale

The humpback whale (*Megaptera novaeangliae*) is a large aquatic mammal up to 15 metres long, with a humped back that carries a small fin. The tail and long flippers have white patterns or markings that are unique to each whale. The head, jaws and flippers also have noticeable bumps or knobs on them. Humpback whales are filter feeders. Instead of teeth they have baleen plates on their upper jaw that sieve or filter small organisms from the water. An adult female produces a single offspring every 2–3 years. The estimated life span of a humpback whale is more than 70 years.

Distribution

Humpback whales have a world-wide distribution. There are two distinct large groups—the northern hemisphere and southern hemisphere humpback whales—and each group is made up of different geographical populations. All the populations are migratory, moving from cold subpolar feeding grounds in summer to warm tropical breeding grounds in winter (Figure 1.10). In Australian waters there are two distinct populations: those that migrate along the coast of Western Australia and those that migrate along the eastern coast.

Abundance

The humpback whale is classified as a 'vulnerable' species. It was hunted extensively throughout its range until the mid-twentieth century. The eastern Australian population fell from an estimated 10000 whales to 200–500 by 1962. The population is now increasing, and by 2008 was about 5000 whales. The Western Australian humpback whales were reduced from about 17000 to fewer than 1000 by 1962, when whaling in Australian waters was banned. Their numbers too are recovering, but not at the same rate as those of the eastern Australian population.



Figure 1.9 A humpback whale 'breaching'. Note the bumps on the jaws and flipper.

Estimates of abundance are conducted by shore-, aerial- and water-based observations (whale-watching), including photographic identification of individual whales. This method is possible because the **migration** routes of these whales are known. Capture–recapture, using tags, is possible when the migration movement of a group of whales is unknown. The recovery rate of tagged whales has, however, been very low.

Special factors affecting distribution and abundance

We still know very little about the behaviour and migration of humpback whales, and the factors that control their population numbers in the wild. Arctic and Antarctic waters are rich in krill (small shrimp-like crustaceans) that are the main food of the humpback whale. In summer, the whales feed and grow before moving to warmer waters where their young are born and where they mate. Some of these migrations cover several thousand kilometres.

Their numbers declined so drastically when they were hunted by humans because they were easy to catch. Their feeding, mating and calving grounds are usually found close to shore, they are found in groups, and they are slow swimmers. The humpback whale's low reproductive rate makes the recovery of populations slow.

CASE STUDY 2. The bush rat

The bush rat (*Rattus fuscipes*) is an inconspicuous, nocturnal native rodent. Each individual lives in a burrow and has its own home range or area. Bush rats are **placental** mammals, not **marsupials**. They have a soft furry body and a short, scaly tail. Their adult size ranges from 20 to 40 cm. They have a pair of sharp incisor teeth and pink footpads. They can breed all year round, although most young are born in late spring and summer. Usually about five young are born in each litter. Their life span is, on average, 1 year. They are not endangered and their **conservation** status is 'least concern'.

Distribution

Bush rats live mainly in coastal areas. Only in south-eastern Australia are they found more than 100 kilometres inland. They live in many different habitats, from dry, sandy hills to tropical rainforests, but they are more common in open forests, particularly where there is dense undergrowth, and near watercourses. There are four distinct subspecies, and their ranges do not overlap (Figure 1.11).

Abundance

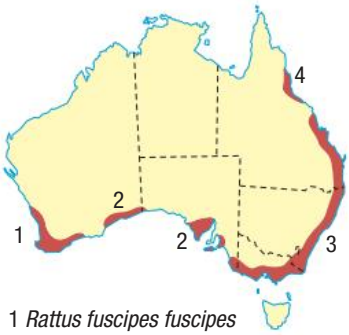
Although bush rats are widespread within their habitats, their population densities tend to be quite low. Numbers estimated using trapping techniques (see p. 15) were between 11 and 22 rats per hectare, depending on the type of forest habitat. Population numbers are lowest in winter and highest in summer, after the main breeding season.

Bush rats living on islands off the coast tend to have higher population densities. Estimates from trapping these rats range from 60 to 150 animals per hectare. A likely reason for this is the lack of predators, such as foxes and cats, on the islands.

a



b



1 *Rattus fuscipes fuscipes*

2 *Rattus fuscipes greyi* Both these rats are small with long, soft grey-brown coats

3 *Rattus fuscipes assimilis* a large rat with a dark-grey shaggy coat

4 *Rattus fuscipes coracius* a large rat with a reddish-brown, short, smooth coat

Figure 1.11 (a) The bush rat, *Rattus fuscipes*. (b) The distribution of the four subspecies of bush rat.

Special factors affecting distribution and abundance

Bush rats can live successfully in a wide range of habitats, limited only by their need for water. They can survive only 4 days without water.

They eat a broad range of foods. Their diet includes insects, fungi, plant materials such as seeds, mosses, roots, berries, grasses and herbs, and occasionally small vertebrates such as mice. They have a high reproductive capacity (females can breed at 3 months old and gestation lasts 22–25 days) and they can reproduce all year round if environmental conditions are favourable.

Population estimates

A group of similar organisms living in a given area at the same time is known as a population.

A group of similar organisms living in a given area at the same time is known as a **population**.

In your field studies, you will measure the distribution and abundance of different populations in your chosen ecosystem. This could be done directly, but usually involves making population estimates because of the difficulty in describing in detail any large area. It would be impractical and time-consuming to count every living thing, even if this were possible. It would also cause considerable damage to the environment! Scientists have developed methods called **sampling methods** to make estimates of the distribution and abundance of species.

Measuring distribution

A transect is a narrow strip that crosses the area being studied, from one side to another. Transects are used mainly to study the distribution of species in the area being studied.

When studying organisms in the field, it is usual to describe their distributions on a sketch of the area, as in Figures 1.6 and 1.7 (pp. 9–10). The sketch may be an aerial view (plan) or a side view (profile) that you draw yourself. If the area is too large to be drawn entirely, take a narrow section of it, called a **transect**. This is a strip that crosses the entire area from one side to the other. You work only within the transect, recording what organisms are found as you cross the field. On your sketch, you indicate the types or names of organisms found in each place.

Measuring abundance

You could measure the abundance of a species simply by counting all the individuals that occur in the area. If a certain tree is scattered through the area you are studying and the area is not too large, it might be quite realistic to walk around the area recording each tree as you find it. But this would be very time-consuming and difficult to do if there were a lot of species to measure. Plants and small invertebrates might be too numerous to count reliably. Many animals are not always visible and can move rapidly. The technique used to estimate abundance must be carefully chosen, and often depends on the type of organism you are studying.



Figure 1.12 A transect is a narrow strip through the area you are studying.

Plant abundance

A useful method in a small area is to estimate the percentage cover. To record the abundance of grass in a field, or algae in a pool, simply estimate how much of the area is covered by the plant and record it as a percentage.

Often, however, this is impossible to do. When organisms are very numerous or scattered over a huge area, it is quicker and easier to study small, randomly chosen areas of vegetation, called **quadrats**, and count the numbers or estimate

the percentage covers in them. By comparing the size of the quadrats to the total area, we can estimate the total abundance. Quadrats can be any size, depending on the type of vegetation, but they are usually between 1 and 50 metres square. If you are studying a 1 × 1 metre quadrat, you can use a ready-made square frame, so that every quadrat will be exactly the right size (Figure 1.13).

A quadrat is a small area that represents the larger area being studied. Quadrats are used mainly to study the abundance of species in the area being studied.



Figure 1.13 Using a ready-made frame to mark out a 1 × 1 metre quadrat.

If your quadrat is one metre square you can easily calculate the number of organisms per square metre, and from this estimate the total in the area you are studying.

Animal abundance

If the species we are studying is constantly on the move, it may be easier to use the technique that is known as **capture–recapture**.

With this technique, you capture and tag a sample (e.g. five) of the species then release them. After they have had time to mix, you recapture a sample (e.g. ten) and count the number of tagged animals. If only one of them is tagged, it is reasonable to expect that the original five tagged animals represent 10% of the total population. So the total population is probably about 50 (Figure 1.14).

$$\text{abundance} = \frac{\text{number captured} \times \text{number recaptured}}{\text{number marked in recapture}}$$

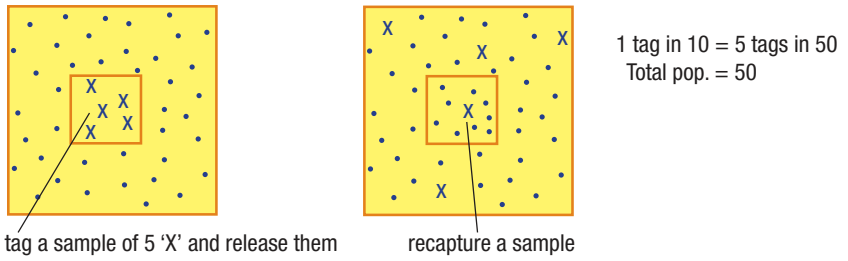


Figure 1.14 The capture–recapture method. Tagged animals are shown as 'X', and others as dots.

Capturing animals requires various trapping techniques. These include using specially designed traps and nets that catch animals alive and unhurt, digging small pits into which small animals will fall, and using spotlights at night and then catching the located animal with a net.

BIOFACT

Biologists cannot always catch the animals they are studying, so they use many other techniques for finding out what animals are present in an area. They include:

- scat analysis. Analysing animal droppings (scats) to find out what animal made them and (if it is a predator) what animals it had eaten
- tracks. Checking tracks in sandy or muddy areas to see what animals made them
- bones. Identifying animals from old bones (skulls are best, especially if they still have teeth)
- call recognition. Analysing animal calls to identify the species (especially birds, bats and frogs)
- photo traps. Setting up still or video cameras to record every animal that passes by
- hair-tube analysis. Setting special traps to catch samples of fur from animals that brush past; the fur can be analysed to find out the species it came from
- aerial surveillance. Patrolling an area with small aircraft to identify large animals or birds
- radio tracking. Fitting an animal with a radio transmitter which emits signals that can enable the animal to be located. Three radio-tracking techniques are commonly used: very high frequency (VHF), satellite, and global positioning system (GPS). This tracking gives real-time information. These systems are used worldwide to follow the movements of many migratory species such as birds, sharks and turtles.

INVESTIGATION 1.1

Sampling studies

Students will: process and analyse information obtained from a variety of sampling studies to justify the use of different sampling techniques to make population estimates when total counts cannot be performed.

Skills and outcomes

P2, P11, P12, P13, P14, P15, P16

Type of activity

First-hand investigation

Materials (per group)

- clipboard
- paper/record book and pencil
- measuring tape (at least 10 m long)
- rope or cord
- reference material to assist with identification of plant species
- quadrat (1 square metre is a suitable size)
- 150 mL beaker
- 500 mL beaker
- 20 white beads
- 300 black beads (approx.)

See First-hand investigations

Introduction

In field studies of ecosystems, it is usual to measure the distribution and abundance of different animal and plant populations. Simply counting all the organisms in a given population is usually not practical, so scientists have developed a variety of sampling methods to estimate the distribution and abundance of a species. The appropriate method should be selected carefully, depending on the type of species. Each method has advantages and disadvantages. Transects and random quadrats may be suitable for plants and very small animals. The capture–recapture method may be suitable for larger animals that move over considerable distances.

A model or simulation can be used to demonstrate how a method works in estimating the numbers in a population.

Purpose

1 To use transects and random quadrats to estimate the population abundance and distribution of a weed species on a lawn.

2 To use a model to demonstrate the capture–recapture method of estimating population size.

3 To analyse the advantages and disadvantages of these sampling techniques and justify the need to use different techniques.

A Transects

A transect is a cross-section through an area. It is used to record the type and number of species present. It is useful for recording the relationship between a species and the physical (abiotic) factors in the area.

Procedure

Investigation of the distribution of a weed species on a lawn

1 Select a suitable area of lawn that has populations of different weed species. Choose the weed that you want to investigate. Try to identify it by using available references.

2 Record the name of the weed in your workbook. Several groups should investigate the same species so that data can be compared. If you are unable to identify it, refer to it as Weed A.

3 Plan your transect. Before beginning this activity, the group will have to consider:
- any physical (abiotic) factors such as slope, drainage, amount of shade
- the length of the transect that will be suitable for this area of lawn

- the number of transects to be carried out
- the position of the transect(s) on the lawn.

4 Prepare a scale drawing of your transect line that will allow you to record the number of weeds that the transect passes under, over or through, every 50 cm.

5 Work along the line, counting and recording the numbers of weeds that the transect passes over, under or through, every 50 cm.

6 Record the result in your workbook or spreadsheet.

7 Repeat, according to the number of transects your group has decided to carry out.

8 Share your results with other groups investigating the same weed species.

Discussion

1 What kind of information can be obtained by using a transect to investigate a plant population?

2 Discuss the positioning of transects. Why is it better to collect data from more than one transect if possible?

3 What did the information obtained from your transect(s) suggest about the distribution of the weed species on this lawn?

4 Explain any changes in your knowledge of the distribution of this weed species after sharing information with other groups.

8 Random quadrats

A quadrat is a square, rectangular or circular frame of chosen size. It is used to mark out an area in which the vegetation is to be sampled. The shape and size of the quadrat depends on the type of vegetation. A square with 1 m sides would be suitable for sampling a lawn, while a square with 10 m sides could be used for sampling a forest. Quadrats may be located randomly over the area being sampled, or at regular intervals along a transect or grid.

Procedure

Investigation of the abundance of a weed species on a lawn

1 Work out a way to determine the total area of the lawn.

2 Record the area of the lawn in your workbook.

3 Discuss in your group the number of quadrats that you are going to use and whether they should be located randomly or along a grid.

4 Draw up a table in your workbook similar to Table 1.2 or create a spreadsheet. Allow enough rows for the number of quadrats you are going to sample.

5 Locate the first quadrat, using the method outlined by your group.

6 Count the number of weed plants in the quadrat. If a plant does not lie completely within the quadrat, only count it if more than half of the plant lies inside the frame.

Results

1 Record the count in Table 1.2 or your spreadsheet.

2 Calculate and record the average number of weeds per quadrat.

3 Calculate and record the average weed density; that is, the number of weeds per square metre.

4 Using your estimate of the area of the lawn, calculate and record your estimate of the total size of the weed population on the lawn.

TABLE 1.2

Quadrat no.	No. of weeds
1	
2	
etc.	
Total	

5 Combine your data with that of other groups investigating the same weed species and recalculate your average number of weeds per quadrat, average weed density and total weed population.

Discussion

1 What kind of information can be obtained by using quadrats to investigate a plant population?
2 Did the estimates of total population size calculated using your group's data differ from those calculated using the combined data? Suggest a reason for any difference.
3 Which of the two estimates of population size from the previous question should be more accurate? Explain the reason for your answer.
4 Suggest any animal populations that could be investigated by using transects or quadrats.

C Capture–recapture

It is generally much more difficult to estimate populations of animals than plants. Transects and random quadrats can only be used on animals that move very slowly or not at all. Animals can be scared off by the experimenter, or they might be nocturnal or hiding. One of the most commonly used methods for estimating animal populations is capture–recapture. This method involves tagging or marking a sample of the population and then releasing it. The proportion of marked animals in subsequent recaptured samples gives a reasonable estimate of the total population:

$$\text{abundance} = \frac{\text{number captured} \times \text{number recaptured}}{\text{number marked in recapture}}$$

For a worked example using this equation, see page 15 or enter values into the spreadsheet provided.

Procedure

Using a model to demonstrate the capture–recapture method of estimating population size

In this model, beads represent a population of animals. White beads represent individuals captured, tagged and released. Black beads represent other individuals in the population.

1 Fill a 150 mL beaker with black beads.
2 Tip these beads (uncounted) into the 500 mL beaker, and then mix in the 20 white beads (representing the tagged individuals). This is the total population.
3 Pick out 15 beads without looking, and note how many are white. Return them to the large beaker.
4 Repeat step 3 until you have 12 recordings.

Results

1 Draw up a table or spreadsheet to record the number of white beads in each of the 12 samples.
2 Total the results and calculate the average number of white beads per sample.
3 Use the calculation above to work out an estimate of the total population.
4 Check your estimate by counting the actual number of beads in the beaker.

Discussion

1 How close to the actual number was your estimate of the population?
2 Can you account for any discrepancy?
3 Would you ever expect this method to be 100% accurate? Give your reasons.
4 Would this be a suitable method to determine the number of trees in a forest?
5 Give examples of animal populations that could be estimated by this method.

Summary

1 Outline the purpose of each of the three sampling techniques investigated in this activity.
2 List the advantages and problems associated with using each technique.
3 Justify the need to use different techniques.

Photosynthesis and respiration

describe the roles of photosynthesis and respiration in ecosystems

Photosynthesis is the process by which plant cells capture energy from sunlight and use it to combine carbon dioxide and water to make sugars and oxygen (see Chapter 2, p. 101). All living things ultimately depend on this process. The compounds plants make during photosynthesis provide nutrients and energy to organisms that consume plants. Organisms that consume the plant-eaters gain nutrients and energy from them, so both energy and materials are passed from organism to organism.

Photosynthesis is the process by which plant cells capture energy from sunlight and use it to combine carbon dioxide and water to make sugars and oxygen.

Respiration is the process by which cells obtain energy. In this process, organic molecules, particularly sugars, are broken down to produce carbon dioxide and water, and energy is released.

Respiration is the process by which cells obtain energy.

When we look at these two processes, they appear to be almost the reverse of each other. However, this is not true: the sequence in one is *not* the reverse in the other. The processes themselves are related because energy from the Sun is incorporated into the products of photosynthesis, which are used by plants. When animals consume plants, they obtain nutrients that are used in respiration in their body cells, so that they too can obtain energy. This energy drives all the metabolic processes in an organism such as growth and repair, and ultimately also drives ecosystems.

In photosynthesis, plants capture light energy and transform it into chemical energy. This chemical energy, which is stored in complex organic compounds, is transferred from plants to animals via food chains. In the process of respiration, which releases energy for organisms to use, some of the chemical energy is transformed to heat energy and lost.

Energy is needed to sustain ecosystems. The ultimate source of all energy for life on Earth is the Sun. Plants use chlorophyll to capture some of the Sun's energy in photosynthesis. This energy then flows through ecosystems and keeps them functioning.

In an ecosystem there is no re-use of energy: it is either used by a living thing or lost as heat. Because of this, a continual input of energy is needed to keep living systems functioning.

identify uses of energy by living organisms

Uses of energy by organisms

Some of the energy from respiration is released as heat, which is useful because cells and enzymes function best at warm temperatures in endothermic animals (see *Heinemann Biology Third Edition HSC,* Chapter 1). The energy that is released is also used by organisms in a number of cellular processes including:

- *synthesis* of complex molecules such as proteins, lipids, carbohydrates and nucleic acids
- *growth* involving the division, elongation and differentiation of cells
- *repair* and maintenance of damaged or old cells
- *active transport* of materials across cell membranes
- *functioning* of special cells that need extra energy, such as nerves, muscles, liver and kidney cells in mammals
- *transport* of materials within organisms, such as in the phloem of plants (see Chapter 2, p. 131) and circulatory systems of animals (see pp. 138–139).

identify the general equation for aerobic cellular respiration and outline this as a summary of a chain of biochemical reactions

Aerobic cellular respiration

All living cells need energy all the time to stay alive. Energy-rich food materials, either made by a plant during photosynthesis or consumed by an animal, are used by cells in the process of aerobic respiration.

Aerobic means requiring the presence of oxygen.

Respiration involves a chain of biochemical reactions. It is a controlled process, occurring as a sequence of about 50 different reactions, each one **catalysed** by a different **enzyme**. Energy is released slowly in small amounts. The chemical energy held in the bonds of complex organic molecules, such as sugar, is released when the bonds are broken. The energy is transferred to the energy carrier molecule **ATP**.

An enzyme is a substance that alters the rate at which a reaction occurs, but is not used up in the reaction.

ATP is produced at several points along the way. The process begins in the **cytoplasm**, but most ATP comes from the steps that occur in a cellular organelle called a mitochondrion.

Glucose is a carbohydrate and contains carbon, hydrogen and oxygen. When glucose is broken down, carbon dioxide and water are formed. We can represent respiration by the following generalised equation:

$$\text{glucose + oxygen} \rightarrow \text{carbon dioxide + water + energy}$$

ATP is the energy store of the cell. When energy is available, another molecule, ADP, collects it and forms ATP. When energy is needed, ATP supplies it. In fact, respiration can be thought of as the process by which ATP molecules are made in a cell. For each molecule of glucose that is broken down to carbon dioxide and water, about 38 molecules of ATP are produced from 38 molecules of ADP.

$$\text{ADP + P + glucose + oxygen} \xrightarrow{\text{many reactions}} \text{carbon dioxide + water + ATP}$$

$$38\text{ADP} + 38\text{P} + C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + 38\text{ATP}$$

This general equation is a summary of a chain of biochemical reactions.

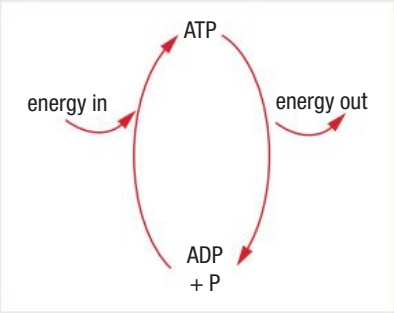
Energy in cells

The ATP (adenosine triphosphate) molecule consists of a base-sugar group (adenosine) linked to three phosphate groups:

A–P–P–P

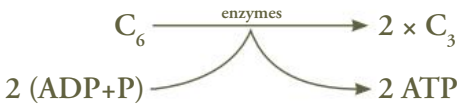
If either of the two end phosphate groups is removed, a large amount of energy is released from the bond. When one phosphate group detaches from ATP, ADP (adenosine diphosphate) forms and energy is released. The reaction is reversible; if enough energy is available, ADP and phosphate can combine to form ATP.

ATP is the form in which energy is carried in cells and made available when needed.



Stages of respiration

The process of respiration can be thought of as occurring in two stages. The first stage occurs in the cytoplasm of the cell and results in the splitting of the 6-carbon sugar molecule into two 3-carbon molecules. This process involves at least 12 steps. The 3-carbon molecules formed are called pyruvate, and two molecules of ATP are gained.



The second stage occurs in the mitochondria (see Chapter 2, p. 75). It involves the use of oxygen and results in the complete breakdown of pyruvate into carbon dioxide and water. A total of 36 molecules of ATP can form in this series of reactions. The energy is released gradually; it is 'packaged' as ATP and released at several points in the pathway.

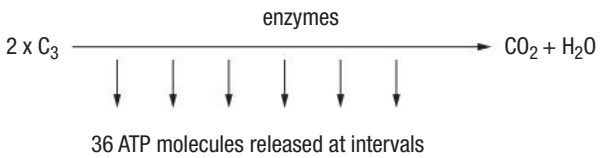


Figure 1.15 The second stage of respiration.

Overall 40% of the energy in glucose is converted to ATP. The rest is lost as heat.

BIOFACT

Aerobic respiration is also called 'oxidation' because it uses oxygen.

In oxidation, oxygen is added or hydrogen removed from a substance. If you burned sugar in the laboratory, oxygen from the air would be used up. The reaction would form carbon dioxide and water, and energy would be released as light and heat.

UNIT REVIEW 1.1

Terrestrial and aquatic environments

The distribution, diversity and numbers of plants and animals found in ecosystems are determined by biotic and abiotic factors.

Summary

- The distribution, diversity and abundance of organisms in an ecosystem are determined by both abiotic and biotic factors.
- Ecosystems are the systems formed by organisms interacting with each other and with their environment. These systems can be terrestrial (on land), aquatic (in water), or a combination of both.
- Abiotic factors are the non-living components of an ecosystem, such as availability of gases, rainfall and temperature. The abiotic factors of terrestrial environments are very different from those of aquatic environments. Biotic factors are the living organisms in an ecosystem, such as vegetation, mates, predators and prey.
- Methods used to investigate ecosystems include observing, measuring, collecting and making estimates of populations by using particular sampling techniques, such as transects and quadrats.
- Photosynthesis is the process by which plants capture the radiant energy from sunlight to produce simple organic compounds (sugars). Respiration is the process by which all living organisms obtain energy to use to perform all their activities.
- In respiration, energy is released from reactions involving sugars and oxygen, and water and carbon dioxide are produced. This general statement for aerobic respiration in cells is a summary of a sequence of many biochemical reactions.
- Energy is used by organisms in all their activities, including growth, general body metabolism and reproduction.

Questions

1 Which statement best defines the term 'environment'?

A All the surroundings, conditions and influences that affect an organism.

B All the ecosystems in the world.

C The layer containing living organisms that surrounds the Earth.

D The abiotic factors that interact with living organisms.

2 Which group below contains abiotic factors only?

A kangaroo, eucalyptus, possum, grass

B potatoes, soil, fertiliser, tractor

C rock, seawater, sand, oyster

D humidity, soil pH, light, wind

3 A small patch of native grassland of area 5000 m^2 contains a large number of the broad-leaved herb chamomile burr daisy (*Calotis anthemoides*) distributed randomly. Which of the following methods would be the simplest, most reliable method of estimating the abundance of these plants?

A Count all the herbs individually.

B Use one quadrat in an average-looking area of the grassland.

C Use a number of random quadrats.

D Take a line transect through the thickest patch of the herbs.

4 The following features are part of a granite hilltop ecosystem.
Identify which are biotic factors, and which are abiotic:

rain	snow-grass	snail	air	sunlight	earthworm
dragonfly	eucalypt	wind	temperature	frog	phosphorus
rock	wallaby	butterfly	soil	moss	shelter
altitude	predator	bacteria			

5 Compare the abiotic characteristics of aquatic and terrestrial environments by completing this table.

Abiotic characteristic	Aquatic environment	Terrestrial environment
Viscosity		
Buoyancy		
Temperature variation		
Pressure variation		
Availability of gases		

6 a Distinguish between the 'distribution' and the 'abundance' of a species.

b Identify some factors that affect the distribution and abundance of a named aquatic organism and a named terrestrial organism.

7 a Define what is meant by the 'resources' that an organism needs.

b Make a list of the general resources that must be available to the following organisms if they are to survive in their environments.

i a plant

ii an animal

8 a Define photosynthesis.

b Describe the role of photosynthesis in ecosystems.

9 a Describe the role of respiration in ecosystems and identify a general equation for this process.

b Identify the ways living organisms use the energy made available through cellular respiration.

10 a Explain how transects and quadrats can be used to estimate the distributions and abundances of organisms. Use diagrams in your answers.

b Animals cannot always be seen or captured during field studies. Describe other methods scientists can use to determine the presence and abundance of animals.

c Justify the use of different sampling techniques to make population estimates when total counts cannot be performed.

1.2 LOCAL ECOSYSTEMS: INTERACTIONS AND RESPONSES

Each local aquatic or terrestrial ecosystem is unique.

STUDENT LEARNING

In this unit students will:

- examine trends in population estimates for some plant and animal species within an ecosystem
- outline factors that affect numbers in predator and prey populations in the area studied
- identify examples of allelopathy, parasitism, mutualism and commensalism in an ecosystem, and the role of organisms in each type of relationship
- describe the role of decomposers in ecosystems
- explain trophic interactions between organisms in an ecosystem using food chains, food webs and pyramids of biomass and energy
- define the term 'adaptation' and discuss the problems associated with inferring characteristics of organisms as adaptations for living in a particular habitat
- identify some adaptations of living things to factors in their environment
- identify and describe in detail adaptations of a plant and an animal from the local ecosystem
- describe and explain the short-term and long-term consequences on the ecosystem of species competing for resources
- identify the impact of humans in the ecosystem studied.

STUDENT ACTIVITY

Students will:

- choose equipment and undertake a field study of a local ecosystem, identify data sources and gather, analyse and present data collected
- gather information from first-hand and secondary sources to construct food chains and webs to illustrate the relationships between member species in an ecosystem
- process and analyse information, and present a report of the investigation of an ecosystem in which the purpose is introduced, the methods described and the results shown graphically, and use available evidence to discuss their relevance.



Population trends

examine trends in population estimates for some plant and animal species within an ecosystem

Populations of organisms do not remain at a constant level within an ecosystem. Many factors may affect their numbers. When the same **species** is found in an ecosystem year after year in approximately the same numbers, scientists say the population is stable or in balance. In other words, the resources required by that species are sufficient to maintain steady population numbers within that ecosystem. Sometimes the numbers in a population increase dramatically; we refer to this as a **population explosion**.

When the number of organisms in a population increases dramatically in a short time, we say there has been a 'population explosion'.

Population numbers may also decline. Disease, predation, competition from other species, and human activities can all contribute to the decline and possible extinction of an organism in an ecosystem. The population of most Australian mammals has fallen dramatically over the past 200 years, and many populations have reached levels where their survival is endangered.

Even in stable populations, numbers are never constant. They show cyclical or periodic changes, usually related to the availability of food and water, predation levels and the species' own reproductive rates.

An individual species can show regular fluctuations in numbers, because of the changing availability of food throughout the year. Abiotic factors such as drought or unseasonably low temperatures may reduce plant growth levels. Sufficient water and warm temperatures may produce a surge in plant growth, making more food available for animals. Animals might move in and out of ecosystems according to the availability of food.

The reproductive cycle of organisms also causes numbers to rise and fall, usually in an annual cycle. An increase in the number of plants in an area is usually followed by a rise in the numbers of one or more animal species. Can you think why this might be?

In your field studies on distribution and abundance of organisms in your local ecosystem, it is important to look for trends in population numbers and to try to explain them.

Exploding jellyfish!

Population explosions of jellyfish occur seasonally worldwide when environmental conditions are favourable. In recent years, there has been an increase in jellyfish 'blooms'. This has been attributed to the global warming of the oceans, which has caused food supplies of zooplankton to increase, combined with over-fishing by humans, which has removed both jellyfish predators and competitors.

In recent years, warming waters have caused population explosions of the giant jellyfish, *Nemopilema nomurai*, in the Sea of Japan. More usually found in waters off China and Korea, these large jellyfish can reach 2 metres in diameter and 200 kg in weight. They cause considerable damage to boats and fishing nets.



Figure 1.16 *Catostylus mosaicus* (jelly blubber or blue blubber jellyfish) are the most commonly found jellyfish along the east coast of Australia. The colour varies depending on the type of symbiotic algae living in their tissues. In 2004, a population explosion occurred in Brisbane Harbour. A cruise ship was prevented from leaving when jellyfish were sucked into the ship's water intake.



In Europe in 2007, populations of the mauve stinger jellyfish, *Pelagia noctiluca*, exploded in the Mediterranean Sea. Many drifted northwards along the coastline of the United Kingdom. Millions in a swarm 26 km wide and 10 metres deep drifted into a salmon farm in the Irish Sea and killed over 100 000 fish.

It has been suggested that the future may hold oceans full of jellyfish rather than fish. Jellyfish are already harvested commercially, including in Australia. They can be turned into fertiliser, used in the cosmetics industry and even eaten.

Figure 1.17 *Phyllorhiza punctata* (the Australian spotted or white-spotted jellyfish) is common in the oceans around Australia, but populations are also found elsewhere. They often form immense swarms. In 2000, a population explosion in the Gulf of Mexico was triggered by favourable environmental conditions and a lack of natural predators.

The decline of a wombat



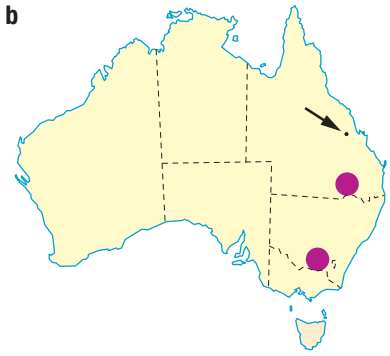


Figure 1.18 (a) The northern hairy-nosed wombat, *Lasiorhinus kreftii*, and (b) its past (pink areas) and present distribution (arrow).

The northern hairy-nosed wombat, *Lasiorhinus kreftii*, is a heavily built **marsupial** weighing about 35 kg (Figure 1.18a). It has a distinctive nose covered with short brown hair. It has soft fur, mainly brown but mottled with grey, fawn and black. It has black patches around its eyes, and its ears are slightly long and pointed, with white fur on the edges. Females have a backward-facing pouch.

Its short, strong legs and claws are used to dig burrows or to help it collect plants, including the native grasses that form much of its diet.

The northern hairy-nosed wombat is active at night. Although it tends to live by itself, it often shares burrows with other wombats. The female gives birth to a single young during the wet season (November–April). The young wombat stays in the mother's pouch for up to 9 months, finally becoming independent at about 12 months.

Fossil records show that the northern hairy-nosed wombat once inhabited a wide area. But since the 1800s it has been found in only three areas: near Deniliquin, in south-central New South Wales; Moonie River near St George, south Queensland; and Epping Forest, near Clermont in central Queensland. Today, the species' conservation status is critically endangered. It is known to occur only in the Epping Forest National Park.

Causes

What caused this species to become endangered? The main reason is the loss of its natural habitat caused by farming. Competition with rabbits, sheep and cattle for food, and the effects of long droughts, have led to a decline in numbers of the wombat. The small populations that remain are susceptible to disease, fire and inbreeding, and also to predators such as dingoes and foxes. Dingoes caused the death of an estimated 10% of the population in 2000–2001. The population is unbalanced in terms of gender, there being only an estimated 35 females in the current population of 113.

Solutions

In 1971, the Epping Forest National Park was established to protect the habitat of the northern hairy-nosed wombat. The park was fenced to keep out sheep and cattle. In 1982, cattle were removed from the park, and by 1989 wombat numbers had increased from 35 to about 70. In 2002, a new dingo-proof fence was erected. The recovery plan includes programs to control introduced grasses, and to improve the supply of native grasses, which provide more nutrition for the wombats. Access to the park is restricted to park management staff and researchers, who are examining the population and feeding ecology of the wombats. In particular, they are monitoring the size and distribution of the population, the wombats' diet, body condition and activity pattern. The researchers are determining the extent of genetic variation within the population, and the amount of inbreeding that is occurring. They are also monitoring the effects of predators and competitors. A captive breeding program is now being undertaken to try to rescue the northern hairy-nosed wombat from the edge of extinction.



Figure 1.19 Populations of the Tasmanian Devil (*Sarcophilus harrisii*) have been in decline since the 1990s due to the Devil Facial Tumour disease. In 2008 the status of the Tasmanian devil was upgraded from vulnerable to endangered.

Interactions between organisms

outline factors that affect numbers in predator and prey populations in the area studied

Organisms that live in the same ecosystem can either increase or decrease each other's chances of survival. These interactions can be between members of the same species or members of different species.

Predation

This is a feeding relationship in which one animal, the **predator**, obtains its food by killing another animal, its **prey** (Figure 1.20). This relationship increases the predator's chance of survival and reproduction at the expense of the prey's. Predator–prey relationships may be one reason to account for fluctuating population numbers in an ecosystem. Rises and falls in predator numbers usually follow rises and falls in prey numbers.

The numbers of predators and prey in an ecosystem depend on a number of factors.

- The size of any given ecosystem will determine how many organisms it can support.
- There are usually fewer predators than prey.
- The availability of the prey's food will largely determine the number of prey at any given time. This can depend on factors such as the time of year and the weather.
- The reproductive cycles of both prey and predator affect their numbers. Large numbers of young prey may be followed by an increase in predator numbers. The prey are eaten, their numbers decline, and numbers of predators then also decrease.
- There is often competition between predators for the same prey. For example, cormorants and gannets compete with large fish for the smaller fish they all prey on.



Figure 1.20 The laughing kookaburra (*Dacelo gigas*) is a common predator in forests and woodlands. It sits on a low branch until it spots its prey, which might be a small snake, lizard, rodent or worm, then swoops quickly to the ground and seizes the prey in its powerful beak.

Predation is a feeding relationship in which one animal, the predator, obtains its food by killing another animal, its prey.

identify examples of allelopathy, parasitism, mutualism and commensalism in an ecosystem, and the role of organisms in each type of relationship

Allelopathy—the production of allelochemicals by plants which affect other plants—is another factor affecting the distribution and abundance of plants in ecosystems.



Figure 1.21 *Callistemon citrinus* secretes chemicals from its roots that prevent other plants germinating nearby.

Symbiosis is a type of interaction between organisms where two different species live together in a close association.

- Diseases can affect both predators and prey. If prey is affected, then the food supply for predators will be less and they will also decline in number. If predators are affected, then the numbers of prey will increase.
- Seasonal migrations of predators or prey will affect populations. When prey is abundant, some predators might move into an ecosystem to take advantage of the abundance.

Allelopathy

Allelopathy is the production by a plant of specific chemicals (allelochemicals) that can be detrimental or beneficial to other organisms. These chemicals are released into the environment where they can influence the growth and development of neighbouring plants by repelling predators and parasites, or poisoning competitors. The chemicals can be released from any part of the plant. For example, many types of eucalypts produce chemicals from their roots or in their leaf litter that prevent the growth of some soil microorganisms and other plants. In the case of the blackbutt (*Eucalyptus pilularis*), the chemicals inhibit the germination of its own seeds close to the parent plant. Chemicals from the leaf litter of the horsetail she-oak (*Casuarina equisetifolia*) and from the roots of the lemon bottlebrush (*Callistemon citrinus*) also prevent the germination of other plants nearby. Similarly, very few plants grow near where the gidgee or stinking wattle (*Acacia cambagei*) grows in north-west Queensland and central Australia.

The visible effects of allelochemicals on nearby plants include prevention of seed germination, deformed roots (including the death of root tips and lack of root hairs), slow growth and poor reproduction. In these examples, the allelochemicals are acting as natural herbicides.

When the allelochemicals of a plant benefit another type of plant, this can lead to enhanced survival and growth for both species. In farming and horticulture, this is known as 'companion planting'. The chemicals secreted by companion plants may act as pest repellents, weed suppressors, soil enrichers and insect attractants. Examples include many strong-smelling or aromatic plants such as lavender, sage, mint, garlic and onions. Growing garlic with rose bushes, for example, is a gardener's traditional method of keeping aphid pests away from the roses.

Parasitism

A **parasite** obtains its food from a host. Although the host is harmed in some way, it does not necessarily die. Most free-living organisms have parasites. Many bacteria, **viruses** and fungi which cause diseases are parasites. Other examples of parasitic relationships involve ticks, fleas and tapeworms (Figure 1.22). The host also provides a safe place to live for the parasite. The parasite benefits and may increase its own chance of survival and reproduction at the expense of its host.

Commensalism and mutualism

Symbiosis is a type of interaction between organisms where two different species live together in a close association. The association benefits at least one of them, and the other may or may not be disadvantaged. The two common types of symbiosis are commensalism and mutualism.

Commensalism describes a relationship that benefits one species and does not harm the other. The organisms are not dependent on this type of relationship: they could survive without each other (Figure 1.24).

Mutualism occurs when two organisms are more closely associated so that both benefit. For example, lichens are an association between an alga and a fungus (Figure 1.23). The cells of the alga are found among the hyphae of the fungus. The alga provides food and oxygen by photosynthesis and the fungus provides a moist environment for the alga. Together they can survive in environments where at least one, if not both, could not survive on their own.



Figure 1.23 An example of mutualism. A lichen consists of an alga and a fungus growing together as a single organism. Both the alga and the fungus benefit from this arrangement.

A mutualistic relationship exists between emus and the nitre bush. Emus live almost exclusively on the fruit of this bush when it is available in late summer. This benefits the nitre bush because digestion of the seed coat increases its rate of germination—only 6% of seeds falling from the bush germinate, compared to 62% of seeds passed out by emus.

In some cases, the relationship is so strong that survival of one member is impossible without the other. For example, termites chew and swallow wood but cannot digest the cellulose. Protozoans living in their gut do this for them. The termite is provided with food, and the protozoans obtain food and a safe place to live (Figure 1.25).



Figure 1.25 The gut of the termite (a) contains microscopic protozoans (b) that digest the cellulose that the termite eats.



Figure 1.22 The tapeworm is an example of a parasite. The tapeworm gains nutrients and a safe habitat within its host, while its host is usually seriously ill and receives no benefits at all.



Figure 1.24 An example of commensalism. The ferns growing on the tree trunk are epiphytes. They are supported by the tree but do not obtain food from it, and they do not affect the health of the tree.

Living in groups

Organisms of the same type are often found in groups (Figure 1.26). Some plants may form large groups, or even **dominant** communities, in ecosystems. This increases the chances of pollination, and may reduce the risk of damage to individual plants. For animals, living in groups may improve an individual's chances of finding a mate, avoiding predators and getting enough to eat.

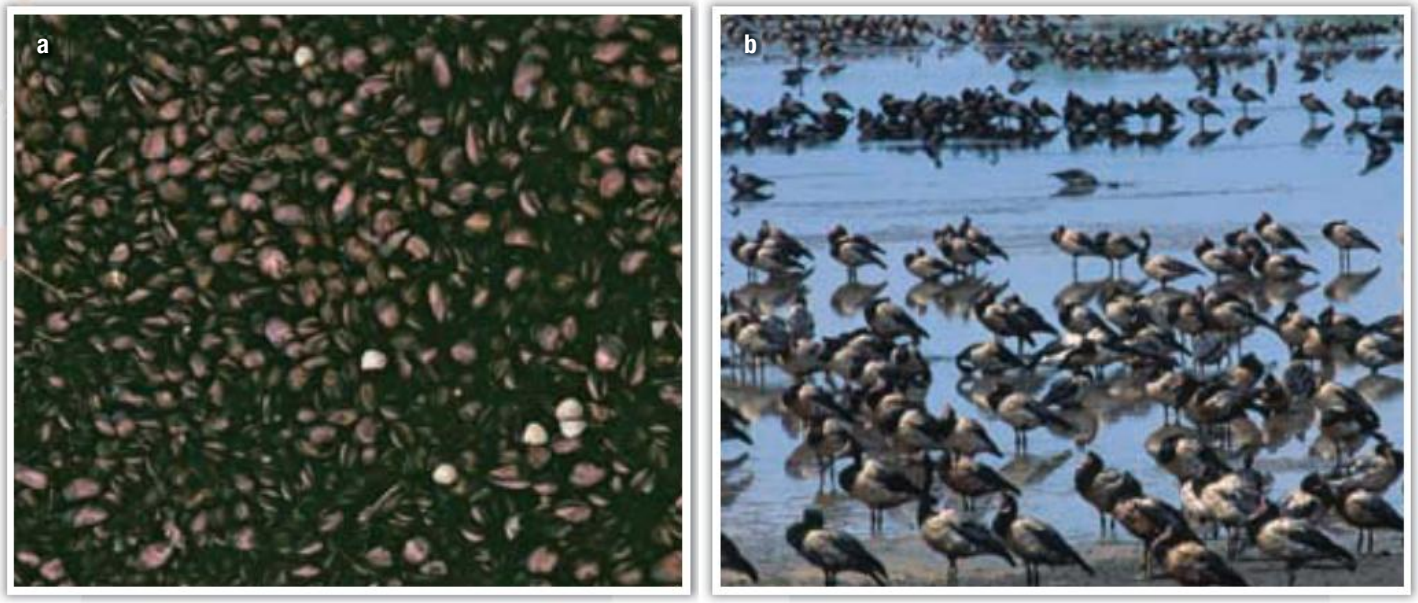


Figure 1.26 Two examples of animals that form groups: (a) beaked mussels (*Brachidontes rostratus*), and (b) magpie geese (*Anseranas semipalmata*).

describe the role of decomposers in ecosystems

The role of decomposers

Decomposers have an important role to play in ecosystems—they absorb nutrients from dead organisms or waste materials and return organic matter to the soil.

Detritus is dead organic matter derived from plants, animals or other organisms. This material is eaten by detritivores such as snails, worms, termites, millipedes and mites, and by decomposers—bacteria and fungi. Detritivores play a critical role in breaking down organic matter into smaller particles that are finally consumed by decomposers. Bacteria and fungi secrete digestive enzymes that break down detritus into soluble organic molecules such as sugars, and eventually into inorganic molecules such as carbon dioxide and nitrogen.

Many food chains and webs involving decomposers exist in forests, woodlands and other terrestrial ecosystems where dead plant matter accumulates, and also in freshwater and saltwater aquatic ecosystems.

explain trophic interactions between organisms in an ecosystem using food chains, food webs and pyramids of biomass and energy

Trophic interactions

Trophic interactions are feeding relationships between organisms. 'Trophic' comes from the Greek word *trophikos*, meaning 'relating to food'.

Autotrophs (self-feeders), for example plants, make their own food. **Heterotrophs** (other-feeders), for example animals, obtain their own food from other living things.

Trophic interactions are feeding relationships between organisms.

Food chains

A **food chain** represents the flow of energy from one living thing to the next.

green plant → plant eater → animal eater

Food chains in the ocean are usually longer than terrestrial ones. For example:

phytoplankton → zooplankton → small fish → bigger fish → even bigger fish → shark

'Plankton' means all the floating microorganisms in the water. These may be either plants (phytoplankton) or animals (zooplankton).

Food chains begin with producers, which are usually plants or algae. Plant eaters are **herbivores**. Animal eaters are **carnivores**. Animals that eat both plants and animals are **omnivores**. Herbivores, carnivores and omnivores are all consumers. The first consumer in a food chain (a herbivore) is called a primary consumer; it is eaten by the secondary consumer, which in turn may be eaten by a tertiary consumer, and so on.

Scavengers are consumers that eat dead animals. **Decomposers** are organisms such as fungi and bacteria that cause decay. Decomposers have an important role to play—they make the materials produced by decomposition available to plants. It is then recycled into the food chains.

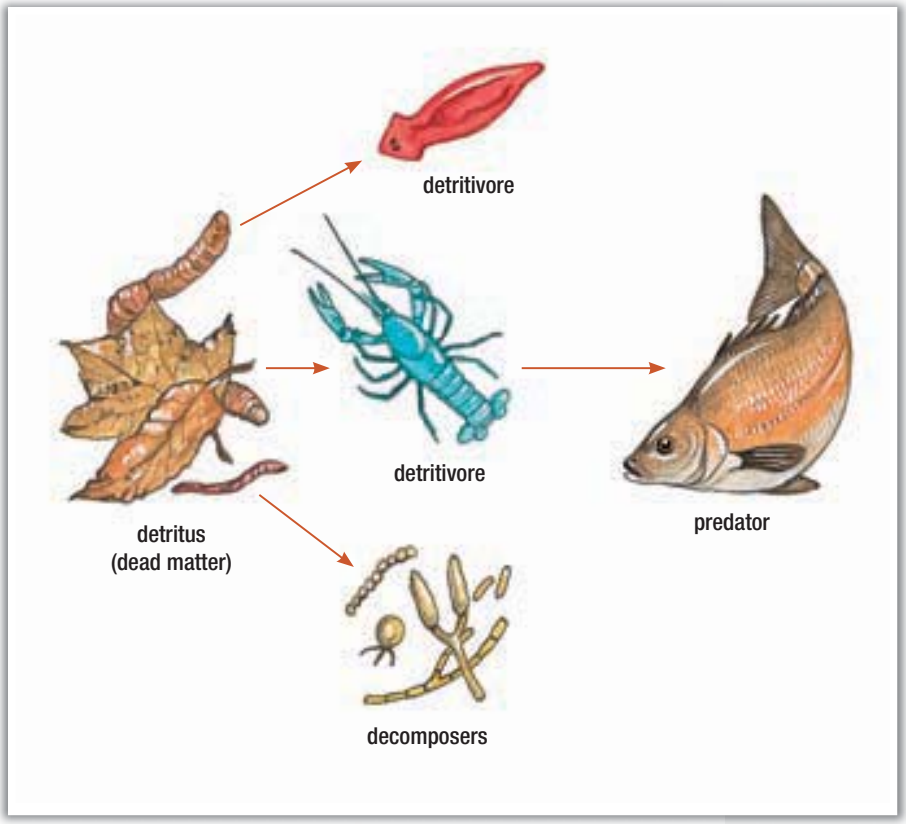


Figure 1.27 Detritivore and decomposer food chains in the pond start with dead organic matter.

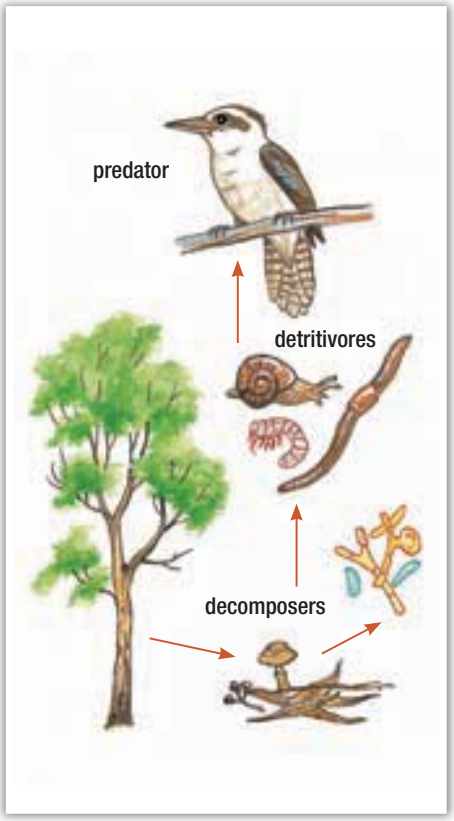


Figure 1.28 Detritivore and decomposer food chains are very important in terrestrial ecosystems such as forests, where plant litter accumulates on the ground.

Food webs

In most ecosystems there is more than one primary consumer, and animals often eat more than one thing. To show the complex feeding interactions in an ecosystem, we use a **food web**.

The role of an organism in a series of relationships is its **niche**. For example, in Figure 1.29 the fish occupies a carnivore niche.

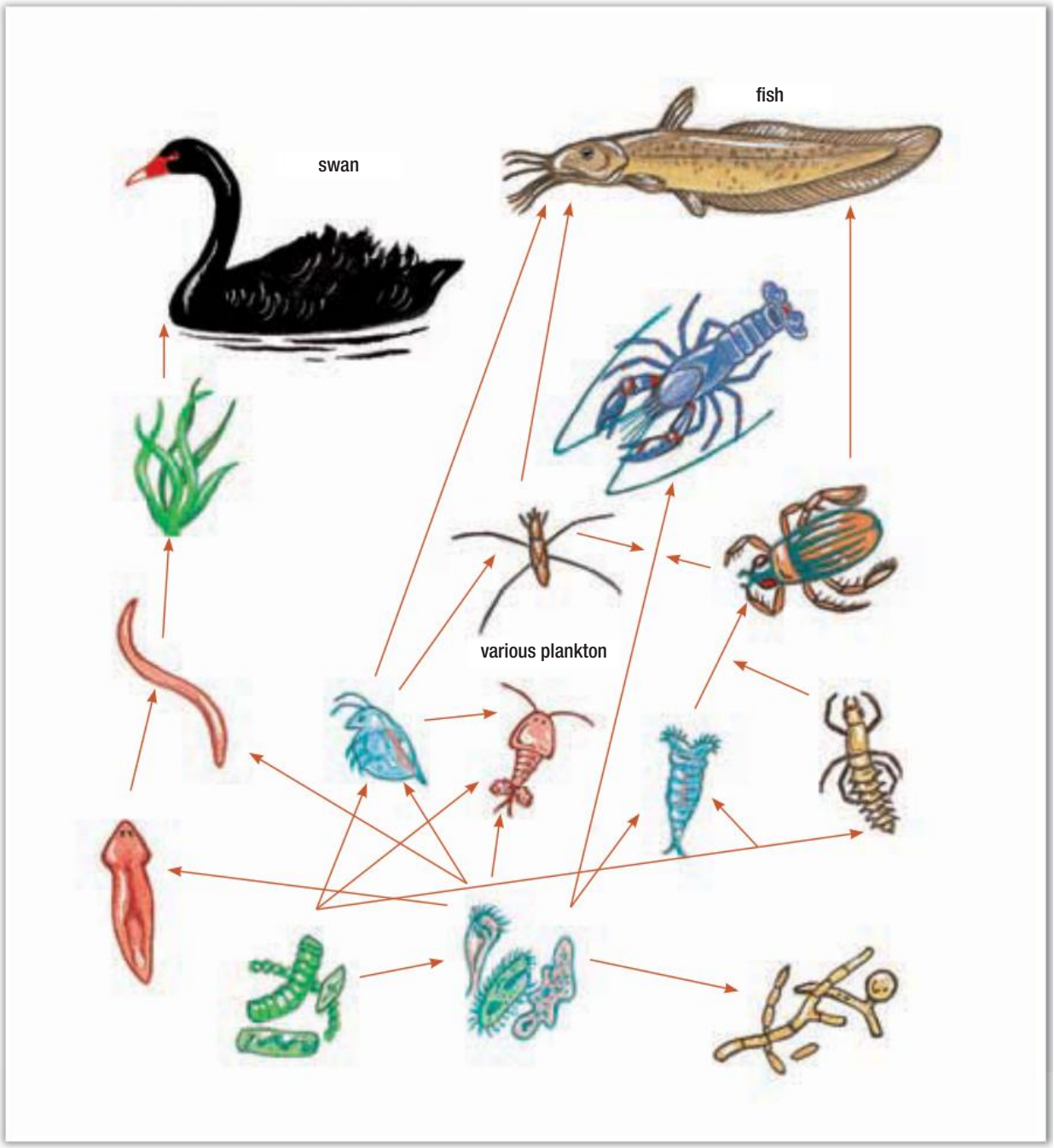


Figure 1.29 A food web in a pond ecosystem.

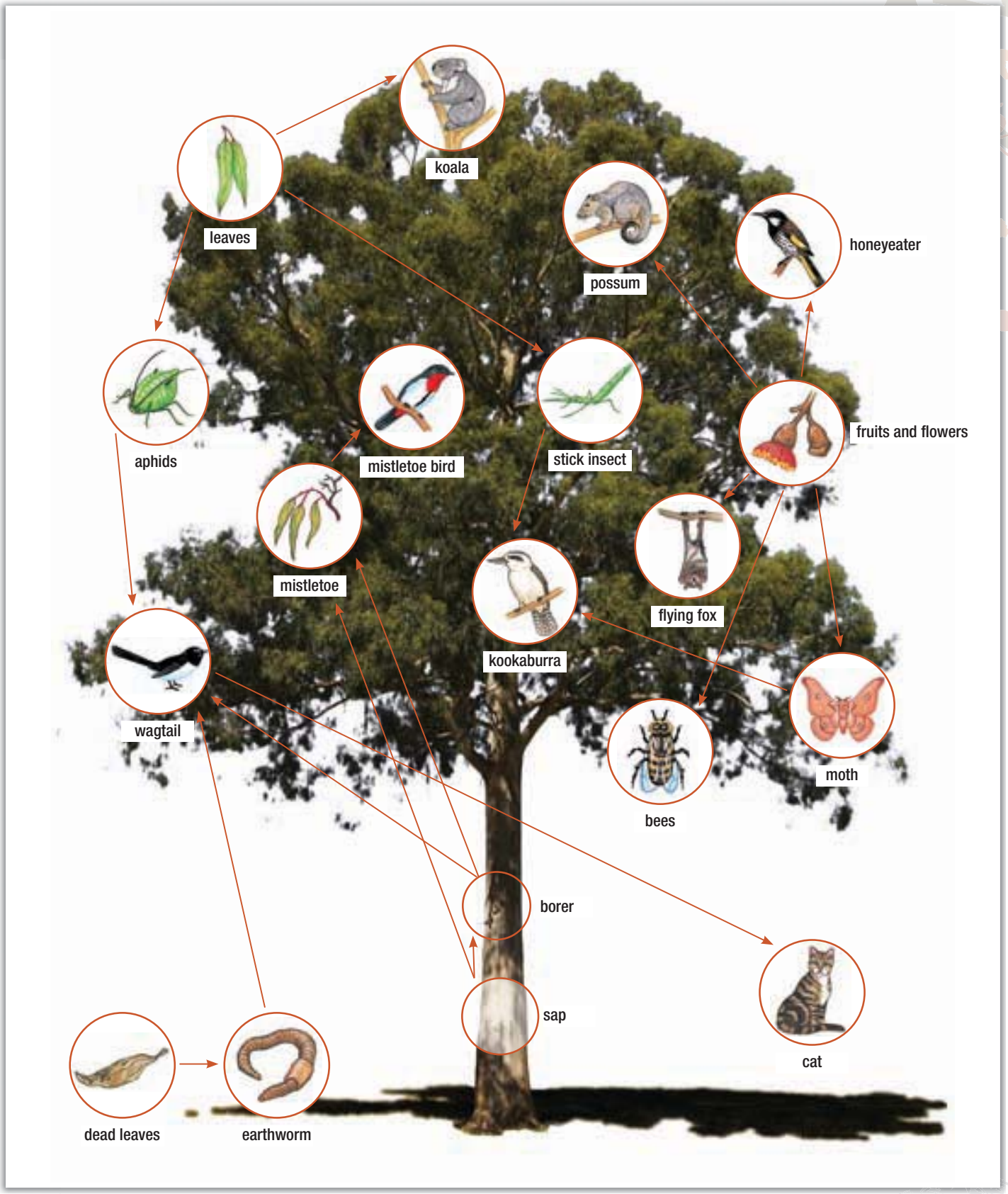


Figure 1.30 A food web in a forest ecosystem.

Biomass is the amount of living material in an organism or group of organisms at any one time.

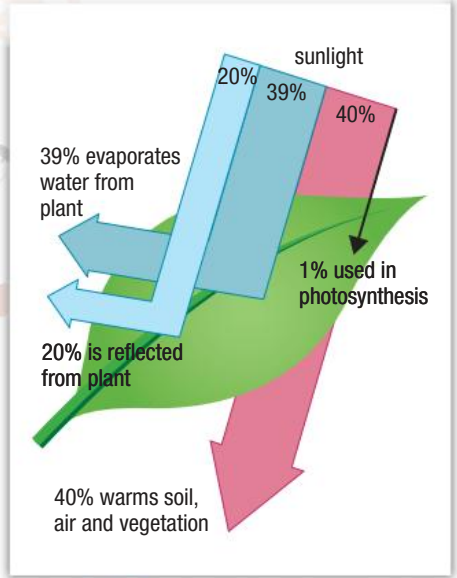


Figure 1.31 Absorption of energy from sunlight by the leaf of a photosynthetic plant. Only 1% of the available energy is used for photosynthesis. The rest is reflected from the leaf or passes through it.

BIOFACT

Humans make up about 0.000 000 000 005% of the mass of the Earth—about 3×10^{11} kg out of 5.976×10^{24} kg.

Biomass and energy pyramids

Producer organisms trap energy from sunlight and use it to make simple organic compounds in the process of photosynthesis. These compounds are then used to build the more complex compounds that make up plant tissues. Less than 1% of the Sun's energy that reaches the Earth's surface is used for photosynthesis (Figure 1.31).

Biomass is the amount of living material in an organism or group of organisms at any one time. The amount of mass of living plant material produced by photosynthesis in an ecosystem is the plant biomass. Because they are producers, plants have the greatest biomass of all organisms in terrestrial ecosystems. It has been estimated that only about 10% of the available plant biomass is consumed by animals. Of this, most is lost (Figure 1.32), so the herbivore biomass is much less than the plant biomass.

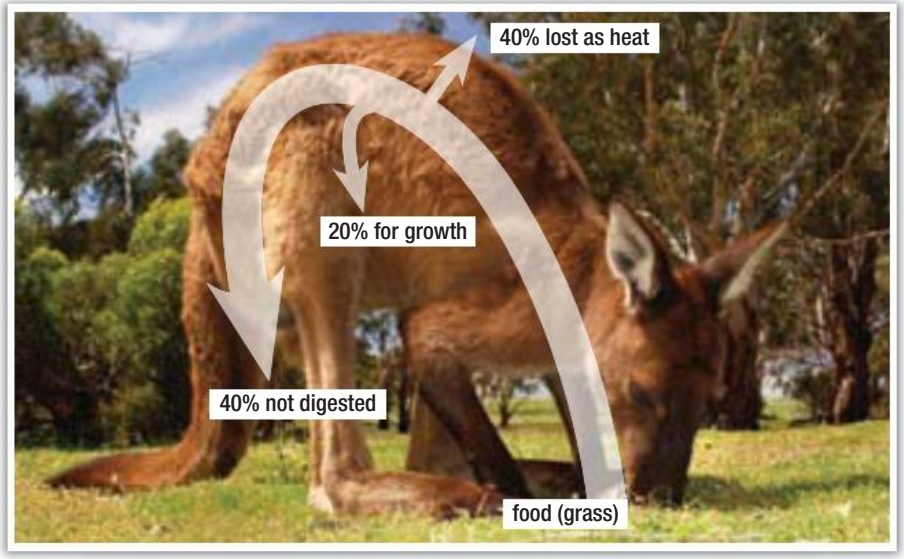


Figure 1.32 A kangaroo obtains energy from the plants that it eats, but only about 20% of the food it eats is converted into animal tissue. About 40% is used by the kangaroo in respiration to provide energy for its activities, and this energy is eventually lost as heat. The remaining 40% is lost in faeces and urine.

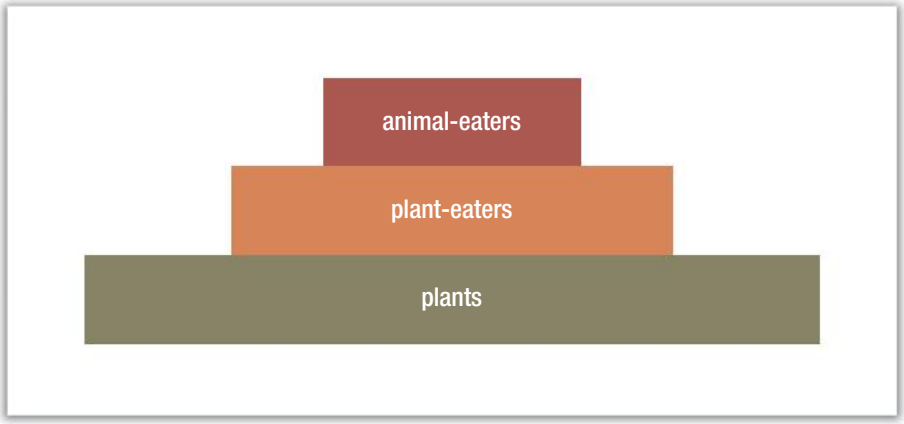


Figure 1.33 A simple biomass pyramid. A biomass pyramid shows the amount of matter (biomass) in the organisms at each trophic level.

Similarly, carnivores have less biomass as a group than herbivores. The biomass therefore decreases along the food chain. Herbivores have a greater biomass than carnivores, and the top consumer usually has the lowest biomass (Figure 1.33).

At each step in a food chain, energy is also lost. The amount of energy at each trophic level can be shown by an energy pyramid. Energy pyramids look very similar to **biomass pyramids** because the energy is transferred in food that makes up the biomass. Energy pyramids indicate that the further along a food chain an organism is, the less energy is available to it (Figure 1.34).

Both energy and matter are lost at different feeding or trophic levels—energy is mostly lost as heat, and matter is lost as undigested food and wastes. As much as 90% of energy and matter is lost at each level along a food chain.

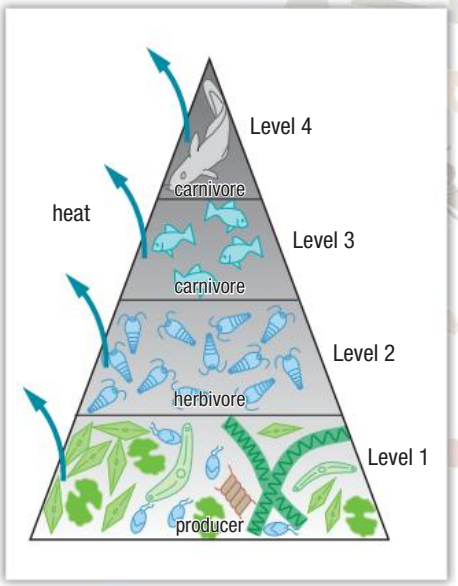


Figure 1.34 A pyramid showing the decline in biomass and energy along a food chain, from producer to herbivore to top carnivore. In general about 10% of the energy at one level appears in the next.

Adaptations

An **adaptation** is a feature of an organism that makes it suited to its environment and helps it survive and reproduce. Adaptations can be:

- *structural*—physical characteristics relating to the structure of an organism's body
- *physiological*—related to the way an organism functions
- *behavioural*—how an organism responds to its environment.

Adaptations help an organism to survive and reproduce in an ecosystem.

When looking at an organism, it is helpful to know as much as possible about where it lives and the conditions of its environment. What is the availability of water? What are the daily and seasonal temperatures like? What sort of predators does it have? If it's an animal, what does it eat and how does it move about? Knowing this information can help to relate any features the organism shows to conditions in its environment. Without it, trying to explain any of an organism's features is just guesswork. It is hard to infer that a characteristic is an adaptation without knowing about its environment.

Adaptations are inherited characteristics. They are the result of **natural selection**. When looking for adaptations in organisms, make sure that the characteristics are in fact inheritable, and not the result of a particular individual's life history (see Chapter 4, p. 238).

define the term 'adaptation' and discuss the problem associated with inferring characteristics of organisms as adaptations for living in a particular habitat

An adaptation is a feature of an organism that makes it suited to its environment and helps it to survive and reproduce

Adaptations are inherited characteristics. They are the result of natural selection.

Adaptations: case studies

When looking at organisms in your local environment, you will try to identify features which can be interpreted as adaptations. The two examples below may help you in your understanding of how organisms are suited to their environments.

identify some adaptations of living things to factors in their environment

identify and describe in detail adaptations of a plant and an animal from the local ecosystem

CASE STUDY 1. Mangroves

Mangroves form woody plant communities in warm, shallow tidal water over more than half of the Australian coastline. Twenty-nine species occur along the tropical north coast of Australia, but the number of species decreases further south. Around Sydney, only two species are found: the grey mangrove (*Avicennia marina*) and the river mangrove (*Aegiceras corniculatum*). In South Australia and southern Victoria only the grey mangrove is found. There are none in Tasmania.

Mangroves are found on sheltered muddy shores and along estuaries. Depending on the conditions and the species, they range from 2-metre-high shrubs to 30-metre-high trees.

Support and movement

Mangroves are upright woody plants. They are anchored by complex root systems in the shifting environment of tidal mud flats. They have vertical anchor roots to which are attached spreading cable roots. Together, these form a dense mass that helps stabilise the mud. Some mangroves support themselves on 'stilt' roots that lift the plant out of the salty water (Figure 1.35a).

Gaseous exchange

There is a lack of oxygen in the water-logged soil, which is exposed at low tide but covered with water at high tide. Mangroves of the genus *Avicennia* have aerial roots or pneumatophores which push upwards through the mud and salt water. Their tips have pores or lenticels through which gaseous exchange can occur (Figure 1.35b).





Figure 1.35 Two adaptations of mangroves: (a) stilt roots and (b) pneumatophores.

Control of water balance

Mangroves are **halophytes** (salt-tolerant plants). The water available to them is sea water with a high ion concentration. Mangroves control the salt level in three ways:

- *accumulation/storage*—in some mangroves, salt accumulates in selected parts of the plant, for example in some leaves, until it reaches a certain concentration. That part of the plant is then shed.
- *excretion*—some mangroves have salt glands on the upper surface of their leaves, which actively excrete salt.
- *exclusion*—the membranes in the root system of some mangroves filter the sea water, allowing water to pass into the plant, but excluding most of the salt.

Control of internal temperature

Mangrove leaves have thick cuticles and are hard and leathery. These features help to control water loss and prevent wilting in hot weather.

In dense mangrove swamps, the thick canopy of leaves helps maintain a lower temperature in the lower layers.

Obtaining light

Mangroves are the dominant plant in their community. The shape of the plant and arrangement of leaves ensure that abundant light is available for photosynthesis.

The leaves are dark green because they are rich in chlorophyll. The leaves high on the plant are angled and those lower down are horizontal in order to best capture sunlight.

Reproduction

Mangroves have flowers and, following pollination and fertilisation, fruits containing one seed develop. These seeds begin germination before they drop from the parent plant (Figure 1.36). The seeds are buoyant and dispersed by the tide. Their initial development, particularly of the root system, ensures that the new plant can rapidly anchor itself and grow quickly once it is deposited in the mud.

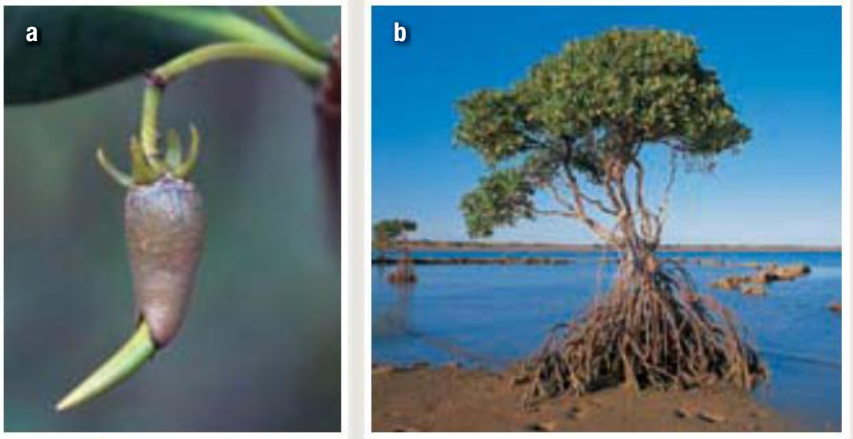


Figure 1.36 In some mangroves the seeds germinate while still attached to the plant. When fully formed these propagules drop from the plant and spear into the mud, where they begin to grow. (a) *Ceriops*, (b) *Bruguiera*.

BIOFACT

22% of Australia's coastline is fringed with mangroves. There continues to be a loss of mangrove ecosystems due to land reclamation and pollution.

CASE STUDY 2. Kangaroos

Members of the genus *Macropus* are all physically very similar. Larger specimens (over 20 kg) are called kangaroos, and smaller species are known as wallabies and wallaroos. Species inhabiting steep, hilly areas rather than flat plains are usually called wallaroos. Few species are solitary—most congregate in groups or mobs.

Kangaroos are widespread across Australia. They are all grazing herbivores that feed on grasses and herbs.

The red kangaroo inhabits inland plains. The western and eastern grey kangaroos are found in grasslands, eucalypt woodlands and open forests from Tasmania to central Queensland and across to Western Australia. The antelopine wallaroo is found in the tropical north of Australia from



Figure 1.37 The long tail of kangaroos and their relatives is an adaptation that helps the animals to balance when hopping.

Queensland across to Western Australia. The euro, or common wallaroo, is found in central and southern Australia.

Support and movement

Kangaroos have an internal bony skeleton. Their well-muscled hind legs are far larger than their forelegs (Figure 1.37). Only the hind legs are used when the animal is travelling at high speed. This method of bounding along is more efficient in terms of energy use than when animals run on all four legs.

When moving slowly, kangaroos 'hop'. Their weight is pressed down on their forelimbs and tail, and their large hind legs are swung forwards.

The long tail of the kangaroo is a useful structure. It is used as a balancing counterweight when bounding, as an extra limb when hopping, and to help the kangaroo to remain upright when standing still.

Gaseous exchange

Kangaroos have lungs as internal respiratory surfaces.

Control of water balance

Kangaroos in arid areas, such as the red kangaroo and euro, can survive for long periods without drinking water, provided there is sufficient green plant material available. Kangaroos reduce water loss by sweating only during exercise. When they stop moving, sweating stops.

Control of body temperature

Kangaroos that live in hot, dry regions seek the shade of rock crevices and caves during the hottest part of the day. Kangaroos in other areas will bask in the sunshine, but when conditions are hot they seek the shade of trees and bushes.

When the weather is hot, euros may lick their forelimbs where the blood vessels run close to the surface and heat is lost from the body. It is thought that the evaporation of the saliva has a cooling effect.

Obtaining light

Kangaroos have binocular vision. They are mainly nocturnal animals, but can also be active in early morning and early evening.

Reproduction

Kangaroos are marsupial mammals. They have internal fertilisation and a very short gestation period in the uterus. At birth, the young climb into the mother's forward-opening pouch. They attach to a teat and continue development while suckling (Figure 1.38). When they leave the pouch, there is a weaning period before parental care ends.

Young red kangaroo are born after 33 days in the uterus and weigh less than a gram. They remain suckling in the pouch for 235 days. They leave the pouch weighing 4–5 kg and have a weaning period of up to 4 months, during which they suckle and eat grass.

Kangaroo population numbers are controlled through reproduction.

BIOFACT

The crew of the *Endeavour* were the first Europeans to encounter kangaroos. In June 1770, Lieutenant James Cook wrote in his ship's log: 'I saw myself this morning... one of these Animals... it was of a light Mouse colour and the full size of a grey hound and shaped in every respect like one, with a long tail which it carried like a grey hound... it jumped like a Hare or a deer.'

Under good environmental conditions, numbers can increase rapidly, because adult female kangaroos can be almost continuously pregnant. They mate again directly after giving birth. If the mother is still suckling her newborn young, the fertilised egg does not develop until the young leaves the pouch. This is known as delayed implantation. At any one time, a female kangaroo may have a joey (young kangaroo) being weaned, a young one being suckled in the pouch and an **embryo** in the uterus awaiting development.

Kangaroos have the amazing ability to produce two kinds of milk at the same time. The milk produced by the teat for the developing young in the pouch contains much less fat than the milk produced by the teat being used by the joey outside the pouch.

When environmental conditions are not good, such as in times of drought, young joeys do not survive and any fertilised egg does not implant. Females do not begin reproducing again until conditions improve.



Figure 1.38 A newborn kangaroo suckling in the mother's pouch.

BIOFACT

There are 48 species of kangaroo. The four species that are killed commercially for their meat—the red kangaroo, the western and eastern grey kangaroos and the euro—are abundant and widespread, although their numbers can fluctuate from season to season. Other kangaroos, such as some species of tree kangaroo and the tropical antilopine wallaroos, are threatened and in need of protection.

Competitive interactions

describe and explain the short-term and long-term consequences on the ecosystem of species competing for resources

Competition in ecosystems is the struggle between organisms for the same resource. A particular ecosystem can support only a certain number of each type of species. Competition may be between members of the same species, or between members of different species. In the short term, competition reduces the chance of survival and restricts the abundance of all the competitors. In the long term, one of the competitors will usually be more successful and drive out or significantly reduce the numbers of other competitors.

Competition is the struggle between organisms for the same resource.

Each year, most organisms produce many more offspring than can survive. While some young will be consumed as food by other organisms, many die in the competition for limited resources.

A eucalyptus tree may produce thousands of gum nuts each year but only a few of the germinating seedlings will survive in the competition for light, nutrients and space.

Different species of intertidal molluscs often occur together, eating the algae that grow on the rocks. Two such molluscs are the black nerite, *Nerita melanostragus*, and the variegated limpet, *Cellana tramoserica* (Figure 1.39). If algae are in short supply, the faster-moving nerites remove most of the algae and the limpet may starve.

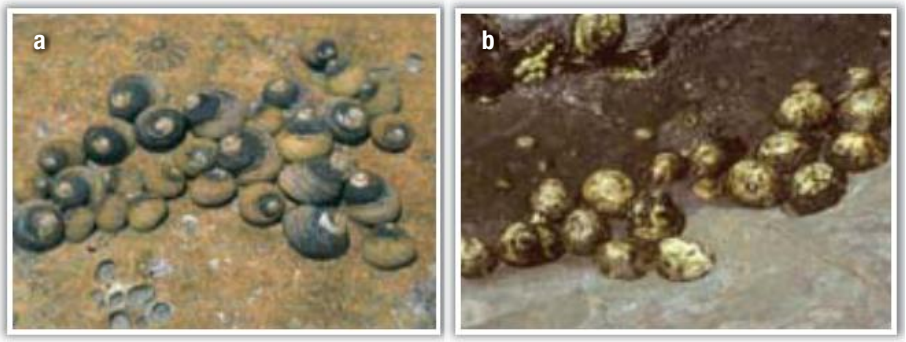


Figure 1.39 (a) The fast-moving black nerite, *Nerita melanostragus*, and (b) the slow-moving variegated limpet, *Cellana tramoserica*, compete for the same food on seashore rocks.

Species that are introduced into natural ecosystems by humans often successfully compete with the native inhabitants, because they may not have the same predators or diseases. For example, feral goats use rock shelters and food needed by rock wallabies in the Flinders Ranges of South Australia, and have caused a decline in the number of rock wallabies.

More usually in ecosystems, organisms within the same habitat do not compete directly for the same resource. For example, different species of lizards living in the same desert ecosystem may eat different sizes of insects. Similarly, in urban gardens the common garden orb weaver spider, *Eriphora transmarina*, catches and eats larger insects than the St Andrew's Cross spider, *Argiope keyserlingi*, does.

The impact of humans on ecosystems

identify the impact of humans in the ecosystem studied

Human activities have a great impact on ecosystems. We are members of many ecosystems, but unlike most other organisms we deliberately change our environment to suit our own needs. In doing so, we bring about rapid alterations and widespread change. Our effect is often destructive to the original environment and its other inhabitants.

Seven major impacts on ecosystems resulting from human activities are land clearing, habitat loss, soil erosion, salinity, introduced species, pollution, and increasing carbon dioxide emissions.

Land clearing

In Australia, more than 50% of eucalypt forests and 75% of rainforests have been cleared or modified since the arrival of Europeans. Land clearing destroys habitats and leads to soil erosion and land degradation. In many areas, there has been increased salinity of both soil and water. The debate about this problem involves environmental, political and economic issues. Progress is being made in reducing the rate of clearing and increasing areas for reserves and revegetation.

BIOFACT

Habitat fragmentation is the division of a once large area into smaller, unconnected fragments through clearing or other disturbance. Each fragment by itself is too small to maintain the original ecosystem. The self-sustaining cycle of materials and the flow of energy breaks down, and species are lost from the fragments, leading to local extinctions. If the fragmentation occurs over a wide area, species can become extinct.

Salinity—salting of a river system

The Murray–Darling River system in eastern Australia (Figure 1.40a) is one of the longest river systems in the world. About three-quarters of all the water used in Australia for domestic, industrial and agricultural purposes comes from it. The Murray–Darling region supports much of Australia's food production. Unfortunately, the rivers and the country that they drain are suffering enormous problems of salinity and land degradation.

Much of the salt in the Murray River comes from an increase in the inflow of water caused by rising water tables in the surrounding country. As the water rises through the soil, it picks up dissolved salts, mainly sodium chloride. The salty groundwater is sometimes so close to the soil surface that it kills crops, and the land becomes an unproductive salt flat (Figure 1.40b). The salty water also flows into rivers, and this explains the saltiness in the Murray.





Figure 1.40 (a) The Murray–Darling river system connects three Australian states—New South Wales, Victoria and South Australia. (b) A devastated landscape, the result of salinity caused by over-irrigation.

Water tables have risen as a result of clearing native vegetation and irrigating crops. Without a full cover of native vegetation that can use up the water, groundwater levels have risen. Adding water to the land through irrigation has caused the water table to rise further.

The Basin Salinity Management Strategy 2001–2015 was set up to guide governments and communities to help control salinity levels. Part of this strategy has been to construct salt interception works and to target reforestation and vegetation management. Since the strategies have commenced, salinity levels have begun to fall.

The problems of salinity for the Murray–Darling river system have been compounded by the recent extended period of drought. There have been record low levels of water inflows from rainfall and run-off into the river. The lower rainfall and reduced run-off have been linked to global warming weather patterns.

In 2008, it was estimated that 10% of the river length was severely impaired, 95% was degraded and all the reaches and catchments were disturbed. An additional development has been the threat to the freshwater lakes at the river mouth of irreversible destruction by acid sulfate poisoning because of low water levels. The Australian government has negotiated a national Memorandum of Agreement on the Murray–Darling basin with a view to adjusting water allocations, reducing waste and protecting the environment. The problem has become an urgent one if the Murray–Darling River system is to survive.

BIOFACT

Ecosystem services is the name given to the benefits people obtain from ecosystems. The essential elements of ecosystems, made up of a combination of soil, animals, plants, water and air, can be seen as the underlying assets that provide the ecosystem services. The services they provide include food, medicines, productive soil and clean water and air. If these assets are depleted, then so are the services.

Environmental pests and weeds can be controlled by physical, chemical or biological means.

- Physical control includes shooting animals and cutting down or digging out plants.
- Chemical control includes using poison baits and insecticides for animals and herbicides for plants.
- Biological control involves introducing a predator, parasite or pathogen.

BIOFACT

The use of motor vehicles and the combustion of fuel, such as wood and gas, account for most of the air pollution in Australian cities.

For recent statistics of environmental issues and trends, visit the Australian Bureau of Statistics website.

Pollution is the spoiling or poisoning of the environment through human activity.

Introduced species

In Australia many introduced species have become pests, for example the red fox, cane toad (Figure 1.42), European carp, lantana and privet.



Figure 1.41 The cane toad (*Bufo marinus*), a species from tropical South America, was introduced into Queensland in 1935 to control cane beetles in sugar cane crops. However, the cane toad was no better than the native frogs at controlling the beetles, and became a pest itself. It breeds rapidly, has no major predators, and has few competitors or parasites. The toxin from its poison glands kills many would-be predators. It is rapidly extending its range into the Northern Territory and New South Wales. Cane toads have reached Darwin and are heading to the Western Australian border. They have reached northern New South Wales and are migrating south at a rate of about 1.3 km per year. As they are tropical animals, environmental factors such as cold and drought are currently the only controlling factors limiting their spread.

Pollution

Air and water pollution and the dumping of wastes spoil and poison the environment for all organisms, including humans.

Increased carbon dioxide emissions

As human populations and urbanisation increase, so do the consumption of fossil fuels and simultaneous land clearing. We burn fuels to produce energy for human activities such as transport, industry, heating, cooling and lighting, and this has resulted in increased emissions of carbon dioxide into the atmosphere.

Land clearing results in reduced uptake of carbon dioxide by plants in photosynthesis. This causes even more rapid increases in atmospheric carbon dioxide levels.

The environmental impacts of this appear potentially devastating, including global warming, rising sea levels and ocean acidification. To address some of these problems, in 2008, the Australian government proposed a national scheme to set renewable energy targets and implement a carbon trading scheme for industrial producers of carbon dioxide.



Figure 1.42 In large cities such as Sydney, photochemical smog caused by gas emissions from vehicles and factories can be an extremely serious problem.

Extinction of other species

By destroying habitats and hunting without constraints, we have caused the extinction of many species of animals and plants. Currently there are 788 Australian plants and animals listed as **threatened**. This includes 44 species of bird, 38 species of reptile, 48 species of amphibians and 57 species of mammal. Australia has the worst rate of mammal extinctions in the world.

Conserving the environment is a global issue. In Australia, national, state and local governments, community groups and individuals are working to find the balance between human activities, the need to protect the quality of the environment and the need to conserve our unique plants and animals.

BIOFACT

The Landcare movement has developed in Australia over the past 25 years as a partnership between landholders, land managers, industry and government. There are more than 1800 Landcare groups in New South Wales. These groups are concerned with managing all natural resources in their areas in a more sustainable way. For more information, visit the Landcare NSW website.



Figure 1.43 A flagship species—the black cockatoo.

BIOFACT

A flagship species is a threatened species selected to act as a symbol or icon for a particular environmental cause. By conserving that species, many other species in the same habitat will also be saved.

The World Wildlife Fund has identified a number of national flagship species including:

- black cockatoos
- quolls
- bilbies
- gouldian finches
- migratory shorebirds.

For more information, visit the WWF website.

INVESTIGATION 1.2

A local ecosystem field study

Students will:

- choose equipment or resources and undertake a field study of a local terrestrial or aquatic ecosystem to identify data sources and:
  - measure abiotic variables in the ecosystem being studied, using appropriate instruments, and relate this data to the distribution of organisms
  - estimate the size of a plant population and an animal population in the ecosystem using transects and/or random quadrats
  - collect, analyse and present data to describe the distribution of the plant and animal species whose abundance has been estimated
  - describe two trophic interactions found between organisms in the area studied
  - identify data sources and gather, present and analyse data by:
    - tabulation of data collected in the study
    - calculation of mean values within ranges
    - graphing changes with time in the measured abiotic data
    - evaluating variability in measurements made during scientific investigations.

Skills and outcomes

P2, P4, P7, P8, P11, P12, P13, P14, P15, P16

Type of activity

First-hand investigation

Materials

- clipboard
- note paper
- unlined paper for diagrams
- pencils
- equipment for specific data collection, as required

See:
- First-hand investigations
- Presenting information

Introduction

This activity gives you an opportunity to visit a local ecosystem, with the aim of conducting a first-hand field study. Remember that nature reserves are set aside by authorities to protect native plant and animal species, and to encourage population growth. This is especially so for species whose numbers are dwindling. For these reasons, it is important to cause the least possible disturbance during your visit. Ensure that you have permission from the appropriate authority if you must collect specimens for analysis back in the school laboratory. If allowed, perform any monitoring and analysis in the field that can be done there. Make sure that a risk assessment for this study has been conducted.

Take along field guides and keys for the identification of plants and animals. Take care to protect yourself from stinging or biting insects and spiders when observing particular parts of the ecosystem. For example, use a stick or pencil to gently lift the bark of trees or to lift leaf litter. Rubber gloves may be useful. If you upturn rocks during investigations, replace them in their original position.

You need to be familiar with different kinds of aquatic and terrestrial ecosystems, so background reading is recommended. In this activity, you should classify the ecosystem you visit. You also need to be able to choose and conduct appropriate sampling techniques for estimating population sizes for plant and animal species.

In many cases, you might be working as part of a small group or team, and you may be contributing only part of the overall data. Follow-up work back in the classroom and repeat visits to the ecosystem may be required. All the data collected should be collated, analysed and presented as graphically as possible.

You will be using this data in Investigation 1.4 where you will write up a report describing what you did and discussing the relevance of the evidence you collected.

Purpose

1 To undertake a study of a local terrestrial or aquatic ecosystem.
2 To determine the abiotic and biotic factors that make up an ecosystem.
3 To estimate the abundance and distribution of selected organisms within an ecosystem and consider the factors that might affect these.

Procedure

In the field, you will be actively collecting data. Collate and present this information in the best possible way either in the field or back in the classroom. This could involve tabulating the data, drawing graphs or calculating the mean of various measurements.

A The general area

1 When you arrive at the chosen study site, spend a few minutes looking around. Observe the main features, prominent landmarks, the kinds of vegetation in the area, dominant plant species and weather conditions.
2 Write a general description of the area including non-living (abiotic) and living (biotic) features. Abiotic features will include geographical characteristics as well as local weather conditions. In describing biotic features, mention the type and density of vegetation. Consider features that will help you classify this ecosystem. For example, for terrestrial ecosystems consider the amount of sunlight that penetrates the foliage of trees to reach the ground. For aquatic ecosystems think about the salt or freshwater nature of the water. Is the body of water a lake, stream, river or sea? Give a name to the kind of ecosystem you are studying.
3 Make two diagrams to represent the area—a plan sketch and a profile sketch. Either label your diagrams to indicate various features or use a key. Figures 1.44 and 1.45 provide a useful guide.

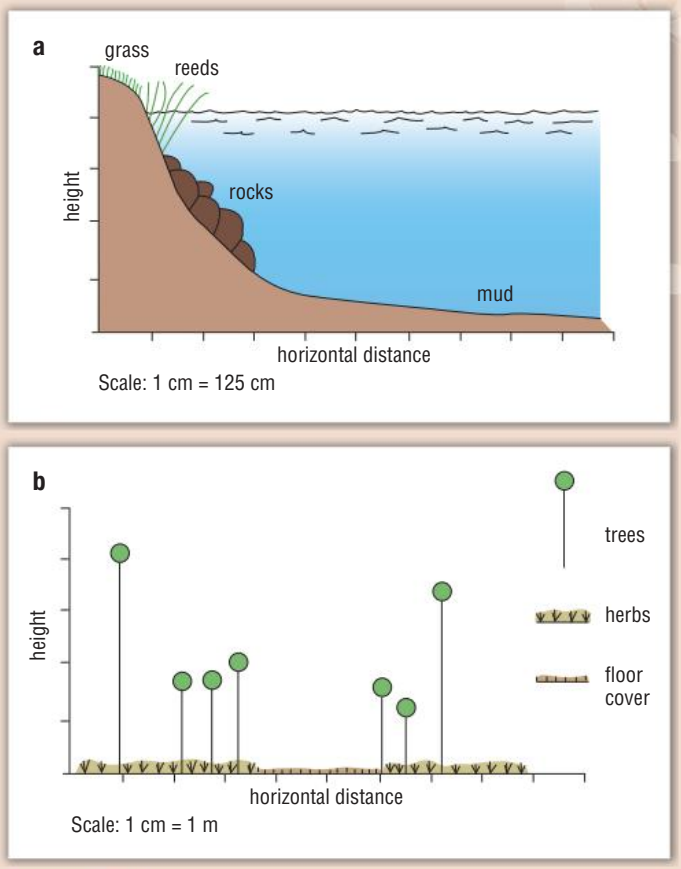


Figure 1.44 Profile sketch of (a) an aquatic ecosystem and (b) a terrestrial ecosystem.

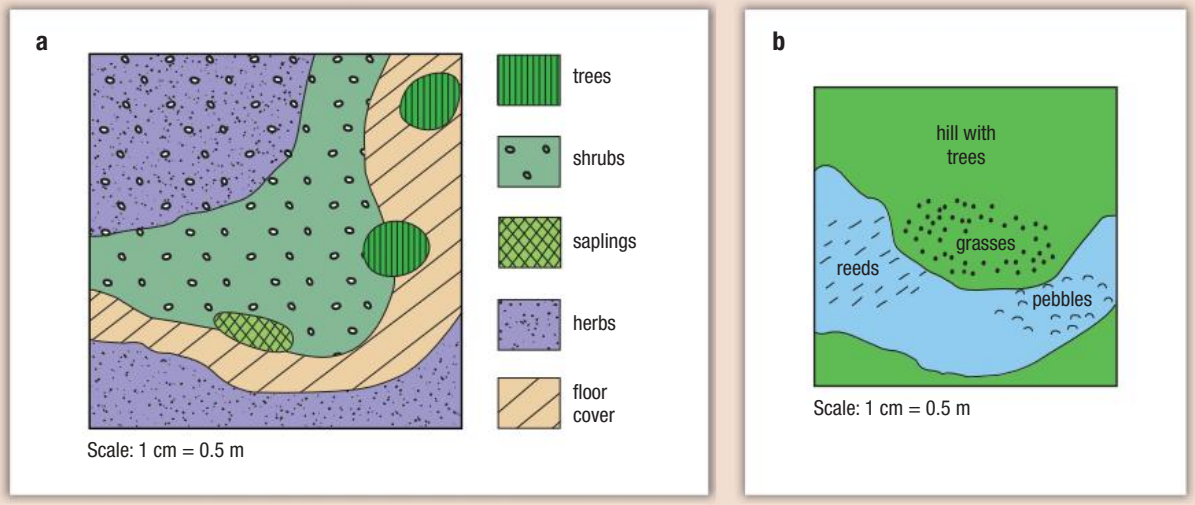


Figure 1.45 Plan sketch of (a) a terrestrial ecosystem and (b) an aquatic ecosystem.

Materials

Additional materials for part B:

- see Table 1.3 for equipment required for monitoring abiotic factors

Additional materials for part C:

- measuring tape (at least 10 m long)
- rope or cord
- 1 m × 1 m quadrat

4 At the right-hand margin of your profile sketch, mark in a 'light intensity' column. Shade the column to indicate the relative amount of light that penetrates the ecosystem.

Discussion

1 Name and briefly describe the ecosystem you are studying.

B Abiotic factors

1 Copy the first two columns of Table 1.3 into your notes. The third column of the table provides information about taking specific measurements.

2 Measure as many abiotic factors as possible for your ecosystem, recording the results of each test as you go.

3 Identify any other abiotic factors in the ecosystem.

4 Compare the air temperature you measured with the forecast temperature for your regional area. Try to explain any difference.

TABLE 1.3 Measuring abiotic factors

Abiotic factor	Measurement	Equipment and notes
Air temperature • at ground level • at 1 metre		100°C thermometer
Humidity		Wet and dry bulb thermometer
Soil temperature		Thermometer or temperature probe if one is available
Water temperature		Thermometer or temperature probe if one is available
Light intensity		Photographic light meter
Wind speed		Anemometer, or devise and use a 5-point scale
Soil pH		pH meter, pH indicator paper or pH probe*
Water pH		pH meter, pH indicator paper or pH probe*
Water turbidity		Secchi disk or turbidity tube
Flow rate of water		Place an object in the water and measure the distance covered over a given time, e.g. metres per minute
Dissolved oxygen content of water		Oxygen meter or oxygen probe

*You could use a datalogger with the appropriate probe, or a Streamwatch kit.

Discussion

1 Name the two abiotic factors you consider most important in this ecosystem and explain why.

2 Describe a microhabitat in your ecosystem and explain how the abiotic factors there vary compared to the general area

C Population abundance and distribution

In this part of the activity, you will use some sampling techniques to gather data related to the distribution and abundance of organisms.

1 Use the rope and measuring tape to mark a transect line of at least 10 metres, but preferably 50 metres, long, through a selected area of the ecosystem. Make sure your transect line runs through an area that varies over the distance selected. For example, the vegetation might change, there might be a watery area somewhere in the transect line, or there might be variations in the undulation of the area.

2 Draw a profile sketch of the ecosystem represented by the transect line (see Figure 1.45).

3 Walk the length of the transect line, observing plant and animal species along the way.

4 Prepare two lists, one each for the plant and animal species observed along the transect line. Where you cannot name an organism, call them by their type and give them a number, e.g. grass 1 and grass 2.

5 Choose a plant from your list. Set up the 1 m × 1 m quadrat at one end of the transect line. Count the individual plants of the species within the quadrat.

6 Record your data in a table similar to Table 1.4.

7 Repeat the procedure for quadrats set at regular intervals along the transect line to give a random selection of the plant type you are investigating. Decide how many quadrats you will need. (Note: A spreadsheet will be useful in completing this part of the activity.)

8 Describe the distribution of the plant species along the transect line.

9 Account for any differences in distribution that you have observed.

10 Discuss with other members of your group how to estimate the 'abundance' of this plant species in the area of the ecosystem you are studying. Decide how many quadrats to use and where these should be placed to achieve meaningful results.

11 Estimate the total area of the study site for this population of plant species.

12 Set out the quadrats and count the plants in each. Record the data in a table similar to Table 1.4.

13 Calculate the average size of the plant population per quadrat.

14 Use the data you have obtained to estimate the abundance of the plant species in the area.

15 Comment on the variability of the measurements made in different quadrats.

16 Choose a small animal, for example an insect species, from your list of animals.

17 Discuss with the members of your group a suitable way of estimating the abundance of this species in the area.

18 Estimate the abundance of the animal species in the area. Remember to record the date and time you made your estimate and any special environmental circumstances.

19 Describe how the animal species is distributed in the area. (Hint: Look at the features of the ecosystem that provide the optimum conditions for your animal; for example, shade plants, rocks for shelter.)

TABLE 1.4

Quadrat no.	No. of plants
1	
2	
3	
etc.	
Total	

Discussion

1 Outline some factors that could account for the abundance and distribution of organisms in the ecosystem.

2 Describe the habitats of four different kinds of organisms living in the ecosystem.

3 For a named animal in your ecosystem, describe a sampling technique you could use to estimate the population size. Justify the use of this technique.

D Adaptations

1 Select a named plant and a named animal that lives in the ecosystem.

2 For each organism prepare a detailed description of any adaptations they have to factors in their environment. Diagrams or photographs may be used.

Discussion

1 Describe the features of a named plant that enable it to survive in the ecosystem.

2 Describe the features of a named animal that enable it to survive in the ecosystem.

E Change over time

1 Revisit the ecosystem at different times of the day and at different times of the year. Monitor the same abiotic factors to investigate how these seasonal changes could affect the ecosystem and the organisms living there. Keeping a record of precipitation in the area will be useful. (Note: A spreadsheet is a useful way to record data.)

2 Graph the changes with time in the abiotic data you have collected.

3 Observe and record changes in the type, abundance and distribution of the living organisms.

4 Graph the changes over time in the abundance of an animal in the ecosystem.

5 Compare the changes with time in abundance of a plant and an animal species in the ecosystem.

Discussion

1 Suggest how the abiotic factors in this ecosystem are likely to change over a 24-hour period.

2 Explain, using examples from your ecosystem, how the distribution and abundance of organisms changes according to the time of day and the season.

F The impact of humans

1 Observe and record signs of human impact in the ecosystem. This may include deliberate changes or indirect effects that have occurred because of human activity outside the ecosystem. Examples of human activity could include pollution (air, noise, water), clearing of land, building, fencing, use of water bodies, recreational use of land/water, or introduced species of plants or animals.

Discussion

1 Describe the impact of human activities on the ecosystem you studied.

2 Suggest how the quality of the ecosystem you studied could be improved, maintained or preserved.

1.3 INVESTIGATION

Trophic relationships

Students will: gather information from first-hand and secondary sources to construct food chains and food webs to illustrate the relationships between member species in an ecosystem.

Purpose

1 To identify producers, consumers and decomposers in the ecosystem.
2 To construct food chains and food webs to demonstrate trophic relationships.

Procedure

1 Observe the ecosystem closely, looking out for any plant and animal life. You could photograph what you see.
2 Write a list of the plant life you can see about you. This should include the types of plants—for example, trees, grasses, herbs, ferns—as well as specific names of plants you are able to identify. Look closely at some parts of the ecosystem for evidence of tiny plants—for example, mosses and lichens growing on trees or algae in the water. Include any observations of fungi growing on decaying bark.
3 Stand or sit quietly (for at least 5 minutes) to determine the kinds of animals in the ecosystem. Use other senses as well as sight to determine their presence. Listen for sounds. Look closely at the bark of trees where tiny animals may be camouflaged. Look for evidence of the existence of animals—for example, nests, spider webs, scats, footprints, trails, burrows, chewed leaves.
4 Prepare a list of the types of animals present in the ecosystem and identify as many as you can by their specific name.
5 Using your knowledge of interactions between organisms within ecosystems and your observations, draw four different food chains for this ecosystem.
6 Prepare a food web for this ecosystem that includes at least two different plant species and at least four different animal species. Try combining your food chains.
7 Draw a food pyramid representing each of the trophic levels in your food web.

Discussion

1 Use the food chains and food web you constructed in this activity to explain how energy moves through ecosystems.

Skills and outcomes

P2, P4, P7, P8, P11, P12, P13, P14, P15, P16

Type of activity

First-hand investigation

Materials

- clipboard
- note paper
- unlined paper for diagrams
- pencils
- equipment for specific data collection, as required
- field guides and reference books
- (optional) camera

See First-hand investigtations

INVESTIGATION 1.4

An ecosystem report

Students will: process and analyse information and present a report of the investigation of an ecosystem in which the purpose is introduced, the methods described and the results shown graphically, and use available evidence to discuss their relevance.

Skills and outcomes

P2, P4, P7, P8, P11, P12, P13, P14, P15, P16

Type of activity

First-hand investigation

Materials

- data collected on the field study in Investigations 1.2 and 1.3
- answers to questions from Investigations 1.2 and 1.3

See Writing a scientific report

Purpose

To write up a report presenting and evaluating the data from your local ecosystem field study.

Procedure

1 Once you have assembled a full set of field study data and completed Investigations 1.1–1.3, you are ready to use this information to write up your report. The report should include why you did the study, how you did it and what you found. It should also include a discussion and evaluation of the findings as well as any valid conclusions that you can draw from the data.

2 Your report should include the following headings:
- **Procedure**—name the ecosystem you studied and explain what you were investigating.
- **Methods**—describe the methods used to conduct the study.
- **Results**—present your results as graphically as possible.
- **Discussion**—discuss how your results can be interpreted, their relevance, and any valid conclusions that can be drawn from them.

3 Your report should include information about:
- the abiotic factors and how these affect the distribution of organisms
- an estimation of the abundance and distribution of one plant and one animal in the ecosystem
- the trophic interactions of at least two plant and two animal species, and how these interactions may affect distribution and abundance
- the impact of humans and the future of the ecosystem.

4 Use the information above to write up your report or produce a multimedia presentation.

1.2 UNIT REVIEW

Local ecosystems: Interactions and responses

Each local aquatic or terrestrial ecosystem is unique.

Summary

- Population estimates can change over season and time. Factors affecting numbers in predator and prey populations include the size of the ecosystem, the availability of the prey's food, reproductive cycles, competition and disease.
- Interactions between organisms, such as commensalism and mutualism, benefit at least one organism. Other interactions, such as predation and parasitism, can be harmful to one of the organisms. In allelopathy, chemicals from one plant can affect other organisms in its environment.
- Decomposers are important in ecosystems. They break down dead plants and animals and their wastes to simple compounds that are recycled and used by other organisms.
- The flow of energy from one living thing to another can be shown in a food chain. The trophic or feeding interactions that occur in an ecosystem can be represented in a food web.
- An adaptation is a feature of an organism that makes it suited to its environment and helps it to survive and reproduce. Adaptations can be physiological, structural or behavioural.
- Competitive interactions are when organisms compete for the same resource. These relationships may be between members of the same species or between different species. The result of these interactions affects the numbers of the organisms in an ecosystem.
- In the short term, competition reduces the chance of survival and restricts the abundance of all competitors. In the long term, one competitor is usually more successful and reduces the number of other competitors.
- Human activities, such as pollution, land clearing and the introduction of new species, can have a severe impact on natural ecosystems.

Questions

1 The golden-shouldered parrot of far north Queensland shown in Figure 1.46 lays its eggs in a nest in a termite mound. The antbed parrot moth lays its eggs in the same nest. Both sets of eggs hatch at the same time. The young moth larvae keep the nest clean by feeding on the dung and moulted feathers of the baby parrots. When the parrots are ready to leave the nest, the moth larvae pupate at the nest entrance.



Figure 1.46
The golden-shouldered parrot.

Which term best describes the relationship between the golden-shouldered parrot and the antbed parrot moth?

A mutualism
B parasitism
C succession
D competition

2 The numbers of producers, herbivores and carnivores in an area of grassland were estimated and the information is shown in the table.

Type of organism	Biomass of each type (kg/dry mass/hectare)
X	5000
Y	10
Z	1

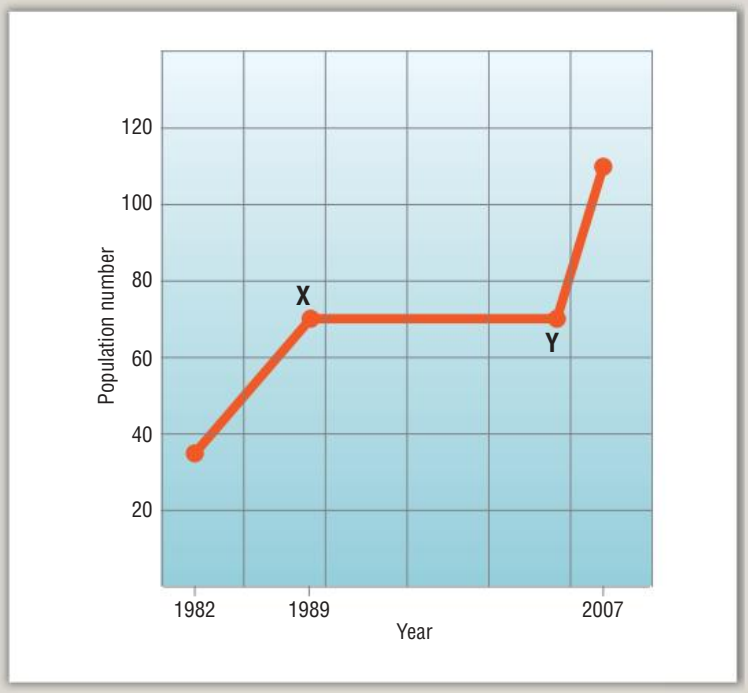
What types of organism are represented by X, Y and Z, respectively?

A herbivores, producers, carnivores
B producers, consumers, humans
C producers, herbivores, carnivores
D herbivores, carnivores, top-order consumers

3 Which statement best defines the biomass of an ecosystem?

A Biomass is the total mass of all producer organisms.
B Biomass is the total mass of all organic material.
C Biomass is the total mass of all consumer organisms.
D Biomass is the total mass of all decomposers.

4 Examine the following graph of trends in the hairy-nosed wombat population in Epping National Park from 1982 to 2007.



a Describe what the graph shows about the population over this time.

b Propose what could have happened at times X and Y, and what happened between these times.

5 Describe each of the following kinds of relationships that exist between organisms in ecosystems, and identify an Australian example of each. You may want to present your information in a table.

a allelopathy

b parasite–host

c commensalism

d predator–prey

6 Outline the role of each of the following types of consumers in ecosystems, giving one Australian example of each.

a herbivore

b carnivore

c omnivore

d scavenger

e decomposer

7 Consider the food web in Figure 1.30 on page 33.

a Identify the producers, primary consumers, decomposers and top-order consumer.

b Construct a food chain for this food web which shows an animal in the position of:

i secondary consumer

ii tertiary consumer.

c Explain, using an example from this food web, why food webs are more stable than food chains.

8 a Define the term 'adaptation'.

b Describe an adaptation to an environmental factor displayed by an Australian:

i animal

ii plant.

c Explain the problems associated with inferring that these characteristics are adaptations.

9 Describe the impact of one human activity on a named ecosystem.

10 Assess the balance required between the needs and activities of humans and the need to conserve, maintain and protect the environment.

11 a In the ecosystem you studied, outline factors that affect numbers in predator and prey populations.

b Predict the impact of the weather on a population you studied.

CHAPTER 1

EXAM-STYLE QUESTIONS

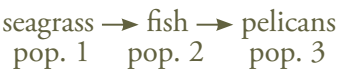
MULTIPLE CHOICE

1 Which statement best describes an organism's environment?
- A It is the ecosystem in which it lives.
- B It is the sum of all of the living and non-living things that affect it.
- C It is the set of physical factors that influence its survival.
- D It is the place where it lives.

2 Which phrase best classifies deserts, woodlands, grasslands and forests?
- A They are examples of ecosystems found in parts of Australia with different climates.
- B They are examples of the interactions of living organisms.
- C They are stages in the succession of ecosystems.
- D They have the same inputs, outputs and processes.

3 Which description best explains the environmental factors of temperature, availability of gases and amount of light?
- A They are biotic factors that can influence the distribution and abundance of species.
- B They are abiotic factors that can influence the distribution and abundance of species.
- C They are biotic and abiotic factors in the environment.
- D They are physical factors that affect the distribution of plants, but not animals.

4 Which of the following is true for the distribution of a particular species?
- A It does not usually vary much.
- B It can be changed by human activities but not by natural processes.
- C It is determined by the availability of its requirements.
- D It tells us the numbers to be found in a particular area.

5


The diagram shows three populations which make up a food chain. If a new predator moves in that also feeds on fish, predict what might happen to the numbers in the three populations.
- A Numbers in all three populations decline.
- B Numbers in Population 2 decline, but those of 1 and 3 increase.
- C Numbers in Population 1 increase, but those of 2 and 3 decline.
- D Numbers in Population 2 decline, but those of 1 and 3 stay the same.

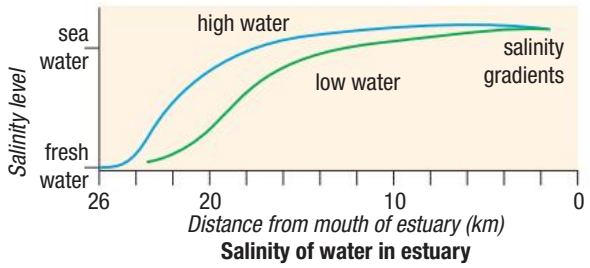
6 Explain why we use transects and quadrats when studying population size.
- A To determine the number of organisms in an ecosystem.
- B To ensure random sampling of an ecosystem.
- C To estimate the distribution of a population.
- D To estimate the abundance of a population.

7 Why is aerobic cellular respiration an important process in ecosystems?
- A It transforms light energy into energy-rich organic compounds.
- B It releases energy stored in organic compounds.
- C It creates the energy that cells need.
- D It involves a series of important chemical reactions in cells.

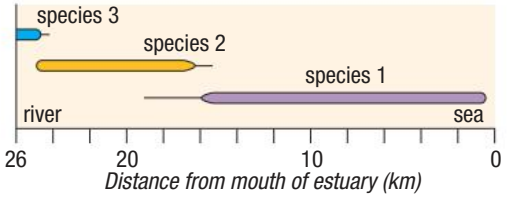
SHORT ANSWERS

1 You are on a field trip to Cope Creek on the Bogong High Plains of Victoria to investigate the revegetation of areas where cattle are now excluded. Your task is to estimate the population of the silver snow daisy in a fenced plot. **Outline** a sampling technique that would allow you to estimate the plant population without counting every plant of that species in the plot.

2 Three species of small arthropods are found living in a river estuary. The diagram and graph show the distribution of these species and the water salinity in the estuary.
- a **Describe** how the salinity of the water affects the distribution of each species.
- b Suggest another environmental factor that may affect the distribution of each species.

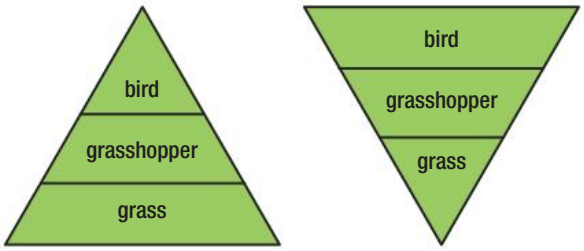


Salinity of water in estuary



Distribution of three arthropod species in estuary

3 Study the following two diagrams. Explain which diagram best represents the feeding relationships in a field. Justify your choice.

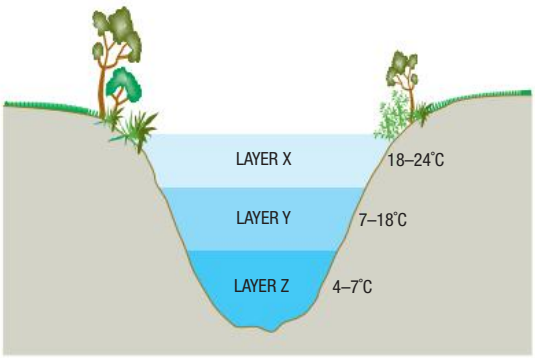


4 Locust plagues are common in some inland areas of Australia following seasons of good rainfall.

a Describe the short-term effect on an ecosystem of the arrival of the locust plague.

b Predict the long-term effect on the ecosystem.

5 Study the following cross-sectional diagram of a lake in summer.



a Describe the relationship between depth and temperature.

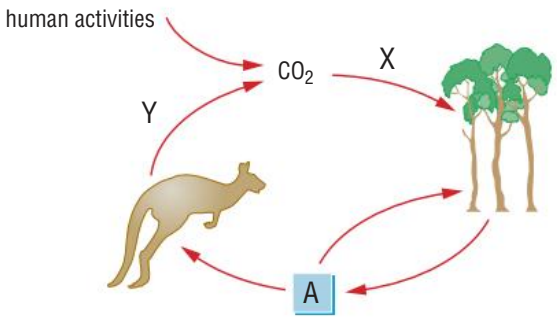
b i Describe the relationship you would expect between depth and light penetration.

ii Explain how light penetration is likely to affect the distribution of plants in the lake.

iii Predict In which layer (X, Y or Z) you would expect the greatest abundance of animal life. Explain your answer.

c Identify two other physical factors that might affect the organisms living in the lake.

6 Study the following diagram.



a Name the two processes X and Y represented in the diagram.

b Name substance A.

c List three uses of energy by the kangaroo.

7 Study the food web shown in Figure 1.30 on page 33.

a Identify the producer organisms in this food web.

b Describe three predator–prey relationships that are represented.

c Explain the relationship between the forest tree and the mistletoe plant.

d Construct a food pyramid that is representative of all of the organisms in the food web.

8 For an example of either commensalism or parasitism you have studied, analyse the relationship between the organisms involved. Include any implications for both the organisms concerned and the ecosystem.

9 For the ecosystem you studied in this chapter, evaluate the effectiveness of the techniques you used to collect your data. Make recommendations to improve data collection for your next field trip.

10 Summarise the impact of human activities in the ecosystem you studied and assess how these may affect the abiotic and biotic characteristics in the future.

Exam-style questions 1

CHAPTER 2

PATTERNS IN NATURE

PFA: This chapter increases students' understanding of the history, applications and uses of biology.



When we examine general features across a range of living organisms, patterns in structure and function can be identified. The fundamental processes in living things are concerned with inputs (absorbing necessary chemicals) and outputs (releasing wastes).

Cells are the building blocks from which all living organisms are made. Patterns in their structure and function can be seen at the microscopic and biochemical level. Structural similarities reflect similar biochemical processes. The fundamental difference between plant cells and animal cells is related to the process of photosynthesis, which occurs only in plant cells.

To take in materials and remove wastes efficiently, living things have evolved systems that are often complex and have large surface areas. The collection and distribution of nutrients and wastes is performed by specialised transport systems.

In living things, the processes of sexual reproduction show similar patterns, reflecting similar functions. It is likely that these patterns may reflect common evolutionary origins for multicellular organisms, both plants and animals.

Assumed knowledge

Refer to the Board of Studies NSW Years 7–10 Syllabus.

- Construct word equations from observations and written descriptions of a range of chemical reactions (5.7.3c).
- Explain that systems in multicellular organisms serve the needs of cells (5.8.1a).
- Identify the role of cell division in growth, repair and reproduction in multicellular organisms (5.8.1b).
- Identify that information is transferred as DNA on chromosomes when cells reproduce themselves (5.8.2c).
- Identify that genes are part of DNA (5.8.2d).

Preliminary Course Outcomes

Prescribed focus areas

P1 Outlines the historical development of major biological principles, concepts and ideas.

P2 Applies the processes that are used to test and validate models, theories and laws of science, with particular emphasis on first-hand investigations in biology.

P3 Assesses the impact of particular technological advances on understanding in biology.

P4 Describes applications of biology which affect society or the environment.

P5 Describes the scientific principles employed in particular areas of biological research.

Domain knowledge

P6 Explains how cell ultrastructure and the coordinated activities of cells, tissues and organs contribute to macroscopic processes in organisms.

P7 Describes the range of organisms in terms of specialisation for a habitat.

P8 Analyses the interrelationships of organisms within the ecosystem.

P9 Explains how processes of reproduction ensure continuity of species.

Domain skills

P11 Identifies and implements improvements to investigation plans.

P12 Discusses the validity and reliability of data gathered from first-hand investigations and secondary sources.

P13 Identifies appropriate terminology and reporting styles to communicate information and understanding in biology.

P14 Draws valid conclusions from gathered data and information.

P15 Implements strategies to work effectively as an individual and as a team member.

Values and attitudes

P16 Demonstrates positive values about and attitudes towards both the living and non-living components of the environment, ethical behaviour and a desire for a critical evaluation of the consequences of the applications of science.

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PATTERNS IN NATURE continued



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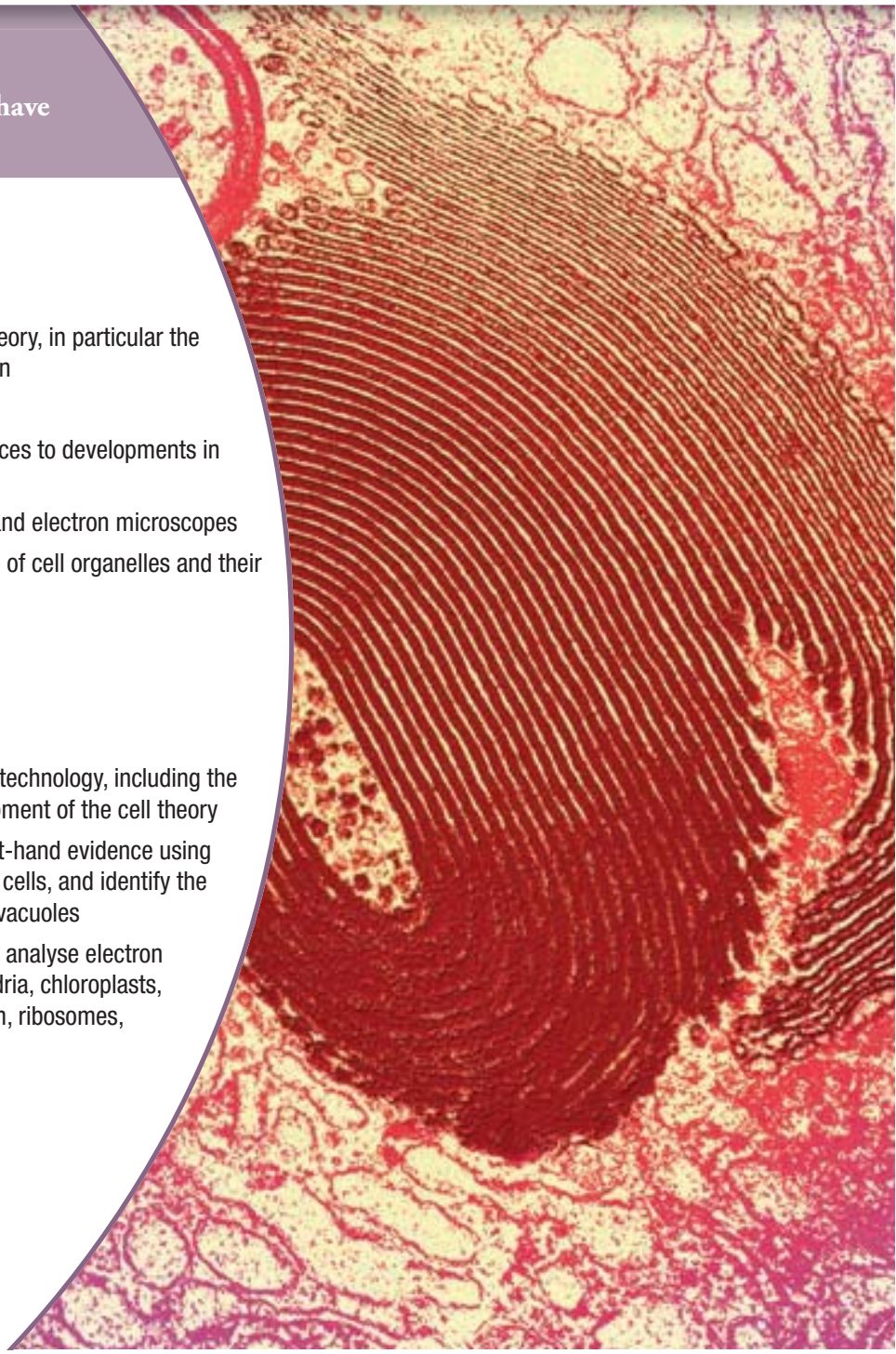
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2.1 ORGANISMS: CELLS AND STRUCTURE

Organisms are made of cells that have similar structural characteristics.



STUDENT LEARNING

In this unit students will:

- outline the historical development of the cell theory, in particular the contributions of Robert Hooke and Robert Brown
- describe evidence to support the cell theory
- discuss the significance of technological advances to developments in the cell theory
- identify cell organelles seen with current light and electron microscopes
- describe the relationship between the structure of cell organelles and their function.

STUDENT ACTIVITY

Students will:

- use available evidence to assess the impact of technology, including the development of the microscope, on the development of the cell theory
- perform a first-hand investigation to gather first-hand evidence using a light microscope to observe plant and animal cells, and identify the nucleus, cytoplasm, cell wall, chloroplasts and vacuoles
- process information from secondary sources to analyse electron micrographs of cells and identify the mitochondria, chloroplasts, Golgi bodies, lysosomes, endoplasmic reticulum, ribosomes, nucleus, nucleolus and cell membranes.

The cell theory

outline the historical development of the cell theory, in particular the contributions of Robert Hooke and Robert Brown

Over the past few hundred years, biologists have found that all life forms share a fundamental similarity. They are all made up of units that we call **cells**. Cells are the building blocks of which all living organisms are made. The basic structure of all cells is similar and they have many chemical substances in common. They also have similar basic functions.

Using cells, plants and animals can build specialised structures (tissues and organs) as part of their bodies, for a variety of purposes. This gives us the great diversity of living things that we see today.

In 1839, the German biologists Matthias Schleiden and Theodor Schwann stated their **cell theory**, as follows:

1 Cells are the smallest units of life.

2 All living things are made up of cells.

In 1858 another German, Rudolf Virchow, added a further point to the theory:

3 All cells come from pre-existing cells.

These three statements form the modern-day cell theory.

The cell theory states that:

1 Cells are the smallest units of life.

2 All living things are made up of cells.

3 All cells come from pre-existing cells.

Spontaneous generation vs cell theory

Prior to the seventeenth century, biologists developed a theory—the 'theory of spontaneous generation'—that some animals such as worms and frogs could spontaneously emerge from mud or water, and that organisms such as maggots developed from rotting meat. However, the Italian scientist Francesco Redi showed that maggots developed only on meat that flies had laid their eggs on.

In the nineteenth century, the theory of spontaneous generation was finally shown to be fundamentally incorrect when Louis Pasteur's experiments proved that microorganisms arose only from other microorganisms. As a result, the 'cell theory' developed, which in turn formed the scientific basis for the 'germ theory of infection' and revolutionised the development of antiseptic procedures in medicine.

Historical development

Magnifying devices have been used since ancient times. Chinese porcelain vases, dated to around 1000 BC, show people wearing glasses, and the Greeks and Romans used glass flasks filled with water to magnify small objects. Table 2.1 shows the historical development of the cell theory.

Most cells are so small that a microscope is needed to see them. The development of the cell theory went hand-in-hand with technological advances in the manufacture of lenses and magnifying devices. The first recorded study of cells was by Robert Hooke in the seventeenth century.

TABLE 2.1 Historical development of the cell theory

Time	Event
13th century	Roger Bacon (1214–1294) used a convex lens as a magnifying glass.
1485	Leonardo da Vinci (1452–1519) used glass lenses to study small objects.
about 1600	Two spectacle-makers, Hans and Zacharias Janssen, constructed the first compound microscope using two lenses inside a tube.
1665	Robert Hooke (1635–1703) further developed the compound microscope, including the use of the iris diaphragm. Hooke kept a detailed record of his observations. He first described cells (or rather, plant cells) in his description of a slice of cork he observed under the microscope. He described it as '… all perforated and porous, much like a honeycomb… the pores or cells… consisted of a great many little boxes…'
1672	Marcello Malpighi (1628–1699) stated that all plants are built of chambers ('utricles').
1676	Anton van Leeuwenhoek (1632–1723) described unicellular organisms from his observations of a drop of stagnant rainwater as 'animalcules'. Leeuwenhoek also soaked some peppercorns in water for several days. When he examined a drop of this water under his microscope, he did not find the little needles he expected that made pepper 'hot', just more unicellular organisms.
1683	Leeuwenhoek discovered bacteria from his observations of saliva.
1824	René Dutrochet (1776–1847) stated that all animals and plants are made up of cells.
1831	Robert Brown (1773–1858) noted that the cells of orchids he was observing under the microscope contained a structure inside the cell. He called this the 'nucleus'.
1839	Matthias Schleiden (1804–1881) and Theodor Schwann (1810–1882) formulated the cell theory that all living matter is composed of small units called cells.
19th century	Johannes Purkinje (1787–1869) used the word 'protoplasm' for the contents a cell.
1858	Rudolf Virchow (1821–1902) stated that 'where a cell exists there must have been a pre-existing cell, just as the animal arises only from an animal and the plant only from a plant.'
1877	Carl Zeiss and Ernst Abbe produced the first oil immersion objectives. Images could be magnified over 1000×.
1880	Walther Flemming (1843–1905) described cell division (mitosis) from observations on living and stained cells.
1933	Ernst Ruska built the first electron microscope. Transmission electron microscopes and scanning electron microscopes were developed in the following decades. Details of internal cell structures were revealed.
1938	The Dutch physicist Fritz Zernicke developed the phase contrast microscope that enabled unstained, living cells to be viewed more clearly.
1930s–1950s	X-ray crystallography, developed at the beginning of the 20th century, used hard X-rays to produce diffraction images of crystallised biological molecules, including proteins. An image of crystalline DNA helped James Watson and Francis Crick to reveal the structure of DNA in 1953.
1948	Paul Kirkpatrick and Albert Baez built the first X-ray microscope that used soft X-rays. Soft X-rays produce diffraction images that allow non-crystalline specimens, from single protein molecules to cells, to be viewed.
1950	The first synchrotron became operational in the USA.
1955	Marvin Minsky developed the first confocal microscope. These laser-based scanning microscopes can produce three-dimensional images of cells and cell structures.
1959	The first synchrotron operational in Europe.
1990	Two-photon fluorescence microscope developed by Winfried Denk. This massive microscope uses laser light that creates three-dimensional images within tissues, without damaging cells
The future	The International Linear Collider, to be constructed between 2015 and 2020, will be the largest, most powerful synchrotron ever built. In contrast, compact X-ray microscopes or 'mini synchrotrons' are being developed that can be used on bench tops.

The iris diaphragm on a light microscope sits between the light source and the object being viewed. A lever adjusts a ring of overlapping metal plates to regulate the size of the opening, controlling the amount of light entering the microscope.

The contributions of Robert Hooke and Robert Brown

Robert Hooke helped in the development of the compound light microscope, including the use of the **iris diaphragm**. In 1665, he used a microscope he had developed to view a thin piece of cork (Figure 2.1). He was the first to describe what he saw as 'pores or cells'.

Robert Brown identified structures inside plant cells. In 1831, he was the first to identify the nucleus as a large body found inside cells.

BIOFACT

Robert Brown is not only remembered for his discovery of the nucleus in cells. He was already a famous naturalist and a friend of Charles Darwin, and had travelled all round the world discovering and describing new plants and animals. He arrived in Australia with Matthew Flinders aboard HMS *Investigator* in 1798, and spent several years investigating the strange new plants he found here, many of which he described and named. The Australian plant family *Brunoniaceae* and its single species, *Brunonia australis*, are named after him.

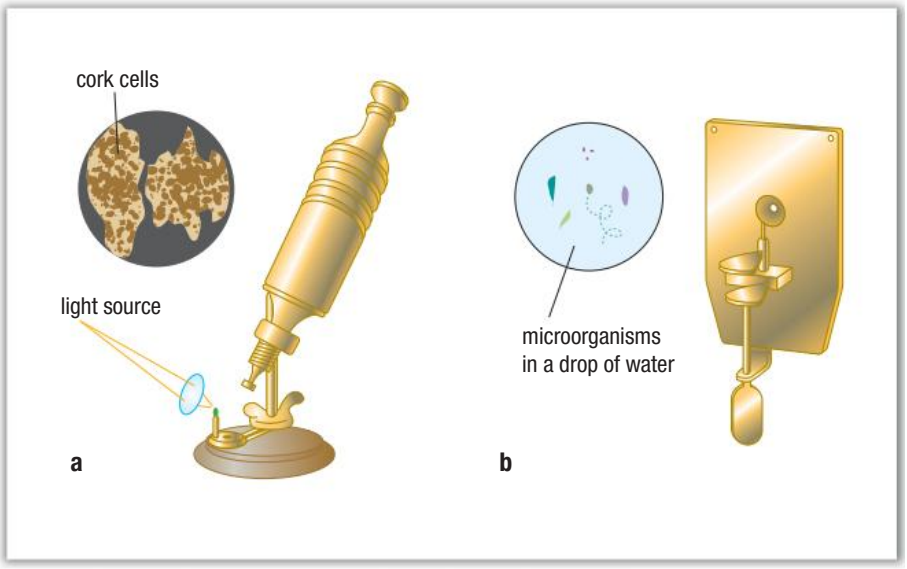


Figure 2.1 (a) Hooke's microscope, and what he saw.
(b) Leeuwenhoek's microscope, and what he saw.

describe evidence to support the cell theory

Evidence that supports the cell theory

All the knowledge and data that has accumulated and developed over time as a result of the investigations by scientists into the structure of living organisms supports the idea that all living things are made up of cells and all cells come from pre-existing cells. The evidence from increasingly detailed microscopic and biochemical studies, made possible by developments in technology, all support the cell theory. See Table 2.1 and page 61.

discuss the significance of technological advances to developments in the cell theory

The significance of technological advances

All scientific research is limited by the technology—that is, the equipment and techniques available. As technology advances, so can our knowledge. Technological advances in different areas have played an enormous role in providing evidence to support the cell theory.

Microscopes

See Table 2.1 and the box 'Inside microscopes' on pages 64–65 for advances in the type and design of microscopes.

Lenses

Advances in lens design in light microscopes, particularly to reduce distortions, plus the use of multiple lenses and focusing screws have improved not only magnifying power, but also the resolving power of microscopes.

Light sources

As well as improvements in the optics of microscopes, the sources of light for light microscopes have also improved. The light source used in microscopes has improved from daylight, to tungsten filament lamps and now LED (light emitting diode) lamps. Filters and condensers are also used to provide bright, uniform light.

Light from electron beams, lasers and X rays has provided greater penetrating power, enabling more cellular structures to be identified in biological specimens.

Preparation of materials

The thinner and more transparent a specimen, the easier it is to see the cells and their contents. Cutting biological specimens has advanced from manually slicing material to using machines called **microtomes** to cut extremely fine sections. The first microtomes were invented in the nineteenth century.

Modern microtomes are precision instruments that can slice uniform sections between 1 and 25 micrometres thick. They may be manually operated or controlled by a computer processor. The knives used in cutting have traditionally been made from stainless steel. Glass, diamond and sapphire knives are used when ultra-fine sectioning is required.



Figure 2.2 This microscope was one of the best available in the early nineteenth century. It enabled cells and their contents to be seen in detail.

All knowledge and information that has been collected by scientists from increasingly detailed microscopic and biochemical studies of living organisms supports the cell theory.



Figure 2.3 A microtome can cut extremely fine sections.



Figure 2.4 A modern compound light microscope, which can magnify up to ×1000.

The significance of advances in technology to the development of the cell theory is that as new technologies were developed, their use led to the accumulation of more evidence to support the cell theory.

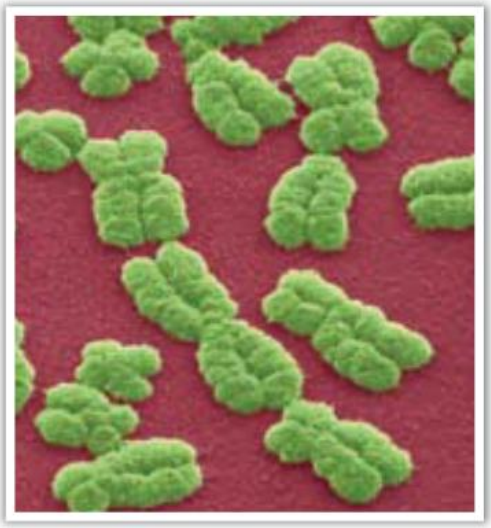


Figure 2.5 Human chromosomes seen under a scanning electron microscope.

Staining techniques

To provide contrast, thin sections of cells may be stained using a variety of chemicals. Chromosomes were first seen by Walther Flemming in 1880 because they absorbed aniline dye readily. Today microinjection with fluorescent markers can highlight components of cells previously not visible.

Computer technology

The modern day use of computers with microscopes has been particularly important in the production of three-dimensional images of cells, their contents and molecular structures. Computer imaging systems can take a series of two-dimensional views of a specimen and build a three-dimensional image that can be displayed and manipulated on a monitor.

Computer microprocessors may also be used in microscopes, where fine automated movements are required. One example of this is the computer-controlled scanning mirrors which move laser beams at the focal plane of specimens in laser scanning microscopes.

As technologies have advanced, so has our understanding of cells. From the plant cell walls shown by the first microscopes, to details of the contents of cells, including the molecules they are made of, we have continued to expand our knowledge of the structure and function of cells.

Inside microscopes

A compound light microscope passes a focused beam of light through the specimen. This light passes through the objective lens, then up the barrel to the ocular lens (the eyepiece) and into the eye, where a magnified image is formed.

An **electron microscope** uses a beam of electrons to enable us to see cells and their contents at extremely high magnification, and with great clarity. The image from an electron microscope can be produced on a TV screen or a photographic plate. There are two main types of electron microscope: transmission and scanning.

Transmission electron microscopes require specimens which are so thin that electrons can pass through them to form an image. They are used to show internal detail, such as the internal structure of cells. Scanning electron microscopes produce images of the surface features of objects. Specimens are usually coated with a very thin layer of metal atoms to enhance the image.

Living cells can be observed using a laser scanning microscope. A computer-controlled scanning mirror moves a beam of laser light across a section or slice of the specimen. The light signal from the specimen is detected and converted into a digital image that can be stored or displayed on a computer screen. Using scans at different positions, a three-dimensional image of the specimen can be constructed.

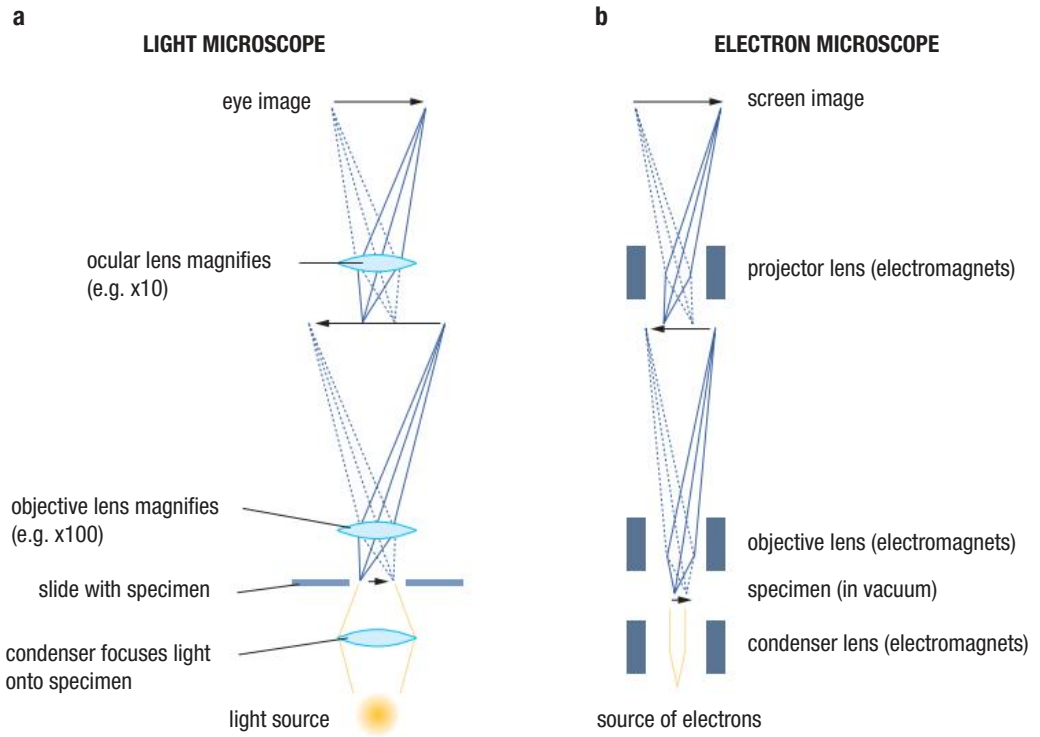


Figure 2.6 The operation of (a) a compound light microscope, and (b) a transmission electron microscope.

There are two forms of laser scanning microscopy, confocal and multiphoton. Confocal laser scanning uses gas lasers and allows thick specimens to be examined. Fluorescence from the specimen is focused by the objective lens through a pinhole aperture to reduce blurring of the image.

Multiphoton laser scanning uses solid-state lasers, which do not require a pinhole aperture. The longer wavelengths of light that are produced are more penetrating and cause less damage to cellular matter.

X-ray microscopy uses soft X-rays (which have a 2–4 nanometre wavelength) to penetrate specimens. A two-dimensional diffraction pattern is produced. A technique known as 3D tomography can combine a series of these two-dimensional images into a high resolution three-dimensional image of the specimen, or even an image of a single molecule.



Figure 2.7 A confocal laser-scanning microscope.

BIOFACT

Because they are so small, objects viewed under microscopes are measured in micrometres and nanometres.

- One micrometre (µm) is one millionth of a metre, or 10^{-6} m.
- One nanometre (nm) is one thousand millionth of a metre, or 10^{-9} m.

Plant and animal cells range in size from 5 to over 100 µm wide (see Figure 2.8).

Magnification and resolution

Light microscopes magnify objects about 1000 times and electron microscopes magnify objects up to 1 million times.

Microscopes enable us to distinguish two objects close together as separate objects; in other words, they allow us to see detail. The degree to which a microscope can do this is called its 'resolving power'. The resolving power of the human eye is 100 µm. If two points are 0.1 mm apart (100 µm), your eyes see them as two points; if they are any closer, they appear as one point.

The resolution of the light microscope can be up to 0.2 µm, or about 500 times better than the human eye. The resolution of the best electron microscope today is about 0.0002 µm, which is about 5 million times better than our eyes. The electron microscope gives us greater magnification of cells, with very clear details of their contents (Figure 2.8).

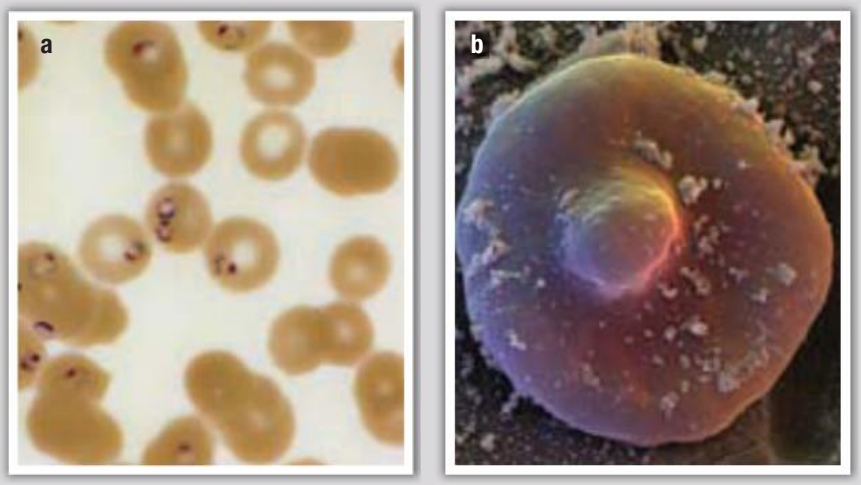


Figure 2.8 Human red blood cells infected with malaria under a light microscope ×2000 (a), and the same cells under an electron microscope ×23 000 (b).

Synchrotrons

Sometimes referred to as a 'supermicroscope', a **synchrotron** is a large facility that produces beams of very bright light used by scientists to examine matter at an atomic level.

In a synchrotron, electrons are emitted by an electron gun and then accelerated in a linear accelerator. They pass to a circular accelerator or booster synchrotron and then into a large, ring-shaped vacuum tunnel with a circumference of 1000 to 1500 metres. Magnets on the tunnel walls bend the electrons as they travel through the tunnel at almost the speed of light. This causes the electrons to emit radiation, which is formed into beams. The beams are then directed to experimental stations where scientists can use the radiation for research. Special mirrors, lenses and filters are used to focus and direct the radiation onto sample materials.

While the radiation produced spans the whole of the electromagnetic spectrum, synchrotrons can be designed to produce beams of specific wavelengths. Light of shorter wavelengths, such as ultraviolet (UV) light and X-rays, are particularly useful because they can be used to view atoms and molecules that are only a few nanometers in size. For biologists, the use of X-ray microscopes using synchrotron radiation is leading to a better understanding of cellular structures and biological systems at the molecular level. Both living and non-living samples can be examined, the arrangements of complex molecular structures such as proteins can be identified, and biochemical processes can be tracked.

There are about fifty synchrotrons worldwide. Australia's first synchrotron in Melbourne opened in 2007. For more information, visit the Australian Synchrotron website.

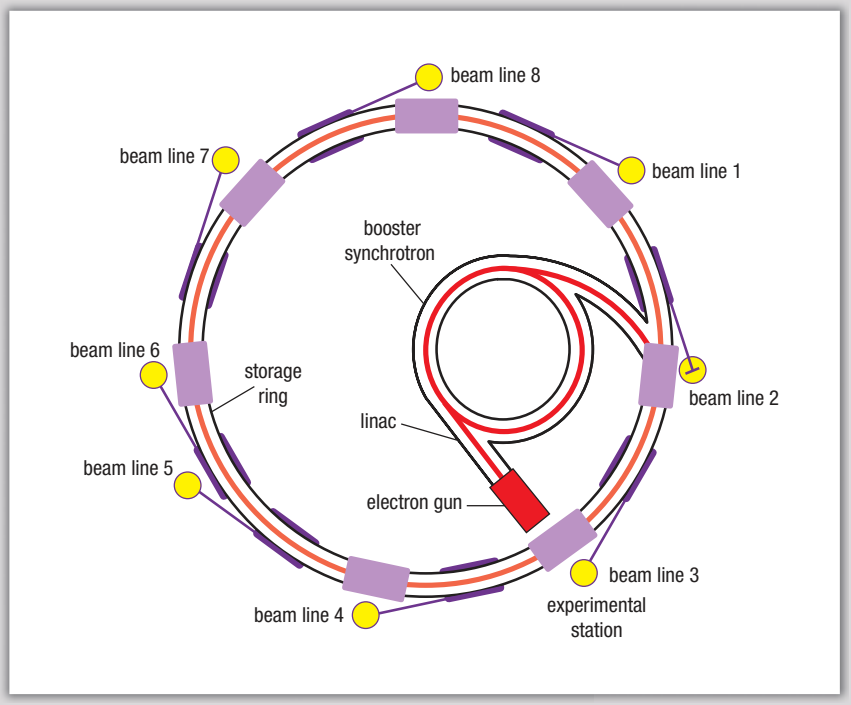


Figure 2.9 Plan view of a synchrotron. There is a station at the end of each beam line where scientists can use the radiation beam to examine samples at the molecular level.



Figure 2.10 The first synchrotron to be built in Australia. It is about the same size as a football field.

INVESTIGATION 2.1

Technology and the cell theory

Students will: use available evidence to assess the impact of technology, including the development of the microscope, on the development of the cell theory.

Skills and outcomes

P2, P3, P5, P14

Type of activity

Second-hand data investigation

Materials

- reference books, journals, Internet sites

See Analysing information

Introduction

The development of the cell theory occurred because of the investigations by scientists into the structure of living things. Over the past 400 years, new technologies have provided evidence that support the three statements that make up the cell theory.

In this investigation you are asked to assess the impact of technology on the development of the cell theory. Assessing involves making a judgement of the value of something—in this case, the impact of technology. To assess, you must first collect your evidence, then analyse it, and finally form an opinion or judgement about it.

Purpose

To assess the impact of technology on the development of the cell theory.

Procedure

1. Read pages 60–67, particularly Table 2.1 and the section titled 'The significance of technological advances'.
2. Use other available resources to research the early microscopists, their microscopes and preparation techniques for observing cells.
3. Use other available resources to research the work of current scientists, their microscopes and preparation techniques for observing cells.
4. Compare early diagrams of cells with modern images of cells.

Discussion

1. Suggest why there are no descriptions of cells in the writings of biologists 400 years ago.
2. The preparation of materials for viewing under the microscope typically involves four steps: fix, embed, slice, and stain. Outline how technologies have changed over time in these four areas.
3. The light microscope, electron microscope and X-ray microscope all contribute to our knowledge of cell structure. Briefly explain the contribution made by each of these microscopes.

Conclusion

Write a paragraph giving your assessment of the impact of technology on the development of the cell theory.

Cell contents

The cell under the light microscope

identify cell organelles seen with current light and electron microscopes

All cells have a clearly defined shape or boundary. This is maintained by a flexible cell membrane, which encloses the internal contents of the cell.

The light microscope revealed that cells are not empty, and that **protoplasm** (the contents of a cell) is not uniform in structure. Although cells show great variation, they have certain structures in common.

All cells have a clearly defined shape or boundary. This is maintained by a flexible **cell membrane**, which encloses the internal contents of the cell. Sometimes this membrane is called the **plasma membrane**.

The protoplasm inside most cells reveals definite structures, called **organelles** ('little organs'). Organelles have a particular job to do for the cell. They are either enclosed in or made up of membranes. Organelles and the cell membrane are continually changing, breaking down and reforming in a dynamic pattern of activity.

One organelle that can be seen with the light microscope is the **nucleus**. Inside the nucleus is a darker staining area called the **nucleolus**; the small threads which show up clearly in some nuclei, by staining, are the **chromosomes**. The contents of the cell between the nucleus and cell membrane is called the cytoplasm.

Cytoplasm looks like a clear fluid with particles in it. The clear fluid is known as the **cytosol**. Some of the particles or granules in the cytoplasm are easily visible with the light microscope, but others cannot be distinguished clearly. Some of the granules visible in the cytoplasm may be food reserves or **food vacuoles**. The food they contain, such as starch or oils, may be made visible by selective staining techniques.

With the best light microscopes, small structures called **mitochondria** (singular—mitochondrion) can be seen, but not in detail. The smaller details of internal cell structures are distinguishable only with an electron microscope.

When cells were first examined under the light microscope, it became apparent that there are two basic and commonly seen cell types. One is surrounded by a cell membrane only, and the other has a much thicker **cell wall** around it. Cell walls are non-living structures which give shape and rigidity to the cell they surround. The cell membrane still surrounds the internal cell contents, but is often not visible because it is pressed up against the cell wall.

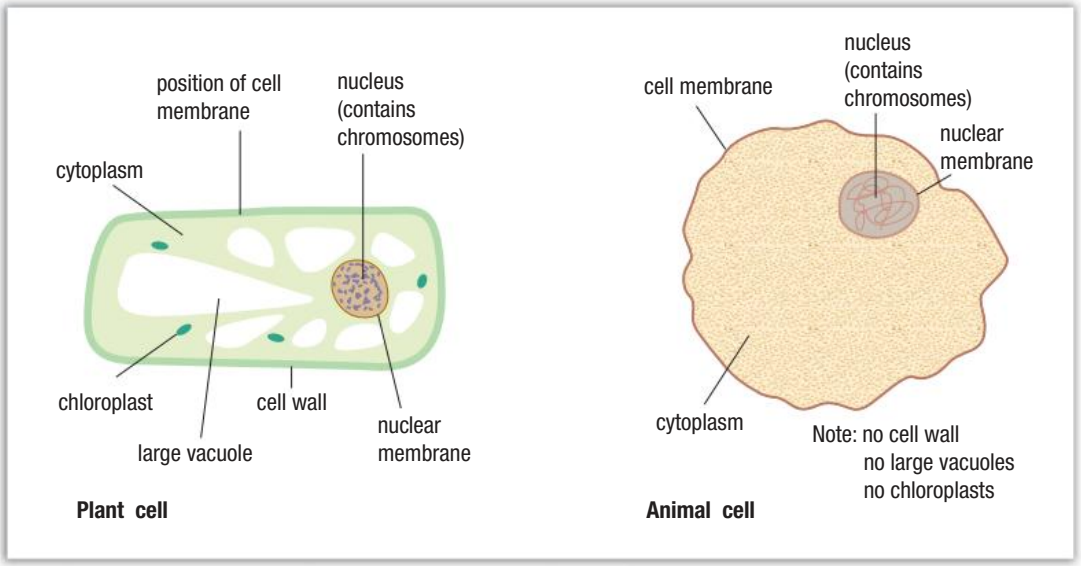


Figure 2.11 Generalised cells seen through a light microscope (×1000).

The cell wall, found in plant cells, consists of a network of cellulose microfibrils (long strands of cellulose molecules) in a cement of pectin and other substances.

The cell wall, found in plant cells, consists of a network of **cellulose** microfibrils (long strands of cellulose molecules) in a cement of pectin and other substances. **Lignin** (wood) may be one of these. The wall protects and supports the cell.

Many cells with cell walls may also contain large round or oval membrane-bound organelles, called **plastids**, which are easily seen in the cytoplasm. They are found only in cells taken from plants. Plastids often contain pigment. Green-coloured plastids or **chloroplasts** contain the pigment chlorophyll, which gives plants their green colour. **Chromoplasts** produce the colours of flowers and fruits, and **leucoplasts** store nutrients such as starch.

Vacuoles are sacs surrounded by a single membrane. Vacuoles may be temporary structures, such as food vacuoles, which contain substances brought into the cell from outside. Plant cells usually also contain a large central vacuole. It is filled with a fluid called the **cell sap**, which consists mainly of water and dissolved substances such as sugars, salts and sometimes coloured pigments. In some plant cells, the vacuole may occupy 80–90% of the total cell volume.

TABLE 2.2 Main cell structures visible with a light microscope

Name	Function
Nucleus	contains the chromosomes; the information in the chromosomes is used to control the development and functioning of the whole cell; without a nucleus most cells will die
Cell membrane	forms the boundary between the cytoplasm and the outside environment; controls the entry and exit of substances to and from the cell
Cytoplasm	contains many organelles; is where most cell activities are carried out
Cell wall	gives protection, support and shape; all plant cells have a cell wall
Chloroplasts	contain the green pigment chlorophyll; are the site of food manufacture (photosynthesis) in plants
Vacuoles	store water and other substances; are large and important in plant cells

TABLE 2.3 A comparison between plant and animal cells

Plant cells	Animal cells
cell walls made of cellulose	no cell walls
the cell has a definite outline and regular shape due to the cell wall	the cell has a more flexible and variable shape
although there is a wide variation in size, plant cells tend to be larger on average than animal cells	tend to be smaller than plant cells
chloroplasts present in many plant cells	chloroplasts never present
usually contain a large central vacuole	vacuoles not usual; if present, vacuoles are smaller and often temporary
no centrioles	centrioles present

2.2 INVESTIGATION
Observing cells using a light microscope

Students will: perform a first-hand investigation to gather first-hand evidence using a light microscope to observe cells in plants and animals, and identify the nucleus, cytoplasm, cell wall, chloroplast and vacuoles.

Introduction

In 1665, Robert Hooke used a rudimentary microscope to view living tissue and observe cells for the first time. The development of the light microscope was a significant event in our understanding of the structure of living things. It revealed that living things are made up of cells. It showed that although cells are very diverse in form, there are many common features shared by cells within an organism and between organisms, even those that are vastly different from one another.

Light microscopy also revealed the cell's ultrastructure—that is, structures with particular functions found within cells. These structures are called organelles. Only some of these organelles are large enough to be seen using the light microscope—for example, the nucleus, chloroplasts and vacuoles.

Purpose

To use a light microscope to observe a variety of plant and animal cells and identify cell organelles.

Procedure

Onion cells

1. Copy Table 2.4 into your workbook.
2. Remove the outer papery skin from an onion. Pull away one layer of the onion and place the layer, shiny side up, on a white tile. Make a cut into the surface of the shiny side. Use the forceps to pull away a small section of this shiny outer skin. Mount the section on a microscope slide. Add a drop of iodine and cover with a coverslip. Use a piece of paper toweling to soak up any excess iodine.
3. Focus under low power before viewing under high power.
4. Make a large labelled diagram of a cell as seen under high power.
5. Record your observations in Table 2.4. Use a tick to indicate an observed structure and a dash to indicate a structure you are not able to see.

Elodea leaf

1. Mount a leaf of Elodea on a microscope slide. Add a drop of water and cover with a coverslip. Use a piece of paper towel to soak up any excess water.
2. Focus under low power before viewing under high power.
3. Make a large labelled diagram of a cell as seen under high power.
4. Record your observations in Table 2.4.

Skills and outcomes

P1, P3, P12, P14

Type of activity

First-hand investigation

Materials

- light microscope
- microscope lamp
- onion
- Elodea leaf
- celery stem
- potato
- toothpicks
- microscope slides
- coverslips
- teat pipette
- small beaker of water
- white tile
- scalpel
- forceps
- iodine
- paper towel
- prepared slides of human cheek cells, muscle cells, nerve cells, squamous epithelium, blood, sperm

See First-hand investigations

TABLE 2.4 Recording your observations for each type of cell

Cell type	Size	Cell membrane	Cell wall	Nucleus	Cytoplasm	Vacuole	Chloroplast	Plant or animal

Caution

- Scalpel blades are very sharp. Take special care when using these instruments. Do not leave them close to the edge of your bench. Dispose of used scalpel blades in a sharps container.
- Take care with iodine. If you spill any on your skin, wipe it off and rinse the area well with water.

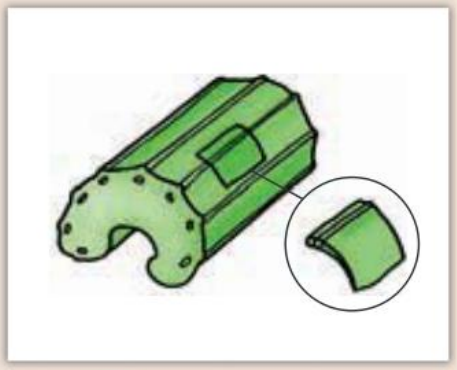


Figure 2.12 Cutting the celery stem.

Celery stem

1 Cut a small section (1 cm^2) of the surface layer of a celery stem, making sure to include a ridge (see Figure 2.12). Using a pair of forceps, pull away the cut section by grasping the cut ridge. A very thin layer of surface cells will be pulled away at the same time.
2 Mount in a drop of water and cut off the ridge using a scalpel. Place a coverslip over the specimen and soak up excess fluid using paper towel. View under low power. Locate a suitably thin section of the tissue (preferably one cell layer thick) and set your microscope to high power.
3 Make a large labelled diagram of a cell as seen under high power.
4 Record your observations in Table 2.4.

Potato cells

1 Cut a thin square of potato and remove the skin. Place the square on a white tile and cut a few very thin sections with the scalpel blade. You should aim to cut sections so thin that they are transparent. Choose the thinnest section to mount on a microscope slide. Add a drop of iodine. Place a coverslip over the specimen and soak up excess liquid with paper towel.
2 Focus under low power first, locating the thinnest section of potato. Set to high power.
3 Make a large labelled diagram of a cell as seen under high power.
4 Record your observations in Table 2.4.

Animal cells

1 View each of the prepared slides of animal cells in turn.
2 Make labelled diagrams and record your observations in Table 2.4.

Discussion

Using your diagrams and the completed Table 2.4:

1 List the similarities between plant and animal cells.
2 Outline the differences you have observed between plant and animal cells.
3 List some differences between plant cells.
4 List any differences between the animal cells you observed.
5 Draw a large labelled diagram of a typical animal cell and a large labelled diagram of a typical plant cell.

The cell under the electron microscope

Figure 2.13 shows cell structures visible with an electron microscope. You will see that it shows some organelles that are not visible with the light microscope; for example, the mitochondria.

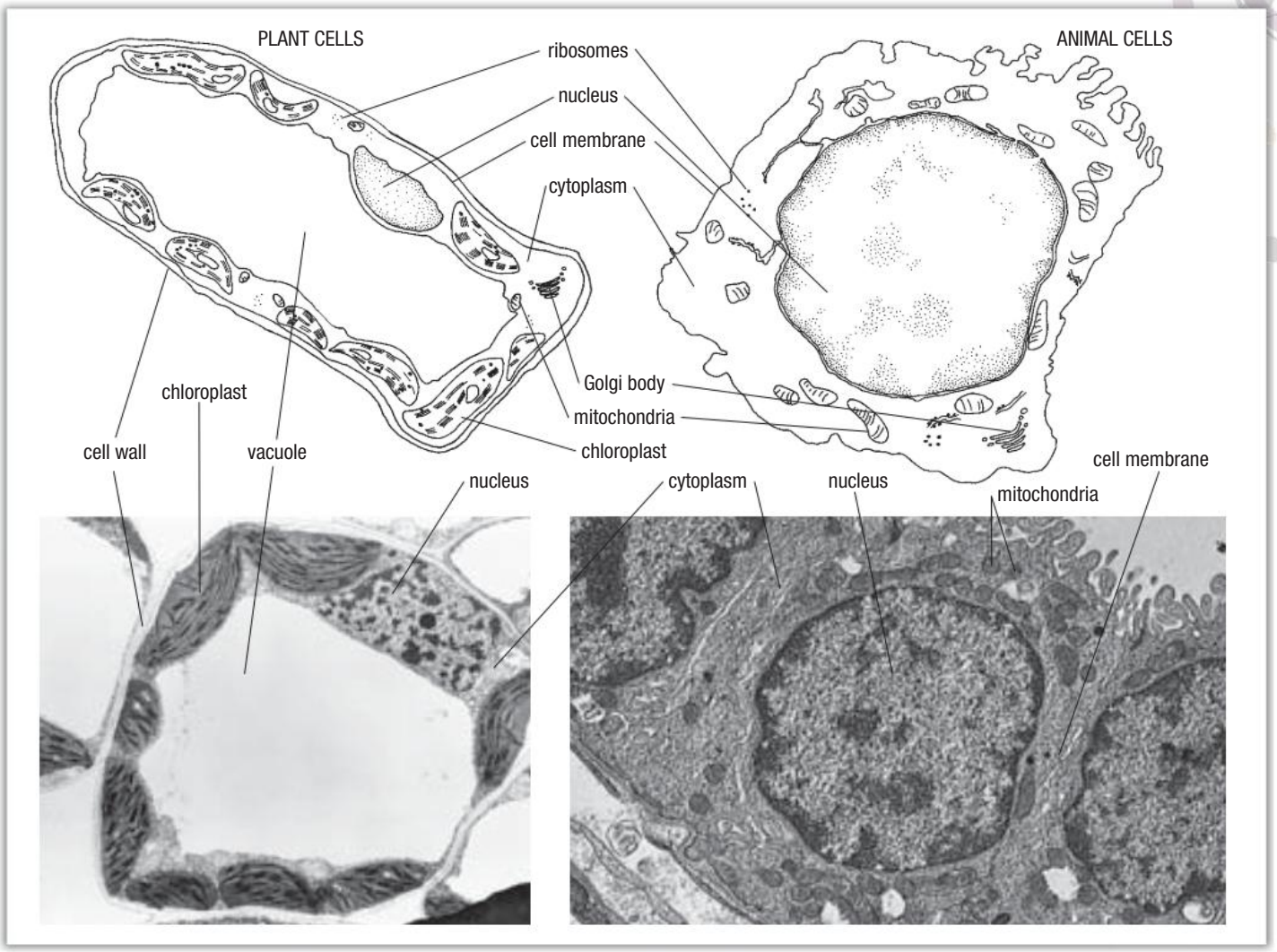


Figure 2.13 The parts of plant and animal cells.

Cell membrane: a complex structure which contains the cytoplasm and controls movement of substances into and out of the cell.

Cytoplasm: the fluid content of the cell. It is more than 90% water and contains ions, salts, enzymes, food molecules and organelles other than the nucleus.

Nucleus: a large organelle that is surrounded by a double layer of membrane. It stains differently from cytoplasm and so often looks darker in prepared slides. The nucleus contains genetic material and controls cellular activities.

Mitochondrion: an organelle composed of many folded layers of membrane. Michochondria are involved in the energy transformations that take place in cells.

Ribosomes: tiny organelles that are sites of production of proteins.

Golgi body: a stack of flat membrane sacs where final synthesis and packaging of protein in membrane-bound vesicles occurs before secretion.

Cell wall: a non-living cellulose structure outside the cell membrane in plant cells. The cell wall provides support, prevents expansion of the cells and allows water and dissolved substances to pass freely through it.

Vacuoles: membrane-bound structures found in most cells. They may contain food, enzymes or fluid. Plant cells typically have large fluid-filled vacuoles that provide support.

Chloroplasts: green organelles, found in those plant cells in which photosynthesis takes place. They are composed of many folded layers of membrane.

Organelles and their functions

describe the relationship between the structure of cell organelles and their function

Organelles are the functional units of cells. All organelles are surrounded by a membrane and have a particular job to do for the cell. Because they are surrounded by a membrane, they are easily identifiable.

The **nucleus** is spherical and relatively large in terms of other cell structures (see Figure 2.16). It is surrounded by a double membrane, called the nuclear envelope, which has pores in it to allow larger molecules in and out. The nucleus contains most of the genetic material of the cell. The nucleus controls the activities of the cell by controlling which proteins are made in the cell.

In a non-dividing cell, the genetic material is seen as **chromatin**. Chromatin is darkly staining material that is a combination of **DNA**, **RNA** and protein. The nucleolus is often a conspicuous structure. It is the region where the genes for ribosomal RNA are found and is the site of ribosome formation. When a cell is about to divide, the chromatin becomes compacted to form the chromosomes. The chromosomes contain the **genes**, the inherited information that determines whether proteins are made or not made (see *Heinemann Biology Third Edition HSC,* Chapter 2). At each end of a chromosome is a cap called a **telomere** (see Biofact p. 147). Telomeres prevent loss of DNA from the chromosome.

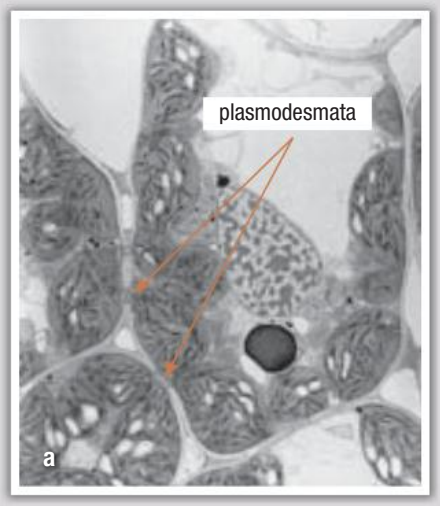
Intercellular connections

Tissues are organised groups of similar cells, which combine together to form organs—structures with particular functions. The connections between the cells in a tissue or organ are critical to its function.

Plant cells are separated from one another by cell walls, and adjacent cells are connected by plasmodesmata, which are cytoplasmic strands that pass along channels through the cell walls (Figure 2.14a).

Cells in animal tissues are held together by junctions between the cell membranes. These junctions fall into three main groups (Figure 2.14b). Dense fibrous connections (desmosomes) hold cells of a tissue together, giving it mechanical strength. Tight junctions between cell membranes limit the movement of fluid outside cells. For example, in the lining of the gut, tight junctions prevent the gut contents leaking out into the body. Gap junctions allow nutrients and ions to pass from the cytoplasm of one cell to another.

Cells in animal tissues communicate and transfer large molecules such as proteins and cell organelles between each other via very delicate structures known as tunnelling or membrane nanotubes.



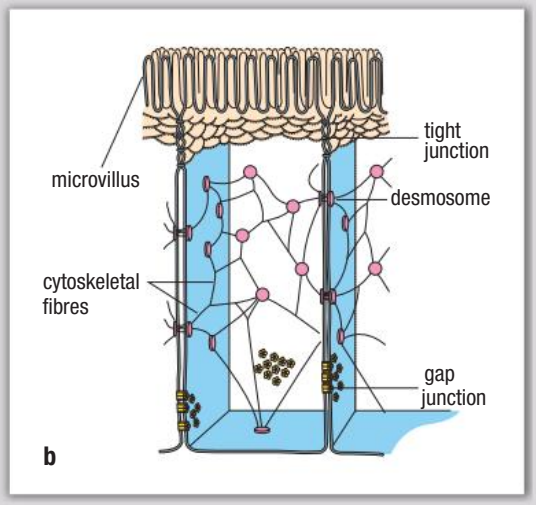


Figure 2.14 (a) A leaf cell, showing a plasmodesmata (×4000). (b) Diagram of an animal cell, showing a desmosome, tight junction and gap junction.

Mitochondria are usually about 0.5 µm wide and up to 7 µm long (see Figure 2.19). They are surrounded by a double membrane; the outer membrane is smooth, but the inner membrane is greatly folded. On these finger-like folds, called cristae (singular crista), the chemical reactions of respiration occur, producing energy for the cell. The folding greatly increases the surface area over which the reactions can occur. Mitochondria also contain ribosomes, DNA and RNA (see p. 85).

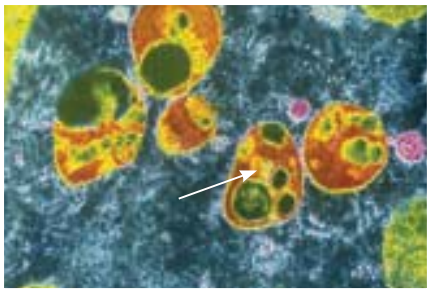


Figure 2.15 An electron micrograph showing a lysosome (arrow) in the process of breaking down unwanted material.

Lysosomes are small, spherical, membrane-bound organelles about 0.4 µm in diameter. They are very common in animal cells but are rare in plant cells. Lysosomes are very acidic and contain digestive enzymes. They fuse with vacuoles containing food or other substances that have been taken into the cell, or with old and damaged organelles within the cell, and digest them. If lysosome enzymes are released into the cell, they will break it down and destroy it.

Peroxisomes are small, spherical membrane-bound organelles between 0.5 and 1.5 µm in diameter (see Figure 2.20). They are found in both plant and animal cells. They contain enzymes that use oxygen to break down toxic materials in the cell, producing poisonous hydrogen peroxide. The hydrogen peroxide is immediately converted to oxygen and water. Peroxisomes also play a part in lipid metabolism and produce cholesterol. Once they reach a certain size they split into two.

Microtubules are tiny hollow tubes only about 25 nm in diameter. They help control the shape of the cell and assist with movement. Cytoplasmic extensions, such as **cilia** and **flagella**, consist of microtubules.

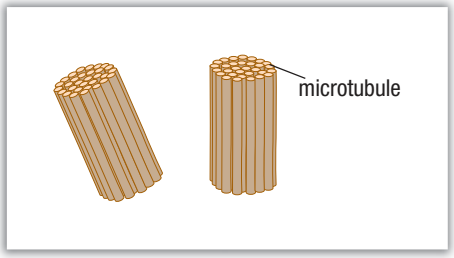


Figure 2.17 Centrioles consist of bundles of microtubules.

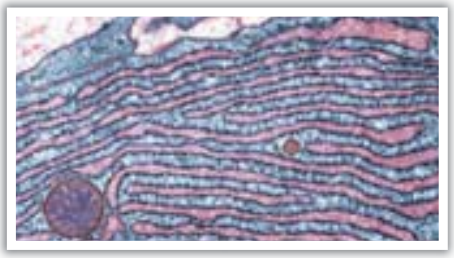


Figure 2.18 Rough endoplasmic reticulum from the intestine of a mouse (×24 000).

Centrioles are found in pairs in animal cells, and are made up of microtubules. They organise the formation of the spindle, also made of microtubules, during the process of mitosis. (This process is described on p. 143.)

The **endoplasmic reticulum** (which means 'a network inside the cell') is a system of membranous sacs and tubules that is connected to the nuclear envelope. It provides an internal surface for many of the chemical reactions in the cell, and a series of channels through which material can be circulated. 'Rough' endoplasmic reticulum has tiny grains (ribosomes) attached. Proteins are made in the ribosomes and transported from the endoplasmic reticulum to the Golgi body in **transport vesicles**. 'Smooth' endoplasmic reticulum has no

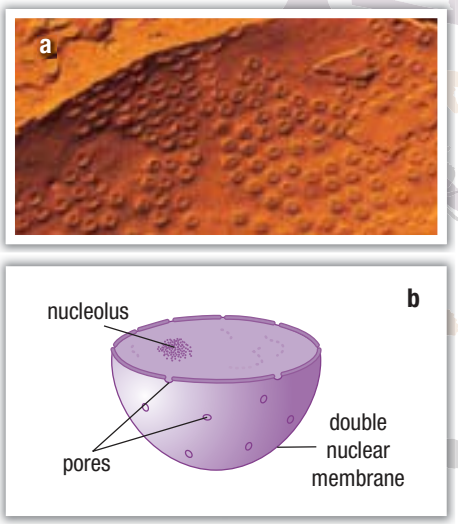
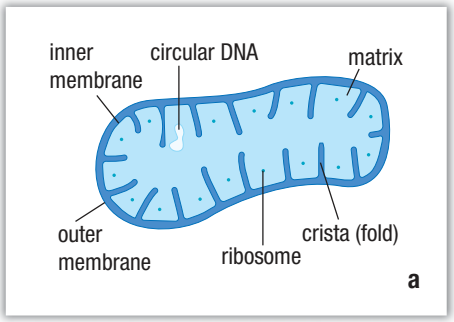


Figure 2.16 (a) Electron micrograph and (b) diagram of a nucleus, showing the nuclear pores.



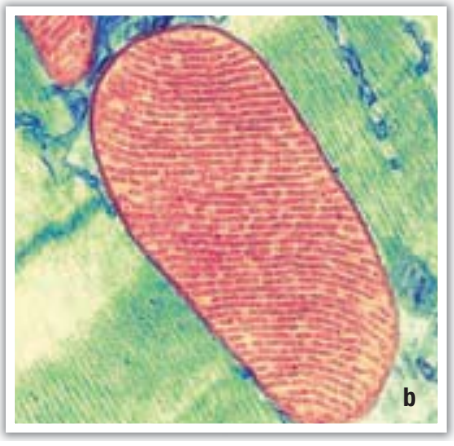


Figure 2.19 (a) Diagram of a mitochondrion. (b) A mitochondrion from a mouse's intestine (×28 000).

Organelles are the functional units of cells. All organelles are surrounded by a membrane and have a particular job to do for the cell.

ribosomes attached. It is the site of lipid manufacture and also helps to inactivate some drugs, such as alcohol and barbiturates.

Ribosomes are tiny spherical bodies made of RNA and protein, and are approximately 20 nm in size. They may be attached to the endoplasmic reticulum or lie freely in the cytoplasm. Each ribosome is made up of two sub-units, one large and one small. Ribosomes are made in the nucleolus area of the nucleus. They are the site of protein synthesis (manufacture).

The **Golgi body** (also called the Golgi apparatus or Golgi complex) consists of stacks of flattened membrane sacs. It chemically modifies, stores and distributes substances made by the endoplasmic reticulum. These are received in transport vesicles from the endoplasmic reticulum and repackaged, ready for secretion either into or out of the cell.

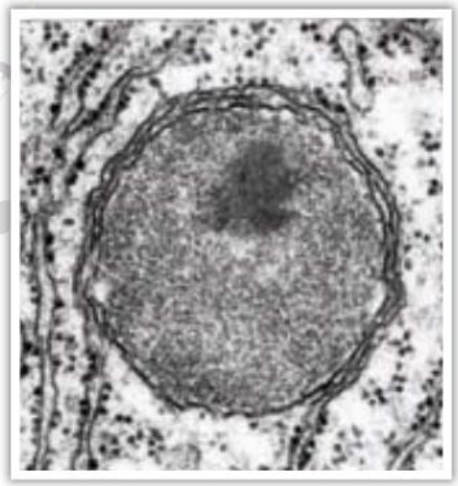


Figure 2.20 An electron micrograph of a peroxisome inside a cell.

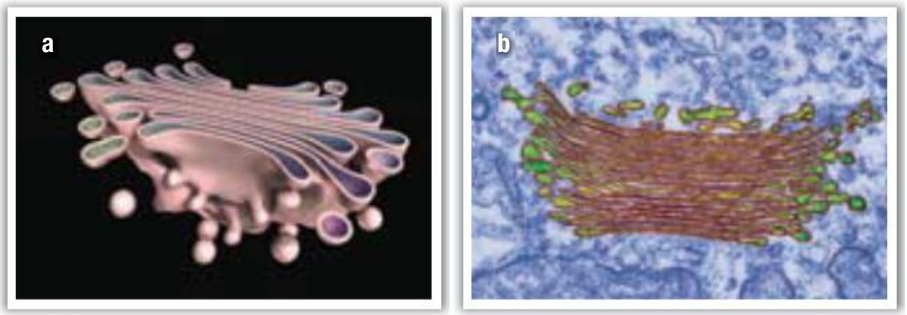


Figure 2.21 (a) A Golgi body. (b) Electron micrograph of a Golgi body in a cell from the intestinal wall of a mouse (×9000).

Chloroplasts are green plastids found only in green plant cells.

Chloroplasts are green plastids found only in green plant cells. They are 4–6 µm in diameter, surrounded by a double membrane. Their internal area, the stroma, contains a complex system of membranes or lamellae. Photosynthetic lamellae are also called **thylakoids**. These thylakoids occur in stacks called grana. The membranes of the thylakoids contain the chlorophyll pigments and enzymes needed for photosynthesis. They also contain ribosomes and DNA.

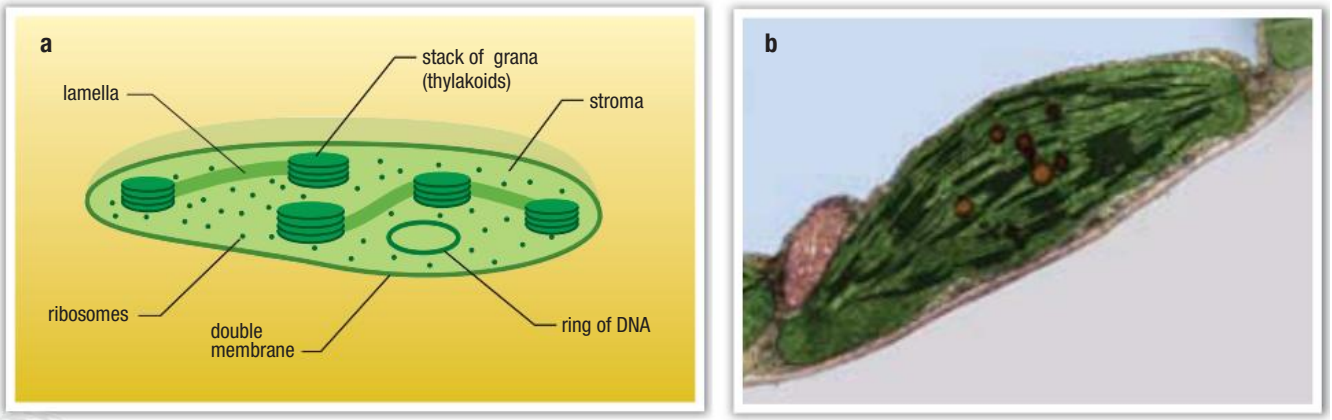


Figure 2.22 (a) Diagram of a chloroplast. (b) Chloroplast of a plant cell (×4500).

2.3 INVESTIGATION
Cells and the electron microscope

Students will: process information from secondary sources to analyse electron micrographs of cells and identify mitochondria, chloroplasts, Golgi bodies, lysosomes, endoplasmic reticulum, ribosomes, nucleus, nucleolus and cell membranes.

Introduction

The development of the electron microscope enabled cells and their contents to be seen in greater detail. Smaller organelles that could not be seen with a light microscope were discovered. Electron microscopes produce highly detailed photographs of specimens, called electron micrographs. Electron microscopy has opened the window on our knowledge and understanding of the fine ultrastructure of cells.

Purpose

To identify cell organelles of plant and animal cells by analysing electron micrographs.

Procedure

1 Copy Table 2.5 into your workbook.

TABLE 2.5 Organelles observed in electron micrographs of cells

Name of organelle	Size (µm)	Description	Function	Found in plant or animal cells?

2 Study the electron micrographs provided and the information about the different cell organelles on pp. 69–76.

3 Use your observations of the micrographs along with any information provided in the captions to complete Table 2.5.

Discussion

1 What is the structural characteristic that all cell organelles share?

2 Cell organelles are often described as the functional units of cells. What do you think is meant by this?

3 Draw up a table to compare the information about cells you are able to obtain with a light microscope with the information you are able to obtain from the electron micrographs.

Skills and outcomes

P1, P3, P12, P14

Type of activity

Second-hand data activity

Materials

- electron micrographs of various cell organelles

SKILLS See:
- Presenting information
- Analysing information

UNIT REVIEW 2.1

Organisms: cells and structure

Organisms are made of cells that have similar structural characteristics.

Summary

- The cell theory states that (1) cells are the smallest units of life, (2) all living organisms are made up of cells, and (3) all cells come from pre-existing cells.
- The cell theory was developed over several hundred years with contributions from many scientists, including Robert Hooke (in 1665) and Robert Brown (in 1831).
- Observations of the microscopic structure of living organisms provide evidence to support the cell theory.
- Technological advances in the development of microscopes and tissue preparation techniques have led to further development in our understanding of cell structure.
- Cell organelles that can be seen with present-day light and electron microscopes include the nucleus, mitochondria, lysosomes, microtubules, endoplasmic reticulum, ribosomes, centrioles, Golgi bodies and chloroplasts.
- Each type of organelle has a particular function in the cell, and its structure can be related to its function.

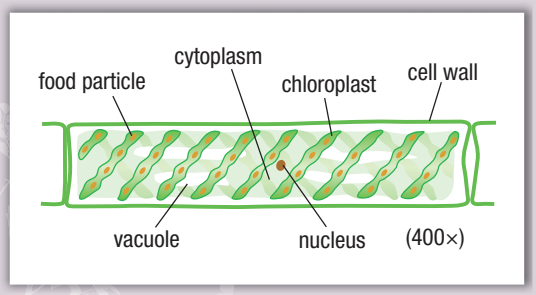
Questions

1 Which statement is true of the cell theory?

A All living things are made of cells.
B All cells come from pre-existing cells.
C Cells are the smallest units of life.
D All of the above.

2 Identify four cell structures visible with an electron microscope, but not a standard light microscope.

A Golgi body, ribosome, nucleolus, mitochondria
B nucleus, cell wall, chloroplast, vacuole
C cell membrane, ribosome, mitochondria, desmosome
D Golgi body, ribosome, chloroplast, plasmodesmata



3 Study this diagram of a cell seen under a microscope at magnification ×400. Identify three contents that suggest this is a diagram of a plant cell.

A food particles, cell wall, chloroplasts
B cell wall, chloroplasts, large vacuole
C cytoplasm, cell wall, cell membrane
D food particles, nucleus, large vacuole

4 Outline the contributions of Robert Hooke and Robert Brown to the development of the cell theory.

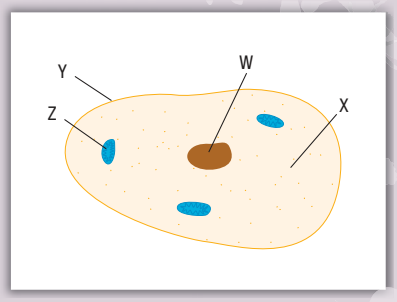
5 The cell theory is accepted by scientists today. Outline the evidence that supports the cell theory.

6 Discuss the role of technology in the development of the cell theory.

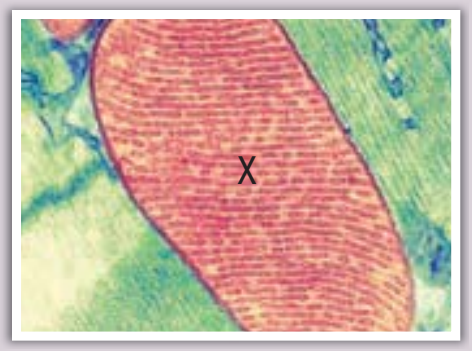
7 Describe two major differences between light microscopes and electron microscopes. For each difference, indicate whether this is an advantage or disadvantage when viewing cells and cell structures.

8 a Identify the structures labelled W, X, Y and Z on the diagram of the cell shown to the right.

b Describe the function of each of the organelles you have identified in (a).



9 Study the following electron micrographs.







a Name each of the organelles labelled X, Y and Z.

b Describe the function of each organelle.

c Discuss the relationship between the structural features shown and the function you have stated.

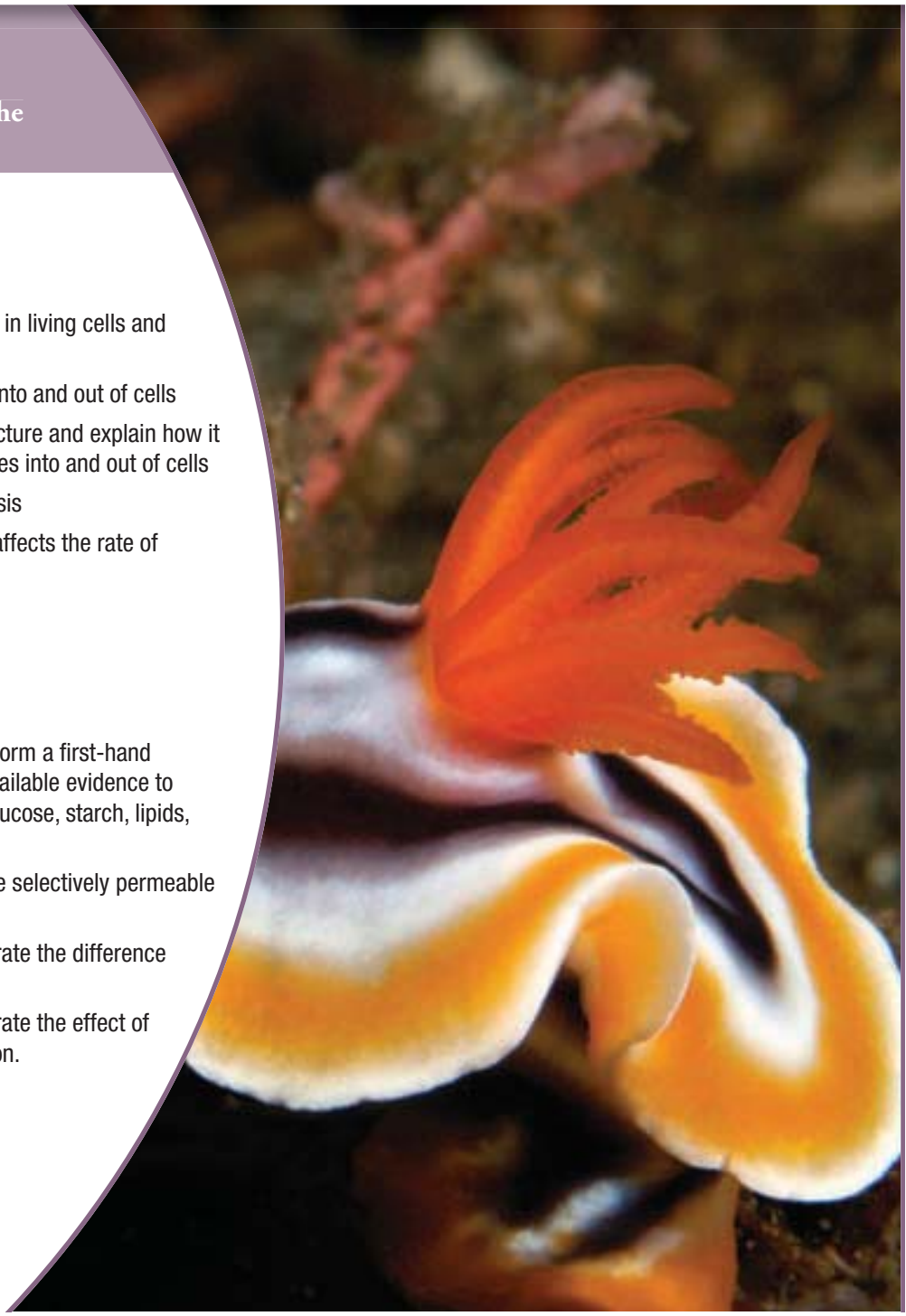
10 Match the term listed in the left column with its correct description or role in the right column.

Structure	Description
organelle	dark-staining area within nucleus
protoplasm	membrane-bound sac within cytoplasm; can contain dissolved nutrients or wastes for storage
cell wall	small spherical body; site of protein production
nucleolus	sub-cellular structure with a particular function
vacuole	rigid cellulose structure surrounding plant cells; provides support for cells
chloroplast	contents of cell
ribosome	stack of flattened membrane sacs that stores and distributes substances within cell and secretes substances out of cell
Golgi body	green plastid found in plant cells; site of photosynthesis

11 From the evidence you have found in this unit of work, decide what have been the technological advances most important to the development of the cell theory. Justify your opinion.

2.2 CELL MEMBRANES: FORM AND FUNCTION

Membranes around cells provide separation from and links with the external environment.



STUDENT LEARNING

In this unit students will:

- identify the major groups of substances found in living cells and their uses in cell activities
- identify that there is movement of molecules into and out of cells
- describe the current model of membrane structure and explain how it accounts for the movement of some substances into and out of cells
- compare the processes of diffusion and osmosis
- explain how the surface area to volume ratio affects the rate of movement of substances into and out of cells.

STUDENT ACTIVITY

Students will:

- plan, choose equipment or resources and perform a first-hand investigation to gather information and use available evidence to identify the following substances in tissues: glucose, starch, lipids, proteins, chloride ions and lignin
- perform a first-hand investigation to model the selectively permeable nature of a cell membrane
- perform a first-hand investigation to demonstrate the difference between osmosis and diffusion
- perform a first-hand investigation to demonstrate the effect of surface area to volume ratio on rate of diffusion.

The substances in cells

identify the major groups of substances found in living cells and their uses in cell activities

All substances are either organic or inorganic. Living things are composed of organic substances, but they also contain inorganic substances.

Organic molecules always contain carbon atoms. The major groups of organic molecules found in cells are carbohydrates, lipids, proteins and nucleic acids.

Inorganic molecules do not usually contain carbon atoms and are found in living and non-living things. Some simple carbon compounds, including carbon dioxide (CO_2), are often considered to be inorganic even though they contain carbon.

Inorganic substances

Organic molecules always contain carbon atoms.

Inorganic molecules do not usually contain carbon atoms and are found in living and non-living things.

Cells contain the following inorganic substances: water, oxygen and salts. Examples of salts are chlorides, phosphates and sulfates of various metals such as sodium, potassium and calcium. These salts are usually present in the form of ions (Table 2.6). For example, sodium chloride or common salt (NaCl) dissolves in the water in the human body, forming sodium ions (Na^+) and chloride ions (Cl^-).

TABLE 2.6 How the human body uses some inorganic substances

Name	Symbol	Use in the body
calcium ion	Ca^{2+}	builds strong bones and teeth; helps blood clotting and proper nerve and muscle functions
iron ion	Fe^{2+}	carries oxygen (attached to haemoglobin in red blood cells)
oxygen gas	O_2	used to release energy in respiration
phosphate ion	PO_4^{3-}	part of ATP, the substance that stores energy; also found in nucleic acids and bones
sodium ion	Na^+	functioning of nerves

Water (H_2O) is the most abundant inorganic compound in the body. About 70% of the body's molecules are water molecules. Water is needed by all cells. Most of the substances involved in cell chemistry are dissolved in water. For example, most nutrients and wastes dissolve in water in the blood, which transports them around the body to the various sites where they are either used or eliminated. Water is required for many cell processes, and is also often produced as a result of them.

Organic substances

Carbohydrates

Carbohydrates are compounds consisting of carbon, hydrogen and oxygen atoms (C, H and O).

Carbohydrates are compounds consisting of carbon, hydrogen and oxygen atoms (C, H and O). The general formula for carbohydrates is $(CH_2O)_n$ where n can be any number. Thus the ratio of hydrogen to oxygen is 2 : 1, as in water (H_2O).

Carbohydrates are important sources of energy in cells; they are broken down to glucose when energy is required. When humans eat more carbohydrate than they need, it is converted to fat and stored. The body never wastes energy; any excess is stored as fat under the skin or around the organs. To lose weight, less energy must be taken in than is needed, so that the fat stores are used up. Some carbohydrates are important in cell structure; for example, plant cell walls are made of a complex carbohydrate called cellulose.



Figure 2.23 Some animals store fat in specialised body parts. The fat-tailed dunnart (*Sminthopsis crassicaudata*) survives over winter by using fat stored in its swollen tail.

Monosaccharides are the simplest carbohydrates, consisting of single units of sugar.

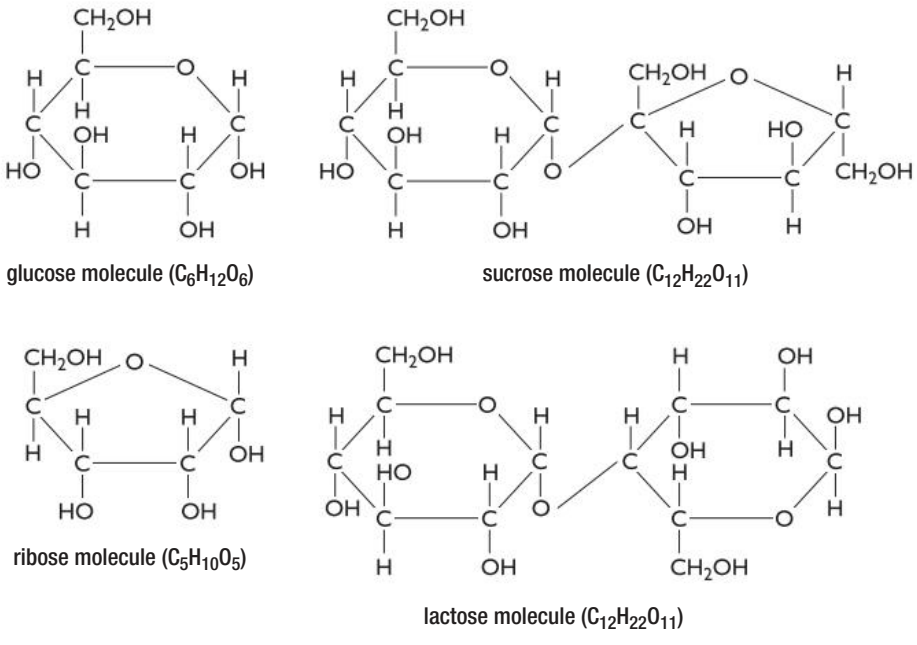
Disaccharides are also simple carbohydrates, consisting of double units of sugar.

Monosaccharides and disaccharides

There are three groups of carbohydrates: monosaccharides, disaccharides and polysaccharides. **Monosaccharides** are the simplest carbohydrates, consisting of single units of sugar. They include glucose, the 'instant energy' in many sports drinks; fructose, a sugar in fruits; and ribose, a sugar in nucleic acids. All the monosaccharides are soluble in water. Monosaccharides are the basic building blocks of more complex carbohydrates.

Disaccharides are also simple carbohydrates, consisting of double units of sugar. They include **sucrose** (table sugar), which consists of a glucose molecule and a fructose molecule joined together. Lactose (milk sugar) contains one molecule of glucose linked with one molecule of galactose; **maltose** contains two linked molecules of glucose.

Figure 2.24 Some monosaccharides and disaccharides.



When two organic molecules link up, a water molecule is produced. This reaction is called **condensation**.

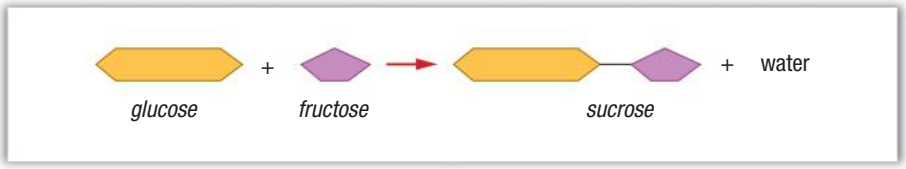


Figure 2.25 The process of condensation.

Polysaccharides

Polysaccharides are complex carbohydrates consisting of multiple sugar units condensed to form huge molecules. **Starch** is a polysaccharide that is the main food store in plants such as potatoes and beans. One starch molecule contains 2000–3000 condensed glucose molecules. Cellulose, the main component of plant cell walls, contains more than 2000 condensed glucose molecules. Polysaccharides are insoluble in water.

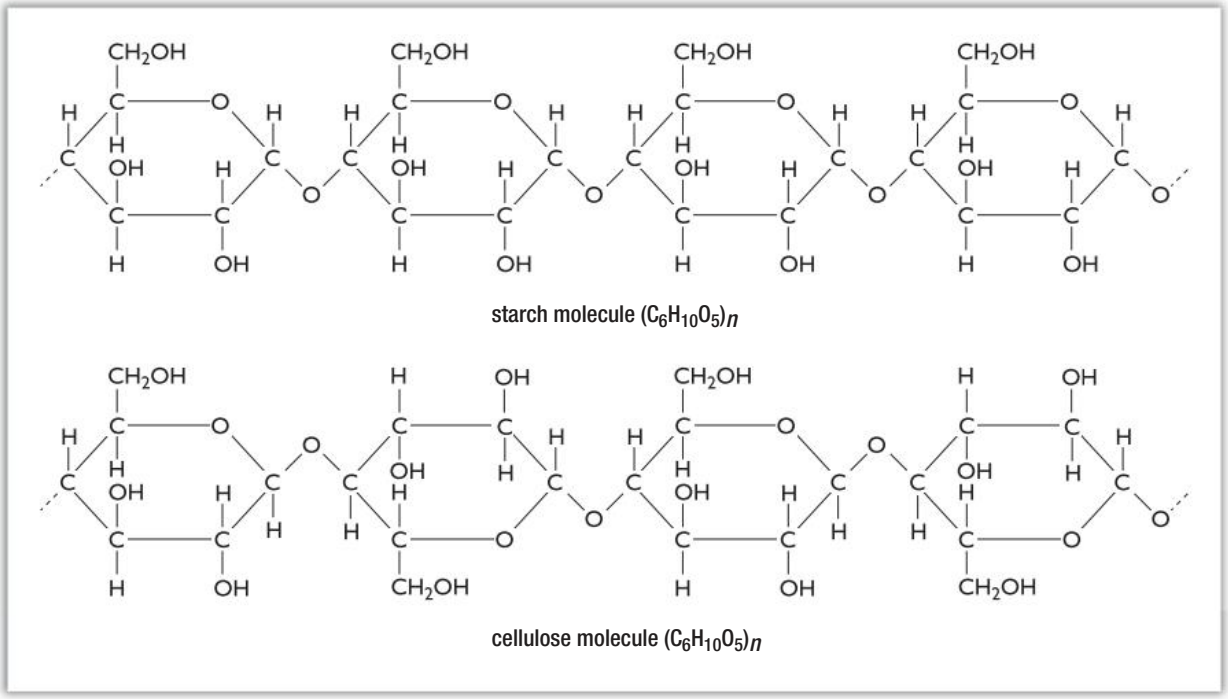


Figure 2.26 Two polysaccharides: starch and cellulose.

Lipids

Lipids contain carbon, hydrogen and oxygen (C, H and O), but the ratio of H to O is never 2 : 1. There is very little oxygen in lipid molecules. A typical lipid in your body has the structure shown in Figure 2.27. Lipids are usually insoluble in water. This large group of organic molecules includes fats, oils, waxes and steroids. Fats contain more than twice the energy of carbohydrates.

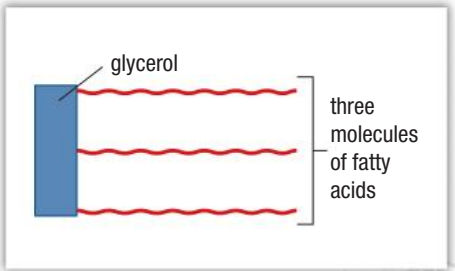


Figure 2.27 A triglyceride: a typical lipid.

TABLE 2.7 Some lipids and their properties and uses

Lipid	Properties	Uses
fats	usually solids at 20°C; highly saturated molecules; common in animals	used as stores of energy, e.g. fat tissue
oils	usually liquids at 20°C; unsaturated molecules; common in plants	used as stores of energy, e.g. coconut oil
waxes	more common in plants than animals	used as waterproof coatings on leaves and fruits, e.g. the leaf cuticle
steroids	have many important roles in plants and animals	form part of membranes, e.g. cholesterol; coordinate an animal's functions, e.g. cortisone and sex hormones

Proteins

Proteins are the most abundant organic molecules in cells, and they are needed by the body for growth and repair. Proteins contain atoms of carbon, hydrogen, oxygen and nitrogen (C, H, O and N). They are large molecules made up of smaller molecules called **amino acids** joined together by **peptide bonds** to form a **polypeptide**.

A polypeptide may contain between 50 and 1000 amino acids linked in various sequences. Polypeptide chains fold and twist into various shapes (Figure 2.28).

There are 20 different amino acids in cells, and they can combine in many different ways. To give you an idea of the number of possible combinations, imagine the number of words you could make using a 20-letter alphabet.

The 20 amino acids are:		
alanine	arginine	asparagine
aspartic acid	cysteine	glutamic acid
glutamine	glycine	histidine
isoleucine	leucine	lysine
methionine	phenylalanine	proline
serine	threonine	tryptophan
tyrosine	valine	

Proteins are large molecules made up of smaller molecules called amino acids joined together. The bonds linking the amino acids are called peptide bonds. A chain of linked amino acids is called a polypeptide.

The name 'protein' means 'most important'. Proteins are certainly very important to cells: the structure and function of cells depend on the proteins from which they are made.

The structure of proteins

A protein consists of one or more polypeptide chains. Different amino acids in the polypeptides have different side groups attached, and these side groups behave in particular ways. Some side groups are attracted to the water around them, some are attracted to other side groups in the chain, and others are repelled by the water or by neighbouring side groups. This occurs spontaneously.

All the competing forces interact to produce a particular shape of protein molecule which is stable and specific to that molecule.

The three-dimensional shape of the protein molecule causes particular side groups to be exposed, and these determine the chemical behaviour of the protein.

BIOFACT

Spider webs, silk, wool and feathers all consist of proteins. Feathers consist mostly of the same protein, keratin, that also makes up human nails and hair.

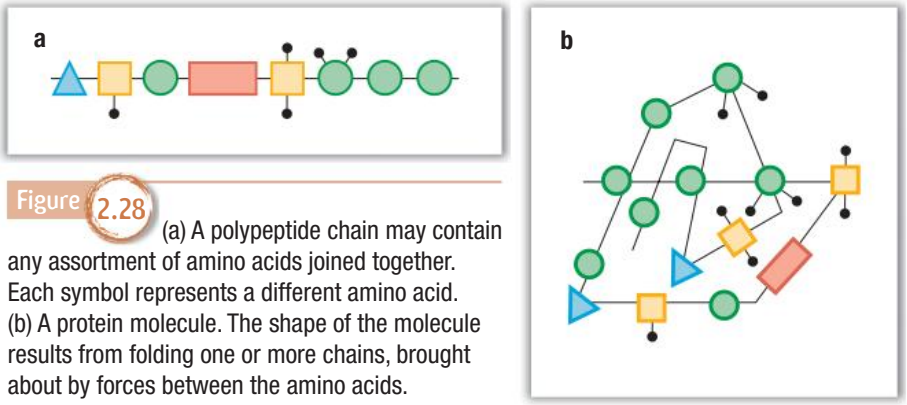


Figure 2.28 (a) A polypeptide chain may contain any assortment of amino acids joined together. Each symbol represents a different amino acid. (b) A protein molecule. The shape of the molecule results from folding one or more chains, brought about by forces between the amino acids.

The primary protein structure is the unique sequence of amino acids forming a polypeptide chain.

The secondary structure is the initial folding or coiling of the polypeptide chain.

The tertiary structure is the linking between side chains to form the final specific shape of the protein.

The quaternary structure is the final shape of a protein if more than one polypeptide chain makes up the protein.

For example, it determines the shape and nature of the active site of an enzyme, the electric charge and the **pH** (acidity) on the outside of the molecule (see *Heinemann Biology Third Edition HSC,* Chapter 1), and whether it is attracted to oils or water. When a protein is heated, the atoms within may move apart, and the three-dimensional structure may be altered. This results in an alteration of the protein's behaviour, a process called **denaturing**. You can observe this when egg white, which is made of protein, is cooked and 'sets'.

Nucleic acids

Nucleic acids are organic molecules which contain linked sugar molecules, nitrogen bases and phosphate groups. These molecules play an important part in determining heredity. Figure 2.29 represents the structure of a nucleic acid. The base–sugar–phosphate unit is called a **nucleotide**; it may be repeated hundreds of times or more in one nucleic acid molecule. There are two types of nucleic acid. Deoxyribonucleic acid (DNA) is mostly found in the chromosomes. Ribonucleic acid (RNA) is found throughout the cell and is needed for the manufacture of proteins.

Both contain a pentose (5-carbon) sugar. RNA contains the sugar ribose. DNA contains the sugar **deoxyribose** (ribose with some oxygen missing).

Nucleic acids are organic molecules which contain linked sugar molecules, nitrogen bases and phosphate groups.

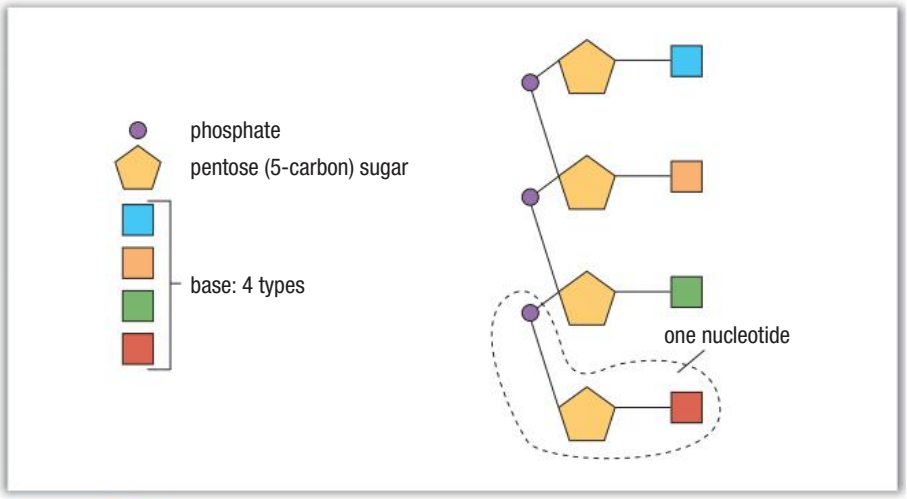


Figure 2.29 The structure of a nucleic acid.

INVESTIGATION 2.4
Chemical substances found in tissues

Students will: plan, choose equipment or resources and perform a first-hand investigation to gather information and use available evidence to identify the following substances in tissues: glucose, starch, lipids, proteins, chloride ions and lignin.

Skills and outcomes

P11, P12, P13, P14, P15

Type of activity

First-hand investigation, student-design activity

Materials

- chemical reagents as shown in Table 2.8
- safety glasses
- scalpels
- slides and coverslips
- Bunsen burner, spirit burner and matches
- mortar and pestle
- small test-tubes
- test-tube peg
- pipettes
- light microscope
- plant and animal tissues—for example, peas, potatoes, peanuts, apple, celery, woody stem material, raw fish or meat

See First-hand investigations

Introduction

The following table provides information about how to chemically test for various substances found within tissues.

TABLE 2.8 Testing for substances

Test for	Reagent to test with	Treatment	Positive result
protein	Biuret—sodium hydroxide and copper sulfate solutions	Add a few drops to sample. If using separate solutions, add sodium hydroxide and then copper sulfate.	purple
glucose	Clinistix	Rest paper on moist sample for ten seconds.	blue
	Tes Tape	Rest paper on moist sample for ten seconds.	green
	Benedict's solution	Add a few drops to sample and warm.	orange–red
starch	iodine	Add a few drops to sample.	blue–black
lipid	brown paper	Rub sample on paper.	translucent mark
chloride ions	silver nitrate (1%) Caution: this solution stains	Add a few drops to sample solution.	white precipitate
lignin	phloroglucinol/ HCl	Add a few drops to sample, leave for 10 minutes.	red

Purpose

To plan and perform an investigation to identify chemical substances in living tissues.

Procedure

1 Use Table 2.8 and the materials listed to design your own investigation to identify the substances found in a named tissue.

2 List all the materials and equipment you will require. Write down details of how you will conduct your investigation. Include any preparations, precautions, safety equipment and safety measures.
3 Design a results table that will help you accurately record all the data you are hoping to analyse at the completion of the investigation.
4 You may want to section some of the material. Practise your method to ensure that thin slices are obtained. After staining, mount in a drop of water or glycerine for observation under the microscope.
5 Carry out your investigation and record the results you obtain.
6 If time allows, repeat with a different tissue sample.
7 Write up your investigation to include a Title, Purpose, Materials list, Procedure, Results and Conclusion.

Discussion

1 For each tissue, try to explain the positive or negative results in terms of the tissue's function in the living organism.
2 Compare your results with the tissues tested by other groups. What differences were there? Try to explain these in terms of the type and function of the tissues.
3 Testing tissue with chemical reagents requires care, and results are variable. From your experience, to assist students who will conduct this investigation in the future, give:
   a two safety tips
   b two ways to improve the validity of the results.

Caution

- Handling chemicals (especially acids) must always be done with care. Clean up spills immediately. Wash your hands after handling chemicals. Wear safety glasses.
- Wash your hands after handling plant and animal tissues, especially raw fish and meat. Dispose of materials as directed by your teacher.

The movement of molecules

Molecules move in and out of cells. Living cells are continually exchanging materials with their external environment.

identify that there is movement of molecules into and out of cells

Membrane structure: the fluid mosaic model

Every cell is surrounded by the cell (or plasma) membrane. The cell membrane regulates the flow of substances into and out of the cell. It is differentially or **selectively permeable**; that is, only certain substances can cross it. Cell membranes appear to be dynamic structures that can form, reform and change. The **fluid mosaic model** (Figure 2.30) has been proposed to best account for these features.

describe the current model of membrane structure and explain how it accounts for the movement of some substances into and out of cells

It is known that the cell membrane is composed of about 40% lipid and 60% protein. According to the fluid mosaic model, the cell membrane is a thin sheet composed of two layers like a sandwich (a 'bilayer') of special lipids called **phospholipids**. The sheet is very fluid and the phospholipids can move about

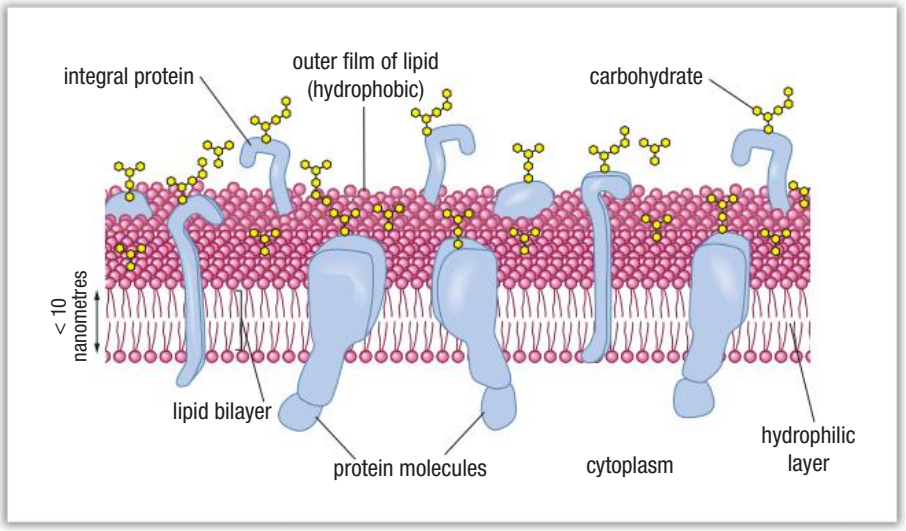


Figure 2.30 The fluid mosaic model of membrane structure.

quite easily within it. Other lipids such as cholesterol are also found within the membrane. Phospholipids have a 'hydrophilic' (water-loving) phosphate portion that can dissolve in water. Phospholipids also have a 'hydrophobic' (water-hating) lipid portion that repels water and is soluble only in fats. The lipid portions are attracted to each other and line up in the centre of the sandwich (Figure 2.30).

Proteins are scattered throughout the lipid bilayer. These are of two types: integral proteins which span the membrane, and peripheral proteins which are attached to the integral proteins on the inside or the outside of the membrane. The proteins are also capable of movement within the membrane.

This structure accounts for the way that membranes prevent or allow materials to move across them by both passive and active means, as described below.

Diffusion is the passive movement of molecules from a region where the concentration of those molecules is high to a region where the concentration is low.

Diffusion

Diffusion is very important to living cells. It is one way they take in materials from the environment; it is also one way they rid themselves of unwanted materials produced in the cell. A diffusion gradient exists whenever two areas have different concentrations of a substance; the substance moves until the two concentrations are equal. This requires no energy. Movement requiring no energy is known as **passive transport**. Water, oxygen, carbon dioxide and other small ions and molecules can diffuse freely through cell membranes (Figure 2.31).

Facilitated diffusion

Facilitated diffusion is a type of passive transport in cells in which substances are moved down a concentration gradient by 'carrier proteins' in the cell membrane.

The membrane is a barrier to many water-soluble substances, such as glucose, urea and many ions. However, some fat-soluble substances such as oxygen, carbon dioxide and alcohol can cross the membrane. The proteins and cholesterol that are able to move within the membrane also affect its permeability. This is why it is called a selectively permeable membrane—it lets some molecules through, but not others.

Membranes thus control separation from, and links with, the external environment.

Osmosis

Osmosis is a special case of passive transport involving the diffusion of water molecules across a selectively permeable membrane. Water will move by diffusion from an area where there is more of it to an area where there is less of it. This results in the movement of water from a dilute (less concentrated) solution to a stronger (more concentrated) solution. This process is how water enters or leaves cells.

Diffusion and osmosis compared

Both osmosis and diffusion involve the passive spreading of molecules from regions where they are more concentrated to regions where they are less concentrated.

Osmosis is the movement of a solvent, usually water, through a semipermeable membrane. The membrane allows the solvent through, but not larger molecules. The solvent moves across the membrane from where it is in high concentration to where it is in low concentration, until the two concentrations are equal.

Diffusion is the movement or spreading out of any type of molecules, whether liquid or gas, from where they are more concentrated to where they are less concentrated. Diffusion occurs whether or not a membrane exists.

Two solutions of equal concentration are said to be isotonic; a more concentrated solution is hypertonic and a more dilute solution is hypotonic.

compare the processes of diffusion and osmosis

Osmosis is the movement of water molecules across a selectively permeable membrane from a dilute solution (where the number of water molecules is high) to a more concentrated solution (where the number of water molecules is lower).

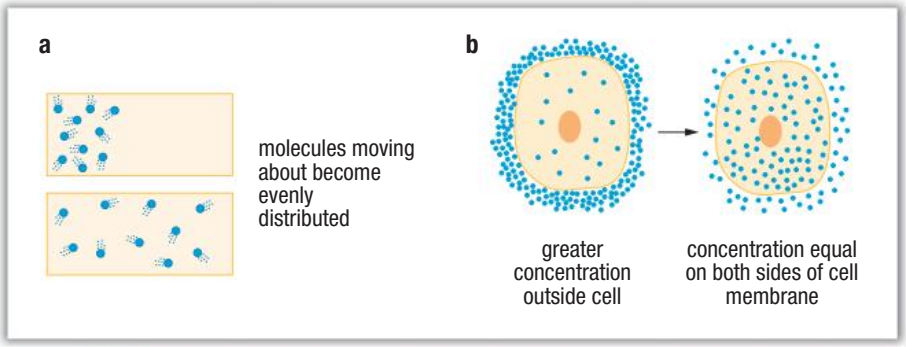


Figure 2.31 The process of diffusion. (a) Molecules move from regions of higher concentration to regions of lower concentration. (b) If the concentration is higher outside the cell, molecules will diffuse through the cell membrane into the intracellular fluid.

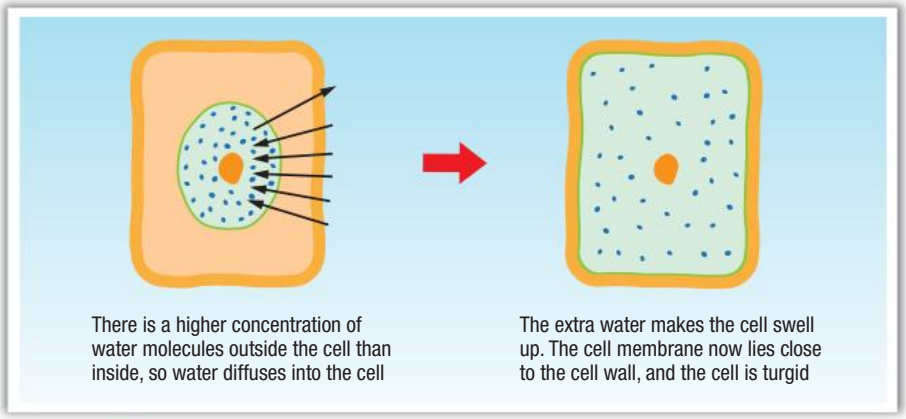


Figure 2.32 Osmosis in a plant cell.

INVESTIGATION 2.5

Modelling a cell membrane

Students will: perform a first-hand investigation to model the selectively permeable nature of a cell membrane.

Skills and outcomes

P2, P12, P13, P14, P15

Type of activity

First-hand investigation

Materials

- bag made of netting, such as a string bag, or plastic fruit bag
- tray or small carton
- a selection of different materials such as beads, balls, small plastic objects, seeds, dried beans, grains, for example, rice, which differ in size and shape

See First-hand investigations

Introduction

All cells are surrounded by a cell membrane which regulates the movement of substances into and out of the cell.

Cell membranes are selective and allow some molecules through, but not all. They are selectively permeable.

Purpose

To perform a first-hand investigation to model the selectively permeable nature of a cell membrane.

Procedure

1. Hold the netting bag suspended over the carton.
2. Place a selection of the materials provided inside the bag.
3. Gently shake the bag.
4. Observe what happens to the contents of the bag.

Results

Write a statement describing the result you observed.

Discussion

1. Is the bag permeable to all its contents?
2. Is the bag selectively permeable? Justify your answer.
3. What property of the bag made it select one material over another?
4. If the bag were a cell membrane, what other properties might affect its ability to select which materials move through and which do not?
5. What properties of the materials might affect their ability to move through the cell membrane?
6. What are the advantages and disadvantages of using models to demonstrate processes from living cells?

2.6 INVESTIGATION

Diffusion and Osmosis

Students will: perform a first-hand investigation to demonstrate the difference between osmosis and diffusion.

Introduction

Diffusion is an important biological process. Among other things, it is the process by which gases are exchanged in the lungs and in the leaves of green plants. The spreading of molecules of any substance from regions of high concentration to regions of low concentration is known as diffusion.

In a solution, the solute is the substance being dissolved and the solvent is the substance in which the solute dissolves. Water is the most common solvent in cells. In the first activity, solute molecules (potassium permanganate) are dissolved in a solvent, water. The solute molecules are coloured, so their movement can be followed.

Cell membranes are known to be selectively permeable—that is, they will let certain small molecules such as water pass through them, while excluding larger molecules.

The movement of water molecules across a selectively permeable membrane is known as osmosis. The movement of water from the soil into the root hair cells of plants is one example of osmosis (see pp. 107–108).

In the second activity, brown iodine/potassium iodide solution is used to show where water moves in a model of a cell. On contact with starch, a blue–black colour appears.

Purpose

To observe and compare examples of diffusion and osmosis.

Procedure

1. Half fill a 600 mL beaker with water and leave it where it will be undisturbed. Wait 5 minutes to let the contents settle.
2. Using the straw, carefully position a crystal of solute at the bottom of the beaker as shown in Figure 2.33. Try not to disturb the water as the straw is withdrawn, and leave the beaker for at least 5 minutes.

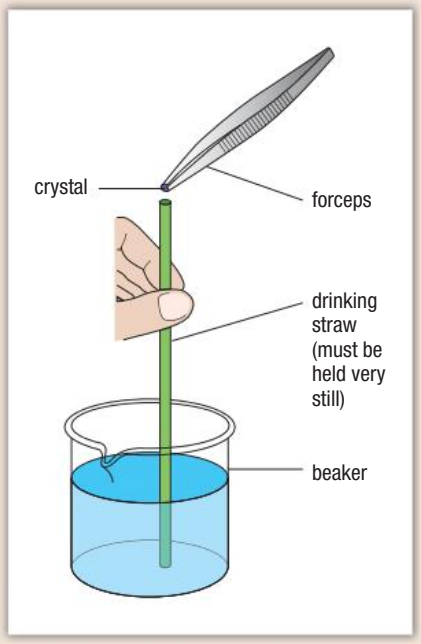


Figure 2.33 Placing the crystal of potassium permanganate in the water.

Skills and outcomes

P2, P6, P12, P13, P14

Type of activity

First-hand investigation

Materials

- two 600 mL beakers
- marking pen or sticky labels
- drinking straw
- fine forceps
- one large crystal of potassium permanganate (Condy's crystals)
- iodine/potassium iodide solution
- stirring rod
- 20 cm strip of dialysis tubing, 2 or 3 cm wide
- 100 mL beaker, three-quarters filled with 5% starch solution
- thistle funnel
- retort stand and clamp
- rubber band

Investigation 2.6

See First-hand investigations

Caution

Handling chemicals (especially acids) must always be done with care. Clean up spills immediately. Wash your hands after handling chemicals.

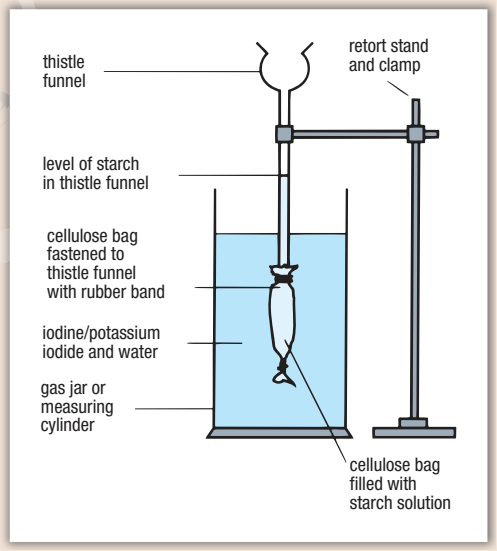


Figure 2.34 Equipment set-up for the experiment.

3 Now set up the apparatus as shown in Figure 2.34. Moisten the dialysis tubing and tie a very tight knot in one end. Insert the stem of the thistle funnel into the other end and fasten it firmly with the rubber band.

4 Pour starch solution through the thistle funnel into the dialysis bag until the bag is full and the starch level is 2–3 cm up the stem of the funnel. Make sure that there are no air bubbles trapped in the bag. Rinse the outside of the bag and funnel with water to remove any traces of starch.

5 Take a 600 mL beaker, half fill it with water, then slowly add some concentrated iodine/potassium iodide solution. Stir the mixture and note the colour of the water as it changes. Add enough to produce a dark brown solution.

6 Mark the level of starch on the funnel stem, and then suspend the apparatus as shown in Figure 2.34.

7 Let the apparatus stand undisturbed for 30 to 60 minutes.

Results

1 Note the changes you observe in:
   a the beaker with the potassium permanganate crystal
   b the beaker with iodine/potassium iodide solution
   c the level of the liquid in the stem of the funnel.

Discussion

1 Suggest an explanation for your observations of changes in the colour of the solution in each of the two beakers. These are examples of diffusion.

2 Suggest an explanation for your observations of changes in the level of liquid in the stem of the funnel. This is an example of osmosis.

3 Molecules of water, iodine/potassium iodide and starch are present in your second experiment. From your results, what is the evidence that some of these molecules have moved through the dialysis bag? In which direction has there been a net (overall) movement of each type of molecule?

4 Suggest a reason why some molecules have moved through the dialysis bag while others have not.

5 Is there any evidence that there has been a net movement of water into the dialysis bag? Explain how you decided whether such a movement occurred.

Conclusion

1 Write a paragraph to summarise your observations about diffusion. You should relate the direction of movement of the coloured solute molecules to differences in solute concentration. Use the following terms: solvent, high solute concentration, low solute concentration, concentration gradient.

2 Based on your observations, and referring to your textbook if necessary, write down a definition of osmosis. Use the following terms: water, selectively permeable, membrane, higher concentration, lower concentration.

3 This experiment modelled the movement of water in living cells.
   a What did the dialysis bag represent in this model?
   b What did the starch solution represent?
   c From your observations, explain how water enters living cells.

4 Write a summary paragraph describing the differences between diffusion and osmosis.

Active transport across membranes

It can be difficult for some molecules to pass through a membrane; they might be blocked because of a diffusion gradient or because of their own properties. For example, some molecules cannot cross the membrane if they are too large, if they cannot dissolve in the membrane, or if they carry electric charges or fatty sections that bind them to the membrane. In **active transport**, specific carrier proteins in the membrane bind with these molecules and carry them through the membrane.

This process requires the expenditure of energy. Receptor molecules on the outer surface of the membrane bind to their specific substrate molecules, activating the protein-carrier molecules or membrane channels, thus allowing the previously excluded molecules to enter the cells. For example, the hormone insulin binds to insulin receptors on the membranes, which then become permeable to glucose molecules.

Endocytosis

Endocytosis is a type of active transport in which large molecules are transported across a membrane. The molecules are enclosed in a vacuole or vesicle formed by the membrane, and then discharged on the other side.

There are three types of endocytosis. In pinocytosis the material transported is a liquid. In phagocytosis the material is solid. In receptor-mediated endocytosis the molecules bind to specific receptor sites on the membrane called coated pits.

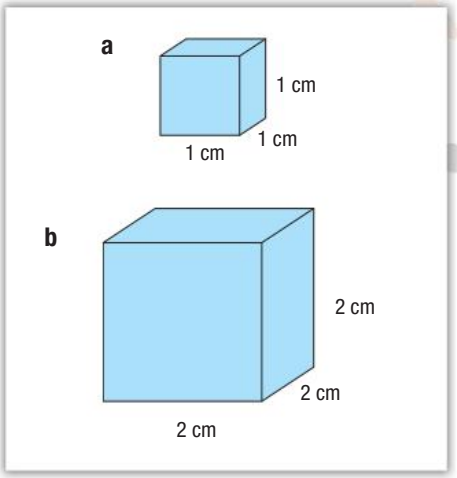


Figure 2.35 A larger cube has a smaller surface area to volume ratio.

explain how the surface area to volume ratio affects the rate of movement of substances into and out of cells.

Surface area to volume ratio

Consider a new cell beginning to grow. It needs nutrients, and takes them in through its surface membrane. The area of this surface affects the rate at which nutrients can enter the cell, as well as the rate at which wastes can leave. As the cell grows, its needs are probably greater, but the rate of exchange of materials with its surroundings falls. We can use a model to see why this is so.

Figure 2.35a shows a cube with faces 1 cm × 1 cm.

total surface area = $6 \times 1 \times 1$ = $6\ cm^2$

volume = $1 \times 1 \times 1$ = $1\ cm^3$

surface area to volume ratio = 6 : 1

Figure 2.35b shows a cube with faces 2 cm × 2 cm.

total surface area = $6 \times 2 \times 2$ cm = $24\ cm^2$

volume = $2 \times 2 \times 2$ cm = $8\ cm^3$

surface area to volume ratio = 24 : 8 = 3 : 1

So as the cube increases in size, the relative amount of surface decreases. This is why the capacity to take in enough nutrients and lose wastes decreases as cells grow.

One reason for the small size of cells could be that the rate of exchange of substances through the membrane is more efficient than in a large cell. When a cell reaches a certain size, it divides into two smaller cells, restoring a more favourable surface area to volume ratio.

In multicellular organisms, tissues and organs involved in the exchange of materials with the external environment often have large surface areas in relation to their volumes, to enable the exchange to be conducted efficiently (Figure 2.36).



Figure 2.36 Many planarians (flatworms) are very thin, so their surface area to volume ratio is very large.

INVESTIGATION 2.7

Surface area to volume ratio

Students will: perform a first-hand investigation to demonstrate the effect of surface area to volume ratio on rate of diffusion.

Skills and outcomes

P12, P13, P14

Type of activity

First-hand investigation

Materials

- prepared sheets of agar-phenolphthalein jelly: 20 mm (2 cm) thick, 10 mm (1 cm) thick, 5 mm (0.5 mm) thick
- safety glasses
- shared supply of 0.1 M sulfuric acid
- 250 mL beaker
- plastic teaspoon
- flat blade knife, e.g. kitchen knife or scalpel
- clear plastic ruler (marked in mm)
- tile or large petri dish lid
- strip of paper towel
- disposable polythene gloves
- calculator

See First-hand investigations

Introduction

The different shapes of organisms can be simulated by making them out of blocks of jelly. The jelly is pink due to the presence of sodium hydroxide (a base) and phenolphthalein (an indicator). Phenolphthalein is colourless in acid. When blocks are placed in an acid solution, the acid diffuses into the jelly. A chemical reaction causes the jelly to change from pink to clear. The time taken for the block to go totally clear is a measure of the amount of acid diffusion into the jelly.

Purpose

To investigate the relationship between the surface area to volume ratio of an object and the rate of diffusion of a substance into it.

Procedure

1 Copy Table 2.9 into your workbook.

TABLE 2.9

Property	Block number		
	1	2	3
Block dimensions (mm)	20 × 20 × 20	20 × 20 × 10	20 × 20 × 5
Order of clearing (actual or predicted)			
Depth of clear part of block (mm)			
Surface area (mm^2)			
Volume (mm^3)			
Surface area to volume ratio (SA ÷ V)	: 1	: 1	: 1

Points to note:

- Be as accurate as you can when cutting the agar jelly shapes.
- Use the clear plastic ruler for your measurements.
- The jelly is alkaline and has a soapy feel. Wear disposable gloves when handling it.
- Carefully dispose of the agar shapes and acid on completion.
- All measurements are given in mm.

2 Accurately cut a 20 mm × 20 mm piece of jelly from each of the sheets provided, i.e. 20 mm, 10 mm and 5 mm thick.

3 Half fill the 250 mL beaker with sulfuric acid.

4 Add the blocks to the acid and gently stir with the plastic spoon. Watch until the first block goes completely clear, then proceed to step 6 immediately.

5 Record in Table 2.9 which size block was the first to go clear.

6 Do not wait for the other blocks to go clear. Remove all the blocks from the acid with the spoon, rinse well in water and pat them dry with the paper towel. Working quickly, cut them in half with the knife and then measure in millimetres the depth of the clear layer in each.

7 Record this information in Table 2.9. Use a calculator to help you complete Table 2.9.

Discussion

1 What causes the blocks to become clear?

2 What can you assume regarding the movement of acid when part of a block becomes clear?

3 Which block was the first to go clear?

4 From your observations of the other two blocks, predict which would be the next to go clear. Explain your prediction.

5 From Table 2.9, which block has the largest surface area (SA)?

6 From Table 2.9, which block has the largest volume (V)?

7 From Table 2.9, which block has the largest surface area in proportion to its volume (i.e. surface area to volume ratio or SA : V)?

8 What happens to the SA : V of a block as its size gets smaller?

9 Does the size of a block influence the rate at which acid diffuses into it? Use data from Table 2.9 to help with your explanation.

Conclusion

1 From your investigation, what is the relationship between surface area and rate of diffusion?

2 Given that cells need to be able to obtain their requirements from, and get rid of wastes to, the surrounding environment, suggest reasons why cells are usually microscopic in size.

Further activity

1 Consider the following shapes cut from agar jelly:

   a 30 mm × 20 mm from 3 mm thick jelly

   b 10 mm × 18 mm from 10 mm thick jelly

   c 15 mm diameter sphere

   Each of these shapes has approximately the same volume. Predict the order in which the blocks will go clear, and explain the reasons for your predictions. (You may need to use a calculator.)

Caution

Take care when handling acids and alkalis. Wear disposable gloves and safety glasses. Dispose of as directed by your teacher.

Further calculations

1 Calculate the percentage by volume of the coloured parts of Block 1 from the original experiment as follows:

Depth of penetration of the acid in mm = X

Length of side (S) not penetrated = (S – 2X)

Volume of cube still coloured (V_c) = $(S – 2X)^3$

Percentage (C%) of the still coloured volume (V_c) compared to the original volume:

$C\% = (V_c/V) \times 100$

2 Calculate the percentage volumes of the clear parts of Block 1 as follows:

Percentage (P%) of the clear volume of the cube (i.e. penetrated by the acid):

$P\% = 100 – C\%$

3 Record your calculations in Table 2.10.

TABLE 2.10

Side of cube (mm)	Volume (mm^3)	SA : V ratio	Depth of acid (mm)	V_c (mm^3)	C%	P%
20						

4 Complete similar calculations for a cube of side 10 mm and a cube of side 5 mm. Record these calculations in the table. (Assume the depth of acid penetration to be the same in each case.)

5 Explain why you can assume the depth of acid penetration to be the same.

6 What do the figures you have calculated tell you about diffusion into different sized blocks?

7 How can you relate this information to the size of cells?

2.2 UNIT REVIEW

Cell membranes: form and function

Membranes around cells provide separation from and links with the external environment.

Summary

- The major groups of substances found in living cells are carbohydrates, lipids, proteins and nucleic acids, inorganic minerals and ions. All these substances are used by the cell. Carbohydrates are energy sources, lipids are energy stores, proteins determine the nature and activity of a cell, nucleic acids contain inherited information, and inorganic minerals and ions are essential components in some cell structures and activities.
- Selectively permeable membranes separate the internal contents of cells from the external environment. Molecules move in and out of cells across the membranes.
- The fluid mosaic model of membrane structure can account for the movement of substances in and out of cells by both passive and active processes.
- The double layer of phospholipids and the membrane proteins allow some small molecules to diffuse through, but many other molecules must be actively transported through the membrane.
- Diffusion and osmosis are two passive processes by which substances move in and out of cells. Osmosis is the movement of water through the selectively permeable membrane.
- The surface area to volume ratio affects the rate of movement of substances in and out of cells. Cells maintain a large surface area compared to their volume. This enables them to exchange materials efficiently with their environment.

Questions

1 Which list contains only inorganic molecules?

A water, oxygen, carbon dioxide
B glucose, hydrogen, oxygen
C starch, iron, calcium
D sodium, chloride, water, sugar

2 Which one of the following statements is true?

A Osmosis and diffusion are both passive processes in which molecules spread across a membrane.
B Osmosis and diffusion are both active processes in which water molecules spread from a region of high concentration to one of lower concentration.
C Osmosis involves the uptake of water through a selectively permeable membrane.
D Osmosis involves the diffusion of a solvent through a selectively permeable membrane.

3 Which statement best describes the structure of a molecule of DNA?

A chains of ribonucleic acid coiled and joined together

B deoxyribose, nitrogen and acid joined together

C sugar molecules, bases and phosphate groups joined together

D deoxyribose and amino acids joined together

4 a Explain the difference between organic and inorganic substances. Include three examples of each type of substance in your answer.

b Complete the following table summarising the major groups of organic compounds found in living things.

Organic compound	Elements	Function
carbohydrates		
proteins		
lipids		
nucleic acids		

5 Identify the key role of cell membranes. Define the term 'selectively permeable'.

6 Describe the fluid mosaic model of the cell membrane.

7 Define osmosis and describe how water in the soil enters the root cells of a plant by this process.

8 a Compare the processes of diffusion, osmosis and active transport in cells. Use diagrams to illustrate your answer.

b List the substances that move across cell membranes by each of the different processes described in (a).

9 Define 'facilitated diffusion'.

10 a Explain what is meant by 'surface area to volume ratio'.

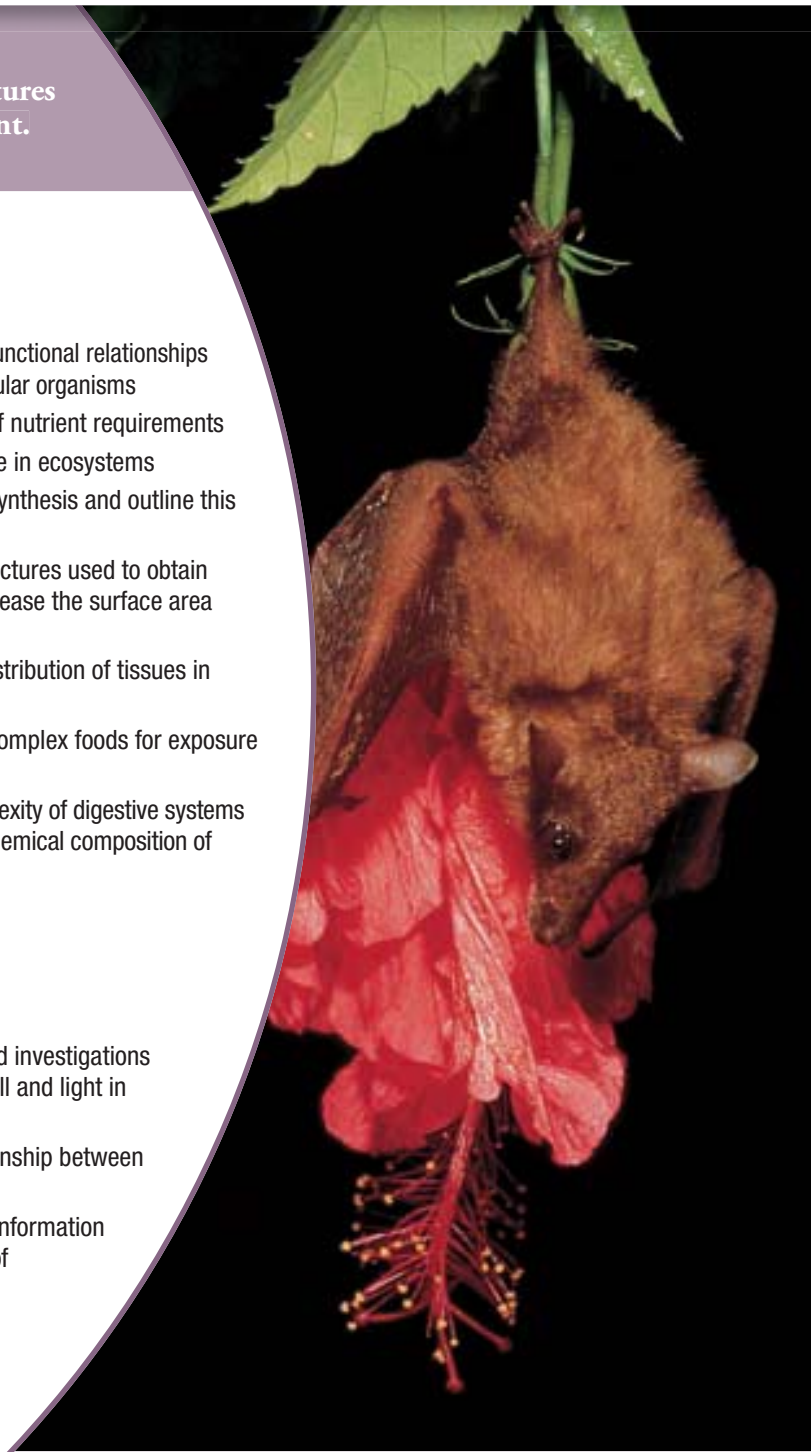
b Cells have a large surface area to volume ratio. Explain why this is important.

11 a Distinguish between the internal and external environments of a cell.

b Clarify the role of the cell membrane in relation to these two environments.

2.3 OBTAINING NUTRIENTS

Plants and animals have specialised structures to obtain nutrients from their environment.



STUDENT LEARNING

In this unit students will:

- identify some examples that demonstrate the structural and functional relationships between cells, tissues, organs and organ systems in multicellular organisms
- distinguish between autotrophs and heterotrophs in terms of nutrient requirements
- identify the materials required for photosynthesis and its role in ecosystems
- identify the general word equation for the process of photosynthesis and outline this as a summary of a chain of biochemical reactions
- explain the relationship between the organisation of the structures used to obtain water and minerals in a range of plants and the need to increase the surface area available for absorption
- explain the relationship between the shape of leaves, the distribution of tissues in them and their role
- describe the role of teeth in increasing the surface area of complex foods for exposure to digestive chemicals
- explain the relationship between the length and overall complexity of digestive systems of a vertebrate herbivore and carnivore, with respect to the chemical composition of their diet and the functions of the structures involved.

STUDENT ACTIVITY

Students will:

- plan, choose equipment or resources, and perform first-hand investigations to gather information to demonstrate the need for chlorophyll and light in photosynthesis
- perform a first-hand investigation to demonstrate the relationship between surface area and rate of reaction
- identify data sources, gather, process, analyse and present information from secondary sources to compare the digestive systems of mammals, including a grazing herbivore, a carnivore and a predominantly nectar-feeding animal.

Cells and systems

identify some examples that demonstrate the structural and functional relationships between cells, tissues, organs and organ systems in multicellular organisms

In multicellular organisms, different cells can become specialised to perform different functions. Different types of cells have different structures and activities, but they work together so that the organism functions as a coordinated whole.

Groups of cells that are similar in structure and function are called tissues. Groups of tissues make up **organs**. Organs make up systems within the body, such as the digestive system in humans (Figure 2.37).

For an example of the types of cells and their functions in the small intestine of the digestive system, see page 114 and Figure 2.58. For an example of the types of cells and their functions in the leaf of a plant, see p. 110 and Figure 2.52.

Multicellular organisms are composed of many cells. There is an enormous range of multicellular organisms, including all plants, animals and fungi, and most algae. A human is a multicellular organism consisting of trillions of cells packed together.

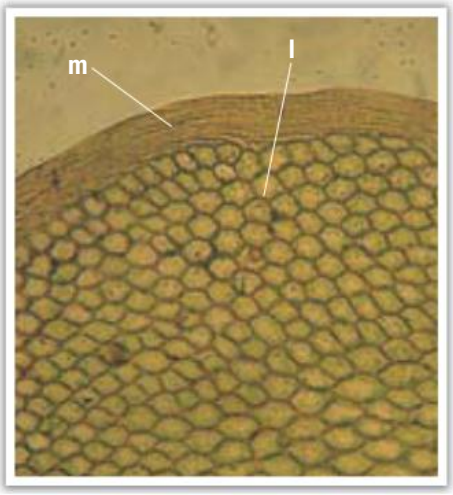


Figure 2.37 The leaves of the moss *Calyptrochaeta apiculata* contain two types of cells with different functions. The hexagonal lamina cells (l) carry out photosynthesis and the other normal functions of leaf cells. The longer, narrower marginal cells (m) give the leaf strength and protect it from mechanical damage.

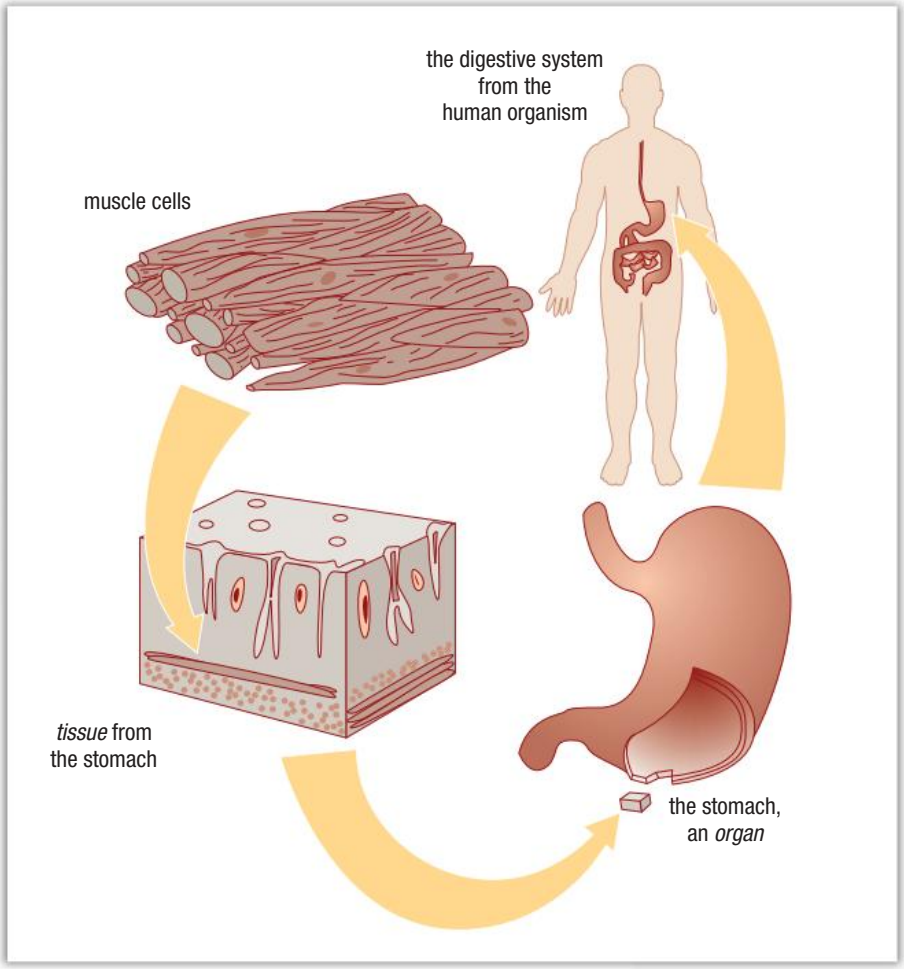


Figure 2.38 How cells, tissues and organs make up the human digestive system.

Autotrophic and heterotrophic cells

distinguish between autotrophs and heterotrophs in terms of nutrient requirements

There are many different types of cells—there is no such thing as a 'typical' cell. But we can talk in general terms about common characteristics of plant cells, and compare them with the common characteristics of animal cells.

One essential difference is that plant cells are autotrophic, while animal cells are heterotrophic. Autotrophic means 'self-feeding'. Plant cells which contain chloroplasts are able to produce their own nutrients by photosynthesis.

Heterotrophic means 'feeding on something different'. Animal cells do not contain chloroplasts. They must obtain the substances they need from their external environment.

The autotrophic nature of green plants is fundamental to the existence of all organisms: all heterotrophic organisms depend ultimately on the ability of autotrophs to synthesise organic materials.

Revise the differences between plant and animal cells (see p. 70).

Photosynthesis

Materials for photosynthesis, and its role in ecosystems

identify the materials required for photosynthesis and its role in ecosystems

Photosynthesis can occur only if plant cells can obtain carbon dioxide, water and light from their external environment. The products of photosynthesis are sugars and oxygen.

All living things ultimately depend on the process of photosynthesis, which provides the continuous input of energy necessary to sustain ecosystems. Photosynthesis enables green plants to obtain energy directly; animals obtain this energy indirectly from the food they eat.

All living things ultimately depend on the process of photosynthesis.

The photosynthesis equation

identify the general word equation for the process of photosynthesis and outline this as a summary of a chain of biochemical reactions

A generalised equation for photosynthesis can be written as follows:

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

In fact, this equation is more correctly written as:

$$6CO_2 + 12H_2O \rightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$$

Notice that six H_2O molecules have been added to each side of the equation. This is done to show that all the oxygen released comes from the water, not the carbon dioxide. There are 12 atoms of oxygen in the six molecules of oxygen gas on the right-hand side now, and 12 atoms of oxygen in the water on the left-hand side.

The process of photosynthesis can be thought of as occurring in two sets of reactions or stages, although it is actually continuous: the products of the first stage become the raw materials of the second stage. Only the first set of reactions use light; these are called the 'light reactions of photosynthesis'. The second set use carbon dioxide and are light-independent; they are also called the 'carbon-fixation stage of photosynthesis'.

Word equations can be used to describe reactions. They are a useful way to summarise the process of photosynthesis:

$$\text{carbon dioxide + water} \xrightarrow[\text{chlorophyll}]{\text{light energy}} \text{sugar + oxygen}$$

BIOFACT

Chemosynthetic or chemoautotrophic organisms obtain their energy from inorganic sources. Sulfur bacteria such as *Thiobacillus* obtain their energy from the oxidation of hydrogen sulfide. (See also p. 191.)

Light reactions of photosynthesis

Radiant energy from sunlight is absorbed by the chlorophyll pigment in the chloroplasts of green plant cells and is converted to chemical energy. Some of this energy is used to split water molecules into hydrogen and oxygen, as expressed in

The term 'photolysis' is often used for the process by which light splits water; 'photo' means light, and 'lysis' means to split.

the following equation:

$$\text{water} \xrightarrow{\text{light}} \text{hydrogen + oxygen}$$

This stage occurs on the internal membranes of the chloroplasts (thylakoids) in plant cells (see p. 76).

Radioactive tracing

The fact that water not carbon dioxide is the source of the oxygen released in photosynthesis was revealed by the use of radioactive isotopes. This method is called radioactive tracing because it tells us precisely where atoms come from and where they go. The first tracer experiments were performed in 1920, and tracers have since been used by many scientists to follow chemicals in living systems in plants and animals. For example, when photosynthesising plants are watered with H_2O containing radioactive atoms of oxygen, all the radioactive atoms are eventually lost from the cells as oxygen gas (O_2). Figure 2.39 shows an example of a radioactive tracer experiment.

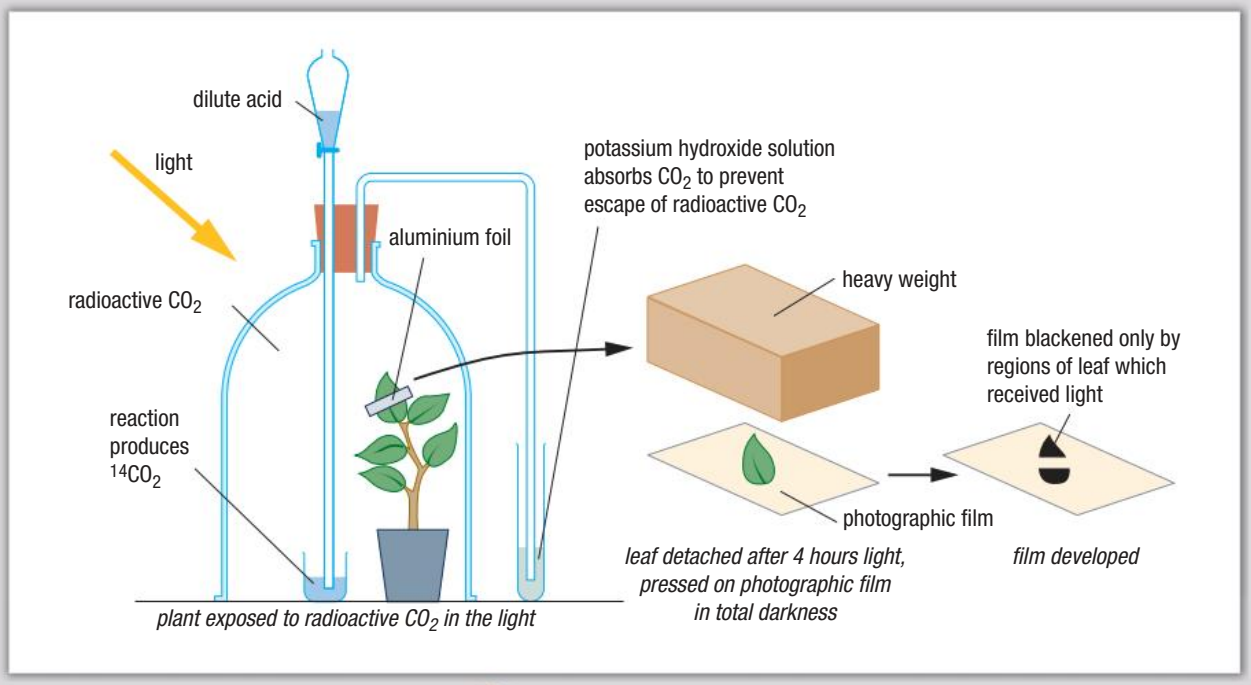


Figure 2.39 A radioactive tracer experiment.

Light-independent reactions of photosynthesis

Hydrogen released from the first reactions combines with carbon dioxide to form sugars. This process, which is a building-up reaction, requires energy. The energy needed is supplied from some of the energy absorbed from light in the first set of reactions in photosynthesis or from energy stores (ATP) in the plant.

$$\text{hydrogen + carbon dioxide} \xrightarrow{\text{energy}} \text{sugars}$$

These reactions occur in the stroma or fluid matrix of chloroplasts. At least two different pathways are known. In many plants, the C_3 or Calvin cycle occurs. In the Calvin cycle, the first stable compound produced contains three carbon atoms. In some plants, such as sugar cane and corn, the C_4 pathway occurs, resulting in the first stable compound produced having four carbon atoms.

The production of sugars

The sugars made in cells may be used in cell respiration as soon as they are formed. During the day there is usually enough light for photosynthesis to produce sugars faster than they are used in respiration. As a result, sugars are converted to starch and stored in the cells. This is why we test a green leaf for starch when we are looking for evidence of photosynthesis (Figure 2.40).

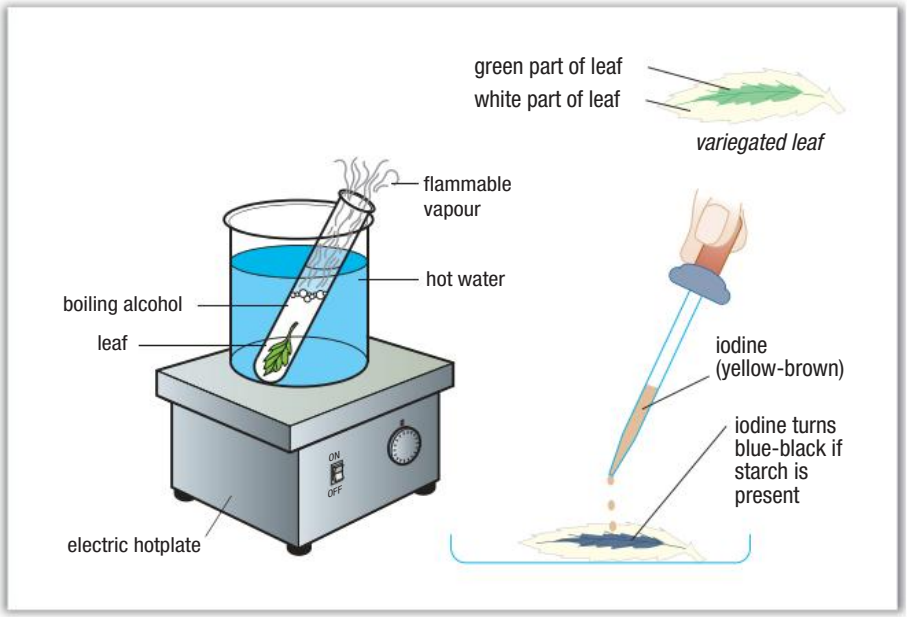


Figure 2.40 Testing a leaf for starch.

At night, some starch is converted back into sugars, which are transported in the phloem to any cells that need it for respiration. Sugars that are not used in respiration may be built up into proteins, helping the plant to grow, or may be stored as starch or lipids (Figure 2.41).

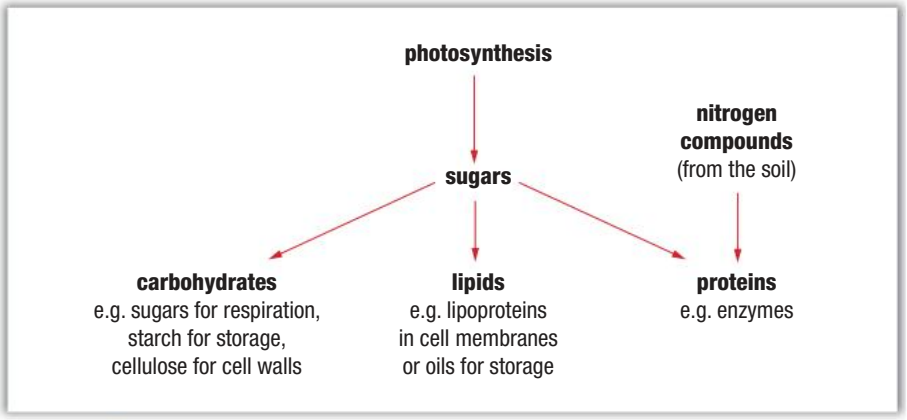


Figure 2.41 Organic molecules made by plants from the products of photosynthesis.

BIOFACT

The light-independent reactions are sometimes referred to as dark reactions. However, most biologists now avoid this term because the whole process of photosynthesis takes place in sunlight, and because these reactions must have the products of the light reactions to operate.

BIOFACT

Most sugars contain 6 or 12 carbon atoms in each molecule. Common household sugar is sucrose, a disaccharide (see p. 82). In Australia this is obtained mostly from sugar cane, which is grown in Queensland and northern New South Wales. In some countries, such as the USA, the main source of household sugar is sugar beet. Sucrose is a compound of two other sugars: fructose and glucose.

The role of enzymes in photosynthesis

Enzymes are substances that speed up the rate of reactions, without being used up in the reaction. Each of the many reactions in photosynthesis is controlled by a particular enzyme. The enzyme molecule provides a site (called the active site) at which the reactants can come together. On the active site, the reaction occurs faster than it would otherwise do. When the reaction is complete, the products leave the active site and the enzyme is free to be used again (see *Heinemann Biology Third Edition HSC* Chapter 1).

Factors affecting the rate of photosynthesis

The rate of photosynthesis, like all chemical reactions, depends on the availability of the required substances. The concentration of carbon dioxide, the availability of water and the intensity of light are all important factors in this process (Figure 2.42). If the supply of any one of these is low, it is described as a limiting factor because it limits the rate at which the whole process of photosynthesis can occur. The rate of photosynthesis also increases with temperature, mainly because the activity of the enzymes involved increases. However, very high temperatures can slow down the reaction.

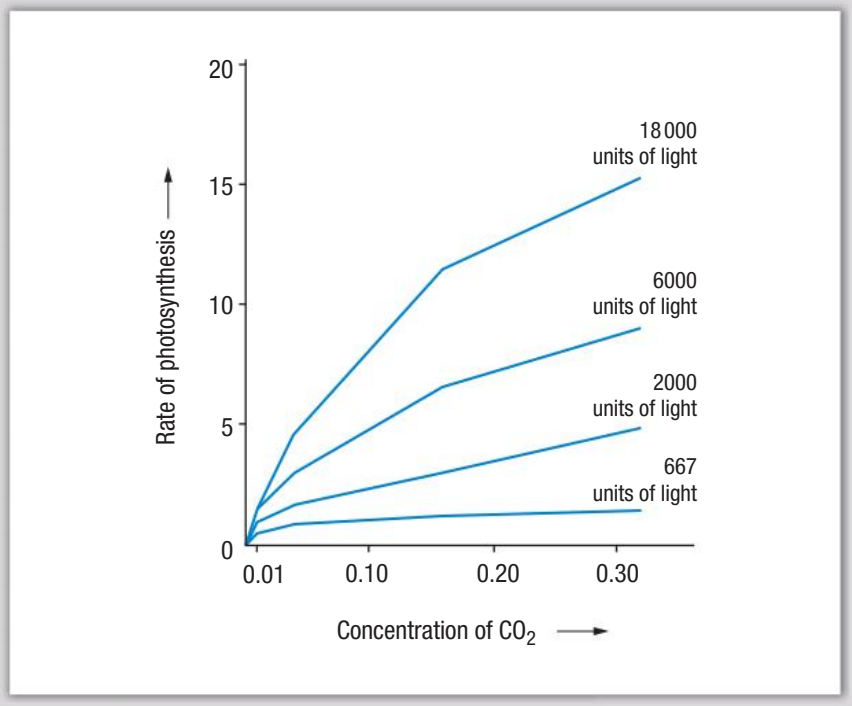


Figure 2.42 The effect of light intensity and carbon dioxide concentration on the rate of photosynthesis. Note how the amount of light limits the rate of photosynthesis, even though the rate increases with increasing carbon dioxide concentration.

2.8 INVESTIGATION

Photosynthesis

Students will: plan, choose equipment or resources and perform first-hand investigations to gather information and use available evidence to demonstrate the need for chlorophyll and light in photosynthesis.

Introduction

Photosynthesis is the process by which green plants are able to manufacture the carbohydrate glucose from water and carbon dioxide. Glucose is an important source of energy. Many glucose molecules join together to form starch, the main carbohydrate storage molecule in plants. If starch can be identified in leaves, it is an indication that photosynthesis has occurred there.

The procedure that you will follow in this activity was developed many years ago to demonstrate the presence of starch in leaves. The pigment chlorophyll, which gives plants their green colour, can be extracted by boiling in alcohol. The presence of starch can be detected using iodine/potassium iodide solution.

The experiment you will design is to find out more about the requirements necessary for starch formation.

Purpose

1 To determine whether chlorophyll is necessary for starch formation.

2 To determine whether light is necessary for starch formation.

A Testing a leaf for starch

Procedure

1 Set up burner, tripod and gauze and bring about 75 mL of water in the 100 mL beaker to the boil. Turn off the burner.

2 Place any leaves to be tested in the boiling water until they go limp (1–2 minutes). This kills the cells and softens the leaves. Remove the leaves with forceps and place them in one of the evaporating dishes.

3 Collect a tube of alcohol. Use forceps to put the softened leaves into the tube. Place the tube in the nearly boiling water on the hotplate (see Figure 2.40 on p. 103). Note the caution. In a short time the alcohol will start to boil (it boils at a lower temperature than water), and it will take on a green colour as the pigment from the leaves dissolves.

4 After 5–10 minutes the leaves should look uniformly pale. If they are not, continue with step 3 for a little longer.

5 Remove the leaves from the alcohol with the stirring rod and place them in an evaporating dish. Return the alcohol tube.

Skills and outcomes

P11, P12, P13, P14, P15

Type of activity

First-hand investigation, student-design activity

Materials (per class)

- electric hotplates
- 600 mL beaker, two-thirds full of water at about 90°C, on hotplate with a thermostat set to maintain the temperature (per group)
- safety glasses
- Bunsen burner, tripod and wire gauze
- 100 mL beaker
- two large white evaporating dishes
- scissors and forceps
- glass stirring rod long enough to reach to the bottom of the alcohol test-tube
- test-tube holder and test-tube rack
- test-tube (30 mm × 180 mm) containing ethanol or methylated spirits (this should be collected when instructed to do so in the procedure, then returned afterwards)
- 50 mL iodine/potassium iodide solution in 100 mL beaker
- soft green leaves

Caution

Use an electric hotplate for Step 3 of Procedure A and take extreme care when using a flammable liquid. Do not use a Bunsen burner. Alcohol vapour will readily catch fire if put anywhere near a naked flame. In the event of fire, immediately smother the flame with sand from the fire bucket. Do not try to blow the flame out. If someone's clothing catches fire, wrap a fire blanket around them.



See First-hand investigations

Materials

For part B:

- plant material
- a number of healthy, well-watered pots of the plant species chosen: the plant must have a normal (fully green) form and a variegated form. Examples include border geranium, *Tradescantia* and *Nasturtium*
- fluorescent or low voltage cold-type lights suitable for 24 hour illumination
- access to a dark cupboard

6 Use forceps to quickly dip each leaf (to soften them) in the hot water on the tripod and then place one in each of the evaporating dishes.

7 Cover each leaf with iodine/potassium iodide solution and allow them to stand for a minute. Pour excess iodine solution back into the beaker and gently wash and float out the leaves with water. Note that iodine/potassium iodide turns blue–black if starch is present.

8 The leaves are now ready for observation.

B Designing your own experiment

Design your own experiment to answer the following questions:

Experiment 1: Is chlorophyll necessary for starch production?

Experiment 2: Is light necessary for starch formation?

Note: You need to set up your experiments at least 24 hours before you test any leaves for starch.

Some factors to consider when designing your experiment might be:

- What sort of plants are needed?
- What environmental conditions do the plants need to be in, before the day of the experiment?
- How can the leaves be identified when the chlorophyll has been extracted?
- What results can be expected?
- How will the actual results be recorded?
- Are any controls needed?
- Are there any anticipated problems with the design?

Procedure

1 Write down the details of how you will conduct your two experiments.

2 Set up your experiments and leave for 24 hours.

3 Test the leaves from your experimental plants for starch, following the procedure given in Part A.

4 Record your observations of the leaves tested in both experiments.

Conclusion

1 Explain why the areas of a leaf stained with iodine indicate where photosynthesis has occurred.

2 In Experiment 1, how do the areas stained with iodine compare with the distribution of chlorophyll in a leaf?

3 In Experiment 2, how do the leaves stained with iodine relate to the conditions under which the plant was kept?

4 From your investigations, are chlorophyll and light necessary for starch formation?

Obtaining nutrients—plants

Plants use specialised structures to obtain the materials required for photosynthesis from their environment.

Obtaining water and minerals

explain the relationship between the organisation of the structures used to obtain water and minerals in a range of plants and the need to increase the surface area available for absorption

In an aquatic environment, water and minerals can be absorbed across the whole surface of the plant. In most terrestrial plants, water and minerals are obtained through root systems, which also anchor the plants in the soil. Plant roots need a large surface area over which absorption can occur. They achieve this by having a branching structure, and root hairs just behind the root tips.

Different types of roots

Figure 2.43 shows the two major types of root systems found in flowering plants. Tap root systems have a main root from which side (lateral) roots emerge. Tap roots may penetrate deeply into the soil. Some tap roots may act as storage organs and swell up as food reserves are deposited. Carrots, beetroots and parsnips are examples of this.

Fibrous roots Form a network of roots close to the soil surface. They may spread out widely to anchor the plant, helping to bind the soil and preventing erosion.

Some types of plants, for example *Banksia*, form **cluster roots**. These are groups of many tiny roots. These increase the surface area for the uptake of mineral ions in nutrient-poor soils.

Mycorrhiza Over 90% of flowering plants have their root systems associated with fungi. The fungi provide the plant with additional mineral nutrients and the plant provides the fungus with carbon products from photosynthesis. Fungal threads (hyphae) may form a sheath surrounding the roots of the plant.

Aerial roots In some plants, roots may grow above the ground. These may help to support the plant and are often called prop roots or buttress roots. Some plants that grow in wet or waterlogged conditions produce aerial roots that help in gas exchange (see p. 36).

Rhizoids Mosses, liverworts and hornworts do not have true roots. They are anchored to their substratum by hair-like structures called rhizoids.

External root structure

The root system of a plant is usually entirely below ground. Because roots do not contain chloroplasts, they do not photosynthesise. They also do not have leaves or buds. The roots of most plants grow down into the soil. Their growing point is protected by a root cap.

As roots grow through the soil, they form a branching network which helps to anchor the plant. Just behind the growing point is the region of **root hairs**, which provide a large surface area where most of the absorption of water and mineral ions takes place.

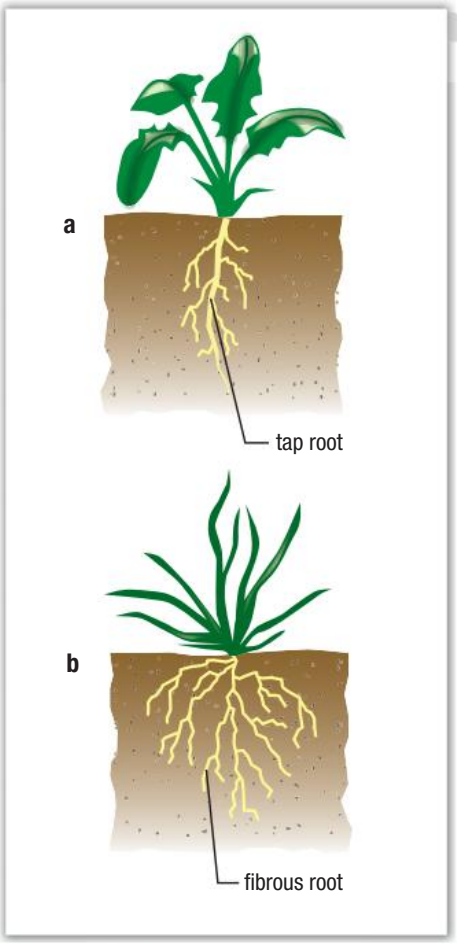


Figure 2.43 Two types of root systems.

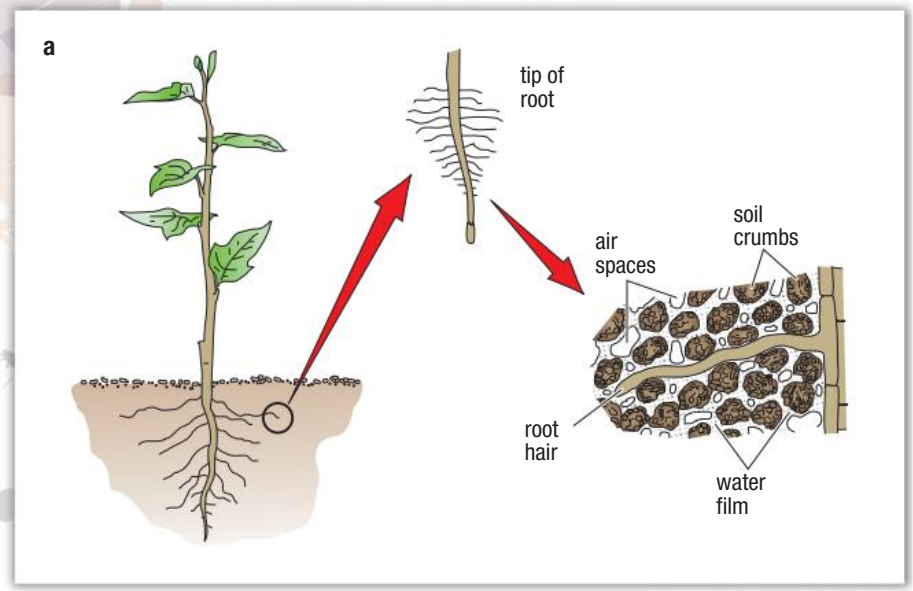




Figure 2.44 (a) The external structure of a root. (b) Root hairs on a radish seedling.

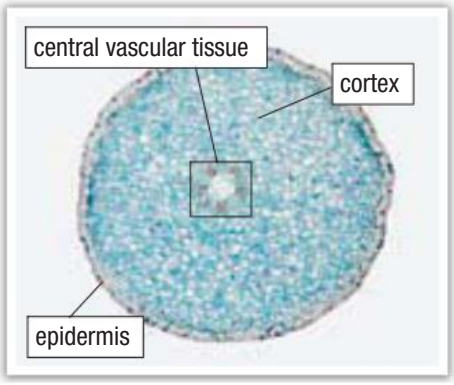


Figure 2.45 Cross-section of a *Ranunculus* root.

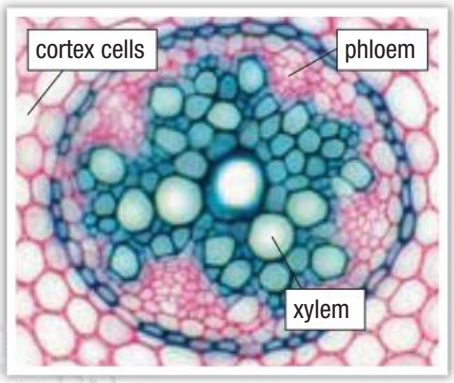


Figure 2.46 Central vascular tissue of a *Ranunculus* root.

Internal root structure

Epidermis The protective outer layer or epidermis of roots usually lacks a cuticle. In many young roots, the epidermis is covered with a slimy coating or sheath called **mucigel**.

Cortex In the roots of many plants, the large cells of the cortex act as a storage area for excess materials. There are air spaces between the cells for the circulation of gases.

Vascular tissue In roots the vascular tissue forms a cylinder in the centre. It consists of **xylem** and **phloem** (see pp. 127–128), and is sometimes called the **stele**.

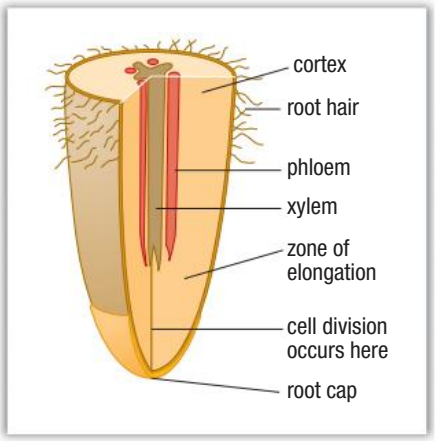


Figure 2.47 Internal root structure.

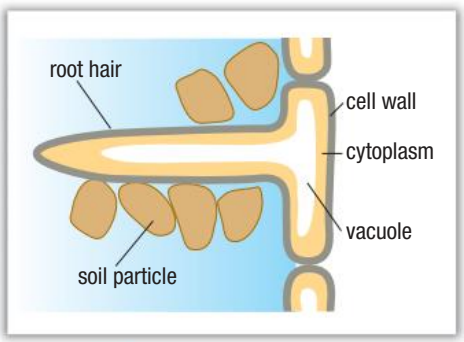


Figure 2.48 Cross-section of epidermal cell, showing root hair.

Obtaining sunlight and carbon dioxide

explain the relationship between the shape of leaves, the distribution of tissues in them and their role

All plants need light to photosynthesise. Some aquatic plants drift in the surface layers of oceans or large bodies of fresh water. Aquatic plants that remain anchored by root systems must be in shallow water in order to obtain sufficient light. On land, most plants are anchored in the soil and must be exposed to enough light in order to survive.

Plants require carbon dioxide for photosynthesis. They obtain it either from the water if they are submerged aquatic plants, or from the air. The specialised plant structure for obtaining light and carbon dioxide in most plants is the leaf. It is in the leaf where most photosynthesis occurs.



Figure 2.49 Water lilies have long stems that enable them to be anchored in the mud in shallow water, while having the floating leaves fully exposed to sunlight.

The structure of a leaf

The *external* structure of a typical leaf is visible to the naked eye. It consists of a **lamina** (the blade of the leaf), a **petiole** which joins the leaf to the stem, and a network of veins (Figure 2.50).

The *internal* structure of a leaf is visible through a microscope, which reveals specialised tissues (Figure 2.52). These structures are all related to the main function of the leaf as the organ of photosynthesis for the plant.

External leaf structure

Arrangement Leaves are usually arranged along the stems of plants in a way that exposes them to the maximum amount of sunlight possible. They are usually angled so that the sunlight strikes the upper surface of the leaves.

Shape Most leaves are broad, thin and flat (Figure 2.51). This gives them a large surface area for the capture of sunlight and the exchange with the environment of gases needed in photosynthesis and respiration.

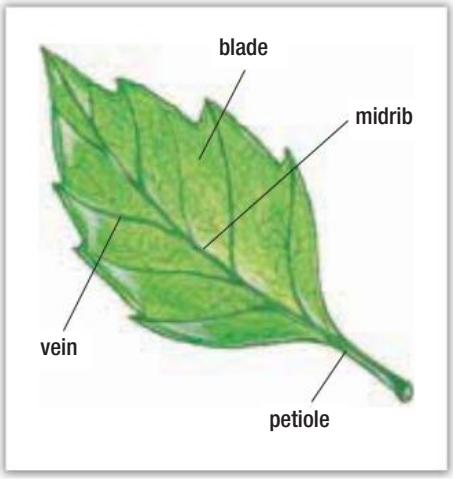


Figure 2.50 The external structure of a typical leaf.

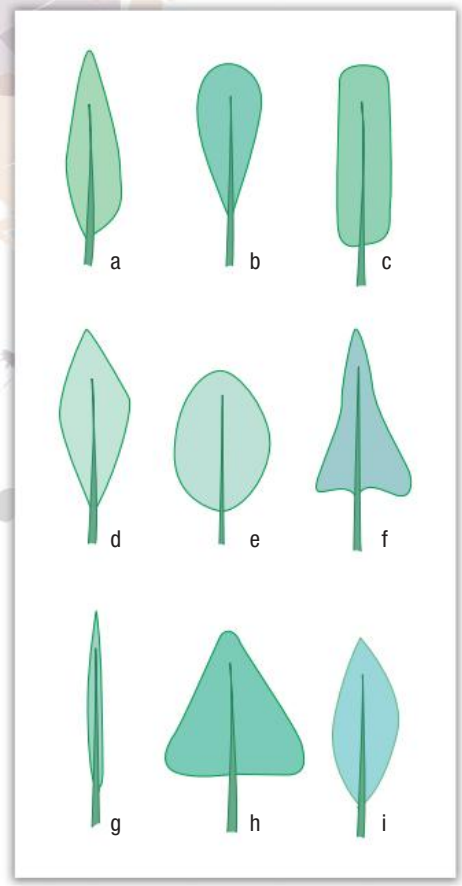


Figure 2.51 Some common leaf shapes; (a) lanceolate, (b) obovate, (c) oblong, (d) rhomboidal, (e) ovate, (f) sagittate, (g) linear, (h) deltoid, (i) elliptical.

Internal leaf structure

Cuticle Leaves secrete a waxy substance which forms an outer layer or cuticle. This helps to maintain the shape of the leaf and provides protection. In terrestrial plants it plays an important role in reducing water loss by evaporation. It may be thin or absent in aquatic plants.

Epidermis The epidermis forms a single protective layer of cells on the upper and lower surfaces of the leaf. It is transparent, so sunlight can readily penetrate through to the photosynthetic cells within.

Stomates Stomates are pores in the leaf that can open and close. When open they permit the exchange of gases between the leaf and the external environment. At the same time, however, water is lost by evaporation.

Mesophyll The word mesophyll means 'middle leaf'. The mesophyll cells in the centre of the leaf consist of two types (Figure 2.52). **Palisade mesophyll** cells are found most commonly in one or two rows below the upper epidermis. They are regularly arranged, elongated cells packed with green chloroplasts. It is in these cells that most of the plant's photosynthesis occurs. **Spongy mesophyll** cells are usually situated between the palisade cells and the lower epidermis. They contain fewer chloroplasts than palisade cells and are irregularly arranged with large spaces between them. This arrangement enables gases and water vapour to move easily between the cells and stomates.

Veins Veins are tubes of vascular tissues consisting of xylem and phloem cells, which transport materials to and from the leaf. The xylem transports water and mineral ions from the roots to the leaves; the phloem transports the products of photosynthesis from the leaves to the rest of the plant (see p. 131). Veins form a branching network throughout the leaf. This helps give rigidity to the leaf, maintains its shape and structure, and ensures that every leaf cell is close to a vein.

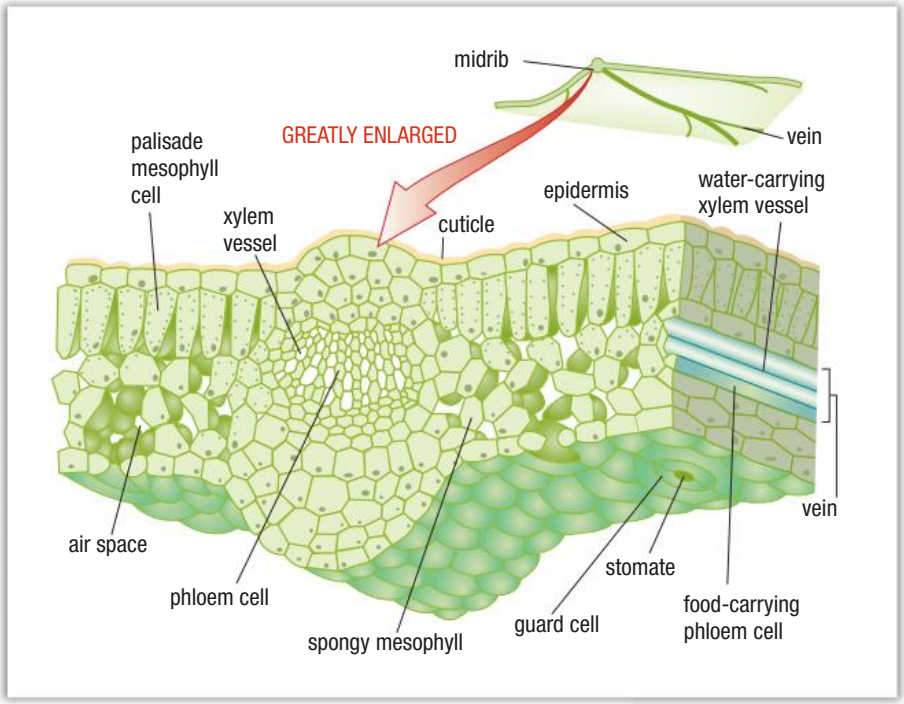


Figure 2.52 The internal structure of a leaf.

Mammalian digestion

The digestive system

describe the role of teeth in increasing the surface area of complex foods for exposure to digestive chemicals

Animal cells are heterotrophic. Unlike plant cells, they cannot make their own food, so they must obtain it from their external environment.

In heterotrophic organisms such as mammals, the **digestive system** provides the means by which external nutrients required by cells are taken into the organism and broken down or digested. Large, insoluble food molecules are converted into small, soluble ones that can be absorbed and made available to the body cells.

In mammals, the process of **digestion** involves both the mechanical and chemical breakdown of food. This is followed by its absorption into the body. Complex molecules are broken down into simple molecules by the action of specialised proteins called enzymes. Most digestive enzymes split food molecules by hydrolysis, in which a molecule is split at a particular point by adding a water molecule. There are three kinds of digestive enzymes:

- amylases, which act on carbohydrates
- proteases, which act on proteins
- lipases, which act on lipids.

These enzymes are produced by specific cells along the length of the gut, as well as in the salivary glands and pancreas. Large food molecules might need to be broken down by several enzymes acting in sequence.

An overview of the structure and function of mammalian digestive systems is illustrated in Figure 2.55, using the human digestive system as an example.

Herbivores and carnivores compared

The mouth and teeth

In the mouth, food is usually broken up by the teeth and mixed with saliva, which lubricates the food so it is easier to swallow. Chemical digestion of carbohydrates may also begin.

The action of teeth greatly increases the surface area of foods to expose them to the digestive chemicals that will help to break them down. Most mammals have four kinds of teeth: incisors and canines (which are single teeth for cutting), and premolars and molars (which are double teeth for grinding). Think about the way you bite and chew an apple. The single teeth cut it and the double teeth grind it.

In mammals, the type of teeth depend largely on the sorts of food eaten. Carnivores (animals that eat other animals) have large canines. Their cheek teeth are specialised for a slicing action to cut and tear flesh and bones. The jaws of a carnivore are short and have a powerful bite. They can only move up and down. Carnivores typically gulp their food. Carnivorous mammals include dogs, cats, tiger quolls and Tasmanian devils.

Herbivores (animals that eat plants) have no canines, but have large, flat double teeth to grind plant food with jaws that can move from side to side. Herbivorous mammals include cows, kangaroos and koalas.

Omnivores (animals that eat both plants and animals) have some teeth for tearing and cutting meat, and others for grinding plant food. Omnivorous mammals include humans, pigs and some rodents.

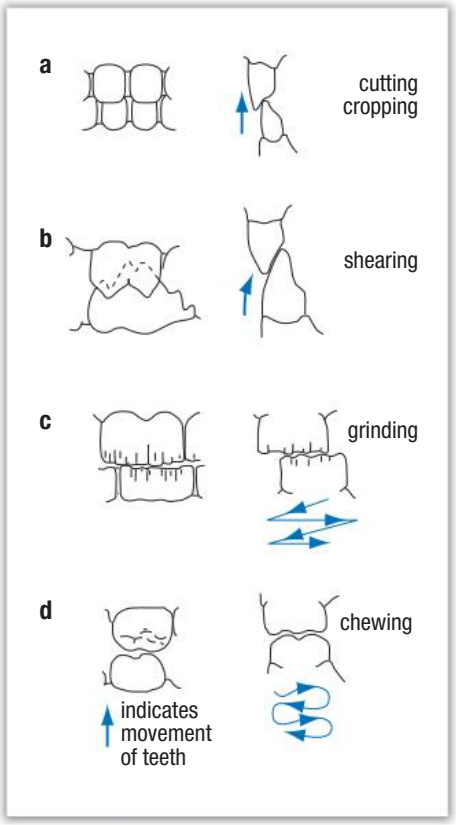


Figure 2.53 In mammals, tooth structure is adapted for the mechanical breakdown of different types of foods. (a) Incisors are typically used for cutting and tearing. (b) Carnivores have large, powerful cheek teeth that shear through tough sinews and bones. (c) Herbivores have molars that continuously grind fibrous plant foods. (d) Omnivores, such as ourselves, have molars that roll and crush a variety of foods.



Figure 2.54 Some bats have an almost liquid diet. Flying foxes and fruit bats feed on soft fruits, nectar, pollen and small seeds. Flattened molar teeth and a ridged palate (roof of the mouth) crush the fruit; the juice is swallowed and the fibre spat out. Blossom bats (pictured) feed on pollen and nectar, using a brush-tipped tongue to reach deep into flowers. The digestive tract in nectar feeders is very short and unspecialised, and because the diet is low in fibre, food passes through it very quickly.

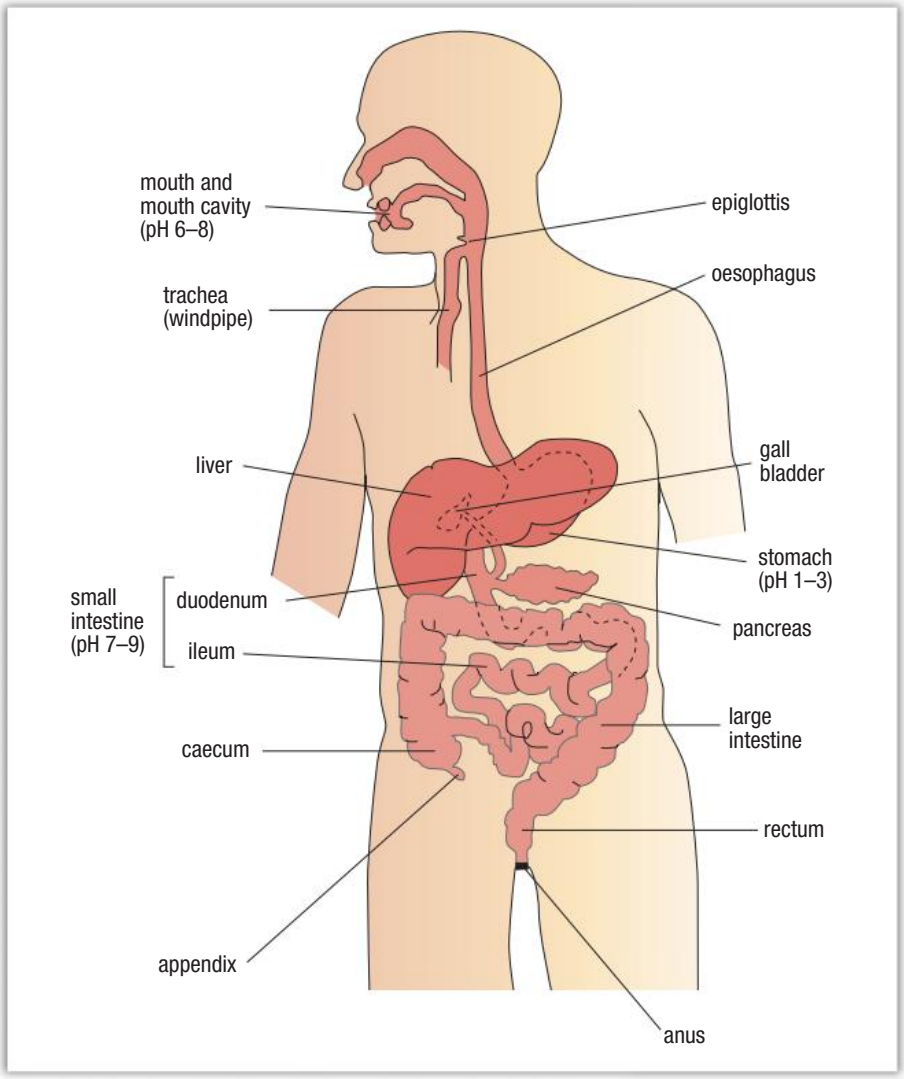


Figure 2.55 The human digestive system.

Mouth and mouth cavity: teeth mechanically break food into pieces, saliva lubricates food, amylase digests starch into maltose.

Epiglottis: closes off the trachea so food goes down oesophagus.

Oesophagus: peristalsis carries food to stomach.

Stomach: proteases begin the digestion of proteins, and food is churned.

Pancreas: produces enzymes and neutralises acid.

Liver: produces bile which emulsifies fats, regulates and stores some products of digestion.

Gall bladder: stores bile.

Small intestine: digestion is completed by enzymes from the pancreas and the small intestine itself; nutrients and water are absorbed.

Large intestine: water is absorbed with soluble compounds like vitamins and minerals; undigested food leaves body as faeces via the anus.

Oesophagus

The tube between the mouth and stomach is called the oesophagus. The food is pushed along the oesophagus and along the length of the digestive tract by rhythmic muscle contractions, known as peristalsis (see Figure 2.56).

Stomach

In the stomach, chemical digestion of food, particularly proteins, begins. Mechanical digestion also continues through the churning of food. The length of time food spends in the stomach of a mammal is related to the type of diet. Carnivores have simple stomachs; herbivores with fore-gut digestion of cellulose may have complex stomachs, and food may remain in their stomach for a long time. See Figure 2.57 for examples of these digestive systems.

Small intestine

Much of the process of chemical digestion occurs in the small intestine. As soon as food is broken down into small enough molecules, these are absorbed through the walls of the digestive system into the blood to be transported to the body cells. Most absorption occurs in the small intestine.

The inside of the small intestine is constructed of folds called villi (singular villus) (Figure 2.58a). The epithelial cells on the surface of the villi have small finger-like projections called **microvilli** (Figure 2.58b). These folds and projections provide a large surface area, enabling material in the small intestine to be absorbed quickly.

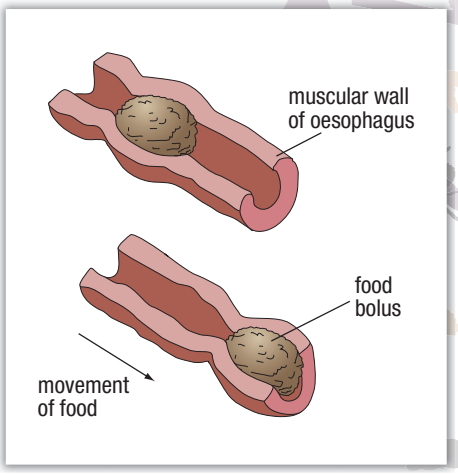


Figure 2.56 A rhythmic contraction of the oesophagus wall, called peristalsis, moves food from the mouth to the stomach.

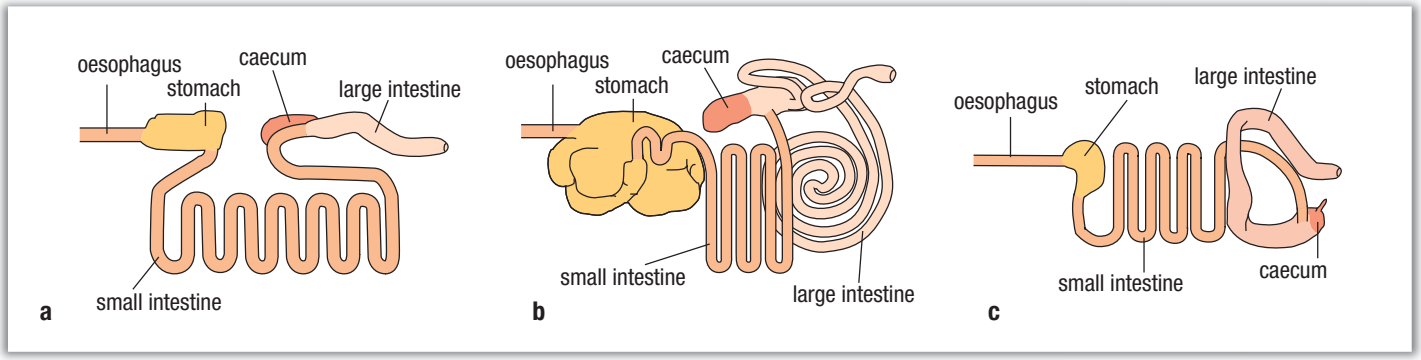


Figure 2.57 The digestive systems of (a) a carnivore (dog), (b) a herbivore (cow), and (c) an omnivore (human).

Large intestine

Water and salts are absorbed in the large intestine. Materials that remain undigested and unabsorbed, together with bacteria, cellular material from the walls of the intestines, and some water and salts, are eliminated from the digestive system as **faeces**. Herbivores usually produce greater quantities of large, more fibrous faeces than carnivores.

Herbivores with hind-gut fermentation have an enlarged **caecum** at the start of the large intestine. Bacterial fermentation of plant material occurs here to break down cellulose fibres. Some absorption of the products of this digestion can then occur in the large intestine. To ensure as much advantage as possible is taken of these nutrients, some hind-gut fermenters, such as possums and rabbits, produce two types of faeces. During the day, dry, fibrous faeces is released. At night, soft, moist faeces is released from the caecum. These are re-eaten by the animal. This ensures that the nutrients released by the action of the bacteria can be absorbed by the animal more effectively in the small intestine.

Carnivores have a much shorter large intestine and a small caecum. Their food requires little if any fermentation.

BIOFACT

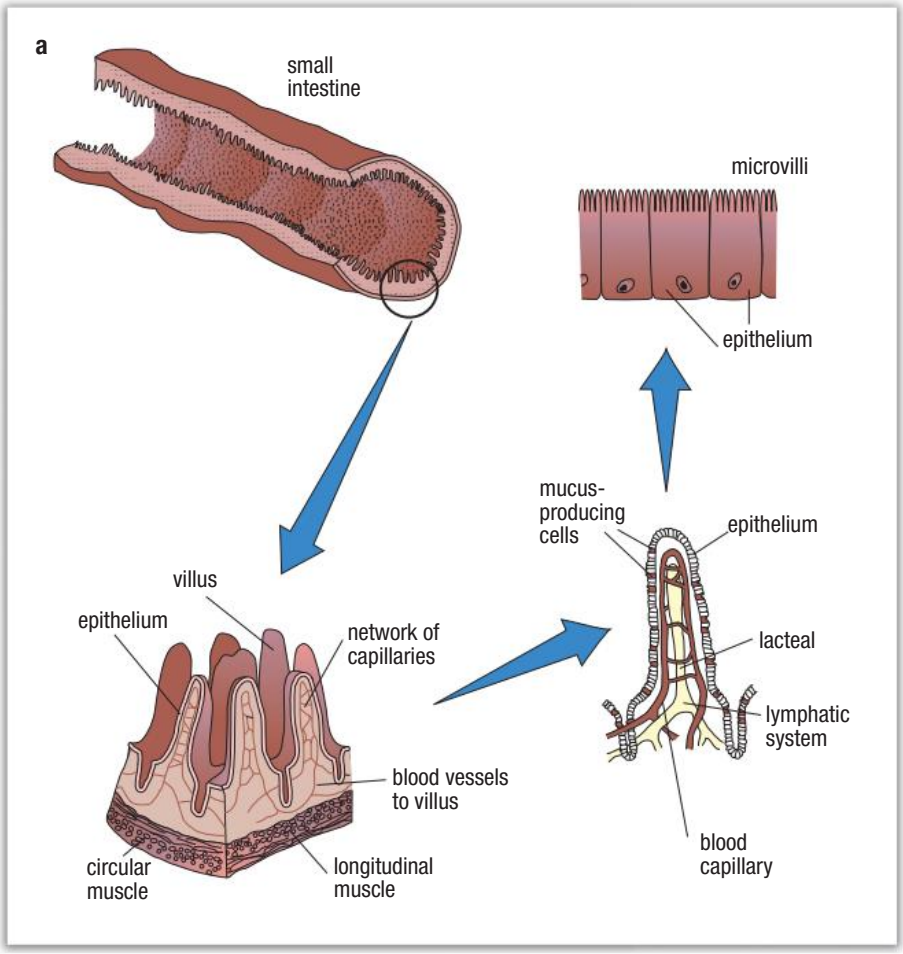
Infections of the gut often result in diarrhoea (very watery faeces) because the food moves so quickly along the intestine that there is insufficient time for normal levels of uptake of digested food and the subsequent absorption of water by osmosis.

Proteins are absorbed after being broken down to amino acids.

Carbohydrates are absorbed after being broken down to simple sugars (monosaccharides).

Lipids are absorbed after being broken down to fatty acids and glycerol.

Vitamins, minerals and water are absorbed directly.



BIOFACT

- An adult koala eats about 0.5 kg of leaves per day.
- The caecum in an adult koala is 2.4 m long—the longest of any mammal.
- The metabolic rate of koalas is about half the mammalian average.

Figure 2.58 (a) The internal surface of the small intestine is highly specialised for absorption. Villi and microvilli greatly increase the surface area, and there are many blood and lymphatic vessels to carry away the absorbed products of digestion.
(b) An electron micrograph showing microvilli on the inner surface of the intestinal epithelial cells.

All gummed up: koalas and digestion

The koala is notable for its exclusive diet; it eats only the leaves of eucalypt trees (gum leaves). Of around 700 species of *Eucalyptus*, only about 20 are eaten and, in a particular area, three or four species will be favoured. Although more than 90% of Australia's forest trees are eucalypts, only four marsupials (the koala, greater glider, ringtail possum and brushtail possum) include them as a significant component of their diet, and only the koala eats them exclusively. Gum leaves contain only about 50% water, very little nitrogen, large amounts of fibre (including components that are difficult or impossible to digest), and potentially toxic oils. How do koalas cope?

They prefer young, soft leaves and chew these to a fine paste. Most of the digestible contents are absorbed in the stomach.

Both the caecum and the first part of the colon of the koala are greatly enlarged to allow for a high level of bacterial fermentation, but even so, very little energy is released from eucalypt cell walls because they are so indigestible. In fact, koalas get only about 10% of their energy from fermentation, and they rely heavily on cell contents for nutrition. Bulky, indigestible fibre is selectively and speedily egested from the gut to make way for more food.



Figure 2.59 The koala's digestive system is specially adapted to its diet of eucalypt leaves.

Because of the energy and nutrient costs of detoxifying some of the leaf oils, the less food a koala has to eat to survive, the better. As a group, marsupials have a lower metabolic rate than placental mammals, so the koala's basal energy requirements are less. Also the characteristic slow and 'lazy' behaviour of the koalas mean that they do not use up much energy for physical activity.

Guts: the inside story

Plant matter is more difficult to digest than animal tissues. Plant cells have tough cellulose cell walls that must be broken down before the cell contents can be released. Animals are not able to do this unaided. Herbivores use microorganisms that live symbiotically in their digestive systems to help them. The breakdown of cellulose occurs during a fermentation process in a specialised part in the digestive tract. These structures are found in either the fore-gut or the hind-gut of different parts of the digestive system (see Figure 2.60):

- Fore-gut fermenters carry out digestion in a chamber that is situated before the stomach. In cattle, this is called the **rumen**. Sheep, kangaroos and wallabies are other examples of fore-gut fermenters.
- Hind-gut fermenters carry out cellulose digestion in the caecum, a chamber that comes after the small intestine or **colon**, before the large intestine. Horses, rabbits, possums and koalas are examples of hind-gut fermenters.

Carnivores do not have to consume the large quantity of materials that herbivores do to obtain the same amount of nutrients. This is because animal cells do not have a cell wall and so can be digested more rapidly. Muscle (meat) contains a lot of protein, so plant cells also provide less energy than meat per gram eaten and their breakdown time in the digestive system is much longer. In contrast, animal foods release a higher proportion of energy per gram and they can be digested much more quickly.

explain the relationship between the length and overall complexity of digestive systems of a vertebrate herbivore and carnivore, with respect to:
- the chemical composition of their diet
- the functions of the structures involved

As a result, carnivore digestive systems are shorter and less complex than those of herbivores. The structures and functions found within the digestive systems of different animals can usually be clearly related to their dietary patterns; that is, to the types of food they eat.

Food does not spend long in a carnivore's mouth and is quickly gulped down. A dog, for example, may spend only 15 minutes per day eating. The intestines are short and unspecialised compared with those of herbivores.

Carnivores in the wild are hunters and eat irregularly. Herbivores, such as as cows and kangaroos, spend much of the day chewing grass and other soft plants.

Omnivores usually eat for a moderate amount of time each day; humans typically eat for about 90 minutes each day. Our digestive systems are intermediate in length between herbivores and carnivores, and do not show particular specialisation. We cannot digest cellulose—it is passed through as 'roughage'.

Koalas and wombats are hind-gut fermenters. Koalas carry out cellulose digestion in the caecum and first part of the large intestine, wombats carry out cellulose digestion in all parts of the large intestine. Kangaroos are fore-gut fermenters, and cellulose digestion occurs in their long, large stomachs.

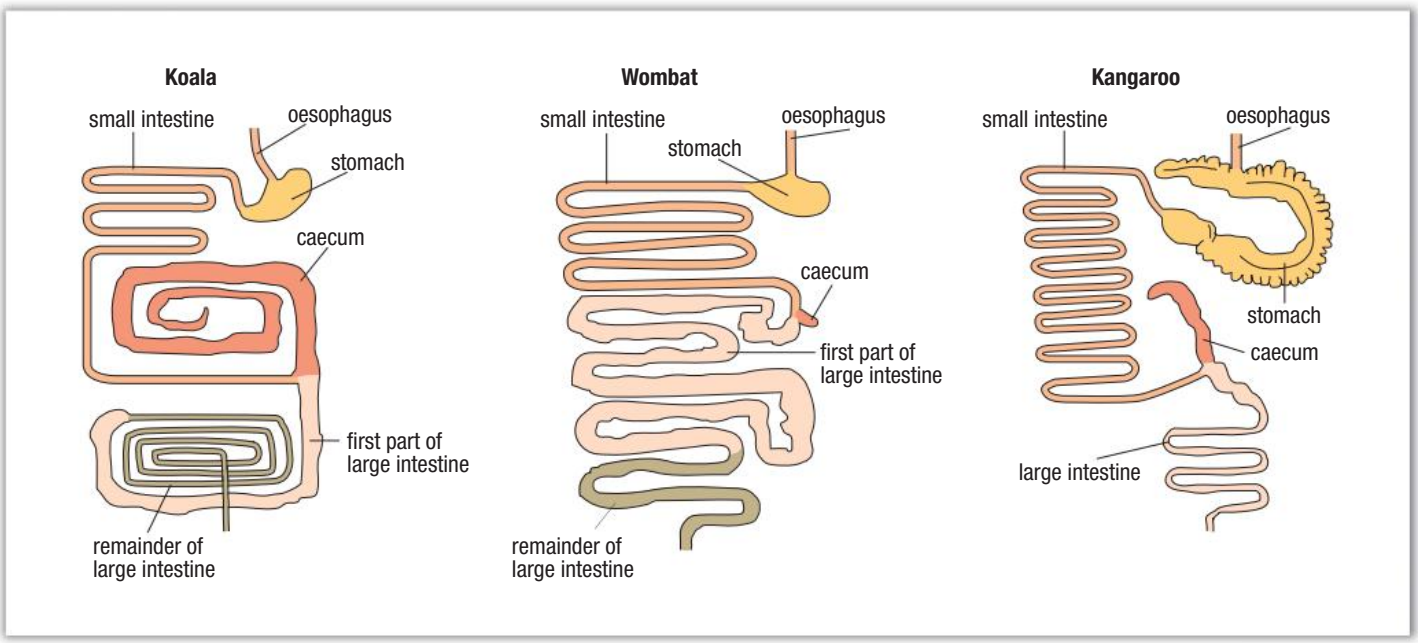


Figure 2.60 Koalas, wombats and kangaroos are herbivores and use symbiotic bacteria for the digestion of cellulose.

2.9 INVESTIGATION
Surface area and rate of reaction

Students will: perform a first-hand investigation to demonstrate the relationship between surface area and rate of reaction.

Introduction

In mammals, chewing food particles to reduce their size prepares them for further chemical digestion. This experiment simulates the process of digestion using nuts (the food) and hydrogen peroxide (the digestive chemical). When the two come into contact, a reaction occurs in which bubbles of oxygen are released, causing fizzing. The rate at which oxygen bubbles out is a measure of the rate of the reaction between the peroxide and the nuts.

Purpose

To demonstrate the relationship between surface area and rate of reaction.

Procedure

1. Take equal weights of whole and chopped nuts.
2. Place the whole nuts into the tube labelled A and the chopped nuts into the tube labelled B.
3. Draw up 10 mL of hydrogen peroxide solution.
4. Pour the hydrogen peroxide simultaneously into the two test-tubes. Observe the reactions for 1 minute and after 3–5 minutes.

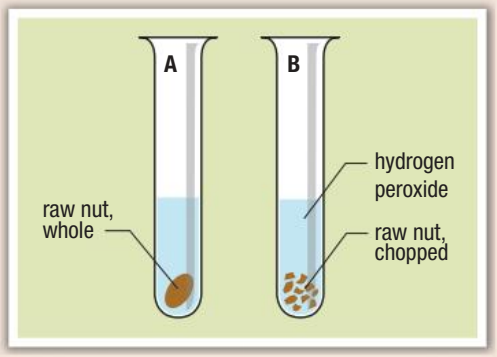


Figure 2.61 Diagram of experimental apparatus.

Results

Describe what you saw in each test tube

Discussion

1. State in words the differences between the reactions you observed
2. How could you explain the differences in your results?
3. Explain what is meant by the terms 'surface area' and 'rate of reaction'.

Conclusion

Explain the relationship between surface area and rate of reaction.

Skills and outcomes

P12, P13, P14

Type of activity

First-hand investigation

Materials

- two test-tubes, labelled A and B in a test-tube rack
- two syringes, measuring cylinders or a 10 mL pipette
- hydrogen peroxide solution (3%)
- raw nuts, whole and chopped, e.g. peanuts, walnuts, pine nuts

Caution

Handling chemicals must always be done with care. Clean up spills immediately. If you come into contact with the hydrogen peroxide solution, immediately rinse the affected area under cool running water. If you are allergic to nuts, tell your teacher before attempting the experiments.

See First-hand investigations

INVESTIGATION 2.10

Comparison of mammalian digestive systems

Students will: identify data sources, gather, process, analyse and present information from secondary sources and use available evidence to compare the digestive systems of mammals, including a grazing herbivore, carnivore and a predominantly nectar-feeding animal.

Skills and outcomes

P12, P13, P14

Type of activity

Second-hand data activity

Materials

books, journals, Internet sites

See Analysing information

Introduction

The feeding behaviour of a mammal, and the shape and structure of its digestive system, are related to the type of food it eats. The simplest digestive system in animals is a straight 'food tube'. Different digestive enzymes are secreted into the tube, and digested nutrients are absorbed from the tube. Undigested material is passed out. A mammal obtains the nutrients it requires from its diet.

Purpose

1 To compare the digestive systems of three mammals.

2 To make some inferences about their structure and digestive function, as well as their diet and method of feeding.

Procedure

Read the following information and answer the questions. (See also pp. 111–116 and other available resources as required.)

Cow

Cows spend much of their time eating grass. This is quite an inactive process. At certain times of the day they can be observed sitting quietly and chewing. Cow's teeth are quite different in appearance from those of a dog. Apart from the cutting teeth at the front, the back teeth have flat surfaces that are good for grinding. The main nutrient in plant material is the complex carbohydrate cellulose, which must be broken down into smaller molecules before it can be absorbed. Mammals are unable to manufacture cellulase (the enzyme that breaks down cellulose) and so they must rely on the activity of microorganisms to do this. These microorganisms are found in specialised fermentation chambers in the gut. The process is slow and not very efficient.

Dog

Dogs are very active and spend only a small amount of time feeding. They mostly eat food of animal origin (meat, bones, etc.) which they are able to tear apart with their specialised teeth. The food is usually ingested in a series of rapid gulps. These foods have a much higher energy content per gram than plant foods, and a dog's gut produces all the enzymes necessary to digest them. As a result, digestion is rapid and efficient.

Honey possum

The honey possum (*Tarsipes rostratus*) is a tiny but very active marsupial mammal that lives in the heathlands of south-western Western Australia. During the day it sleeps in crevices or tree-hollows, but at night it climbs with agility through flowering plants, especially banksias, bottlebrushes and hakeas, to feed on nectar and pollen. Nectar is a

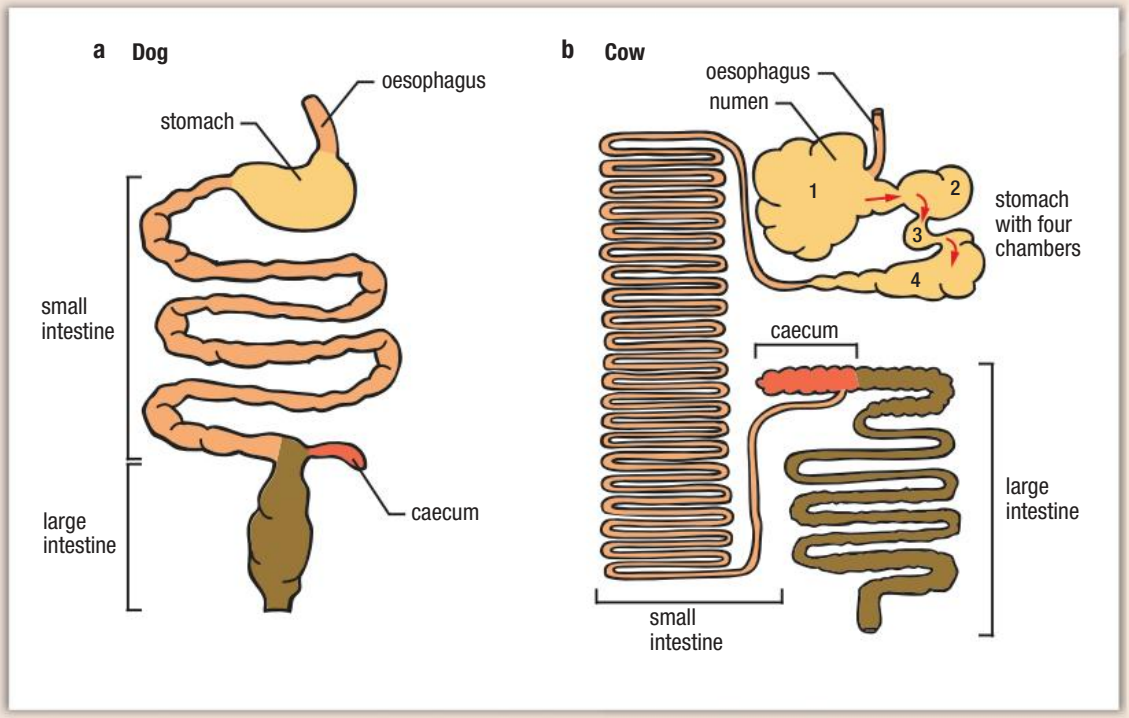


Figure 2.62 Digestive system of a dog (a) and a cow (b) compared.

sugary solution and pollen contains protein, carbohydrate and lipids. This diet is low in fibre and cellulose.

The honey possum has narrow, tapering jaws with only a few small teeth. The tongue is long and stiff and has finger-like or brush-like projections to collect the pollen. The pollen is scraped off the tongue by ridges on the roof of the mouth and swallowed. Large amounts of nectar may be consumed in a short time. The stomach has two chambers where the nectar and pollen are stored. No protein-digesting enzyme is secreted by the stomach. The intestines are relatively short and it is hard to distinguish between the small and large intestine, and there is no caecum. This digestive system is unspecialised. The main adaptations shown by the honey possum in relation to its diet are its specialised mouth and tongue.

Figures 2.62 and 2.63 compare the digestive systems of a dog, a cow and a honey possum. The relative lengths of the sections are in proportion.

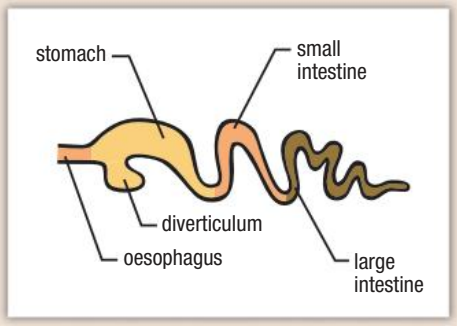


Figure 2.63 The digestive system of the honey possum.

Discussion

1 What is the purpose of digestion?
2 What is the name given to mammals that eat only meat?
3 What is the name given to mammals that eat only plant material?
4 What is the difference between a fore-gut fermenter and a hind-gut fermenter? Give examples of mammals in each category.
5 What is the purpose of a cow 'sitting quietly chewing'?
6 Compare the relative size and shape of the stomach of the three mammals in Figures 2.62 and 2.63. Explain the differences in terms of the type of food eaten and the amount of digestion that is required. Think carefully about each mammal's diet.
7 Compare the relative length of the small intestine in the three mammals in Figures 2.62 and 2.63 and attempt to relate differences in length to differences in diet.

UNIT REVIEW 2.3

Obtaining nutrients

Plants and animals have specialised structures to obtain nutrients from their environment.

Summary

- Multicellular organisms are made up of cells, tissues, organs and organ systems. The structural and functional relationship between these parts ensures that the organism functions in a coordinated way.
- Autotrophs obtain their nutrients from simple inorganic materials in their environment. Heterotrophs obtain their nutrients from complex organic substances found in other living organisms.
- Autotrophs require carbon dioxide and water for the process of photosynthesis. All ecosystems depend on photosynthesis by autotrophs to provide the energy to sustain them.
- In photosynthesis, light energy is trapped and used to combine carbon dioxide and water to form sugars. The overall equation for photosynthesis is a summary of a chain of biochemical reactions that occur in this process.
- The structures used by plants to obtain water and minerals require a large surface area for absorption. In land plants this is provided by the structure of roots and root hair cells.
- The thin, flat shape of leaves and the distribution of tissues, including stomates, ensure a large surface area for the absorption of light and the exchange of gases in photosynthesis.
- The teeth of mammals break food into smaller particles to increase the surface area that is exposed to digestive chemicals.
- The length and complexity of vertebrate digestive systems is related to the food the vertebrate eats. Herbivores with a diet high in cellulose have a longer and more complex digestive system than carnivores, which have a high protein diet.

Questions

1 Which of the following could be a group of cells that are similar in structure and work together as a tissue?

A a layer of muscle cells in the wall of the stomach

B the incisor teeth in the mouth of a herbivore

C the cells in a leaf aligned to capture sunlight

D the oesophagus, stomach and intestine of a mammal

2 Which of the following statements is true when we compare autotrophic and heterotrophic cells?

A All heterotrophic cells are animal cells.

B All autotrophic cells contain chlorophyll.

C Autotrophic cells depend on heterotrophic cells for nutrients.

D Plant cells are autotrophic and animal cells are heterotrophic.

3 Which statement correctly compares the diet and digestive systems of herbivores and carnivores?

A Herbivores eat more regularly and have a longer system than carnivores.

B Herbivores and carnivores all have similar stomachs, but the intestine is longer in herbivores.

C Only carnivores have villi and microvilli to aid digestion of their dietary protein.

D Herbivores have no specialised teeth for cutting and grinding food, and rely on chemical digestion in their larger stomachs.

4 Cell specialisation in multicellular organisms is an adaptation that allows all of the organism's requirements to be met. Complete the table below, which displays some different kinds of specialised cells in multicellular organisms and their functions.

Cell type	Plant/animal	Diagram	Function	How structure relates to function
nerve cell				
lining cell of small intestine				
root hair cell				
leaf mesophyll cell				

5 a Explain the following statement: 'All living things depend on plants.'

b Write out the word equation that summarises the process of photosynthesis.

6 a Compare aquatic and terrestrial plants in relation to the site of water and mineral uptake.

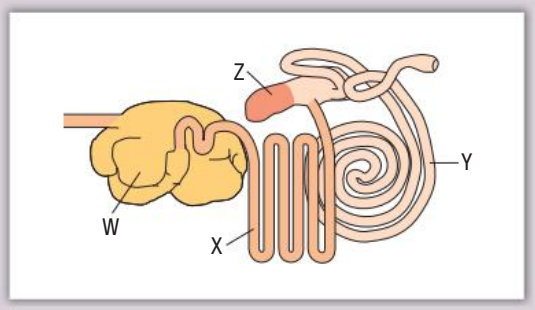
b Terrestrial plants need a large surface area in order to maximise water uptake. Explain how this is achieved.

7 Explain how the structure of typical leaves and the distribution of specialised tissue within them are adaptations to photosynthesis. Use clearly labelled diagrams in your answer.

8 a Explain the difference between mechanical and chemical digestion.

b Teeth are involved in the process of mechanical digestion. Describe the significance of their role in terms of preparing foods for chemical digestion.

9 Identify the structures labelled W, X, Y and Z in the diagram of the herbivore digestive system shown. Name the major function of each structure you have identified.



10 a Compare the digestive systems of dogs (Figure 2.57a on p. 113) and koalas (Figure 2.60 on p. 116) with respect to the length, complexity and role of the different structures found.

b Explain the relationship between the length and complexity of the digestive systems of dogs and koalas, and the chemical composition of their respective diets.

11 Analyse the relationship between the structure of the digestive systems and the chemical composition of the diet of a named grazing herbivore and a named predominantly nectar-feeding animal.

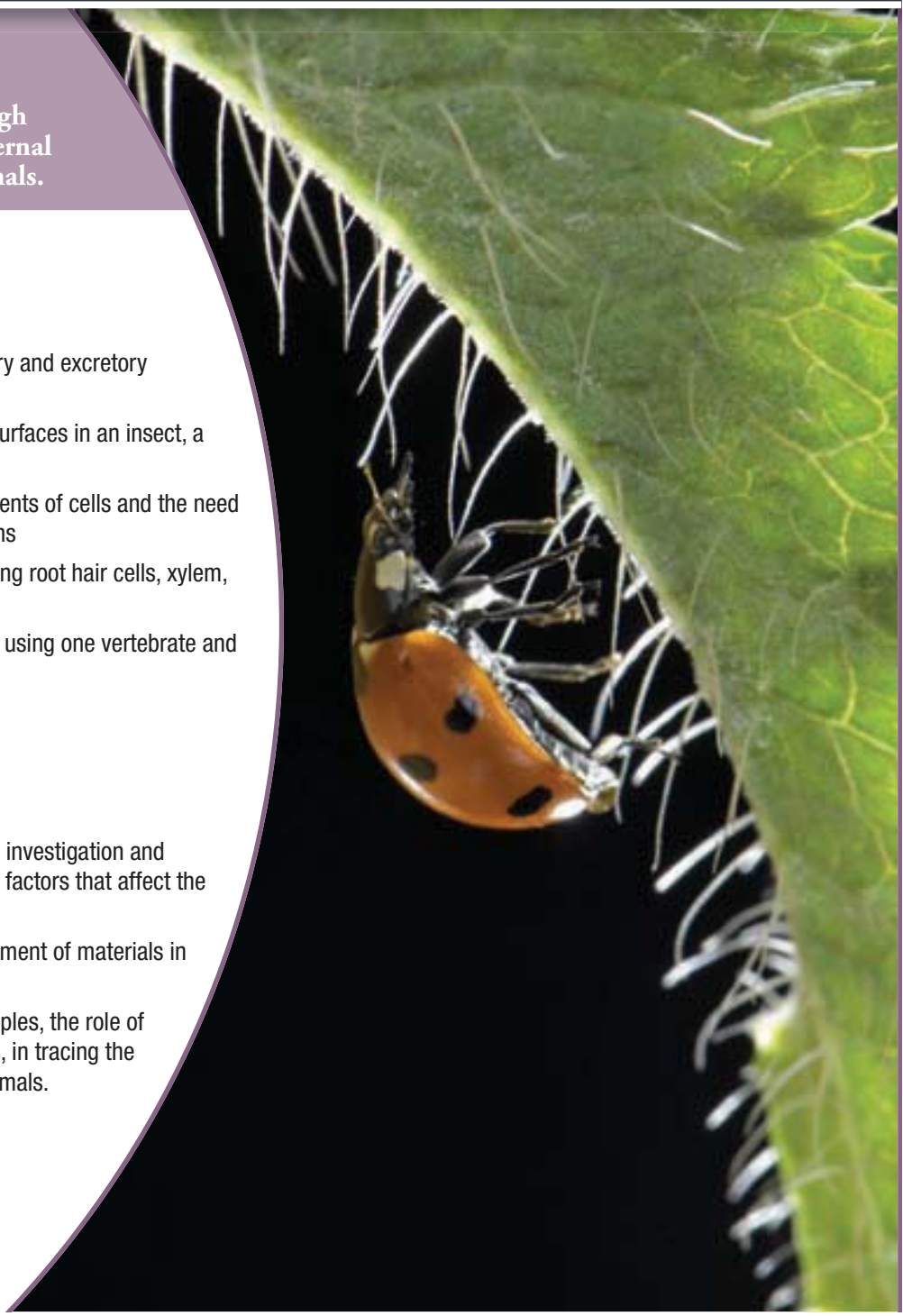
12 Summarise the specialised structures needed to obtain nutrients from the environment in:

a plants

b animals.

2.4 EXCHANGING GASES

Gaseous exchange and transport systems transfer chemicals through the internal and between the external environments of plants and animals.



STUDENT LEARNING

In this unit students will:

- compare the roles of the respiratory, circulatory and excretory systems
- identify and compare the gaseous exchange surfaces in an insect, a fish, a frog and a mammal
- explain the relationship between the requirements of cells and the need for transport systems in multicellular organisms
- outline the transport systems in plants, including root hair cells, xylem, phloem, stomates and lenticels
- compare open and closed circulatory systems using one vertebrate and one invertebrate as examples.

STUDENT ACTIVITY

Students will:

- use available evidence to perform a first-hand investigation and gather first-hand data to identify and describe factors that affect the rate of transpiration
- perform a first-hand investigation of the movement of materials in xylem or phloem
- use available evidence to discuss, using examples, the role of technologies, such as the use of radioisotopes, in tracing the path of elements through living plants and animals.

The roles of respiratory, circulatory and excretory systems

compare the roles of the respiratory, circulatory and excretory systems

In plants and animals, chemicals are moved within the internal environment and between the internal and external environments. The movement of these chemicals occurs in specialised exchange and transport systems. Respiratory systems transfer gases in and out. In animals, the gases of the process of respiration are exchanged–oxygen is taken into the organism and carbon dioxide is removed into the environment. In plants, the gases of respiration and photosynthesis are exchanged.

Respiratory systems must connect with the external and internal environments. They have specialised gaseous exchange surfaces where the two environments meet and allow these exchanges to occur as efficiently as possible.

Circulatory systems move chemicals in solution around the internal environment of organisms, usually in specialised vessels. In animals, the fluids are often pumped by a **heart**. The system has close contact with all the internal organs as it circulates, bringing in nutrients and collecting products, including wastes. In plants, food materials and water are transported in different directions, in separate vessels, not circulated as in animals.

Excretory systems eliminate wastes produced by the chemical activities of the cells. They absorb these from the internal environment and release them into the external environment. In animals they also assist in water balance.

Gas exchange in animals

identify and compare the gaseous exchange surfaces in an insect, a fish, a frog and a mammal

All organisms respire; they take in oxygen from their external environment and release carbon dioxide. To obtain the oxygen required by cells in respiration and to get rid of unwanted carbon dioxide produced, multicellular animals have developed specialised gas exchange or **respiratory surfaces**.

Respiratory surfaces must be thin and moist, with a large surface area so that the gases can diffuse through. They must also bring together the internal and external environments so that gases can be exchanged between the cells and the organism's surroundings.

The respiratory surfaces of aquatic animals are more exposed to the external environment than those of land animals. Land animals have internal respiratory surfaces that they can keep moist without too much loss of water from evaporation.

Insects

Insects have a system of interconnecting tubes called **tracheae** within their body (Figure 2.64). These tracheae are lined with cuticle and open to the external environment through pores, or spiracles, on the segments of the abdomen. In many insects, especially those that fly, the **tracheal system** includes inflatable air sacs that hold a reserve of air that can be pumped to tissues needing an extra supply, such as wing muscles. The spiracles are divided into air-intake spiracles and air-expiration spiracles. The spiracle openings are attached to muscles that can adjust the size of the opening and can be closed to prevent water loss.

Insects have a system of branching tubes called tracheae within their body. The tracheae branch throughout the tissues of the insect, bringing air directly to the cells.

The cuticle lining the tracheae lacks the cement and wax layers of normal cuticle, and it is therefore permeable to water. The tracheae branch throughout the tissues of the insect, bringing air directly to the cells. The endings of the tracheae, called tracheoles, are normally filled with fluid. The volume occupied by the tracheal system is relatively large (up to half the total body volume), so the surface area of the tracheae is sufficient to supply all the body cells with oxygen and remove carbon dioxide.

Aquatic insects, including the aquatic larval stage of many terrestrial insects, usually have a modified system of spiracles or gas gills that take in air directly, either at the water surface or from bubbles of air trapped against the body. In some groups, such as dragonflies and mayflies, the aquatic larvae have feathery gills that take oxygen from the water by diffusion.

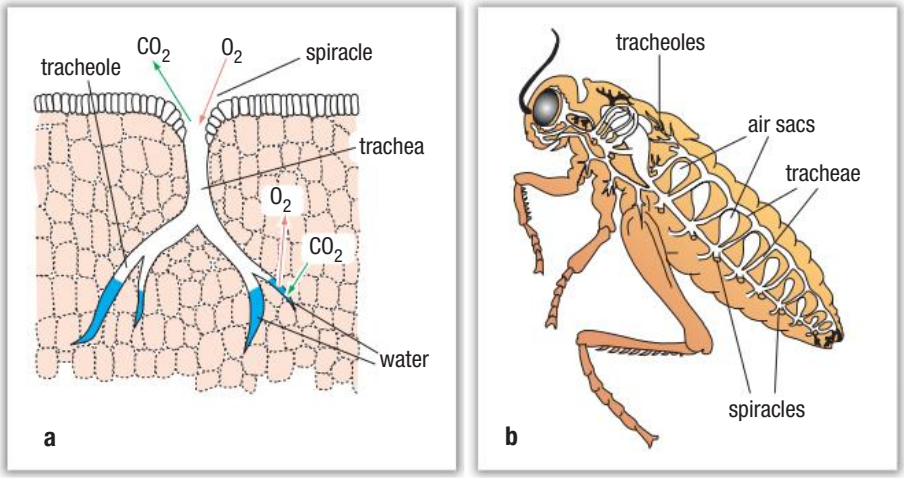




Figure 2.64 (a) Insects do not have lungs or blood vessels. They have a system of air-filled tubes called tracheae and finer tubes called tracheoles, which penetrate every tissue, bringing air into close contact with their cells. Air enters the tracheae through spiracles. (b) Some insects, such as grasshoppers, also have air sacs that can be pumped like bellows to move air through the system. (c) A mayfly nymph, with its spiny gills visible along the length of the abdomen.

Fish

In fish, the respiratory surfaces are usually **gills** over which water flows (Figure 2.65). Some animals have exposed gills (e.g. sharks) and others have gills covered by an operculum (e.g. bony fish). Gills are usually finely divided, and the incoming water flows over a large surface area at the one time. There is a plentiful blood supply to transport the gases to and from the gills (Figure 2.66). The blood flows in the opposite direction to the flow of water. This counter-current blood flow increases the efficiency of the gas exchange process.

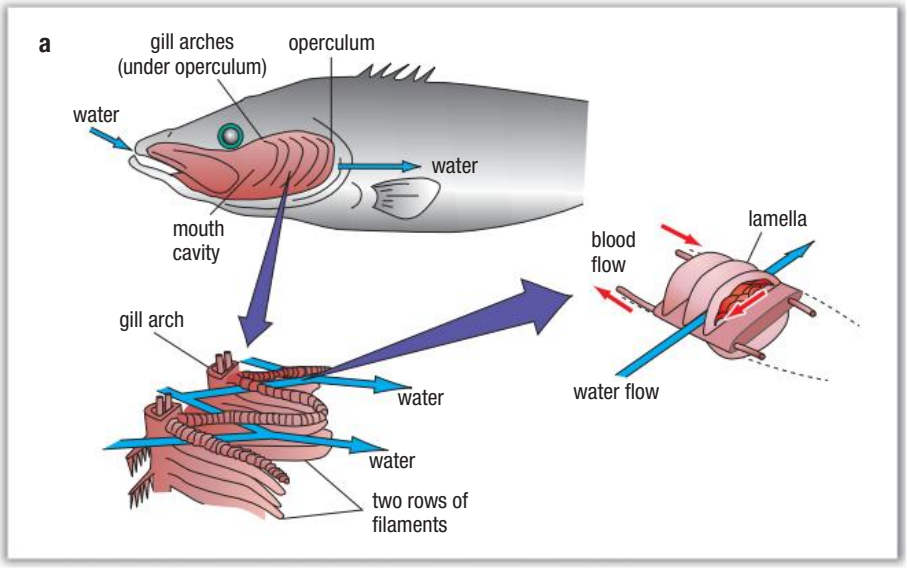


Figure 2.65 (a) Water flows across fish gills in one direction, through the mouth and pharynx, past the gills and out under the operculum. Each gill arch has many finger-like gill filaments and each of these has a row of closely packed, flat, leaf-like lamellae across which gas exchange occurs. The lamellae provide a large surface area for exchange and are visibly red because they contain many blood vessels. Water and blood flow in opposite directions through the lamellae, which increases the amount of gas exchanged. (b) A row of lamellae along the gill filament of a rainbow trout.

Frogs

Frogs have two respiratory surfaces: the **lungs** and the skin. The surface of the skin is usually kept moist and has a very well developed blood supply to it. Oxygen from the air diffuses into the moist skin (subcutaneous breathing) and is transported by the blood to the heart, from where it is sent directly to the body. Frog lungs are simpler structures with a smaller surface area than those of mammals. The paired lungs hang in the frog's abdominal cavity. The frog has no diaphragm. Air is passed in and out by the pumping movement of the floor of the mouth (known as the buccal pump), and the opening and closing of the nostrils (Figure 2.67).

Mammals

In mammals, gases are exchanged in the lungs (Figure 2.68). These surfaces are protected from desiccation by being inside the body's waterproof covering. The surface area of contact between the blood and air is increased by the convolution of the lungs into lobes, by the branching of the bronchioles into smaller and smaller tubules, and by the division of the tubules into clusters of tiny air sacs called **alveoli**. Gas exchange occurs across the thin walls of the alveoli. There is a plentiful blood supply to transport gases to and from the lungs. Air is moved in and out of the lungs in the process of breathing brought about by muscles of the chest wall and diaphragm.

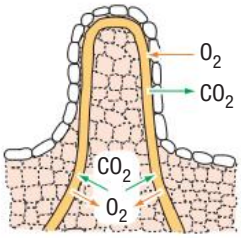


Figure 2.66 Gas exchange in a simple gill.

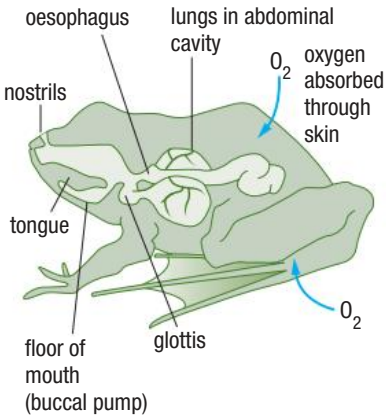


Figure 2.67 The respiratory system of a frog.

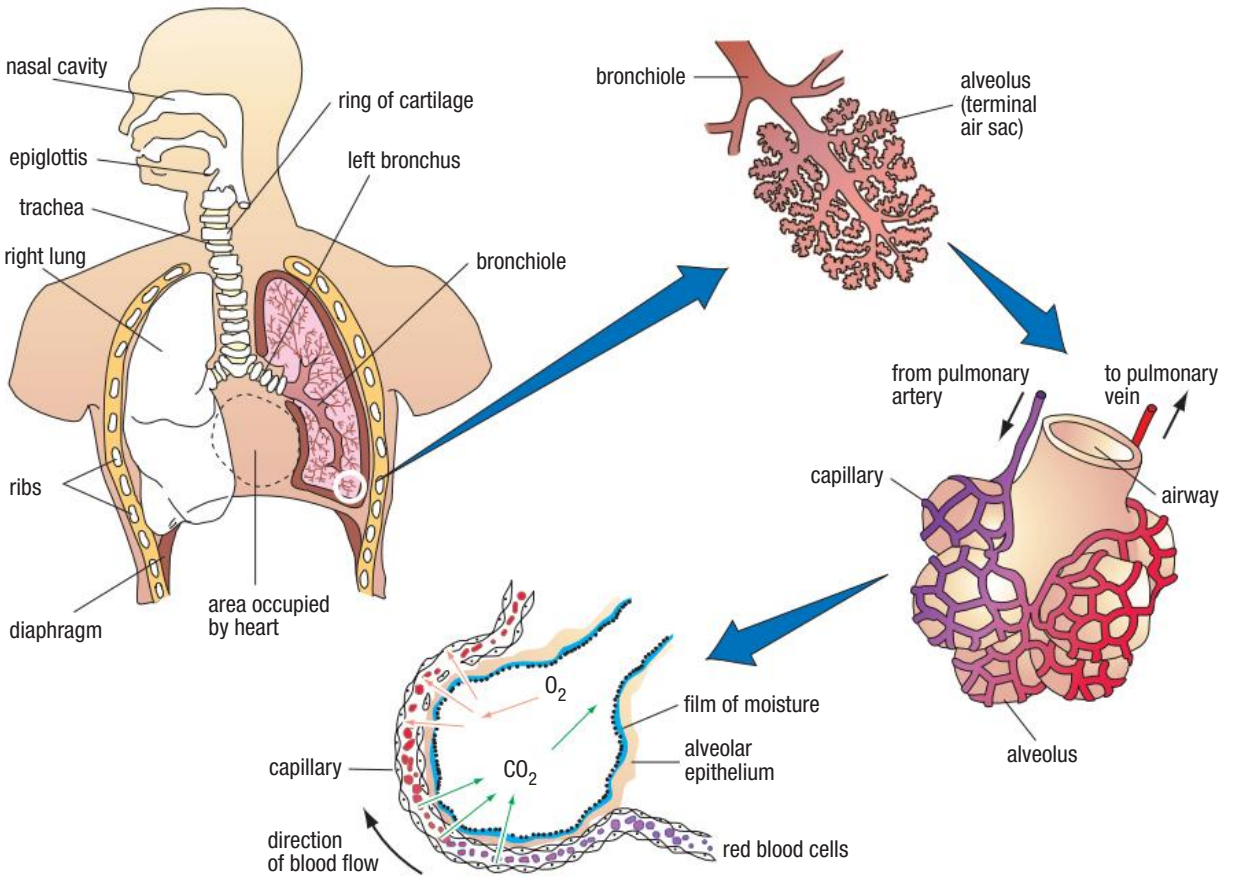


Figure 2.68 The human respiratory system. Air moves in small volumes into and out of the lungs. Gas exchange occurs across thin alveolar walls.

TABLE 2.11 Comparing the gaseous exchange surfaces in some animals

Organism	Name of respiratory organ	Name of respiratory surface	Location	How surface area for gas exchange is increased	How oxygen reaches the exchange surfaces	Additional forces
insect	tracheae	tracheoles	internal	branched tracheae and finely branched tracheoles	by diffusion of air into spiracles on thorax and abdominal segments	wing movements and pumping of air sacs
fish	gills	filaments	external	finely divided filaments	by water flowing across the gills	counter-current blood flow in gills
frog	(a) skin (b) simple lungs	(a) skin (b) inner folds of lung	(a) external (b) internal	(a) use of whole body surface (b) folded inner surface of lungs	(a) by diffusion across moist body surface (b) by breathing air into the lungs	buccal or mouth breathing
mammal	lobed lungs	alveoli	internal	branched bronchioles and alveoli	by breathing air into the lungs	breathing muscles in chest, including diaphragm

The need for transport systems

To ensure that cells are supplied with the nutrients they need and that wastes do not accumulate, multicellular organisms have transport systems that enable substances to be moved to and from the internal body cells. These transport systems are specialised to exchange materials between the internal environment of the cells and the external environment.

explain the relationship between the requirements of cells and the need for transport systems in multicellular organisms

Transport systems in flowering plants

In flowering plants the transport system is called vascular or conducting tissue. It runs in long tubes through the roots, stems and leaves. It consists of two separate transport systems: xylem and phloem. These two systems run close to each other throughout the plant (Figure 2.69). In the root, the xylem and phloem tubes form a central cylinder known as the stele. In young stems they form a ring of vascular bundles. In the leaf, the vascular bundles are visible as veins. In flowering plants, no plant cell is far from vascular tissue.

outline the transport systems in plants, including root hair cells, xylem, phloem, stomates and lenticels

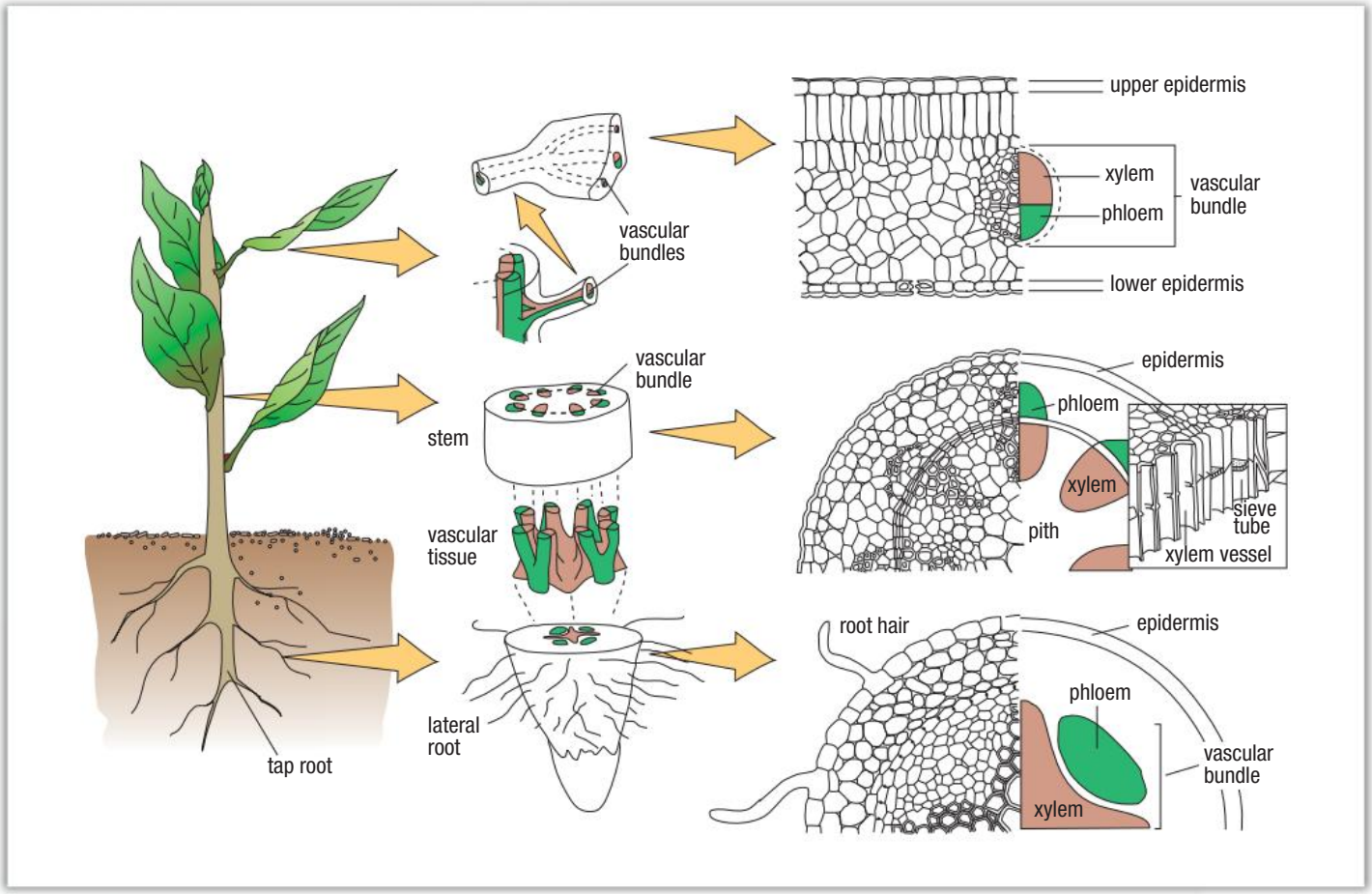


Figure 2.69 Transport systems in plants are continuous through roots, stems and leaves. The vascular tissues, xylem and phloem, are tubular pathways through which fluids travel.

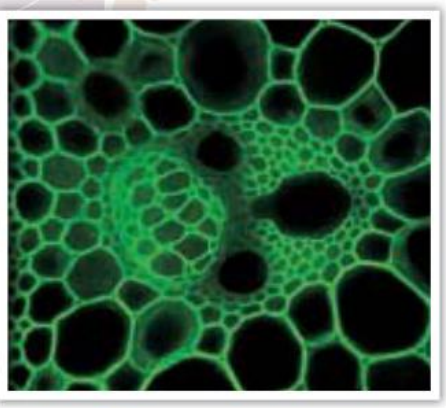


Figure 2.70 A stem cross-section showing xylem and phloem in a vascular bundle (×400).

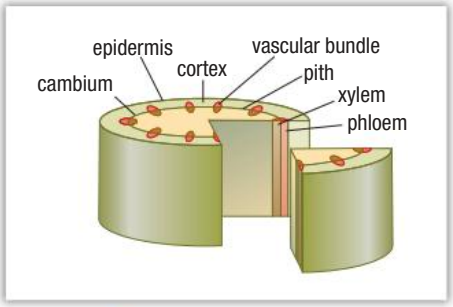


Figure 2.71 The internal structure of a stem.

Xylem vessels consist of dead cells, thickened with woody material, whose cross-walls have broken down, forming a continuous system of tubes.

Water and mineral ions are transported upwards in the xylem, and organic materials are transported both up and down the plant in the phloem. Compare the arrangement of the vascular tissue in stems and roots (Figure 2.69) to see how they differ. Biologists suggest that this arrangement is structurally the most effective in counteracting the bending stresses and strains on the plant when it is blown by the wind.

Water transport

Water and mineral ions flow through plants in an upward stream. They enter via the roots and travel upwards in the xylem tubes. Water is lost from the plant by transpiration.

Root hair cells

Water is taken in by plants through their roots from the soil. The water in the soil has a low concentration of solutes (soluble substances) and is therefore a dilute solution. Inside the plant, water in the cytoplasm of cells has a high concentration of solutes and is therefore a more concentrated solution. Water moves by diffusion down its concentration gradient by osmosis from the soil into the root cells.

The **root hairs** provide a large surface area for the uptake of water (see p. 93). The water moves through to the centre of the root and enters the xylem.

Xylem

The main conducting cells are known as xylem vessels. They consist of dead cells, thickened with woody material, whose cross-walls have broken down, forming a continuous system of tubes. Xylem tubes may be up to 1 metre long. Lying alongside the xylem vessels are strengthening fibres and other conducting cells. Xylem gives support, strength and rigidity to the stem. Water entering the xylem in the roots is transported upwards through the stem to the leaves.

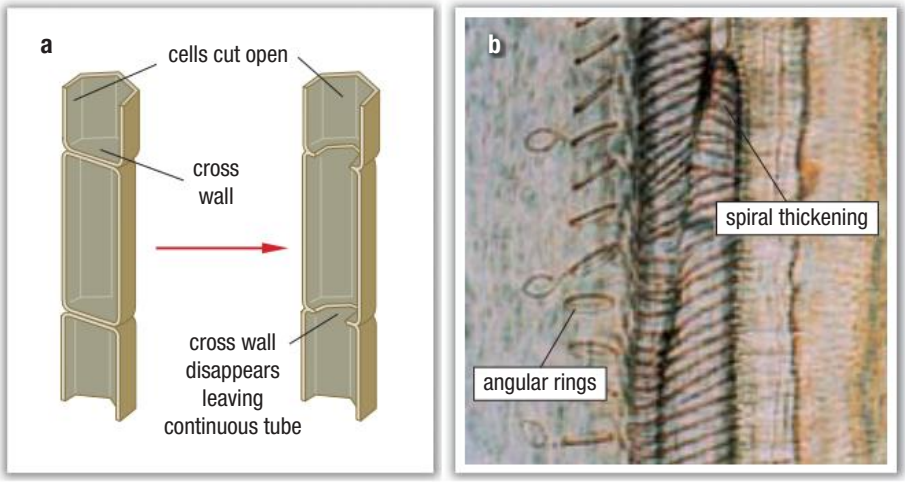


Figure 2.72 (a) Xylem vessels form when the cross-walls break down, leaving a continuous tube. (b) Longitudinal section of xylem. Note the spiral thickenings of the cellulose wall, which add support.

Transpiration

When the stomates of a leaf are open, carbon dioxide, which is required for photosynthesis, can enter a leaf by diffusion. But at the same time, water molecules are lost through diffusion because of the higher water concentration inside the plant. Water evaporates from the cell surfaces, diffuses through the intercellular spaces, and leaves through the stomates. This diffusion of water from a plant is called **transpiration**.

Water loss by transpiration is unavoidable when a plant has its stomates open. Water lost in this way needs to be replaced by water taken in through the roots. The constant upward flow of water through a plant is known as the **transpiration stream** (Figure 2.74).

If water loss exceeds water uptake, the stomates close and cells lose their turgidity. The stems and leaves wilt and the plant may die. When stomates are closed, the transpiration rate drops and diffusion occurs at a much slower rate through the cuticle. Normally stomates are open during the day for the exchange of gases in photosynthesis, and are closed at night.

Some plants have special features (adaptations) to reduce the transpiration rate. These may include a very thick cuticle, sunken stomates, hairs or reduced leaf size. In plants in hot dry environments, this may include the closure of the stomates during the middle of the day.

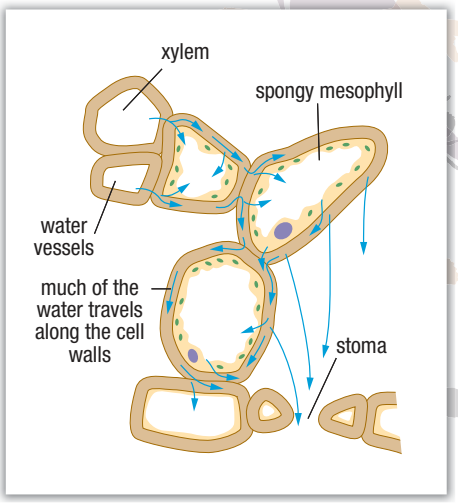


Figure 2.73 Transpiration in leaf cells.

The diffusion of water from a plant is called transpiration.

External factors affecting transpiration

Temperature In high temperatures, diffusion is more rapid (warm air holds more water than cold air).

Humidity If the atmosphere is saturated with water vapour (conditions of high humidity), the transpiration is decreased.

Wind Moving air increases the transpiration rate. Water vapour is carried away from the leaf and a high diffusion gradient is maintained.

Light Light intensity affects stomatal opening, and this in turn affects the transpiration rate.

Soil The water content of the soil and the solute concentration affect the rate at which water can be taken up by a plant.

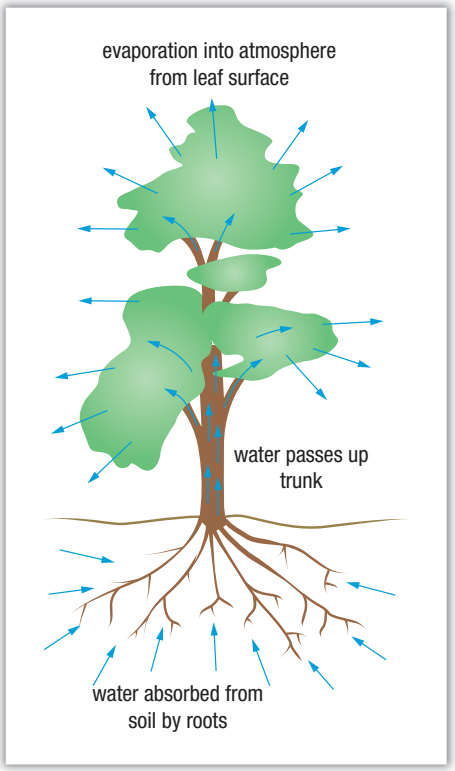


Figure 2.74 The transpiration stream.

INVESTIGATION 2.11

Transpiration

Students will: use available evidence to perform a first-hand investigation and gather first-hand data to identify and describe factors that affect the rate of transpiration.

Skills and outcomes

P6, P11, P12, P13, P14

Type of activity

First-hand investigation

Materials

- 5 pieces of filter paper
- weighing scales (accurate to 0.01 g)
- small plastic bag
- electric fan
- oven

Introduction

Transpiration is the loss of water vapour from the leaves of plants. This occurs when heat from the Sun causes some of the water molecules in the leaves to break their cohesive bonds with other water molecules and evaporate. Transpiration occurs through specialised structures in the leaves called stomates. These structures can either be open, allowing movement of water out of the leaves and carbon dioxide into the leaf, or closed, preventing movement of either substance.

The rate of transpiration from the leaves of plants can be affected by a number of factors. This investigation will allow you to determine some of these factors (see pp. 128–129).

Purpose

To identify and describe factors that affect the rate of transpiration.

Procedure

1 Soak five pieces of filter paper in water. Allow any of the excess water to drain off.

2 Weigh each piece of paper and record the weights in Table 2.12.

TABLE 2.12

Paper number	Weight of paper at start: W1 (g)	Weight of paper after 10 minutes: W2 (g)	Difference: W1 – W2 (g)	Percentage change (%)
1. room temperature				
2. sealed bag				
3. sunlight				
4. oven				
5. fan				

See First-hand investigations

3 Place the first piece of filter paper on the bench.

4 Place the second piece of paper in a small plastic bag. Tie a knot in the end of the bag and leave it on the bench beside the first piece.

5 Place the third piece of paper in a sunny area inside.

6 Place the fourth piece of paper in an oven at 35°C.
7 Place the fifth piece of paper in front of an electric fan operating at low speed.
8 After 10 minutes, re-weigh all five pieces of paper using the same set of scales.
9 Record the weights of each in Table 2.12 and then fill in the last column.

Discussion

1 What environmental conditions are represented by the five experimental conditions?
2 Under what conditions is evaporation from the pieces of filter paper fastest?
3 Under what conditions is the rate of evaporation the slowest?
4 On what type of day would you expect transpiration from a plant that had all of its stomates open to be the greatest? On what type of day would transpiration be the lowest?

Conclusion

Identify and describe some factors that affect the rate of transpiration.

Phloem

Sugars produced in photosynthesis, mostly in the leaves, are stored as starch in the leaf during the day. At night they are converted back to sugars and transported to other plant tissues in the phloem. Phloem consists of long columns of living **sieve tube cells** with perforated end walls, so that the cytoplasm is continuous between one cell and the next. Lying alongside the sieve tube cells are **companion cells** and other supporting tissue. Organic materials in the phloem are transported both upwards and downwards within the plant. This movement is called **translocation** (see *Heinemann Biology Third Edition HSC,* Chapter 1).

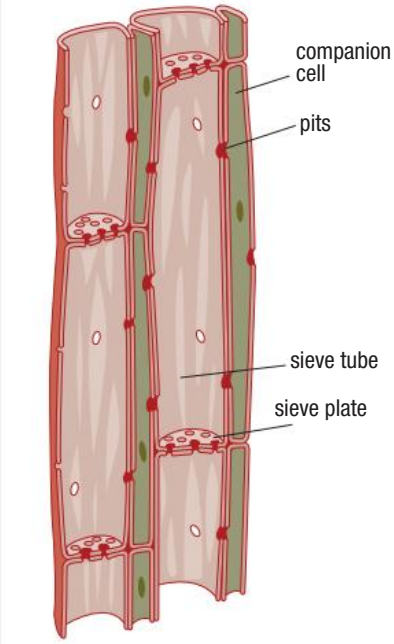


Figure 2.75 Sieve tubes and companion cells.

Gaseous exchange in plants

Plants exchange gases (oxygen and carbon dioxide) with the environment for both respiration and photosynthesis. In aquatic plants such as algae, gases simply diffuse across any exposed surfaces. In land plants, diffusion can occur directly across most surfaces, but both the leaf and stem have specialised structures that help increase the rate at which gases can be exchanged.

Stomates

The leaf is the specialised site of photosynthesis for the plant. Leaves are usually flat and thin, with a large surface area, and covered with stomates. Stomates are pores in the leaf through which gases can diffuse.

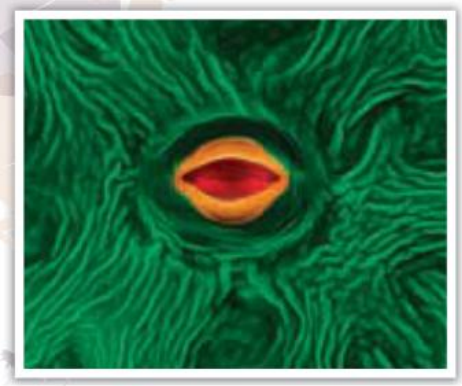


Figure 2.76 Stomate surrounded by guard cells (surface view, ×400).

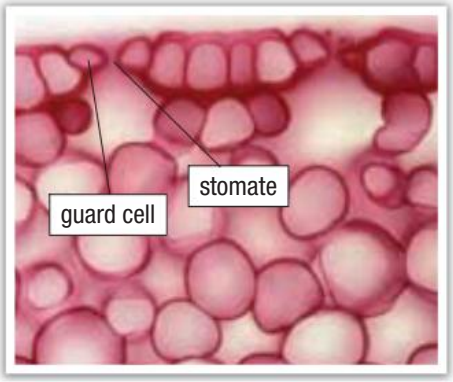


Figure 2.77 Electron micrograph of a stomate and its guard cells (longitudinal section, ×400).

TABLE 2.13 The distribution of stomates on the leaves of different species

Species	Average number of stomates per mm²	
	Upper epidermis	Lower epidermis
Runner bean (*Phaseolus vulgaris*)	40	281
Geranium (*Pelargonium sp.*)	19	59
Corn or maize (*Zea mays*)	52	68
Nasturtium (*Tropaeolum majus*)	0	130
Sunflower (*Helianthus annuus*)	85	156

The number and arrangement of stomates vary in each plant species (Table 2.13). They may be present on both upper and lower epidermal surfaces, or only on one, usually the lower surface.

Stomates can open and close (Figure 2.78). When open, gases can diffuse freely and the rate of photosynthesis increases. When closed, the rate of photosynthesis slows. The transpiration rate (see p. 129) is also controlled by the opening and closing of stomates.

Guard cells control the opening and closing of the stomates. When stomates are open, the guard cells are distended with water and are said to be turgid. When stomates are closed, the guard cells are less distended. The mechanism for opening and closing therefore depends on the change in shape of the guard cells as a result of a change in their water content or turgidity. This change is brought about by the concentration of potassium ions in the cell. As the potassium concentration increases, water is drawn into the cell by osmosis. As potassium levels decrease, water leaves the cell.

The two guard cells are next to each other, joined at either end, and have thickened cell walls between them. The arrangement of the bands of inelastic cellulose microfibrils around the cells maximises the opening of the pore as water enters and the cells expand.

Stomates are usually open during the day and closed at night. Guard cells open and close in response to a variety of internal and external stimuli:

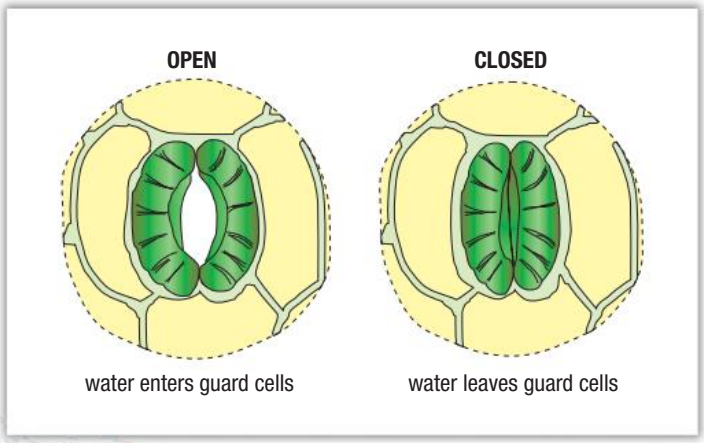


Figure 2.78 The opening and closing of a stomate.

Light Guard cells have a blue-light receptor. Light stimulates the entry of potassium ions into the guard cells, causing the stomates to open.

Low carbon dioxide levels When photosynthesis begins, carbon dioxide is used by the cells. Low carbon dioxide levels in the air spaces of the leaf will trigger the opening of stomates. If a plant is placed in the dark in an atmosphere free of carbon dioxide, the stomates open.

An internal clock The stomates open and close in a daily rhythm. The regular opening and closing occurs even if a plant is kept in the dark.

Water deficiency If the plant is unable to replace the water it is losing by evaporation, the stomates will close.

High temperatures Hot conditions cause the stomates to close.

Lenticels

Lenticels are pores in the woody stems of plants. Gases needed for respiration by the cells of the stem are exchanged by diffusion. Oxygen diffuses in and carbon dioxide diffuses out.



Figure 2.79 Hairs on leaves help to reduce evaporation from leaf surfaces.

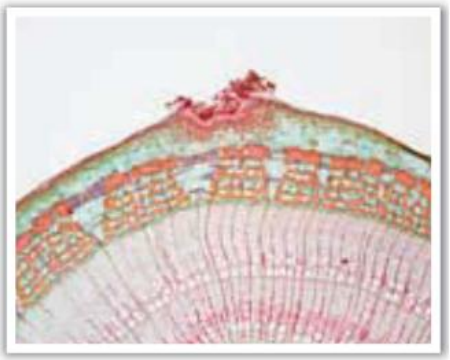


Figure 2.80 Cross-section through a stem, showing a lenticel.

Radioisotopes

Radioactive forms of certain elements, called **radioactive isotopes**, may be used to trace biochemical pathways. Radioactive isotopes can participate in reactions in the same way as the non-radioactive elements. For example, autoradiography is a technique used to trace the movements of certain substances around plants. It involves the following steps:

1 Carbon-14, a radioactive isotope, is added to the carbon dioxide supply of a plant to study the movement of the products of photosynthesis.

2 The plant takes up the carbon-14 radioactive isotope.

3 Carbon-14 is used by the plant in the process of photosynthesis.

4 The movement of the radioactive isotope can be traced by taking an autoradiograph.

An autoradiograph is produced when the plant is placed against photographic film. The areas of the plant in which the carbon-14 has accumulated can be seen as dark shadows on the film.

Radioactive isotopes can also be used as diagnostic tools in medicine. Thallium-201 is used to detect damaged heart muscle after a heart attack. This isotope will accumulate only in normal, undamaged heart muscle. This allows doctors to determine where and to what extent a heart has been damaged.

Technetium-99 is an isotope of the artificial element technetium. It emits gamma radiation and is useful in scintigraphy—a method of scanning that is used to examine the organs of the body in the diagnosis of cancer and other diseases.



Figure 2.81 An autoradiograph. The dark areas contain accumulated carbon-14.

INVESTIGATION 2.12

The movement of materials in plants

Students will: perform a first-hand investigation of the movement of materials in xylem or phloem.

Skills and outcomes

P12, P13, P14, P15

Type of activity

Part A first-hand investigation, Part B (optional) second-hand data activity

Materials

Part A

- cut plant stem such as a celery stick or *Tradescantia* stem
- beaker of water
- water-soluble dye such as eosin, safranin or food colouring
- scalpel
- white tile

Part B

- textbooks, reference books, Internet sites

Caution

Scalpel blades are very sharp. Take special care when using these instruments. Do not leave close to the edge of your bench. Dispose of used scalpel blades in a sharps container.

See:
- First-hand investigations
- Analysing information

Introduction

When cut plant stems are placed in a container of water, observations show that the water level in the container slowly goes down. If water is moving into the plant, where does it go?

Sugars are produced by photosynthesis, mainly in the leaves, and are transported to different parts of the plant. Do they travel both up to the tips and down to the roots? How do we know this? This activity investigates the movement of materials in the plant transport system.

The transport system in flowering plants is called vascular tissue. It forms a system of tubes that reach all parts of the plant, transporting materials to and from the cells. Xylem and phloem are found as part of the central vascular tissue in roots, and in vascular bundles in the stem and leaves. Xylem tubes transport water and phloem tubes transport organic materials, mainly sugars. (See pages 128 and 131).

Purpose

1. To investigate the movement of materials in xylem.
2. To investigate the two-way flow of material in phloem.

A The movement of materials in xylem

Procedure

1. Add a few drops of dye to a beaker of water. Place the plant stem in it and leave for several hours or overnight.
2. Remove the plant from the dye solution, rinse in clean water and examine.
3. Place the stem on a white tile and use a scalpel to make transverse cuts across the stem (see Figure 2.82). Observe the cut surfaces.
4. Cut a piece of stem about 2 cm long and use the scalpel to cut longitudinally (lengthwise) down the stem. Observe the stained areas.

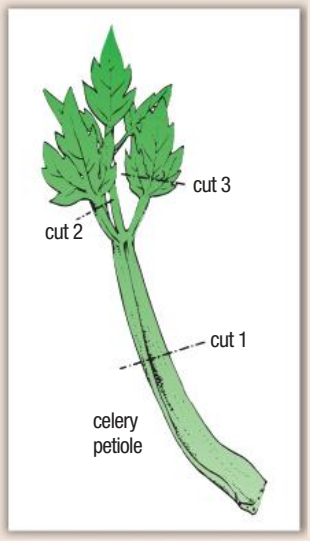


Figure 2.82 Positions for cutting celery.

Results

1 Describe how far up the stem the dye has travelled. How can you tell?
2 Describe where the dye can be seen in the stem in the transverse cuts you made. A diagram may be useful to illustrate this.
3 Describe where the dye can be seen in the longitudinal cuts you made. How does this relate to the structure and location of the vascular tissue? (See p. 128)
4 What further steps would you need to take to confirm the reliability of your observations about the route travelled by the dye?

Conclusion

Write a paragraph to summarise what you have discovered about the movement of water in a stem.

B The two-way flow of material in phloem

Procedure

1 Divide into small groups. Each person in the group should select materials from different sources to research the movement of materials in the phloem.
2 Collect useful information, diagrams and experimental evidence, and summarise where necessary.
3 As a group, review the information collected. Select the data that provides the best evidence for the two-way flow of materials in the phloem.

Discussion

With contributions from each person in the group, present this evidence as a detective story using the following headings:

1 **The mystery of phloem movement—do materials in the phloem flow upwards, downwards or in both directions?** Begin your presentation with a large diagram, picture or photograph explaining what phloem is and what it transports.
2 **Investigating the mystery. Describe** at least two ways that scientists have investigated the problem. **Describe** the results of each type of investigation. Include photographs, diagrams or tables of data to show what was done and the results obtained.
3 **Solving the mystery. Explain** how the results from these investigations provide evidence to solve the mystery of the direction of movement of materials in phloem.

Further activity

1 Place a small piece of cut stem from part A on a microscope slide in a drop of water and observe under a stereoscopic microscope.
2 Use a dissecting needle to tease the stem tissues in a longitudinal slice apart.
3 Look for the tubes of the vascular system.

INVESTIGATION 2.13

The use of radioisotopes

Students will: use available evidence to discuss, using examples, the role of technologies, such as the use of radioisotopes, in tracing the path of elements through living plants and animals.

Skills and outcomes

P3, P13, P14

Type of activity

Second-hand data activity

Materials

books, journals, Internet sites

See Analysing information

Introduction

The path of elements through living plants and animals can be traced by using radioactive isotopes (radioisotopes). Isotopes are atoms of the same element that are chemically identical, but vary in the number of neutrons they contain. For example, carbon-12 is the most common isotope of carbon, and carbon-14 is the radioactive form. It is possible to track the pathway of radioactive isotopes through a plant or animal body, and through many biochemical reactions. This provides useful information about various biological processes.

Technology such as nuclear reactors and cyclotrons allow us to produce many different radioisotopes. Geiger counters, autoradiography, gamma ray spectrometers and nuclear imaging allow the radioactivity from these isotopes to be detected. Substances containing radioactive compounds can be analysed by radioimmunoassays.

Purpose

To discuss, using examples, the role of radioisotopes in tracing the path of elements through living plants and animals.

Procedure

For parts A and B, read the information provided, including page 133, and gather data from other sources to answer the questions.

A Plant biochemistry

In 1961, Melvin Calvin was awarded the Nobel Prize in chemistry for his work in mapping the complete path of carbon in the process of photosynthesis. He did this using the radioisotope carbon-14 and new technologies (at the time), such as paper chromatography and autoradiography.

Discussion

1 What is a radioisotope?

2 How are radioisotopes used in tracing the movement of substances through plants? Give an example.

8 Radioisotopes in medicine

Nuclear medicine uses radioisotopes to investigate the functioning of particular organs. Radiotherapy uses radiation as treatment for some diseases. In Australia, the National Medical Cyclotron facility was opened in 1992 at the Royal Prince Alfred Hospital in Sydney. The cyclotron produces short-lived radioisotopes that are administered immediately to patients.

A technique known as Positron Emission Tomography (PET) uses a camera to detect the gamma rays emitted from the body and to pinpoint their exact location. The data from the camera is translated into a computer image that is viewed by the doctor. Disease may be indicated if an organ takes up too much isotope, or not enough, or if there is an unusual pattern or rate of movement of the isotope through the body.

Technetium-99m is a commonly used radioisotope in medical diagnosis. It is used particularly to image the skeleton and heart, but can be used for most body organs. Iodine-131 is used to look at the functioning of the thyroid gland, blood flow through the kidneys and abnormal liver functioning. Phosphorus-32 can be used to detect malignant tumours, as cancerous cells tend to accumulate more phosphates than normal cells.

Discussion

1 If a person is sick, why might a doctor suggest the use of radioisotopes? Give an example.

2 Why is this branch of medicine known as 'nuclear' medicine?

Conclusion

1 Our knowledge of biological processes has been dependent on our ability to detect what is happening in chemical reactions in the bodies of plants and animals. Explain the role radioisotopes have played in increasing this knowledge.

2 Our use of radioisotopes—their production, detection and analysis—has been dependent on the development of new technologies. Name and briefly describe two of these technologies.

Further activity

Find out more about Australia's National Medical Cyclotron by visiting the website and present your findings as a poster.

Circulatory systems in animals

compare open and closed circulatory systems using one vertebrate and one invertebrate as examples

Transport systems are needed by multicellular organisms to ensure that all the requirements of their cells are met.

Multicellular animals need to transport or circulate materials around their bodies to supply cells with nutrients and remove wastes. The flow of materials is usually maintained by a circulatory system that pumps material around the body. Circulatory systems may be open or closed.

Open circulatory systems

Invertebrates such as arthropods and molluscs have **open circulatory systems** (see Figure 2.83a).

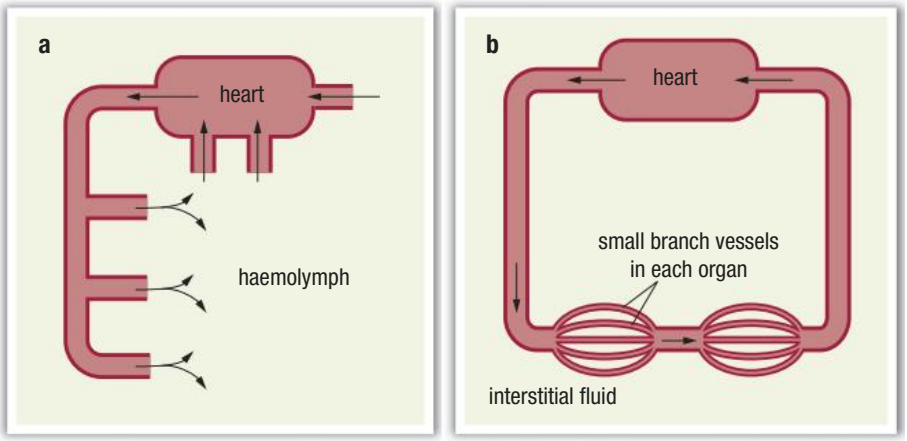


Figure 2.83 (a) A simple representation of an open circulatory system. (b) A simple representation of a closed circulatory system.

Insects

In insects the circulation of body fluid, known as **haemolymph**, around the body is achieved by a simple pumping system consisting of one or more tubular hearts. Haemolymph bathes the tissues and accumulates in large spaces within the insect. Any vessels that assist the transport of the fluid are open at each end. Fluid is sucked into the tubular heart(s) through small holes. It is then pumped forwards to the front end of the insect and flows slowly backwards through the spaces surrounding the various organs. The pressure in an open system is low, so the body fluid circulates slowly.

Open circulatory systems suit the needs of smaller animals. In insects they do not have to transport respiratory gases, but only distribute and collect food and wastes, and sometimes store them temporarily.

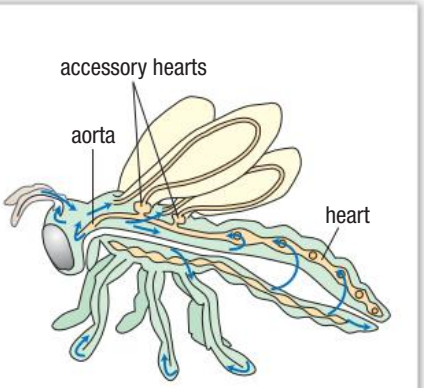


Figure 2.84 Insects have an open circulation system. It consists of a dorsal longitudinal vessel (the heart) that contracts, forcing the fluid out at the anterior end. This fluid flows through tissue spaces and finally re-enters the dorsal vessel through a series of openings. Accessory hearts may help supply fluid to the wings and other distant structures.

Closed circulatory systems

Large, active animals such as vertebrates and squids have **closed circulatory systems** (Figure 2.83b). In humans, the circulatory system consists of a muscular pump (the heart) that forces a fluid (**blood**) through a closed system of tubes (blood vessels), which carry materials rapidly throughout the body. No cell in the body is very far from a blood vessel. Nutrients, wastes and gases exchanged in respiration are carried in the blood. To reach the body cells, materials in the blood must pass into the surrounding body fluid before reaching the cells.

Fluid from the blood may pass through the blood vessel walls to become part of the interstitial or body fluid, which bathes all cells and keeps them moist. Some of this body fluid is reabsorbed in the blood, and the rest drains slowly into other small tubes, the lymphatic vessels. These join up to form larger vessels which eventually return the fluid they contain, now called **lymph**, to the blood.

Both the **lymphatic system** and the blood system are concerned with transporting materials and maintaining the circulation of fluids within the body.

Closed circulatory systems meet the needs of large, active animals. They provide nutrients and oxygen to cells and carry away wastes and carbon dioxide. However, they use more energy to provide the faster service required.

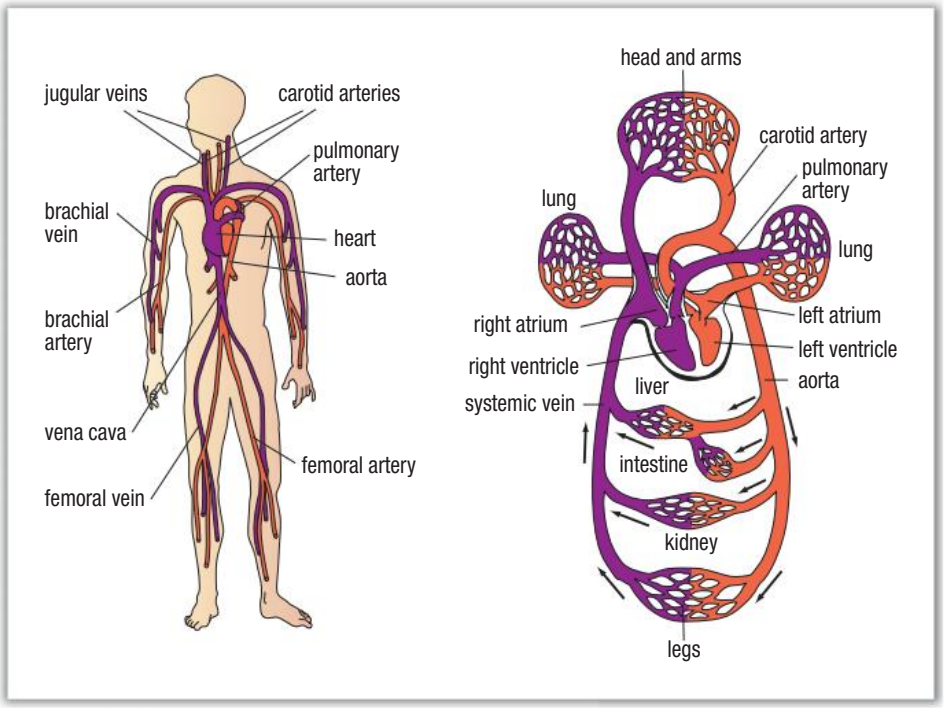


Figure 2.85 The human circulatory system.

UNIT REVIEW 2.4

Exchanging gases

Plants and animals have specialised structures to obtain nutrients from their environment.

Summary

- Respiratory systems exchange gases between the internal and external environment. Circulatory systems transport materials around the internal environment of animals. Excretory systems remove chemical wastes from the internal to the external environment.
- Animals have specialised surfaces for exchanging gases with the environment. Insects have tracheae, fish have gills, mammals have lungs, and frogs use both lungs and their skin for the exchange of respiratory gases.
- In a multicellular organism, cells require a supply of nutrients and gases, and the removal of waste products. Transport systems transfer these chemicals to and from cells within the organism.
- The transport systems of plants are the xylem and phloem. Xylem transports water and mineral ions upwards from the roots to the leaves. The water is pulled upwards in the transpiration stream. Phloem transports nutrients and other substances upwards and downwards in a plant. Root hair cells, stomates and lenticels provide exchange areas between the plant and the external environment.
- Animal circulatory systems transport nutrients, gases and wastes. They may be open or closed systems.

Questions

1 Which three systems could be used by plants and animals to transport materials between the external and internal environments?

A digestive, urinary, circulatory
B respiratory, urinary, circulatory
C lungs, heart, kidneys
D transpiration, circulatory, excretory

2 Which features do all respiratory surfaces have in common?

A air sacs, capillaries, water
B diffusion, circulation, absorption
C thin, moist, large surface area
D carbon dioxide, water, oxygen

3 What are the key differences between the circulatory systems in vertebrates and invertebrates?

A Vertebrates have a heart, arteries and veins, but invertebrates have only specialised tubes.
B Vertebrates transport food, gases and wastes, invertebrates transport only gases.
C Vertebrates transport blood and lymph, invertebrates transport only blood.
D Vertebrates have closed systems and invertebrates have open systems.

4 Compare the roles of respiratory, circulatory and excretory systems.

5 Most organisms require oxygen for respiration. This oxygen is obtained from the environment. Insects, fish, frogs and mammals all have different structures to facilitate the exchange of gases with the external environment.

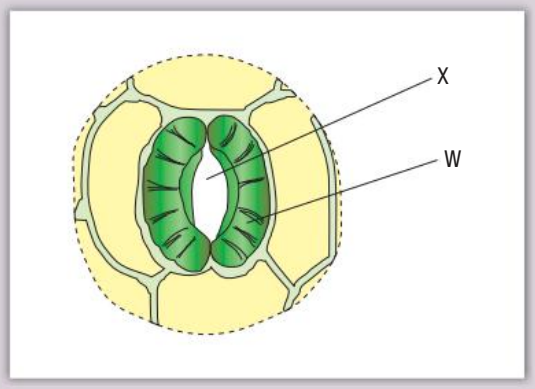
a Complete the following table which summarises the structure and function of respiratory systems in different kinds of animals.

Organism	Name of respiratory surface	Diagram of respiratory system	Description of process by which gas exchange occurs
insect			
fish			
frog			
mammal			

b List the features that all respiratory surfaces have in common. Explain how each feature facilitates gaseous exchange.

6 Explain the relationship between the requirements of cells and the need for specialised transport systems.

7 a Label X and W on the diagram of a stomate.



b Describe the role of stomates.

c Outline the mechanism by which stomates open and close.

8 Draw a cross-sectional diagram of a stem, showing the arrangement of xylem and phloem tissue in vascular bundles.

9 a Define 'transpiration'.

b Describe the process of transpiration that occurs in plants, from the entry point of water at the root hairs, its route through the plant, to its exit at the stomates.

c Discuss the factors that affect the rate of transpiration.

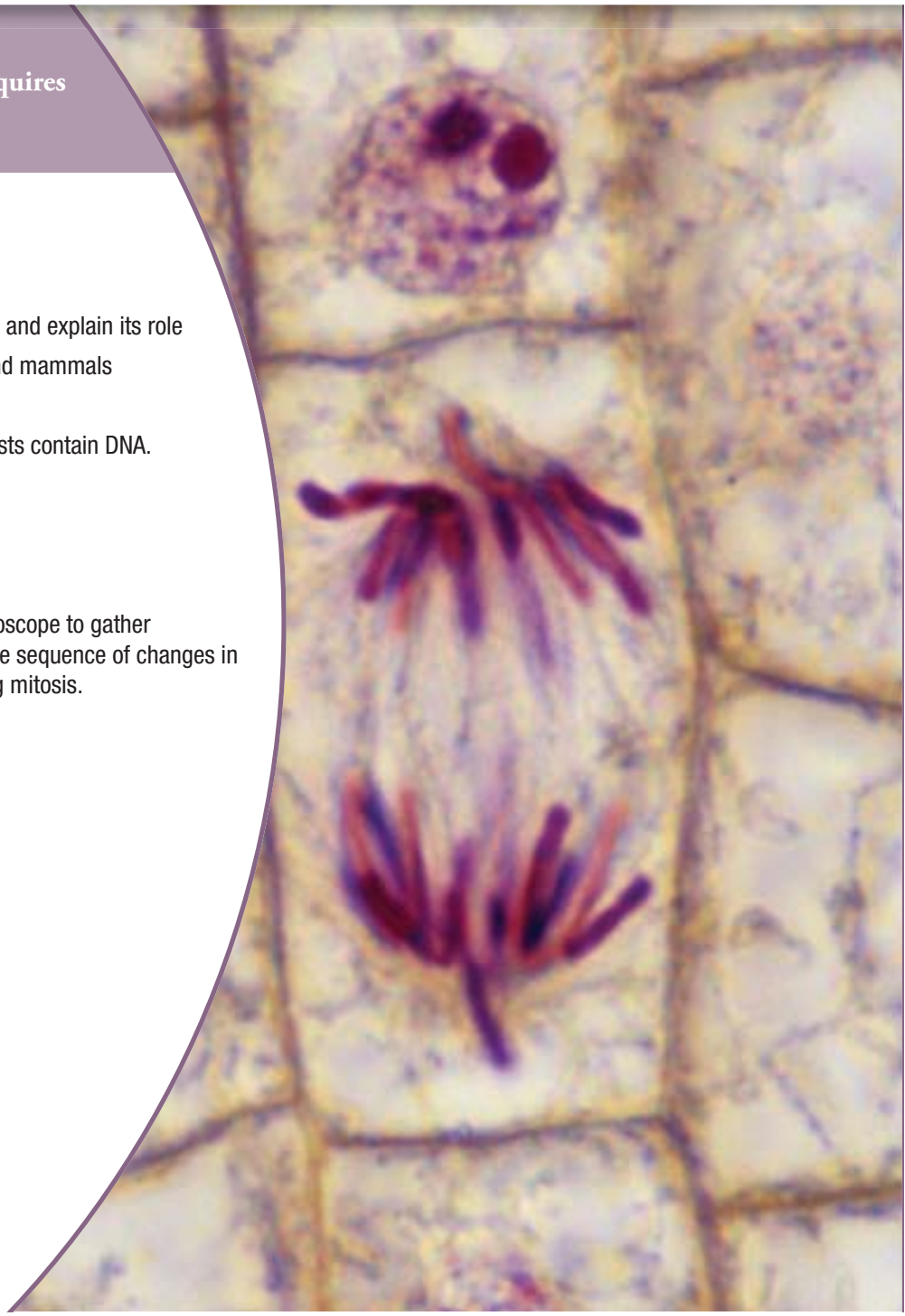
10 Compare the open and closed circulatory systems of an invertebrate and a vertebrate.

11 Prepare a chart comparing xylem and phloem tissue. Include a description of the tissues, substances transported and direction of flow.

12 Discuss, using examples, the role of technologies in tracing the path of elements through living plants and animals.

2.5 GROWTH AND REPAIR

The maintenance of organisms requires growth and repair.



STUDENT LEARNING

In this unit students will:

- identify mitosis as a process of nuclear division and explain its role
- identify the sites of mitosis in plants, insects and mammals
- explain the need for cytokinesis in cell division
- identify that nuclei, mitochondria and chloroplasts contain DNA.

STUDENT ACTIVITY

Students will:

- perform a first-hand investigation using a microscope to gather information from prepared slides to describe the sequence of changes in the nucleus of a plant or animal cell undergoing mitosis.

Mitosis

identify mitosis as a process of nuclear division and explain its role

Mitosis is the process by which a multicellular organism grows, repairs, maintains and reproduces itself. It is a process of cell division that results in the production of cells which are identical to the original cell. Mitosis is the process of division of the nucleus, and **cytokinesis** is the division of the cytoplasm. The nucleus contains inherited structures (chromosomes) that carry the information which controls all the cell's activities. The single cell from which you developed had 46 chromosomes. In fact, each of your body's cells has this number of chromosomes. Chromosomes become visible under the light microscope when a cell is about to divide.

Prior to mitosis, the original set of 46 chromosomes is copied (duplicated), and in mitosis one copy of each chromosome is distributed to each new cell as it forms. The period when the cells are not dividing is called interphase. During interphase the chromosomes are duplicating, but they are not visible.

Chromosomes appear as dark-stained threads in the nucleus prior to cell division. They are composed of proteins and the nucleic acid DNA. Chromosomes carry the cell's genetic information. Each type of organism has a particular constant number of chromosomes in each of its cells.

Mitosis is a type of cell division that results in the production of cells which are identical to the original cell.

Chromatids are the daughter strands of a replicated chromosome. On separation in mitosis, each becomes a daughter chromosome.

The stages of mitosis

Prophase (early stage) Each chromosome is visible as two identical, joined strands, called **chromatids**. The nuclear membrane breaks down and disappears by late prophase.

Metaphase (middle stage) A tapered system of microtubules stretches across the cell, forming a spindle. The chromosomes line up at the centre of the cell, attached to the spindle fibres at the point known as the **centromere**. The chromatids separate. (Note: in animal cells, the centriole is involved in spindle formation. Centrioles are absent in plants; the spindle attaches to the plant cell wall.)

Anaphase (towards end stage) The chromatids, now referred to as single-stranded chromosomes, move towards opposite poles, carried on the spindle fibres.

Telophase (end phase) The spindle disappears. New nuclear membranes form around the two sets of chromosomes.

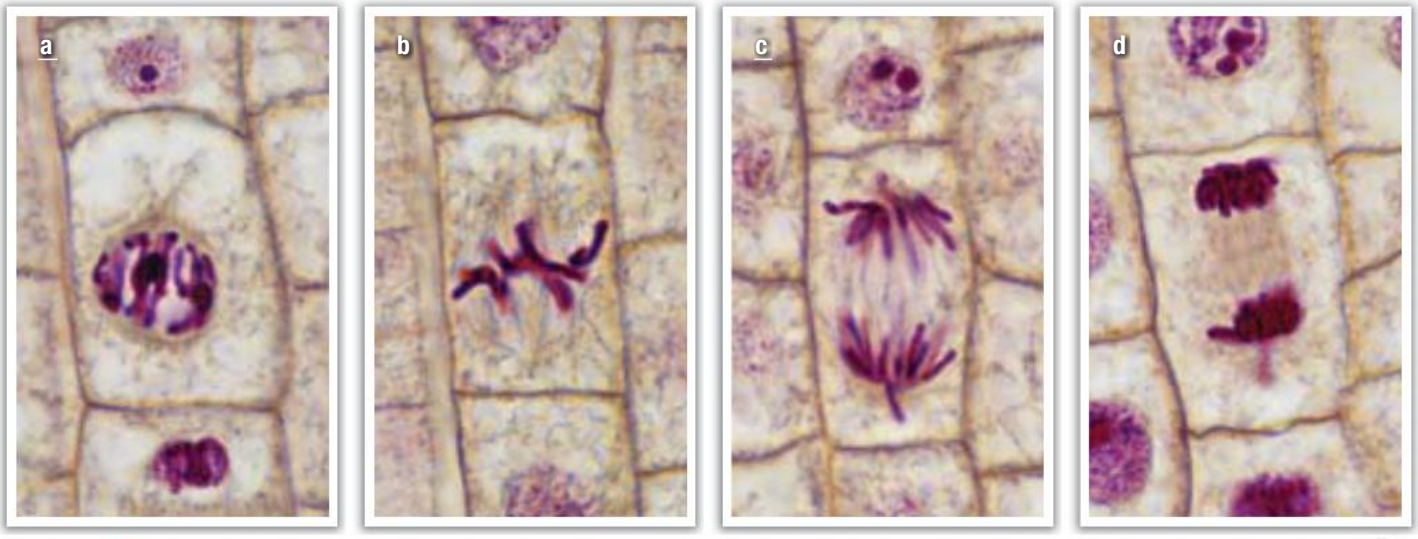


Figure 2.86 Mitosis in onion root-tip cells: (a) prophase, (b) metaphase, (c) anaphase and (d) telophase.

Sites of mitosis

identify the sites of mitosis in plants, insects and mammals

All living organisms commence life as a single cell. They grow and develop, become mature, then age and die.

Young multicellular organisms grow rapidly due to mitosis, which increases the number of cells. Mitosis continues in adult organisms in certain areas. It provides a 'repair and maintenance' service to old and damaged body cells.

In unicellular organisms, mitosis is the means of reproduction: one cell becomes two, two cells become four, and so on.

Plants

In mature plants, mitosis occurs in the tips of roots and stems, causing an increase in length. Mitosis in special cells in the stem results in an increase in its width.

Plants continue to grow throughout their life from cells capable of mitosis known as meristematic cells. Primary growth occurs from apical **meristems**. An apical meristem is the growing point where mitosis occurs at the tips of roots and stems. Stages in this growth are shown in Figure 2.88. There is a region of rapid mitosis, followed by cell enlargement and then **differentiation** of mature cells. In the root this results in growth in length as the root pushes through the soil. In the stem this results in growth in length of the above-ground shoots.

Buds are regions of potential growth, containing meristematic cells, in leaf axils (where the leaves join the stem). They might or might not develop further. If the tip of the stem is cut off or damaged, one or more buds will form new shoots.

Secondary growth is an increase in thickness or diameter of the plant. **Cambium** cells are meristemic cells. Cell division occurs in the vascular cambium of roots and shoots, and in the cork cambium of stems (Figure 2.87). Tissues formed as a result of these cell divisions are called **secondary tissues**. Secondary xylem is known as wood.

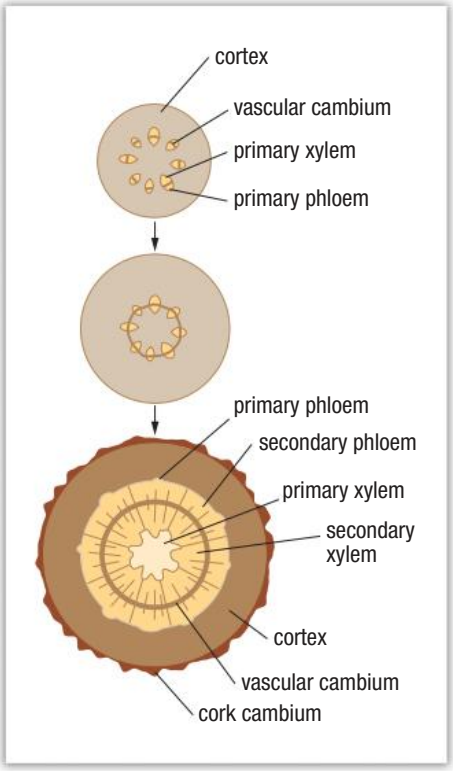


Figure 2.87 Secondary growth in woody plants arises from secondary meristem tissues, including the vascular cambium and cork cambium.

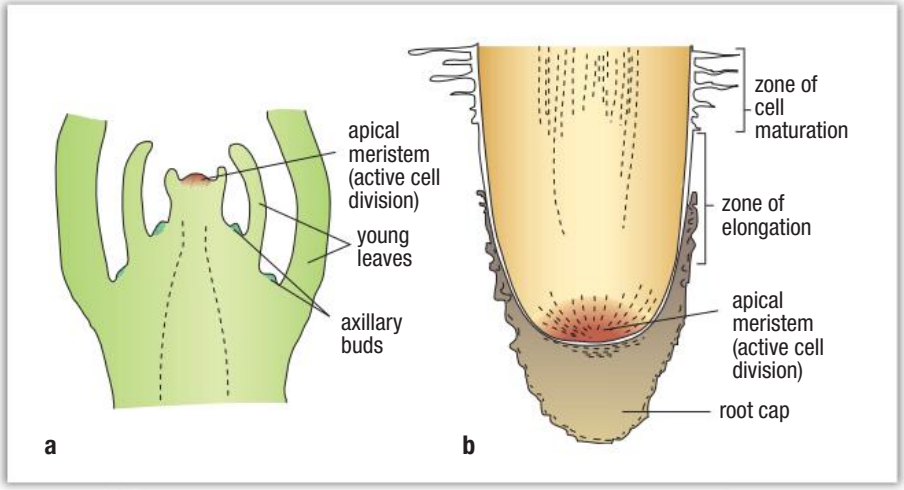


Figure 2.88 The primary growth of a seedling is caused by rapid cell division in the apical meristems of the shoot and root. (a) A shoot tip, showing regions of active cell division (apical meristem) and developing leaves. (b) A root tip, showing protective root cap and zones of active cell division (apical meristem), elongation and cell maturation.

Insects

Insects usually have complex life histories, passing from immature to mature forms. Most insects have immature forms known as larvae. When larvae hatch from the egg, they grow and increase in size, but this is a result of cell *enlargement*, not cell *division*. In the pupal form, the larval cells break down, and previously inactive groups of cells known as imaginal discs start to divide. They grow in both size and number to form the adult insect or imago.

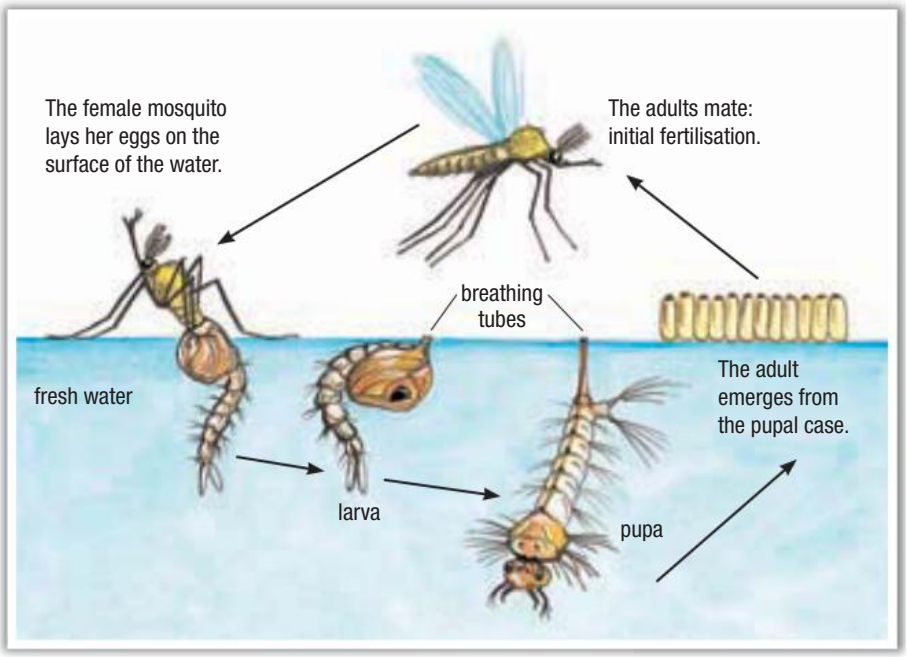


Figure 2.89 The life cycle of a mosquito. Many insects have internal fertilisation, but the female then lays her eggs in water and leaves them to develop externally.

Mammals

In young mammals, mitosis rates are high and growth is rapid in all areas of the body. At maturity, growth ceases but the repair and maintenance of cells continues.

In adult mammals, mitosis occurs in the skin, replacing the cells that continually flake off, and causing hair/fur and nails/claws to grow. New blood cells are made every day in the bone marrow, and the cells lining the digestive system are constantly being replaced.

The need for cytokinesis

explain the need for cytokinesis in cell division

Division of the cytoplasm usually occurs immediately after mitosis (Figure 2.90). This is necessary to ensure that the chromosome number in each cell remains constant. The chromosome number doubles in mitosis, and one cell now contains two sets of chromosomes. Division of the cytoplasm (cytokinesis) results in two cells, each with a set of chromosomes. In animal cells, the cytoplasm constricts at the centre in a process called **cleavage**. A ring of **microfilaments** forms in the centre of the cell. As they constrict, the cell begins to 'pinch' or cleave into two. The cell surfaces show very active movement or 'bubbling' as they separate. In plant cells, a dividing plate (the cell plate) forms across the centre of the cell, separating the two new cells, called **daughter cells**. A new cell wall is built from this plate.

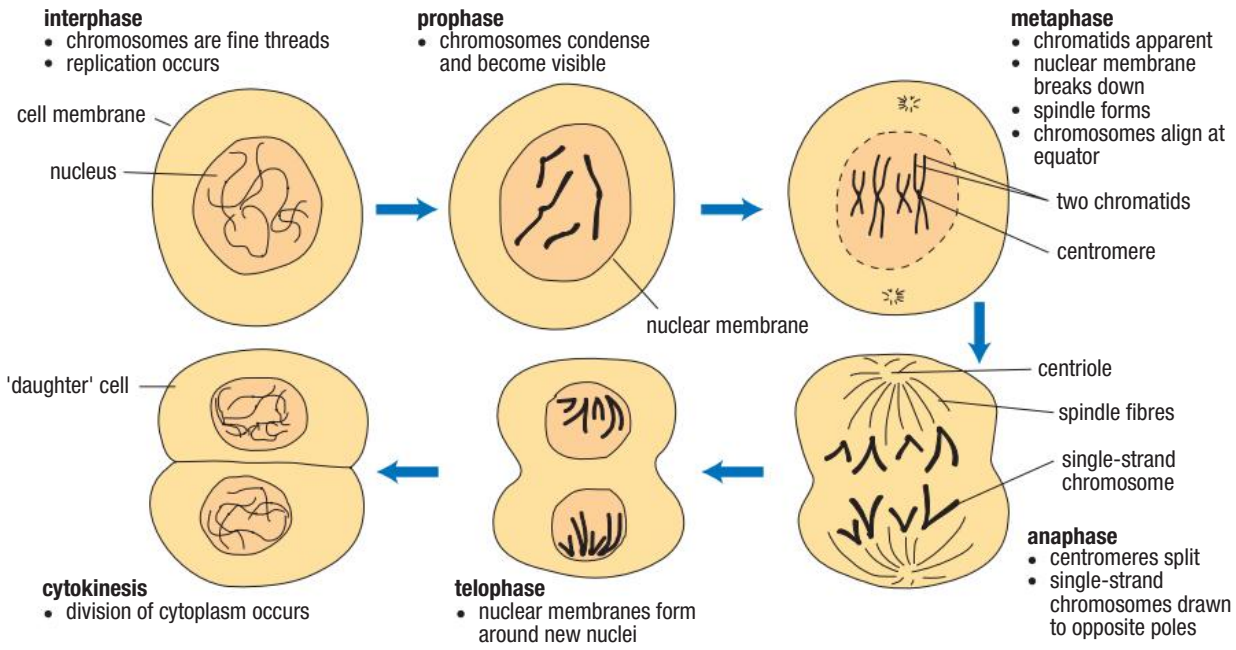


Figure 2.90 Mitosis and cytokinesis in an animal cell containing four chromosomes.

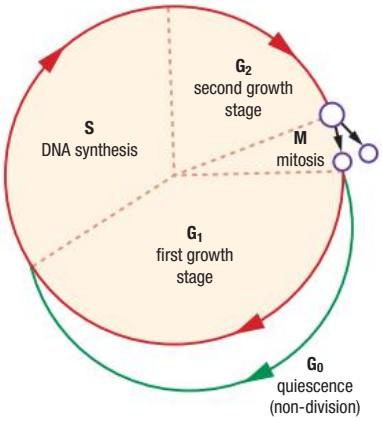


Figure 2.91 The cell cycle.

The cell cycle

The names prophase, metaphase, anaphase and telophase were first used in the 1880s by the first scientists to describe mitosis. Because chromosomes are not visible during interphase, it was not known what was happening to them between divisions. Today, using new stains, autoradiography and measurements of cell components, we know that interphase can be divided into three periods, called G_1, S and G_2.

G_1 = the time gap between the end of mitosis and the start of chromosome duplication

S = the synthesis phase when the chromosomes become double-stranded

G_2 = the time gap between the end of synthesis and the start of mitosis

M = mitosis, the separation of the duplicated chromosomes to form two daughter nuclei

G_0 = state where cell division no longer occurs

The length of this cycle varies for different types of cells. In cells that are actively growing and dividing, the cycle is short. Mammal cells grown in the laboratory can repeat this sequence every 16 hours.

The G_1 phase is the most variable. Cells may spend days, months or years in this phase. Some cells which lose the power to divide as they become older and more specialised, such as nerve cells, are arrested in the G_1 phase and remain in the G_0 state.

Permanent cells

In the tissues of some animals there is no turnover of cells. Sufficient numbers of specialised cells are produced during development to last the entire life of the organism. These permanent cells include:

- nerve cells, which can repair themselves to a certain extent. Appropriate nerve connections form during development in an interactive way as the organs form. It would be impossible for a new nerve cell to reconnect specific parts of the nervous system, which are often widely separated in the adult.
- retinal cells develop specific links between the eye and the brain during development which cannot be replaced.
- the cells of the lens of the eye, which are transparent.
- cardiac muscle cells, which can become larger through exercise but do not increase in number.

Not surprisingly, most permanent cells are able to repair themselves to a considerable extent by the replacement of various organelles. For example, rods and cones in the retina replace the photoreceptive membranes, which contain the receptors that respond to light. In replacing a severed hand, microsurgeons sew the ends of nerve bundles together so that, if the nerves are able to recover, the sheaths around the nerve bundles guide the regenerating nerve terminals to the right sites.

BIOFACT

At each end of a chromosome is a cap called a **telomere**. A telomere is made up of specialised proteins plus a DNA sequence that is repeated many times. Telomeres ensure the stability of chromosomes as they attach to the spindle fibres and move around during cell division. They prevent loss of chromosomal DNA and tangling or fusion with other DNA strands. With each cell division the telomeres become slightly shorter.

Cell growth and differentiation

Cell growth or enlargement precedes each cell division. If this did not happen, cells would become smaller and smaller after each division. The rate of growth depends on the cell's environment (e.g. the temperature and the amount of food available) and the cell's own activity. Cells grow only to a certain size that is governed by surface area to volume ratio considerations (see p. 93) and the type of cell they become.

Cell differentiation is the process in multicellular organisms by which similar cells become dissimilar and specialised; they are no longer identical to the original parent cell in structure or function.

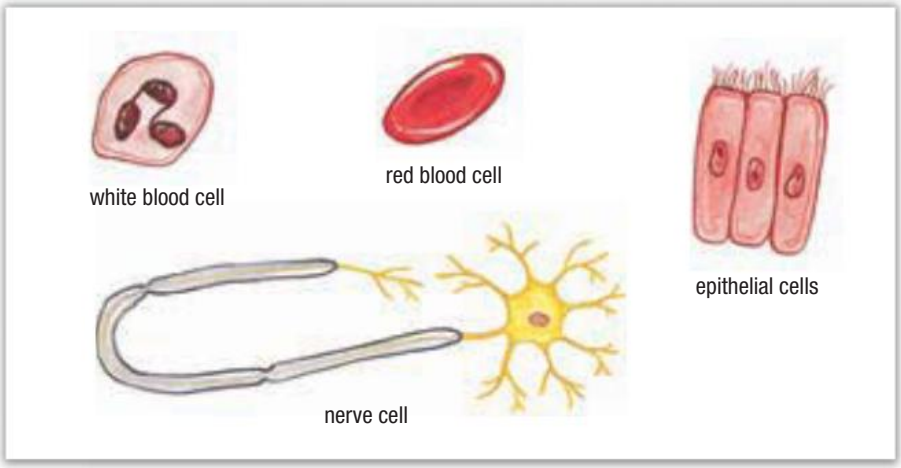


Figure 2.92 Some differentiated cells.

The single cell from which you developed had 46 chromosomes, carrying all the information needed to produce a human being. All daughter cells formed by mitosis carry this information, but the total amount of information is not expressed in every cell. Some cells become blood cells, others become nerve cells, and so on. In other words, the cells undergo differentiation.

The first visible sign of differentiation is that the structure of a cell begins to change. At the molecular level, proteins specific to a particular type of cell begin to form. This implies that some genes on the chromosomes are being activated, with other genes remaining inactive or being switched off. The location of the cell is also important—the type of cell that develops depends on where it is in the body. The same types of tissue, such as bone or muscle in mammals, are found throughout the organism, but the arrangement or pattern of tissues depends on its position in the body. How differentiation and development occur is still not entirely understood.

Uncontrolled cell growth

In healthy tissues, mitosis stops when damaged cells have been replaced. As the new cells grow, they differentiate and function correctly, and have a limited life span. They also adhere to similar cells. Uncontrolled cell division produces a mass of abnormal cells known as a **tumour**. A benign tumour is surrounded by a capsule and does not invade healthy tissue.

In **cancers** the cells divide in an unlimited and disordered way, forming tumours whose abnormal cells will adhere to any nearby cells. Some cells may break off and spread to other parts of the body; this is known as a malignant tumour. Cancer cells never mature and most do not differentiate, or do not do so normally. Some cancers may be curable when differentiation is understood completely, so that it can be induced and regulated. Other cancers may be curable when cell division can be regulated.

DNA

identify that nuclei, mitochondria and chloroplasts contain DNA

Chromosomes are composed of proteins and the nucleic acid DNA (deoxyribonucleic acid). Chromosomes are the genetic material found in the nucleus of cells and contain the coded chemical instructions that direct the growth, differentiation and functioning of a cell. The separate instructions that code particular activities or characteristics are called genes. **Genes** are short lengths of a chromosome and consist of DNA. This information is transferred via the chromosomes from cell to cell in the process of mitosis.

The nucleus is not the only part of a cell to contain DNA. DNA is also found in mitochondria and chloroplasts.

2.14 INVESTIGATION

Mitosis—somatic cell division

Students will: perform a first-hand investigation using a microscope to gather information from prepared slides to describe the sequences of changes in the nucleus of plant or animal cells undergoing mitosis.

Introduction

Cell division occurs in multicellular organisms when they are growing, or when damaged or old cells need replacing. The process can be considered as occurring in separate stages. Remember, however, that these stages are part of a continuous sequence.

Mitosis can be investigated using prepared slides of onion root tip cells and whitefish eggs, or by finding relevant pictures of these on the Internet. Slides are stained to show the chromosomal movements that occur in the nucleus when cells divide. In the onion tip, the region of cell division is found just behind the tip, which is protected by the root cap. Dividing cells are small and square, and the chromosomes are clearly visible as darkly stained threads (see Figure 2.94).

Purpose

To describe the sequence of changes in the nucleus of plant or animal cells undergoing mitosis.

Procedure

1. Refer to images of mitosis that show the different stages of mitosis, and the changes in chromosome structure and number at each stage. Refer to pages 143–146 or other relevant sources, including any relevant Internet sites.
2. Decide whether you will study mitosis in plant or animal cells, and collect the relevant materials you will need.
3. Figure 2.94 is a diagram of onion root tip cells that have been stained to show the presence of DNA. The preparation has been squashed to separate the cells for clearer viewing. Some of the cells have been labelled.
4. Examine the prepared slide of the longitudinal section of an onion tip or whitefish eggs under low power, then high power. Identify and count cells at each stage of mitosis. Use Figure 2.94 as a guide, along with other references.
5. Record your results in a table similar to Table 2.14, or create a spreadsheet.

Skills and outcomes

P3, P6, P12, P13, P14

Type of activity

First-hand investigation

Materials

- microscope
- images of mitosis from print or electronic sources
- video clips of mitosis
- prepared slide of longitudinal section onion root tip and/or images of plant-cell mitosis
- prepared slide of whitefish eggs and/or images of animal-cell mitosis
- access to the Internet

SKILLS See First-hand investigations

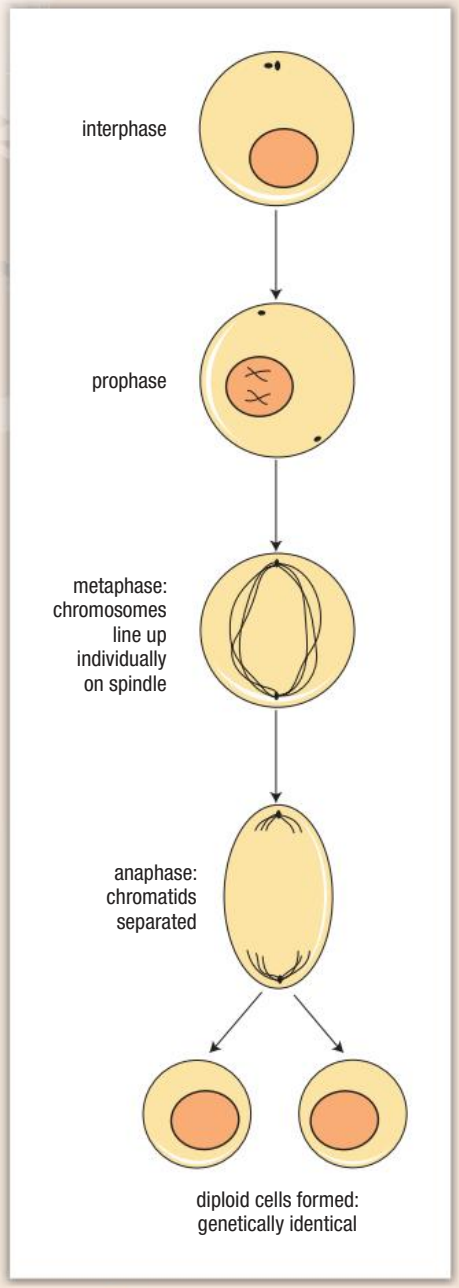


Figure 2.93 Diagram of stages in mitosis for completion.

TABLE 2.14 Number of cells in each stage of mitosis

Stage of mitosis	Cells in stage	
	Number	%
interphase		
prophase		
metaphase		
anaphase (early)		
telophase		

Discussion

1 The prepared slide and other images you looked at can be regarded as a 'frozen instant in time'.

   a In which of the stages listed in Table 2.14 are most cells to be found?

   b Use your knowledge of what goes on during this stage to work out a hypothesis as to why most cells are found in this stage.

2 Summarise the changes in chromosomes during mitosis by drawing in the chromosomes in Figure 2.93.

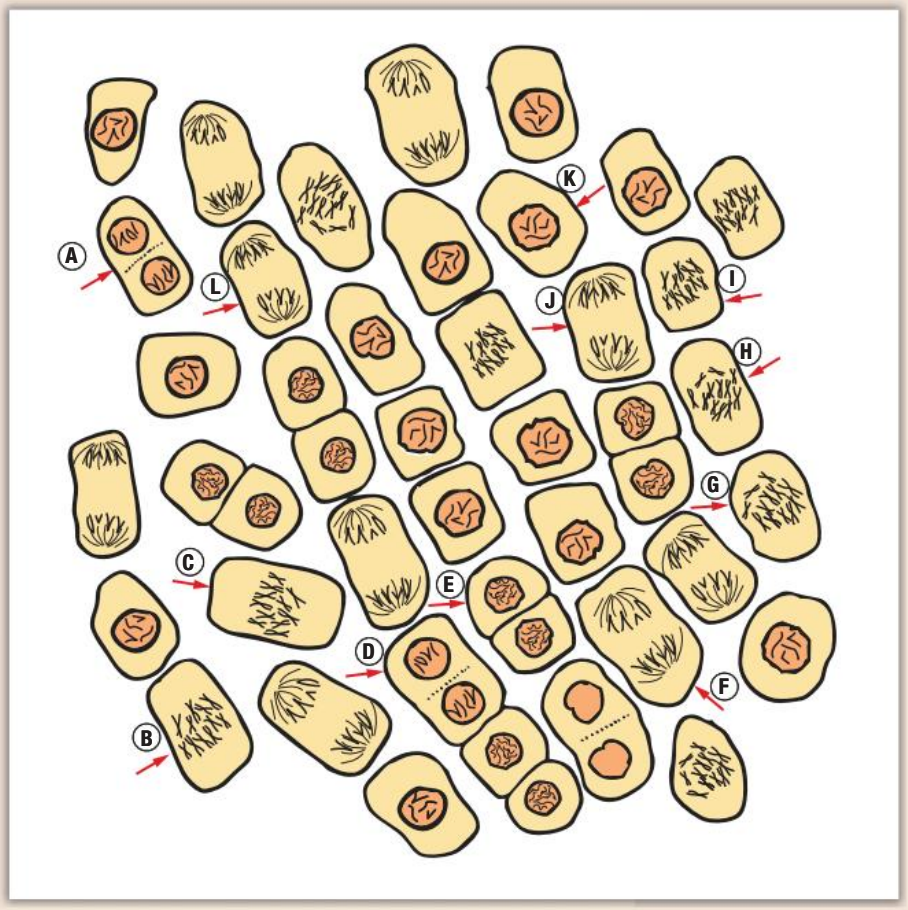


Figure 2.94 Diagram of onion root tip showing cells at different stages of mitosis.

2.5 UNIT REVIEW

Growth and repair

Maintenance of organisms requires growth and repair.

Summary

- Mitosis is a process of nuclear division. Its role is to provide new cells for organisms in growth, repair and maintenance, and reproduction.
- The sites of mitosis vary in plants, insects and mammals, and are also related to the age of the organism.
- Mitosis is followed by cytokinesis, which is the division of the cytoplasm to form two new cells.
- DNA is found in nuclei and also in mitochondria and chloroplasts.

Questions

1 What is the important outcome of mitosis in multicellular plants and animals?

A reproduction and maintenance of the species

B production of cells which all contain 46 chromosomes

C careful division of the nucleus and cytoplasm

D growth and repair of tissues by duplicating the cells

2 Where does mitosis occur in plants and insects?

A In the tip of the plant stem and in the larva of the insect.

B In the plant meristems and in the insect pupal imaginal cells.

C In the tips of plant stems and roots, and in the imago of the adult insect.

D In the meristems of the plant and in all areas of the insect's body.

3 Which of the following statements is true?

A Chromosomes contain proteins and DNA.

B DNA contains proteins and genes.

C Chromosomes are found in the nucleus, mitochondria and chloroplasts.

D DNA is only found in the nucleus of animal cells.

4 a Define 'mitosis' and explain its role.

b Identify the sites of mitosis in plants, insects and mammals.

5 Define 'cytokinesis.' Explain the need for cytokinesis in cell division.

6 Describe what happens during the four phases of the cell cycle. Use diagrams to illustrate your answer.

7 a Define 'cell differentiation'.

b Outline the importance of cell differentiation in multicellular organisms.

8 Identify the stages of mitosis illustrated in the following photographs.





9 Discuss some of the outcomes of uncontrolled cell growth in multicellular organisms.

10 a Outline the role of the nucleus in cells.

b Explain the importance of DNA in the functioning of cells.

c Identify three organelles that contain DNA.

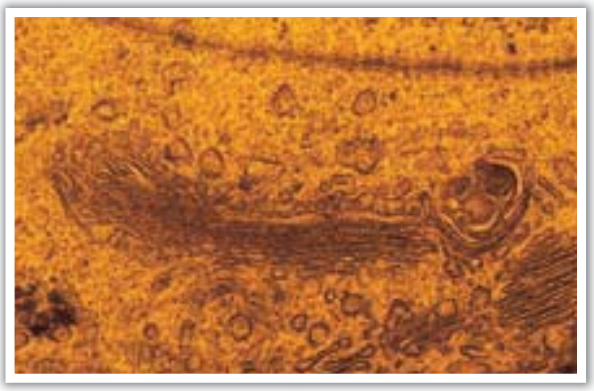
11 Synthesise the elements of cell division to describe how the growth and repair of cells results in maintenance of the whole organism.

CHAPTER 2
EXAM-STYLE QUESTIONS

MULTIPLE CHOICE

1 Which of the following three structures are visible with the light microscope?
- A nucleus, chloroplast, Golgi apparatus
- B nucleus, vacuole, chloroplast
- C mitochondrion, vacuole, microtubule
- D centriole, ribosome, chloroplast

2 What is the function of the organelle shown below?



- A photosynthesis
- B to act as the site of protein synthesis
- C to package cellular secretions
- D respiration

3 Which of the following compounds are made up of carbon, hydrogen and oxygen only?
- A carbohydrates and lipids
- B lipids and enzymes
- C carbohydrates and nucleic acids
- D proteins and glucose

4 Which statement best describes what happens during the process of osmosis in cells?
- A Energy is expended.
- B Substances such as salts move from an area of high concentration to an area of low concentration.
- C Water moves across the selectively permeable membrane from the more dilute solution to the more concentrated one.
- D Carrier proteins are involved in the transport of substances across the cell membrane.

5 What happens to the surface area to volume ratio as a cell grows?
- A It increases.
- B It decreases.
- C It remains the same.
- D It disappears.

6 Which of the following animals have both lungs and blood vessels?
- A fish and insects
- B fish and frogs
- C insects and humans
- D frogs and humans

7 Identify the function of xylem tissue in a plant stem.
- A To transport water and mineral ions up and down the stem.
- B To transport organic substances up and down the stem.
- C To transport water and mineral ions upwards to the leaves.
- D To transport organic substances downwards to the roots.

8 A large surface area, thin walls and a good blood supply allow the rapid and efficient transfer of materials to meet the body's needs. Which two areas in a mammalian body have this structure?
- A heart and lungs
- B small intestine and kidney nephrons
- C skin surface and capillary network
- D lungs and small intestine

9 Which statement best describes closed circulatory systems?
- A They are found in large, active animals such as mammals and birds.
- B They allow blood to leave the blood vessels and bathe the body cells directly.
- C They transport digested nutrients and waste materials, but not respiratory gases.
- D They use less energy than open circulatory systems.

10 Which statement best describes the process of mitosis?

A It occurs in the maintenance of permanent cells.

B It results in variation in the cells of the next generation.

C It is important in growth, repair and reproduction in multicellular organisms.

D It is the key activity of the nucleus during interphase in the cell cycle.

SHORT ANSWERS

1 a State the cell theory.

b Use an example to describe how technological advances have supported the cell theory.

2 a Name the major groups of organic substances found in cells.

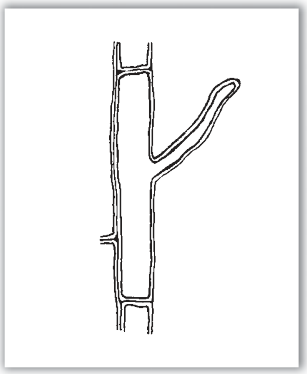
b Describe the role of each of these organic substances in cells.

3 Starch is an example of an organic molecule found in plant cells. It turns purple–black in the presence of iodine. Outline a simple experiment using cellulose tubing, water, starch and iodine to demonstrate that starch molecules are too large to pass across a selectively permeable membrane.

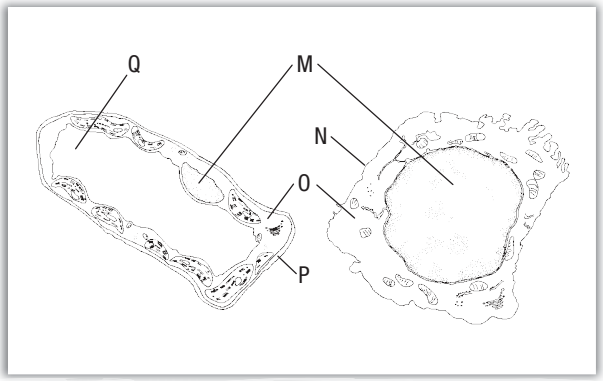
4 Consider the following diagram of a specialised plant cell.

a Identify the function of this cell.

b Describe the structural adaptation of this cell, and explain how this feature helps the cell to undertake its function.



5 The outline diagrams shown are taken from an electron micrograph of a plant cell and an animal cell.

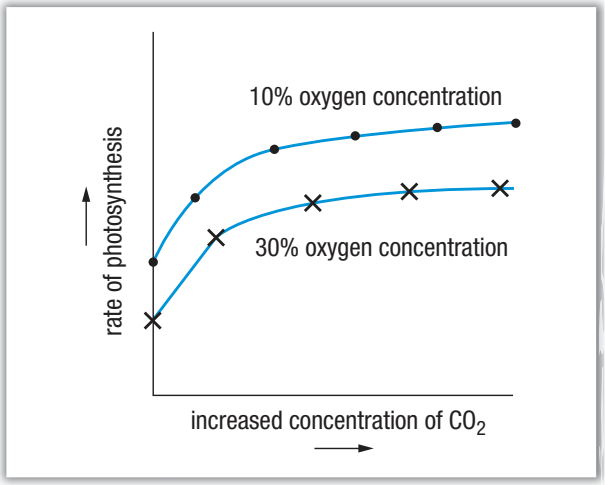


a Identify structures M, N, O, P, Q.

b Outline the role of each of these structures.

c Which cell represents the animal cell and which represents the plant cell? Give three reasons why you think so.

6 The following graph shows the rate of photosynthesis in a sunflower leaf exposed to two different oxygen concentrations in an environment of increasing carbon dioxide concentration. The level of light intensity remained constant throughout the experiment.



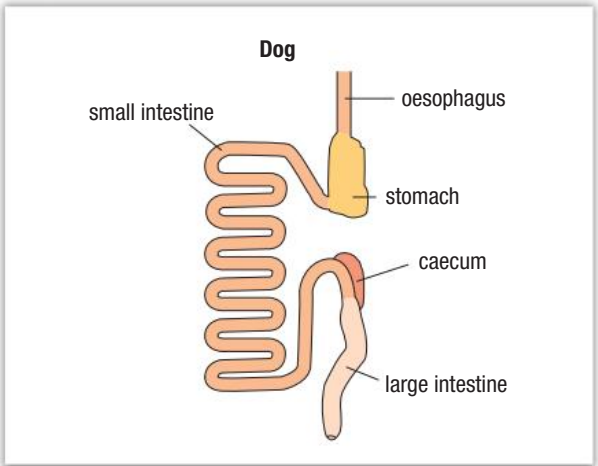
a Write out the balanced chemical equation for the process of photosynthesis.

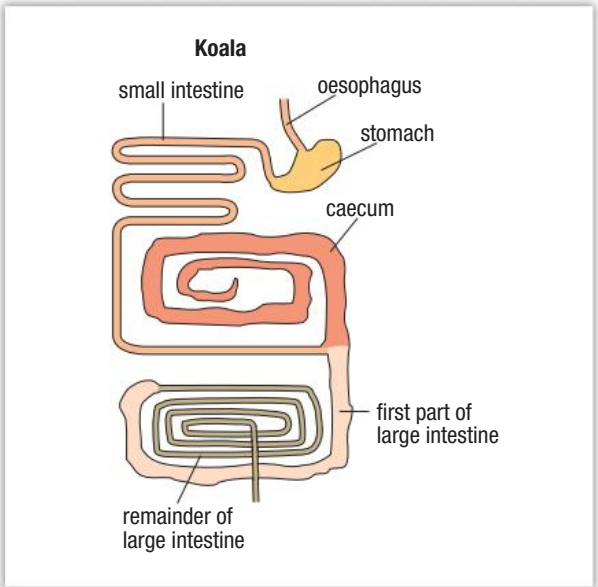
b What happened to the rate of photosynthesis as the carbon dioxide concentration increased? Account for this observation.

c Compare the rate of photosynthesis at the two different oxygen concentrations.

d It has been observed that oxygen and carbon dioxide compete for the active site of an enzyme involved in photosynthesis. Use this information to account for the graphs at the two different oxygen concentrations.

7 Study the simplified diagrams comparing the digestive systems of dogs and koalas.





Account for the differences observed between the digestive systems of these two mammals. Your explanation should include a discussion of diet and the roles of the parts of the digestive system.

8 a Name and describe the organs of gas exchange in
- i insects
- ii fish
- iii frogs
- iv mammals.

b The respiratory surfaces of animals must have particular features that allow efficient gas exchange. Complete the table (top right), which relates the structure of respiratory surfaces to the function of gas exchange.

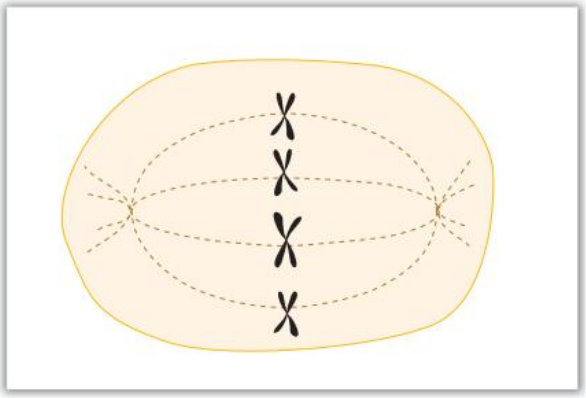
Feature	Function
large surface area	
thin, moist walls	
rich supply of blood	

9 a Outline the pathway taken by water as it enters a plant at the roots, moves through the stem and exits at the leaves. In your answer, name the process and tissues involved.

b Cacti are plants adapted to conditions of high temperatures and low water availability. In cacti, stomates are often sunken into pits on stems and leaves, and remain closed during the hottest part of the day. The stomates are the site of gas exchange in plants. When stomates are open, water can be lost to the atmosphere through evaporation.
- i Outline the role of stomates in relation to gas exchange and water movement in plants.
- ii Explain the role of stomates in water conservation for desert-adapted plants, such as cacti, during the hottest part of the day.
- iii How would you expect this response to affect the rate of photosynthesis and plant growth? Explain your answer.

10 a Mitosis is the process by which the nucleus of a cell divides. Explain the significance of this process for cells.

b Study the following cell from a multicellular organism, which is undergoing mitosis.



- i Identify the phase of mitosis.
- ii Does the cell represent a plant or animal cell? Give two reasons for your answer.

c Define 'cytokinesis'. Explain its importance in the process of cell division.

CHAPTER 3

LIFE ON EARTH

PFA: This chapter increases students' understanding of the history, nature and practice of biology, and of current issues, research and developments in biology.



Life does not need ideal conditions to evolve. Living things have been found to exist in the most hostile of conditions on Earth, and Australian scientists have discovered that bacteria exist far down in the Earth's crust, and have done so for millions of years.

The early Earth was a violent and reactive place. There was no oxygen in the atmosphere, lightning was common, and ultraviolet radiation streamed down from space unhindered. These conditions, which are very different to those found today on Earth, proved ideal for the formation of the chemicals of life. Some of these chemicals eventually formed membranes that separated organic compounds from the environment. The first primitive cells had arrived.

These cells were capable of carrying out chemical reactions that allowed them to reproduce and sustain themselves. Some produced oxygen as a byproduct in the reaction of photosynthesis. The atmosphere was altered forever, and higher oxygen levels allowed more complex life forms to evolve.

Since that time, life has existed continuously on Earth. The fossil evidence indicates many species have come and gone, yet many have remained relatively unchanged. To further their understanding of living things, scientists have developed classification systems that group organisms according to their structural or genetic similarity.

We can better describe the origins, processes and evolution of life as new technologies and techniques are developed.

Assumed knowledge

Refer to the Board of Studies NSW Science Years 7–10 Syllabus.

- Discuss evidence that present-day organisms have evolved from organisms in the distant past (5.8.3a).
- Describe conditions under which fossils form (5.9.4b).
- Relate the fossil record to the age of Earth and the time over which life has been evolving (5.9.4c).

Preliminary Course Outcomes

Prescribed Focus Areas

P1 Outlines the historical development of major biological principles, concepts and ideas.

P2 Applies the processes that are used to test and validate models, theories and laws of science, with particular emphasis on first-hand investigations in biology.

P3 Assesses the impact of particular technological advances on understanding in biology.

P4 Describes applications of biology which affect society or the environment.

P5 Describes the scientific principles employed in particular areas of biological research.

Domain Knowledge

P6 Explains how cell ultrastructure and the coordinated activities of cells, tissues and organs contribute to macroscopic processes in organisms.

P7 Describes the range of organisms in terms of specialization for a habitat.

P8 Analyses the interrelationships of organisms within the ecosystem.

P10 Identifies and describes the evidence for evolution.

Domain Skills

P11 Identifies and implements improvements to investigation plans

P12 Discusses the validity and reliability of data gathered from first-hand investigations and secondary sources.

P13 Identifies appropriate terminology and reporting styles to communicate information and understanding in biology.

P14 Draws valid conclusions from gathered data and information.

P15 Implements strategies to work effectively as an individual and as a team member.

Values and attitudes

P16 Demonstrates positive values about and attitudes towards both the living and non-living components of the environment, ethical behaviour and a desire for a critical evaluation of the consequences of the applications of science.

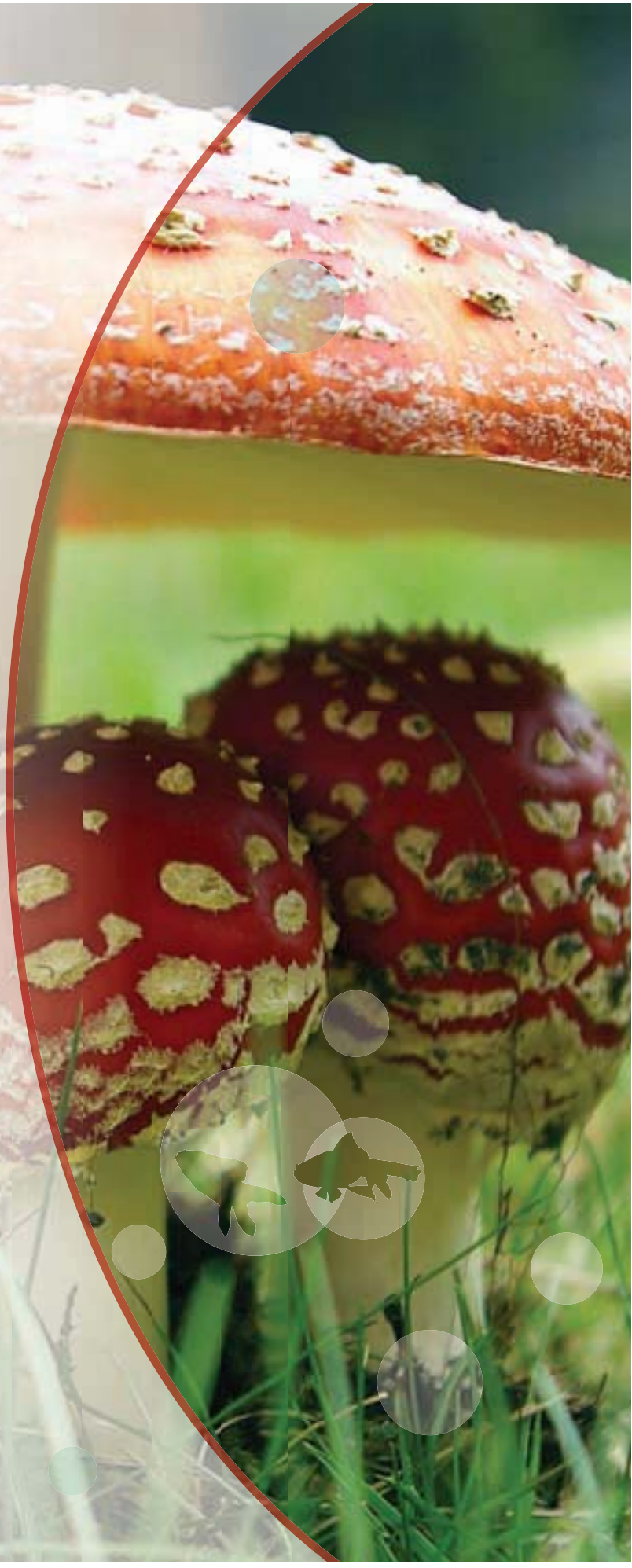
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LIFE ON EARTH



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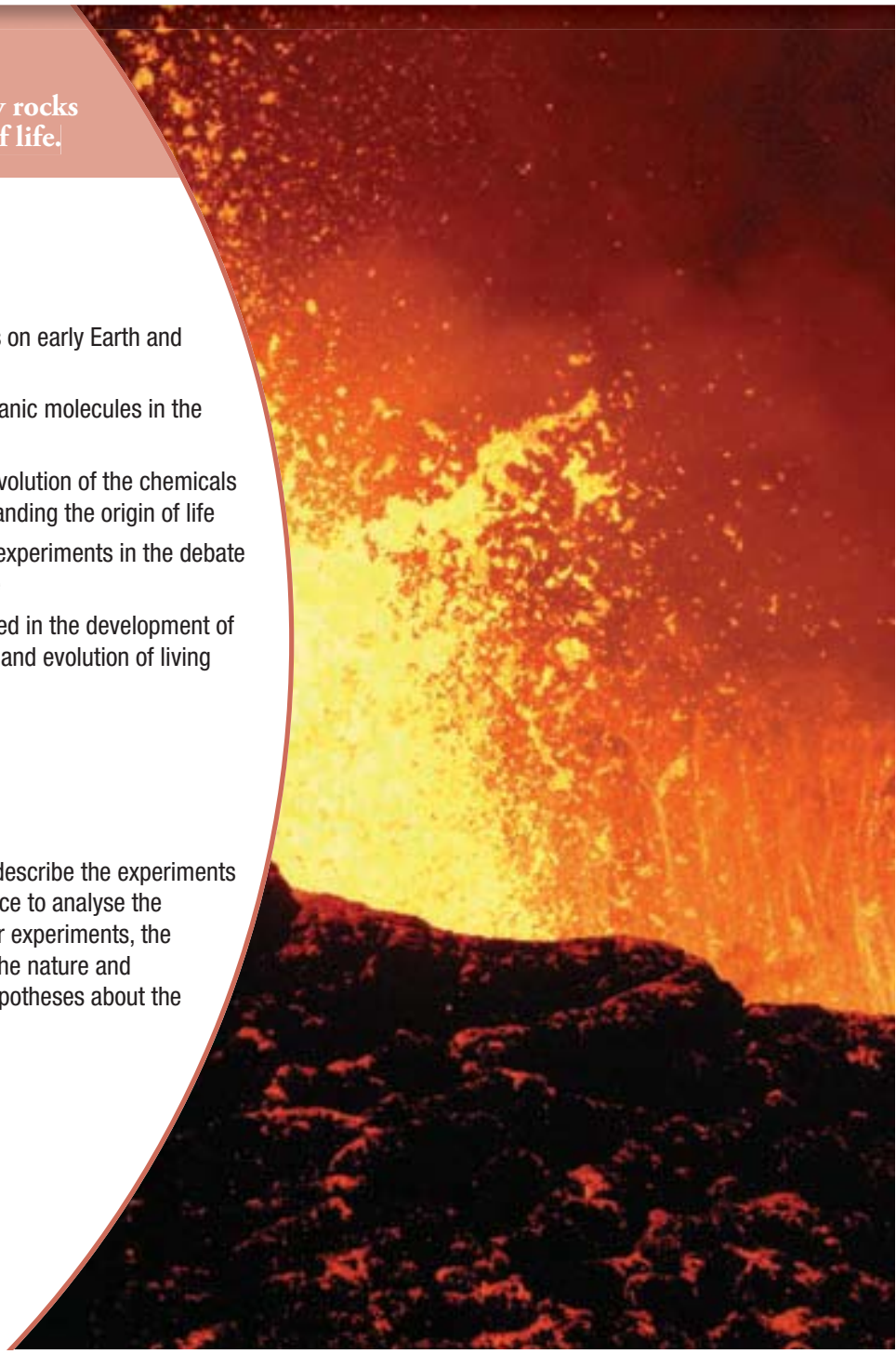
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3.1 THE ORIGINS OF LIFE



Analysis of the oldest sedimentary rocks provides evidence for the origin of life.

STUDENT LEARNING

In this unit students will:

- identify the relationship between the conditions on early Earth and the origin of organic molecules
- discuss the implications of the existence of organic molecules in the cosmos for the origin of life on Earth
- describe two scientific theories related to the evolution of the chemicals of life and discuss their significance in understanding the origin of life
- discuss the significance of the Urey and Miller experiments in the debate on the composition of the primitive atmosphere
- identify changes in technology that have assisted in the development of an increased understanding of the origin of life and evolution of living things.

STUDENT ACTIVITY

Students will:

- gather information from secondary sources to describe the experiments of Urey and Miller, and use the available evidence to analyse the reason for their experiments, the results of their experiments, the importance of their experiments in illustrating the nature and practice of science, and their contribution to hypotheses about the origin of life.

identify the relationship between the conditions on early Earth and the origin of organic molecules

All living things are made up of cells. But where did cells come from? How did life originate? Different cultures have developed different ideas to try to explain the origins of life. In this section we will look at some scientific evidence and the way scientific knowledge about the evolution of life on Earth has developed.

BIOFACT

Scientists might have found some of the earliest signs of life on Earth in Australia in 2008. Diamond and graphite grains containing carbon-12, the form of carbon found in living cells, were found trapped in mineral deposits in Western Australia. The deposits were estimated to be 4.2 billion years old. While this could indicate that life existed at this time, it may also be further support that concentrations of the right chemicals required for the formation of life were already in existence.

Conditions on early Earth

Many thousands of millions of years ago, according to physicists, the region of space now occupied by the solar system consisted mostly of scattered interstellar gases. Then an event occurred that would eventually enable life to exist. A nearby star exploded, sending massive shock waves through space, like the sound of a thunderclap through the air. This shock wave caused the interstellar gases to collect into much denser clouds. It is thought that these clouds condensed over a very long period of time, finally becoming dense enough to trigger the nuclear reactions needed to form a star—the Sun—about 4600 million years ago. The cooling solar gases surrounding the star coalesced into fragments, which came together to form the planets. By 4500 million years ago, our Earth had formed. There is evidence of liquid water on Earth 4.4 billion years ago, so life could have emerged some time after this, possibly 4.2 billion years ago.

1 billion = 1000 million

What was it like on this 'primeval' Earth?

Our current knowledge suggests that massive oceans existed, with only the beginnings of landmasses above the surface of the water. There was no **ozone layer**. So large amounts of ultraviolet solar radiation reached the Earth. The atmosphere contained some water vapour, hydrogen, hydrogen cyanide, abundant carbon dioxide, nitrogen, and possibly ammonia and methane. There was no free oxygen. Volcanic activity four billion years ago produced heat and sent large amounts of gases, ash and dust into the atmosphere. Violent electrical storms were common.

discuss the implications of the existence of organic molecules in the cosmos for the origin of life on Earth

Organic molecules—the chemicals of life

For life to have originated, the required chemicals (Table 3.1) need to have been formed and then come together as a self-replicating system. This system would need some form of protection for its chemical constituents, and had to be able to use an energy source to replicate itself. We know that living things do this using the structure of the cell.

Where did the chemicals of life come from? Were all the basic components present on early Earth? If so, we need to establish a relationship between the conditions on early Earth and the formation of organic molecules. Otherwise the implication is that organic molecules did not have to be present on Earth for life to have originated, they could exist in the cosmos and have arrived somehow on Earth. Let us look at two different scientific theories that relate to the evolution of the chemicals of life and the significance of these in understanding the origin of life on Earth.

BIOFACT

The living things on Earth today have not always been here; life on Earth is constantly changing. The idea of evolution is simply one of change. The theory of biological evolution states that life on Earth has changed with time: different species have gradually developed in response to changing environments. These changes have occurred slowly—often over millions of years. The groups of organisms in different populations have changed from ancestral types to modern-day types.

TABLE 3.1 The chemical components of life

Compound	Elements
water	hydrogen, oxygen
carbohydrates	carbon, hydrogen, oxygen
lipids	carbon, hydrogen, oxygen
proteins (made up from building blocks of 20 amino acids)	carbon, hydrogen, oxygen, nitrogen; other common elements include phosphorus and sulfur
nucleic acids (DNA and RNA)	carbon, hydrogen, oxygen, nitrogen, phosphorus

Theory 1: The chemicals for life came from outer space—a cosmic origin

describe two scientific theories related to the evolution of the chemicals of life and discuss their significance in understanding the origin of life

Panspermia

In the early 1900s a Swedish chemist, Svante Arrhenius, developed the theory of **panspermia** (which means 'seeds everywhere'). Arrhenius theorised that individual bacterial spores could drift across space, propelled by the pressure of light, and that these were the seeds of life on Earth. The panspermia theory has been used by others to develop ideas about evolution and the origins of life on Earth. Generally, theories of cosmic ancestry state that life on Earth was seeded from space, and that the evolution of life is based on genetic programs and systems that have come from other worlds.

Evidence in meteorites

Scientists believe that the Earth was heavily bombarded with **meteorites** during the early years of its formation, about 4.4 billion years ago. When certain types of meteorites, called carbonaceous chondrites, were first analysed in the 1970s, they were found to contain organic molecules, including amino acids. This provided evidence of the existence of organic molecules elsewhere in the cosmos. It is possible that meteorites falling on the early Earth could have contributed some of the organic molecules required by living systems.

The Ames Research Center of the US National Aeronautics and Space Administration (NASA) has conducted laboratory simulations of cold interstellar space and exposed interstellar ice to ultraviolet radiation. Analysis of the resulting materials has shown bubble-like structures that look very like cells with an inside and an outside layer. Scientists have suggested that this is further evidence that the chemicals for life could have come from outer space, from meteorites, comets or interplanetary dust.

In 1996, NASA announced that fossilised evidence of ancient life was found in a meteorite that had originated on Mars. But scientists could not prove that the microscopic formations were really the remains of living organisms, because no comparisons could be made with anything living or dead on Earth. In March 1999, NASA scientists announced that even stronger fossilised evidence for past life on Mars had been found in two other meteorites. These findings inspired NASA to prepare space probes to collect soil, rock and dust samples from space in perfectly sterile conditions, so that they can be analysed for microscopic life. A number of probes, including *Stardust*, *Deep Impact* and *EPOXI* have been and are on missions to collect further data.



Figure 3.1 Fragments of the Murchison meteorite. See Biofact on p. 162.

A meteorite is a rock that has struck the surface of the Earth from outer space.

NASA has a long-term Mars exploration program over the next 20 years which includes setting up an astrobiology field laboratory to continue to search for life on Mars.

BIOFACT

Meteorites have been hitting the Earth since its formation. Most of the rocks that enter the Earth's atmosphere burn up before they reach the ground because of the great heat produced by the friction with the air. However, a few are so large that they do not disintegrate completely before hitting the Earth's surface.

The Murchison meteorite, which struck the Earth near the Victorian town of Murchison in 1969, is a carbon-containing meteorite. Chemical analysis identified 92 amino acids. Nineteen of these were similar to those found on Earth, but the remainder were unlike any found on Earth. Recently the nucleic acid base uracil and the organic compound xanthine have also been identified from the meteorite.

Nanobes

Soon after the Martian meteorite discovery, geologist Dr Philippa Unwins, from the University of Queensland, discovered what might prove to be evidence that the fossilised organisms found in the Martian meteorite could have come from ultra-microscopic organisms similar to those on Earth. The growths that she found on rock samples from the Earth were named 'nanobes'. Dr Unwins' analysis showed that, like single-celled organisms, nanobes have a membranous wall and a nuclear core. They also contain the major building blocks for life: oxygen, nitrogen and carbon. Nanobes have since been detected in many environments, although it is still a matter of debate as to whether these are living organisms or not.

Theory 2: The chemicals of life were formed on Earth

Oparin and Haldane

In the 1920s, Russian scientist Alexander Oparin and British scientist John Haldane both suggested that the early atmosphere of Earth contained all the necessary basic chemical components for life. They hypothesised that more complex organic molecules could have been created in slow spontaneous reactions using energy from ultraviolet radiation or lightning discharges. Oparin suggested that organic molecules slowly collected in the surface layers of the oceans, forming an organic 'soup'. These molecules could then have combined to form larger structures, eventually forming cells.

Urey and Miller's experiment

Oparin and Haldane's theories remained untested until1953, when two American scientists, Harold Urey and Stanley Miller, performed the following experiment.

discuss the significance of the Urey and Miller experiments in the debate on the composition of the primitive atmosphere

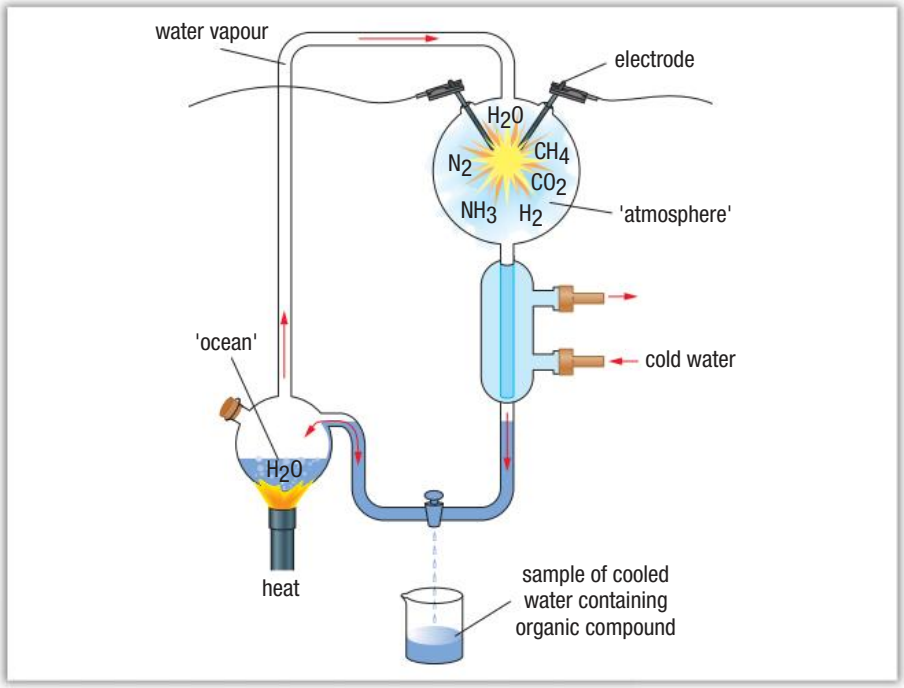


Figure 3.2 The design of the apparatus used in Urey and Miller's experiment, in which they showed that organic molecules could form in the environment of the early Earth.

A closed system was set up and powerful electrical sparks were discharged into a glass chamber containing ammonia (NH_3), hydrogen (H_2) and methane (CH_4)

(Figure 3.2). After only one week of continuous electrical discharges and recycling steam through the apparatus, the condensed water in the flask became red and turbid. When Urey and Miller analysed the liquid using paper chromatography techniques, they found it contained a number of amino acids.

Urey and Miller's experiment was significant because it supported Oparin and Haldane's theories and demonstrated that complex organic molecules, such as amino acids, can be produced naturally from more basic chemical components.

Current knowledge

Since Urey and Miller's classic experiment, scientists have further developed Oparin and Haldane's theories on the origin of life. Recent experiments have demonstrated that amino acids can be produced under conditions more like those of early Earth, using ultraviolet light instead of electrical discharges, and carbon dioxide instead of ammonia and methane. If hydrogen cyanide (HCN) is included, a greater variety of amino acids is produced.

Other theories have also been put forward suggesting other ways that the basic chemical components already existing on Earth could have been brought together to form the complex organic molecules found in living cells.

The astrobiologist Zachary Adam, in late 2007, claimed that life could have begun on a radioactive beach. Radioactive sand grains combined with powerful wave action could have provided the environment to generate the complex molecules found in cells. Laboratory experiments simulating this have confirmed that biological molecules can be produced in this way.

Another theory suggests that the chemicals for life could have been formed deep in the ocean around deep sea hydrothermal vents. In the zone between the very hot water from the vents and the cold ocean water there is a zone where the temperature would be suitable for the formation of organic molecules. As hot volcanic gases, containing molecules such as carbon monoxide and cyanide, rose up through vents, they would combine with seawater and metal atoms such as nickel and iron. Simulations have shown that under these circumstances the metal atoms can catalyse the formation of amino acids and even link them together to form peptides. The procaryotic organisms that are found there today (see p. 191) could possibly be some of the earliest living organisms on Earth.

BIOFACT

A reducing atmosphere is one which favours reactions of chemical reduction. This would be rich in hydrogen (H_2), methane (CH_4) and ammonia (NH_3), and lacking in oxygen.

Recent evidence from chondrites (meteorites containing material from ancient nebular gases) supports the theory that the atmosphere on early Earth was a reducing one.

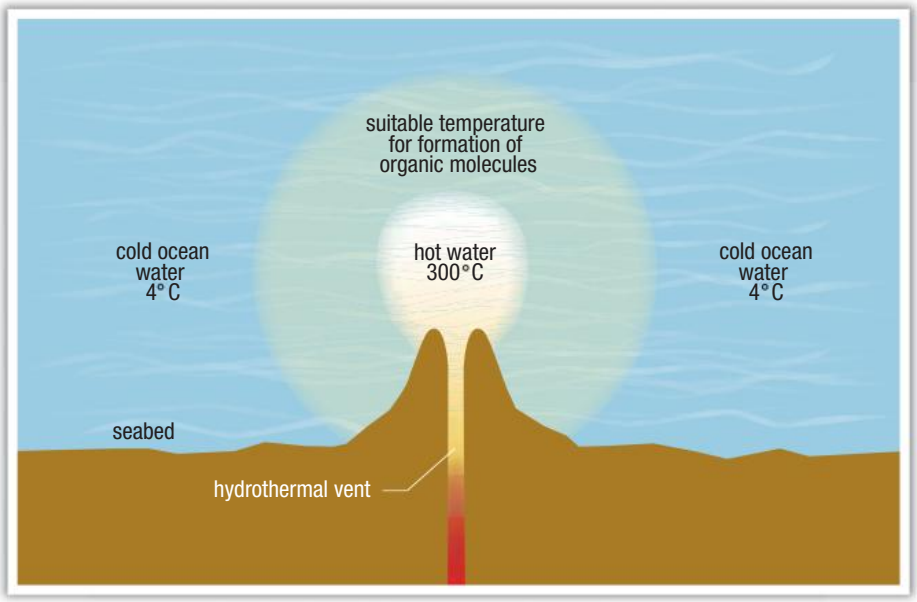


Figure 3.3 The chemicals of life could have formed deep in the ocean.

The thick orange hazy atmosphere discovered surrounding the planet Saturn's largest moon, Titan, has given rise to a further theory. Titan's atmosphere is made up of nitrogen, methane and hydrocarbons. It has been suggested that an atmosphere like this could have surrounded early Earth. In the laboratory, methane has been exposed to ultraviolet light and mixed with carbon dioxide. From the haze, large organic molecules form and slowly float downwards. If early Earth had a similar haze, then organic molecules could have fallen to the Earth's surface and provided a source of nutrients for the beginnings of life.

Astrobiology

Astrobiology is the study of life in the universe. It includes research into the origins and early evolution of life on Earth, as well as looking for evidence of life on other planets. It is multidisciplinary, including astronomy, astrophysics, biology, chemistry, palaeontology, geology, engineering, computing and mathematics.

The Australian Centre for Astrobiology was opened in 2008 at the University of New South Wales. It aims to contribute to the understanding of the origin of life on Earth and to send an Australian life-seeking instrument to Mars.

The Centre is affiliated with the NASA (National Aeronautics and Space Administration) Astrobiology Institute. The NASA Astrobiology Program is seeking to provide answers to three questions:

- How does life begin and evolve?
- Is there life beyond Earth and, if so, how can we detect it?
- What is the future of life on Earth and in the universe?

Astrobiologists are interested in studying Earth's extremophiles (see pp. 190–191) as many of these organisms can survive in environments similar to those known to exist on other planets.

identify changes in technology that have assisted in the development of an increased understanding of the origin of life and evolution of living things

BIOFACT

Nanotechnology is the research, development and manufacture of objects at the molecular level. It uses microanalytical techniques from chemistry and engineering to study and manipulate atomic and molecular structures from both physical and biological systems. Nanotechnologists usually work with materials that are smaller than 100 nanometres, or 10^{-7} metres—the average size of a virus. Within the next 20 years, nanotechnology will have a huge impact on the way things are designed and constructed in our society. Some surgery will be conducted at the cellular level; computers and other machines will be smaller, more powerful and more precise, and the artificial manufacture of any type of material will be possible.

Changes in technology

Our ability to describe the origins, processes and evolution of living things has been made possible by advances in science and technology, particularly in computing, mathematics, molecular biology and biochemistry. Scientists and engineers have developed many techniques to find out more about the Earth, its history and the living organisms that occupy it.

Developments in engineering have enabled both space and deep-sea exploration. Developments in **nanotechnology** have enabled samples of all types of materials to be analysed to the sub-molecular level. Chemical separation techniques, such as chromatography, help to isolate molecules for further study. The ages of rocks and fossils can be dated by radiometric dating methods. Developments in geophysics and seismology have led to greater understanding of the history of Earth's structure and processes involved in its formation. Developments in microscopy, particularly the electron and X-ray microscopes, have led to a new understanding of structures at the molecular level. Biochemical analysis, particularly of DNA, has enabled scientists to undertake comparative studies of different organisms. Genetic engineering techniques continue to help scientists to understand how change can

take place in living organisms, and thus we can better understand the relationship between organisms and their possible evolutionary pathways.

The use of these new technologies has led to a better understanding of the origins of life and the evolution of living things. Examples of all the techniques named above can be found in this book. In your reading and research, both in this book and elsewhere, you will find examples of how advances in science go hand-in-hand with advances in technology.

Nanotechnology

Nanotechnology is the research, development and manufacture of objects at the molecular level. It uses microanalytical techniques from chemistry and engineering to study and manipulate atomic and molecular structures from both physical and biological systems. Nanotechnologists usually work with materials that are smaller than 100 nanometres, or 10^{-7} metres—the average size of a virus. Within the next 20 years, nanotechnology will have a huge impact on the way things are designed and constructed in our society. Some surgery will be conducted at the cellular level; computers and other machines will be smaller, more powerful and more precise, and the artificial manufacture of any type of material will be possible.

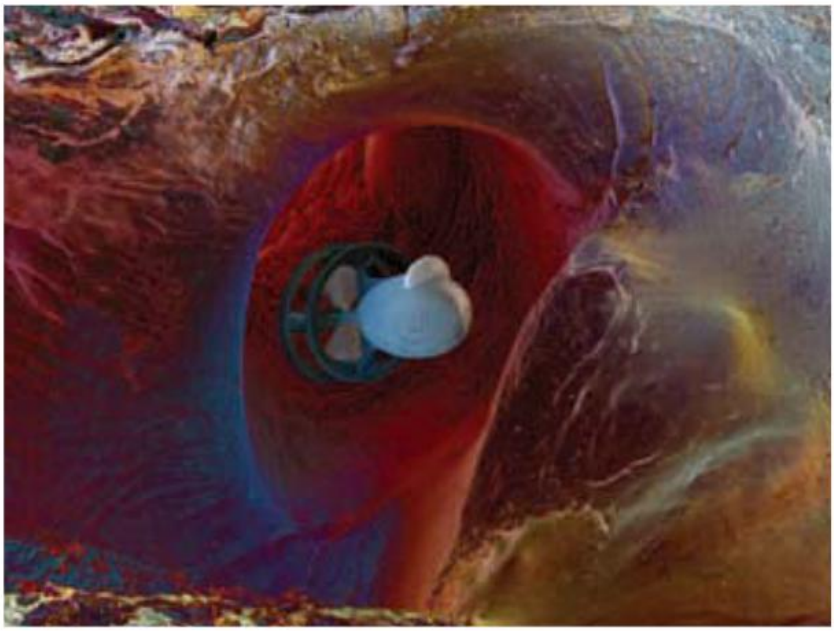


Figure 3.4 Nanorobots might one day be able to travel through blood vessels inside your body and repair any damage.

INVESTIGATION 3.1

Urey and Miller's experiment

Students will: gather information from secondary sources to describe the experiments of Urey and Miller, and use the available evidence to analyse: the reason for their experiments; the results of their experiments; the importance of their experiments in illustrating the nature and practice of science; their contribution to hypotheses about the origin of life.

Skills and outcomes

P2, P5, P10, P12, P14

Type of activity

Second-hand data activity

Materials

- books, journals, Internet sites

See Analysing information

Introduction

The chemical origin of life was proposed by Alexander Oparin and John Haldane in the 1920s. They suggested that the early atmosphere of Earth contained all the necessary basic chemical components for life. They hypothesised that more complex organic molecules could have been created in slow, spontaneous reactions using energy from ultraviolet radiation or lightning discharges. This theory was first tested by the experiments of Harold Urey and Stanley Miller in the 1950s.

Purpose

To investigate the experiments of Urey and Miller.

Procedure

Read pp. 162–163 and other sources of information about Urey and Miller's experiments.

Discussion

1 Using Figure 3.2 on p. 162, answer the following questions.
2 Why did Urey and Miller carry out their experiments?
3 In the apparatus used by Urey and Miller, what did the following represent:
   a the electrical discharges
   b the gases used
   c the water in the flask?
4 Why was the water heated and then cooled?
5 What was the result of their experiments?
6 What do their experiments illustrate about the nature and practice of science?
7 What contribution did Urey and Miller's experiments make to hypotheses about the origin of life?

3.1 UNIT REVIEW

Life on Earth

Analysis of the oldest sedimentary rocks provides evidence for the origin of life.

Summary

- Conditions on early Earth were very different from those found today. The composition of the atmosphere, the high levels of ultraviolet radiation and violent electrical storms could have provided the conditions necessary for the production of organic molecules.
- Organic molecules found in meteorites from space imply that life may not be unique to Earth.
- Two theories to explain the origins of life on Earth are that organic molecules (a) arrived from space on meteorites, or (b) were formed as a result of conditions on the early Earth.
- Urey and Miller's experiment demonstrated that the composition of the primitive atmosphere on early Earth could have produced organic molecules.
- As new technologies have been developed, they have increased our understanding of the origin of life and the evolution of living things.

Questions

1 Which statement best describes conditions on the early Earth?

A hot with volcanic activity and electrical storms
B dark and dusty with abundant water
C dry land covered with volcanic dust and ash
D cold with oceans, like a primordial soup

2 Which list includes three chemicals that probably occurred on early Earth?

A oxygen, carbon dioxide, ammonia
B water, chlorophyll, methane
C sugars, amino acids, hydrocarbons
D carbon dioxide, hydrogen, water

3 What is meant by the term 'evolution'?

A change over time
B mutation
C increasing in complexity
D increasing in numbers

4 Outline the evidence that indicates that life may not be unique to Earth.

5 Describe the conditions on early Earth that explain the origin of life.

6 Describe Urey and Miller's experiment, outlining the procedure and the results.

7 Discuss the significance of the results of Urey and Miller's experiments in the debate on the composition of the primitive atmosphere.

8 Evaluate three technological advances that have assisted in the development of our understanding of the origins of life.

3.2 FOSSILS AND THE EVOLUTION OF LIFE



The fossil record provides information about the subsequent evolution of living things.

STUDENT LEARNING

In this unit students will:

- identify the major stages in the evolution of living things, including the formation of organic molecules, membranes, procaryotic heterotrophic cells, procaryotic autotrophic cells, eucaryotic cells, colonial organisms and multicellular organisms
- describe some of the palaeontological and geological evidence that suggests when life originated on Earth
- explain why the change from an anoxic to an oxic atmosphere was significant in the the evolution of living things
- discuss the ways in which development in scientific knowledge may conflict with the ideas about the origins of life developed by different cultures.

STUDENT ACTIVITY

Students will:

- process and analyse information to construct a timeline of the main events that occurred during the evolution of life on Earth
- gather first-hand or secondary information to make observations of a range of plant and animal fossils
- identify data sources, gather, process, analyse and present information from secondary sources to evaluate the impact of increased understanding of the fossil record on the development of ideas about the history of life on Earth

Major stages in the evolution of life

identify the major stages in the evolution of living things, including the formation of organic molecules, membranes, procaryotic heterotrophic cells, procaryotic autotrophic cells, eucaryotic cells, colonial organisms and multicellular organisms

The following steps are believed to be the major stages in the evolution of life on Earth:

1 **The formation of organic molecules**
Complex organic molecules formed in water on the early Earth.

2 **The formation of membranes**
A membrane developed to isolate and protect the system of large complex organic molecules, which evolved to include nucleic acids and became capable of self-replication.

3 **Procaryotic cells**
The first cells were simple structures known as procaryotes (see p. 188). They are the earliest type of fossil found.

4 **Eucaryotic cells**
Cells containing a membrane-bound nucleus and cell organelles developed (see Chapter 2, p. 69).

5 **Colonial organisms**
Multicellular organisms may have originated when daughter cells became bound together after cell division to form an aggregation of similar cells, also called a 'colony'.

6 **Multicellular organisms**
Multicellular organisms contain cells that show specialisation of function. Each cell has its own particular function and is dependent on others. Each organism, however, functions as a coordinated whole.

Complex organic molecules known as phospholipids can combine in water to form spherical structures with a boundary layer similar to cell membranes. These are called liposomes. The layer acts as a selectively permeable membrane and absorbs organic molecules from water.

The evolution of organisms

The study of fossils shows us that there has been a great diversity of living organisms from Precambrian times (Table 3.2, pp. 174–175). The types and abundance of organisms, however, have changed over time. With a knowledge of present-day diversity we can trace back the evolutionary pathways of living organisms. Some appear to have changed greatly over time, others have remained the same for millions of years, and some forms have become extinct and are no longer found today (Figure 3.5). We can relate the fossil record to the time over which living things have been evolving on Earth.

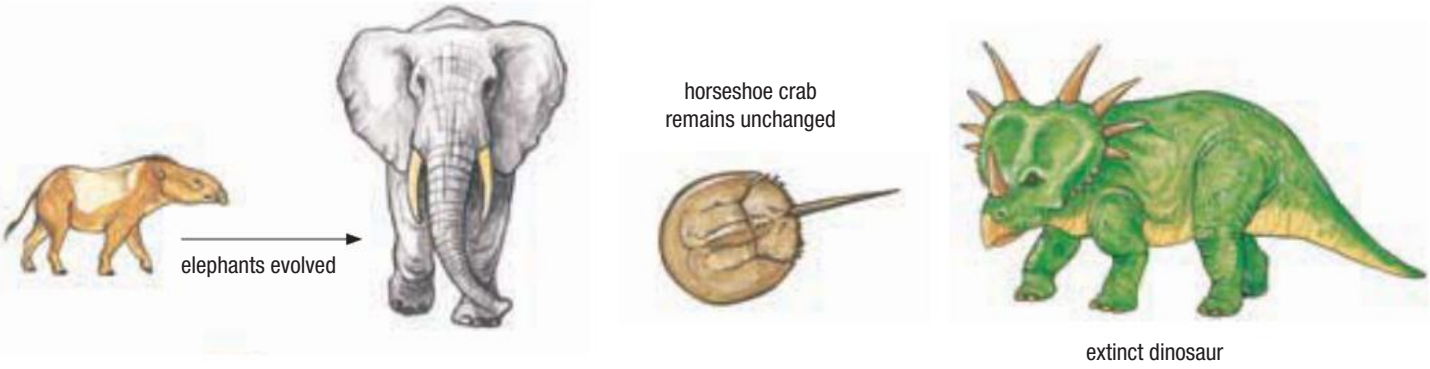


Figure 3.5 Some examples of evolutionary pathways. Most species, such as elephants, have evolved from other species; some, such as horseshoe crabs, have remained the same for millions of years. Many species, such as the dinosaurs, have become extinct.



Figure 3.6 Ginkgos were once known only from fossil leaves like this one, which was found at Koonwarra in southern Victoria. But in the 1930s the ginkgo or maidenhair tree, *Ginkgo biloba*, was discovered as a living tree in central Asia, and is now widely cultivated in gardens. It is called a 'living fossil' because it is the last survivor of a group of plants that has all but died out.

Fossils

The study of fossils is called **palaeontology**. Fossils are any preserved remains or traces of past life found in sedimentary rocks or other material of different ages. **Taphonomy** is the study of the processes by which dead organisms become fossils. Fossilisation is a rare event and it is rare for a complete fossil to be found. Dead organisms may be eaten or partly eaten by predators and scavengers, soft parts will decay, and bones may be transported by earth or water movements before the final remains are fossilised. Hard parts such as bones, teeth and shells of animals, and wood, pollen and spores of plants are most commonly preserved.

Traces of organisms such as footprints, trails, burrows and even animal excreta (called coprolites) can also tell us something about the organisms that made them. Occasionally fossils, particularly more recent ones, may be preserved whole as a result of an unusual event. These fossils are particularly useful for comparison with living forms. For example:

- Woolly mammoths more than 10 000 years old have been found frozen in the permanently frozen soil of Siberia.
- Resin from coniferous trees may trap insects and preserve them whole when the resin hardens to form amber.
- Peat bogs may preserve whole organisms in a mummified condition.

These remains are often called 'subfossils'.

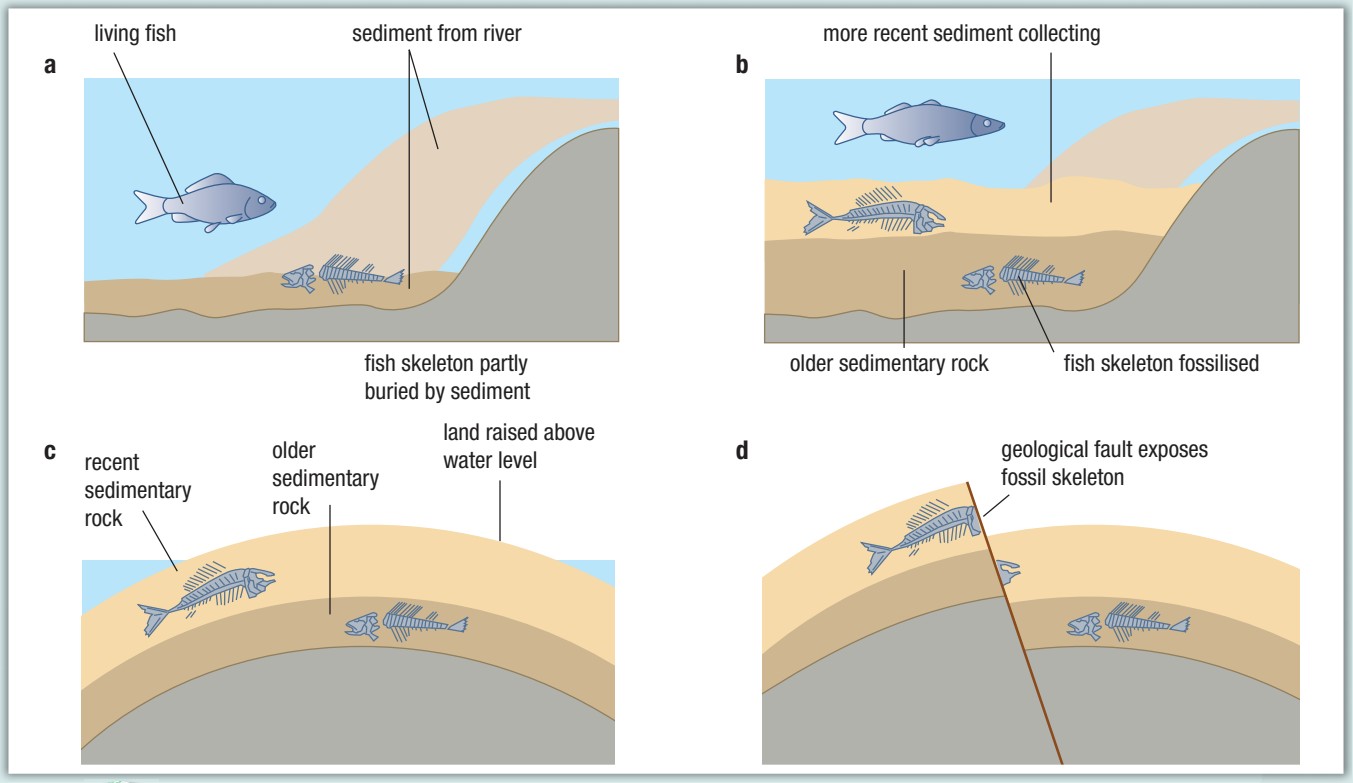


Figure 3.7 The formation of a typical fossil. (a) The dead fish is quickly buried by sediment. (b) The sediment is covered by more layers, and the pressure consolidates it into soft sedimentary rock. As this happens, the bones of the fish disintegrate and the spaces left behind are replaced by chemicals that form a hard rock. (c) The rocks containing the fossil are raised above sea level by Earth movements. (d) Weathering (or a palaeontologist's hammer) exposes the fossil.

Palaeontological and geological evidence of early life

The study of rocks and fossils can also provide evidence of early life forms and their activities. The oldest sedimentary rocks on Earth are about 3800 million years old.

describe some of the palaeontological and geological evidence that suggests when life originated on Earth

Palaeontological evidence

Palaeontology is the study of life in ancient (geological) times, through the fossil record.

Fossil evidence in very ancient rocks is scarce compared with the abundance of fossils found in rocks formed over the past 600 million years.

The earliest fossils found are of two types: **microfossils** which are similar to present-day single-celled anaerobic **procaryotic organisms**, and **stromatolites**, which are layered mats of photosynthetic procaryotic cells called **cyanobacteria** (see p. 193), found today only in a few isolated areas (see Figure 3.8).

These two types of fossils are found in rocks 3400 to 3500 million years old from the Warrawoona Group in Western Australia. Stromatolites are also found in the 2800 to 3000 million-year-old Fig Tree Group of rocks in South Africa and in 2000 million-year-old Gunflint Chert rock found on the shores of Lake Superior in North America.



Figure 3.8 Living stromatolites are found in only a few places on Earth, usually in very saline or alkaline water, for example the saline waters of Shark Bay in Western Australia and the alkaline lakes in Nevada, USA. The stromatolites shown here in Shark Bay were discovered in the 1990s. They grow at the rate of about 1 mm per year.

Geological evidence

Geology is the study of rocks and the Earth's crust.

The first primitive cells were heterotrophic—they obtained energy by consuming other organic compounds. Then cells containing pigments developed. These cells were able to capture light energy from the Sun and use it to convert carbon dioxide to more complex organic compounds for their own use—in other words, they photosynthesised. As a byproduct of this process, oxygen was produced.

The evolution of photosynthesis had a dramatic effect on the environment of Earth. It led to an explosion in the abundance of photosynthetic organisms. These organisms used up carbon dioxide, which gradually reduced the levels present in the atmosphere. The oxygen produced did not at first build up in the atmosphere but was taken up by rocks. These **oxidised rocks** can be seen today in the ancient banded iron and red bedrock formations (Figure 3.9).

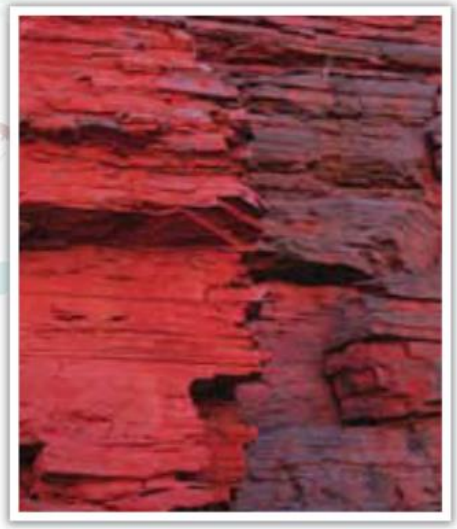


Figure 3.9 Red bedrock formations were formed when the oxygen produced by early organisms was taken up by rocks.

How old is that rock?

Igneous rocks are formed by volcanic activity. The age of igneous rocks is estimated using radiometric dating methods. These methods are based on the principle that radioactive elements decay to different forms (for example, uranium to lead, rubidium to strontium) at rates that are constant for each element. This rate of decay is independent of the nature of the rocks or the environmental conditions to which they are exposed.

Uranium has a half-life of 4500 million years. This is the time taken for half of the atoms in a sample of uranium to decay to lead. By comparing the relative ratio of uranium to lead, the age of the rock can be calculated. This can be done only with igneous rocks because, as they cooled, those that contained uranium formed crystals that contained no lead. Similar calculations can be made using other radioactive elements in rocks such as strontium.

Because igneous rocks are formed by cooling of molten rock that reaches the surface of the Earth, they do not contain fossils. But they can be used as reference points to compare the age of sedimentary rocks above (younger) or below (older) the igneous rock layer. For example, if a sedimentary layer containing fossils lies below igneous rock that was dated at 200 million years old, then the fossils must be at least that age or older.

Fossils that contain carbon can be analysed by radiocarbon dating. The unstable carbon isotope ^{14}C (carbon-14) has a half-life of 5730 years and decays to ^{12}C. This ratio is constant in the CO_2 of the atmosphere, but once CO_2 is incorporated into organic compounds such as plant cellulose, the ratio decreases steadily. This is because no new ^{14}C is taken into the plant. So the ratio of ^{14}C to ^{12}C can be used to find out how long ago a plant fossil formed. This method is limited to samples no older than about 50 000 years, because by that age there is not enough ^{14}C left to measure.

Sometimes the only way to determine the age of a fossil bed is by 'indicator fossils'. A coal deposit at Anglesea in Victoria contains many important flowering plant fossils, including relatives of modern banksias. The coal is dated at 40 million years old by the presence of certain fossils, such as pollen grains, whose ages are well known from geological strata found elsewhere.

BIOFACT

Banded iron rock formations (2000–2800 million years old) have a high oxygen concentration present as magnetite (Fe_3O_4). This type of rock is no longer formed.

Red bed rock formations are also highly oxidised and contain oxygen present as hematite (Fe_2O_3).

explain why the change from an anoxic to an oxic atmosphere was significant in the evolution of living things

The changing atmosphere

When all oxidisable surface rock had been saturated with oxygen, oxygen began to build up as a gas in the Earth's atmosphere. Ultraviolet radiation from the Sun reacted with some of the oxygen gas to form ozone (Figure 3.10). As the amount of oxygen in the atmosphere increased, more and more could be converted to ozone, until an ozone layer formed around the Earth, high in the atmosphere.

This ozone layer acted as a shield, absorbing ultraviolet radiation so that less reached the surface of Earth.

The significance of the change from an **anoxic** atmosphere to an **oxic** atmosphere was that anaerobic organisms declined. As oxygen levels rose, photosynthetic organisms became more abundant, while the growth and **metabolism** of anaerobic organisms were inhibited by the presence of oxygen. Today anaerobic organisms survive only where there is a very low oxygen concentration, such as in the mud in swamps and bogs, and deep underground or in deep ocean hydrothermal vents (see pp. 190–191).

The ozone layer protected living things from the harmful effects of ultraviolet radiation. This protection enabled living things to colonise the land.

As oxygen levels rose in the atmosphere, living systems developed ways to use oxygen directly to produce chemical energy. Aerobic organisms evolved that produced energy more efficiently by the process of respiration (see pp. 19–20). Greater metabolic activity became possible and organisms could be more active. The result was an increase in the size and complexity of organisms. Eucaryotic cells evolved, as did multicellular plants and animals.

With the evolution of photosynthesis and respiration, life on Earth has changed forever. The conditions under which life was originally formed have been replaced by new conditions. The presence of oxygen in the atmosphere inhibits the formation of complex organic molecules such as amino acids, and the abundance of basic chemical components has also been depleted and locked up in existing life forms. The abundance of life forms competing for survival would now not allow the slow rise of living systems as occurred on the early Earth.

Anerobic organisms are those that do not use oxygen for respiration

Aerobic organisms use oxygen for respiration

Conditions needed for eucaryotic life are:
- protection from ultraviolet radiation
- free oxygen in the atmosphere
- liquid water.

A steady state cycle of gases in the atmosphere now exists between photosynthesising organisms, which use carbon dioxide and produce oxygen, and aerobic organisms which use oxygen and produce carbon dioxide.

The restriction that respiration places on aerobic organisms is their absolute dependency on the availability of oxygen, either as free oxygen in the atmosphere or as dissolved oxygen in water. Without oxygen, aerobic organisms do not survive.

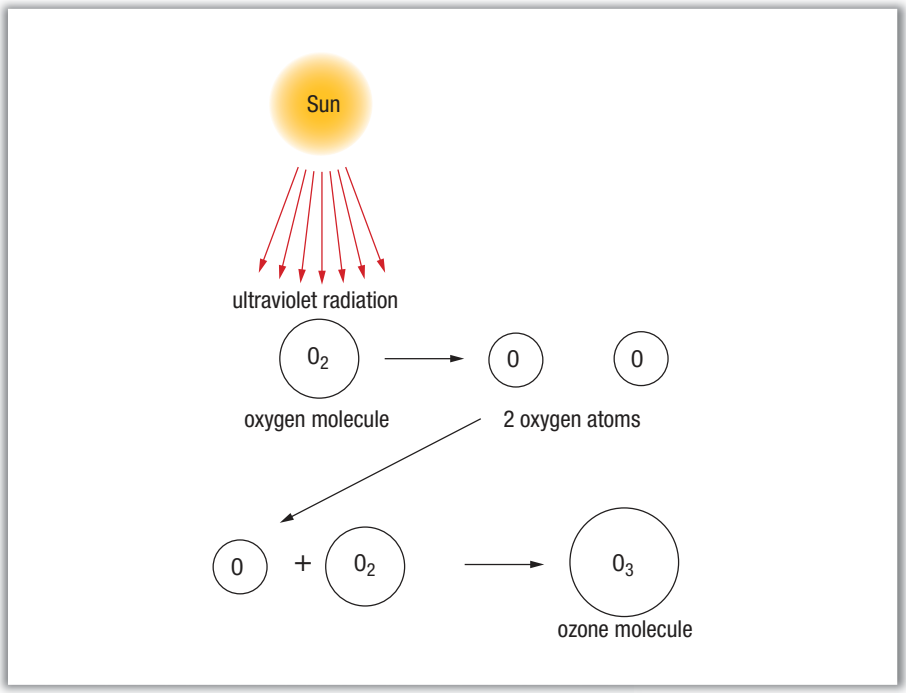


Figure 3.10 The formation of ozone. Ultraviolet light splits oxygen molecules (O_2). Each atom combines with an O_2 molecule to form ozone (O_3). The free oxygen atoms are called 'oxygen-derived free radicals'. They are extremely reactive and toxic to living cells.

discuss the ways in which development in scientific knowledge may conflict with the ideas about the origins of life developed by different cultures

Other ideas about the origins of life

Different cultures have developed different ideas to try to explain the origins of life. Some of these ideas are many thousands of years old. They are very often linked to the religious and spiritual beliefs of a culture.

The development of scientific knowledge about the origins of life may conflict with some of these ideas.

Scientific knowledge is developed and tested using scientific methods. It grows and changes only if it is supported by rigorous testing. Religious and cultural beliefs are usually strongly held, and are ideas which an individual or culture has developed to explain the world.

TABLE 3.2 A timeline for the evolution of plants and animals

Era	Period	Started (mya)*
Cainozoic	**Quaternary**	
	Recent	0.1
	Pleistocene	1.8
Tertiary sub-era	**Neogene**	
	Pliocene	5.32
	Miocene	23.8
Tertiary sub-era	**Palaeogene**	
	Eocene	33.7
	Oligocene	54.8
	Palaeocene	65
Mesozoic	**Cretaceous**	141
	Jurassic	205
	Triassic	251
Palaeozoic	**Permian**	298
	Carboniferous	354
	Devonian	410
	Silurian	434
	Ordovician	490
	Cambrian	545
Precambrian	**Neoproteozoic**	900
	Mesoproteozoic	1600
	Paleoproteozoic	2500
	Archaean	3900
	Hadean	4600

* millions of years ago

	Evolution of plants	Evolution of animals
	• increase in number of herbs	• rise of human civilisations • first *Homo* species
		• first hominids (human ancestors)
	• land dominated by angiosperms	• land dominated by mammals (including apes), birds and insects • radiation of mammals
	• angiosperms (flowering plants) arise and expand as gymnosperms decline	• last of the dinosaurs; second great expansion of insects • dinosaurs abundant; first birds
	• last of the seeds ferns	• first dinosaurs, first mammals
	• land dominated by gymnosperms	• rise of reptiles; first land vertebrates
	• great coal-forming forests; beginning of evolution of ferns and gymnosperms	• age of amphibians; first reptiles; first great expansion of insect species
	• expansion of primitive vascular plants; origin of first seed plants towards end of period; first liverworts	• age of fishes; first amphibians and insects; corals dominant
	• invasion of land by first vascular plants towards end of period	• invasion of land by a few arthropods
	• marine algae abundant	• invertebrates dominant; first corals; first vertebrates (fish)
	• primitive marine algae	• marine invertebrates abundant, including representatives of most modern phyla
	• Ediacaran biota	
	• first eucaryotes	
	• transition to oxic atmosphere	
	• oldest known fossils, oldest known rocks	
	• formation of the Earth	

Cells within cells

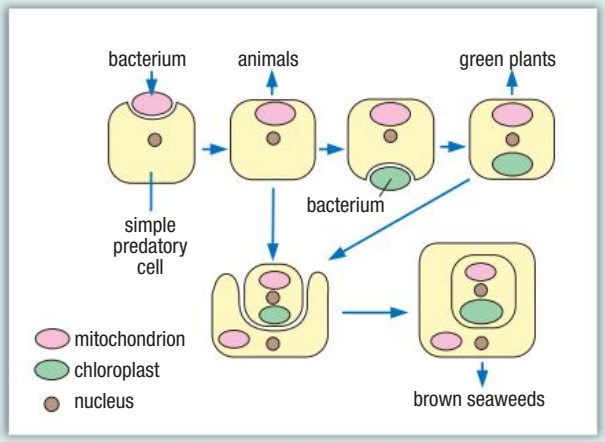


Figure 3.11 The endosymbiotic theory of evolution of eucaryotic cells suggests that primitive cells engulfed different forms of bacteria, resulting in more complex cells. (See pp. 69–70.)

Both mitochondria and chloroplasts have their own DNA, and they produce their own membranes and ribosomes, and some of their proteins. Their DNA and ribosomes are more similar to the DNA and ribosomes in bacterial cells than in plant and animal cells.

These observations have led to an intriguing theory, now widely accepted, about the evolution of cells. This theory proposes that, about 1.5 billion years ago, an aerobic bacterium was engulfed by a simple predatory cell with a membrane-bound nucleus, and the bacterium continued to live symbiotically within its host (Figure 3.11). This 'guest' became the forerunner of mitochondria, and the predatory cell became the first of a new type of cell, which eventually gave rise to protists, fungi, plants and animals.

Some time later, another engulfment took place; this time it was of a photosynthetic bacterium, which became the forerunner of chloroplasts. This second event led to the evolution of green plants. Recent studies have shown that there is a double membrane envelope around the chloroplasts of brown algae, suggesting that a third engulfment (probably of an ancestral red seaweed) may have taken place. A nucleus-like structure has been found between the two chloroplast membranes.



Figure 3.12 An Ediacaran fossil.

The Ediacaran biota

About 580 million years ago, the last of the major Ice Ages of the Precambrian period came to an end. During this period, known as 'Snowball Earth', most of the planet was frozen over. With the thaw came huge increases in oxygen levels in the oceans, plus immense quantities of dissolved organic matter was released by melting glaciers. Within 10 million years of this melting, an explosion of complex multicellular organisms occurred—the Ediacaran biota.

The first fossils discovered by Reginald Sprigg, an Australian geologist in the Ediacaran Hills of South Australia, were mistakenly thought to be Cambrian. Later identification, plus further fossils finds in Siberia, Canada, Namibia, USA, China, Scandinavia and England, have confirmed the existence of totally distinct Precambrian multicellular life forms.

The Ediacaran biota were found in the oceans in the late Precambrian between 575 and 542 million years ago. The Ediacaran biota were all soft-bodied and immobile, all lived in the sea and fed by absorbing organic matter. Some reached large sizes—the largest known is over 4 metres. Early forms lived deep in the oceans, but later forms are found in shallower waters. They include all forms of symmetry, from radially symmetric, to bisymmetrical and even trisymmetrical forms. Some looked like jellyfish, others were reminiscent of fern fronds, worms or sponges.

By the Cambrian period they had all vanished. Did they all die out? The large forms certainly disappeared and there are no links connecting them to Cambrian life forms. Some scientists, however, believe that a group of small Ediacarans look very like and are the possible ancestors of early arthropods and echinoderms.

Creation and cultures

Ancient cultures developed explanations of the origins of the universe and everything in it. These explanations are called **creation myths** or cosmogenies. They are among the earliest attempts by many cultures to explain some of the most profound questions about the nature and origin of the universe, and of life. To the Egyptians and Babylonians, creation occurred not long before they had come into existence. To these cultures, gods were responsible for all aspects of the world.

According to the most common cosmogeny in Chinese culture, the first living being was P'an Ku, who evolved inside a gigantic cosmic egg. This egg contained all the elements of the Universe, totally intermingled. P'an Ku grew about 3 metres every day. During this process he separated the Earth and the sky within the egg, and gradually separated nature's opposites: male and female, light and dark, and so on. As he grew, P'an Ku also created the first humans. The egg hatched after 18000 years, and P'an Ku died from this massive effort of creation. Eventually, from his sweat, rain and dew appeared; from his eyes, the Sun and the Moon; from his voice, thunder; and from his body, Earth's natural surface and features were created.

Australian Aboriginal people believe in a creation time, called the alcheringa or Dreaming. The cosmogenies of different Aboriginal peoples vary. Generally, the Dreaming was the time when ancestral beings emerged from beneath the ground, and the time when humans, animals, plants, the world, the Sun, Moon and stars were created. According to one tradition, two superhuman beings came down to the Earth from the west. These beings formed humans from strange creatures that had themselves evolved from animals and plants.

Greek cosmogenies were more definite and methodical than those of many other cultures. Aristotle's theory of creation lasted for more than 2000 years in Western cultures. He based his idea on systematic and common-sense observations. He thought that everything in existence was positioned in an immense and complex hierarchy that did not change. This hierarchy ranged from rocks, up through plants and animals, to humans, and finally to God.

Lucretius, a Roman philosopher and poet who died around 50 BC, believed that the Universe could not have been created by a divine power because it was so imperfect. He thought that the Earth formed first by the gradual coming together of particles, and that the rest of the universe was formed by the lighter particles, including fire and water, that were squeezed out as the Earth formed. He thought that, although this process started long ago, the Earth was formed very recently. He said that plants grew from the Earth like the feathers from a bird, and that the ancestors of all the animals had been born from the Mother Earth, and these species remained the same ever since, although some had perished.



Figure 3.13 According to the Old Testament of the Bible, the creation of the Earth by God was followed by the creation of humans (Adam and Eve) and all the creatures and plants of the Earth.

INVESTIGATION 3.2

A timeline for life on Earth

Students will: process and analyse information to construct a timeline of the main events that occurred during the evolution of life on Earth.

Skills and outcomes

P12, P13, P14, P15

Type of activity

Second-hand data activity

Materials

- books, journals, Internet sites

See Presenting information

Introduction

Living things have been on Earth for many millions of years. Different geological periods stretching from the Earth's formation over 4700 million years ago to the present day reveal evidence of change in living organisms. Scientists have identified major stages in the evolution of life on Earth, from the first single cells to complex multicellular organisms.

The way that information is presented depends on the audience and the type of medium used. Scientific information in particular may be over-simplified, or sometimes presented in a more complex way than necessary.

Purpose

To construct a timeline of the main events that occurred during the evolution of life on Earth.

Procedure

1. In groups, plan the research and presentation of your timeline. Select a target audience for your information—for example, primary school children, high school students, readers of a daily newspaper or university researchers.
2. Choose a suitable method of presentation and medium to suit your audience. This could be a junior science textbook, a poster for a secondary school science laboratory, a PowerPoint presentation or web page, a news report or an appendix to a research paper.
3. Choose the resources you will need and research the information you require about the main events in the evolution of life on Earth (see pp. 169–175 and other sources).
4. Construct the timeline in your chosen medium. Your timeline should include the major geological periods, their dates and the type of organisms present. Remember your target audience and make sure your language level is appropriate, the amount of information is suitable and that your method of presentation will be of interest to your audience.
5. Present your information to the class.
6. Compare your information and presentation with other groups.

Discussion

1. Describe any difficulties you had in your research on this topic, with regard to variations in different resources you consulted. Can you explain why this variation occurred?
2. Explain which sources of information you regarded as being the most accurate.
3. Describe the problems you faced when selecting a suitable scale for your timeline.
4. Explain, with reasons, the way you decided to present your timeline to suit your target audience.
5. Describe the differences between the way your timeline was presented and the way another group presented theirs. Relate this to the target audience and the method of presentation selected.

Further activity

Choose a topic related to the evolution of life on Earth—for example, fossils or dinosaurs. Find one resource produced for young children and another for adults on the same topic and compare the information presented in terms of accuracy, clarity of presentation and level of detail.

INVESTIGATION 3.3

Looking at fossils

Students will: gather first-hand or secondary information to make observations of a range of plant and animal fossils.

Skills and outcomes

P2, P10, P12, P13, P14

Type of activity

First-hand investigation, second-hand data activity

Materials

- fossil specimens including skull(s) and shell(s), a whole frozen fish, petrified wood, any other relevant specimens and photographs
- hand lens or stereoscopic microscope

See:
- First-hand investigations
- Analysing information

Introduction

Most of the information we have about the organisms that have inhabited our planet in the past has come from careful observation and interpretation of fossils. Fossils are found in rocks and are evidence of organisms that lived in the past. Plants, animal and bacteria can all be fossilised. However, fossilisation is not a common event because many factors impact on its occurrence.

A fossil can be formed in several ways:

- preserved remains of an organism, usually bones, shells and teeth (see Figure 3.14)
- an impression left by an organism, preserved in rocks (see Figure 3.15)
- a cast that has resulted from an organism being 'trapped' in rock, much like a mould made from plaster (see Figure 3.16)
- a trace fossil that provides indirect evidence about an organism, including footprints, tracks, burrows and faeces (coprolites) (see Figure 3.17).

Retrieving fossils from rocks is a delicate process undertaken by scientists. However, the information they provide about the organisms that once lived, where they existed and when, is invaluable to our understanding of biological change and evolution (see p. 170).



Figure 3.14 An ancient diprotodon skull.



Figure 3.15 Impressions of leaves were made in this rock, providing information about this ancient plant species.

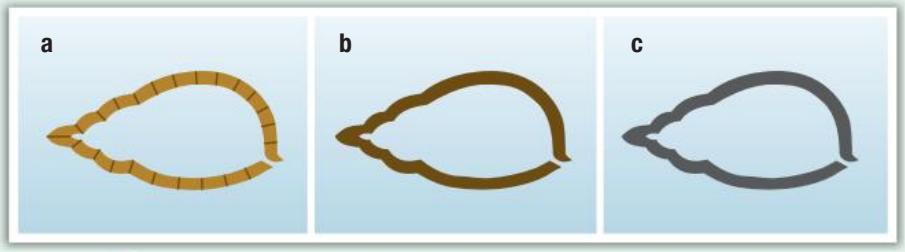


Figure 3.16 How fossils of shelled animals are formed: (a) After death the animal is buried. The openings in the outer shell are filled with sediment. (b) The sediment turns to rock due to the pressure from other layers. Impressions of the inside and outside of the shell are made. If the shell dissolves, a mould will remain. (c) Minerals can fill the gap left by the shell, producing a cast.



Figure 3.17 A dinosaur's footprint from Gantheaurne Point, Broome.

Purpose

To make observations of a variety of fossils and draw conclusions about the nature and usefulness of the information they provide.

Procedure

1 Examine each of the fossils carefully and classify according to type—for example, cast, impression, preserved skeleton.

2 Make a labelled sketch of each fossil. Include information about age, size, shape, colour, texture and how much of the organism is represented by each specimen.

3 Copy Table 3.3 into your workbook and summarise your data using the categories in the table. For the last four columns specify if the fossil enabled you to gather information about each feature.

TABLE 3.3 Summary of fossil observations

Fossil name	Type of fossil	Colour	Size, shape and structure	Diet	Environment where it lived

Discussion

1 What information can be obtained from fossils about organisms that lived in the past? What type of fossil provides the most details about organisms? Suggest a reason why.

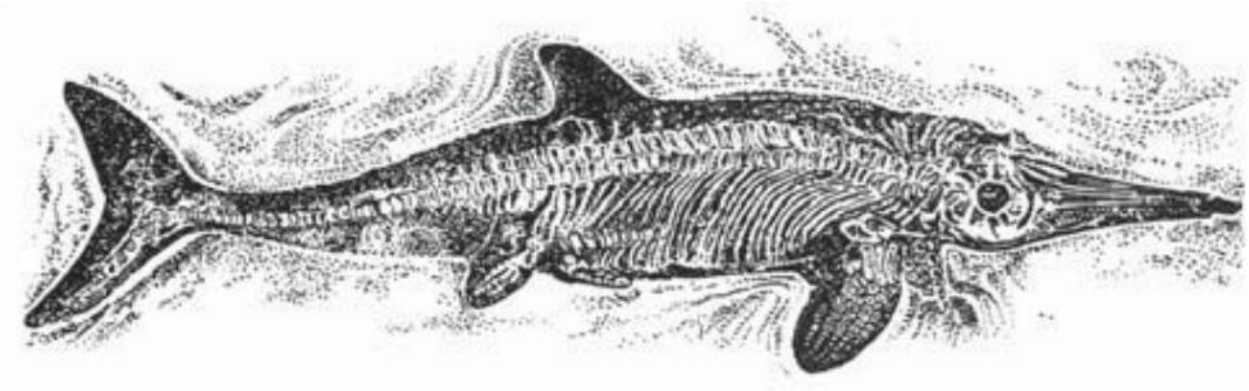


Figure 3.18 A fossilised ichthyosaurus, a transitional marine dinosaur.



Figure 3.19 *Glossopteris* is a fossil plant found in rocks. This specimen is about 200 million years old.

2 Examine Figure 3.18.

3 List any structural features you observe—for example, a streamlined body—and suggest what these indicate about the animal's way of life.

4 Write a brief description of the animal, the environment in which it lived, and its lifestyle. What features of this organism's lifestyle may have contributed to it being fossilised in such a complete form?

5 Examine Figure 3.19.

6 List the structural features of the *Glossopteris* leaf—for example, its shape. Suggest some characteristics and functions of the plant from which this leaf may have come, and the environment in which it lived.

7 How useful is this specimen in determining the size and shape of the whole plant? Explain your answer.

8 Not all organisms will be fossilised. Suggest some modern-day organisms that are unlikely to be fossilised and explain why.

Conclusion

1 Write a brief paragraph or create a web page to summarise the information you have learnt about fossils and their formation from this activity.

2 Explain how the fossil record can assist in understanding biological evolution.

Further activity

Visit the following Internet sites for information about Australian fossils:

- Riversleigh Fossils Centre
- Australian Museum

3.4 INVESTIGATION

Learning about the past

Students will: identify data sources, gather, process, analyse and present information from secondary sources to evaluate the impact of increased understanding of the fossil record on the development of ideas about the history of life on Earth.

Introduction

Major stages in the evolution of life from organic molecules are believed to be the formation of:

- organic molecules
- membranes
- procaryotic cells
- eucaryotic cells
- colonial cells
- multicellular organisms.

See pages 169–172 for further information about these stages.

Multicellular organisms appear in many sizes and shapes. The types and numbers have changed over time. The fossil record is the ever-increasing collection of fossils that are discovered and recorded by scientists worldwide. Examination of the fossil record provides us with evidence to increase our understanding of the history of life on Earth.

Purpose

To investigate the fossil record.

Procedure

1. Identify data sources and research the fossil record, collecting information about the types and appearance of fossils from the Precambrian to the Cainozoic.
2. Choose a fossil that appeared and then disappeared from the fossil record. Research why this may have happened.
3. Research a fossil that had a great impact when it was discovered and find out the reasons for this.
4. Assemble your information into a file in chronological order and use it to answer the following questions.

Discussion

1. When do we believe life on Earth originated? What do we believe was happening in the period between this event and the appearance of the first fossil procaryotic cells?
2. Why is fossil evidence in rocks older than 600 million years scarce compared with the numbers of fossils found in younger rocks?

Skills and outcomes

P10, P12, P14, P15

Type of activity

Second-hand data activity

Materials

- books, journals, Internet sites

See:
- Presenting information
- Analysing information

3 What type of organism is most likely to be fossilised? How has this affected our knowledge of the development of life on Earth?

4 The fossil record extends over millions of years. Looking at the different fossils found over this time, what sort of changes occur?

5 The fossil record gives evidence of the appearance and disappearance of many types of fossil. Give two reasons to account for the disappearance of a fossil species. From your research, give an example of a fossil type that disappeared and explain possible reasons why this happened.

6 The discovery of new fossils can affect our ideas about the evolution of entire groups of organisms. From your research, describe the impact of a fossil discovery that changed our thinking about the history of a plant or animal group.

7 Fossils found in rocks in the Neogene and Quaternary periods are often identical to living species found today. What is the explanation for this?

Conclusion

Evaluate the importance of the fossil record, and how our increased understanding impacts on the development of ideas about the history of life on Earth.

Further investigation

1 a Research one of the following:
   - i stromatolites
   - ii the Ediacaran biota
   - iii the Burgess Shale fossils.

   b Write a brief report or multimedia presentation evaluating the importance of these fossils to our understanding of the origins of life and the processes involved in the evolution of living things.

3.2 UNIT REVIEW

Fossils and the evolution of life

The fossil record provides information about the subsequent evolution of living things.

Summary

- Major stages in the evolution of life on Earth have been identified. Cell formation and the later evolution of autotrophic cells were critical stages. Life evolved from single cells to multicellular organisms.
- Palaeontological (fossil) and geological evidence has been used to construct a timescale for the evolution of living things spanning about 4500 million years.
- The change from an anoxic to an oxic atmosphere on Earth was significant in a number of ways. The formation of the ozone layer protected living things from harmful radiation. Anaerobic organisms declined, and the process of respiration, which uses oxygen directly, provided more energy for living organisms leading to the evolution of larger, more complex organisms.
- Scientific knowledge usually differs from traditional cultural beliefs about the origins of life.

Questions

1 Select the best definition of a fossil from the following statements.

A A fossil is an imprint in a rock that is evidence of past life.

B A fossil is any preserved remains or evidence of past life.

C A fossil is sedimentary rock that contains the remains of a plant or animal.

D A fossil is an extinct or ancient form of past life.

2 Identify two pieces of evidence that support the theory that life existed on Earth 3000 million years ago.

A fossilised procaryotes and cyanobacteria in ancient rocks

B ancient fossils and radiocarbon dating

C the discovery of stromatolites and microfossils

D the study of paleontology and geology

3 Identify the three conditions that are needed for eucaryotic organisms to survive:

A soil, sunlight, chorophyll

B warmth, air, water

C carbon, hydrogen, oxygen

D water, oxygen, protection from UV radiation.

4 Identify the major stages in the evolution of living things, from the formation of organic molecules to multicellular organisms. Next to each stage, write a brief sentence about its significance, giving an example in each case.

5 A newspaper report claims that dinosaur fossils have been found in the red bedrock of a Sydney railway cutting. Write a letter to the editor explaining why this could not be true.

6 Explain what the fossil record tells us about life in the past.

7 a Explain why igneous rock does not contain fossils.

b How is igneous rock important to the interpretation of the fossil record?

8 Investigate some of the different theories that have been suggested to account for the extinction of the dinosaurs. Display your findings in a way suitable for giving a class presentation; for example, overhead transparencies, a computer display such as PowerPoint, or a poster.

9 Explain why the development of photosynthesis was so important for the evolution of living things on Earth.

10 Research the ideas about the origins of life from an ancient culture. Present these ideas as pictures or a story for children.

11 Construct a timeline of the main events during the evolution of life on Earth.

12 a Describe at least two possible environments in which life on Earth may have originated.

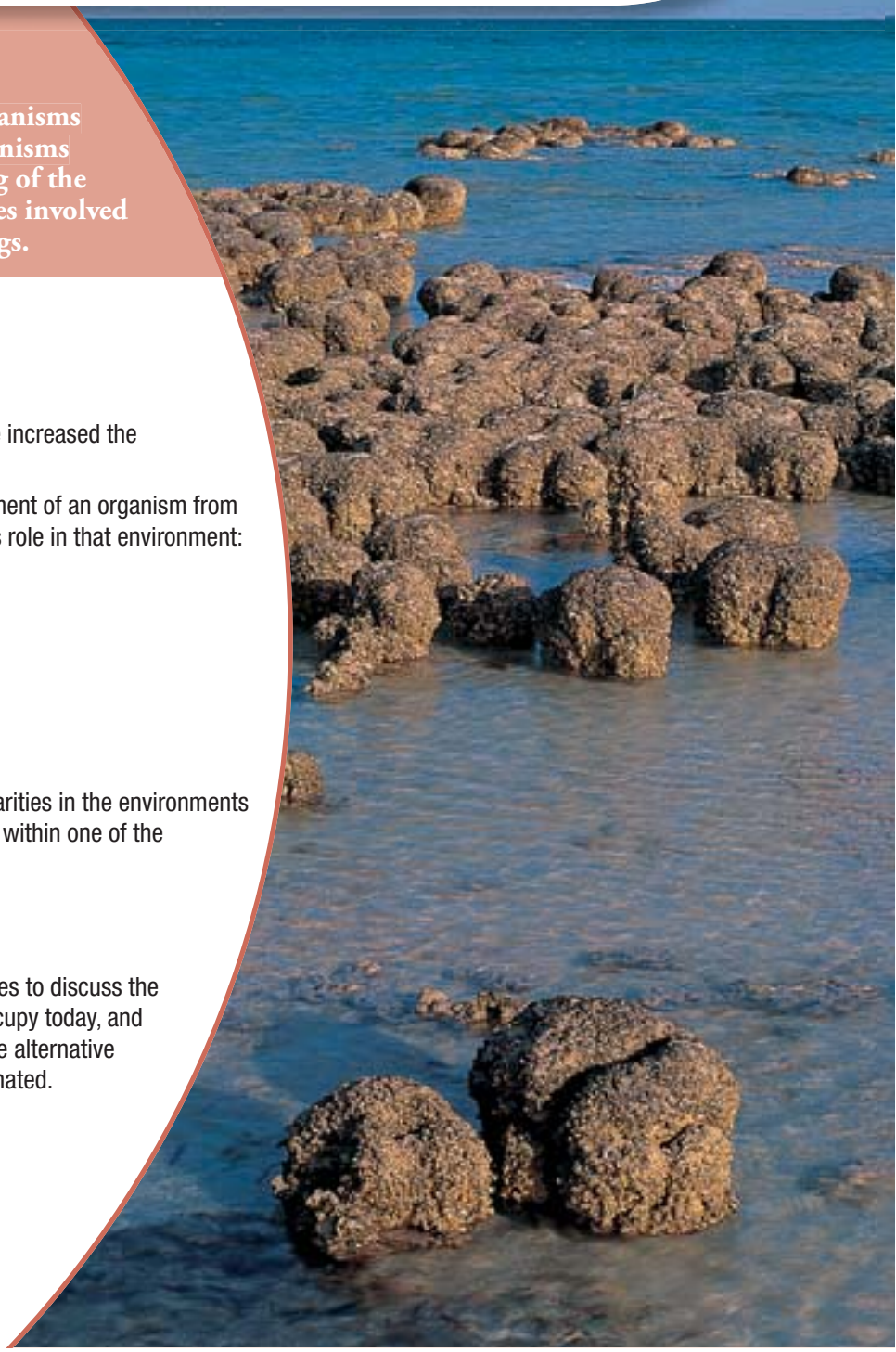
b Select the environment that you think has the most valid evidence to support it and justify your choice.

13 Evaluate the impact of increased understanding of the fossil record on the development of ideas about the history of life on Earth.

3.3

PROCARYOTES: THE FIRST LIVING THINGS

Further developments in our knowledge of present-day organisms and the discovery of new organisms allow for better understanding of the origins of life and the processes involved in the evolution of living things.



STUDENT LEARNING

In this unit students will:

- describe technological advances that have increased the knowledge of procaryotic organisms
- describe the main features of the environment of an organism from one of the following groups and identify its role in that environment:
  - Archaea
  - Bacteria.

STUDENT ACTIVITY

Students will:

- use the available evidence to outline similarities in the environments past and present for a group of organisms within one of the following groups:
  - Archaea
  - Bacteria
- analyse information from secondary sources to discuss the diverse environments that living things occupy today, and use available evidence to describe possible alternative environments in which life may have originated.

describe technological advances that have increased the knowledge of procaryotic organisms

What are procaryotic organisms?

Scientists believe that procaryotic organisms were the first type of cells to evolve about 3050 million years ago, and that for about 550 million years they were the only living things on Earth. Procaryotic cells are still the most abundant life form on Earth and play an important role in all ecosystems.

Technological advances

The electron microscope revealed that cells could be of two types: eucaryotic and procaryotic. Procaryotic cells differ fundamentally in structure from eucaryotic cells (see Table 3.4). Further technological advances in electron microscopy and biochemical analysis have increased our knowledge of procaryotic organisms—their cellular structure and function. In particular, Carl Woese discovered the existence of two fundamentally different types of procaryotes, using the genetic technique of comparative DNA sequencing (see pp. 202–203).

Structure of procaryotic organisms

Procaryotic cells differ fundamentally in structure from **eucaryotic** cells (see Table 3.4).

All procaryotes are independent unicellular organisms, although some may aggregate in colonies or as long filaments. Sometimes this is because the cells secrete a slimy sheath around themselves. Procaryotic cells are small, typically about 1 µm in diameter. They lack a nuclear membrane and membrane-bound internal organelles (see Figure 3.20).

TABLE 3.4 Procaryotic and eucaryotic cells compared

Feature	Procaryotic cells examples: archaea and bacteria	Eucaryotic cells examples: plants, animals and fungi
membrane-bound organelles	absent	present
chromosome	single strand of DNA, often circular	more than one chromosome
nucleolus	absent	present
ribosomes	present but small	present
endoplasmic reticulum	absent	present
microtubules	absent	present
enzymes of respiration	attached in infoldings of cell membrane	attached to internal membranes of mitochondria
photosynthetic pigments	attached in infoldings of cell membrane	attached to internal membranes of chloroplasts (plants only)
cellular nature	unicellular	unicellular or multicellular
cell division	not by mitosis	by mitosis
average cell size	1 µm	10–100 µm

There is a cell envelope consisting of a cell membrane, a cell wall, and in many procaryotes an additional protective layer, known as a capsule. Appendages may be attached to the cell surface. These may be flagella or **pili**. On the cell membrane, which may have some inward folds, are the sites for respiration and photosynthesis. The cytoplasmic region contains a single DNA chromosome, ribosomes and various inclusions (see Figure 3.20). The single chromosome is circular and has no membrane around it. Many procaryotes also have small circular DNA pieces called **plasmids**. Plasmids are self-replicating and are not essential for the survival of the cell. They are often used in genetic engineering experiments.

All multicellular organisms have eucaryotic cells. Eucaryotic cells all have a nuclear membrane and membrane-bound organelles.

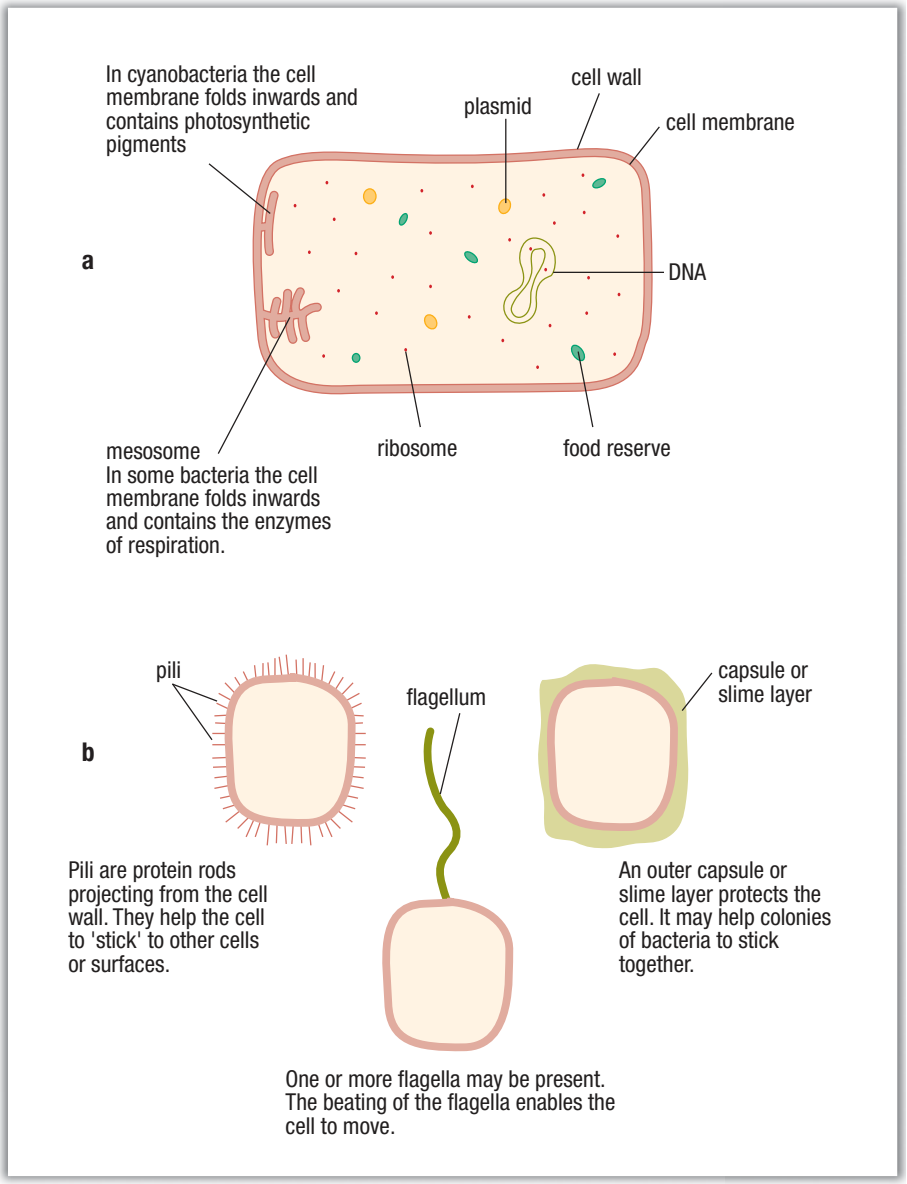


Figure 3.20 The structure of procaryotic cells as revealed by the electron microscope. (a) A generalised diagram of a procaryotic cell. (b) Structures that can be present outside the cell wall of procaryotic cells.

BIOFACT

In the oceans, procaryotes make up 90% of the weight of all marine organisms. On land a single gram of soil may contain 10^9 procaryotic cells. It has been estimated that the biomass of undersea procaryotes, including those found in the rocks beneath the oceans, could be equivalent to all the plants on Earth.

When procaryotic cells reproduce, the DNA strand replicates. Each strand attaches to the cell membrane. The membrane between the two strands elongates and pinches inwards, forming two new cells. There are no microtubules or centromeres present in procaryotic cells, so no spindle is formed, unlike normal mitosis.

Ribosomes in procaryotic cells are smaller than those of eucaryotes. Inclusions are normally food reserves, but may sometimes be collections of pigments or enzymes.

Classification of procaryotes

Procaryotes can be divided into two distinct groups, **Archaea** and **Bacteria**. Table 3.5 lists the differences between them. Note that all these differences are at the molecular level; they are not visible structural differences.

The cell walls of bacteria are made of a unique disaccharide-amino acid complex known as murein.

Archaea are microscopic, single-celled organisms with no membrane-bound organelles

BIOFACT

Extremophiles is the name given to microorganisms that live in extreme environments that would kill other organisms. Most archaea and some bacteria are extremophiles.

Extremophiles are usually classified according to the conditions in which they are found: acidophiles at pH 3, alkaliphiles at pH 9, thermophiles at temperatures between 60 and 120 °C, as well as extremes of cold, dryness, high pressure, or high concentrations of salt, sugar, methane or other toxic materials.

Astrobiologists (see p. 164) believe that the existence of extremophiles on Earth supports the idea that other planets could sustain life forms. Other scientists are researching extremophiles to find uses for them in medicine and industry.

TABLE 3.5 Differences between archaea and bacteria

Feature	Archaea	Bacteria
murein	no murein in cell wall	cell wall composed of murein
lipids in cell membrane	branched	unbranched
RNA synthesis	one large enzyme involved	one small enzyme involved
sensitivity to the antibiotics	not sensitive	sensitive to streptomycin and chloramphenicol

describe the main features of the environment of an organism from one of the following groups and identify its role in that environment:

- Archaea
- Bacteria

Procaryotic organisms

Procaryotic organisms occupy every environment on Earth, including the most extreme ones. They are found in water, whether salt or fresh, hot or cold. They are found on land and in the air. Their major role in ecosystems is to recycle nutrients. Procaryotes are the major contributors to the recycling of the world's oxygen, carbon, nitrogen and sulfur. They may be found in ecosystems as producers, consumers, decomposers, symbionts and parasites.

Archaea

Three major groups of the Archaea are the methanogens, halophiles and thermophiles. They are all found in unusual or extreme environments. They are collectively called **extremophiles**.

Methanogens

Environment

Methanogens are found in bogs and deep soils, in marine and freshwater sediments, in the intestinal tracts of herbivores and in sewage treatment facilities. They are anaerobic and cannot tolerate exposure to oxygen. In a unique process, they use hydrogen (H_2) as an energy source and carbon dioxide (CO_2) as a carbon source

for growth, producing methane gas (CH_4) in the process. Methanogen activity created most of the Earth's natural gas deposits. Cattle have methanogens in their stomach and belch about 50 litres of methane a day when chewing the cud.

Role in ecosystem

Methanogens play a role in the recycling of carbon and are important decomposers. The methane they release into the atmosphere contributes to the carbon cycle. Where methanogens are found in symbiotic relationships, such as in the gut of cattle or termites, their role is to assist the breakdown of cellulose and thus aid digestion for their hosts. There has been a large rise in the amount of methane in the Earth's atmosphere in recent years, mainly because of the increase in domestic cattle kept for human consumption.

Halophiles

Environment

Halophiles are found in environments where the salt concentration is very high, such as the Dead Sea in the Middle East, the Great Salt Lake in the USA, and evaporating ponds of saline water. They are all aerobic.

Halophiles are aerobic organisms, but they also have another system of producing energy. Their red colour is caused by a unique pigment called bacteriorhodopsin, which enables them to photosynthesise and produce energy without using oxygen.

Role in ecosystem

In their ecosystem, halophiles are part of the food chain and are consumed by filter feeders. Very little is known about their role in ecosystems, and further research is needed.

Thermophiles

Environment

Thermophiles require high temperatures for growth (60–120°C). They are found in areas of volcanic activity such as hot springs, geysers, and hydrothermal vents and cracks in the ocean floor. The thermophiles that live in the hydrothermal vents in the depths of the ocean are sometimes called deep-sea bacteria. Thermophiles use sulfur as an energy source.

Role in ecosystem

The deep-sea sulfur-oxidising bacteria in hydrothermal vents are the primary producers (chemoautotrophs) in the deep-sea food web and support an amazing community of organisms. While the bacteria may form large mats on the sea floor, and some organisms feed on them directly, other vent organisms have developed a symbiotic relationship with the bacteria. The organism provides the shelter and the bacteria provide the nutrients.

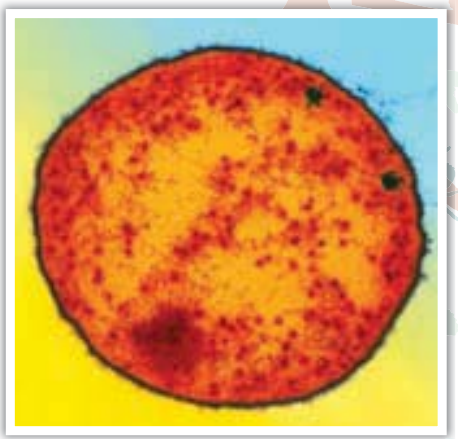


Figure 3.21 Photomicrograph of *Methanococcoides burtonii*, a methanogen species.

BIOFACT

Deep-sea hydrothermal vents occur along mid-ocean ridges. Hot, mineral-rich water flows out from rocks and cracks in the ocean floor. The minerals are precipitated on contact with the cold ocean water, forming large deposits. The mounds formed are rich in minerals such as sulfides, lead, copper, cobalt and zinc. Chimney-like structures called 'black smokers' are created when sulfide minerals crystallise from the hot water. The crystals form hollow chimneys through which hot water continues to flow. When the hot water flowing out mixes with the cold ocean water, the minerals are precipitated as tiny particles that make the water appear black and give black smokers their name.

BIOFACT

The giant tube worm *Riftia pachyptila*, which lives in hydrothermal vents, can grow to over a metre in length and has no mouth, gut or anus. It obtains all its nutrition from sulfur bacteria that live inside it in a special organ called a trophosome.

Bacteria

Environment

Bacteria (Figures 3.22, 3.23) are found everywhere: in soil, water, air, decaying organic material and inside other living organisms. With fungi they play an important role as decomposers of organic matter for recycling in nature. While most bacteria are harmless, some may cause disease in other organisms. Human diseases caused by bacteria include cholera, typhoid, tuberculosis and boils.

Bacteria can be classified into a number of different groups, including green bacteria, purple bacteria, spirochaetes, Gram-positive bacteria and cyanobacteria.

Role in ecosystem

As decomposers, soil bacteria secrete enzymes on dead organic material. Once material is broken down to simpler compounds, the bacteria absorb those they require. Decomposers play a large role in maintaining soil fertility.

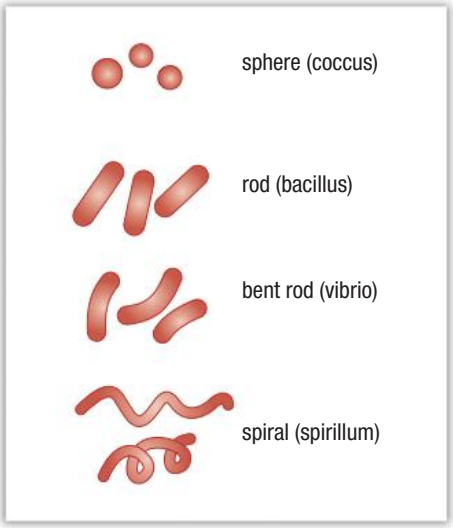


Figure 3.22 Some common shapes of bacteria.

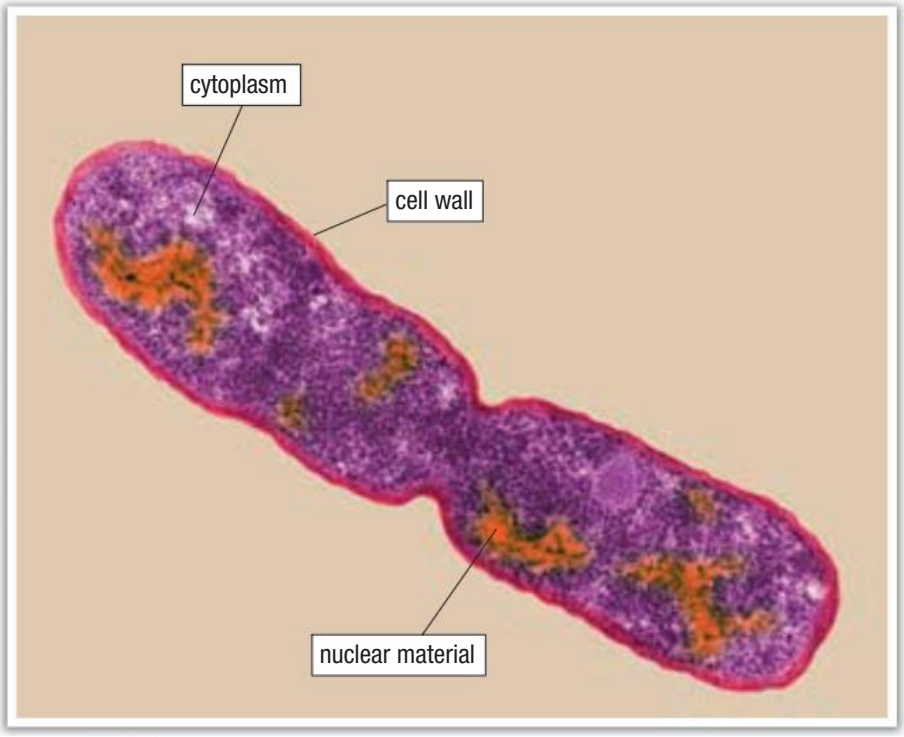


Figure 3.23 This is the bacterium *Escherichia coli* (*E. coli*), which is naturally present in the human intestine. An unusually high level of this bacterium in water may be an indication of faecal contamination. The photograph shows the bacterium magnified about 32 000 times its normal size.

Cyanobacteria

Environment

Cyanobacteria (Figures 3.24, 3.25) were once called blue–green algae and classified with the simple algae. Recent studies have found that they are more closely related to bacteria. All cyanobacteria contain a blue pigment called phycocyanin, from which they derive their name. They occur naturally in wet or damp situations: ponds, streams, wet rocks and soil. They flourish in warm conditions, particularly where the water contains dissolved organic material. Like bacteria, they are small. Many form individual filaments, while others form slimy masses. Some cyanobacteria produce toxins, and can reproduce so rapidly that they form a vast, slimy mat (a 'bloom') that poisons the water in lakes and slow-flowing streams.

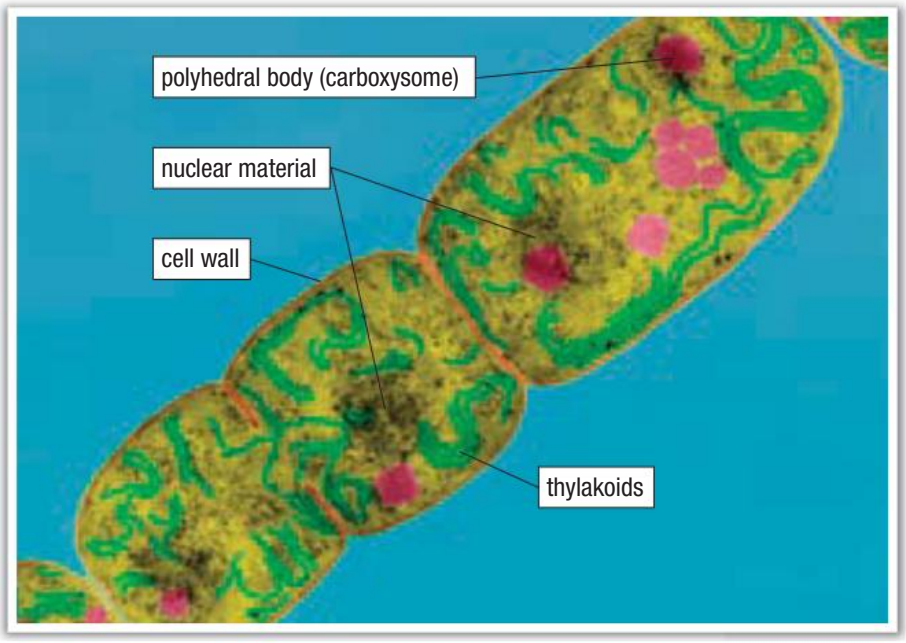


Figure 3.24 Cyanobacteria flourish in water containing high levels of dissolved nutrients. This cyanobacterium is from the genus *Nostoc*, magnified about 30 000 times its normal size.

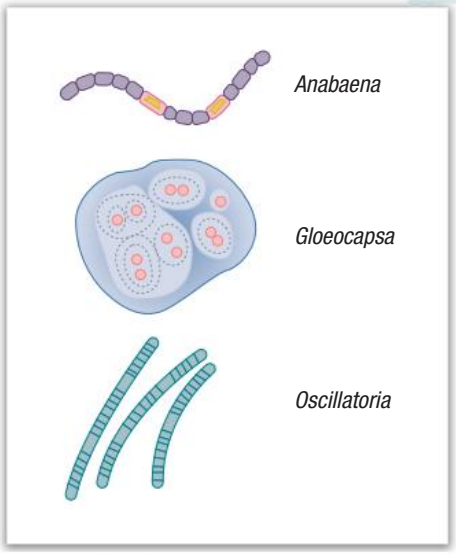


Figure 3.25 Some common shapes of cyanobacteria.

Role in ecosystem

Cyanobacteria are photosynthetic organisms. They are primary producers at the base of the food chain within their ecosystem. Cyanobacteria in the Earth's oceans generate large quantities of oxygen, and they are sometimes called the 'grass of the sea' because of their role as primary producers. Some cyanobacteria also fix nitrogen from the air (see p. 194).

Stromatolites are structures made by communities of cyanobacteria, first discovered as fossils more than 3000 million years old (see p. 171). Their abundance and carbon-fixation ability in photosynthesis over millions of years contributed to the reduction in carbon dioxide and increase in free oxygen in the Earth's atmosphere.



Figure 3.26 The black bands on the sandstone beehive domes of the Bungle Bungle ranges in Western Australia are a coating, only a few millimetres thick, of cyanobacteria. Forming colonies of several types of cyanobacteria, they are a dull grey and dormant in the dry season, and become shiny dark green to black and active during the wet season. Their presence helps protect the sandstone from erosion.

Nitrogen-fixing bacteria

Environment

Most nitrogen-fixing bacteria occur in the soil. They may be aerobic or anaerobic, free-living or symbiotic. Symbiotic nitrogen-fixing bacteria occur in nodules on the root systems of many plants, for example, legumes, she-oaks and acacias.

Role in ecosystem

Nitrogen-fixing bacteria play an important role in the nitrogen cycle, and their activity is the only way that atmospheric nitrogen is made available for use by living things. **Nitrogen fixation** is the transformation of nitrogen from the air to ammonia. After being fixed, the nitrogen is then incorporated into organic compounds such as proteins and nucleic acids in microorganisms and plants, and from there through the food chain to animals.

Nitrogen-fixing bacteria, often found in a symbiotic relationship in plant roots, take nitrogen from the air and convert it into more complex compounds such as nitrates which can be used by plants. This allows the plants to grow in nutrient-poor soils.

BIOFACT

About 90% of the nitrogen that enters the biosphere comes from nitrogen fixation by procaryotes. The remaining 10% comes from the combustion of fossil fuels and from lightning strikes.



Figure 3.27 Root nodules (arrowed) on legumes contain *Rhizobium* bacteria, which fix nitrogen. The nitrogen is taken up by the host plant, and any excess is released into the soil.

3.5 INVESTIGATION

Procaryotic environments

Students will: use the available evidence to outline similarities in the environments past and present for a group of organisms within one of the following:

- Archaea
- Bacteria.

Introduction

Procaryotes are the most abundant life form on Earth, existing in all environments and playing vital roles in all ecosystems. Procaryotes are believed to be the earliest forms of life—they created the oxygen-rich atmosphere we now have, and gave rise to the range of life that now exists. By studying the past and present environments of procaryotes and their role in ecosystems, we can trace the patterns of evolution of life.

Archaea inhabit some of the most extreme environments, including hot springs, deep sea vents, or very alkaline, acidic or saline waters. Archaeans are not restricted to extreme environments and are also abundant as plankton in the oceans.

Bacteria are found in soil, water, air, decaying organic material and inside other living organisms.

Purpose

To investigate the past and present environments occupied by a named group within either Archaea or Bacteria.

Procedure

1 Select the group of organisms you want to investigate.

2 Identify data sources and gather information about your chosen group. In addition to features of the group, also find out about its present day environment and any information about its existence in the past.

Conclusion

1 Summarise your information onto one page under the following headings:
- Name of group
- Features of the group
- Present-day environment (that is, where they are found today)
- Past environment (indicate what conditions were like on Earth when this group first evolved).

Space permitting, give named examples, diagrams or photos, and any other interesting facts you have discovered.

2 Present your information to other class members. You could create a multimedia presentation.

Skills and outcomes

P7, P8, P13, P14, P15

Type of activity

Second-hand data activity

Materials

- books, journals, Internet sites

See:
- Presenting information
- Analysing information

INVESTIGATION 3.6

Environments of living things—past and present

Students will: analyse information from secondary sources to discuss the diverse environments that living things occupy today, and use available evidence to describe possible alternative environments in which life may have originated.

Skills and outcomes

P8, P10, P14

Type of activity

Second-hand data activity

Materials

- books, journals, Internet sites

See Analysing information

Introduction

Living things occupy a wide variety of environments. These environments each have different characteristics and support different forms of life. Are any of the environments on Earth today similar to those where life first originated?

Purpose

1 To identify the diverse environments occupied by living organisms today.
2 To discuss possible alternative environments in which life may have originated.

Procedure

1 Read pages 5–6 to revise different ecosystems and their features.
2 Read pages 160 and 163 to revise what we believe conditions may have been like on the early Earth and the origins of life.
3 Read pages 190–191 to revise the environments occupied today by halophiles, thermophiles and methanogens.
4 Identify data sources and research extremophiles, collecting information about extreme environments and the organisms found there.

Discussion

1 Procaryotic organisms are found in all environments on Earth today. In some extreme environments they are the only life forms present. Name three extreme environments and explain why they are called 'extreme'.
2 Scientists believe life originated in an aquatic environment. What evidence is there for this?
3 The formation of photosynthetic organisms dramatically changed the environment of the Earth and led to the decline of anaerobic organisms.
   a What environmental change did photosynthesis bring?
   b List the environments where anaerobic organisms are found today.
4 What do we believe the environment was like on the early Earth?
5 In which of the environments on Earth today could life have originated? Give reasons for your answers.

3.3 UNIT REVIEW

Procaryotes: the first living things

Further developments in our knowledge of present-day organisms and the discovery of new organisms allows for better understanding of the origins of life and the processes involved in the evolution of living things.

Summary

- Technological advances in the development of microscopy, particularly the development of the electron microscope, have increased our knowledge of procaryotic organisms.
- Different types of procaryotes, such as archaea, bacteria and cyanobacteria, have highly specific roles in the varying environments they occupy. For example, the role of a cyanobacterium is as a producer in any ecosystem in which it is found.

Questions

1 Which statement identifies a main difference between procaryotic and eucaryotic cells?

A Eucaryotic cells have DNA, procaryotic cells have RNA.

B Eucaryotic cells are never unicellular, procaryotic cells always are.

C Procaryotic cells have no internal membranes, eucaryotic cells always do.

D Procaryotic cells are always autotrophic, eurocaryotic cells can be autotrophic or heterotrophic.

2 What is a plasmid?

A A common unicellular procaryotic cell.

B A pigment attached to the infoldings of a procaryotic cell membrane.

C A primitive bacterium, possibly the earliest form of life on Earth.

D A small, circular piece of DNA within a procaryotic cell.

3 Identify the two groups into which procaryotes are divided:

A Archaea and Bacteria

B Unicellular and Multicellular

C Plasmids and Archaea

D Halophiles and Thermophiles

4 Explain how the following things have increased our knowledge and understanding of procaryotic organisms:

a the electron microscope

b advances in molecular biology.

5 Describe the distinguishing features for each group of procaryotes.

6 For any one named type of procaryotic organism:
   a describe the main features of its environment
   b identify the role of this organism in its ecosystem.

7 a Nitrogen is abundant in the atmosphere as a gas (N_2), but plants and animals cannot use it in this form.
      i Why is nitrogen an important nutrient for plants and animals?
      ii Explain how plants obtain nitrogen.
      iii How do animals obtain nitrogen?
   b How are legumes such as peas, beans and lentils different from other plants?
   c Legumes are beneficial plants to grow in domestic vegetable gardens and in larger quantities on farms. Explain the benefits offered by growing legumes.

8 Outline similarities in the environments past and present for a group of either archaea or bacteria.

9 Stromatolites that exist today are also represented by fossil remains that date back more than 3000 million years.
   a What kind of organism is a stromatolite?
   b Explain how stromatolites contributed to changes in environmental conditions over millions of years.

10 List five different environments in which life is found today, and give an example of a group of procaryotic organisms that live there.

11 In 2008, fossils of anaerobic bacteria were found in petroleum samples taken from deep underground deposits in three separate continents and were dated as being 145 million years old.
   a Explain whether you would class these bacteria as extremophiles.
   b Propose a hypothesis about the origin of life on Earth and the evolution of living things that is valid from these finds, and explain your reasoning.

3.4 TAXONOMY: CLASSIFYING ORGANISMS



The study of present-day organisms increases our understanding of past organisms and environments.

STUDENT LEARNING

In this unit students will:

- explain the need for scientists to classify organisms
- describe the selection criteria used in different classification systems and discuss the advantages and disadvantages of each system
- explain how levels of organisation in a hierarchical system assist classification
- discuss, using examples, the impact of changes in technology on the development and revision of biological classification systems
- describe the main features of the binomial system in naming organisms and relate these to the concepts of genus and species
- identify and discuss the difficulties experienced in classifying extinct organisms
- explain how classification of organisms can assist in developing an understanding of present and past life on Earth.

STUDENT ACTIVITY

Students will:

- perform a first-hand investigation and gather information to construct and use simple dichotomous keys, and show how they can be used to identify a range of plants and animals using live and preserved specimens, photographs or diagrams of plants and animals.

explain the need for scientists to classify organisms

BIOFACT

Most taxonomists work in herbaria, botanic gardens, museums or universities. The results of their work are usually published in scientific journals. When a taxonomist publishes new ideas about the classification of organisms, other taxonomists may decide to accept or reject the ideas. Sometimes a new idea takes many years to become accepted.

describe the selection criteria used in different classification systems and discuss the advantages and disadvantages of each system

BIOFACT

Australia's Virtual Herbarium is an online botanical information resource. It provides access to and information about all the plant specimens that have been classified in Australia.

The Atlas of Living Australia is a five year project (2008–2013) to put together an online, freely accessible database of information on every species in Australia. Each entry, together with images and maps, will include a species' identity, description, genome, habitat, distribution and ecological relationships.

The Encyclopedia of Life is a project that commenced in the USA in 2007. It aims to document all species of life on Earth and to make this information freely accessible online.

Why classify?

About 1.7 million different types of living things on Earth have been found and described in detail. Each year this number increases. In order to make the study of this enormous diversity of life easier, biologists group together organisms that have similar characteristics. The way that the organisms are grouped is called a **classification** system.

Classification systems help biologists to understand the relationships between organisms, and to talk to other biologists about organisms without having to describe the organisms in detail (see p. 209).

The science of identifying, classifying and naming organisms is known as **taxonomy**. The science of studying the relationships between organisms is known as **systematics**. Together, this work has resulted in classification systems that aim to reflect our current knowledge of the world of living things. To cope with the huge and increasing volume of knowledge, biologists are continually devising and changing classification schemes. Classification systems are considered to be arbitrary (uncertain) because each one reflects the views of the biologist who devised it. Although most biologists use an internationally agreed classification system, there are many variations, and the system is always changing to allow for new knowledge about organisms and the relationships between them.

Features used to classify organisms

In any system of classification, organisms need to be studied closely. Organisms may differ in the following ways: anatomy (structure), physiology (functioning), behaviour (doing) and biochemistry (molecular activity). At the genetic level, there may be differences in chromosome number and structure. While all of these criteria can be used, the most practical one for use in the field is anatomical structure.

Structure is easily observed in an organism, whether it is living or dead, or found as a fossil. Structure is more constant in an organism's lifetime than other features that may change seasonally or with maturity. The classification of animals is based mainly on structure, and the classification of plants is based on both structure and means of reproduction. The means of reproduction, however, can usually be inferred from the structures present. Increasingly, molecular structure—similarities in DNA and proteins—is being used by scientists to help classify organisms (see pp. 202–203).

Classification systems

There have been many ways that living things have been classified at the kingdom level, the first step in classification (Table 3.6). In 1735 Carolus Linnaeus first divided the world into animal, vegetable and mineral kingdoms, in the first edition of his great work *Systema Naturae*. The French preferred their own classification systems, which were developed later by Georges Cuvier (for animals) and Antoine-Laurent de Jussieu (for plants). In 1866 a German biologist, Ernst Haeckel, created a kingdom for all microscopic unicellular organisms, which he called Protista.

The development of the electron microscope in the 1950s revealed procaryotic cells. These were placed in a separate kingdom, the Monera. In 1967, R. H. Whittaker's classification system identified the Fungi as a separate multicellular eucaryotic kingdom. In 1977, Carl Woese discovered a further fundamental

division within the Monera, which became divided into the Archaea and Bacteria. Some scientists consider these to be separate kingdoms.

TABLE 3.5 Living things can be classified into up to six different groups at the kingdom level

2 kingdoms	plants, animals
3 kingdoms	protists, plants, animals
4 kingdoms	monera, protists, plants, animals
5 kingdoms	fungi, monera, protists, plants, animals
6 kingdoms	fungi, archaea, bacteria, protists, plants, animals

The following is the most common classification system, which recognises five kingdoms:

Plants (kingdom Plantae) are those organisms which contain chlorophyll and make their own food. Their cells are eucaryotic and are surrounded by a cellulose cell wall.

Animals (kingdom Animalia) are those organisms which do not contain chlorophyll and cannot make their own food. Their cells are eucaryotic and have no cell wall. Animals can be unicellular or multicellular.

Protists (kingdom Protista) are single-celled organisms whose cells are eucaryotic; for example, **protozoans** and some algae.

Monera (kingdom Monera) are single-celled organisms whose cells are procaryotic, for example, archaea and bacteria.

Fungi (kingdom Fungi) are organisms which do not contain chlorophyll, but their cells are eucaryotic and surrounded by a cellulose cell wall. Some fungi are unicellular (yeasts), while others appear to be multicellular.

All systems of classification have advantages and disadvantages. Because they are human constructs (that is, they are made up by people), the features selected to separate organisms into groups may lead to difficulties in classifying some organisms.

Fungi are a problem for taxonomists. Should they be classified as plants or protists, or put in a group by themselves? Depending on the criteria used, algae may be classified as protist or as plant. Lichens consist of a fungus and an alga: which group should they belong to? Is it best to classify organisms at the cellular level?

The five kingdoms model recognises two major cellular structural divisions within living things—procaryotes and **eucaryotes**. Procaryotes are now identified as two structurally different groups—the Bacteria and Archaea. American scientist Carl Woese has subsequently proposed a scheme of classification at the cellular level. He has divided living things into three domains: Bacteria, Archaea and Eucaryotes (see Figure 3.29). This classification system is now widely accepted by scientists.

Viruses and prions (see *Heinemann Biology Third Edition HSC*, Chapter 3) still remain outside any of these classification schemes. There is plenty of opportunity left for classification schemes to be further revised!

Figure 3.29 Classification into three domains.

BIOFACT

Until the 19th century, Latin was the universal language of science, so most scientists gave themselves Latin names. Linnaeus published his work under the name of Carolus Linnaeus. His real name was Carl von Linné.

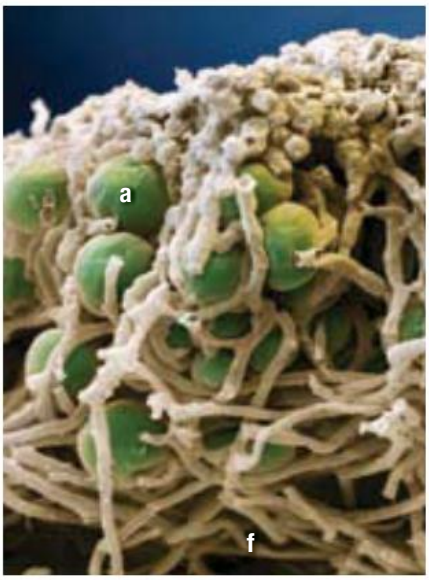
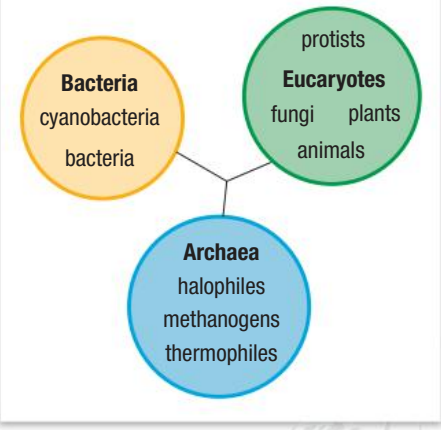


Figure 3.28 Although lichens are a symbiosis between fungi and algae, they are currently classified in the kingdom Fungi, according to their fungal symbiont. This cross-section of a lichen thallus shows the layer of darker, green algae (a) above an open network of fungal hyphae (f).



explain how levels of organisation in a hierarchical system assist classification

Levels of organisation

Classification systems use a hierarchical system in which organisms are placed into groups, at different levels, according to the features they share. A branching pattern or 'tree' emerges which assists us to see the relationships between organisms. Figure 3.29 shows the hierarchical system used for both plants and animals. Organisms become more similar as we move through the levels from kingdoms to species.

KINGDOM	PHYLUM	CLASS	ORDER	FAMILY	GENUS	SPECIES
King	Phil	Classed	Ordinary	Families as	Generous and	Special

Figure 3.30 The classification hierarchy developed by Linnaeus, which is still used today. 'King Phil' will help you remember the order of the different classification levels.

BIOFACT

Mammoths were the first extinct animals to have their genome sequenced in 2008. The DNA was extracted from the hair of mammoths frozen in permafrost. Genetic analysis revealed that mammoths split into two distinct populations 2 million years ago. One group became extinct 45 000 years ago, the other group only 10 000 years ago.



Figure 3.31 The genome of the wooly mammoth was sequenced in 2008.

Modern tools for classifying organisms

The science of taxonomy became more precise when evolution and the theory of natural selection were explained. Organisms that have a common ancestor are thought to be related, so they are grouped together.

The fossil record and homologous structures have been used traditionally by taxonomists as evidence for classification. But fossils and homologous structures can sometimes be misleading or inconclusive, and the presence of structures with a similar function can result from convergent evolution (see *Heinemann Biology HSC,* Chapter 2), instead of ancestral relationships. Over time, other evidence has come to be used.

Embryonic development

As microscopes were improved, taxonomists began to use the new information they provided to identify relationships among organisms. For example, comparative embryology has revealed that the major group to which vertebrates, including humans, belong is closely related to the group that includes the starfish and its relatives.

Classifying by molecular structure

Today, studies at the molecular level play a large part in determining evolutionary relationships. Analyses of proteins and DNA can reveal relationships that could not be determined in any other way. Organisms that have many proteins or bases in common are closely related.

Gene sequencing

The technique of gene sequencing and then comparing similar sequences of DNA between different organisms has led to continued revisions of traditional classification groupings. In 1998 an international group of botanists published a new classification for the families of flowering plants. It

used not only the traditional structural appearance of plants but also results from gene sequencing. Plants were grouped according to similarities in the analysis of the detailed structure of their DNA. The results suggested some evolutionary relationships not previously realised. For example, the Australian family Proteaceae, which includes banksias, grevilleas and waratahs, was shown to be related to the northern hemisphere family Platanaceae, the plane trees.

Using mitochondrial DNA

DNA does not only reveal close evolutionary relationships. It can also be used to determine when two related organisms began to evolve from a common ancestor. For example, scientists believe that mitochondrial DNA mutates at predictable rates, so it is like a molecular clock that can be used to date evolutionary events. By comparing the differences in the base sequences of DNA and using the predicted mutation rates, it is possible to determine the time over which two types of organisms have been diverging. For example, this sort of analysis indicates that chimpanzees and humans began to evolve from a common ancestor about 5 million years ago.

Whole genome analysis

An organism's **genome** is all the genetic information or DNA that it contains. The ability to sequence whole genomes is allowing new connections to be made in many areas of biology, including taxonomy.

In 2000 the Human Genome Project analysed the human genome. This was followed by the first plant genome, a small flowering plant known as *Arabidopsa thaliana*. Many other organisms have subsequently had their genomes analysed. In 2008, an analysis of the platypus genome confirmed it had features that were part bird, part reptile and part mammal. In 2007, analysis of the flooded gum tree *Eucalyptus grandis* commenced and is due to be released in 2010.

Advances through new technology

Biological classification systems are continually revised because of the impact of technology. The development of the light microscope first revealed that living things were made up of cells. Improved light microscopes and then the electron microscope revealed more and more levels of detail of their internal structure. This knowledge expanded the number of kingdoms of living things from two to five.

Advances in molecular biology and biochemistry are causing further revisions. For example, Woese's discovery of two major groups within the Monera was based largely on differences at the molecular level, not on anatomical structure.

Recent advances in molecular techniques, such as comparing the sequences of amino acids in proteins or the sequencing of DNA bases along short lengths of chromosomes (genes) from related organisms, and whole genome analysis, have considerably added to our knowledge of evolutionary relationships between organisms. This knowledge has enabled taxonomists to continually change and refine the existing classification system. Computer-assisted statistical analyses and predictions further add new ideas. Gene frequency studies and mitochondrial DNA studies help to create '**gene trees**' to describe relationships between organisms.



Figure 3.32 The Tammar wallaby genome was mapped in 2008.

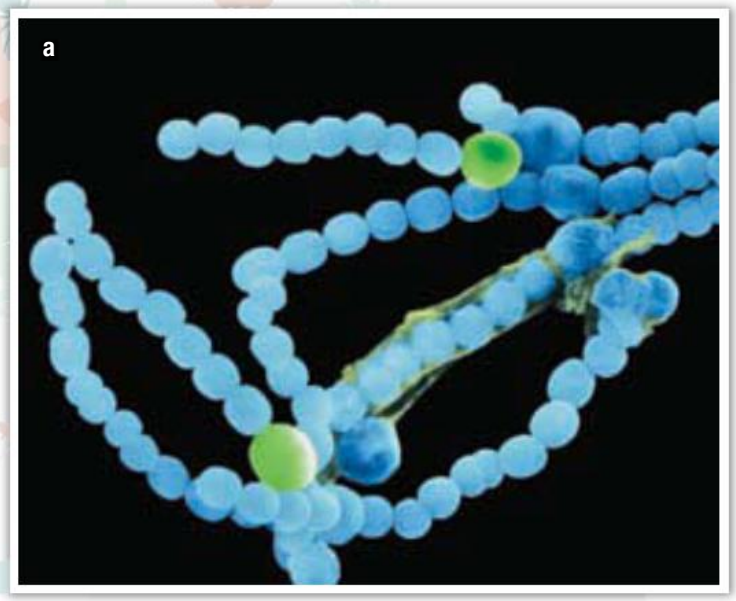
A genome is all the genetic information (DNA) possessed by an organism.

A gene tree is a branching diagram that shows relationships between groups of genes. This can suggest relationships between different groups of organisms.

discuss, using examples, the impact of changes in technology on the development and revision of biological classification systems

BIOFACT

Similar sequences of amino acids are evidence of a common ancestry. One technique compares a protein called cytochrome C that is present in the mitochondria of almost all organisms. The amino acid sequences of this protein in humans and chimpanzees are identical for all 104 positions. Human cytochrome C differs from that of dogs by 13 amino acid sequences.



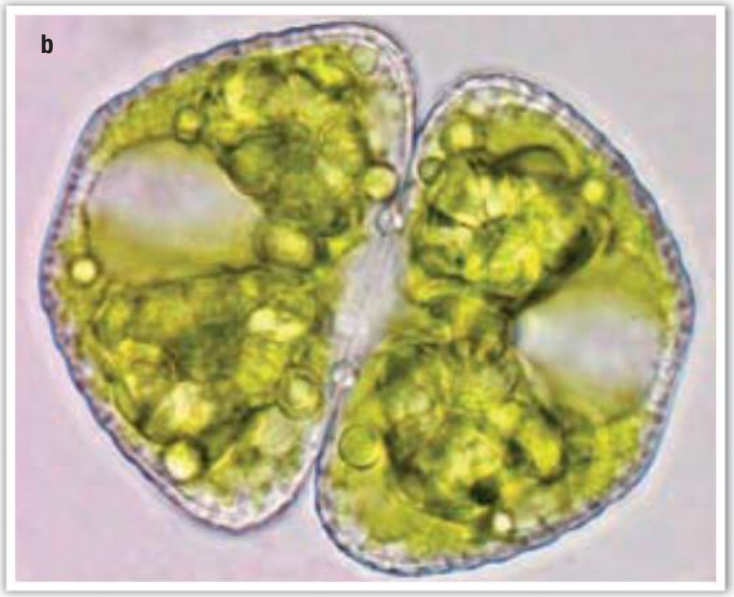


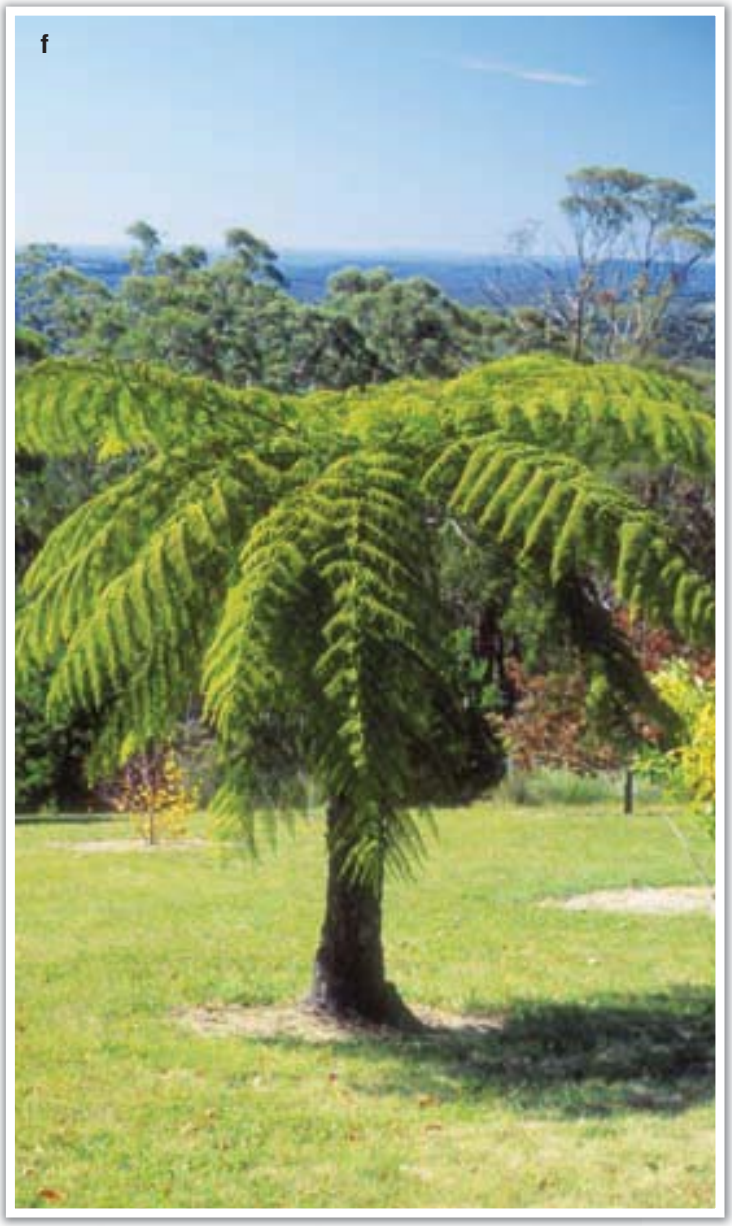






Figure 3.33 Examples of organisms from the five kingdoms. (photos not to scale).

(a) Monera: *Anabaena*, a cyanobacterium.
(b) Protista: a desmid alga, *Cosmarium* sp.
(c) Fungi: red star fungus, *Aseroe rubra*.
(d) Plantae: a moss, *Rosulabryum billardierei*.
(e) Fungi: a lichen, *Hypogymnia subphysodes*.
(f) Plantae: rough tree-fern, *Cyathea australis*.
(g) Plantae: mountain gentian, *Chionogentias muelleriana*.
(h) Plantae: drooping she-oak, *Allocasuarina verticillata*.
(i) Animalia: marbled gecko, *Phyllodactylus marmoratus*.
(j) Animalia: eustheniid stonefly, *Eusthenia venosa*.


f


g


h


i


j



Figure 3.34 These two species grow in vastly different places, but are closely related. (a) Common heath (*Epacris impressa*) from south-eastern Australia. (b) A rhododendron (*Rhododendron fragrantissimum*) from central Asia.

The binomial system of nomenclature

describe the main features of the binomial system in naming organisms and relate these to the concepts of genus and species

Although many organisms have 'common' names, like Australian magpie and great white shark, these names vary greatly from place to place. Sometimes one animal can have several different common names, such as the striated fieldwren, which is also called the cocktail, fieldlark, reedlark and sandplain-wren. Sometimes one common name can be used for several animals, such as the name swamp gum, which is used in Tasmania for one eucalypt, but in Victoria for another eucalypt. To overcome this problem, scientists use a **binomial system** to give every type of organism only one name, which is called the scientific name. This system was developed by Linnaeus in the 18th century, but has been extended by many other people since. Linnaeus used Latin because it was the language of European academics.

A binomial name consists of two words. The first is the genus name, and the second is the species name.

In the binomial system of classification, an organism is given a name consisting of two words. The first word has a capital letter and represents the genus to which the organism belongs. The second word represents the species within the genus to which the organism belongs. Both words are always printed in italics.

The species is the basic group in classification. All organisms in a species closely resemble one another, although there are usually differences between individuals. They can interbreed and produce fertile offspring.

The animal shown in Figure 3.35a is *Petauroides volans*. The genus name *Petauroides* comes from the Greek word for a rope-dancer or tightrope walker, *petaurista*. The species name *volans* means 'flying' in Latin. This is the greater glider, a very agile flying mammal of wet forests in south-eastern Australia.

Many organisms are named after the person who first discovered them. The plant shown in Figure 3.35b is *Banksia coccinea*. The genus name *Banksia* tells us it was named after Joseph Banks, a famous botanist who came to Australia with James Cook on board the *Endeavour*. The species name *coccinea* is Latin for scarlet, referring to the brilliant colour of the flowers.

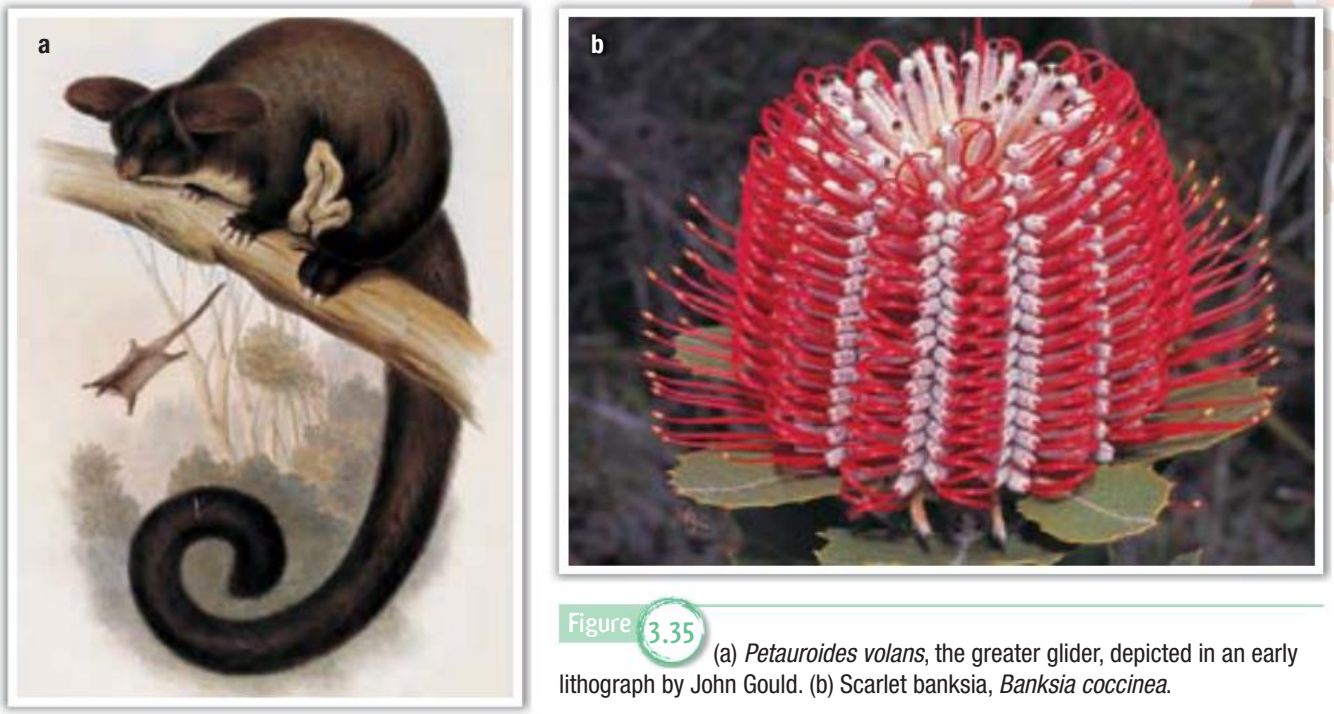


Figure 3.35 (a) *Petauroides volans*, the greater glider, depicted in an early lithograph by John Gould. (b) Scarlet banksia, *Banksia coccinea*.

Keys

Names and descriptions of all known living organisms can be found in reference books, scientific journals and in the collections of various scientific institutions. Searching through such a vast literature in order to identify an unknown specimen is slow and tedious. To make identification easier, keys have been developed. The most common type of key contains pairs of alternative descriptions of an unknown organism. This is called a dichotomous key. By observing the organism and deciding which descriptions are the most appropriate, you can work through the key and establish the organism's identity.

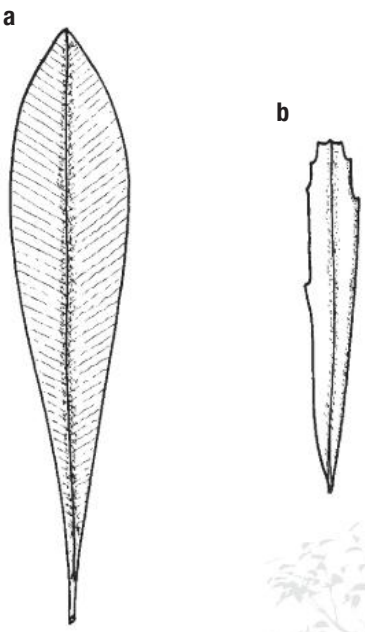
BIOFACT

A practical application of the need to classify organisms is the identification of pests, pathogens (disease causing organisms) and weeds in order to control invasive species affecting health, agriculture, fisheries and forestry.

Using a key

Use the following key to identify the two adult *Banksia* leaves pictured on this page. By answering the questions correctly, and following the directions to the next question in sequence (the numbers on the right refer to the numbered questions on the left), an unknown individual object or specimen can be identified. The answers are at the bottom of page 209.

1a	Leaves small and narrow, 1–1.5 cm long	*Banksia ericifolia*
1b	Leaves 2–16 cm long	2
2a	Leaves 2–10 cm long, margins smooth or irregularly toothed	3
2b	Leaves 8–16 cm long, margins distinctly and evenly toothed	*Banksia serrata*
3a	Leaves less than 1 cm wide	*Banksia marginata*
3b	Leaves generally 1–2 cm wide	4
4a	Adult leaves with smooth margins, juvenile leaves toothed	*Banksia integrifolia*
4b	Leaves irregularly toothed; young shoots with covering of rusty hairs	*Banksia asplenifolia*



identify and discuss the difficulties experienced in classifying extinct organisms

Classifying extinct organisms

Fossil remains of organisms may be difficult to classify. The fossil evidence may be *incomplete* or may *not show enough detail* of the organism's structure for classification purposes. If the organism has been extinct for a long period of time, there may be no similar type of living organisms with which to compare it.

The rules for naming organisms allow scientists to name fossils even if they have only a part of the organism. This enables every fossil to be given a name, but it also means that one organism might end up with two or more scientific names. In that case, the first name used would be the correct name.

The International Barcode of Life Project (iBOL)

With more than 1.7 million species described over the past 250 years, it is a slow task for a taxonomist to identify species and describe them according to the binomial system developed by Linnaeus. The aim of the International Barcode of Life Project is to enable rapid species identification. Ultimately, the project hopes to catalogue all life on Earth.

Over the next five years, iBOL will construct a barcode library based on a DNA-based identification system of five million specimens representing 500,000 species. The barcode to be used for animals is a portion of DNA from the mitochondrial gene *Cytochrome C oxidase I* (COI). The barcode for plants is a portion of DNA from the chloroplast gene *matK*.

Once the library is available, samples from unknown specimens can be analysed and the pattern of their DNA observed. They can then be identified as known species or new ones.

This will take place in a laboratory to start with, with centres being established in different countries. Eventually it is hoped that a hand-held device—similar to a supermarket barcode scanner—will be available for scientists to use in the field to identify any animal or plant in about three minutes.

Australia is a participating country in this project. Australian museums, botanic gardens and the CSIRO have so far DNA-tested 3000 species, including butterflies, moths, fish and birds, for the project.

As well as direct scientific benefits in taxonomy and biodiversity, there will be other benefits for society in areas such as pest and disease control, food safety, resource management, conservation, agriculture and medicine.

Classification and understanding

explain how classification of organisms can assist in developing an understanding of present and past life on Earth

The classification of organisms helps us to understand present and past life on Earth in several ways.

Ordering Grouping helps to bring a sense of order to an otherwise vast range of different types. It is a convenient way of organising living things to study them. Classification makes study easier by simplifying the description of living things. One group word can indicate several features. For example, by using the word 'bird' we are saying 'an egg-laying animal with two legs, two wings, feathers and a beak'. The single group word describes many of the organism's characteristics.

Communicating Classification helps us communicate with each other. Biologists throughout the world use the same system for naming organisms. Each living thing has an internationally accepted name and can be distinguished from any other by using that name. The words used are written in Latin, even if they come from English or another language. This international naming system is understood by scientists in all countries, so there is no confusion in communication.

Relationships Classification helps to work out relationships between organisms. Currently there is much speculation, because of our increasing knowledge at the genetic and molecular level, about the relationships between organisms. Traditionally, classification schemes have shown us the diversity of present-day organisms, while at the same time attempting to show how old they are and their evolutionary relationships. Classification systems are called phylogenetic when they try to reflect the evolutionary history of the organisms that are grouped together.

Conservation It is only by observing organisms, describing and classifying them that we are able to build up a picture of the range of organisms in different environments. Classification is the first step in learning about the relationships of organisms with their environment. Once endangered animals and plants have been identified, we can take action to conserve and protect them.

Biodiversity Taxonomy, together with systematics, builds up our knowledge of the Earth's biodiversity, and the classification schemes that are developed assist us in interpreting the diversity of life on Earth within an evolutionary framework.

Classification helps to bring a sense of order to an otherwise vast range of different types of organism.
- Classification helps us communicate with each other.
- Classification helps to work out relationships between organisms.
- Classification is the first step in learning about the relationships of organisms with their environment.

Answer to key question, p. 207
(a) is *Banksia integrifolia*—1b, 2a, 3b, 4a
(b) is *Banksia marginata*—1b, 2a, 3a

INVESTIGATION 3.7

Constructing and using keys

Students will: perform a first-hand investigation and gather information to construct and use simple dichotomous keys, and show how they can be used to identify a range of plants and animals using live and preserved specimens, photographs or diagrams of plants and animals.

Skills and outcomes

P2,P5, P13, P14

Type of activity

First-hand investigation, second-hand data activity

Materials

- sets of pictures of the following animals: red kangaroo (*Macropus rufus*), red fox (*Canis vulpes*), platypus (*Ornithorhynchus anatinus*), laughing kookaburra (*Dacelo gigas*), cane toad (*Bufo marinus*)
- examples of a range of flowering plants (selections may include daffodils, pansies, wattles, lilies)
- numbered specimens from the Arthropod phylum
- numbered green plant specimens
- hand lens
- stereoscopic microscope and lamp

See Analysing information

Introduction

Imagine you come across an unusual and interesting animal while out bushwalking. How would you find out this organism's name so you could further investigate it? One possibility is to search through a book, such as a field guide, and try to find a diagram or description that fits the animal. This could be a tedious and time-consuming task. A better way would be to use a key.

There is an incredible abundance and diversity of life on Earth. In order to best study organisms, biologists have developed a quick and efficient method of identification based on classification, or grouping organisms with similar features. Dichotomous keys are these identification tools. The word dichotomous means 'dividing into two parts'. Such keys use a series of pairs of characteristics (which are often structural) to divide large groups into smaller groups based on the presence or absence of particular features. This process continues until each group contains a single organism and an identification is made (see p. 207).

Purpose

1 To learn how to use a dichotomous key.
2 To develop a dichotomous key to separate a variety of flowering plants.
3 To use dichotomous keys to identify a range of plant and animal specimens.

Procedure

Classifying animals

1 Copy Figure 3.36 into your workbook, or create a web page.
2 Collect a set of animal pictures. Complete the dichotomous key in Figure 3.36 until each animal can be identified. Choose characteristics that will separate the remaining animals—for example, their body covering. Work with the left-hand side of the key first, then the right-hand side, until each side is complete (that is, each grouping contains a single animal). Remember to work with dichotomies or alternatives for each characteristic you choose.
3 Ask another student to work through your key to correctly identify one of the animals.
4 Modify your key if any problems arise. Rewrite your corrected key.
5 Keys are often written in simpler ways. The first part of the key in Figure 3.36 can be written as shown in Figure 3.37 or presented as a web page.

Set out the rest of your key in this form in your workbook or web page.

Remember that when the characteristic exclusively identifies that animal, the animal's name appears at the end of the line, as is the case with *Macropus rufus* in Figure 3.37.

Classifying flowering plants

1. Collect six different examples of flowering plants.
2. Examine each plant with a hand lens or stereoscopic microscope.
3. Draw a diagram of each plant with a description of some key features, particularly the flowers. Label each diagram with the plant's name.
4. Develop a key to classify each of six specimens, as in Figure 3.35. Ask another student or your teacher to work through your key to correctly identify one of the plants.
5. Modify your key if any problems arise. Rewrite your corrected key.
6. Now set out this key in a written form as below.

1a	Body covering is fur	go to 2
1b	Body covering is not fur	go to 3
2a	Female has a pouch	*Macropus rufus*
2b	Female does not have a pouch	go to 4
3a		
3b		

Figure 3.37 Shorthand key.

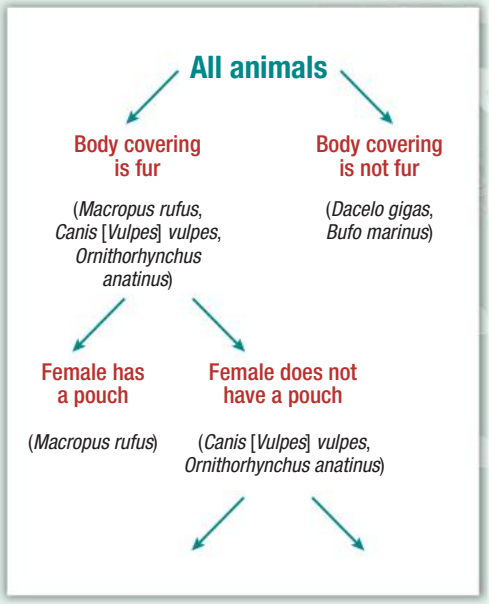


Figure 3.36 A practice key to classify animals.

Classifying arthropods

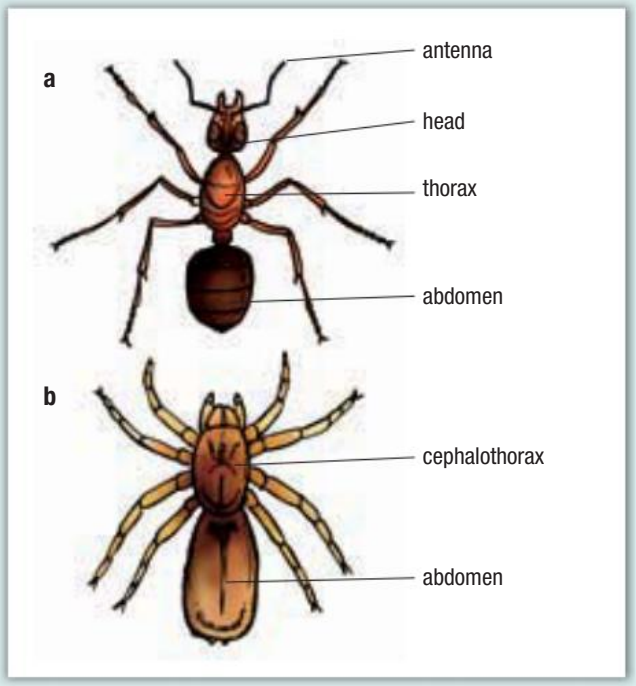
1. Examine each arthropod specimen and classify it using the key on page 212. Use the box of information about arthropods to help you. Check your results.

Figure 3.38 Diagram of (a) insect and (b) spider to show major body parts.

Arthropods

Arthropods are a group of invertebrate animals that are distinguished from other animals by their jointed appendages and jointed exoskeleton made of chitin. Arthropods form a very numerous and diverse phylum and can be divided into groups called 'classes'.

- Chitin is a nitrogen-containing polysaccharide that helps give mechanical strength and chemical resistance to the exoskeleton.
- Segmentation is the division of the body into separate repeating units.
- Antennae are long, paired appendages, often emerging from the head.
- Dorsal refers to the back.
- Ventral refers to the front.
- The main body parts of arthropods are shown in Figure 3.38.



2 Draw up and complete the following table.

TABLE 3.6

Specimen number	Class	Name of specimen

Key for classifying animals in phylum Arthropoda

1a At least a few living species; body segmentation transverse only 2
1b All fossil species; body divided by two longitudinal furrows ..... class Trilobita
2a Body segments grouped into two or three larger sections 3
2b Body segments not grouped 5
3a Three main body parts—head, thorax and abdomen; three pairs of legs attached to thorax ..... class Insecta
3b Two main body parts—cephalothorax and abdomen 4
4a Four pairs of legs attached to cephalothorax; no antennae ..... class Arachnida
4b More than four pairs of legs and two pairs of antennae attached to the cephalothorax ..... class Crustacea
5a One pair of antennae 6
5b Two pairs of antennae ..... class Crustacea
6a Body dorso-ventrally flattened; one pair of legs per segment ..... class Chilopoda
6b Body cylindrical, 2 pairs of legs per segment ..... class Diplopoda

Classifying green plants

1 Examine each green plant specimen and classify it using the key on the next page. Use the box of information about green plants to help you. Check your results.

Green plants

Green plants all contain chlorophyll and obtain their basic organic compounds through the process of photosynthesis.

- A thallus is a plant structure or body lacking true roots, stems and leaves. A thallus often looks rather leaf-like.
- Rhizoids are delicate root-like structures with no vascular tissue.
- Trachaeophytes are vascular plants such as club mosses, ferns, gymnosperms, angiosperms.

2 Draw up and complete the following table.

TABLE 3.7

Specimen number	Major group	Common name

Simple key to green plants

1a True roots, stems and leaves with vascular tissue.....2
1b No true roots, stems or leaves; or has structures resembling roots, stems and leaves, but no vascular tissue 5
2a Reproduce by spores 3
2b Reproduce by seeds.....4
3a Leaves with a single unbranched vein; spores formed in leafy cones mostly on the end of branches .....club mosses
3b Leaves usually dissected, spores on back of leaves.....ferns
4a All woody plants, seeds in cones.....gymnosperms
4b Flowers present, seeds enclosed in fruit.....angiosperms
5a Plant consisting of a thick, fleshy thallus ..... thallose liverwort
5b Plant not a thallus; with structures resembling stems and leaves 6
6a Leaves arranged in two or three rows; spore capsule black and globular, on a white stalk .....leafy liverwort
6b Leaves arranged in many rows around the stem; spore capsule green to brown, stalk not white.....moss

Discussion

1 Could you use the key you constructed to identify any flowering plant that was not under consideration when you made the key? Explain your answer.
2 Would you expect a key for classifying plants in Australia to differ from one in Europe? Give a reason why.
3 In which group are the organisms most alike—kingdom, phylum or class?
4 What characteristics are used to divide arthropods into classes?
5 How can you tell an insect from a spider?
6 What is the distinguishing feature of green plants?
7 How could you distinguish a moss from a fern?
8 Why are ferns, gymnosperms and angiosperms grouped together?
9 How could you distinguish a fern from a flowering plant?

Conclusion

Write a brief paragraph to summarise what you have learnt about the construction and usefulness of keys as identification tools.

UNIT REVIEW 3.4

Taxonomy: classifying organisms

The study of present-day organisms increases our understanding of past organisms and environments.

Summary

- Scientists classify organisms in order to better describe and study them. Classification systems are internationally recognised. This aids communication between scientists.
- Different selection criteria are used in different classification systems. There are advantages and disadvantages with each system. Structural characteristics are still the most useful for sorting organisms into groups.
- Levels of organisation in a hierarchical system help to show relationships between groups. The levels are kingdom, phylum, class, order, family, genus and species.
- New discoveries and changes in technology, for example in molecular biology, are causing continual development and revision of classification systems.
- The binomial (two-name) system is used for naming organisms. A genus name and a species name are given to each organism; these are unique identifiers for that type of organism. The use of keys makes the identification of organisms easier.
- Extinct organisms found only as fossils may be difficult to classify, particularly if they are incomplete or their structural details are not clear.
- Classifying organisms helps us to understand present and past life on Earth.



Questions

1 Use the following key to identify the seaweed shown.

1a	Brown seaweed	2
1b	Green seaweed	4
2a	Fronds large and single	*Laminaria*
2b	Fronds branched	3
3a	Fronds with central axis, flattened, complex branching	*Grystophora*
3b	Fronds jointed and cylindrical	*Hormosira*
4a	Fronds large, thin and membranous	*Ulva*
4b	Fronds fine and thread-like	*Cladophora*

A *Laminaria*
B *Grystophora*
C *Hormosira*
D *Ulva*

2 Identify the most useful characteristic in classifying organisms.

A colour
B structure
C size
D habitat

3 Which of the following statements best explains the difficulties that can arise in classifying extinct organisms?

A The remains of extinct organisms may be misleading because they are incomplete or lacking detail.
B Extinct organisms disappeared before the systems of classification were devised.
C Extinct organisms could be confused with similar, convergent living types.
D Extinct organisms were often soft-bodied and left no fossils.

4 Explain briefly why biologists need to classify organisms.

5 Describe the selection criteria used in two different classification systems, and discuss the advantages and disadvantages of each.

6 Which level of classification contains organisms that are more similar to each other: order or species? Explain how hierachical levels of organisation assist classification.

7 Advances in technology have improved our knowledge of living things. Outline two examples of how technological advances have affected classification systems.

8 a Outline the characteristic features of organisms in the kingdoms Plantae and Animalia.

b List the three other kingdoms. Describe their distinguishing features, providing examples in each case.

9 Describe the binomial system of naming organisms. Include a specific example to illustrate your answer.

CHAPTER 3

EXAM-STYLE QUESTIONS

MULTIPLE CHOICE

1 Which statement best describes the conditions present on Earth when the first life forms are believed to have appeared?
- A Abundant free oxygen and carbon dioxide, as well as water vapour, hydrogen, hydrogen cyanide; violent electrical storms and volcanic activity; a well-developed ozone layer.
- B Abundant carbon dioxide as well as water vapour, hydrogen, hydrogen cyanide, but no free oxygen; violent electrical storms and volcanic activity; a well-developed ozone layer.
- C Abundant carbon dioxide as well as water vapour, hydrogen, hydrogen cyanide, but no free oxygen; violent electrical storms and volcanic activity; no ozone layer.
- D Abundant water vapour, hydrogen, hydrogen cyanide, but no free oxygen or carbon dioxide; violent electrical storms and volcanic activity; no ozone layer.

2 Where does the evidence come from that some of the fundamental chemicals of life originated from elsewhere in the Universe, rather than on Earth?
- A telescopic examination of space matter
- B meteorite analysis that indicates the presence of amino acids
- C the belief that bacterial spores drifting across space 'seeded' the Earth
- D None of the above.

3 What is studied in palaeontology?
- A fossilised plants
- B life forms that existed during the Palaeozoic era
- C fossil-bearing rocks
- D fossils

4 When does the fossilisation of an organism occur?
- A When the remains do not decay.
- B When the remains are buried quickly.
- C When the remains are undisturbed.
- D All of the above.

5 Which of the following represents the correct sequence of major stages in the evolution of life on Earth?
- A organic molecule formation, membrane formation, eucaryotic cells, procaryotic cells, colonial cells, multicellular organisms
- B organic molecule formation, membrane formation, procaryotic cells, eucaryotic cells, colonial cells, multicellular organisms
- C membrane formation, organic molecule formation, procaryotic cells, eucaryotic cells, colonial cells, multicellular organisms
- D multicellular organisms, colonial cells, eucaryotic cells, procaryotic cells, membrane formation, organic molecule formation

6 Which statement best describes procaryotic organisms?
- A They are believed to be the first forms of life on Earth.
- B They are strictly independent, unicellular organisms.
- C They lack a nuclear membrane and other membrane-bound organelles.
- D All of the above.

7 Which statement best describes the role of procaryotic organisms?
- A They play an important role in the recycling of materials within ecosystems.
- B They are the main producer organisms in ecosystems.
- C They are the only decomposer organisms in ecosystems.
- D They are usually parasitic on other organisms.

8 Which list contains the most correct sequence of events in the history of life on Earth?
- A formation of the planet, volcanic activity, organic compounds, living things
- B stromatolites, Ediacara, anaerobic cells, aerobic cells
- C condensation, ice age, volcanoes, warming
- D procaryotes, plants, photosynthesis, respiration

9 When are classification systems least useful?
- A When we are organising the diversity of living things.
- B When we only have structures, not functions, of living things to study.
- C When we are studying the relationships between organisms.
- D When we wish to find out the age of a fossil.

10 Classification systems are revised from time to time when new information informs our understanding of the relationships between organisms. Advances in technology have led to changes in classification groupings of organisms. Which of the following does NOT represent a technological advance that has affected classification systems?

A comparison of anatomical features
B comparisons of DNA sequences
C the development of the light microscope
D the development of the electron microscope

SHORT ANSWERS

1 One scientific theory relating to the evolution of the basic chemicals of life suggests that the chemicals for life originated from outer space. A second theory suggests that they were formed on Earth.

a List three organic compounds necessary for life.
b Outline one piece of evidence that supports each of the two theories.

2 a Explain why soft-bodied organisms are rarely fossilised compared with organisms that have hard parts such as shell or bone, which often are.

b Outline three conditions needed for fossilisation to occur.

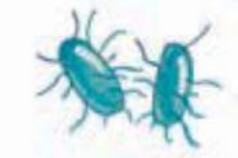
3 A possible classification scheme would be to place all single-celled organisms, such as the ones shown below, in a group together.



Paramecium
a protozoan



yeast



E. coli
rod-shaped bacteria

For each of the three organisms, name a characteristic it possesses which it does not share with the other organisms.

4 In the 1920s, Alexander Oparin and John Haldane hypothesised that the Earth's early atmosphere contained all of the basic chemicals of life, and that more complex organic molecules were produced in conditions of ultraviolet radiation or lightning discharge.

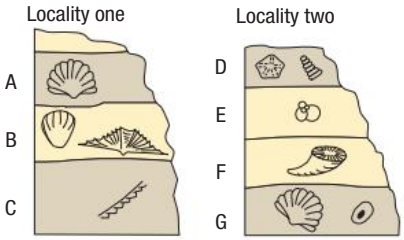
a Describe the experiment conducted by Harold Urey and Stanley Miller in the 1950s that followed up Oparin and Haldane's hypothesis.
b What were the results of the experiment conducted by Urey and Miller?
c Outline the significance of their results.

5 Identify two technological advances that have had an impact on our knowledge of the origins of life, and explain how they had such an impact.

6 a Identify three major stages in the evolution of living things.

b For the three stages you named, outline the basic features shown by living things at this stage.

7 Study the rock strata shown, which represent fossils discovered at two different locations.



a Write down the letters corresponding to each fossil type in order, from most recent to oldest.
b Radiometric carbon dating is used to date fossils that contain carbon. Fossil F has been assessed as being about 40 000 years old using radiometric dating techniques. How can fossils be dated using radioactive carbon?

8 Explain how our knowledge about the history of life on Earth has been increased by:

a the study of extremophiles
b the fossil record.

9 a Outline what is meant by an anoxic atmosphere.
b Explain the significance in the evolution of living things of the change from an anoxic to an oxic atmosphere.

10 Discuss why the ideas of different cultures about the origins of life may conflict with scientific knowledge.

11 You have found a fungus on a bushwalk that you cannot identify.

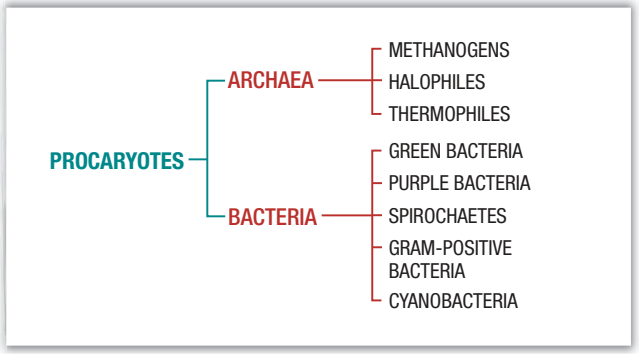


a What features or information would you need to help you identify it?

b How would you try to find out what sort of fungus it was?

c Fungi can be classified into different groups by different biologists. Explain how this can happen.

12 Consider the following tree diagram of procaryotes.



a Describe the common features shared by archaea and bacteria.

b How are archaea and bacteria different from eucaryotic organisms?

c Describe the environment of a named procaryotic organism.

d Outline the role in its ecosystem of the procaryote you named in part (c).

13 Use the partial key provided below to classify the winged insect shown. Write down each of the steps you have taken in reaching your decision.



1a	Adults with wings	2
1b	Adults without wings	24
2a	All wings membranous and usually transparent, or wings with (powdery) scales or hairs covering them	12
2b	One or both pairs of wings partly or wholly hardened, or parchment-like and opaque (not transparent)	3
3a	Forewings forming a pair of hard covers meeting in a straight line down the centre of the back. Mouth parts of biting type	4
3b	Forewings overlapping, not meeting in a straight line down the back. Hindwings membranous and often fan-like	6
4a	Forewings very short, covering less than half the abdomen	5
4b	Forewings covering all or most of the abdomen	Order Coleoptera
5a	Abdomen with two hardened pincer-like or forceps-like extensions behind.	Order Dermaptera
5b	Abdomen without a pair of pincer-like or forceps-like extensions behind (but often with a pair of short segmented processes)	some Order Coleoptera

14 Explain the benefits of classification to our understanding of past and present life on Earth.

CHAPTER 4

EVOLUTION OF AUSTRALIAN BIOTA



PFA: This chapter increases students' understanding of the applications and uses of biology, the implications for society and the environment, and current issues, research and developments in biology.

Australian ecosystems are unique. They contain animals and plants unlike any others in the world. Why is this so? Can we find evidence to help explain modern Australia?

Australia has been an isolated landmass for the past 30 million years. During this time, flora and fauna unique to Australia has evolved.

Throughout this period of isolation, a number of global climatic changes have affected Australian ecosystems. The effects are reflected in the fossil record, which indicates slow but continual changes in living things. Species have come and gone, including megafauna such as giant kangaroos and wombats, ferocious marsupial lions and giant pythons.

Australia's changing environment has made it the driest inhabited continent on Earth. As Australia became warmer and drier, both plants and animals evolved with adaptations that enabled them to survive this increasing aridity and extremes of temperature variation.

Knowledge gained from the study of past environments helps us to better understand present-day ecosystems and allows us to more accurately predict the effects of our actions on the environment.

Assumed knowledge

Refer to the Board of Studies NSW Years 7–10 Syllabus

- Discuss evidence that present-day organisms have evolved from organisms in the distant past (5.8.3a).
- Identify the role of cell division in growth, repair and reproduction in multicellular organisms (5.8.1b).
- Relate natural selection to the theory of evolution (5.8.3b).
- Discuss evidence that suggests crustal plates move over time (5.9.2a).

Preliminary Course Outcomes

Prescribed focus areas

P1 Outlines the historical development of major biological principles, concepts and ideas.

P2 Applies the processes that are used to test and validate models, theories and laws of science, with particular emphasis on first-hand investigations in biology.

P3 Assesses the impact of particular technological advances on understanding in biology.

P5 Describes the scientific principles employed in particular areas of biological research.

Domain knowledge

P6 Explains how cell ultrastructure and the coordinated activities of cells, tissues and organs contribute to macroscopic processes in organisms.

P7 Describes the range of organisms in terms of specialisation for a habitat.

P9 Explains how processes of reproduction ensure continuity of species.

P10 Identifies and describes the evidence for evolution.

Domain skills

P11 Identifies and implements improvements to investigation plans.

P12 Discusses the validity and reliability of data gathered from first-hand investigations and secondary sources.

P13 Identifies appropriate terminology and reporting styles to communicate information and understanding in biology.

P14 Draws valid conclusions from gathered data and information.

P15 Implements strategies to work effectively as an individual and as a team member.

Values and attitudes

P16 Demonstrates positive values about and attitudes towards both the living and non-living components of the environment, ethical behaviour and a desire for a critical evaluation of the consequences of the applications of science.

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EVOLUTION OF AUSTRALIAN BIOTA



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4.1 GONDWANA: ANCIENT SUPER CONTINENT

Evidence for the rearrangement of crustal plates and continental drift indicates that Australia was once part of an ancient super continent.



STUDENT LEARNING

In this unit students will:

- identify and describe evidence that supports the assertion that Australia was once part of a landmass called Gondwana, including:
  - matching continental margins
  - position of mid-ocean ridges
  - spreading zones between continents
  - fossils in common on Gondwanan continents, including *Glossopteris* and *Gangamopteris* flora, and marsupials
  - similarities between present-day organisms on Gondwanan continents
- discuss current research into the evolutionary relationships between extinct species, including megafauna and extant Australian species.

STUDENT ACTIVITY

Students will:

- solve problems to identify the positions of mid-ocean ridges and spreading zones that infer a moving Australian continent
- identify data sources, gather, process and analyse information from secondary sources, and use available evidence to illustrate the changing ideas of scientists in the last 200 years about individual species, such as the platypus, as new information and technologies became available.

The formation of Australia

Australia became a separate continent about 45 million years ago. There is evidence that it was originally part of an ancient super continent, **Pangaea**. About 160 million years ago, in the Jurassic period, Pangaea split into two large continents, Laurasia to the north and **Gondwana** to the south (Figure 4.1).

Laurasia consisted of today's North America, Europe and Asia (except India); Gondwana comprised the current landmasses of South America, Africa, Madagascar, India, Antarctica, Australia and New Zealand. By the end of the Jurassic period, crustal plate movement had separated Africa and South America, and India was drifting northwards. During the Cretaceous period, Madagascar split from Africa, and New Zealand split from Australia. About 60 million years ago, during the Palaeogene period, South America separated from Antarctica and Australia. Australia drifted northwards, and about 55 million years ago it began to break away from Antarctica (Figure 4.2). This separation was not complete until about 45 million years ago. Australia is still drifting north at the rate of about 6 cm each year.

Gondwana comprised the present-day landmasses of South America, Africa, Madagascar, India, Antarctica, Australia and New Zealand.

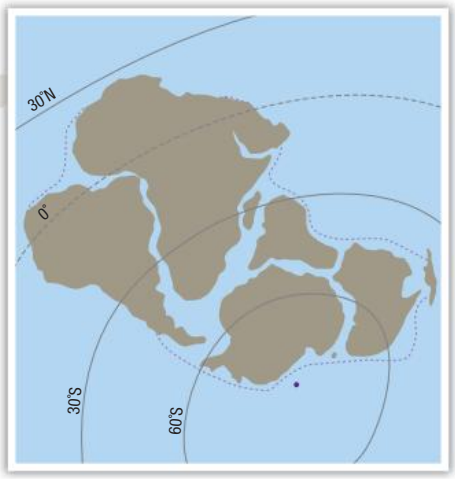


Figure 4.1 Geological evidence has enabled scientists to work out how the present-day continents might have fitted together. This shows how Gondwana might have looked in the early Cretaceous, about 140 million years ago. The dotted lines indicate the possible continental boundary.

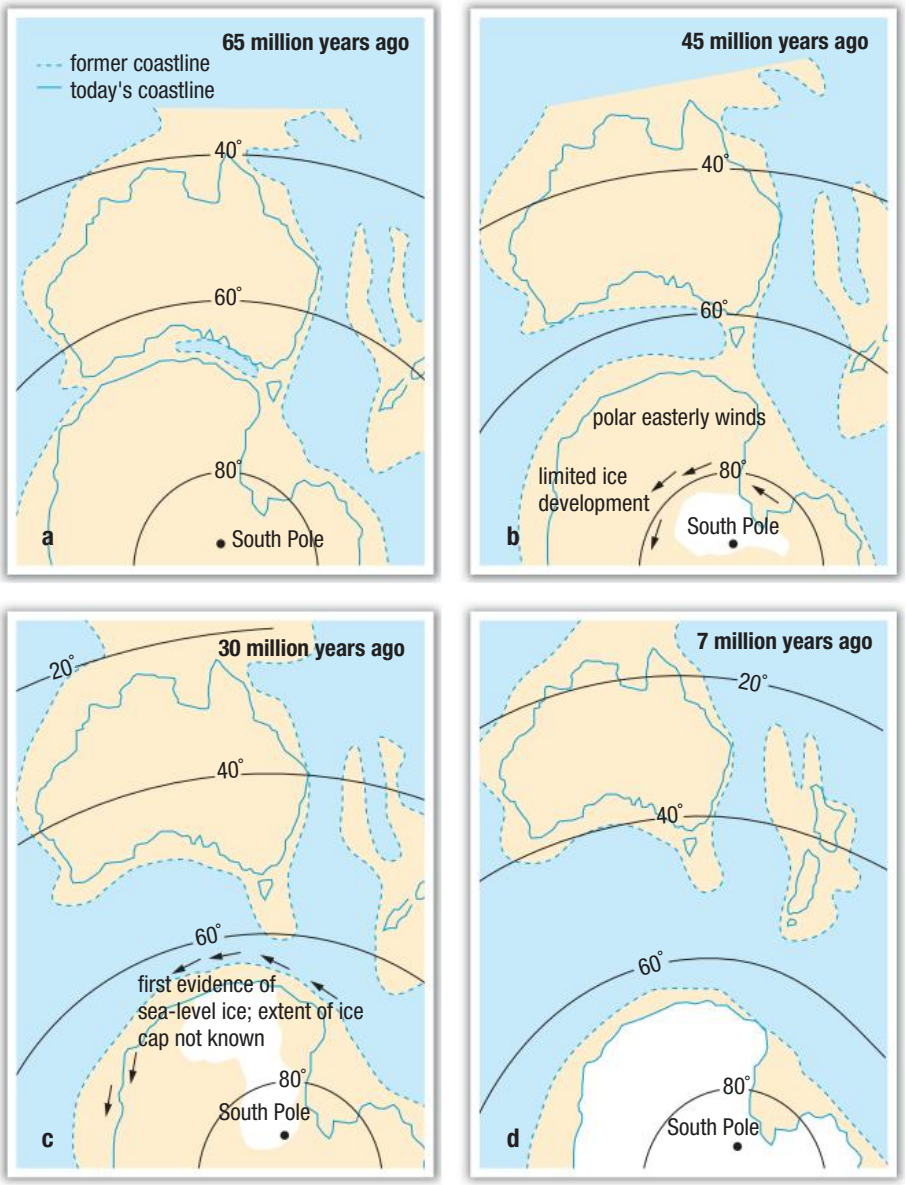


Figure 4.2 (a) 65 million years ago, Australia was still connected to Antarctica. (b) 45 million years ago the two continents were separating. (c) 30 million years ago the separation was complete and a large ice-cap had developed over Antarctica. (d) 7 million years ago the ice-cap was at about its present size.

Plate tectonics

The development of the theories of **continental drift** in the early 1900s and **plate tectonics** over four decades ago gave scientists, for the first time, a sensible way to explain and understand the creation of mountains, volcanoes and oceans. The theories enabled them to explain how mineral and fossil fuel resources originated and where such fuels may be found, and, in recent years, to explain the evolution of different groups of organisms.

The idea of continental drift was first proposed in 1912 by a German astronomer, Alfred Wegener. He theorised that the continents as they exist today were once all attached in a single landmass. He called this concept Pangaea. This landmass was originally surrounded by a global ocean, but then split up into smaller landmasses which drifted to separate places around the Earth.

The theory of plate tectonics, first developed by geologist Harry Hess in the 1960s, holds that continents and oceans are carried on the large crustal plates of the Earth's surface, which move on top of the Earth's semi-molten interior. This movement of pushing parts of the Earth's crust together or pulling them apart creates a ridge marking the edge of two separate plates. As a result, mountain ranges and oceans are created, and devastating earthquakes occur. The plates move only a few centimetres every year, but when measured over tens of millions of years, great distances are covered and great forces are generated. Scientists believe that the Indian plate's push northward into Asia (at a rate of 19 cm a year) uplifted the Himalayas.

It has been suggested that the sites of collision of the continental plates are points of increased biological diversity due to the creation of new environments, with warm currents bringing in new species.

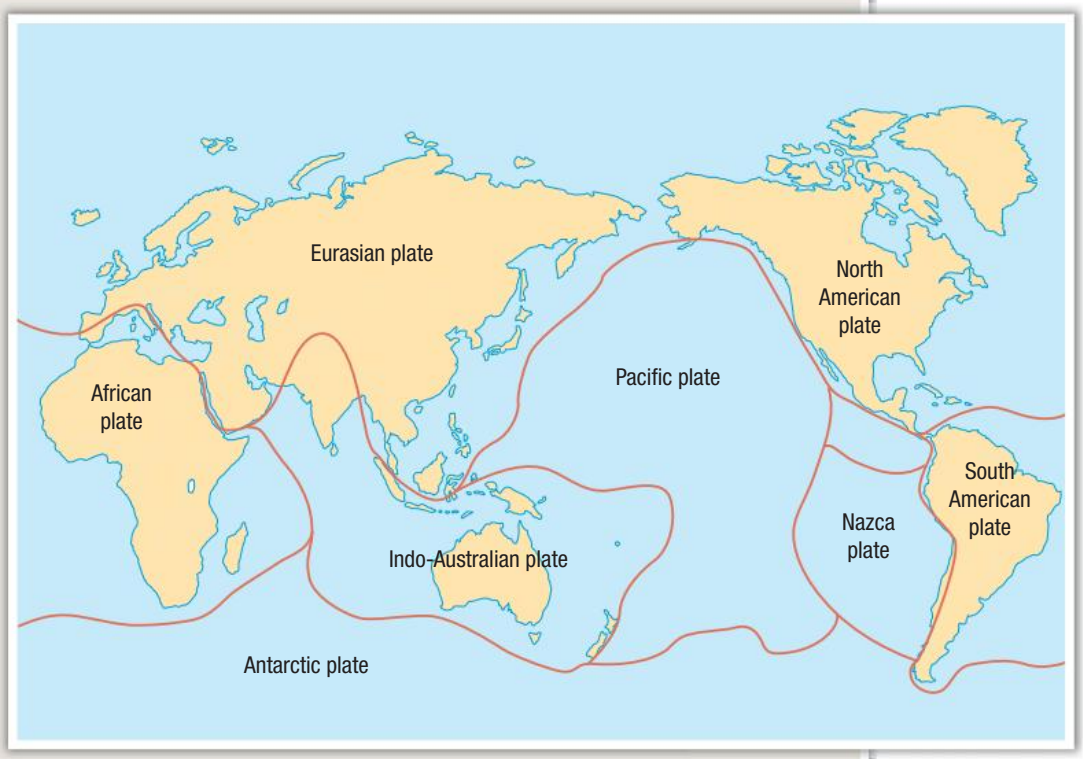


Figure 4.3 The Earth's major continental plates. Australia lies on the Indo-Australian plate.

identify and describe evidence that supports the assertion that Australia was once part of a landmass called Gondwana, including:
- matching continental margins
- position of mid-ocean ridges
- spreading zones between continental plates
- fossils in common on Gondwanan continents, including *Glossopteris* and *Gangamopteris* flora, and marsupials
- similarities between present-day organisms on Gondwanan continents

BIOFACT

The name Gondwana means 'forest of the Gonds'. The Gonds were people who lived in the region of India where the first *Glossopteris* fossil was discovered.

Evidence of Gondwana

How do we know that Australia was once part of Gondwana? The answer comes mostly from our knowledge of geology and biology.

Matching continental margins

Geologists studying the rock strata around the **continental margins** have found that they match perfectly in many places, such as between southern Australia and one section of Antarctica, and between the west coast of Africa and the east coast of South America.

Position of mid-ocean ridges

Deep-sea surveys have discovered **mid-ocean ridges** where the plates are moving apart. The weakness in the crust at the boundaries allows molten mantle material to well up, separating the plates and depositing material, which creates new ocean floor. The surveys found that the rock that forms the ocean floor is increasingly older the further it is from these ridges, indicating that the plates have been moving apart steadily for a long time.

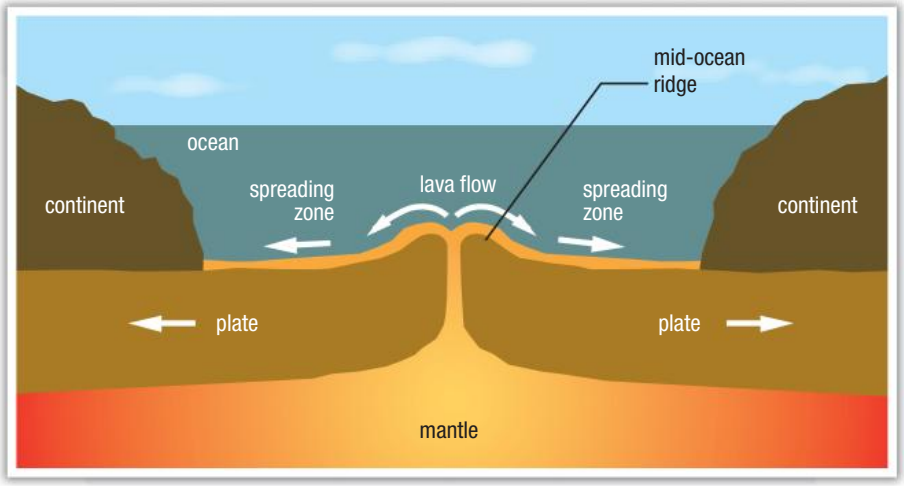


Figure 4.4 Where two plates are moving apart, they form a mid-ocean ridge. Magma wells up and spreads across the ocean floor, moving away from the ridge.

Fossil plants and animals found in Antarctica, including marsupials, are the same as those found in Australia in rocks of the same age.

Spreading zones between continental plates

Areas of new ocean floor forming between continental plates are called **spreading zones**.

All this evidence supports the theory that Australia was once connected to other southern continents as part of the super continent of Gondwana.

Fossils in common on Gondwanan continents

Glossopteris and *Gangamopteris* are fossil plants found in rocks of the same age in Africa, Australia, India, South America, Antarctica and New Zealand. Alfred Wegener used *Glossopteris* as one piece of evidence to support his theory of continental drift.

Marsupial mammals are widespread in Australia. They also have a long fossil record on the continent. Only one marsupial, the opossum, is still found in North and South America, but the fossil record shows marsupials were present on all the continents that we believe made up Gondwana. Fossil plants and animals found in Antarctica, including marsupials, are the same as those found in Australia in rocks of the same age.

Similarities between present-day organisms on Gondwanan continents

Nothofagus, the southern beech trees, are found today in forests in Australia, New Guinea, New Zealand and South America (Figure 4.6). Fossil specimens are also found in Antarctica.

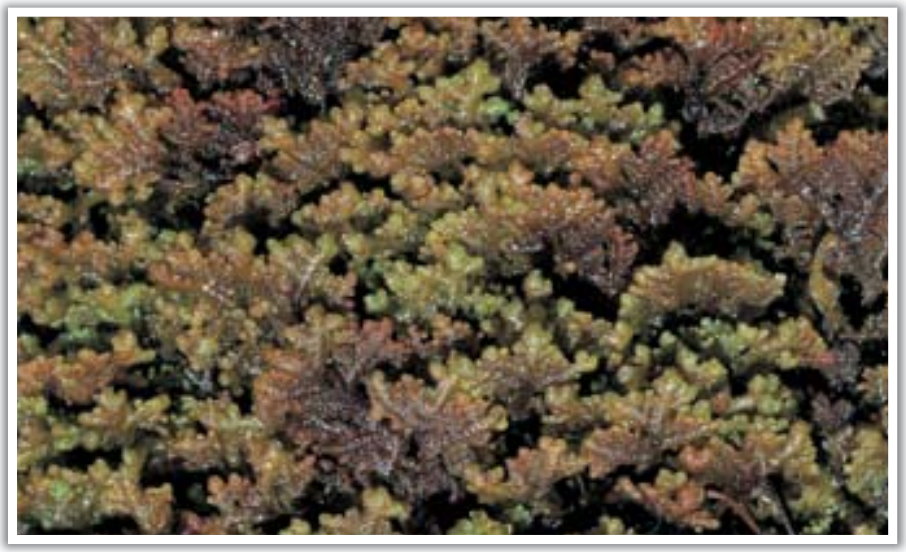
Many plants and animals are found only in the isolated areas where *Nothofagus* is still found, and nowhere else; for example, a parasitic fungus, a liverwort, and small invertebrates which depend on the liverwort (Figure 4.6).

Many groups of animals have close relatives in South America, Africa, India and New Zealand, but not in northern Asia, Europe or North America. They include parrots, the ratites or flightless birds (Figure 4.7), marsupial mammals, chelid turtles, some geckoes, many families of earthworms, terrestrial molluscs, spiders and insects, and the scorpion genus *Cercophonius*.

These biological examples, when considered together with the geological evidence, help to support the theory that landmasses in the southern hemisphere, including Australia, were once connected. A large proportion of Australian animals and plants are unique to Australia, but their ancestry can be traced back to extinct Gondwanan species. The fossil history of Australia shows slow but continual changes in living things. Since Australia became a separate continent, many of the plants and animals that were present then have continued to evolve and spread out to occupy a wide variety of habitats. Current research continues to provide further evidence about the evolutionary relationships between Australia's fossil record and present-day species (see Unit 4.2).



Figure 4.5 A fossil plant called *Glossopteris* is found in rocks of the same age in India, South America, Antarctica, Australia and New Zealand. This fossil specimen is from New South Wales and is about 200 million years old.



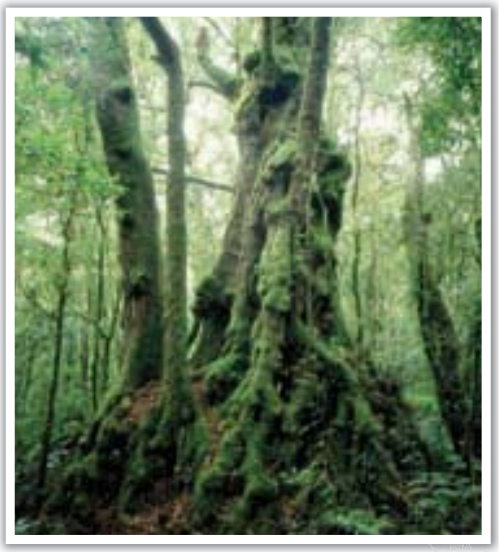


Figure 4.6 The *Nothofagus* rainforests in south-eastern Australia and New Zealand (right) are considered to be relicts of ancient Gondwanan rainforests. They include many species not found in any other habitat, such as the liverwort *Gackstroemia weindorferi* (left).

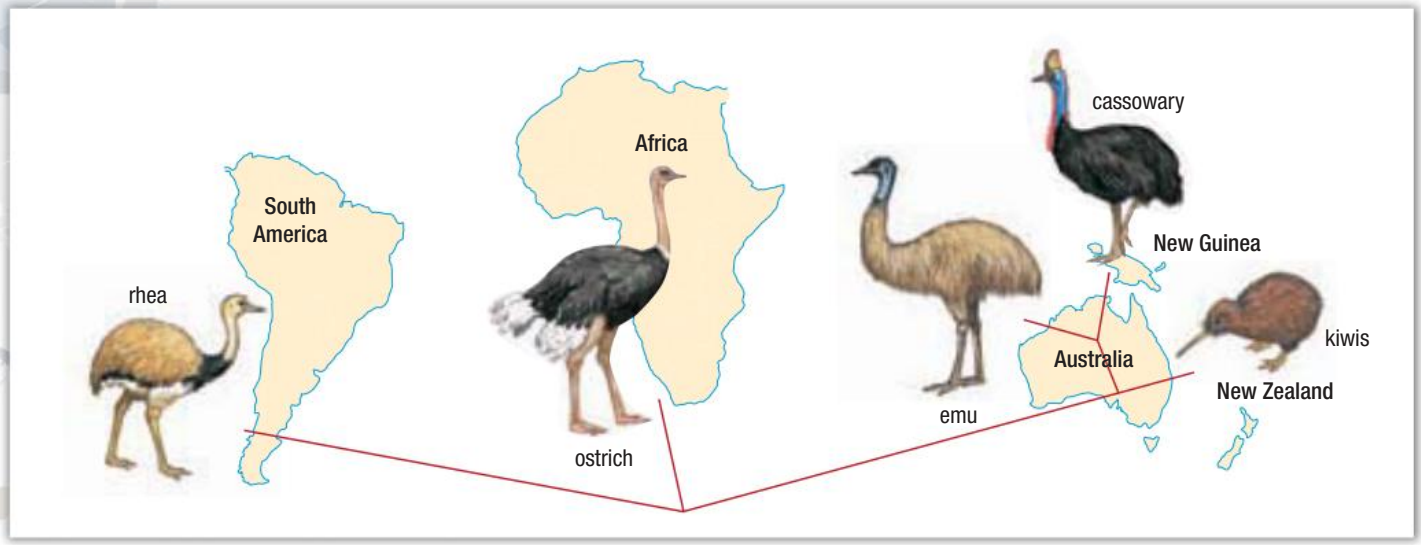


Figure 4.7 The group of flightless birds called ratites occur only in the southern hemisphere. Comparisons of their DNA have given us an idea of their family tree. The Australian emu is most closely related to the cassowary of north-eastern Australia and New Guinea. The New Zealand kiwis are 'second cousins'. The rhea from South America and the ostrich from Africa are more distant relatives—'third cousins'.

Endemic species are native to a particular geographic region

The long isolation of the Australian continent has produced a large number of plants and animals which are endemic to Australia, and has resulted in species richness. Endemic species are those which are unique to a region. In Australia, 85% of flowering plants, 82% of land mammals, 89% of reptile species and 93% of frog species are endemic. Species richness refers to the high number of species in a particular area. For example, Queensland rainforests and the Great Barrier Reef show species richness. Species richness in the Great Barrier Reef includes: 4000 species of molluscs, 1500 species of fish, 400 species of corals, 215 species of birds, 23 species of mammals, and 6 species of turtles.



Figure 4.8 Reef and fringing rainforest at Cape Tribulation, North Queensland.



Figure 4.9 Fossil remains of *Nambaroo gillespieae* , a predecessor of the kangaroo that lived 25 million years ago, was the size of a dog, had canine fangs and lived in thick forest, probably on a diet of fruit and fungi. It had flexible feet with an opposable big toe and while it probably galloped on all fours, it may also have been capable of climbing trees.

4.1 INVESTIGATION

A moving Australian continent

Students will: solve problems to identify the positions of mid-ocean ridges and spreading zones that infer a moving Australian continent.

Introduction

The theory of plate tectonics describes a process whereby rigid plates of rock move across the surface of the Earth's molten interior. This theory has helped to explain the formation of mountains and the distribution of earthquakes and volcanoes on Earth.

Purpose

To investigate and solve problems to identify the position of mid-ocean ridges and spreading zones that infer a moving Australian continent.

Background information

There are seven large and many small tectonic plates, each approximately 120 kilometres thick, covering the Earth's surface (see p. 225). On top of the plates there may be continents or oceans. Each year these plates move a few centimetres in relation to each other. There are three types of movement seen at plate boundaries:

Convergent movement is where two plates are moving towards each other. Mountain systems, such as the Himalayas, may be formed when two continental plates collide. Where an oceanic plate collides with a continental plate, the oceanic plate slides under the continental plate, forming a deep ocean trench. An example of this is where the Nazca plate meets the South American plate.

Divergent movement is where two plates are moving away from each other. Molten rock from the Earth's interior rises between them to form a ridge, cools, and forms new crust. The global mid-ocean ridge is a huge mountain range circling the Earth along the ocean floor. Magma from below the Earth's crust erupts from the ridge and spreads across the ocean floor. This is known as sea-floor spreading. Along the Mid-Atlantic Ridge the rate of spreading is, on average, 2.5 centimetres per year.

Transform-fault movement is where two plates are moving past one another. The best known example is the San Andreas fault where the Pacific plate is moving north-west past the North American plate.

How fast do tectonic plates move?

Geodesy is the science of the size and shape of the Earth. Measurements of the position of tectonic plates can be taken regularly, either on the ground or from space, and compared to determine any change. Ground-based measurements usually involve laser electronic instruments. Satellite-based methods involve taking repeated measurements between precise points on the Earth's surface. The Global Positioning System (GPS) used by the United States Department of Defense uses 21 satellites orbiting 20 000 kilometres above

Skills and outcomes

P3, P10, P14

Type of activity

Second-hand data activity

Materials

- world topographical map
- books, journals, Internet sites

See Analysing information

the Earth. These satellites continuously transmit radio signals back to Earth. Geodetic data from satellite measurements have assisted in confirming the rates and direction of the movement of the Earth's tectonic plates.

Procedure

Using pages 224–225, along with a current world topographical map, identify the tectonic plates and the positions of mid-ocean ridges, trenches and spreading zones.

Discussion

1 Explain how the theory of plate tectonics has changed our ideas about the surface of the Earth.

2 Identify the tectonic plate that is entirely oceanic.

3 a It has been suggested that the Atlantic Ocean is expanding and the Pacific Ocean shrinking. What evidence supports this idea?

b If the sea floor spreads from the mid-Atlantic ridge at the rate of 2.5 cm per year, how many kilometres of new crust will be laid down over one million years?

4 The city of San Francisco has experienced earth tremors and earthquakes over the last 100 years. What is the reason for this?

5 The Earth's crust is recycled over time. Explain how this happens.

6 Name the tectonic plate on which the continent of Australia sits.

7 It has been said that Australia is drifting northwards at a rate of about 6 cm a year. Identify the technological advances that have helped us to measure this.

8 Explain, with examples, how technological advances have increased our understanding of plate tectonics.

discuss current research into the evolutionary relationships between extinct species, including megafauna and extant Australian species

Current research into evolutionary relationships

Palaeobiologists in Australia are currently looking at fossil finds and trying to trace the evolutionary relationships between species that are now extinct and modern forms. Current research not only uses traditional palaeontological techniques, but also modern genetic technologies.

Of particular interest to scientists is Australia's **megafauna**. Megafauna are large animals. Today there are only a few types found on Earth, such as elephants and whales, but in the past they were more common. Over the last 50 000 years most of the world's megafauna have become extinct. Australia, too, had megafauna, but today it is only smaller relatives that survive.

The fossil record, particularly for marsupials, shows a decline in size since the late Pleistocene. Both the eastern grey kangaroo (*Macropus giganteus*) and the red kangaroo (*Macropus rufus*) can be considered megafauna survivors, but they are up to 30% smaller than they were thousands of years ago.

In Australia the oldest DNA analysed is 15–20 000 years old. Scientists would like to obtain DNA older than 40 000 years—from the times when the megafauna inhabited Australia.

BIOFACT

Australia's extinct megafauna include:

- marsupial lion
- diprotodon (a large wombat-like marsupial)
- giant kangaroos
- giant echidna
- giant Tasmanian devil
- giant Australian python
- giant goanna
- giant Australian megapode (a bird similar to the malleefowl)
- *Genyornis* (a giant flightless bird).

DNA degrades over time and degrades faster in warm environments, but new technologies can take and analyse any small fragments that are found. DNA can be extracted from bones, teeth, hair and even fossilised animal droppings or nesting sites. Contamination with human or bacterial DNA can be a problem, and DNA for analysis is best collected in as sterile conditions as possible.

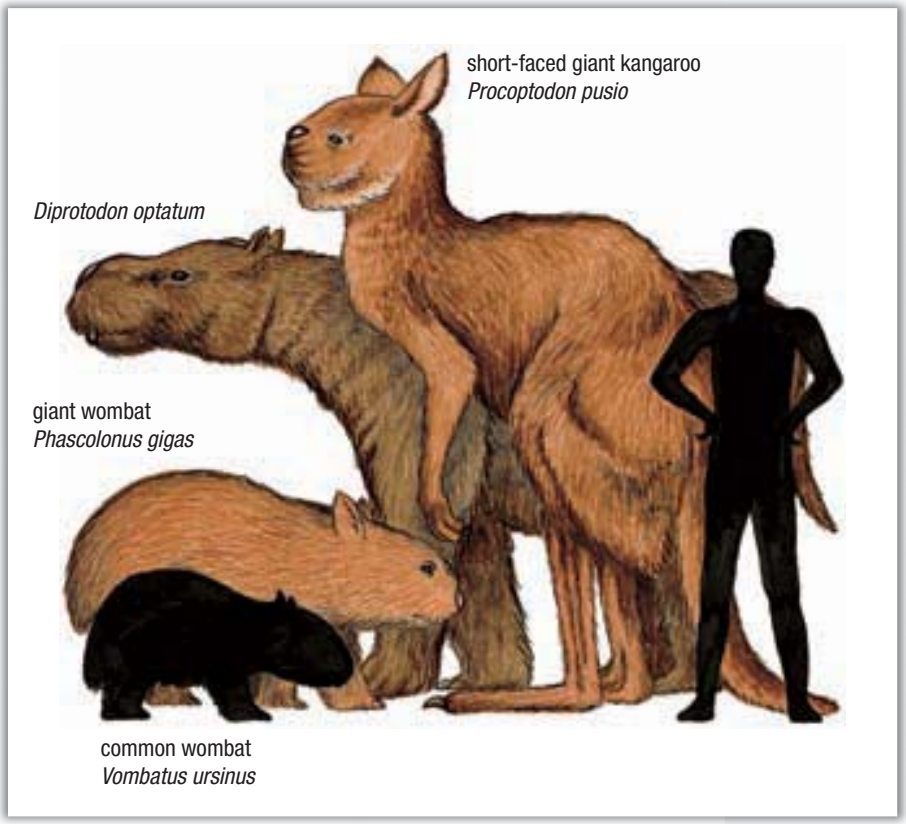


Figure 4.10 Some examples of Australia's extinct megafauna, with a human and present-day wombat for size comparison.

Living fossils—extant species

The evolution of most living organisms can be traced to common ancestors, through their distribution and their fossil record. But some present-day organisms have survived apparently unchanged since ancient times. We call these **extant species** or 'living fossils'. The focus of current research into extant species is to look at the environment in which these species are found, both past and present. **Extant species** are usually found in areas where the environmental conditions have not changed in millions of years. Australia has many examples of these. Stromatolites, found today in Western Australia, are the oldest living fossils known (see p. 171).

The long isolation of the Australian continent has produced a large number of plants and animals which are endemic to Australia, and has resulted in species richness.

BIOFACT

Tim Flannery is an Australian scientist and writer well known for his controversial views on the human impact on Australia's environment through his book *The Future Eaters*, and on climate change in *The Weather Makers*. He suggests that Australia was most sustainable as an ecosystem 50 000 years ago, when the megafauna were still alive and that, without them, the system is out of balance and has become far less productive.

BIOFACT

The Australian Centre for Ancient DNA (ACAD) in South Australia works with scientists from around the world on research projects involving evolutionary biology, population genetics and environmental change. Major topics include the phylogenetic relationships and phylogeography of extinct mammals and birds, including the Australian megafauna, New Zealand birds, Ice Age bison and sabre-tooth cats. In 2008 they began studying the remains of megafauna in tar pits at La Brea in Los Angeles, California. Current research uses newly developed methods of extraction, amplification and analysis of DNA, as well as advances in computer technology.



Figure 4.11 The Wollemi pine was discovered by a park ranger in 1994 in an isolated gorge of the Wollemi National Park. It belongs to a group of plants known previously only from fossils.



Figure 4.13 The short-beaked echidna, *Tachyglossus aculeatus*, is one of three present-day monotreme species—descendants of the earliest mammals.

Plants

Many plants are found in isolated areas today, but are also known from their extensive fossil record. These include plum pines (*Podocarpus*), celery pines (*Phyllocladus*), huon pine (*Lagarostrobus*), kauri pine (*Agathis australis*), the primitive seed-bearing cycads, the Northern Territory palm (*Livistona mariae*) and southern beech trees (*Nothofagus*) (see p. 227). Another species, the Wollemi pine (*Wollemia nobilis*, see Figure 4.11), was discovered in 1994 in an isolated rainforest gorge in the Wollemi National Park, 150 kilometres north-west of Sydney. It belongs to a group of plants known previously only from fossils dating back 150 million years.

Animals

Onychophorans or velvet-worms inhabit damp rainforest floors in only a few locations in the world. They have characteristics of two present-day groups of animals, the arthropods and annelids. They are known from the fossil record from the Cambrian period, over 500 million years ago.

The Queensland lungfish (*Neoceratodus forsteri*) belongs to a group of ancient bony fishes with fossils known from 400 million years ago. The present-day Queensland lungfish appears identical to fossils found in New South Wales that are 100 million years old.



Figure 4.12 The Queensland lungfish is a species of international significance. A recently proposed dam has threatened its habitat and breeding grounds in the Mary River near Gympie.

Two species of crocodiles occur today in Australia: the freshwater crocodile (*Crocodylus johnstoni*) and the saltwater crocodile (*Crocodylus porosus*). Crocodiles are known as fossils from the Triassic period, 220–250 million years ago.

Monotremes (the platypus and echidnas), although highly specialised in their ecological niches today, represent descendents of the earliest mammals, which laid eggs and produced milk for their young.

Today Australia's plants and animals, many of them unique and with origins dating back millions of years, are often referred to by scientists as Australia's 'biological ark'. They are an important heritage for all Australians and significant to anyone who studies the evolution of life on Earth.

4.2 INVESTIGATION

Changing ideas

Students will: identify data sources, gather, process and analyse information from secondary sources and use available evidence to illustrate the changing ideas of scientists in the last 200 years about individual species such as the platypus as new information and technologies became available.

Introduction

When Charles Darwin looked at marsupial fossils in Australia, he did not find them very different from living species. Today we have much more evidence of change in Australia, both in the climate and in living things (see Unit 4.2). The isolation of the Australian continent allowed the evolution of its plants and animals to follow its own course and to develop unique ecosystems. The fossil history of Australia shows slow but continual changes in living things. Current Australian species and fossil records provide evolutionary evidence of international significance in developing the theory of the evolution of life.

Scientists have changed their thinking in the past 200 years. New fossil discoveries have provided invaluable clues. Technologies, such as carbon dating, have allowed greater detail and closer comparison of evidence.

Purpose

To look at the changing ideas of scientists in the last 200 years about a named species.

Procedure

1. Select an Australian species, such as the platypus, for study.
2. Research your chosen species, identifying data sources and collecting information to write a report as outlined below.

Discussion

For a named Australian species, produce an illustrated report that includes the following:

- an outline of the changes we believe have occurred over time
- a description of the evidence for these changes (include both geological and biological evidence)
- a discussion of the ways our ideas have changed over the past 200 years. What new information has become available? What new technologies and/or processes have allowed us to find out more?

Skills and outcomes

P10, P12, P14

Type of activity

Second-hand data activity

Materials

- books, journals, Internet sites

See Analysing information

UNIT REVIEW 4.1

Gondwana: ancient super continent

Evidence for the rearrangement of crustal plates and continental drift indicates that Australia was once part of an ancient super continent.

Summary

- Australia was once part of an ancient landmass we call Gondwana. Geological evidence for this includes matching continental margins, the position of mid-ocean ridges, and the spreading zones between continental plates. Biological evidence includes the same fossils being found on Gondwanan continents, and the similarities between present-day organisms on these continents.
- Australia has been isolated for over 30 million years. During this time its unique flora and fauna evolved, including the now extinct megafauna.

Questions

1 Identify the pieces of evidence that support the theory that Australia was once connected to the super continent called Gondwana.

A matching continental margins
B position of spreading zones
C common fossils
D all of the above.

2 How are mid-ocean ridges formed?

A Ocean ridges form when molten material rises between two continental plates.
B Ocean ridges mark the boundary between two continental plates.
C Ocean ridges are formed from spreading zones.
D Pressure from continental plates forms new ocean ridges.

3 Which list contains the names of fossils found in rocks of the same age in Australia, Antarctica, and South America?

A *Glossopteris*, *Gangamopteris*, marsupials.
B *Nothofagus*, *Glossopteris,* megafauna
C rhea, emu, kiwi
D opossum, ostrich, *Glossopteris*.

4 a Explain how mid-ocean ridges and spreading zones are formed.
b Outline the relationship between these two different features.

5 Draw up a timeline that illustrates the key events in the formation and position of the Australian continent, from its super continent origins to the present.

6 Describe one example of geographical evidence and one example of biological evidence that supports the theory that Australia was once connected to the super continent called Gondwana.

7 Explain how Australia's isolation from other landmasses can be used to account for the large number of endemic species of plants and animals.

8 a List at least three extinct Australian megafauna and outline the two theories that have been proposed to account for the extinction of these organisms.

b Discuss current research into the evolutionary relationships between extinct species.

9 Outline some of the similarities and differences between present-day Australian native animals and their ancient relatives.

10 a Explain what is meant by 'extant Australian species'.

b Use examples to describe similarities between present-day organisms on Gondwanan continents.

11 What does the existence of living fossils suggest about the environment in which they live?

12 Analyse the changing ideas of scientists in the last 200 years about one species you have studied. Include in your answer an outline of the information and technologies that assisted the change in ideas.

4.2 CHANGES IN AUSTRALIAN FLORA AND FAUNA



The changes in Australian flora and fauna over millions of years have happened through evolution.

STUDENT LEARNING

In this unit students will:

- discuss examples of variation between members of a species
- identify the relationship between variation within a species and the chances of survival of species when environmental change occurs
- identify and describe evidence of changing environments in Australia over millions of years
- identify areas within Australia that experience significant variations in temperature and water availability
- identify changes in the distribution of Australian species as rainforests contracted and schlerophyll communities and grasslands spread, as indicated by fossil evidence
- discuss current theories that provide a model to account for these changes
- discuss Darwin's observations of Australian flora and fauna and relate these to his theory of evolution.

STUDENT ACTIVITY

Students will:

- gather, process and analyse information from secondary sources to develop a timeline that identifies key events in the formation of Australia as an island continent from its origins as part of Gondwana



CHANGES IN AUSTRALIAN FLORA AND FAUNA

STUDENT ACTIVITY continued

- gather information from secondary sources to describe some Australian fossils, where these fossils were found and use available evidence to explain how they contribute to the development of understanding about the evolution of species in Australia
- perform a first-hand investigation, gather information of named Australian fossil samples and use available evidence to identify similarities and differences between current and extinct Australian life forms
- present information from secondary sources to discuss the Huxley–Wilberforce debate on Darwin's theory of evolution
- perform a first-hand investigation to gather information of examples of variation in at least two species of living organism.

Evolution and variation in species

It was the observation of **variations** between species and individuals by scientists in the 19th century that led to the proposal by Darwin and Wallace of the theory of natural selection. This theory explains how changes over time, or **evolution**, can occur in living things.

The theory of natural selection

The theory of natural selection explains how changes over time, or evolution, can occur in living things.

The theory of natural selection proposes that it is the environment that selects favourable variations and eliminates harmful ones. After many generations of selection, the characteristics of a population may change and the population becomes adapted to the environment.

Darwin's theory of evolution by natural selection has four main points:

1. In any population there are variations; all the members of one species are not identical.
2. In any generation there are offspring that do not reach maturity and reproduce; the characteristics of these organisms are removed from the population.
3. Those organisms that survive and reproduce are well adapted to that environment; they have favourable variations (survival of the fittest).
4. Favourable variations are passed on to offspring; they become more and more common in the population.

The main contributions by Darwin to the theory of evolution were (a) the idea that species can change over time, and (b) the mechanism of natural selection to explain how change takes place.

The native plants and animals present in Australia today are largely the result of changes over millions of years. But how did these changes come about?

BIOFACT

Alfred Wallace (1823–1913) came to the same conclusions about evolution that Charles Darwin had reached. Their first articles on this subject were published in England in 1858, in the same issue of the *Journal of the Linnean Society*.

Variation within a species—some examples

Differences between organisms belonging to the same species are called variations.

discuss examples of variation between members of a species

When we look at individuals belonging to the same species—just think of yourself and other people you know—we can see differences. These small differences between organisms belonging to the same species are called variations. They include differences in features, such as size and colour of various body parts. Today we can also identify biochemical differences between individuals.

The white-naped honeyeater, *Melithreptus lunatus*, occurs throughout eastern Australia, and also in south-western Western Australia (Figure 4.14). However, populations in different areas show distinct differences in several features. Those in eastern Australia have a short bill and an orange-red eye-patch (Figure 4.14b). These belong to the race *lunatus*. But populations in Western Australia have larger bills and white or green eye-patches (Figure 4.14c). These belong to the races *whitlocki* and *chloropsis*. Because the races in Western Australia cannot interbreed with eastern populations (they are geographically isolated), and are subject to different environmental conditions, they might eventually evolve into a different species. This is probably how separate but similar-looking species have evolved; for example, the crimson rosella of eastern Australia and the Adelaide rosella of South Australia. In Investigation 4.7 you will look at examples of variation within a species (see pp. 256–257).

The floral emblem of Victoria is the common heath, *Epacris impressa*. This plant shows a remarkable variation in the colour of the flowers, from pure white to pink to deep red (Figure 4.15). This variation is so great that for a long time the

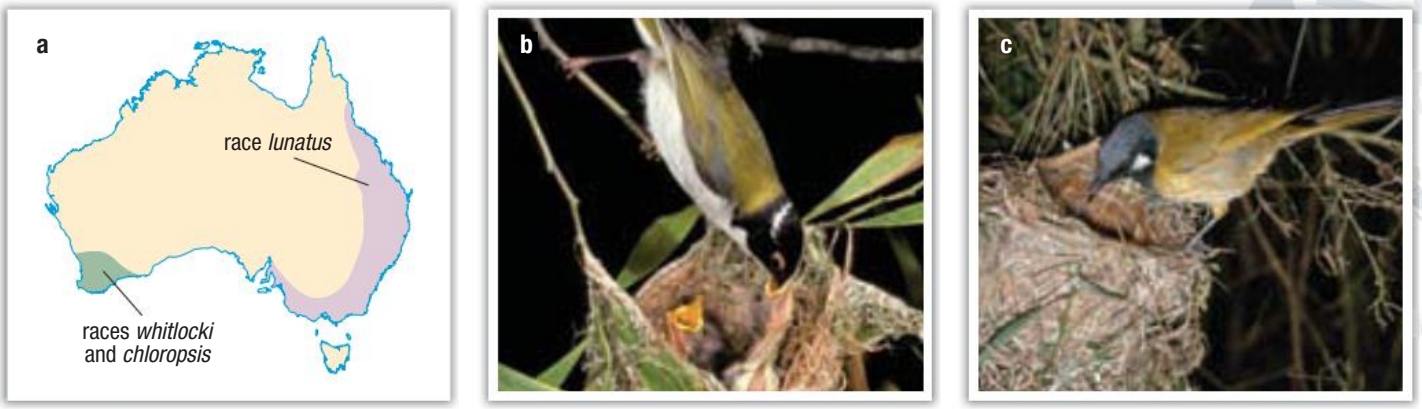


Figure 4.14 (a) Distribution of the white-naped honeyeater, *Melithreptus lunatus*. (b) The eastern form of the white-naped honeyeater (race *lunatus*). Note the eye-patch colour. (c) The western form (race *chloropsis*).



Figure 4.15 Two colour forms of the common heath, *Epacris impressa*.

different forms were classified as different species. It is still not clear what causes the different colours to occur, although soil type might be an important factor.

Variation within a species—chances of survival

identify the relationship between variation within a species and the chances of survival of species when environmental change occurs

Variation within a species becomes important in evolutionary terms when environmental change occurs. We know from past evidence that the environment and ecosystems have changed over time. We are aware that Earth is currently undergoing further climate change, and we are concerned for the survival of many species from both climate change and human activities.

According to Darwin, for an individual organism to survive, it will have favourable variations. These are the features that will enable it to survive and reproduce in its environment. By having variation within a population however, there will be individuals that may survive should there be a change in the environment. When we look at separate species, we can see this variation between different members of a population. If there is an environmental change, having variation within a species will increase the chances of survival of some members, and therefore the chance of survival of the species.

Evidence of Australia's changing environment

identify and describe evidence of changing environments in Australia over millions of years

When Charles Darwin looked at marsupial fossils in Australia, he did not find them very different from living species. Today we have much more evidence of change

in Australia, both to the climate and to living things. When environmental change occurs and the climate becomes hotter, colder, wetter or drier, the distribution and abundance of living things changes. Those organisms with favourable variations may survive the changes, and in doing so bring about a change in species by natural selection. Other organisms die out or move to other environments.

Australia has undergone physical and environmental changes, which have affected its flora and fauna, and changes are still occurring. We find evidence of these changes from studying the geography and geology of Australia, and from the fossils found in the rocks of various ages. These have allowed scientists to build a picture of the history of the changes to Australia's environment.

Geological and geographical evidence

Examples of geological and geographical evidence include:

- The black coal deposits around the Sydney basin are evidence of swampy environments during the Permian period (298 million years ago) and contain fossils of the plants growing there (see Figure 4.5, p. 227).
- Sediments, soils and land structures are evidence of the great inland sea that broke Australia into four large islands during the Cretaceous period 65–141 million years ago. This is supported by the fossil evidence of many marine animals that have been found in outback Australia.
- Studying rocks and landforms has revealed that sea levels have risen and fallen—mainland Australia and Tasmania have been joined and parted at least eight times in the past 30 million years.
- The flatness and lowering of the land surface to make Australia the flattest continent on Earth is evidence of continual erosion over millions of years.
- Volcanic rocks and landforms are evidence of volcanic activity that created extensive lava flows around the east coast of Australia about 35 million years ago.

Fossil evidence

Fossil evidence shows us the plants and animals in a particular place at a particular time. From studying fossil finds, particularly from some key sites such as Naracoorte and Riversleigh (see pages 296 and 298), we are able to build up a picture of the different animals and plants, and the changes that have occurred over time.

As the climate became warmer and drier in the Quaternary era, plant communities changed. For example, pollen found in the Wyrie Swamp, 80 km south of the Naracoorte Victoria cave, suggests that the earlier sediments supported eucalypt forests and scrub plants. These were replaced with open woodland trees and grasses, followed by the *Casuarina* forests 11 000 years ago which are still present there.

Kangaroo fossils found in the Naracoorte caves show a great reduction in diversity and numbers, since the late Pleistocene changes reduced their habitats. The Naracoorte caves contain fossils of thousands of animals—frogs, reptiles, birds and mammals. Most of these are now extinct species. One fossil echidna species found there has been found surviving in New Guinea, but none have been found in Australia.

From evidence such as this, scientists have built up a history of the changing environments, and the changing distribution and diversity of plants and animals in Australia.

4.3 INVESTIGATION

A timeline for Australia

Students will: gather, process and analyse information from secondary sources to develop a timeline that identifies key events in the formation of Australia as an island continent from its origins as part of Gondwana.

Introduction

Scientific evidence suggests that about 160 million years ago Australia was part of a super continent called Gondwana. Over time this large landmass split up to form the separate southern continents we see today, including the island continent of Australia.

The evolution of the Australian continent and its plants and animals can be traced by studying its rocks and fossils. Fossil and biochemical evidence have provided evidence of Australia's early life and activities, and the relationship between past and present.

Purpose

1. To draw up a timeline and identify key events in the formation of Australia from the time of Gondwana.
2. To identify key fossils and explain how fossil evidence contributes to the development of understanding about the evolution of species in Australia.

Procedure

1. Identify data sources and gather data about the key events from the break-up of Gondwana to the formation of Australia as a separate island continent. (Note: A key event is a major happening—for example, the separation of New Zealand from Australia.)
2. Copy out Table 3.2 on pages 174–175, adding two extra columns: 'Australia: Key events' and 'Australia: Key fossils'.
3. Work in teams with each team researching a different era.
4. Research key events in the history of Australia for the relevant era. (See pp. 224–225. Note: Not every period will have a key event.)
5. Enter your data into the appropriate place in your table.
6. Research Australian fossil plants and animals. (See p. 171, pp. 226–227 and pp. 296–298. Note: Not every period will have a key fossil.)
7. Enter your data into the appropriate place in your table. For each example, give the location where this fossil has been found.
8. Share your information with the other teams. Collect information from other teams to complete your table.
9. Australia has a number of key sites that have contributed greatly to our knowledge of the evolution of Australian species. Research the fossil discoveries at one of these sites. (See pp. 297–298.)

Skills and outcomes

P10, P14, P15

Type of activity

Second-hand data activity

Materials

- books, journals, Internet sites, maps, CD-ROMs

See:
- Presenting information
- Analysing information

Discussion

1 Why is evidence of key events important in the development of our understanding of the evolution of our continent?

2 How do fossils contribute to our understanding of life, both past and present?

3 Explain the importance of a named fossil site in Australia, giving at least one example of a fossil found there that has contributed to our understanding of evolution.

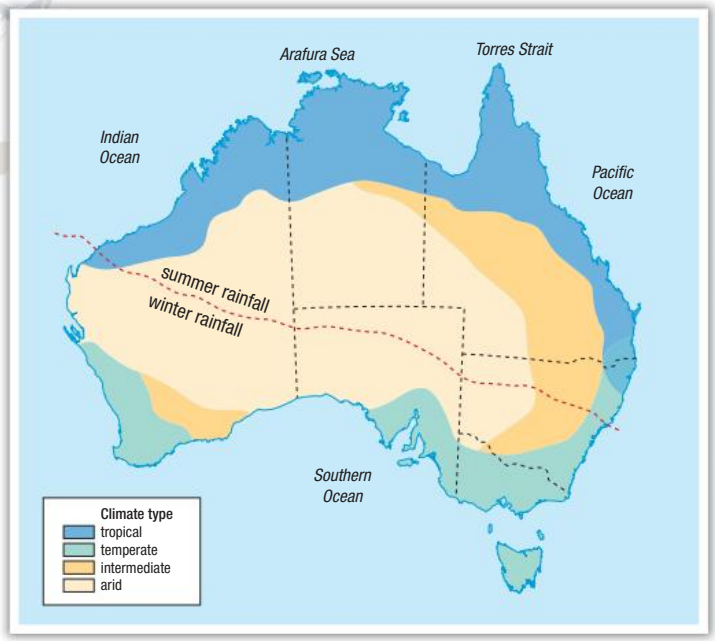


Figure 4.16 Australia is an island continent with a diversity of habitats, plants and animals. Much of the land is below 300 m in altitude and is arid. Only the edge of the continent has enough rainfall to enable tall forests to grow. The climate of northern Australia is tropical; southern Australia is temperate.

The changing climate

When Australia and Antarctica were still joined together, about 65 million years ago, the climate was cool and wet and much of the land was covered with temperate rainforest. About 45 million years ago, as Australia completed its separation from Antarctica and began to drift northwards, the wind patterns changed (see Figure 4.2, p. 224). Warm air moving south from the tropics was blocked as air and ocean currents began to circulate around Antarctica. Antarctica became colder and the ice cap slowly grew. Australia became cooler and drier. As Australia drifted northward, however, it gradually became warmer. The area of rainforest shrank and other types of vegetation increased.

As Australia moved north of the Tropic of Capricorn, the climate in the northern part became tropical. There have been many climatic fluctuations since the late Neogene period, reflecting global cycles. There have been warmer, wetter periods when forests expanded, and cooler, drier periods when grasslands increased. Overall, Australia has become warmer and drier, particularly inland. The current Quaternary period has had dramatic temperature fluctuations, including many ice ages. The last 120 000 years has been a warm period during which fire has become a significant environmental feature.

TABLE 4.1 Summary of Australia's changing climate

Time	Geological history	Australia's climate
65 mya	Australia and Antarctica joined	cool and wet
45 mya	Australia and Antarctica separate	cool and dry
30 mya	Australia drifting north	warmer
7 mya–present	Australia drifting north	warmer and drier

*mya = millions of years ago

The Australian environment

identify areas within Australia that experience significant variations in temperature and water availability

Temperature Australia is a hot continent. The January (summer) maximum and July (winter) minimum temperatures are shown in Figure 4.17. No place in Australia suffers intense cold. Inland, the temperature range is wide because the heat from the day is rapidly lost at night. Most of Australia has tropical or

subtropical temperatures. Only in the south-east and south-west are there milder, temperate conditions.

Temperature variation in Australian inland deserts and grasslands can be very great. Rapid heating in the day can raise the temperature to over 40°C in summer, but rapid cooling at night drops the temperature quickly. In winter, daytime temperatures may be over 20°C but at night can drop to below freezing.

Water availability Australia is the world's driest continent. Three-quarters of Australia receives less than 800 mm annual rainfall (Figure 4.18). Inland Australia and most of the west coast have a low, unreliable rainfall; all seasons are dry. A common pattern over large areas is for droughts and erratic rainfall followed by floods. Along the east coast, rainfall occurs throughout the year. Water availability is usually a problem over large areas of inland Australia. Many bodies of water are temporary and the levels and flow of rivers and creeks are unpredictable. Floods followed by drought is a common pattern.

Large dry air masses (anticyclones) are generally situated over the interior. They move south during the summer, attracting warm moist air from equatorial regions in the form of monsoons and tropical depressions. This gives the northern part of Australia its 'wet' season. In winter, the anticyclones move north and a westerly air stream from the Southern Ocean brings winter rains to the south of the continent.

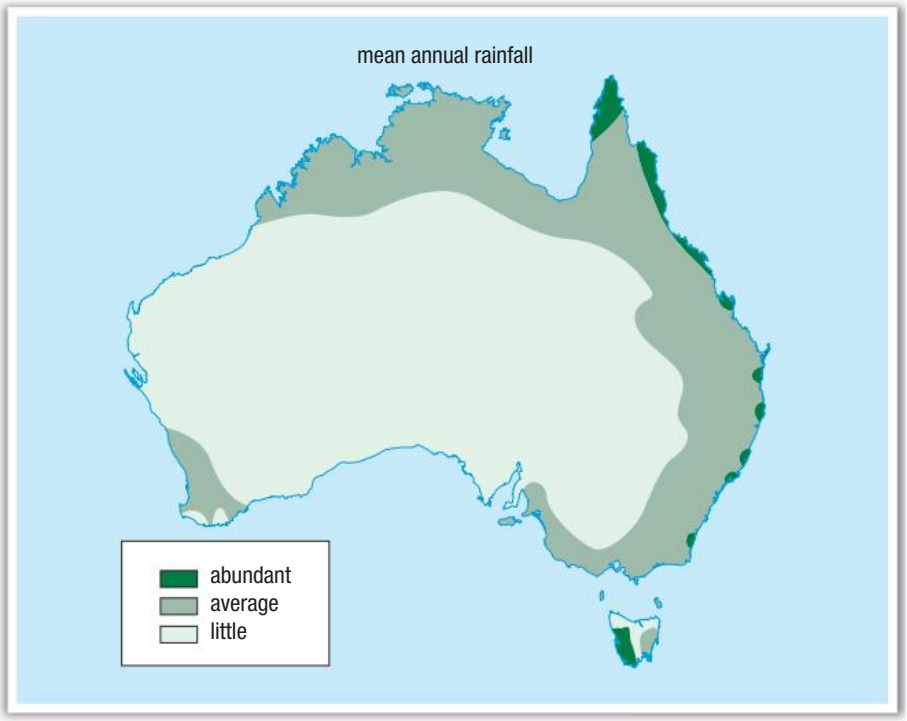


Figure 4.18 The distribution of rainfall in Australia.

Aridity Lack of rainfall, combined with high temperatures means that much of inland Australia is arid. One-third of mainland Australia is desert with an annual rainfall of less than 250 mm. A further third is semi-arid with an annual rainfall between 250 and 500 mm. Overall, Australia's climatic pattern is one of increasing aridity moving inland from the coast, and of increasing temperatures from south to north.

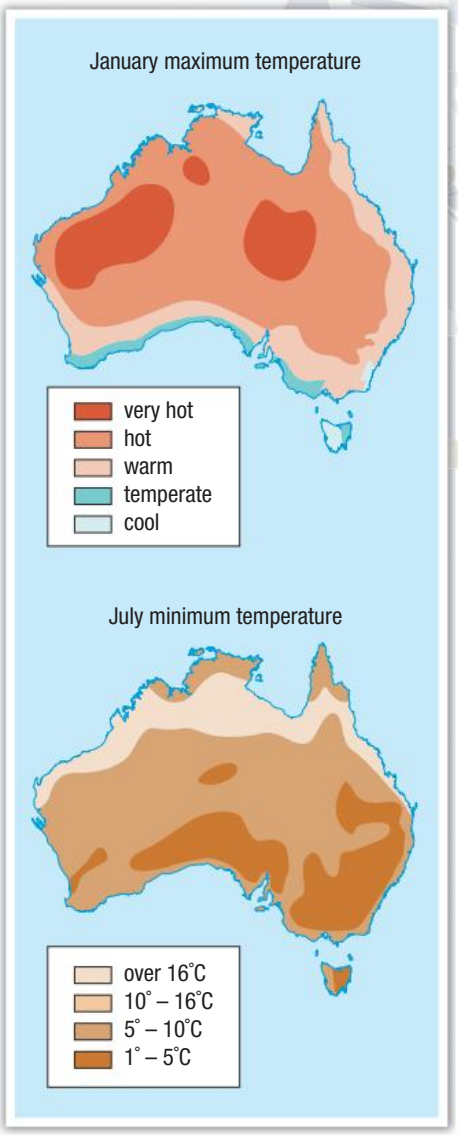


Figure 4.17 Summer maximum and winter minimum temperatures in Australia.

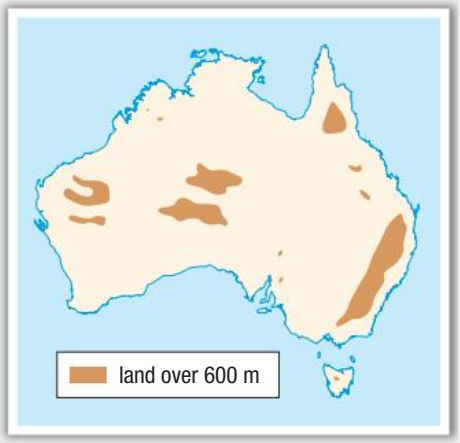


Figure 4.19 Australia is a relatively low, flat continent; few areas are above 600 m in altitude.

The island continent—more facts

Size Australia is an island continent surrounded by ocean. The greatest width of land occurs along the Tropic of Capricorn. Compared with other continents it covers a relatively small area (5.6 million km^2)

Topography Australia is a comparatively low, flat continent. Rainfall and temperature are modified significantly only by the eastern highlands, which produce a definite rain-shadow effect along the east coast and Tasmania.

Ancient soils Australia is geologically stable, its rocks are old and eroded, and it has some of the Earth's poorest soils. The soils are leached and minerals are impoverished over much of the continent. Most soils are deficient in phosphorus, and there is usually only a thin surface layer of nutrients.

Fire Wildfire is a relatively common event in the Australian environment. Many plants have the ability to survive regular burning. It has been estimated that grasslands experience fires every 5–7 years, dry eucalypt forests every 11 years, and tall wet eucalypt forests every 40–50 years.

Vegetation The pattern of increasing aridity inland from the coast is shown in the change from forest ecosystems through to scrub and grasslands.

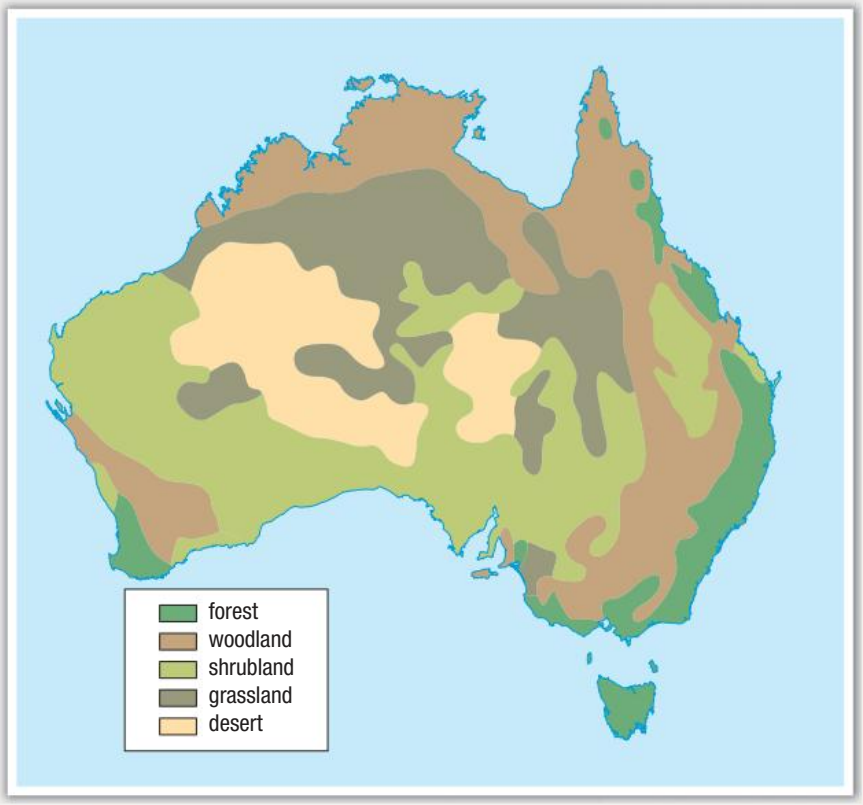


Figure 4.20 The distribution of major vegetation types in Australia.

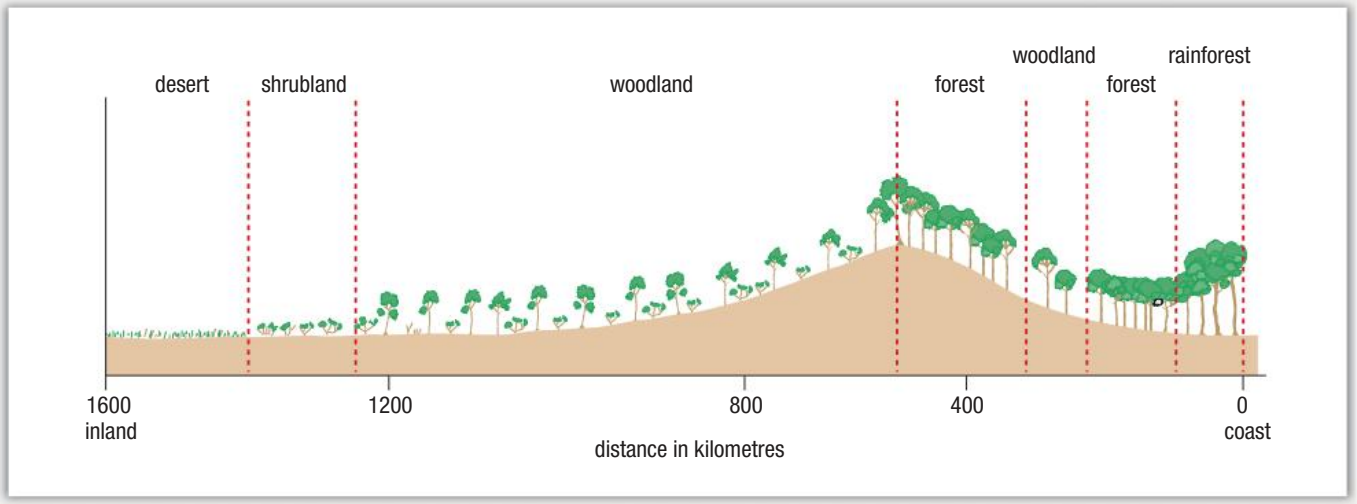


Figure 4.21 Changes in aridity from the coast to the inland in eastern Australia are reflected in vegetation changes.

Changes in the distribution of species

identify changes in the distribution of Australian species, as rainforests contracted and sclerophyll communities and grasslands spread, as indicated by fossil evidence

As climatic conditions changed on the Australian continent, so did the Australian biota. Increasing heat and aridity favoured the plants and animals that could tolerate such conditions, and these spread out to colonise new ecosystems and increased in numbers. Those that could not became restricted in both distribution and abundance. They either died out or became confined to areas which had suitable environmental conditions.

Rainforests contracted and all tall forests became restricted to the edge of the continent. Sclerophyll communities and grasslands increased over time. The face of Australia changed completely, particularly in the centre of the continent.

Sclerophyll (which means 'hard leaves') refers to plants with tough, evergreen leaves such as eucalypts.

Divergent evolution (**adaptive radiation**) is the change in a species from its original form to a different form adapted to different environments or ways of life.

Australia's vegetation is dominated by two groups of flowering plants, which have successfully evolved to colonise a wide variety of habitats: the acacias (wattles) and eucalypts. Both groups of plants have evolved forms which can survive well in hot, arid conditions. The 950 species of acacias are found almost everywhere, from temperate and tropical rainforest to woodlands, arid and semi-arid areas, coastal heaths and sand dunes. The 800 species of eucalypts are found mainly in forests and open woodlands.

Another group of flowering plants, the Proteaceae, has diversified widely since its origins in Gondwana. Thirty-five types are endemic to Australia, including banksias, grevilleas, hakeas and waratahs.

When Australia became a separate continent, it contained three types of mammals—placentals, marsupials and monotremes. The fossil record shows us that the placental mammals, apart from bats, died out. Placental mammals did not reach Australia again until Australia drifted close enough to Asia for colonisation

BIOFACT

Some examples of Australian marsupials with various food preferences are:

- Herbivores—koalas, kangaroos and possums
- Carnivores—quolls
- Insectivores—planigales
- Carrion eaters—Tasmanian devil
- Nectar eaters—pygmy-possums
- Omnivores—bandicoots

As Australia became warmer and drier, both plants and animals with adaptations to enable them to survive this increasing aridity evolved.

to occur from the north. But marsupials diversified, and as the climate became warmer and drier, they spread out to occupy many ecosystems. Today there are 141 species of marsupials in Australia, usually grouped according to their food preferences.

Australian frogs evolved in an interesting way as Australia became warmer and drier. They too have diversified to occupy a wide variety of habitats, including inland arid areas. Compared with amphibians in other areas of the Earth, they show a lack of dependence on permanent water. Many of them (such as the water-holding frog, *Cyclorana platycephala*) breed in temporary pools and have a relatively brief tadpole stage of development.



Figure 4.24 Despite its fierce looks, the Tasmanian devil (*Sarcophilus harrisii*) feeds only on carrion.

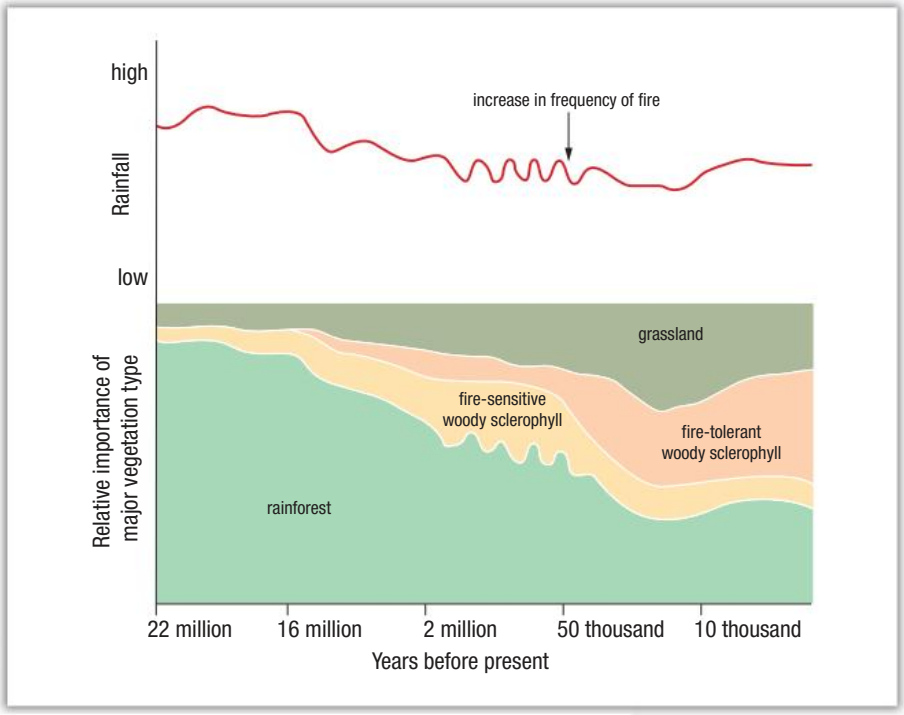


Figure 4.22 Over the last 20 million years, the area of rainforest in Australia has decreased, while the area of sclerophyll forests and grasslands has increased. This fundamental change in vegetation is related to changes in rainfall and an increase in aridity. (From M. Archer and G. Clayton, *Vertebrate Zoogeography and Evolution in Australasia*.)

Figure 4.23 Many acacias have lost their leaves and have flattened photosynthetic leaf stalks called phyllodes.



4.4 INVESTIGATION

Using fossil evidence

Students will: gather information from secondary sources to describe some Australian fossils, where these fossils were found and use available evidence to explain how they contribute to the development of understanding about the evolution of species in Australia.

Introduction

Sixty-five million years ago, when Australia was still part of Gondwana, the climate was cool and wet and much of the land was covered with temperate rainforest. As Australia split from Antarctica and drifted north, the climate changed and Australia became drier and warmer. The rainforests shrank, and new ecosystems such as sclerophyll communities and grasslands emerged.

Pollen grains, produced in the stamens of flowering plants (see p. 272), are enclosed by very hard outer coverings or walls. The surface and shape of the pollen wall varies between plant species and this can be used to distinguish and identify them. Pollen grains are resistant to chemical attack and, as a result, are often found preserved in sediments. Analysis of pollen grains from sediments may indicate the types of plants present when the sediment formed. Knowing the type of climate these plants need in order to survive helps us to infer what the climate was like in the past.

Similarly, the location of fossil finds of animals, plus the characteristics shown by those animals, can help scientists understand the evolution of species in Australia.

Purpose

A To discuss the relationship between changing Australian biota and changing climatic conditions on the Australian continent using evidence from pollen analysis.

B To describe a named Australian fossil and use evidence to explain how it contributes to our understanding of the evolution of its species.

Procedure A

1 Read pages 240–246.

2 Examine Figure 4.25, which shows an analysis of the number and types of pollen grains found in sediments at Lynch's Crater in northeast Queensland.

Discussion

1 Outline the changes that have occurred in the Australian climate as it separated from Antarctica and drifted northward.

2 What happened to the Australian biota as the climate changed?

3 The scientists who analysed the pollen data from Lynch's Crater think the data provides evidence of major changes in the plant community about 75 000 years ago. Examine line A and line B of Figure 4.25.

Skills and outcomes

P7, P10, P12, P14

Type of activity

Second-hand data activity

Materials

- books, journals and Internet access

SKILLS See Analysing information

a What do you think the changes were?

b What environmental factors could have produced these changes?

4 In what type of ecosystem would you expect to find eucalypts (line C) and casuarinas (line D)? Explain your answer.

5 The scientists also concluded that about 7000 years ago there was a significant increase in rainfall. On what evidence did they base this conclusion?

6 The amount of charcoal (fragments of burned trees and shrubs) in the sediments (line E) increased greatly about 38 000 years ago. What other change coincided with this increase?

7 In an attempt to explain the increases in charcoal, the scientists considered two possibilities:

- that a climatic change occurred, which resulted in the development of a plant community that was more prone to bushfire, but that was also capable of regenerating after bushfires
- that something caused an increased occurrence of bushfires, and this in turn produced a change in the vegetation.

a Suggest two possibilities that might have caused an increased occurrence of bushfires.

b What further evidence would help to distinguish between the two possibilities?

Procedure B

1 Choose an Australian animal or plant fossil and research where it was found and its characteristics.

2 Write a description of your chosen fossil, including what its characteristics indicate about where and how it lived.

3 Describe the location of the fossil find and what this tells you about the distribution of the species.

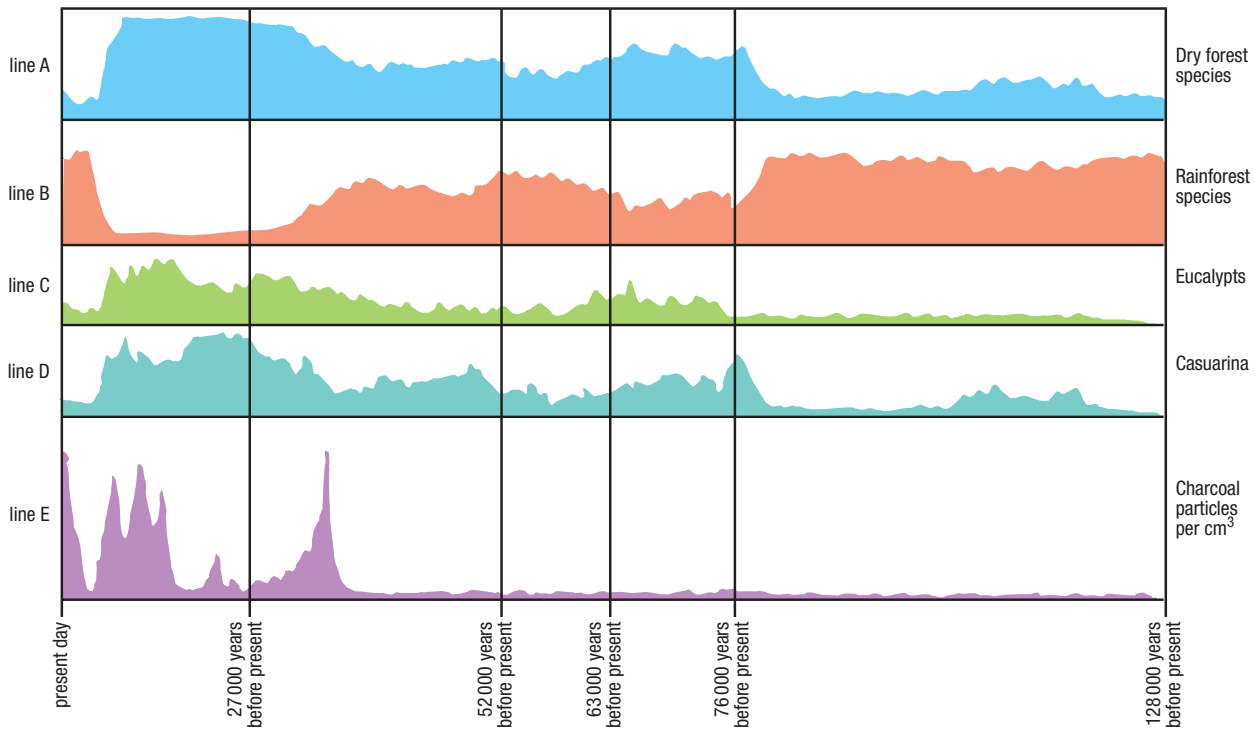
Discussion

Discuss how the fossil you studied contributes to our understanding of the evolution of that particular species.

Conclusion

1 Write a paragraph to explain how analysing pollen data can help to show the type of plant community that existed in the past, and how we can infer what the climate was like from this evidence.

2 Write a paragraph to explain how the study of Australian fossils can contribute to the development of understanding of the evolution of species in Australia.



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Figure 4.25 Diagram to show the number and types of pollen from the analysis of sediments found at Lynch's Crater, Queensland.

Theories about changes to Australian species

Two theories that provide a model to account for the changes, as indicated by fossil evidence, to the distribution and abundance of Australia's species, are climate change and human impact.

discuss current theories that provide a model to account for these changes

Climate change

Many extinctions occurred at about the end of the last Ice Age, in the Pleistocene period (see Table 3.2, pp. 174–175). As the weather warmed and conditions became drier, ecosystems changed and habitats were gained and lost. In Australia, the climate changed from cold and dry to warm and dry, and water became scarce.

All available evidence indicates that the contraction of rainforests and the rise of woodland and grassland communities in Australia is the result of increasing temperature and a decline in the availability of water. At two places in Australia—Riversleigh in northwestern Queensland and Naracoorte in South Australia—fossils have been found that help give us a clearer picture of the evolution of Australian ecosystems to warmer and drier conditions. Riversleigh demonstrates the change from rainforest to dry habitats through its fossil collection, dating from the Miocene to the Pliocene period. Fossils found at Naracoorte, together with pollen data from nearby Wylie Swamp, indicate that, during the Quaternary, inland lakes dried up and vegetation changed from forest to open woodland.

The rise and fall of Australian mammals and the radiation of marsupial groups in terms of their numbers, types and their geographic location can also be shown to be related to climate.

Human impact

Humans have come as invaders to Australia. The megafauna were big and slow, and therefore vulnerable to hunting—in particular to the arrival of skilled hunters. It is thought that the extinction of many of Australia's megafauna occurred at about the time that humans arrived on the continent for the first time. Human use of fire as part of hunting practices also modified the environment.

The arrival of Europeans has changed local ecosystems extensively, particularly through their agricultural methods and the introduction of new species. Tim Flannery, an Australian zoologist and author of the book *The Future Eaters*, suggests that humans have upset the balance of life in Australia so much that we threaten the land that supports us and consequently our own survival.

Human impact has resulted in a loss of Australian species and our farming practices, water use and introduction of species from other parts of the world have contributed to increasing changes to Australian ecosystems.

Climate change and the future

Earth, including Australia, is experiencing rapid climate change. In Australia the following changes have been recorded:

- The average temperatures have increased by 0.90°C since 1910, but mostly since 1950.
- Increase in frequency of heatwaves
- Decrease in frequency of frosts
- Increase in numbers of warm days and nights and decrease in numbers of cool days and nights
- There has been a substantial increase in rainfall in northwest Australia over the last 50 years. There has been a decrease in rainfall in eastern Australia since 1950 and in southwest Western Australia since the 1970s.
- Sea levels have risen by about 10 cm since 1920 and substantial warming has occurred.

Future predictions for Australia include more droughts, more floods, water shortages, rising sea levels, extreme weather such as severe hailstorms in the Sydney area, and an increased risk of bushfires.

Plants and animals in Australia are predicted to suffer drastic reductions in numbers and distribution as a result of changes to their habitats. A significant loss of biodiversity is predicted to occur by 2020.

See the Australian Government's website Climate Change in Australia and the website of the Bureau of Meteorology for more information.

4.5 INVESTIGATION

Current and extinct life forms

Students will: perform a first-hand investigation, gather information of named Australian fossil samples and use available evidence to identify similarities and differences between current and extinct Australian life forms.

Introduction

Australia is renowned for its unique flora and fauna. It should come as no surprise to find that our ancestral flora and fauna is just as unique. Giant kangaroos and wombats, together with marsupial lions, once roamed this continent. Why don't they exist now? What current species have evolved from them, and how do scientists know of their existence? Fossils provide the answer. Fossils help to illustrate the process of evolution and in doing so provide us with some understanding of the ancestry of current organisms.

Purpose

1 To describe a number of named Australian fossils.
2 To identify similarities and differences between current and extinct organisms.

Procedure

This investigation may take place in class, or on a visit to a museum or fossil site.

1 Carefully examine each of the Australian fossil specimens.
2 Make a large, labelled sketch of each fossil.
3 For each fossil, suggest a modern-day representative. Write down this information beside your sketch. If you know of no modern-day equivalent write 'no modern-day representative'.
4 For each fossil, state the supporting evidence—the differences and similarities—that you used in order to identify a modern-day representative. Record this information beside your sketch. If you are unable to find a modern-day representative of a particular fossil, suggest a reason why.

Discussion

1 For a named Australian organism, describe the similarities and differences between the current form and its extinct fossil ancestor.
2 For a named Australian organism, now extinct but known from the fossil record, explain what factors you think may have contributed to its extinction.
3 Explain the advantages in an investigation of examining actual fossils rather than observing photos or diagrams of fossils.
4 Outline how the study of extinct and current Australian organisms provides evidence for evolution.

Skills and outcomes

P10, P12, P14, P15

Type of activity

First-hand investigation, second-hand data activity

Materials

- named Australian fossils
- hand lens or stereoscopic microscope
- books, journals, Internet sites



See:
- First-hand investigations
- Analysing information

Charles Darwin in Australia

discuss Darwin's observations of Australian flora and fauna and relate these to his theory of evolution

Darwin's observations and his theory of evolution

Darwin had abandoned studies in medicine and theology to follow a career as a naturalist. In 1831 he left England on a ship called the *Beagle*, which travelled around the world, mainly to chart the coast of South America. The *Beagle* was away for 5 years. During this time, Darwin observed and collected examples of plants and animals in South America, the Galapagos Islands and Australia. He examined fossils, as well as living specimens, and studied the events of the Earth's geological history.



Figure 4.26 Charles Darwin was only 22 years old when he left England to explore the southern hemisphere on the *Beagle*.

As he puzzled over the variety of organisms he saw, and the adaptive nature of this variety, Darwin began to question the theory of special creation he had been taught.

He tried to explain the similarities between groups he saw: similarities between animals on the Galapagos Islands and those on the South American mainland; similarities between living forms and fossils; and similarities between adjacent species as he travelled south on one continent. He became convinced that new species can develop from an ancestral type. He described an evolutionary 'tree', with a stem that originated 3000 million years ago, and branches to represent the diversity of new species that gradually developed in different environments.

Darwin visited Australia from January to March 1836. He visited New South Wales, staying in Sydney and visiting the area around Bathurst, and also visited Hobart in Tasmania, and Albany in Western Australia. In his letters and diaries, and later his books, he used examples taken from his observations of Australian flora and fauna to support his theory of evolution by means of natural selection.

When staying on a sheep station at Wallerawang, Darwin observed 'crows like our English jackdaws were not uncommon, and another bird something like the magpie'. He saw a rat-kangaroo (a potoroo) which he compared to a European rabbit both in size and behaviour. He watched platypuses playing and diving in the Cox's River 'like so many water rats.' He watched a fly and an ant fall into the conical trap of an ant-lion and wrote 'without doubt this predacious larva belongs to the same genus, but to a different species from the European one'.

In his diary he recorded some of his early thoughts regarding what later developed into his ideas about evolution:

> *Earlier in the evening I had been lying on a sunny bank & reflecting on the strange character of the Animals in this country as compared to the rest of the World. A Disbeliever in everything beyond his own reason, might exclaim, 'Surely two distinct Creators must have been at work'; their object however has been the same & certainly in each case the end is complete.*

About the ant-lion, he wrote 'Would any two workmen ever hit on so beautiful, so simple & yet so artificial a contrivance? I cannot think so.'

Darwin had been looking at different organisms that lived in similar environments and showed similar adaptations. When discussing how animals and plants may become diversified for different 'habits of life' in *The Origin of Species*,

BIOFACT

2009 marked the 200th anniversary of Charles Darwin's birth and the 150th anniversary of the publication of The Origin of Species. Many events and exhibitions were held—new reviews of Darwin's work and his contribution to science were published.

Darwin used Australian marsupials as an example, although he saw them as in an early stage of diversification.

Darwin on eucalypts

When Darwin first ventured into the Australian bush, he noticed how different the trees were:

> *The trees nearly all belong to one family, and mostly have their leaves placed in an upright position instead of, as in Europe, in a nearly horizontal position: the foliage is scanty, and of a peculiar pale green tint, without the gloss; hence the woods appear light and shadowless. This, although a loss of comfort to the traveller under the scorching rays of summer, is of importance to the farmer, as it allows grass to grow where it otherwise would not. The leaves are not shed periodically; and this appears to be the case in the entire southern hemisphere, namely South America, Australia, and the Cape of Good Hope. The inhabitants of this hemisphere and of the intertropical regions thus lose, perhaps, one of the most glorious (though to our eyes common) spectacles in the world—the first bursting into full foliage of the leafless tree. They may, however, say that we pay dearly for this by having the land covered with mere naked skeletons for so many months. This is too true; but our senses thus gain a keen relish for the exquisite green of the spring, which the eyes of those living within the tropics, sated during the long year with the gorgeous productions of those glowing climates, can never experience.*
>
> *The greater number of trees, with the exception of some of the blue-gums, do not attain a large size; but they grow tall and tolerably straight, and stand well apart. The bark of the Eucalyptus falls annually, or hangs dead in long shreds, which swing about in the wind, and give to the woods a desolate and untidy appearance. I cannot imagine a more complete contrast, in every respect, than between the forests of Valdivia or Chiloe and the woods of Australia.*

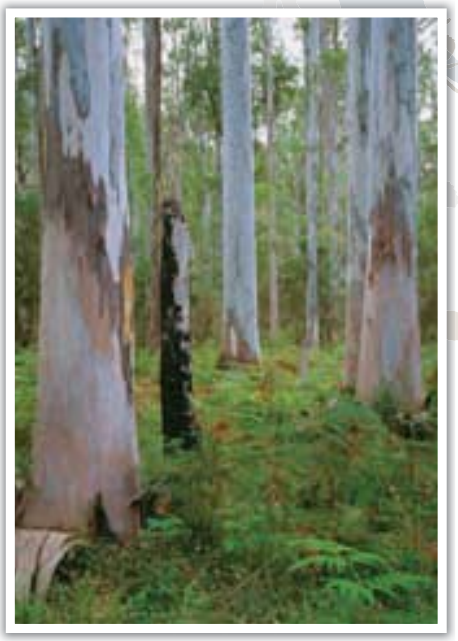


Figure 4.27 The Sydney blue gum (*Eucalyptus saligna*) was a familiar sight for Darwin during his visit to New South Wales in 1836. It grows up to 50 metres tall in deep soils.

The Huxley–Wilberforce debate

Darwin's book *The Origin of Species* created a storm of controversy when it was published in 1859. His theory affected the prevailing beliefs about the creation of humankind, because it suggested that humans were subject to the same evolutionary rules as any other species; we were no longer a special creation in the image of God. At the very heart of the controversy stood religion. What use would religion be now if its teachings over the centuries had been lies? People either believed in the Bible in its entirety, or not at all.

The Church was a profound critic of Darwinism. It strove to prove that the doctrine of creation was more valid than the theory of evolution. The criticism came to a head in June 1860. On the evening of 30 June, an unexpected debate took place during the meeting of the British Association for the Advancement of Science, held at Oxford University. Samuel Wilberforce (1805–1873) was the Bishop of Oxford and a powerful force for conservatism. He was known as 'Soapy Sam' for his slipperiness in debates. He attempted to destroy Darwin's credibility by reading a paper in which he claimed that there was nothing in the theory of evolution: 'rock-pigeons were what rock pigeons had always been', he said. Wilberforce had been coached in his arguments by Richard Owen, a jealous and hostile opponent of Darwin.

At the meeting was Thomas Huxley (1825–1895), an eminent biologist and friend of Darwin. He described himself as the 'gladiator-general' of Darwinism, but was more often known as 'Darwin's Bulldog' for his tenacious and outspoken support for Darwin's theory. Huxley often spoke at public debates and often clashed with the clergy and journalists. He did more than anyone to bring about the acceptance of Darwin's theory among scientists and the general public.

After finishing his paper, Bishop Wilberforce turned to Huxley and asked whether it was 'through his grandfather or his grandmother that Huxley was descended from an ape?' Huxley later described his reply in this way:

> *He [Bishop Wilberforce] performed the operation vulgarly and I determined to punish him—partly on that account and partly because he talked pretentious nonsense… If, then, said I, the question is put to me 'would I rather have a miserable ape for a grandfather, or a man highly endowed by nature and possessed of great means and influence, and yet who employs these faculties and that influence for the mere purpose of introducing ridicule into a grave scientific discussion', I unhesitatingly affirm my preference for the ape. Whereupon there was unextinguishable laughter among the people, and they listened to the rest of my argument with the greatest of attention…*

Richard Dawkins is a prominent scientist and author. In his book *The Selfish Gene* he argues that genes are the fundamental units of natural selection. He has been referred to as 'Darwin's Rottweiler' for his outspoken and fierce support for Darwin's theory of natural selection.

Huxley was of course referring to the bishop himself. The popular version of Huxley's remarks was that Huxley had said he preferred to have an ape for a grandfather, rather than a bishop!

There was much public discussion about the debate, and Wilberforce, Huxley and Darwin were each ridiculed by different editors and journalists. But it was clear that not only Huxley's now famous reply to Wildberforce, but also his brilliant defence of evolution, made him the acknowledged winner of the debate.

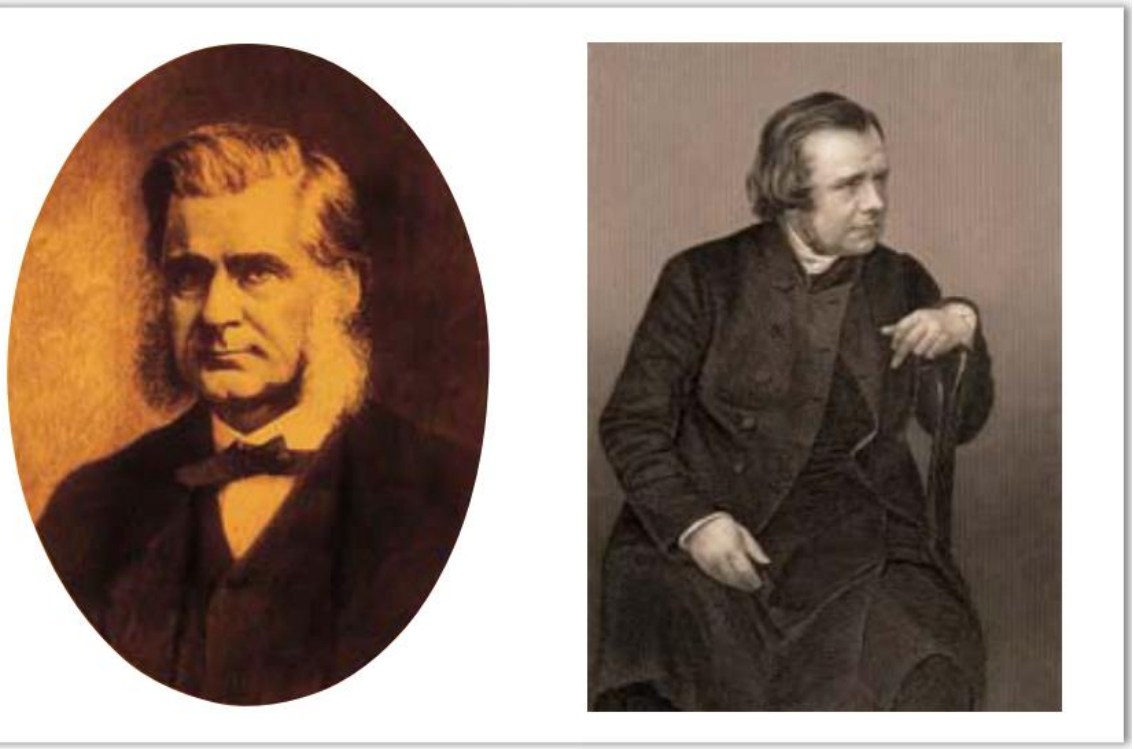


Figure 4.28 The two protagonists: Thomas Huxley (left) and Bishop Samuel Wilberforce.

4.6 INVESTIGATION

The Huxley–Wilberforce debate

Students will: present information from secondary sources to discuss the Huxley–Wilberforce debate on Darwin's theory of evolution.

Introduction

In the nineteenth century, the observations by scientists of variations between individuals and species led to the proposal by Darwin and Wallace of the theory of evolution by means of natural selection. This theory explains how changes over time can occur in living things. The prevailing religious belief in Europe at the time was the Bible's version of creation, along with the idea that humans were set apart from other living things. When Darwin's theory was first published in his book, *The Origin of Species*, it was widely debated. The most famous debate was between Thomas Huxley and Bishop Samuel Wilberforce.

Purpose

To discuss the Huxley–Wilberforce debate on Darwin's theory of evolution.

Procedure

1. Read pages 238–239 to revise the theory of natural selection as put forward by Darwin and Wallace.
2. Read the section entitled 'The Huxley–Wilberforce debate' on pages 253–254.
3. Use books, journals and Internet sites to research further information.

Discussion

1. Outline the theory of evolution by natural selection.
2. What did most people in Europe in the nineteenth century believe about the origins of living things?
3. In the debate, what theory was Huxley supporting? What theory was Wilberforce supporting?
4. Why is this debate so well remembered? What was the outcome of the debate?
5. Present-day apes and humans show many similar features. Several million years ago they shared a common ancestor. Why is it untrue to say that humans are 'descended from apes'?
6. Over 140 years later, why is the topic of evolution still debated?

Skills and outcomes

P1, P3, P10, P14, P16

Type of activity

Second-hand data activity

Materials

- books, journals, Internet sites

See Analysing information

INVESTIGATION 4.7

Variation in a species

Students will: perform a first-hand investigation to gather information of examples of variation in at least two species of living organism.

Skills and outcomes

P7, P10, P13, P14, P15

Type of activity

First-hand investigation

Materials (per pair or group)

- plant species: at least five specimens of a named plant species, preferably fresh. If whole specimens are unavailable, similar parts (e.g. leaves or flowers) should be used.
- animal species: at least five specimens of a named animal species, live or preserved (e.g. insect collections, or pictures of different types of cattle, cats, dogs, etc.). The activity could also be conducted as a class exercise using five students as specimens.
- rulers
- hand lenses

See:
- First-hand investigations
- Presenting information

Introduction

Organisms are classified into groups based on common structures and characteristics. The levels of classification are kingdom, phylum, class, order, family, genus and species. Organisms in the same species are the most similar, but even within a species there is variation between individuals.

Purpose

To examine variation in two species of living organisms.

Procedure

1 Examine the five specimens from one species of plant.
2 Decide on at least four features that you will compare. Look for easily measured or observed characteristics such as size, colour or shape.
3 Make your observations and measurements on each specimen for each feature.
4 Repeat for a named animal species.

Results

1 Draw up a table for the species you are examining, as shown in Table 4.2. Column headings should include the name of each feature you are using.

TABLE 4.2 Comparing features within a species

Name of species:					
Specimen	Feature 1	Feature 2	Feature 3	Feature 4	Comments
1					
2					
3					
4					
5					

2 Complete the table by entering your measurements and observations.
3 Repeat the procedure for the animal species you observe.

Discussion

1. List the features in order from least to most variation. Which feature showed the most variation? Describe the range of variation shown for this feature.
2. Repeat question 1 for each species you examined.
3. How does variation within a species increase the chance of survival of a species?

Further activities

Australian native plants

Australian native plants show a range of variation between species, and within families and genera. The family Proteaceae includes hakeas, grevilleas and banksias. Examine the flower, leaf and fruit structure of specimens from at least two species of hakea, grevillea and banksia. If you cannot obtain fresh or dried specimens, images can be found online. You could also visit a nursery garden to complete the observations.

1. Draw a diagram of the flower, leaf and fruit (if possible) for each species.
2. For each genus—grevillea, hakea, banksia—list the similarities and differences between each species.
3. What features are shared by all members of the family Proteaceae?

Budgerigars

Budgerigars are native Australian birds. The plumage of these native birds is yellow and green, but artificial breeding has led to a range of colours. Research the colours of budgerigars in reference books or online. You could also visit a local pet shop.

1. List the range of colours that can be found in artificially bred budgerigars.
2. Suggest a reason why these colour variations are not found in native birds.

UNIT REVIEW 4.2

Changes in Australian flora and fauna

The changes in Australian flora and fauna over millions of years have happened through evolution.

Summary

- There is variation between members of any one species. Observable differences include variations in size or colour. At the cellular level there may be biochemical differences.
- Variation within a species increases the chance of survival of the species when environmental change occurs.
- Australia's environment has changed over time. The landscape has changed as a result of volcanic activity and erosion. The climate has become warmer and drier as a result of continental drift and global climate changes.
- The inland deserts and grasslands of Australia experience significant variations in temperature between day and night. Australia is the world's driest continent, and water availability is a problem for organisms over a large part of inland and central Australia.
- Fossil evidence, particularly from sites such as Riversleigh and Naracoorte, reveals changes in distribution and abundance of species, both current and extinct, as rainforests contracted and sclerophyll communities and grasslands spread.
- Charles Darwin and Alfred Wallace independently proposed a similar theory of evolution by natural selection that accounts for the changes seen in organisms over time. This theory proposes that organisms that survive and reproduce have favourable variations or adaptations. These are passed on to the next generation so that, over time, these characteristics become more common in the population.
- Charles Darwin's observations of Australian flora and fauna when he visited in 1836 supported his theory of evolution.

Questions

1 Select the best description of Australia's diverse climate.

A As Australia has moved north over the last 65 million years, the climate has become drier throughout.

B Australia experiences tropical conditions in the north, temperate conditions in the south and arid conditions inland.

C Wide fluctuations in temperature and rainfall have created a diversity of habitats throughout the continent.

D The temperature in inland deserts can range from 40°C on summer days to below freezing on winter nights.

2 Which of the following statements about Australian fossils is true?

A Riversleigh fossils show the climate became warmer about 20 million years ago.

B Naracoorte fossils show that in recent times, lakes dried up and forests became open woodland.

C Fossilised pollen grains from South Australia show that grasslands have declined since the Quaternary.

D When Australia separated from Antarctica, it contained no placental mammals.

3 Which of the following statements is true about the formation of Australia as an island?

A Australia became warmer and drier after it separated from Asia and moved south.

B Australia was part of Gondwana until about 25 million years ago.

C Once Australia was a separate island, survival was less competitive and evolution of plants and animals slowed down.

D Australia separated from Antarctica about 45 million years ago, and the climate at that time was cooler and wetter.

4 Use an example of an Australian animal and an Australian plant to demonstrate that variation exists within members of a species.

5 Explain how variation within a species is related to chances of survival of the species when environmental change occurs.

6 Describe the evidence that changes have occurred in the Australian environment over millions of years.

7 a Describe current Australian environmental conditions, identifying those areas that experience wide fluctuations in temperature and water availability.

b Relate the distribution of vegetation to temperature and rainfall patterns.

8 Identify changes in Australian plant communities over time, in terms of both distribution and vegetation type, as rainforests contracted and new communities spread.

9 Discuss current theories that provide a model to account for changes in the distribution of species in Australia.

10 Discuss Charles Darwin's observations of Australian flora and fauna and relate these to his theory of evolution. Use specific examples to clarify your answer.

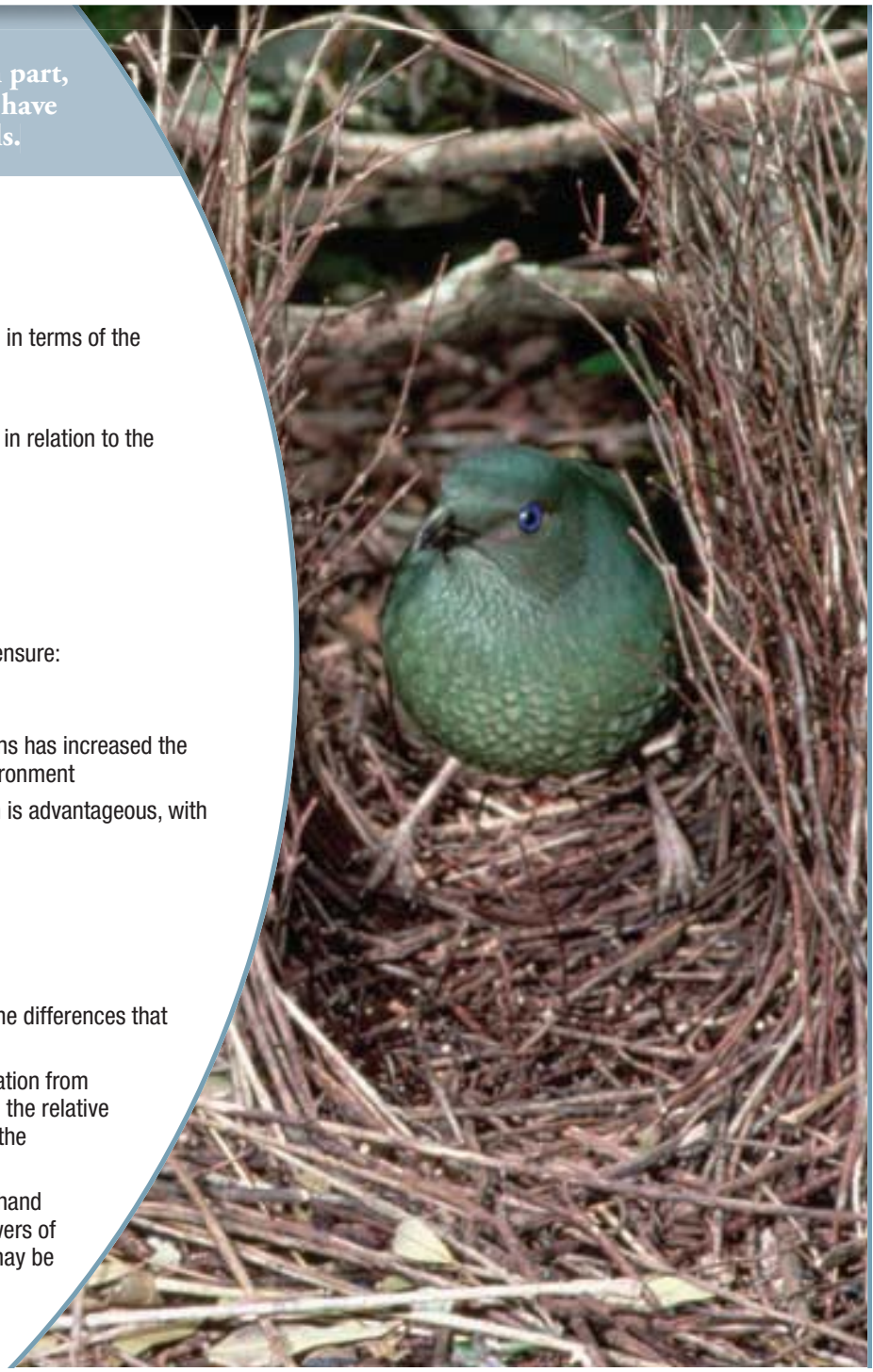
11 a Complete this table, which summarises Australia's changing climate in the last 65 million years.

Time	Geological history	Australia's climate
65 mya	Australia and Antarctica joined	
45 mya	Australia and Antarctica separate	
30 mya	Australia drifting north	
7 mya–present	Australia drifting north	

b Synthesise your understanding of current climate changes to predict a likely scenario for Australia, in terms of climate and vegetation, in the next 50 years.

4.3 THE CONTINUATION OF SPECIES

Continuation of species has resulted, in part, from the reproductive adaptations that have evolved in Australian plants and animals.



STUDENT LEARNING

In this unit students will:

- distinguish between the processes of meiosis and mitosis in terms of the daughter cells produced
- compare and contrast internal and external fertilisation
- discuss the relative success of these forms of fertilisation in relation to the colonisation of terrestrial and aquatic environments
- describe some mechanisms found in Australian flora for:
  - pollination
  - seed dispersal
  - asexual reproduction

  with reference to local examples
- describe some mechanisms found in Australian fauna to ensure:
  - fertilisation
  - survival of the embryo and of the young after birth
- explain how the evolution of these reproductive adaptations has increased the chances of continuity of the species in the Australian environment
- describe the conditions under which asexual reproduction is advantageous, with reference to specific Australian examples.

STUDENT ACTIVITY

Students will:

- analyse information from secondary sources to tabulate the differences that distinguish the processes of mitosis and meiosis
- identify data sources, gather, process and analyse information from secondary sources, and use available evidence to discuss the relative success of internal and external fertilisation in relation to the colonisation of terrestrial and aquatic environments
- plan, choose equipment or resources and perform a first-hand investigation to gather and present information about flowers of native species of angiosperms to indentify features that may be adaptations for wind and insect/bird/mammal pollination.

All living things must eventually die. A species continues because, during the life of an individual, offspring are produced by the process of **reproduction**. The same applies to other species of organisms. Reproduction may be sexual or asexual.

Meiosis

A species continues because, during the life of an individual, offspring are produced by the process of reproduction.

Meiosis is a type of cell division that forms cells with half the number of chromosomes normally found in cells of the species. It usually occurs in the tissues of multicellular organisms that provide the cells involved in sexual reproduction.

In sexual reproduction an organism produces special sex cells or **gametes** in the reproductive organs. Two types of gametes are produced, male and female. One male gamete and one female gamete, usually from two different individuals, the parents, come together and fuse in a process known as **fertilisation**. This results in a cell known as a **zygote**. The single-celled zygote then divides by mitosis to form the new individual. The new organism, although similar to its parents, will not be identical—it will show variation.

The gametes produced by meiosis contain only half the normal number of chromosomes. If they did not, on fertilisation, the chromosome number would be doubled in the new generation.

Most human cells normally contain 46 chromosomes (Figure 4.29). Forty-six is known as our **diploid** number. We use the symbol 2n for the diploid number. Our sex cells or gametes contain 23 chromosomes. Twenty-three is our **haploid** number. We use the symbol n for the haploid number. In animals, meiosis occurs when sex cells are forming, resulting in haploid gametes.

Meiosis is a type of cell division that forms cells with half the number of chromosomes normally found in cells of the species.

Like most animals, humans are unisexual: males produce haploid gametes called sperm, females produce haploid gametes called ova or eggs. Most plants are hermaphrodite: one individual produces both male and female gametes. The function of a gamete is to unite with another gamete in fertilisation to produce the first cell of a new individual. This union of two haploid cells results in a new zygote containing the diploid number of chromosomes.

Further cell division during growth and development is by mitosis (see p. 143), which maintains the diploid number.

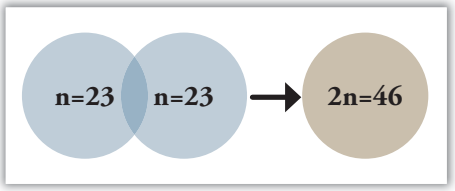


Figure 4.29 Most human beings have a diploid number of 46: we say 2n = 46. We all result from the fertilisation of two cells with n = 23.

TABLE 4.3 Some examples of chromosome numbers

Organism	Diploid number
Unicellular organisms	
Saccharomyces cerevisiae (Brewer's yeast)	30
Euglena gracilis	90
Plants	
Pisum sativum (garden peas)	14
Eucalyptus sp.	22
Lycopersicum solanum (tomato)	24
Archidium stellatum (a moss)	26
Helianthus annuus (sunflower)	34
Arachis hypogaea (peanut)	40
Saccarum officinarum (sugar cane)	80

Organism	Diploid number
Animals	
Drosophila melanogaster (fruit fly)	8
Musca domestica (housefly)	12
Antechinus rosamondi (marsupial mouse)	14
Phascolarctos cinereus (koala)	16
Macropus rufus (red kangaroo)	20
Betta splendens (Siamese fighting fish)	42
Homo sapiens (human)	46
Pan troglodytes (chimpanzee)	48
Ornithorhyncus anatinus (platypus)	52
Canis familiaris (dog)	78
Columba livia (pigeon)	80

Pairing

Similar chromosomes are called homologous chromosomes. Each pair of chromosomes is made up of one chromosome contributed by each parent.

Chromosomes can be matched into pairs, as shown in Figure 4.30. Similar chromosomes are called **homologous chromosomes** (from the Greek homologos = agreeing).

Each pair of chromosomes is made up of one chromosome contributed by each parent. Each chromosome in a pair carries information about the same inherited characteristics.

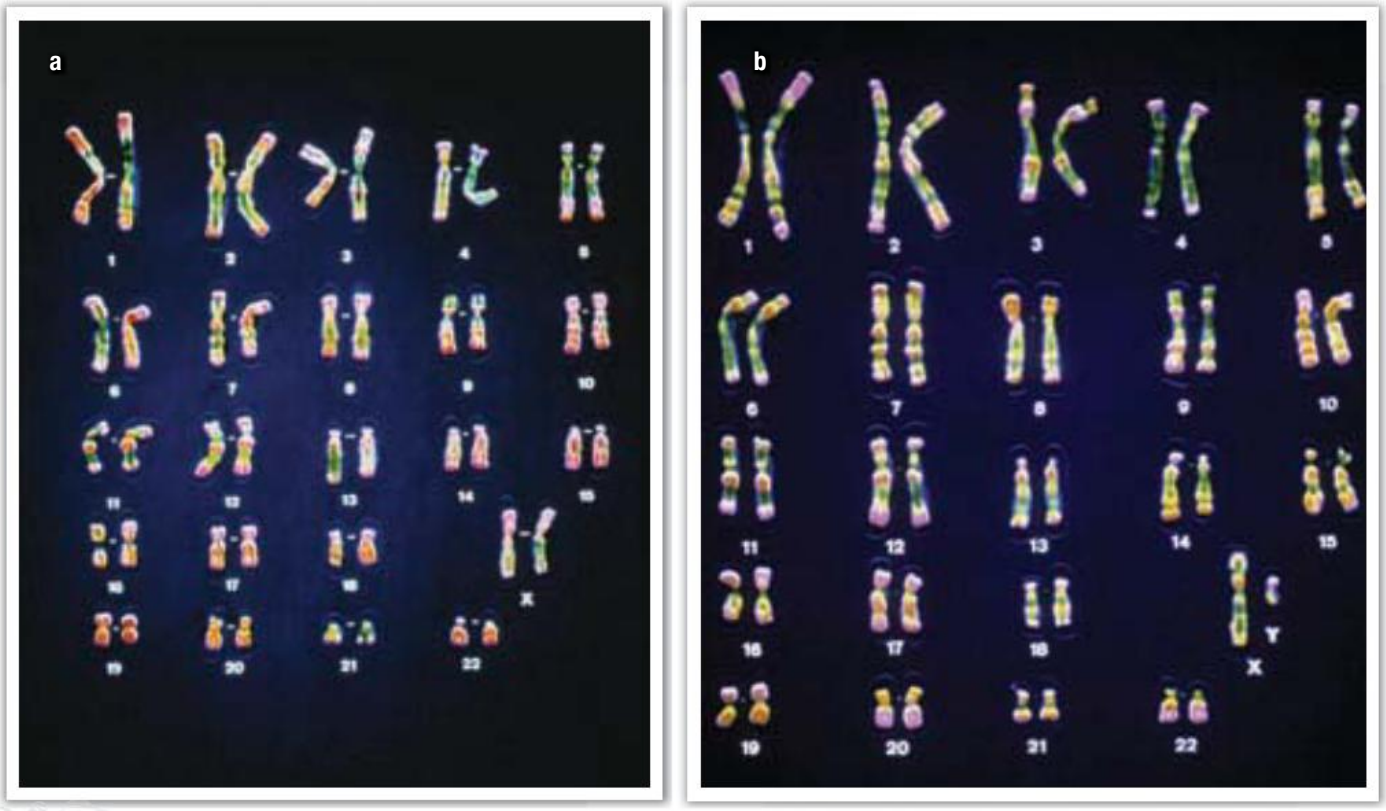
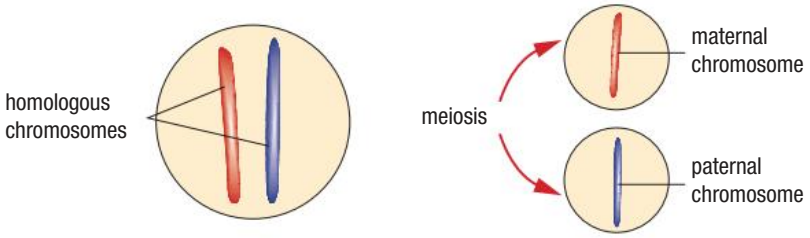


Figure 4.30 The chromosome pairs of (a) a human female and (b) a human male. The chromosomes are shown as double threads. The 23rd pair in each set is the sex chromosomes, XX in females and XY in males.

The process of meiosis

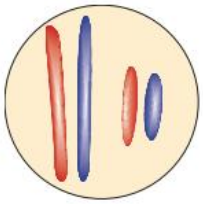
Random segregation

During meiosis, the homologous chromosomes are divided between separate gametes. The imaginary cell shown below has one pair of chromosomes (2n = 2). One has been inherited from the individual's mother (the maternal chromosome) and one from the father (the paternal chromosome).

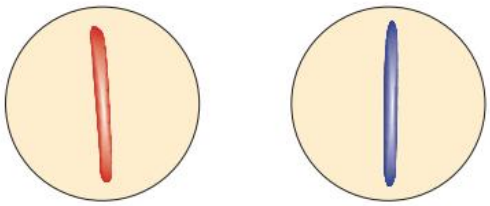


In this example, meiosis results in gametes with n = 1. Each gamete contains one chromosome; one gamete contains the maternal chromosome and the other contains the paternal chromosome.

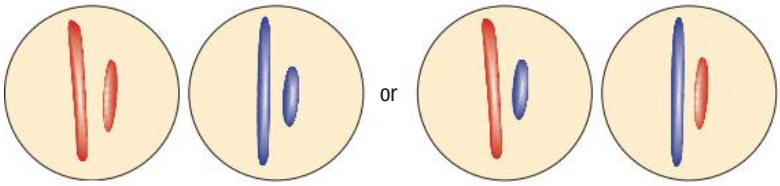
The cell shown below has 2n = 4; it will form gametes with n = 2 (or two chromosomes each). One chromosome comes from each pair.



The gametes contain one long chromosome and one short chromosome. Which short one goes with which long one? There is no reason to keep the chromosomes from the mother together, or those from the father together, although they *could* end up in the same gamete. The chromosome pairs separate independently of each other; the long ones separate:



and the short ones separate:



This process is often called **random segregation** of chromosomes. In our cells, with 2n = 46, random segregation could produce 2^{23} (more than 8 billion) different gametes in each person, assuming that the homologous chromosomes are different. Just one of those gametes unites with one from the other parent. It is no wonder children in the same family are usually noticeably different!

Meiosis involves two cell divisions (see Figure 4.32). The first division separates the homologous chromosomes from each other; the second division separates the daughter strands or chromatids.

If we begin with a cell with four chromosomes, the first division produces two cells with two double-stranded chromosomes. By the end of the second division there are four cells with two single-stranded chromosomes. You can see how complex this is in a human cell, where 2n = 46.

The variety of gametes is enormous. The chromosomes carry the genes, the units of heredity. Meiosis jumbles this inherited information to produce many different combinations of physical features. This is how a baby comes to have 'her father's nose and her mother's eyes'.

Meiosis produces haploid cells that show variation. The variation has been produced by the random segregation of the chromosome pairs.

Mitosis and meiosis compared

distinguish between the processes of meiosis and mitosis in terms of the daughter cells produced

Both mitosis and meiosis are types of cell division. In mitosis a single division results in the formation of two genetically identical diploid daughter cells. This type of cell division in multicellular organisms brings about growth and repair. It is also the basis for asexual reproduction. In meiosis, two divisions result in the formation of four haploid daughter cells, each of which are genetically different. Meiosis is the first stage in the formation of gametes in sexual reproduction in animals and flowering plants.

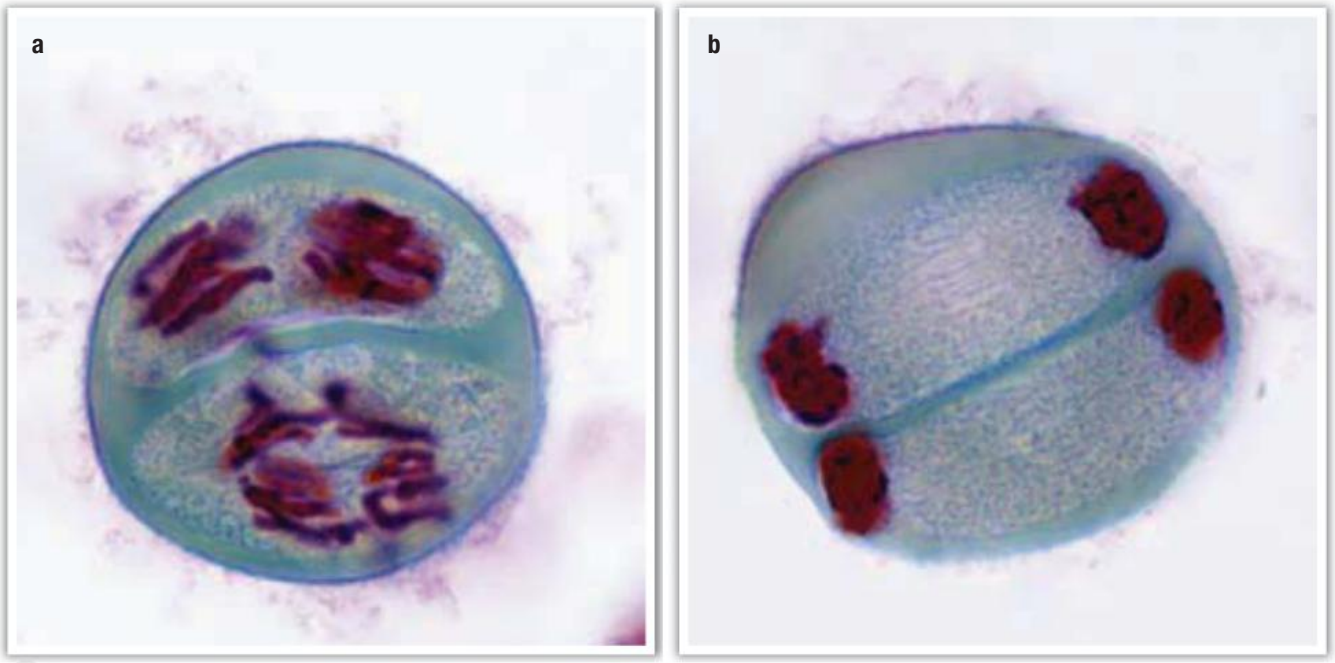
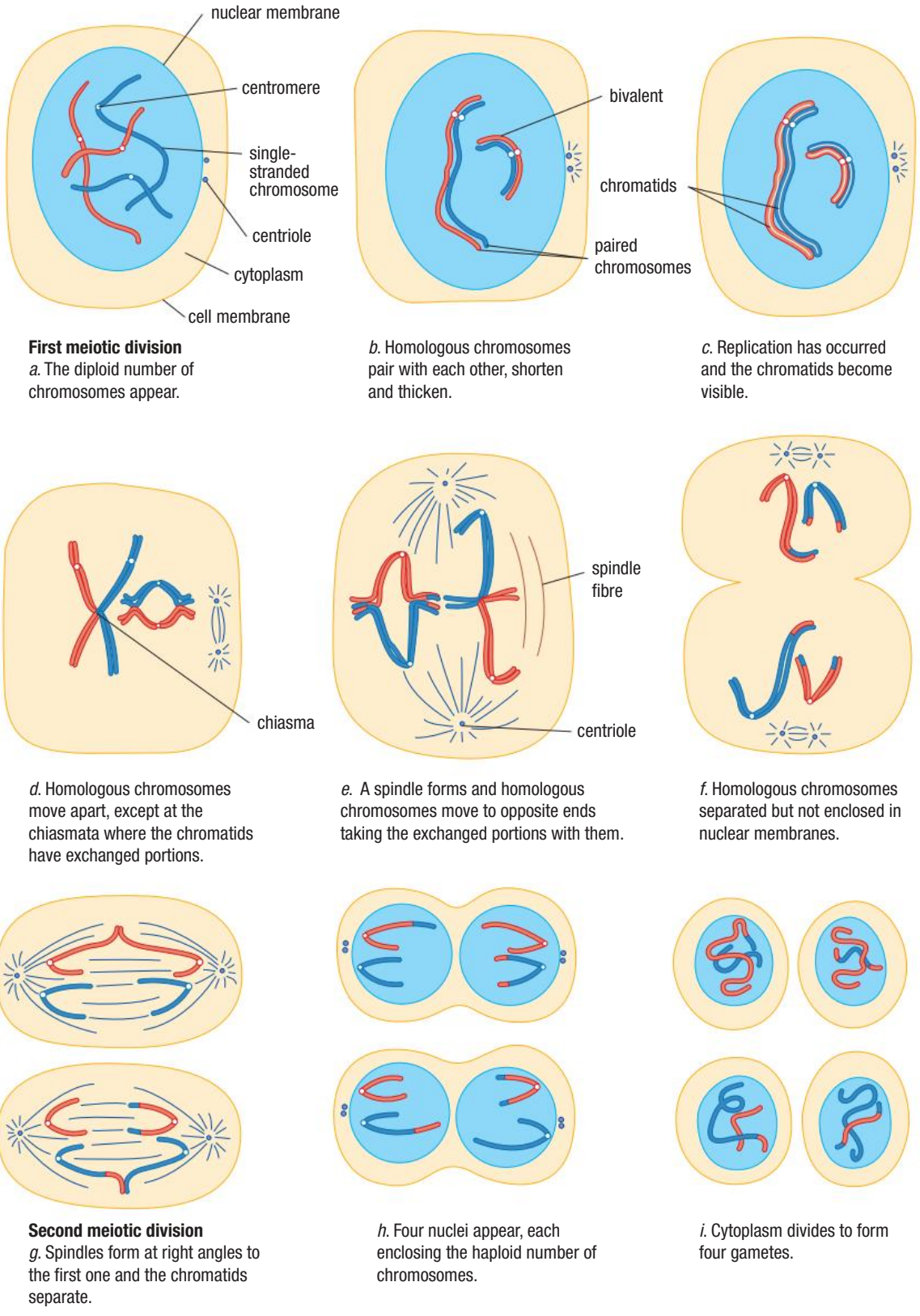


Figure 4.31 This photo shows meiosis in a lily anther. The cells are undergoing the second meiotic division. In (a) the spindles have formed and the chromatids are separating. In (b) the nuclear membranes are reforming around the four haploid sets of chromosomes.



First meiotic division

a. The diploid number of chromosomes appear.

b. Homologous chromosomes pair with each other, shorten and thicken.

c. Replication has occurred and the chromatids become visible.

d. Homologous chromosomes move apart, except at the chiasmata where the chromatids have exchanged portions.

e. A spindle forms and homologous chromosomes move to opposite ends taking the exchanged portions with them.

f. Homologous chromosomes separated but not enclosed in nuclear membranes.

Second meiotic division

g. Spindles form at right angles to the first one and the chromatids separate.

h. Four nuclei appear, each enclosing the haploid number of chromosomes.

i. Cytoplasm divides to form four gametes.

Figure 4.32 The stages in meiosis.

INVESTIGATION 4.8

Mitosis and meiosis compared

Students will: analyse information from secondary sources to tabulate the differences that distinguish the processes of mitosis and meiosis.

Skills and outcomes

P6, P9, P13, P14

Type of activity

Second-hand data activity

Materials

- print and audiovisual resources
- books, journals, Internet sites

See:
- Presenting information
- Analysing information

Introduction

There are two types of nuclear division: mitosis and meiosis. Mitosis typically results in new somatic (body) cells. Formation of an adult organism from a fertilised egg, asexual reproduction, regeneration, and maintenance or repair of body parts are all accomplished through mitotic cell division. Meiosis results in the formation of either gametes (in animals) or spores (in plants). These cells have half the chromosome number of the parent cell.

Purpose

To analyse information from secondary sources and tabulate the differences that distinguish the processes of mitosis and meiosis.

Procedure

1 Revise the process of mitosis by reading pages 143–146. Identify the changes that occur in chromosomes during meiosis by reading pages 263–265.

2 Look at other relevant resources including videos or Internet sites.

3 Copy Table 4.4 into your workbook and use it to summarise the differences between mitosis and meiosis.

TABLE 4.4 Summary of mitosis and meiosis

	Mitosis	Meiosis
Function		
Number of resulting cells		
Haploid or diploid daughter cells		
Number of rounds of nuclear division		
Pairing of homologous chromosomes		
Centromere divides during anaphase		

4 Copy Figure 4.33 into your workbook and complete the number and structure of chromosomes at each stage of mitosis and meiosis.

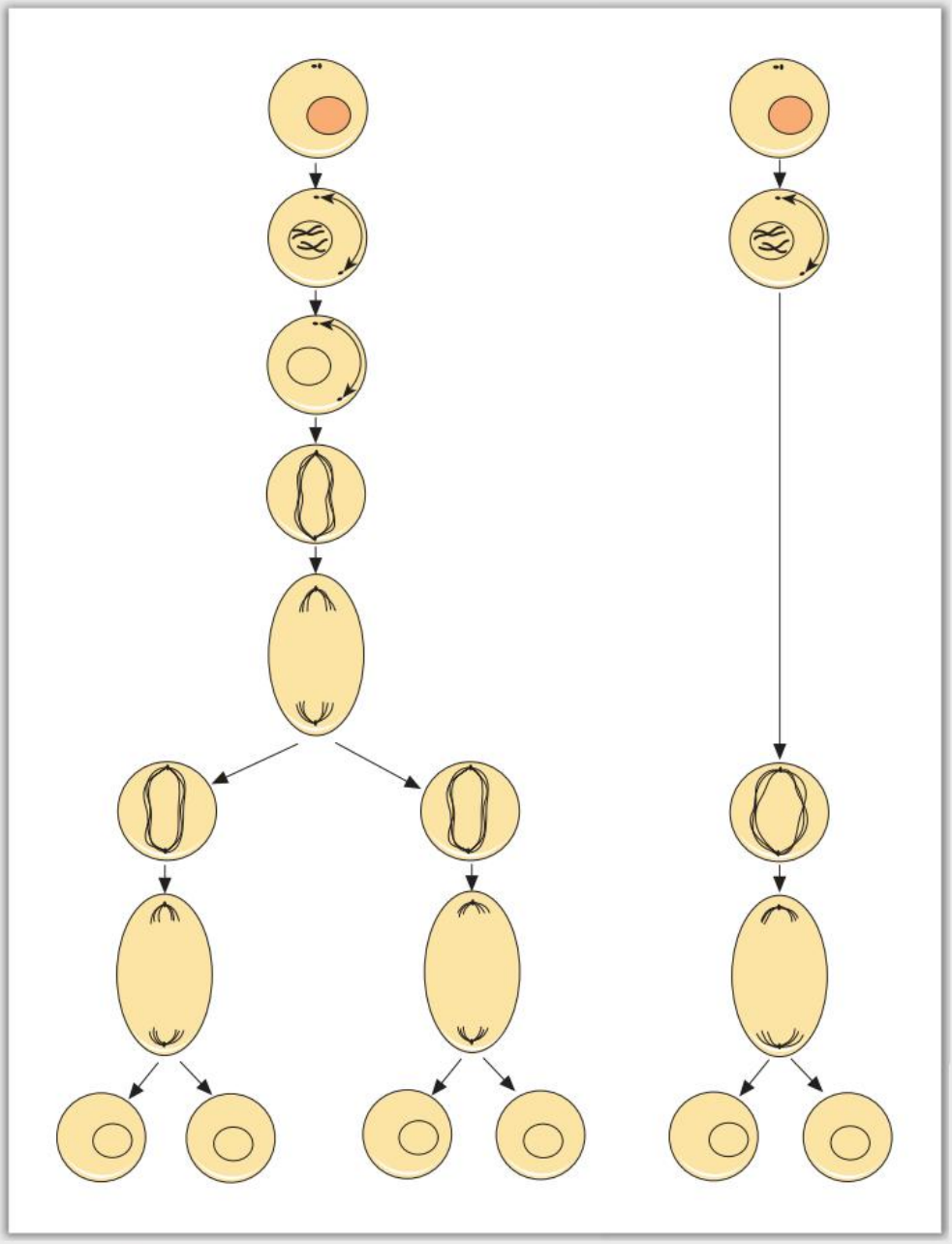


Figure 4.33 Chromosomes during meiosis and mitosis: student to complete.

Conclusion

Explain why mitosis is called 'division for growth' and meiosis is called 'division for reproduction'.

Fertilisation: bringing gametes together

All gametes vary genetically as a result of meiosis. We have seen that fertilisation brings together two gametes which fuse to form a diploid zygote. This new individual is a unique combination of genes, different from either of its parents. Fertilisation in sexual reproduction increases variation in a species because (a) it is sheer chance that determines which gametes will be involved in fertilisation, and (b) the chance of the same type of egg and the same type of sperm again being produced and uniting is remote.

In sexual reproduction, the haploid gametes produced by the parents must be brought together for fertilisation. Fertilisation—the bringing together of haploid gametes—is not as easy a task as it might appear. Firstly, careful timing is required: both male and female gametes need to be produced and ready at the same time. Secondly, arrangements must be made to bring the gametes into contact with each other; and thirdly, water is required. Male gametes must move and swim towards the female gamete. How is all this achieved?

Firstly, an organism must be sexually mature. Mice can breed after they are 6 weeks old, and fruit flies can breed just hours after emerging from the pupal stage, but humans are not sexually mature until they are about 13 years old. Many plants grow, reproduce and die in a single season. Citrus trees take about 4 years before they first flower and fruit, and macadamia trees take 7 years before they first produce nuts.

Once sexual maturity is reached, gamete production and release are often stimulated by environmental factors; for example, seasonal changes such as day length and temperature.

compare and contrast external and internal fertilisation

External and internal fertilisation

External fertilisation

External fertilisation takes place outside the body. It is a characteristic of most aquatic organisms. Gametes are shed directly into the water, fertilisation occurs, and the fertilised eggs develop, according to that organism's life cycle, into adults. Many millions of gametes are usually released to ensure that some will successfully meet, and fertilisation will occur.

External fertilisation is a characteristic of most aquatic organisms. Gametes are shed directly into the water, fertilisation occurs, and the fertilised eggs develop into adults.

While there is no control over the gametes meeting, their chances of doing so are increased by:

- cyclical reproductive behaviours
- synchronised timing of gamete production and release
- the development of courtship and mating behaviours in animals.

This form of fertilisation is successful in an **aquatic** environment, enabling the gametes and young produced after fertilisation to spread out and colonise large bodies of water.

Internal fertilisation

Internal fertilisation occurs inside the body of the female in animals, or in the female part of the plant in sexually reproducing plants. It is a characteristic of most land organisms. After fertilisation, further development of the new organism requires water.

Direct transfer of gametes greatly increases the chance of successful fertilisation. Males still produce large numbers of sperm, but females may produce far fewer eggs. The reproductive strategies involved include bringing the sexes together with courtship and mating behaviours, and having a method of gamete transfer.

Internal fertilisation is a characteristic of most terrestrial organisms. After fertilisation, further development of the new organism requires water.

Successful fertilisation

External fertilisation is successful in an aquatic environment, enabling the gametes and young produced after fertilisation to spread out and colonise large bodies of water.

Internal fertilisation has made it possible for organisms to colonise terrestrial ecosystems by overcoming the need for water in fertilisation. Organisms on land have developed many mechanisms to ensure successful transfer of the male gametes to the female. The female provides a moist environment for the sperm to swim to the egg. Without the need for external water for fertilisation, even the driest environments could be successfully colonised.

discuss the relative success of these forms of fertilisation in relation to the colonisation of terrestrial and aquatic environments



Figure 4.34 Courtship behaviour: Australian brolgas (*Grus rubicundus*) perform an elaborate dance before mating.

INVESTIGATION 4.9

Fertilisation in water and on land

Students will: identify data sources, gather, process and analyse information from secondary sources and use available evidence to discuss the relative success of internal and external fertilisation in relation to the colonisation of terrestrial and aquatic environments.

Skills and outcomes

P9, P12, P13, P14, P15

Type of activity

Second-hand data activity

Materials

- books, journals, Internet sites

See Analysing information

Introduction

The joining of male and female gametes in the process of fertilisation ensures the continuation of the species. In order for fertilisation to take place, male gametes must swim or move towards the female gametes. Organisms living both in water (aquatic) or on land (terrestrial) have developed a number of methods to ensure that their gametes do meet.

Purpose

1 To examine and compare the different reproductive strategies employed by terrestrial and aquatic organisms.
2 To research the reproductive strategies of one aquatic and one terrestrial organism.

A Internal versus external fertilisation

Procedure

1 Identify data sources and gather information about internal and external fertilisation in terrestrial and aquatic organisms.
2 Give a definition of the term 'external fertilisation'.
3 Give a definition of the term 'internal fertilisation'.
4 Copy and complete Table 4.5.

TABLE 4.5 A comparison of internal and external fertilisation

Type of fertilisation	Number of gametes produced	Hazards in process	Strategies to assist with process
external		gametes eaten; current separates gametes	
internal	males produce large numbers of sperm; females produce few eggs		courtship and/or mating behaviour

8 Research investigation: mini case studies

Procedure

1 Research the reproductive strategies of one aquatic and one terrestrial organism. You may select from the list below, or choose a different organism.
   - Aquatic organisms: coral, corroboree frog, crucifix toad, green tree frog, water-holding frog, Australian bass, barramundi, catfish, Macquarie perch
   - Terrestrial organisms: red kangaroo, potoroo, bower bird, brolga, royal spoonbill, lyrebird, brown falcon, wedge-tailed eagle, dingo

2 For each organism, write a case study or create a multimedia presentation that includes the following:
   - the name of the organism
   - the environment in which it lives
   - its method of fertilisation
   - the reproductive strategies it employs to ensure that some of its gametes meet
   - the relative success of the method of fertilisation
   - the source of your data (the references you used).

Conclusion

1 From your investigations, discuss the relative success of internal and external fertilisation in the following environments:
   a an aquatic environment
   b a terrestrial environment.

Sexual reproduction in flowering plants

describe some mechanisms found in Australian flora for:
- pollination
- seed dispersal
- asexual reproduction

with reference to local examples

'Flora' refers to plants.

Flowers are the reproductive organs of angiosperm plants. Different parts of flowers have different functions as part of the reproductive process. The number, shape, size and colour of the different parts depend on the type of plant, and are often used in plant identification and classification.

Flowers are protected when in bud by **sepals**. In many flowers these are petal-like, but sometimes they are fused together into a different structure (see Figure 4.35a on p. 272). The **petals** surround the male and female reproductive organs, and may be brightly coloured. Petals can be separate (Figure 4.35b) or fused into a tube (Figure 4.35c).

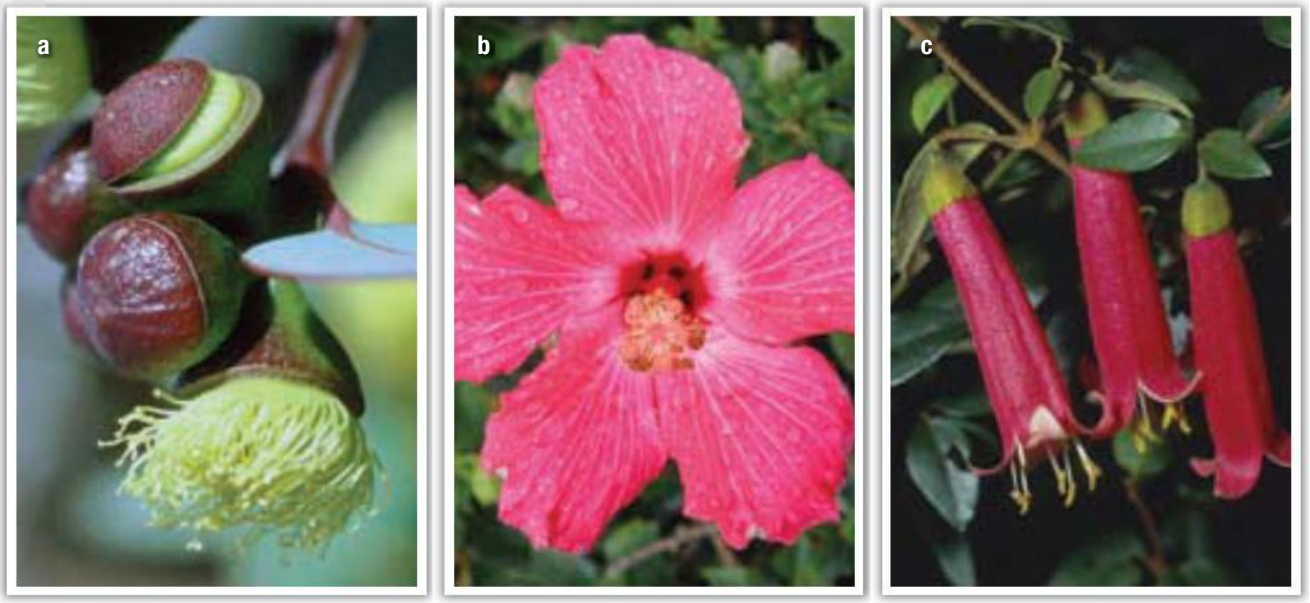


Figure 4.35 (a) Fused sepals form the cap that protects maturing eucalypt flowers. (b) A typical flower, showing the unfolded petals. (c) In some plants, such as this correa, the petals are fused together to form a tube or corolla.



Figure 4.36 Stamens (labelled s) in a tea-tree flower.

Male reproductive organs

The male reproductive organ in plants is called a **stamen**. It consists of two parts: the **anther** and the **filament**. There are usually several stamens in a flower. Some plants produce nectar from nectaries at the base of the filaments.

Meiosis occurs inside the anthers and results in the formation of haploid **pollen** grains. A pollen grain has an outer protective wall and contains two haploid nuclei (Figures 4.37–4.39).

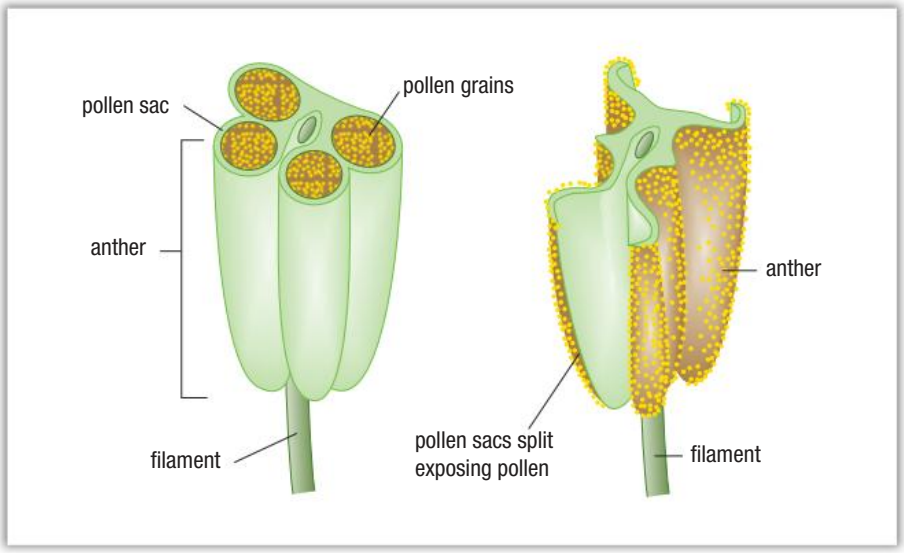
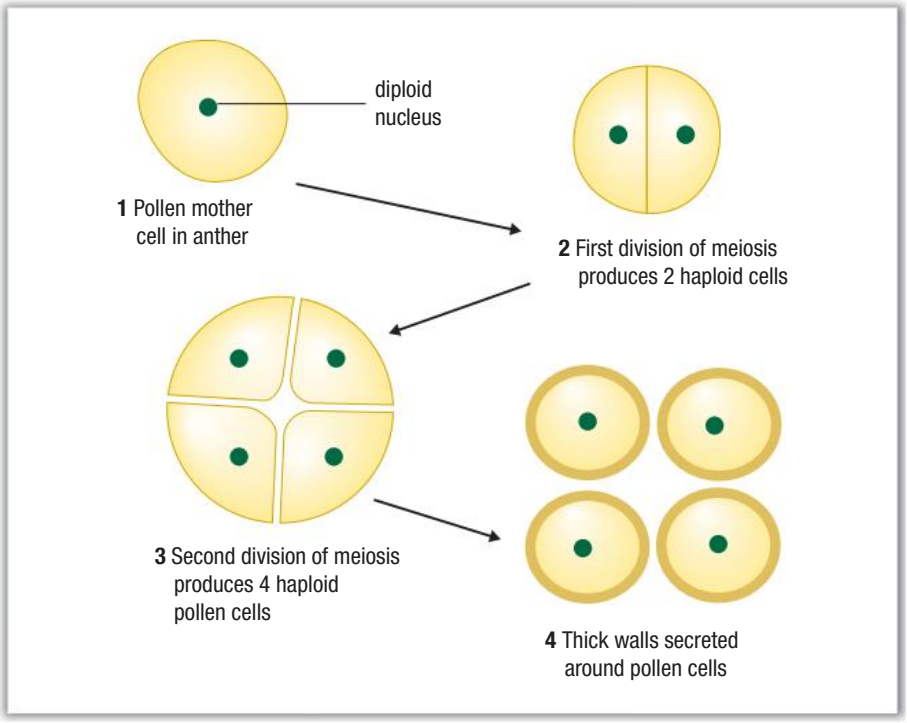


Figure 4.37 Pollen grains form within pollen sacs in the anthers. When the pollen matures, the sacs split open, exposing the pollen for dispersal.



Figure 4.38 Mature pollen grains (highly magnified) from different plant species.



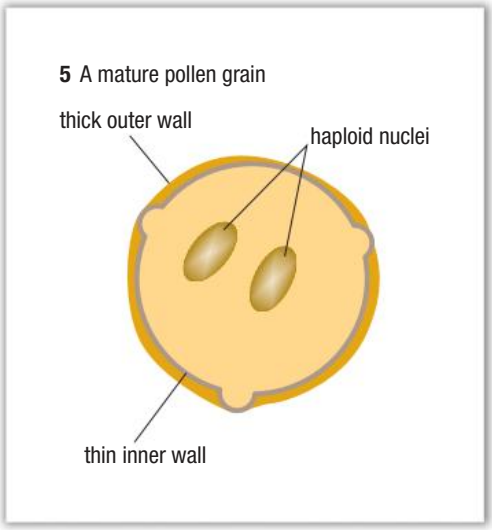


Figure 4.39 Pollen grains form by the meiotic division of mother cells in the anthers. A mature pollen grain contains two haploid nuclei, and is protected by a thick outer wall.

Female reproductive organs

The female reproductive organ is called a **pistil**. It consists of one or more **carpels** in the centre of the flower. Each carpel consists of **stigma**, **style** and **ovary** (Figure 4.40). Inside the ovary are several ovules. Meiosis occurs inside each ovule, resulting in the formation of eight haploid cells, one of which is the **ovum** or egg.

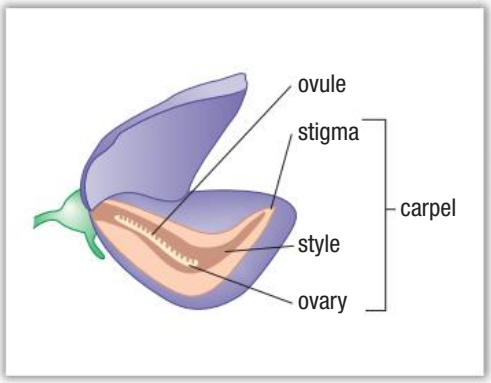


Figure 4.40 The female reproductive organs in a flower.

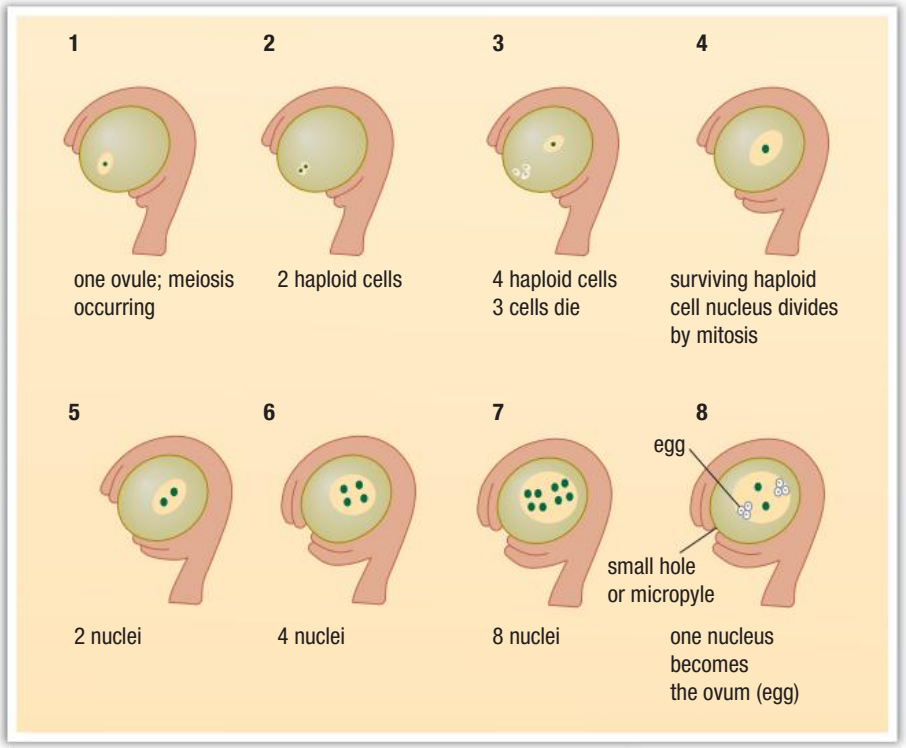


Figure 4.41 Development of the ovum in a flowering plant.

Pollination and fertilisation

Pollination is the transfer of pollen from a stamen to a mature stigma. If this occurs, fertilisation can take place.

Fertilisation is the union of a haploid male gamete from a pollen grain with a haploid cell nucleus in the ovule to form a zygote. The zygote will become a **seed**, the ovary will form the **fruit**.

The process of pollination and fertilisation

A germinating pollen grain sends out a tube, which grows down the style towards the ovary. The two nuclei of the pollen grain travel down this tube. One becomes the tube nucleus. The other male nucleus divides into two (Figure 4.42). The pollen tube enters an ovule through a tiny hole, the micropyle (Figure 4.43). One of the male nuclei fuses with the ovum to form the fertilised zygote. The other fuses with the two other haploid nuclei in the ovule to form a cell containing three fused nuclei (a triploid cell).

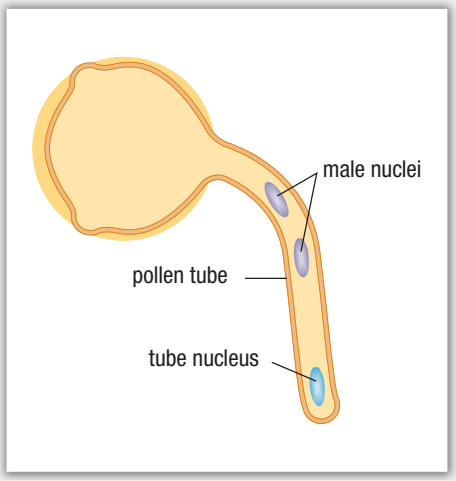


Figure 4.42 Germination of a pollen grain.

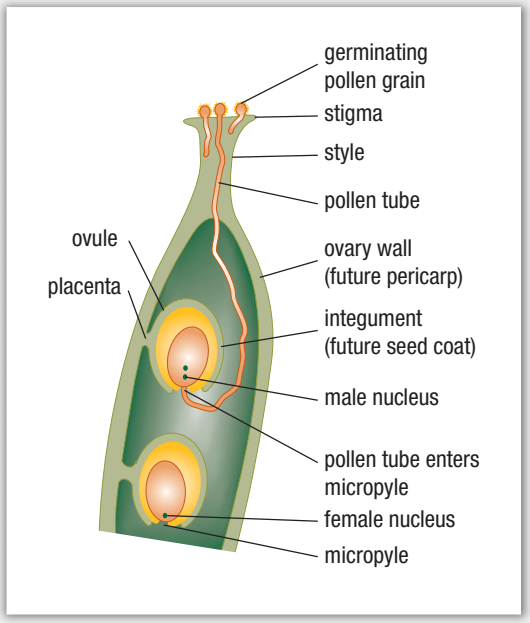


Figure 4.43 The process of fertilisation.

Self-pollination and cross-pollination

If pollination involves pollen and stigma from the same plant, it is known as **self-pollination**. In **cross-pollination**, the pollen from one plant is transferred to a stigma on another plant of the same species.

Self-pollination is prevented in some plants by having the stamens and stigma ripening, or maturing, at different times. Some plants, such as most species of the Australian she-oak family (Casuarinaceae), have male and female flowers on separate plants, so that self-pollination is impossible (Figure 4.44). Some plants are normally self-pollinating. A familiar example is the garden pea, in which pollination occurs before the flower has fully opened. Some plants, such as the dandelion, self-pollinate if cross-pollination fails to occur (Figure 4.45).

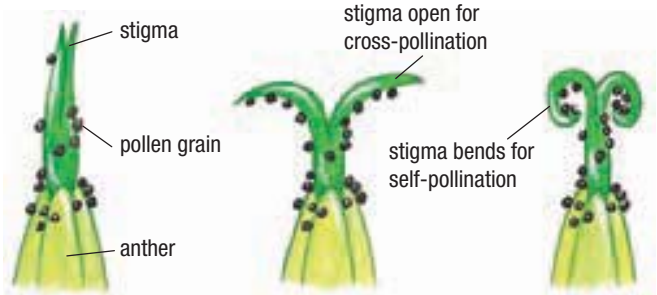


Figure 4.45 Pollination in the dandelion.

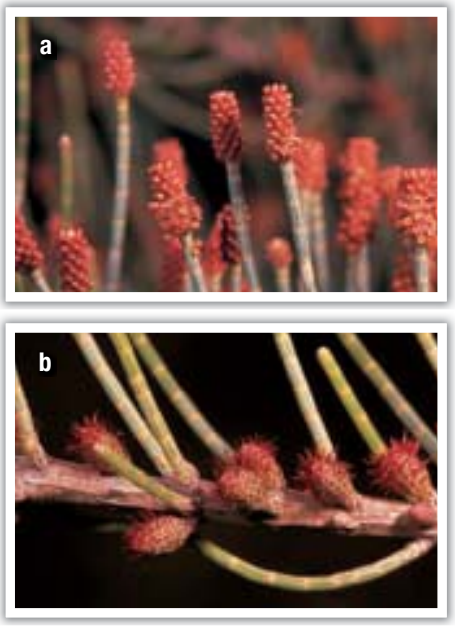


Figure 4.44 Flowers of *Allocasuarina humilis*, a she-oak from Western Australia: (a) male, (b) female.

If fertilisation occurs after self-pollination, the gametes will have come from a single parent. If fertilisation occurs after cross-pollination, the gametes will have come from different parents. There will be greater variation shown by the offspring of plants which cross-pollinate because their parents are different.

Cross-pollination relies on external agents, such as insects, wind and birds. The amount and type of pollen produced differ according to the method used (Table 4.6). In some cases, flowers and their pollinators show specific adaptations (Figure 4.48).

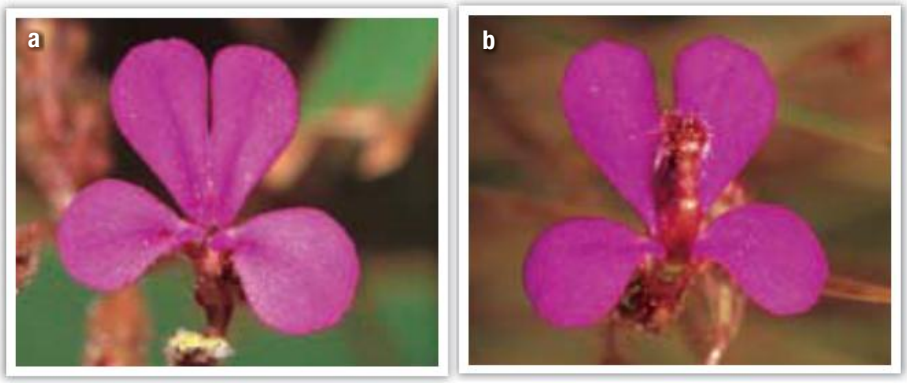
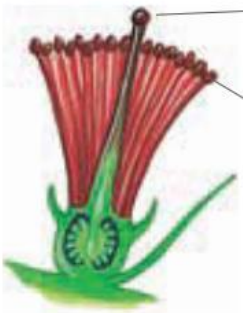
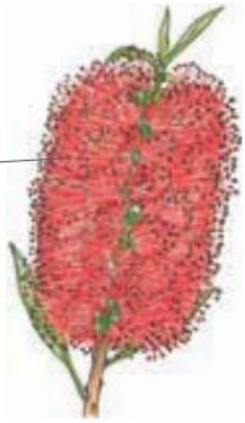
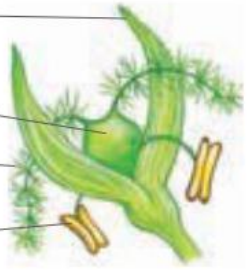
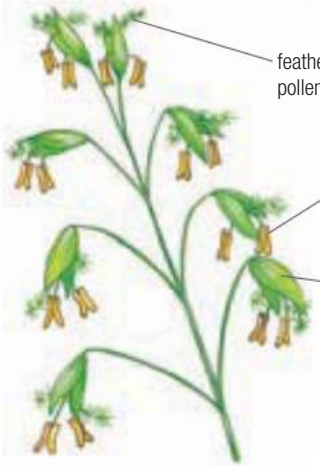


Figure 4.46 The grass-leaved trigger-plant (*Stylidium graminifolium*) has an unusual adaptation for pollination. Only a heavy insect such as a bee can bring about pollination. In (a) the flower is open, ready to receive an insect, with the stigma bent down. When an insect lands on the flower, the stigma springs up, brushing against the insect and picking up any pollen the insect is carrying. In (b) the flower has been triggered, and the stigma is standing up.

TABLE 4.6 Differences between wind-pollinated and insect-pollinated flowers

Insect-pollinated	Wind-pollinated
 ***Callistemon* flower** large conspicuous flowers brightly coloured stamens, sweet scent and nectar (to attract pollinators) pollen produced is heavy and sticky—attaches to insect  ***Callistemon citrinus*** (crimson bottlebrush)	 **grass flower**  **grass inflorescence**

Pollination by animals

Many Australian flowers are pollinated by insects, birds and mammals. Nectar-feeding birds such as honeyeaters (Figure 4.47), and other animals such as the tiny honey-possum (*Tarsipes rostratus*), act as pollinators for many Australian plant species. Fruit bats pollinate many species of eucalypts. The bush rat (*Rattus fuscipes*) and the brown antechinus (*Antechinus stuartii*) are known to pollinate *Banksia ericifolia*.

Insects such as ants, native bees and wasps are important pollinators of many Australian orchids. Orchids have a wide range of methods for attracting pollinators, including scents, colours, nectar, food production and mimicry. Scents vary from honey-sweet to rank and fetid, depending on the type of insect that is sought. Certain colours, especially bright yellows, attract bees seeking nectar. Other orchids produce nectar deep within the flower, forcing insects to brush against anthers and stigmas in order to reach their reward. Members of the genus *Gastrodia* (potato orchids) even produce insect food called 'pseudopollen' as a reward to pollinators that visit their flowers. It is possible that many orchids depend on specific insects for pollination, and that without them the plant species could not survive (Figure 4.48).



Figure 4.47 As this western spinebill (*Acanthorhynchus superciliosus*) feeds on the nectar, it brushes against the stamens, collecting pollen that can be transferred to the stigma of the next flower the bird visits.



Figure 4.48 To a male wasp, the flying duck orchid (*Caleana major*) looks and smells like a female wasp. In trying to mate with it, male wasps transfer pollen from other flying duck orchids they have visited.

INVESTIGATION 4.10

Pollination

Students will: plan, choose equipment or resources and perform a first-hand investigation to gather and present information about flowers of native species of angiosperms to identify features that may be adaptations for wind and insect/bird/mammal pollination.

Skills and outcomes

P11, P13, P14, P15

Type of activity

First-hand investigation, student-designed activity

Materials

- a selection of native Australian flowering plants (for example, *Grevillea, Eucalyptus, Callistemon, Banksia, Leptospermum, Poa, Melaleuca, Pittosporum*)

Suggested equipment:

- hands lens, dissecting microscope, videoflex
- dissecting instruments (e.g. scalpel, forceps)
- dissecting boards or white tile

Caution

Scalpel blades are very sharp. Take special care when using these instruments. Do not leave close to the edge of your bench. Dispose of used scalpel blades in a sharps container.

See First-hand investigations

Introduction

You may appreciate flowers because of their beauty and fragrance, but what is their real purpose? Flowers are the reproductive structures of some plants. They come in a variety of colours, shapes and sizes, all of which can be related to the method by which pollination occurs.

Pollination of plants may involve birds, insects, small mammals or the wind.

Purpose

To plan and carry out an investigation of some Australian flowering plants and the features they possess to ensure pollination.

A Floral structure and pollination

Procedure

1 Copy Figure 4.49 into your workbook.

2 Use two different colours to indicate the male and female structures.

3 What is pollination? Outline the difference between self- and cross-pollination.

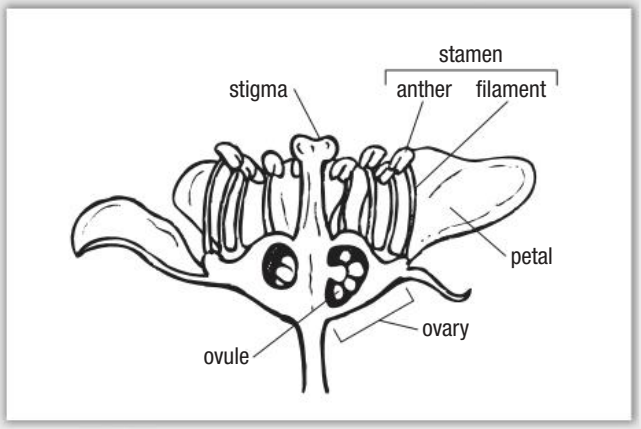


Figure 4.49 Basic flower structure.

4 Refer to Table 4.6 on page 276, then copy and complete Table 4.7 below.

TABLE 4.7 Differences between animal-pollinated and wind-pollinated flowers

Type of pollination	Adaptations
insect/bird/mammal	scent to attract pollinators
wind	anther hangs outside flower exposing pollen to wind

B Adaptations for pollination of Australian native flora

Procedure

In this part of the activity, you will plan and then perform a first-hand investigation to identify features that may be adaptations possessed by native flowering plants to assist in their pollination.

1 Gather a variety of native Australian plants in flower (see the suggestions in the Materials list). If possible, include samples of native grasses in flower. Avoid damaging the environment as you collect the flowers, and if you are in a National Park, observe the regulations regarding removal of plant material.
2 Decide what equipment you will need in order to best examine the floral structures of the selected plants.
3 Decide how many samples you will examine.
4 Decide how you will record your findings. Would a well-labelled diagram be best, or a table listing the plant and its features?
5 Using the information developed in Table 4.7, decide the method of pollination for each sample. Justify your choice.

Conclusion

1 Evaluate your investigation in Part B by listing any problems you had doing the activity.
2 What could you have done differently?



Figure 4.50 A germinating bean seed, showing the embryonic plant with its two cotyledons (seed leaves).



Figure 4.51 In arid areas of Australia, ants are known to help at least 1500 species of plants disperse their seeds. Ants carry the seeds to their nests and eat the special structures (called disseminules) on the outside of the seeds. This is an example of mutualism (see p. 29)—the ant obtains food and the plant has its seeds dispersed.

Refer to your study of a local ecosystem and make sure you include examples of pollination and seed dispersal by the plants in your area.

Seed dispersal

Once pollination and fertilisation have occurred, the zygote divides to become the **embryo**. During the initial stage, the developing embryo receives its nourishment from the parent plant. It is protected during its early development by being enclosed in the ovule and ovary of the parent plant. After fertilisation, changes take place in all parts of the flower. The petals wither and drop off. The ovule swells as the embryo grows to become the seed. The seed contains a food store for the embryo for later in its growth. Development proceeds only to a certain stage, and then the seed becomes dormant.

The ovary swells and elongates to become the fruit. The types of fruits and seeds produced by flowering plants vary enormously. In some cases either the seeds or the fruit may become woody as in a nut, or soft and fleshy as in a berry. In all cases, protection, water and food are provided for the new offspring as it develops and for when it is separated from the parent plant.

Fruits and seeds are dispersed from the parent plant by any of a number of mechanisms (Table 4.8). Whatever the strategy used, the purpose is the same: to disperse the offspring to a place where they are most likely to germinate and survive.

TABLE 4.8 Fruit and seed dispersal mechanisms.

Method of dispersal			
Animals	**Wind**	**Water**	**Self**
after being eaten, the seed passes out in faeces  ***lilly pilly***	parachute  ***conestick***	 ***coconut***	rolling  ***macadamia nut***
the seed catches on the coat of a passing animal  ***'galvanised burr'***	light seeds  ***hovea***  ***'mountain devil'***		catapulting  ***waratah fruit and seed***

Asexual reproduction

Asexual reproduction is reproduction by only one parent. There are no gametes produced and there is no fertilisation (see also pp. 289–291).

Examples of mechanisms of asexual reproduction in Australian plants include new plants from underground and overground stems, lignotubers, bulbs and buds.

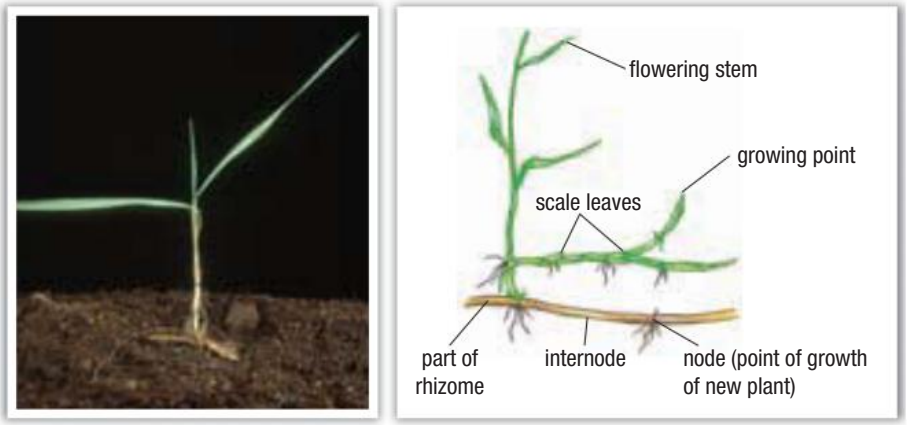


Figure 4.52 Grass can grow by asexual reproduction.



Figure 4.53 Mallee eucalypts can resprout from an underground lignotuber after drought or fire. This lignotuber has been exposed by soil erosion.

Sexual reproduction in animals

The typical stages of the life cycle of animals are represented in Figure 4.54. The adult animal is diploid and produces haploid gametes by meiosis. Two haploid gametes fuse in fertilisation to form a diploid zygote. By mitotic division, the zygote develops to become a mature adult.

describe some mechanisms found in Australian fauna to ensure:
- fertilisation
- survival of the embryo and of the young after birth

'Fauna' refers to animals.

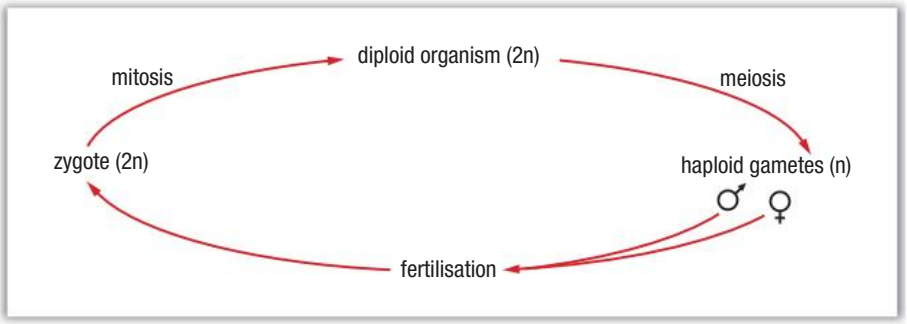


Figure 4.54 The typical life cycle of an animal.

Gamete formation involves cell division by meiosis, followed by cell differentiation to produce highly specialised cells. In males the haploid gametes are called **sperm**. They usually have tails and swim towards the female gamete. In females the haploid gametes are called ova or eggs. They are usually much larger than sperm cells and contain food stores for the developing embryo.



Figure 4.55 Some birds have elaborate courtship rituals to increase their chances of reproducing successfully. Lacking showy plumage, the male satin bowerbird decorates its nest with bright blue objects in an effort to attract a female.

Fertilisation

Sexually mature individuals need to be brought together so that the gametes are close enough for the male gametes to swim towards the female gametes for fertilisation. This process is called **mating**. In animals it is triggered by an environmental stimulus.

The phases of the moon, changing water levels, warmer weather and an abundance of food are examples of external stimuli known to trigger mating behaviour.

In some cases, courtship rituals and recognition displays have developed so that members of the opposite sex of the same species can recognise each other, and know that the other is ready for mating. For most animals on land, these mating rituals need to bring the pair into close contact so that internal fertilisation can take place (Figure 4.34 on p. 269 and Figure 4.55).

Most aquatic animals have external fertilisation. Aquatic invertebrates usually shed their eggs and sperm directly into the water. There is no special method of transfer of gametes, so millions of them are released to increase the chances of successful fertilisation. Synchronised timing of the production and release of the gametes may also help. For example, common coral trout (*Plectropomus leopardus*), which inhabit the Great Barrier Reef, congregate at certain reef sites to spawn (shed their gametes) at the time of the new moon during the breeding season from September to November. Each month at this time they form groups that stay together for about five days and release their gametes before dispersing. It is thought that this reproductive behaviour is triggered by a rise in seawater temperature in spring.

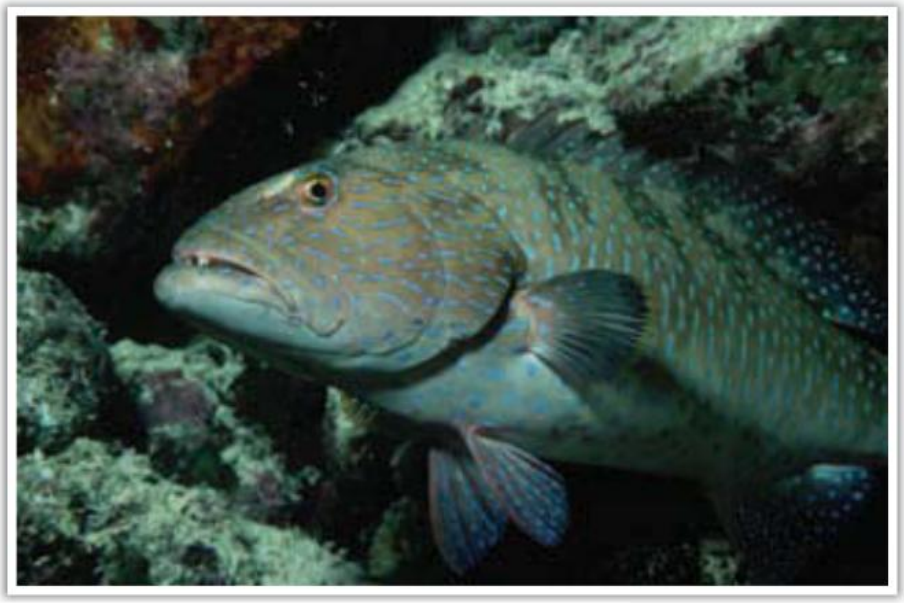


Figure 4.56 The common coral trout, *Plectropomus leopardus*.

Some aquatic vertebrates such as fish show courtship and mating behaviours that bring males and females close together. Although this greatly increases the chances of successful fertilisation, many thousands of gametes are still produced and released.

A few fish, such as sharks, have an increased chance of successful fertilisation because the male transfers his sperm directly into the female's body. Male sharks have a pair of claspers which they insert into the female's urinogenital opening (cloaca), so that the sperm pass along the claspers into the female's reproductive tract.

Aquatic mammals such as whales, seals and dolphins use internal fertilisation, in which sperm is transferred directly from the male into the female. The courtship behaviour of these animals is often spectacular. For example, humpback whales and southern right whales that breed off the coast of Australia may leap, roll and slap the water surface with their flippers.

Amphibians, which live most of their life on land, need to return to an aquatic environment to breed. Because fertilisation occurs in the water, they produce large numbers of gametes and have no special method of transferring the gametes. Frogs attract their mates by calling. Every frog species has a different call. The male eastern banjo frog, also called the pobblebonk, makes a banjo-like 'plonk' sound. This species uses specific waterholes as breeding sites. The female lays about 4000 eggs in a floating foam nest, often attached to vegetation. The male of the endangered corroboree frog, which inhabits the alpine area of New South Wales, digs a small burrow on the edge of a pool in a sphagnum bog, where mating and egg laying occur.

Internal fertilisation is a characteristic of most land organisms. The male transfers his gametes directly into the female's body. This overcomes the need for external water. Direct transfer of gametes greatly increases the chance of successful fertilisation. Internal fertilisation in animals usually occurs in the reproductive tract of the female. Eggs released from the ovary are fertilised by sperm swimming up the reproductive tract. After fertilisation, development of the zygote will continue either internally, inside the body of the female, or externally within a shelled egg.

Survival of the embryo and young

External development

After fertilisation, the zygote commences development. External development in water from fertilised egg to adult is hazardous. Most animals that have external fertilisation provide little or no parental care for the development of their offspring. Environmental conditions may be unfavourable when the young are developing, causing many to die, and many may be eaten by predators. Large numbers of offspring are needed to ensure that at least some survivors will reach adulthood.

Some animals that have internal fertilisation lay their fertilised eggs in water. Others, such as reptiles, birds, spiders and many insects, lay shelled eggs, but mammals, except for monotremes, and a few other animals retain the fertilised eggs within their own bodies for internal development.

Development of offspring may involve larval stages in which the larvae live in different habitats to those of the adults. For example, the developing young of many aquatic invertebrates become part of the plankton for a while.

Developing fish eggs hatch into young known as 'fry'. They too form part of the plankton. Tadpoles emerge from frogs' eggs (Figure 4.60) and are at first herbivorous and later carnivorous.

Some aquatic animals display parental care. For example, male seahorses develop a brood pouch and guard their young as they grow (Figure 4.61).

BIOFACT

Scientists have warned that the rising acidity of the ocean as a result of climate change could reduce fertilisation in marine invertebrates that shed their eggs and sperm directly into the water. Studies at Macquarie University with sea urchins found that increasing acidity slowed the swimming speed of sperm, and fertilisation rates fell by 25%.



Figure 4.57 Sea urchins release millions of eggs and sperm into the water at the same time.

Animal life cycles

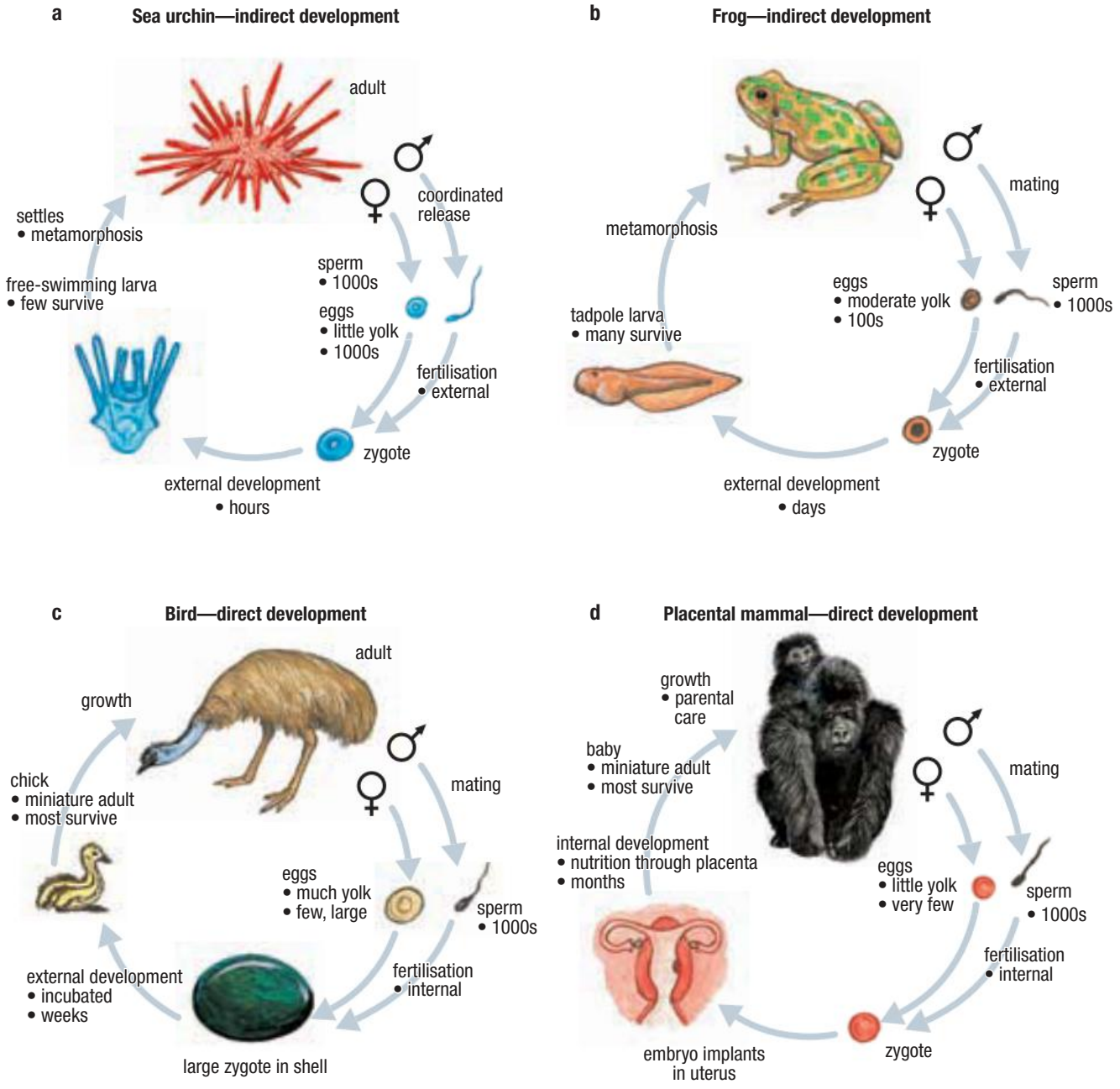


Figure 4.58 (a) Sea urchin—indirect development; (b) frog—indirect development; (c) bird—direct development; (d) placental mammal—direct development.

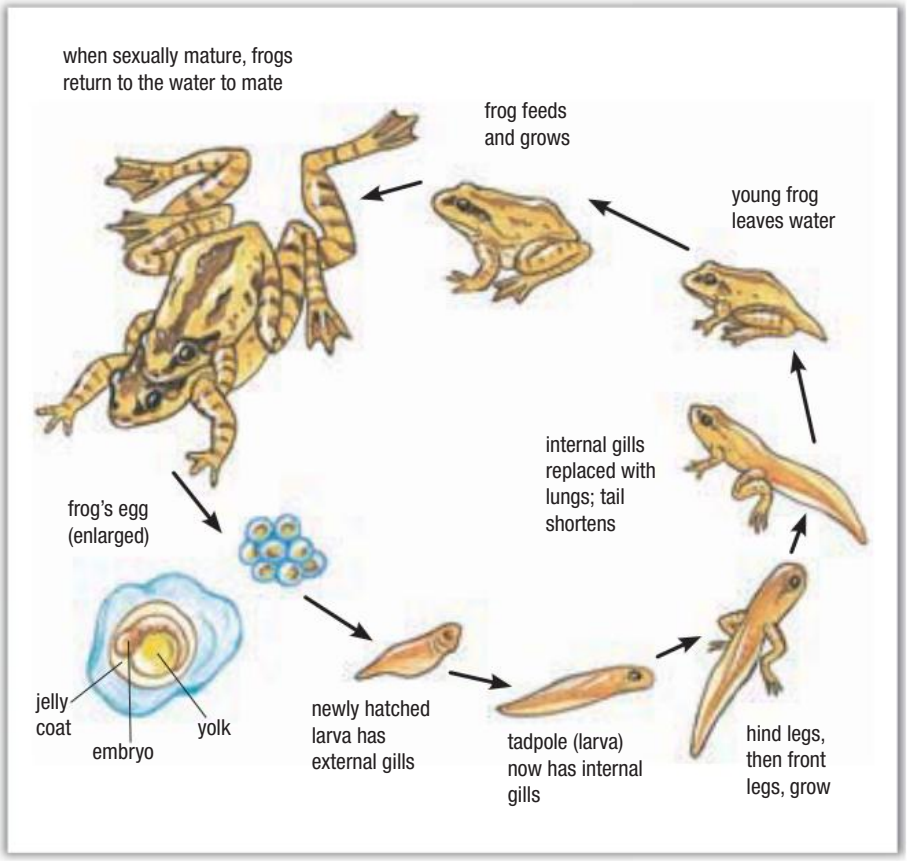


Figure 4.59 The typical life cycle of a frog. Mating involves amplexus, in which the female release eggs that are immediately fertilised by the male. This fertilisation is therefore external.

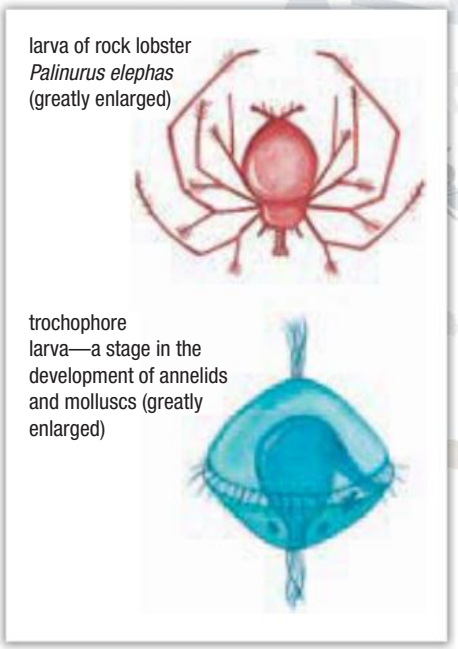


Figure 4.60 The eggs of many invertebrate animals hatch into larvae that look very much unlike the adults. These microscopic larvae live as part of the plankton in the upper layers of the ocean.

Shelled eggs

Land animals such as reptiles, birds, monotremes (echidnas and platypuses), spiders and many insects lay eggs surrounded by hard shells to prevent desiccation. The shell of the egg allows gaseous exchange to occur, but prevents water loss. Eggs are fluid-filled and contain a food store (the yolk) for the developing young (Figure 4.61).

Once the eggs have been laid, the degree of parental care of the developing young varies. Most invertebrates lay their eggs and then leave them. They are usually laid in a position where, on hatching, the larvae will find food.

Reptiles may also abandon their eggs after laying, but they are laid in a specially dug nest or burrow. This provides protection and more stable environmental conditions, particularly in relation to temperature. Crocodiles show the greatest degree of parental care in reptiles. They guard the nest and assist at hatching. After hatching they may protect the young for some months.

Birds show considerable parental care. They build nests and keep the eggs warm and protected during development (Figure 4.64a). On hatching, they feed and guard the chicks until they are able to support themselves (Figure 4.64b).

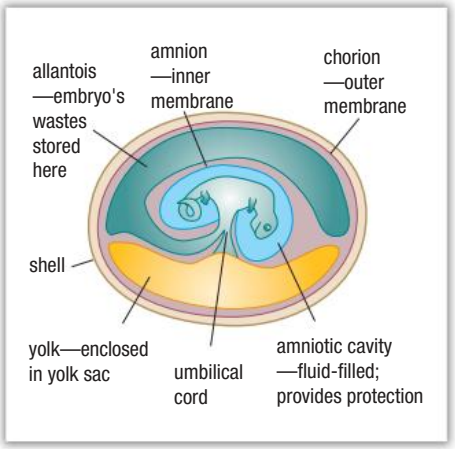


Figure 4.61 The shelled egg of a reptile. The allantois, chorion and amnion form the membrane systems enclosing the egg.

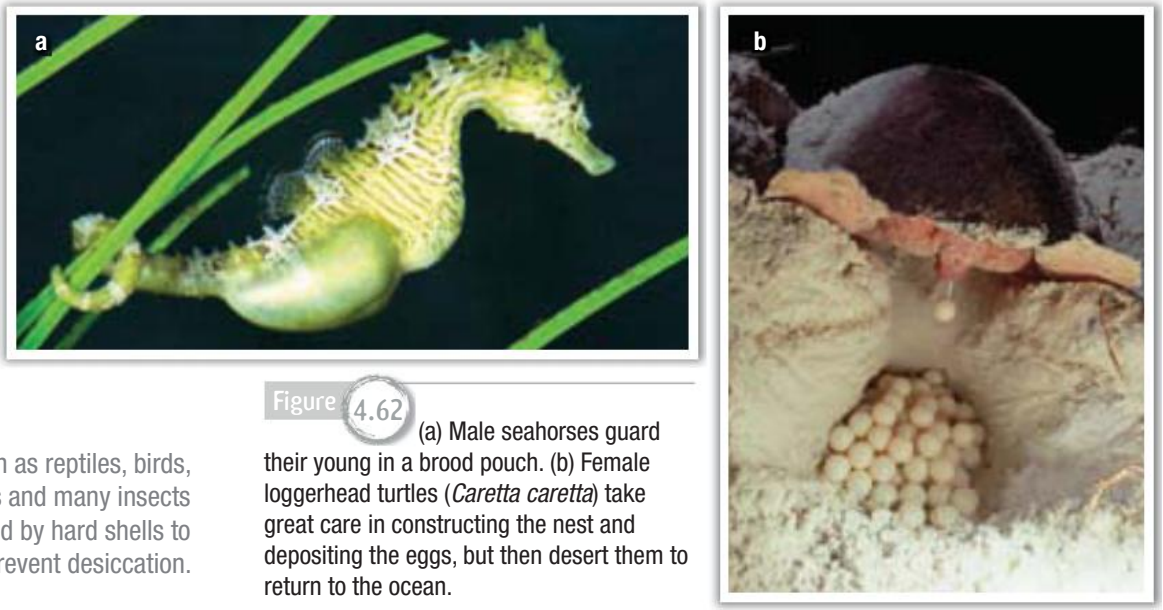


Figure 4.62 (a) Male seahorses guard their young in a brood pouch. (b) Female loggerhead turtles (*Caretta caretta*) take great care in constructing the nest and depositing the eggs, but then desert them to return to the ocean.

Land animals such as reptiles, birds, monotremes, spiders and many insects lay eggs surrounded by hard shells to prevent desiccation.

BIOFACT

Two fish found in the Murray River, the golden perch (*Macquaria ambigua*) and the silver perch (*Bidyanus bidyanus*), reproduce only after the river floods. The young fish are able to grow and develop at a time when there is plenty of water and food available. If flooding does not occur, the female is able to reabsorb any eggs which have commenced production in her body.

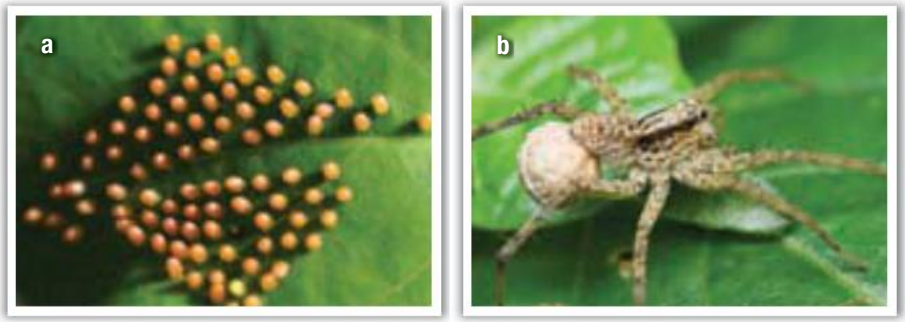


Figure 4.63 (a) Insect eggs are usually laid on the plant that will provide the food source for the young when they hatch. (b) Spiders often guard their eggs until the young hatch.



Figure 4.64 (a) Male and female emperor penguins share the incubation of the egg to begin with, holding it on their feet and covering it with a flap of abdominal skin. The female then returns to the water, leaving the male to guard the egg for about two months.
(b) Hatchling birds are blind and featherless, and need continual parental care to ensure they survive. This includes feeding them, protecting them from predators, and cleaning wastes from the nest.

Internal development

Internal development ensures the developing young have:

- protection
- a supply of nutrients
- a constant temperature
- a constant chemical environment.

In all mammals except monotremes, the young develop in the female's uterus, receiving nutrients via the **placenta**. The young are born alive. This type of reproduction is termed **viviparity**.

Other animals may have internal development of their young. In some fish, some reptiles and many insects, the fertilised egg continues to develop inside the mother, and the young are born alive. This type of reproduction is termed **ovoviviparity** (Figure 4.65).

After birth, mammals suckle their young, providing milk, protection and care until the young are well established. On land a lack of water can restrict the number of offspring produced, but increased parental care assists their survival.

- In placental mammals the young develop within the mother's uterus, receiving nutrients via the placenta.
- In marsupial mammals the young develop for only a short time within the mother's uterus, then complete development in the mother's pouch.
- In monotremes the mother lays eggs in which the young develop.



Figure 4.65 Blue-tongued lizards (*Tiliqua* sp.) can produce up to 20 live young. Their eggs are unshelled and remain in the mother's body while the embryo develops. The young are born fully formed and must immediately fend for themselves.

Reproductive adaptations in the Australian environment: three case studies

The likelihood of survival of young monotremes and marsupials is better than for reptiles because they are born in small numbers, in seasons when temperatures and food are favourable. They are fed and cared for by their mother until they can survive by themselves.

Monotremes

In playtpuses and echidnas the production of gametes is seasonal, and both male and female reproductive organs regress (reduce in size and stop producing gametes) outside the breeding season. Little is known of the early stages of platypus reproduction—egg-laying, incubation and hatching—because, in the wild, these activities take place in an underground burrow,



Figure 4.66 The platypus—an egg-laying mammal

and few platypuses have been bred in captivity. The platypus breeds in late winter and spring. The female digs a long nesting burrow, with a nesting chamber lined with grass and leaves. She plugs the burrow with soil whenever she enters or leaves.

The platypus usually lays two oval eggs less than 20 mm long. The amount of yolk in monotreme eggs is large compared to the eggs of marsupials and placentals, but much less than the amount in reptile eggs. In contrast to reptiles, the platypus embryo develops inside the egg within the uterus for perhaps four weeks. The incubation period after laying appears to be about 10 days. The eggs are tucked under the broad flat tail, and stuck together and to the fur of the abdomen. After hatching, the young platypuses remain in the burrow for several months, obtaining nutrition by suckling from their mother's mammary glands. The young platypuses leave the nest when they have grown fur and are about 30 cm long.



Figure 4.67 Older joeys continue to use the pouch for suckling and protection, but also spend time out of the pouch grazing.

Marsupials

Kangaroos are marsupial mammals. They have internal fertilisation and a very short gestation period in the uterus. At birth, the young climb into the mother's forward-opening pouch. They attach to a teat and continue development while suckling. When they leave the pouch there is a weaning period before parental care ends.

In the red kangaroo, the young weigh less than a gram when born, after 33 days in the uterus. They remain suckling in the pouch for 235 days and leave the pouch weighing 4–5 kilograms. During the weaning period, which lasts up to 4 months, the young kangaroo (joey) suckles and eats grass.

Kangaroo population numbers are controlled through reproduction. Under good environmental conditions, numbers can increase rapidly because adult female kangaroos can be almost continuously pregnant. They can mate again directly after giving birth. If the mother is still suckling her newborn young, the fertilised egg does not develop until the young leaves the pouch. This is known as delayed implantation. At any one time a female kangaroo may have a joey being weaned, as well as a young one being suckled in the pouch and an embryo in the uterus awaiting development.

Female kangaroos are able to produce two kinds of milk at the same time. The milk produced by the teat for the developing young in the pouch contains much less fat than the milk produced by the teat being used by the joey inside the pouch.

Under adverse environmental conditions, such as during drought, young joeys do not survive, and any fertilised egg does not implant. Females do not begin reproducing again until conditions improve.

Amphibians

The gastric-brooding frog, which has been found only in southern Queensland, has a remarkable reproductive behaviour. It exhibits external fertilisation and internal development. The female releases eggs, which are fertilised during amplexus, as in other amphibians. But instead of leaving the eggs to develop alone and unprotected, the female swallows them. The larvae are incubated in the stomach, which functions like a mammalian uterus. This gastric brooding or incubation appears to last 6 or 7 weeks, during which time the mother does not eat. Digestive juices (pepsin) and acid are not released from the lining of the stomach, and stomach movements stop. Thus the mother is prevented from digesting the eggs and tadpoles.

Froglets are born through the mouth of the mother, once they have completed their larval development.

The southern gastric-brooding frog has not been seen for some years, and it is feared that it might have become extinct, for reasons that are not clear.



Figure 4.68 Like other amphibians, the southern gastric-brooding frog exhibits external fertilisation, but incubates the eggs internally in the stomach, which stops digestion until the froglets are 'born' through the mother's mouth.

Increasing the chances of continuity

Reproductive adaptations are features that help an organism to successfully reproduce in its environment. In this unit there are many examples of different types of reproductive adaptations that have evolved in Australian plants and animals. Adaptations may be structural, such as the flower of the trigger plant (see Figure 4.46, p. 276). Colour and scent are also used in both plants to attract pollinators (see p. 277) and in animals to attract the opposite sex (see Figure 4.48, p. 277). Animals may also show behavioural adaptations such as special mating calls (see p. 283) or courtship displays (see Figure 4.34, p. 269).

In all organisms, the careful timing of reproduction ensures that both the environment is favourable and that males and females are both ready to reproduce. Following successful fertilisation and early development of the embryo, either as an animal egg or within a plant fruit, organisms show features that enable them to provide protection and care to their offspring. All of these reproductive adaptations help increase the chances of continuity of a species in its environment.

explain how the evolution of these reproductive adaptations has increased the chances of continuity of the species in the Australian environment

Asexual reproduction

Asexual reproduction is reproduction by only one parent. There are no gametes produced and there is no fertilisation.

The new individuals are produced in a variety of ways, depending on the species. In most cases, asexual reproduction results in the production of an immediately self-sufficient new organism from one parent. In others, an abundant food supply

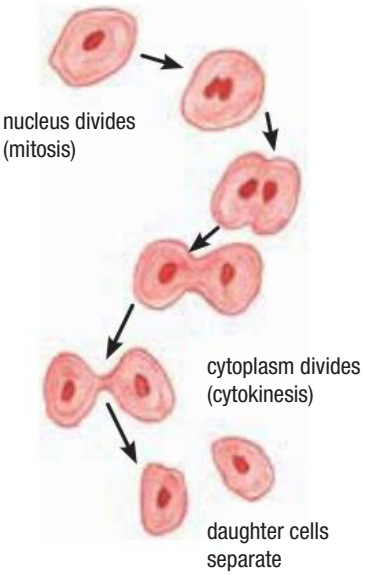


Figure 4.69 Binary fission in an animal cell.

is provided for the growth of the new organism. In suitable conditions asexual reproduction is a means by which an organism can rapidly increase its numbers.

In asexual reproduction, the new offspring are produced by mitosis. They therefore all contain the same genetic information as their parent. We use the word **clone** to refer to members of a species that are genetically identical.

Some examples of asexual reproduction

Binary fission

In all single-celled organisms, such as bacteria and protists, each time the cell undergoes cell division or mitosis, two new individuals are produced (Figure 4.69).

Spore formation

Fungi reproduce asexually by forming thousands of single-celled spores. If conditions are suitable, each spore will germinate to produce a new fungus (Figure 4.70).

Ferns reproduce asexually by producing spores in the spore sacs (sporangia) on the undersurface of their fronds. They are released and dispersed by the wind. If they land in a warm, shady, moist environment, they may germinate after about three months.

Budding

This is another method of asexual reproduction. The parent, by mitosis, forms an outgrowth (a bud) which is a smaller replica of itself. Coral can be formed by budding. The new individual remains attached to the parent, so that eventually a large colony is formed (see Figure 4.72).



Figure 4.70 Spore formation in a fungus.



Figure 4.71 The sporangia of the bird's nest fern (*Asplenium australasicum*), which grows in tropical and temperate Australian rainforests.

Vegetative propagation

Vegetative propagation is the process by which many flowering plants produce new individuals from points on stems or roots called **nodes**. Grasses, in particular, can spread out to cover large areas in this way (Figure 4.53, p. 281).

Gardeners often propagate plants by asexual methods. Taking cuttings, budding, grafting and tissue culture are all techniques by which new plants or parts of a plant can be reproduced from parts of another or the same plant.

Regeneration

Regeneration is the regrowth of parts of an organism that have been removed or lost. This form of reproduction is used in many plant propagation techniques.

In animals the power of regeneration varies. In some invertebrates, such as flatworms, whole new organisms can be regenerated from pieces. This is, in fact, an example of asexual reproduction where more than one organism results from one parent.

Many Australian plants have excellent powers of regeneration, particularly after fire or drought. Many trees and shrubs, such as *Eucalyptus paniculata* and *Banksia aemula*, have thick bark which enables the trunk and main branches to survive fire and produce new shoots from dormant buds. Mallee eucalypts have large, woody underground swellings called lignotubers that resprout after fire, giving these trees a many-stemmed, shrubby look (see Figure 4.52, p. 281).

Some plants are killed by fire, but reproduce from seed that is protected in capsules (e.g. eucalypts, tea-trees), woody cones (e.g. cypress pines) or fruits (e.g. banksias, hakeas).



Figure 4.72 Coral can be formed by budding. The new individual remains attached to the parent, so that eventually a large colony is formed.

Advantages of asexual reproduction

describe the conditions under which asexual reproduction is advantageous, with reference to specific Australian examples

Asexual reproduction can be advantageous when environmental conditions are stable and those conditions are favourable for the organism concerned. Since the offspring produced in asexual reproduction are identical to their parents, these new organisms show no variation. There is little chance of new types evolving. If an organism is successful in its environment, it does not matter if there is no variation. This lack of variation may, in fact, be useful. One type of organism can remain unchanged and successfully reproduce asexually for many generations. The growth of coral to form the Great Barrier Reef is a good example of this. We also find this an advantage in horticulture and agriculture, since it enables us to be sure of breeding plants with the characteristics we want. However, what happens to these organisms if the environment does change? Suppose, for example, a new disease or insect pest attacks members of a particular plant species. If it reproduces by asexual methods only, it is possible that none would survive.

Offspring produced as a result of sexual reproduction show variation. If the environment changes, there is a chance that some of a species which show variation will still survive. It is through variation that natural selection and evolution can take place.

Through natural selection, many Australian species have developed specific reproductive adaptations to the Australian environment. This increases their chance of continuity and the successful survival of the species.

UNIT REVIEW 4.3

The continuation of species

Continuation of species has resulted, in part, from the reproductive adaptations that have evolved in Australian plants and animals.

Summary

- The daughter cells produced as a result of the process of mitosis are identical. The daughter cells produced as a result of meiosis show variation; they are genetically different.
- Fertilisation is the fusion of one male gamete and one female gamete. It requires a watery medium. In external fertilisation, gametes are released directly into the environment. Large numbers are produced to increase the chance of male and female gametes meeting. In internal fertilisation, gametes are transferred from the body of one organism to another. This greatly increases the chances of successful fertilisation.
- External fertilisation occurs mostly in aquatic environments. Internal fertilisation has enabled the colonisation of terrestrial environments where water availability is restricted.
- Australian flora show reproductive mechanisms for pollination (for example, the grass-leaved trigger plant), seed dispersal (for example, the waratah) and asexual reproduction (for example, sphagnum moss).
- Australian fauna show reproductive mechanisms to ensure fertilisation, for example, bower-bird courtship displays, and to ensure the survival of the embryo and the young after birth, for example, the pouch of marsupial mammals.
- The evolution of these reproductive adaptations has increased the chances of continuity of the species in the Australian environment by increasing the chances of fertilisation and survival.
- Asexual reproduction is advantageous in an unchanging environment, for example, the growth of coral on the Great Barrier Reef.

Questions

1 In which way do the daughter cells produced in meiosis and mitosis differ?

A Meiosis produces diploid cells; mitosis produces haploid cells.

B Mitosis produces half as many daughter cells as meiosis.

C All the daughter cells from meiosis are identical.

D Meiosis produces haploid cells, which show variation.

2 Which statement best distinguishes the processes of mitosis and meiosis?

A Mitosis occurs in a single division, which duplicates and separates chromsomes; meiosis occurs in two divisions and halves the chromosome number.

B Mitosis occurs in all the cells of the body; meiosis occurs only in the ovaries in animals and the stamens of plants.

C Meiosis does not involve division of the centromere, as happens in mitosis.

D Meiosis is the basis for reproduction of the species; mitosis is the basis for growth, not reproduction.

3 Study this diagram of a grass flower shown right.

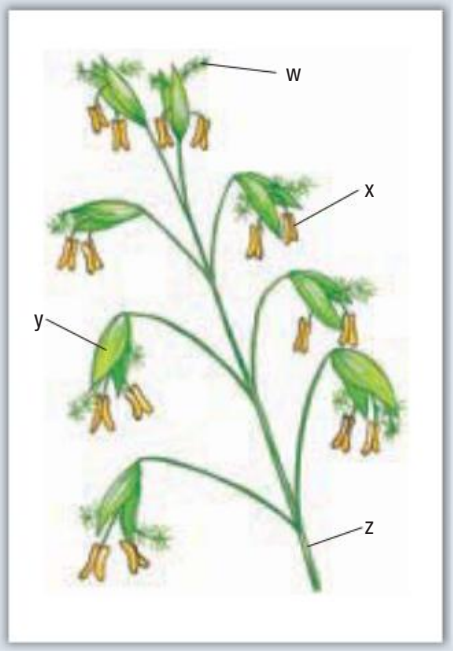
Identify which features are probably adaptations for wind pollination.

A w, x

B x, y

C y, z

D w, z



4 Draw up a table summarising the differences between the processes of internal and external fertilisation.

5 a Fertilisation and the subsequent development of an individual requires a watery environment. Explain how terrestrial organisms have overcome the problem of fertilisation in a dry environment.

b Explain the significance of this in relation to the colonisation of terrestrial environments.

6 Prepare large, labelled diagrams showing the structure of a flower. Describe the function of each structure.

7 Describe, with named examples, some mechanisms found in Australian fauna to ensure each of the following:

- fertilisation
- survival of the embryo
- survival of the young after birth.

8 Explain how each mechanism you have described in Question 7 provides an adaptive advantage in the Australian environment.

9 a Describe some Australian native angiosperms you have studied that are pollinated by animals. Use diagrams to illustrate your answer.

b Identify the features that appear to be adaptations for pollination by insects, birds or mammals.

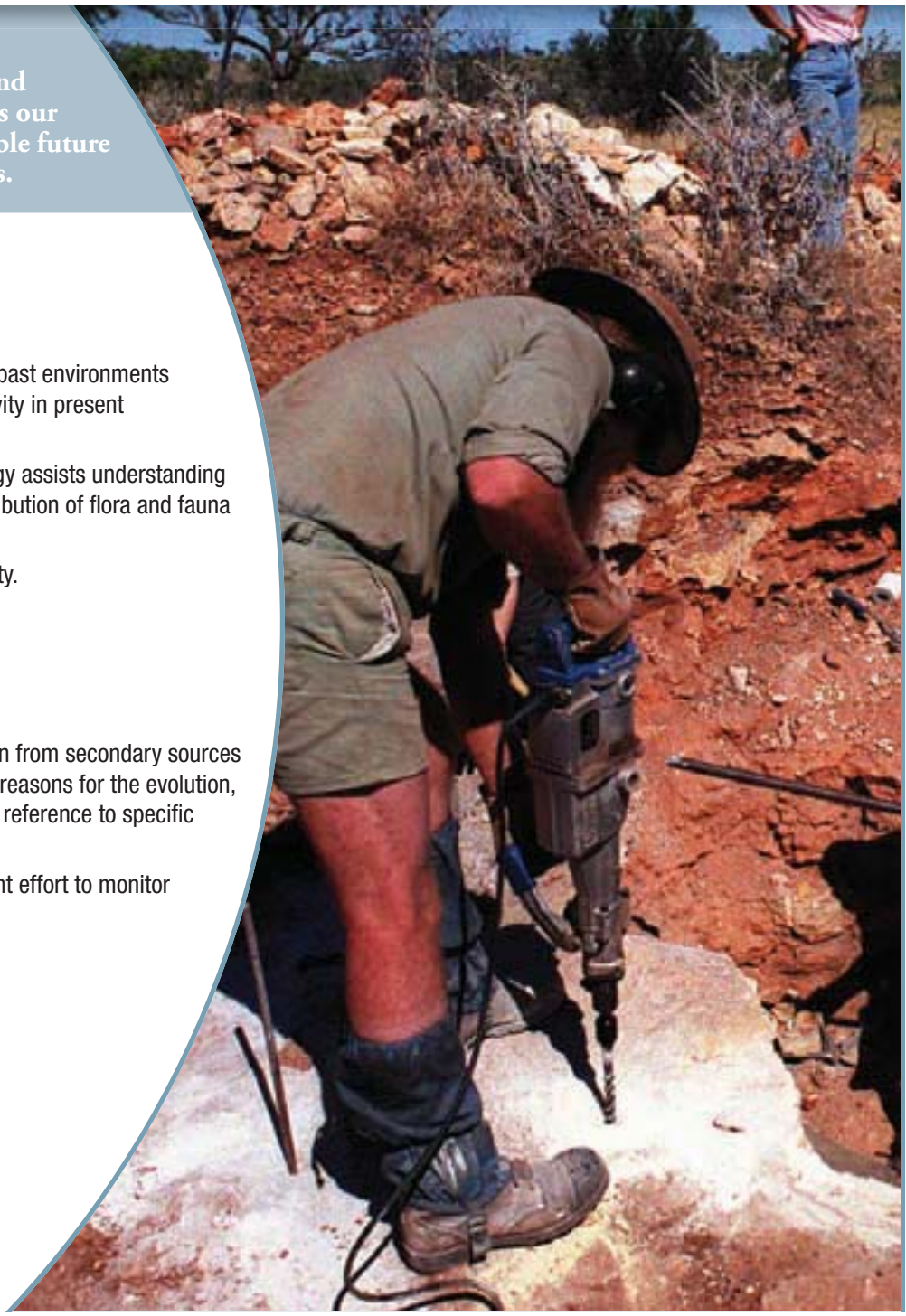
10 Distinguish between sexual and asexual reproduction. Include the differences between process and outcome.

11 a Describe the conditions under which asexual reproduction is advantageous, with reference to specific Australian examples.

b Predict how sexual reproduction could be advantageous in a future Australian environment.

4.4 THE FUTURE OF AUSTRALIA'S BIOTA

A study of palaeontology and past environments increases our understanding of the possible future range of plants and animals.



STUDENT LEARNING

In this unit students will:

- explain the importance of the study of past environments in predicting the impact of human activity in present environments
- identify the ways in which palaeontology assists understanding of the factors that may determine distribution of flora and fauna in present and future environments
- explain the need to maintain biodiversity.

STUDENT ACTIVITY

Students will:

- gather, process and analyse information from secondary sources and use available evidence to propose reasons for the evolution, survival and extinction of species, with reference to specific Australian examples
- process information to discuss a current effort to monitor biodiversity.

Understanding the past

explain the importance of the study of past environments in predicting the impact of human activity in present environments

The knowledge we gain from palaeontology and the study of past environments can help us to understand present-day ecosystems. We can use this knowledge to predict the impact we are having and to determine the future for Australia's plants and animals.

Palaeobiologists build up a picture of the evolution of plants and animals and their environments. They gain knowledge about the long-term changes that have occurred in ecosystems. Australia offers an ideal opportunity to understand these changes—it has been isolated from other terrestrial ecosystems for more than 30 million years and has been mostly geologically stable for more than 300 million years. Research work at Australian universities and at major fossil sites such as Riversleigh and Naracoorte, as well as the many smaller sites such as Murgon and Lightning Ridge, is helping us to appreciate how our unique biota evolved. At Riversleigh the story of 30 million years of evolution of Australia's terrestrial ecosystems is being uncovered.

Present and future environments

identify the ways in which palaeontology assists understanding of the factors that may determine distribution of flora and fauna in present and future environments

We can use our knowledge of past environments to predict the impact we are having now and will have in the future on the distribution of Australia's plants and animals. We know that there has been a loss of biodiversity over time. This loss correlates with the contraction of rainforest over Australia as the continent became drier (see Figure 4.22, p. 246). Over the last 200 years we know that the area covered by forest has been reduced still further because of timber harvesting and clearing for agriculture. Most of our rainforest is now found only in small, isolated pockets near the coast of eastern Australia, and much is now in national parks. Are these pockets large enough for long-term sustainability of rainforest ecosystems? Evidence from other parts of the world suggests that the areas currently protected are not big enough. Plants and small animals may survive, but the larger mammals probably will not.

The history of the thylacine or Tasmanian tiger, *Thylacinus cynocephalus*, is an interesting case study. Thylacines were the largest carnivorous mammals in Australia. The fossil record reveals that six species existed in the past. Over the past 25 million years the number of species declined, and the geographical area in which they were found became smaller. Two hundred years ago, thylacines were already scarce. If the European settlers in Tasmania had known this, would they have tried to conserve them?



Figure 4.73 The last known thylacine died in captivity in Hobart Zoo in 1936.

Understanding the past history of a plant or animal group can help us make decisions about its conservation value. Our knowledge of the plight of the thylacine came too late to prevent us from hunting it to extinction.

Analysis of the fossils of plants, particularly pollen, and animals, together with the sediments in which they are found, helps palaeontologists to put together a picture of an ecosystem and its probable climate. Natural ecosystems, and the distribution and abundance of organisms across Australia today, reflect what has happened in the past. The impact of humans, and in particular their agricultural practices, is having a dramatic impact on the natural ecosystems that remain. Large areas of land are experiencing devastating degradation. The result of this could be that we are presently witnessing a biological catastrophe far greater than the extinctions of the past. Conservation for the future is an important issue. The study of palaeontology shows us what has happened in the past. It is up to us to take this knowledge and use it for the future benefit of Australia's unique plants and animals.

Researching Australian fossils: windows to the past

Fossil sites in Australia (see map below) represent key stages in the development of Australia's fauna. They provide links which afford scientists with a basis for documenting evolutionary change, to enable them to understand how modern biota has developed.

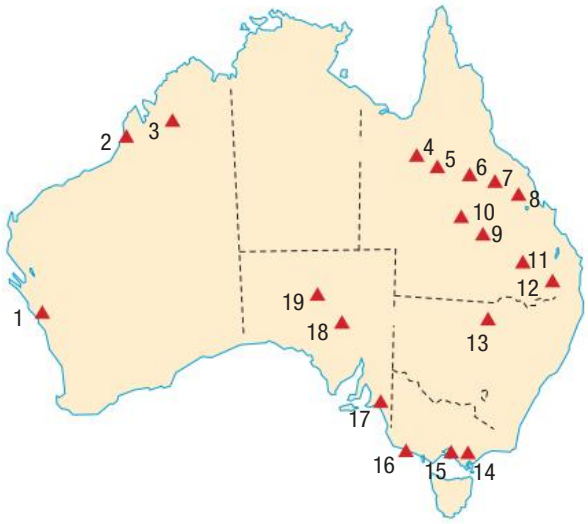


Figure 4.74 Fossil sites in Australia.

Riversleigh: World Heritage fossil site

The fossil sites at Riversleigh, in the southern section of Lawn Hill National Park in northwest Queensland, have yielded one of the world's richest and continuous records of the changes in fauna, habitat and climate at any single locality in the world. There are more than 250 fossil-rich sites at Riversleigh. It has also been recognised as one of the most important fossil sites in the world and was added to the World Heritage List in 1994.

Almost half of what is known about the evolution of Australian mammals in the last 30 million years comes from bones found at a single site at Riversleigh. More than 50 new species of mammals were recovered from this site alone.

The fossils discovered at Riversleigh represent the following periods in Australia's prehistory:

- late Oligocene (25 million years ago)
- early Miocene (20–15 million years ago)
- mid to late Miocene (15–10 million years ago)
- Pliocene (5 million years ago)
- Pleistocene (approximately 40 000 years ago).

The Riversleigh fossils were preserved in very hard limestone. They include birds, reptiles, mammals, fish and insects. Many of the species discovered there, such as the thingodontans and wynyardiids, are unique

and quite different from species living today, while others appear to have been ancestors of species living today, such as kangaroos and koalas. Thingodontans appear to have been mammals somewhere between the carnivorous marsupials and the herbivorous marsupials.

Riversleigh has revealed several different species of fossil thylacines, one of which was the largest living mammalian carnivore in Australia. Recently a 15-million-year-old platypus was found.



Figure 4.75 The dig at Riversleigh.

The Pliocene wetlands of Bluff Downs

Bluff Downs is one of the most significant fossil sites of the Pliocene period in Australia. Many animals of the Pliocene grew very large. For example, the Bluff Downs giant python (*Liasis* sp.) was 8 metres long. It is perhaps the largest snake that ever lived on the Australian continent.

Bluff Downs was a wetland environment, and the home of a rich diversity of animals. Lake and stream deposits contain the bones of ancestors of modern species known today. For example:

- ancestral dasyurids (marsupial carnivores)
- flamingos, which are no longer found in Australia
- *Koobor jimbarretti* (a koala-like mammal).

Murgon: Eocene connection

Murgon is located in southeast Queensland. It is the only Australian fossil site that records a diverse vertebrate fauna from the early Eocene period (55 million years ago), approximately 10 million years after the extinction of the dinosaurs. During this period, Australia was still connected to Antarctica and South America. Murgon's significant fossil records include some of the world's oldest fossil marsupial remains and one of the oldest placental mammals found in Australia, the condylarth.

Lightning Ridge: ancient monotremes

Lightning Ridge, in western New South Wales, is best known for the magnificent opals that have been mined there since the 19th century. But it is also known for its highly significant fossil site. The early Cretaceous Period (110 million years ago) is when the Lightning Ridge fossil deposits formed. The most significant fossils found at Lightning Ridge are the oldest known monotremes—egg-laying mammals.

These fossils were the ancestors of the modern platypus and echidnas of Australia and New Guinea. The Cretaceous monotremes were similar in size and shape to the modern platypus. They have been found with fossils of dinosaurs, other reptiles and lungfish.

The Naracoorte megafauna

The caves at Naracoorte in southeastern South Australia are significant to biologists for two reasons: one is the huge colonies of bats that inhabit them, and the other is the largest and best preserved Pleistocene vertebrate fossil assemblage in Australia. In the Victoria Fossil Cave, at least 100 vertebrate species have been recovered. Species range in size from giant, extinct mammals, birds and reptiles (ice-age megafauna) to modern species such as the Tasmanian thylacine, wallabies, snakes, bats, turtles, lizards, mice, possums, parrots and frogs. In 2007 the caves were added to the National Heritage List.

Ancient mammal and giant amphibians: Inverloch—San Remo



Figure 4.76 *Ausktribosphenos* jaw.

In 1991 a team working with Dr Tom Rich of Museum Victoria discovered a rich fossil site on a rock platform on the Victorian coast, near the town of Inverloch. The site, called Flat Rocks, has yielded a rich collection of dinosaur fossils, but perhaps the most important find so far was very different: it was the jaw of a tiny mammal that lived alongside the dinosaurs. Christened *Ausktribosphenos nyktos*, this is among the oldest known mammals, living about 115 million years ago during the Cretaceous period. It has features that suggest it was a placental mammal, but until now placentals were thought to have arrived in Australia much later from South-East Asia. One theory is that terrestrial placentals, including *Ausktribosphenos*, became extinct in Australia—perhaps being displaced by marsupials—and that another group of terrestrial placentals arrived much later to recolonise Australia.

Another remarkable find in the area was a large amphibian called *Koolasuchus cleelandi*. Two jaws of this 5-metre labyrinthodont were found during the prospecting of a rock platform near the town of San Remo, not far from Inverloch. *Koolasuchus* belongs to a group that includes the ancestors of the salamanders. This group became extinct everywhere else in the Jurassic, and seems to have been the last of its kind anywhere on Earth: all other labyrinthodonts died out more than 140 million years earlier, in the late Permian or Jurassic.

The fossil fishes of Gogo

At a cattle station called Gogo, in the Kimberley region of Western Australia, superb fossil fishes have been discovered. These fishes, trapped in limestone for more than 370 million years, are providing evidence of the origin and evolution of the first four-legged animals, the tetrapods. The Gogo fishes inhabited an ancient reef. They include armoured fishes (now extinct) and bony fishes, including 34 species that were previously unknown.

4.11 INVESTIGATION

Living in the past

Students will: gather, process and analyse information from secondary sources and use available evidence to propose reasons for the evolution, survival and extinction of species, with reference to specific Australian examples.

Introduction

In 1969, after four years of exploration, the palaeontologists Gartrell and Wells stumbled on a fossil fossicker's treasure trove—a long-hidden chamber in a cave at Naracoorte, South Australia, that would yield the fossilised remains of tens of thousands of vertebrate animals. The cave complex at Naracoorte contains over 100 fossil sites, and is the only place in the world to have a continuous record of changing Australian animal species over the last half million years. So far more than 100 separate species have been identified.

The fossils represent examples of extinct species of megafauna such as the giant Tasmanian devil, marsupial lion, giant echidna, diprotodontoids and giant kangaroos, as well as numerous modern-day species including frogs, lizards, turtles, snakes, birds, mice, possums, wallabies, the Tasmanian devil and the now extinct thylacine or Tasmanian tiger. Today the Naracoorte caves complex is renowned as Australia's most significant fossil site in terms of the number of fossil remains, the volume of fossil-containing sediment, the quality of preservation and the sheer diversity of species represented.

Purpose

To propose reasons for the evolution, survival and extinction of species, using Australian examples.

Procedure

Read pages 300–302, along with the information above and other reference material about Naracoorte, then answer the questions below.

Discussion

1 Explain why the uplift caused by the Kanawinka fault 800 000 years ago was an important event in relation to the fossil deposits found in the Naracoorte caves.

2 Outline the scientific evidence that suggests:
   a that the Naracoorte region was once covered by the sea
   b the ages of fossils discovered at different depths within the cave sediments
   c the kinds of vegetation that occurred at different times.

3 Outline the evidence described in the article that indicates when sand dunes were formed.

4 a List some of the species of megafauna that have been fossilised at Naracoorte.
   b Outline one theory that has been proposed to account for the development of megafauna in Australia.

Skills and outcomes

P10, P12, P13, P14

Type of activity

Second-hand data activity

Materials

- books, journals, Internet sites

See Analysing information

c Describe one theory that attempts to explain the decline and extinction of megafauna.

5 Outline the theories that have been put forward to explain how the remains of dead animals ended up in the caves.

6 Although extinct, the Tasmanian tiger represents an example of a modern-day marsupial. The last thylacine in captivity died in the Hobart Zoo in 1936. Suggest a likely reason for the decline and extinction of the thylacine.

7 Some of the species that have been fossilised for tens of thousands of years at the Naracoorte caves still exist today.

a List examples of other modern-day fauna that are represented at the Naracoorte caves.

b What does the presence of modern-day species that have been fossilised for tens of thousands of years suggest about the environment and the species itself?

8 Use the information provided and other material you have found to draw a vertical timeline of events that are thought to have occurred at Naracoorte. Next to the timeline draw up columns representing:

a geological events

b climatic changes

c changes in vegetation

d changes in the kinds of fauna that existed at different times.

9 Naracoorte is just one example of a significant palaeontological site in Australia. Choose from the list of other important sites below. Conduct library or Internet research to find out where the site is, and what story it can offer us about the history of Australian flora and fauna. Present your findings as a brochure, poster or web page.

a Lightning Ridge; Riversleigh; Maxwelton; Minmi Crossing

b Hughenden; Bluff Downs; Muttaburra; Winton

c Roma; Murgon; Coober Pedy; Andamooka

d Dinosaur Cove; Geraldton; Broome; Gogo

e Inverloch—San Remo; Strzelecki Ranges

The fossils at Naracoorte

Scientists exploring and studying the deposits at the Naracoorte Cave complex are trying to put together a puzzle of mammoth proportions—the big picture of what life forms and their environment were like at the time that the fossilised organisms lived, and how and why species have changed or become extinct.

Scientists construct parts of the picture using obscure pieces of the puzzle, such as tiny bones and fossilised teeth, the pollen of plants and geographic features. When the pieces are put together, a meaningful picture begins to emerge.

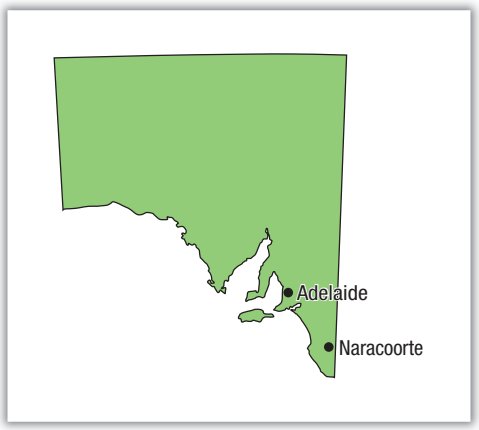


Figure 4.77 The Naracoorte Cave complex, 300 km south-east of Adelaide, achieved World Heritage listing in 1994.

1859	Fossilised bones discovered in Blanche Cave at Naracoorte, South Australia.
1908	Fossil remains of marsupial lion in Specimen Cave reported by Professor Stirling.
1963/4	Cave Exploration Group of South Australia stumble on fossil remains of kangaroos in Haystall Cave—52 specimens representing three extinct species uncovered.
1994	Naracoorte, together with Riversleigh, nominated for World Heritage Listing as the Australian Fossil Mammal Sites World Heritage Area.
Present day	Victoria Fossil Cave open to public, research continues, particularly in Blanche Cave.

Figure 4.78 Timeline of some Naracoorte Cave events.

The puzzle at Naracoorte begins with its geology. The terrain features a limestone plateau along the Kanawinka fault. The limestone itself was deposited up to and including the Miocene epoch, when the region featured a warm, shallow ocean. Naracoorte limestone is richly endowed with the fossils of brachiopods, molluscs, sponges, corals and echinoderms. Fossilised remains of much larger marine species such as whales and sharks have also been reported.

Later in the Miocene, the ocean waters receded, exposing the limestone to weathering. Water filtering through the rock dissolved much of the limestone, resulting in the formation of the many caves that exist there. About 800 000 years ago the Kanawinka fault moved, uplifting the Naracoorte limestone, raising the caves above the water table. Much of the limestone became covered and protected by sand dunes formed by the deposition of sand from the nearby sea.

As water percolated downwards, dissolving some of the sand and limestone, 'pitfall traps' were formed. It is theorised that these pitfall traps claimed many animals for the caves below, accounting for much of the bone deposits. The flow of water into and through the caves would also have been responsible for the deposition of dead remains.

Another theory suggests that some of the smaller animal deposits were made by predators such as owls that may have used the caves as a roost. Some of the animals found there, such as frogs, snakes and bats, probably lived in the caves and subsequently died there. Sediments transported into the caves by flowing water would have covered the dead remains, which eventually fossilised.

Various dating techniques suggest the cave deposits were made over a period of time between 15 000 years before present (BP), and at least 350 000 years BP. Carbon dating of bones in the upper sediments suggest they were deposited between 20 000 and 36 500 years ago. Uranium dating puts some of the older deposits at 280 000 years, and possibly older. Electron spin resonance (ESR) dating of some fossilised teeth indicate an age of 350 000 years BP. Dating of quartz deposits using optically stimulated luminescence (OSL) indicates that sands were deposited in the caves some 200 000 to 300 000 years BP.

While the animal fossils found at the Naracoorte site help to construct a picture of the kinds of fauna that existed at different times, other pieces of evidence are useful in reconstructing climatic conditions. Pollen analysis is a useful indicator of the kinds of flora that existed. Core analysis of pollen samples in the Naracoorte area indicate that Eucalyptus forest, or woodland featuring an understorey of shrubs, was followed by a period of open woodland. This pattern occurred twice in alternating succession between 50 000 and 11 000 years ago. The area then became a Casuarina community that has persisted to the present day.

In general, Australia has experienced an increase in aridity over the last 20 million years, with decreasing rainfall resulting in a contraction of rainforest and an increase in sclerophyll forests and grasslands (see pp. 242–246). Scientists have theorised that these changing climatic conditions have been responsible for changes in species over time.

Some explanations have been hotly debated—for example, one theory suggests that the increase in size of some marsupials to 'giant' proportions may have been related to a decrease in environmental temperatures. This gave an advantage in terms of heat conservation to organisms with a large body and a relatively small surface area.

Attempts at explaining the extinction of species are equally controversial. The decline and extinction of species such as the giant echidna, and more recently the thylacine, is attributed by some to changes in climatic conditions. It is also arguably the result of human intervention that profoundly altered the ecology of native vegetation. Such human intervention includes the activities of Aboriginal peoples, and in very recent history the impact of European settlement.

Further activities

1 Various techniques have been used by scientists in establishing the ages of fossils and rock at Naracoorte. These include carbon dating, uranium dating, Electron spin resonance (ESR) and optically stimulated luminescence (OSL). Choose one of these techniques for further study. Describe the process, outline its applications, and summarise the advantages and limitations of the technique. Report on your findings using a publishing program or a multimedia presentation.

2 Find out more about one species of megafauna listed in the article. Describe the features, lifestyle and habitat of the species. Present your findings as a large educational poster that could be used to teach other classes.

The need to maintain biodiversity

explain the need to maintain biodiversity

The variety of life on Earth is continually changing. A study of the Earth's history and the evolution of living things over time shows that new species arise, while others become extinct.

Today there is international concern that the rate of loss of biodiversity on the planet is increasing. The main cause of this loss is human activity, particularly the destruction of the natural environment, which is causing the rapid extinction of many species. Cities, towns and farms are replacing natural ecosystems. Those natural environments that remain are exposed to pests, introduced species, pollution and **climate change**.

We know that biodiversity is essential for maintaining the functions of natural systems on Earth, such as providing clean water, air and productive soil, and recycling matter. Many human activities depend on biodiversity—for example, agriculture, forestry, fisheries, tourism, construction, textile manufacturing, and medicine.

In 1992 in Rio de Janeiro, 157 countries including Australia signed the Convention on Biodiversity. This was drawn up to ensure that countries take action to protect their biodiversity. The three main aims of the convention are:

1. the conservation of biodiversity
2. the sustainable use of its components
3. the fair and equitable use of the benefits arising from the use of genetic resources.

Countries which signed the Convention agreed to identify important parts of the biological diversity in their own country that needed to be conserved, and to commence action to do so. In 2002, all countries that signed the Convention agreed to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level, as a contribution to poverty alleviation and to the benefit of all life on Earth. This is known as the *2010 Biodiversity Target*.

In 2005 the United Nations released the report of a five-year scientific study, known as the *Millennium Ecosystem Assessment*. The study aimed to better understand the consequences of current changes to ecosystems and to evaluate scenarios for the future. It found that 60% of the services humans use that are provided by nature, for example, water, air and fish, are being degraded or used unsustainably. It warned that the consequences of this degradation would get worse over the next 50 years. The report also warned that it will take a huge effort to achieve the 2010 Biodiversity Target.

In 2008, the International Union for the Conservation of Nature's latest *Red List* shows continuing decline of Earth's biodiversity and an increase in the number of threatened species.

The Australian Government, through the Department of the Environment and Heritage, has a *National Strategy for the Conservation of Australia's Biological Diversity*, and the Government of New South Wales has a *NSW Biodiversity Strategy*. To conserve vulnerable environments and endangered wildlife, we all need to increase our efforts at individual, community and government levels.

BIOFACT

Biological diversity or biodiversity is the variety of all living organisms found on Earth. This variety has three components:

1. At the genetic level there is variation in the genes found within a species.
2. At the species level there is variety in the types of plants, animals and microorganisms found.
3. At the ecosystem level there is a variety of different environments that support different species.

According to the International Union for Conservation of Nature's 2008 *Red List of Threatened Species*, the four countries with the greatest number of threatened species are Brazil, China, Mexico and Australia

See Chapter 1, p. 43.

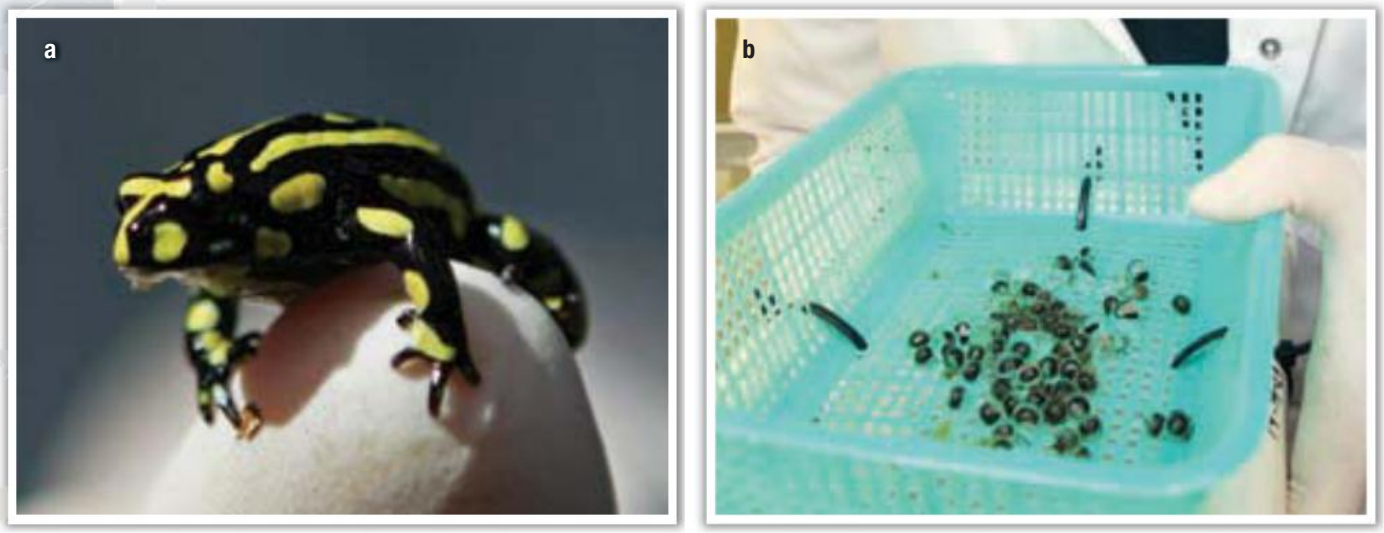


Figure 4.79 (a) The southern corroboree frog (*Pseudophyne corroboree*) is a rare and endangered frog that is found in the Australian Alps. (b) A captive breeding program is part of the ongoing effort to try to prevent its extinction.

Preserving biodiversity in Australia

Seed banks

Seed banks are an important way of preserving and maintaining the genetic diversity of Australian flora. Seeds are usually dried and frozen before storage, and many seeds can be stored in a small amount of space. There are many seed banks in Australia. The New South Wales seed bank is at Mount Annan Botanic Garden. A number of Australian seed banks are collaborating with the Millenium Seed Bank Project in England that was set up to collect seeds from the world's rarest, most threatened and most useful species. Australia is also a contributor to the Svalbard Global Seed Vault that was opened in 2008. This Norwegian storage facility has been set up with the aim to collect and hold seeds from all the known varieties of the Earth's main food crops.

Maintaining Australia's biodiversity hotspots

Biodiversity hotspots are large areas that are still relatively intact in terms of their biodiversity. They contain a high number of endemic species that are not found or are rarely found outside the hotspot.

The Australian Government's *Maintaining Australia's Biodiversity Hotspots Programme* provides funding for active conservation management, whether the land is in public or private hands, to protect these existing ecosystems. So far, 15 biodiversity hotspots have been identified in Australia. The only one in New South Wales is the Border Ranges which lie along the Queensland and New South Wales border. This area includes subtropical rainforest, wet sclerophyll forest, mountain headlands and a huge variety of birds and marsupials.

Australia is also one of the world's marine biodiversity hotspots. CSIRO's Wealth from Oceans Flagship program is working to produce a management system to conserve Australia's marine biodiversity. They hope to create a national representative system of marine protected areas by 2012.

Sustainable agriculture

We obtain all our food from wild and domesticated organisms that are part of the Earth's biodiversity. Five thousand plant species have been used as food by humans, but less than 20 now provide most of the plant food eaten by most of the world's population. As has happened across the globe, the increased land use in Australia to produce more of a fewer number of food products has resulted in a loss of biodiversity and ecosystems. The aim of sustainable agriculture is to manage this balance—to protect and preserve biodiversity while producing enough food for human consumption.

Australia also has a reservoir of genetic diversity for useful food species, such as the macadamia nut and quandong, which increase the potential for enhancing agricultural productivity. We have 15 of the world's 16 species of wild soybean—a group of plants that is becoming increasingly important as a human and stock food. In the future, these species may be extremely valuable genetic stock, because unlike current commercial varieties, many of these wild plants have genes which allow them to resist leaf rust disease.

Native Australian plants have great food potential. 'Bush' foods have high nutritional value. Some even have greater amounts of minerals, **vitamins**, proteins, fat and carbohydrates than cultivated plant foods. Acacia seeds, for example, are superior to rice and wheat in energy, protein and fats. The potential of Australian acacias to enhance diets in Africa has been investigated by CSIRO and researchers in the Niger and Nigeria with success, and is now being adopted by international agencies.

Medicines

Many of the drugs used in medicine are derived from plants, animals and microorganisms. A large number of Australian species are the basis of medicinal products. Two species of corkwood (*Duboisia*) are used to produce hyoscine, a medicine which is used to treat the effects of cancer therapy, motion sickness and stomach disorders. Lymphoid leukaemia is treated by the drug tylocrebrine, which is produced from the vine *Tylophora*. Prostaglandin E2, a substance which could be important in the treatment of gastric ulcers, was first discovered in the two species of gastric-brooding frogs (*Rheobatrachus vitellinus* and *Rheobatrachus silus*), found only in the rainforests of Queensland. These frogs incubate their young in their stomachs. Unfortunately, these frogs have not been seen in the wild for a number of years and are now thought to be extinct.

The search continues for new medically active compounds and other Australian biota to contribute to modern medicine, and for discovering cures for known diseases. Humans are dependent on biodiversity for their health and well-being. Our survival therefore depends on protecting and conserving biodiversity.



Figure 4.80 To remain sustainable, Australian fisheries depend on the maintenance of biodiversity and the protection of ecosystems, especially in breeding and nursery areas for key species such as orange roughy and southern bluefin tuna.

INVESTIGATION 4.12

Biodiversity

Students will: process information to discuss a current effort to monitor biodiversity.

Skills and outcomes

P4, P5, P7, P8, P13, P14, P15, P16

Type of activity

Second-hand data activity

Materials

- books, fact sheets, journals, Internet sites

See Analysing information

Introduction

Biodiversity is the variety of all living organisms found on Earth. Australia has many unique plants and animals, and is considered to be a highly biologically diverse country.

Great changes have occurred in Australia in the past 200 years, resulting in a loss of biodiversity and degrading of many environments. Australia's *National Strategy for the Conservation of Australia's Biological Diversity* provides a framework for state, local and community groups and individuals to take action to conserve biodiversity.

Purpose

To discuss a current effort to monitor biodiversity.

Procedure

1 Read pages 231–232 on Australia's unique plants and animals, and pages 303–305 on the need to maintain biodiversity.

2 Gather information about a current effort to monitor biodiversity. This can be done as individual, group or class work.

3 Discuss the project or case study you have investigated, using the following questions to help you.

Discussion

1 What were the original causes that led to this particular project or case study being undertaken?

2 As a result of this project, what results have been found about:
   a plants in the area
   b animals in the area
   c ecosystem processes?

3 Could the outcomes from this project affect the adjacent ecosystems?

4 If your project is about a single organism, what difference could findings from this project make in the future to the population numbers of this organism?

Conclusion

1 Analyse what is being learned from this project about conserving biodiversity.

2 Evaluate this project. Will it make a lasting difference to the environment?

4.4 UNIT REVIEW

The future of Australia's biota

A study of palaeontology and past environments increases our understanding of the possible future range of plants and animals.

Summary

- A study of past environments is important in predicting the impact of human activity in present environments.
- Palaeontology, the study of fossils, can help us understand the factors that may determine the distribution of flora and fauna in present and future environments.
- Biodiversity is the variety of all the living things on Earth. It is important to preserve this variety to ensure the continuity of the ecosystems on Earth. We need to protect plant and animal species and their environments to maintain the Earth's natural systems and to sustain many human activities.

Questions

1 Which phrase best describes the work of palaeobiologists?

A the study of rocks, including dating techniques
B the study of fossil plants and animals
C the study of ancient climates inferred from fossils
D the study of the evolution of ecosystems

2 Which features of the Australian continent make it an ideal subject for the study of long-term ecological and evolutionary change?

A It has been isolated for more than 30 million years.
B It has been geologically stable for 300 million years.
C It has many fossil-rich sites.
D All of the above.

3 In what way does palaeontology assist our understanding of the flora and fauna of today and in the future?

A It clarifies the story of evolution of the species.
B It reveals the diversity of past ecosytems.
C It demonstrates the effects of climate change on biodiversity.
D All of the above.

4 Outline the evidence that supports the hypothesis that there have been changes in Australian ecosystems over geological time. Also, propose reasons for these changes, using specific examples of species that have:
   a evolved
   b survived
   c become extinct.

5 Outline the effects of humans on Australian ecosystems over the last 200 years. Include a discussion of:
   - changes in the amount of forest cover
   - changes in aquatic environments
   - effects on native flora and fauna.

6 Choose an extinct or endangered animal species for research. Choose from the list provided, or choose another animal in consultation with your teacher.

Extinct	Endangered
thylacine	blue whale
rabbit bandicoot	Leadbeater's possum
gastric-brooding frog	eastern barred bandicoot
King Island emu	green and golden bell frog

   a Describe the organism, its habitat and lifestyle.
   b Propose reasons for its extinction or endangered status.
   c For endangered species outline some conservation strategies that are being or could be implemented to improve the situation.

7 Define biodiversity and explain why is it important.

8 Discuss a current effort to monitor biodiversity in an area you have studied.

9 Outline evidence to support the hypothesis that there has been a loss of biodiversity in Australia in recent times.

10 Describe, with examples, ways in which Australia's biodiversity can be used, enhanced and preserved for future generations.

11 Predict a likely future scenario for the major ecosystems in Australia.

CHAPTER 4
EXAM-STYLE QUESTIONS

MULTIPLE CHOICE

1 Identify which of the following represent evidence that Australia was once part of the super continent of Gondwana.
- A geological evidence of more frequent volcanic activity in Australia in the past
- B similarities between present-day plants and animals on continents currently isolated from one another by the oceans
- C fossilised evidence of extinct Australian megafauna
- D changes in the Australian climate from colder to more temperate over the last 65 million years

2 Geological evidence suggests that South America separated from the Australian-Antarctic landmass around 60 million years ago. Australia is believed to have broken away from Antarctica around 55 million years ago. What does the existence of the American opossum (a marsupial) suggest?
- A Marsupials evolved independently on different landmasses.
- B The opossum migrated to South America at some time after marsupial evolution was completed on the Australian continent.
- C The opossum was brought to the Americas by early nomadic humans.
- D Ancestral marsupials already existed more than 60 million years ago.

3 Australia has a large proportion of endemic species of plants and animals. What factors contribute to Australia's richness of unique species?
- A its long isolation from other landmasses
- B early human activity, such as selective breeding of favourable characteristics
- C travel to Australia by neighbouring islanders, bringing plants and animals with them
- D a change in the climate from warmer to cooler over recent geological time

4 Darwin proposed his theory of natural selection to account for the evolution of species on Earth. Which of the following statements does not represent a key point in this theory?
- A There is variation within every species.
- B Organisms in a population that have favourable characteristics have a greater chance of survival and reproduction compared to those individuals without those characteristics.
- C Individuals that develop favourable variations of a particular characteristic are more likely to survive and reproduce compared to other individuals.
- D Favourable characteristics gradually become more common in a population.

5 Over the last 20 million years, the climate in Australia has become warmer and drier. Identify the change that has resulted from this.
- A There has been an increase in the number of bushfires.
- B There has been an increase in the area covered by tropical rainforest.
- C There has been an increase in the area covered by grassland.
- D There has been a decrease in the area covered by woody sclerophyll forests.

6 The diversity of plant and animal species on Earth is threatened most by which of the following activities?
- A the consumption of plants for food
- B the search for new medications
- C air and water pollution
- D destruction of natural environments

7 How many chromosomes will the body cells of an animal producing gametes with 16 chromosomes usually contain?
- A 8 chromosomes
- B 16 chromosomes
- C 32 chromosomes
- D 64 chromosomes

8 Which of the following adaptations in animals increases the chance of successful fertilisation?
- A laying shelled eggs
- B direct transfer of male gametes into the female body
- C production of large numbers of eggs and sperm
- D internal development of the young

9 Why is the work of palaeobiologists in building a picture of the long-term changes that have occurred in Australian ecosystems important?

A It contributes to our understanding of the evolution of endemic species of plants and animals.
B It enables us to predict the impact of human activity in our present-day environment.
C It helps us to plan appropriate management strategies to protect endangered species.
D All of the above.

10 The Tasmanian tiger or thylacine represents an example of the extinction of a species of Australian mammal. What is the most likely cause of the extinction of the thylacine?

A the activity of early Australians in managing areas of land with fire
B hunting since European settlement
C competition with other species
D the natural decline in global biodiversity

SHORT ANSWERS

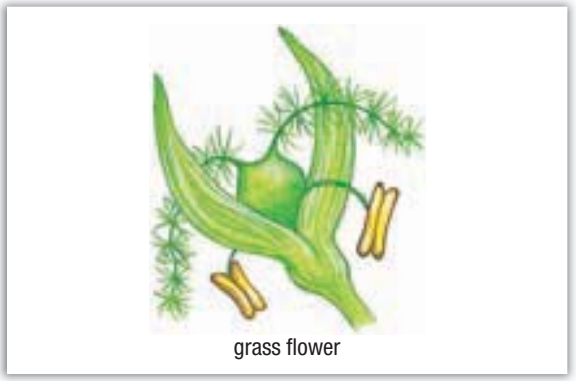
1 Describe how the formation of mid-ocean ridges and spreading zones between continental plates provides evidence that supports the theory of continental drift.

2 a Explain how variation in a population is related to the chances of survival in a changing environment.

b Suggest the likely consequence for a species that is unable to adapt to a changing environment. Explain your answer.

3 A quarry near Melbourne is the site of abundant fossil deposits of different kinds of seed-producing plants. Some resemble casuarinas that grow in tropical Australia; others are fossilised eucalypt leaves that are similar to bloodwood eucalypts that are now found only in far eastern Victoria and southern New South Wales. Palaeontological studies date the fossils at around 22 million years old. Describe the changes in environmental conditions in the area over the last 22 million years, as suggested by the evidence at this site.

4 a Identify two reasons why the flower shown below is likely to be wind pollinated.

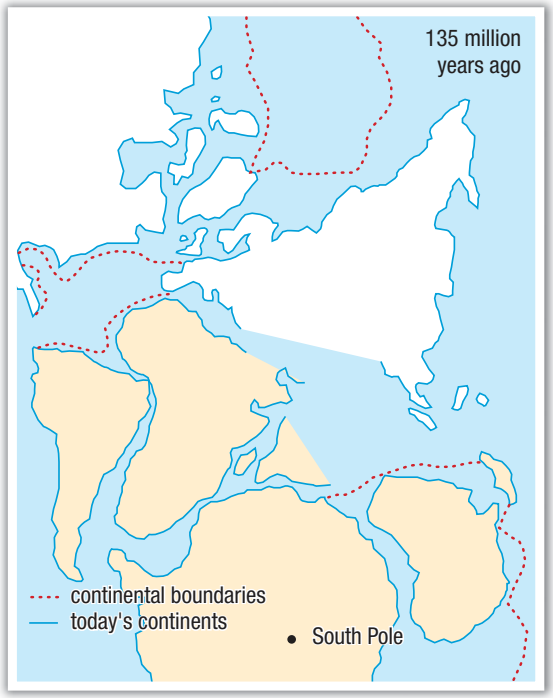

grass flower

b Describe the mechanisms for pollination of a named Australian insect-pollinated flower.

5 The continuation of species relies on successful reproduction between members of the species.

a Identify two events that must coincide in order that successful reproduction occurs within a species.
b Describe two ways in which sexual reproduction increases variation within a species.

6 The following map shows Australia as part of the super continent Gondwana, some 135 million years ago.



a Identify the other modern-day landmasses that were part of Gondwana.

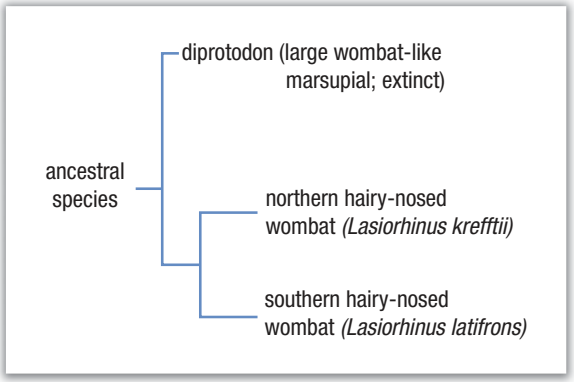
b Describe two pieces of geological evidence that support the theory that the super continent of Gondwana existed.

c Using *Glossopteris* (a kind of primitive seed fern) as an example, explain the biological evidence that supports this idea.

d Describe the changes that have occurred in the Australian climate since its separation from Gondwana.

e The Australian emu, African ostrich and South American rhea are examples of different but related flightless birds that inhabit different continents today. What conclusions can be drawn from this information in relation to the evolution of these different groups of birds?

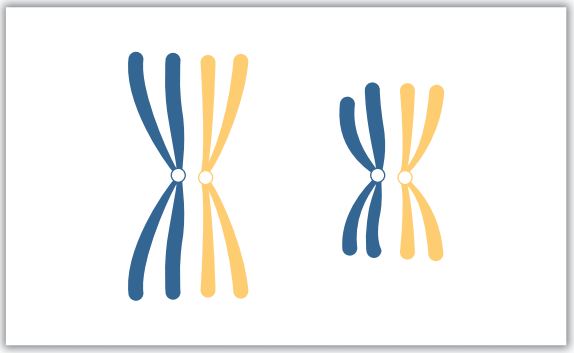
7 Study the evolutionary tree below, which represents examples of extinct and present-day Australian fauna.



a Use Darwin's theory of natural selection to account for the evolution of the two different species of wombat represented in the diagram. Include a discussion of:
- natural variation
- different environmental pressures
- adaptations to different environments
- subsequent generations of offspring.

b Outline two reasons that may account for the disappearance of Australia's megafauna.

8 The diagram shows a cell containing two pairs of chromosomes just before meiosis.



a Draw the daughter cells produced after meiosis has occurred.

b State two differences between the cells you have drawn and the cells produced after mitosis.

c Explain how sexual reproduction results in variation in the offspring.

9 Ascidians (seasquirts) are animals commonly found attached to rocks at low tide. Some species can reproduce both sexually and asexually. Through asexual reproduction, large colonies become established on certain rocks.

a Identify one advantage of asexual reproduction for seasquirts.

b Many Australian plants are capable of reproducing both sexually and asexually. Identify one example of such a plant and describe one condition under which asexual reproduction occurs.

c For the seasquirt and also your named plant, explain the advantage of also being able to reproduce sexually.

CHAPTER 5

SKILLS



The Skills Chapter is located on your ***Exam Café CD***. It is suggested that you copy this onto your computer for instant access, or print it out and file with your notes.

This chapter includes two units: *5.1 Biology Skills* and *5.2 Understanding and Using the BOS Key Terms*. These units can be read as a whole, or you may like to refer to the appropriate sections as the need arises. For example, every time you draw a labelled scientific diagram for a practical report, refer to the checklist in *Unit 5.1 Biology Skills* to ensure you have drawn the diagram correctly. Similarly, when performing a first-hand investigation, refer to this chapter to make sure your investigation is valid, reliable and accurate.

Also, when tackling exam-style questions in this book, or working through the exercises on *Exam Café*, you are advised to review the appropriate sections in *5.2 Understanding and Using the BOS Key Terms*.

Assumed knowledge

During the Preliminary Course, the Board of Studies NSW expects that students will further develop skills in:

- planning and conducting investigations
- communicating information and understanding
- scientific thinking and problem-solving
- working individually and in teams.

Preliminary Course Outcomes

Prescribed Focus Areas

P2 Applies the processes that are used to test and validate models, theories and laws of science, with particular emphasis on first-hand investigations in biology.

Domain Skills

P11 Identifies and implements improvements to investigation plans.

P12 Discusses the validity and reliability of data gathered from first-hand investigations and secondary sources.

P13 Identifies appropriate terminology and reporting styles to communicate information and understanding in biology.

P14 Draws valid conclusions from gathered data and information.

P15 Implements strategies to work effectively as an individual or as part of a team.

Values and Attitudes

P16 Demonstrates positive values about attitudes towards both the living and non-living components of the environment, ethical behaviour and a desire for a critical evaluation of the consequences of the applications of science.

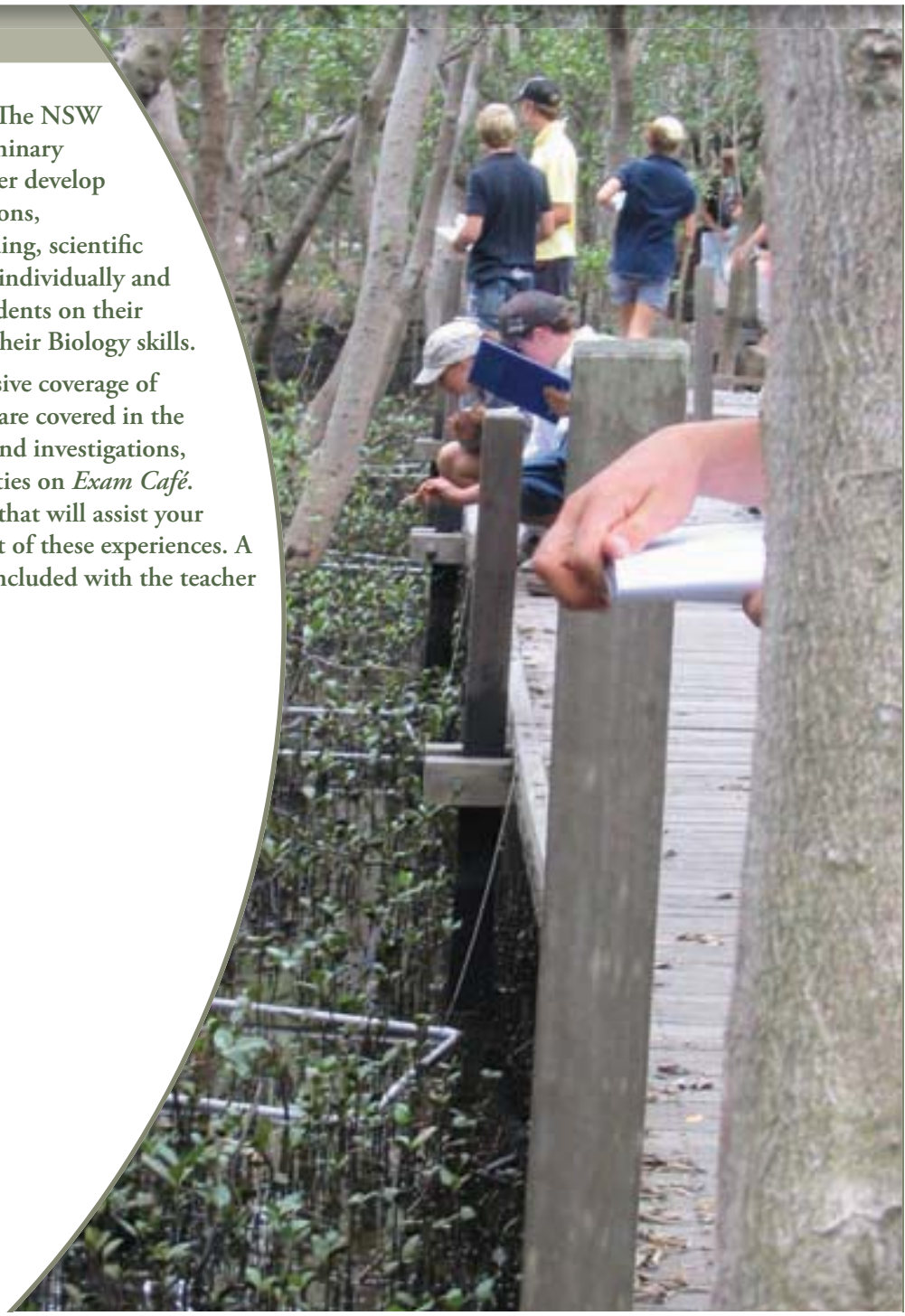
UNIT 5.1 UNIT 5.2

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These units are on your *Exam Café* CD included with this book

5.1 BIOLOGY SKILLS



Investigating is an essential part of Biology. The NSW Biology syllabus states that during the Preliminary course, it is expected that students will further develop skills in planning and conducting investigations, communicating information and understanding, scientific thinking and problem-solving, and working individually and in teams. The HSC examination assesses students on their understanding of the scientific method and their Biology skills.

This unit is not intended to be a comprehensive coverage of those skills mandated by the syllabus. These are covered in the previous chapters in the content, questions and investigations, and are further enhanced with specific activities on *Exam Café*. Instead, this unit represents a range of skills that will assist your understanding and help you get the most out of these experiences. A complete syllabus correllation document is included with the teacher resource material.

This unit can be read as a whole, or you may like to use it when the need arises. For example, every time you draw a labelled scientific diagram for a practical report, refer to the checklist in this chapter to ensure you have drawn the diagram correctly. Similarly, when performing a first-hand investigation, refer to this unit to make sure your investigation is **valid**, reliable and accurate.

First-hand investigations

First-hand investigations are those where you gather the raw data for yourself. These often take the form of experiments, activities, field trips or surveys.

The scientific method

Experiments should follow the scientific method as outlined below:

The scientific method is a specific way of investigating phenomena through experimentation. Hypotheses are tested and observable, ideally measurable, data are collected and analysed.

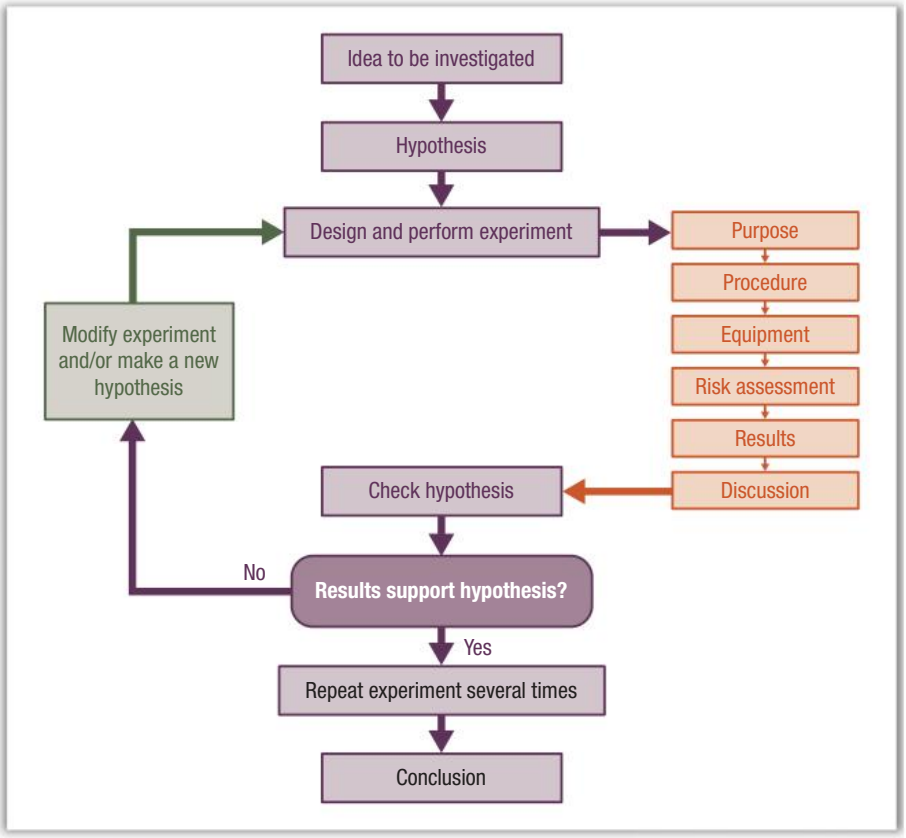


Figure 5.1 Flow chart of the scientific method.

Planning first-hand investigations

The idea for a first-hand investigation of a complex problem arises from prior learning and observations. This tells us that there are questions to be answered, e.g. indoor plants do not grow well in the long term without artificial lighting. This suggests that light is required for photosynthesis in plants, and this aspect of photosynthesis can be researched.

Background research

Find out as much information as you can about the area of investigation before you begin any practical work. This will help to give you a purpose, a reason for conducting your investigation. Other people may have already performed related activities or made relevant observations that could help you. Don't forget to reference these sources in your report.

Hypothesis

A hypothesis is a statement that proposes a relationship between two or more variables.

A hypothesis is a predictive statement that describes a relationship between two or more variables. That statement is based on sound scientific knowledge and can be tested, e.g. 'Light is required for photosynthesis.' An experiment is then designed to test this hypothesis. An investigation is conducted to determine whether or not there is evidence to support the hypothesis.

Variables

The independent variable is the one that you change.
The dependent variable is the one that changes because of the independent variable.
The controlled variables are all of the other variables in the experiment; they are kept the same.

Variables are the factors that can change during an experiment.

The variable that you manipulate during the experiment is the independent variable. It is the one that you are testing. It does not depend on the experiment because you are changing it.

The dependent variable is called this because it depends on the independent variable. It gives you the results of your experiment. The dependent variable is accurately measured during the experiment.

All other variables must be kept constant so that your experiment is a valid and fair test. You should only test one variable at a time. If you don't keep everything else the same then you can't be sure that your experiment is only testing the independent variable.

The control

The control does not contain the independent variable at all.

There must be an identical experimental set-up that does not include the independent variable. This is called the control. The purpose of the control is to show that any changes that result from the experiment are entirely due to the independent variable, e.g. if you were observing transpiration (water loss from the leaves) of a celery stem, your control would be a beaker of water without a celery stem.

Accuracy, reliability and validity of first-hand data

Accuracy is how close something is to the truth.

When gathering data for yourself, it is necessary for that data to be accurate, reliable and valid in order for you to draw the correct conclusion from the activity.

Accuracy is achieved by using the most appropriate equipment for the activity and carrying out a procedure with precision. Accuracy can be improved by using equipment that measures to a smaller degree, thus reducing uncertainty, e.g. using a measuring cylinder rather than a beaker, or a pH probe instead of pH paper and a chart.

Reliability is whether you can trust the information to be true or not.

Reliability is how consistently you get the same result after repeating an experiment. Remember reliability is achieved with replication (remember R-R). In this way, any inconsistent results can be excluded if necessary. Also, an average can be taken of the acceptable results and any small differences will be evened out, making your results more reliable.

Using a control also increases **reliability** because then you can see that what you are testing has given you the results, not some other unknown factor. In some experiments, reliability is increased by sampling from a large population.

Validity is based on evidence gained through a suitable scientific investigation. If you have followed a logical procedure that tests the hypothesis, then validity will be increased. The investigation must be a fair test, where you change only the independent variable and keep all others the same. Remember validity is achieved by choosing the correct variables (remember V-V).

Validity is when a test measures what it is supposed to measure.

Destructive versus non-destructive testing

Destructive testing occurs when the materials used in an experiment cannot be used again, e.g. uprooting a small plant to put in a test-tube to observe transpiration. The plant will not usually survive replanting.

Non-destructive testing enables the materials to be used again after the completion of the experiment, e.g. bagging the leaves of a plant on a tree to observe transpiration.

Non-destructive testing is the preferred option where possible.

Question

1 Which of the following activities involves destructive testing?

- **A** counting humpback whales as they migrate past the coastline
- **B** trapping bushrats for capture–recapture
- **C** using quadrats to estimate percentage of plant cover
- **D** pulling up weeds in the lawn to determine their abundance

Risk assessment

A risk assessment should accompany every activity in Biology. A risk assessment is performed by looking through your procedure and equipment list and assessing potential harm that could result from accidents or misuse. Safety precautions that reduce any risks should be included. A risk assessment may be presented in table form as shown below.

A risk assessment is a means of identifying hazards.

TABLE 5.1 Risk assessment

Equipment	Risk	Precaution
iodine solution	poisonous	do not ingest
	stains skin	wear gloves

Question

2 Which of the following activities poses a risk?

A using a pyrex beaker
B turning on a school power pack
C staining plant material with a chemical
D all of the above

Ethics

As caretakers of the environment, it is important that you are aware of your impact on it when you are carrying out any first-hand investigations.

- On field trips, try to leave the area in the same state as when you arrived.
- Try to use non-destructive methods of testing rather than destructive methods.
- Use minimal amounts of chemicals and generate as little waste as possible.
- Try to recycle materials such as fats and oils, rather than disposing of them into the garbage or sink.
- Always consult your teacher or laboratory technician for disposal of chemicals, sharps or biological material.

In some topics you will be asked to discuss and analyse issues that are emotive. Your own sense of ethics is important here, but be mindful to justify your views with logical scientific arguments and appreciate that others are entitled to differing views.

Working individually or as part of a team

While it is important to gain skills in individual investigations, such as microscopy or writing reports, sometimes in Biology it is more effective to work as part of a team. Obvious advantages include replication and time efficiency, but there are also important values associated with working with other individuals towards a common goal. Ideas can be shared and team members can help each other to gain an understanding of the problem at hand, or suggest new ideas.

Performing the experiment

Equipment

These are the materials that you will need to perform the activity. Try to use the most appropriate equipment for the task. It may be presented as a list and/or a labelled scientific diagram that shows how to set up the equipment.

Collecting data

Collecting data may require the use of instruments such as thermometers, rulers, data loggers with temperature, pH or oxygen probes, and balances. It may also require accurate observations, for instance colour changes or observations using a microscope. Use the most appropriate technique for collecting data. Practise using the equipment before you start the experiment. It is probably best

to record all observations made during the experiment, even the ones that you weren't expecting. They may be useful later.

Quantitative data is generally more accurate than qualitative data, e.g. 'the mass of the dialysis tubing bag and solution changed from 226 g to 240 g after 30 minutes,' as opposed to 'the dialysis tubing bag changed shape'. Quantitative data often requires the use of measuring instruments, but sometimes this degree of accuracy is unnecessary and a waste of time. Sometimes it is enough to observe whether a change has taken place or not, e.g. whether the yellow iodine changed to a blue–black colour or not.

Quantitative data involves quantities or numbers, while qualitative data relies on description using other observations, e.g. a colour change.

Numerical values

In Biology, numbers can be large, such as when looking at populations of grass or insects, and numbers can be very small, such as the size of microorganisms. It is important for you to be familiar with the prefixes used for these numbers.

Values are usually given in multiples of thousands (10^3). The common prefixes used are given in the table below:

TABLE 5.2 Common numerical prefixes

Prefix	Symbol	Value
nano	n	10^{-9}
micro	μ	10^{-6}
milli	m	10^{-3}
kilo	k	10^3
mega	M	10^6
giga	G	10^9
tera	T	10^{12}

Although the centimetre does not fit this pattern, it is a useful length and is still commonly used (1 cm = 10^{-2} m).

For example: if a microorganism appears to be 5 millimetres (mm) under the microscope at 400× magnification, its actual size is given by:

$$5 \div 400\ \text{mm} = 0.0125\ \text{mm}$$

Since there are 10^3 micrometres (μm) in 1 mm, multiply by 10^3 to change mm to μm:

$$0.0125\ \text{mm} \times 10^3 = 12.5\ \mu\text{m}$$

(Remember: micrometres are a thousand times smaller than millimetres, so there will be more of them.)

Units of measurement

Units tell us what it is we're measuring. In Biology, the SI system (*Le Système International d'Unités*) is used as a standard. Below is a table of commonly used units:

TABLE 5.3 Common SI units

Quantity	Unit of measurement	Symbol
length	metre	m
mass	kilogram	kg
time	second	s
temperature	degrees Celsius	°C

Question

3 The correct abbreviation for the SI unit for time is:

A seconds
B secs
C s
D S

Presenting information

After you have collected all of your data from your first-hand investigation, you have to process that data and present it in an appropriate way to communicate your findings as succinctly and clearly as possible. For each investigation you perform, there will be different information to present. The following sections give you some strategies that will help you to become familiar with the variety of graphs, diagrams and tables that you can use to communicate your results in formal scientific reports.

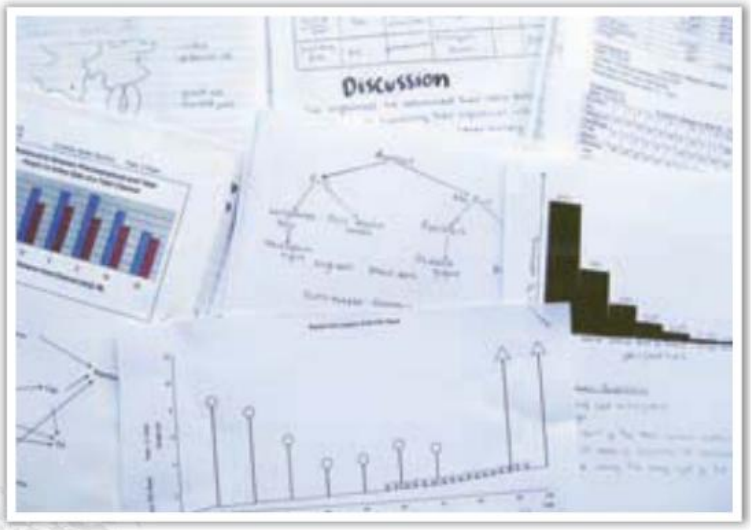


Figure 5.2 Just some of the ways of displaying data.

Tabulating data

One of the easiest ways to collect data is to record it in a table. A table is a box with columns and rows in which information is stored in an organised fashion. It is a good idea to draw up your table before you perform your investigation, or generate one from a computer and record data in the table directly. Follow these guidelines when constructing tables:

- Give your table an underlined title.
- Where appropriate, place the independent variable in the left column or top row.

- Where appropriate, place the dependent variable in the right column or bottom row.
- Place the variable heading in the column above the corresponding data.
- Write appropriate units in brackets with the headings. (Do not write units with data in each cell of the table.)
- Where there is no measurement, display a '–' in the box. There should be no blanks in the table.
- Record zeros with a '0'.
- Make sure all values have the same number of decimal points and try to line up numbers underneath each other in the table, so that the decimal point is in the same position.
- Where appropriate, the table should enable repeat trials and display a labelled average.

Below are two examples of tables.

A table is a box with columns and rows in which information is stored in an organised fashion. To tabulate is to put information into a table.

When averaging results, be careful to maintain the level of precision to which the data was measured.

TABLE 5.4 Changes in crab population near Badu Mangroves Creek

Distance from creek (m)	50	45	40	35	30	25	20	15	10	5
Number of crabs	5	2	2	1	7	4	45	22	11	50

TABLE 5.5 Measurement of water through a potometer to show transpiration

Time (min)	Volume of water displaced (mL)
0	0.0
2	3.0
4	2.0
6	2.5
8	3.0
10	2.5

Average volume of water displaced (mL) = 2.6

Average rate of displacement (mL/min) = 1.3

Sometimes you will wish to investigate complex relationships for a number of variables, for instance, the changes that occur over time in the water surrounding an Elodea plant. The following data was recorded by a data logger over a 32-hour period to investigate the effect of sunlight on the rates of photosynthesis and respiration of the water plant Elodea.

TABLE 5.6 Changes in abiotic factors over time in a tank with Elodea *(Egeria densa)*

Time (hours)	Light (lux)	pH	Oxygen (% sat)	Temperature (°C)
10 am	600	3.57	98.0	22.0
12 pm	1000	4.09	101.7	22.7
2 pm	877	4.33	102.2	23.3
4 pm	135	4.45	105.4	23.3
6 pm	0	3.50	78.5	21.3
8 pm	0	3.80	79.2	21.9
10 pm	0	3.22	58.3	20.3
12 pm	0	3.35	68.1	20.7
2 am	0	3.12	43.4	19.6
4 am	0	3.18	49.7	19.8
6 am	167	3.10	38.1	19.3
8 am	1000	3.09	53.4	21.2
10 am	1000	3.75	77.6	24.5
12 pm	775	5.07	75.8	25.4
2 pm	269	4.31	93.3	26.0
4 pm	157	5.02	82.4	24.0
6 pm	0	4.68	78.9	23.0

Question

4 Three identical potted plants were used in an experiment to observe the effect of available soil water. They were watered equally on Day 1 and then not again for five days. They were weighed on Day 1 and then again on each day for five days. The following results were obtained:

TABLE 5.7 Plant weights

	Weight of Plant 1 (g)	Weight of Plant 2 (g)	Weight of Plant 3 (g)	Average weight (g)
Day 1	15.2	15.0	15.1	
Day 2	16.1	15.9	16.0	
Day 3	17.0	17.2	16.9	
Day 4	14.0	18.1	18.0	
Day 5	18.8	19.0	18.8	

Which of the above data should not be included in the average weight?

A Day 5, 19.0 g
B Day 4, 14.0 g
C Day 3, 16.9 g
D They all should be included.

Drawing graphs

Graphs are effective in showing trends and relationships between data. They are a visual representation of the data, making it easier to interpret. There are many different types of graphs, including line, column, scatter, and pie graphs.

In general, line graphs are used when there is continuous numerical data for the independent and dependent variables, e.g. the change in temperature over time. When the independent variable occurs in discrete categories, a column graph should be used, e.g. amount of glucose in a variety of foods. Scatter graphs are used to see relationships between data, e.g. age and body weight. Sector or pie graphs are used when showing the proportions of a whole, e.g the percentages of different gases in the atmosphere.

The following checklist should be used every time you draw line and scatter graphs.

- The entire graph (including headings and labels) should be done using a sharp HB pencil.
- Give your graph an underlined heading (to be placed above the graph).
- Draw the axes with a ruler.
- Plot the independent variable on the *x*-axis, with the scale increasing to the right.
- Label the *x*-axis underneath the horizontal line and put corresponding units in brackets alongside the label.
- Plot the dependent variable on the *y*-axis, with the scale increasing up.
- Label the *y*-axis on the vertical line side with corresponding units in brackets.
- Make sure scales for both axes are even (increase at a regular rate) and the range of scales fits the data. Check if you need to allow grid space for extrapolation.

A graph is an excellent way to visually represent relationships between data.

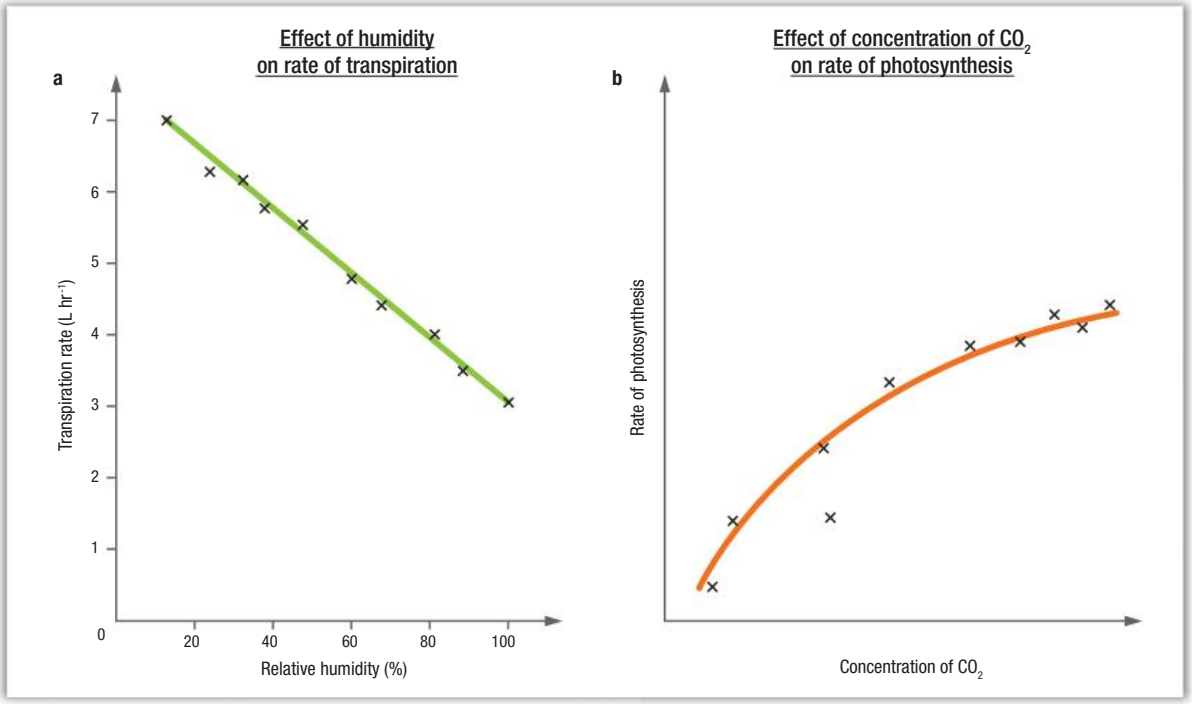


Figure 5.3 Two line graphs—one with straight line, one with curve of best fit.

- Plot data points with a small '×'.
- Draw a freehand curve of best fit through the points. (Do not 'join the dots' unless the relationship is linear, in which case you should use a ruler to draw a straight line.)
- Do not extrapolate the line beyond the data (i.e. don't go back to zero or start at zero if you don't have data for zero).
- If you are asked to extrapolate, draw a dashed line following the line/curve of best fit.
- When plotting multiple lines, use different lines for each one (e.g. ---------- , ———————— , ……), and include a key.

The following checklist should be used every time you draw a column graph.

- Follow the same rules for the line graph as above.
- Columns should be drawn using a ruler, so that there is space between them (they are stand-alone pieces of data).
- Do not shade the columns.
- Columns should be the same width.

The following checklist should be used every time you draw a sector or pie graph.

- Draw a circle with a compass and pencil.
- Calculate your fractions of the whole and translate them to angles (i.e. percentages of 360°). For example, 78% of the atmosphere is nitrogen, so the angle of the sector is 78/100 × 360 = 280°
- Use a protractor to measure and plot the angles for your graph.
- Use a ruler to draw the sector lines.
- Label the sectors directly, or use a key.

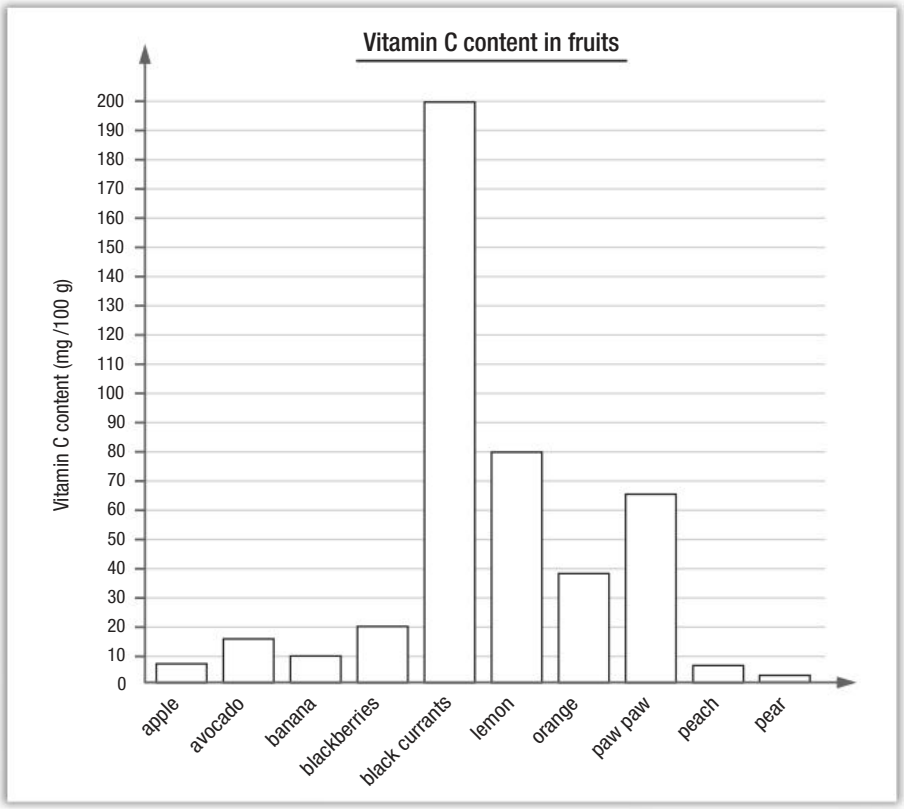


Figure 5.4 Column graph of amount of vitamin C in various fruits.

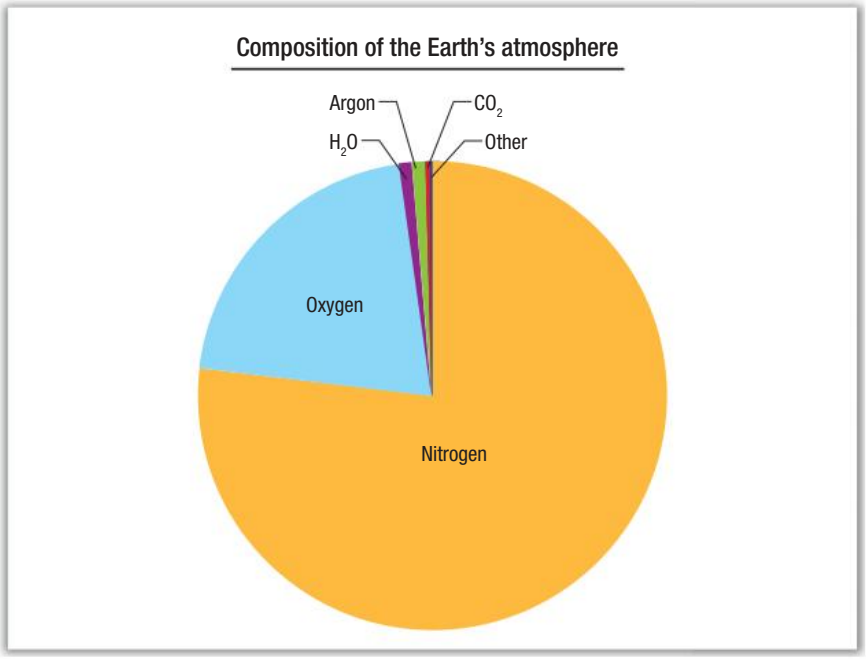


Figure 5.5 A sector graph showing the composition of the Earth's atmosphere.

Question

5 Which one of the following graphs would you use to show how the height of snow gums *(Eucalyptus pauciflora)* changes with altitude?

A sector graph
B column graph
C scatter graph
D line graph

Drawing scientific diagrams

It is important to learn how to draw and label diagrams of equipment and biological specimens in your studies of Biology. There are certain rules you must follow in order to produce a diagram that will be acceptable in your Biology reports and in exams.

When drawing scientific equipment, diagrams should:

- be large, simple, two-dimensional pencil drawings
- have ruled lines where possible
- keep proportions realistic.

When drawing biological specimens:

- Always draw the whole diagram (including labels, lines, magnification, heading and scale) in pencil.
- Do not draw your diagram in a circle representing the field of view.
- Draw your diagram with simple and clear lines (do not sketch).
- Make your diagram as large as possible (at least 10 × 10 cm).
- Lines for labels should be straight, ruled and, where possible, horizontal. Lines should not cross.

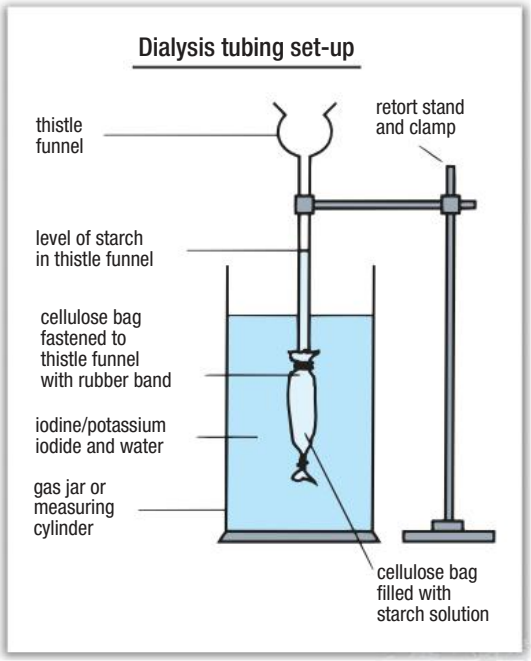


Figure 5.6 Diagram showing dialysis tubing set-up.

- Labels should line up on either side of the diagram (preferably on the right-hand side).
- Do not use arrowheads.
- Your diagram should have an underlined heading at the top.
- Draw a scale at the bottom of your diagram (see p. xxx for how to calculate the field of view and estimate size of specimens).
- Include the magnification at the bottom, e.g. ×400.
- Do not shade your drawing.
- Always underline generic names (e.g. *Saccharomyces cerevisiae*).
- Do not draw structures that cannot be seen, e.g. mitochondria.

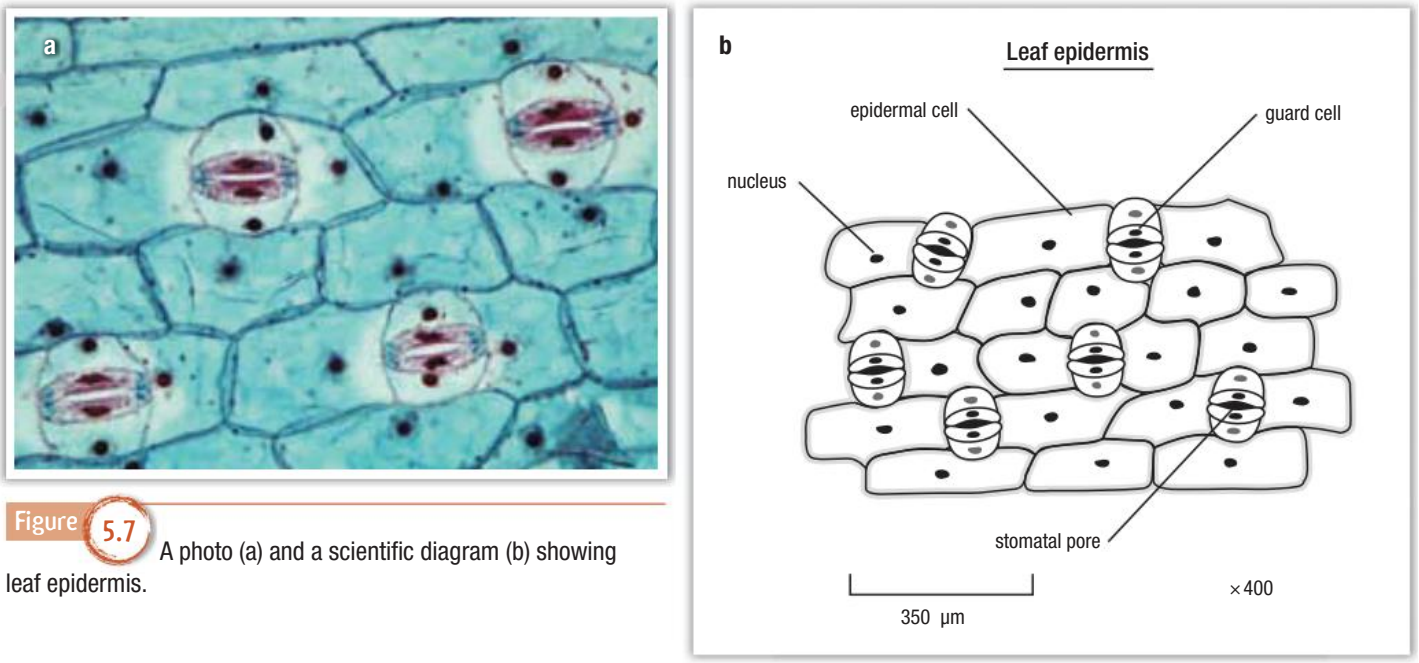


Figure 5.7 A photo (a) and a scientific diagram (b) showing leaf epidermis.

Sometimes if there are lots of cells to show, a map diagram is useful. This is where you show the general structures in a map and then show a section with cellular detail, like in Figure 5.8.

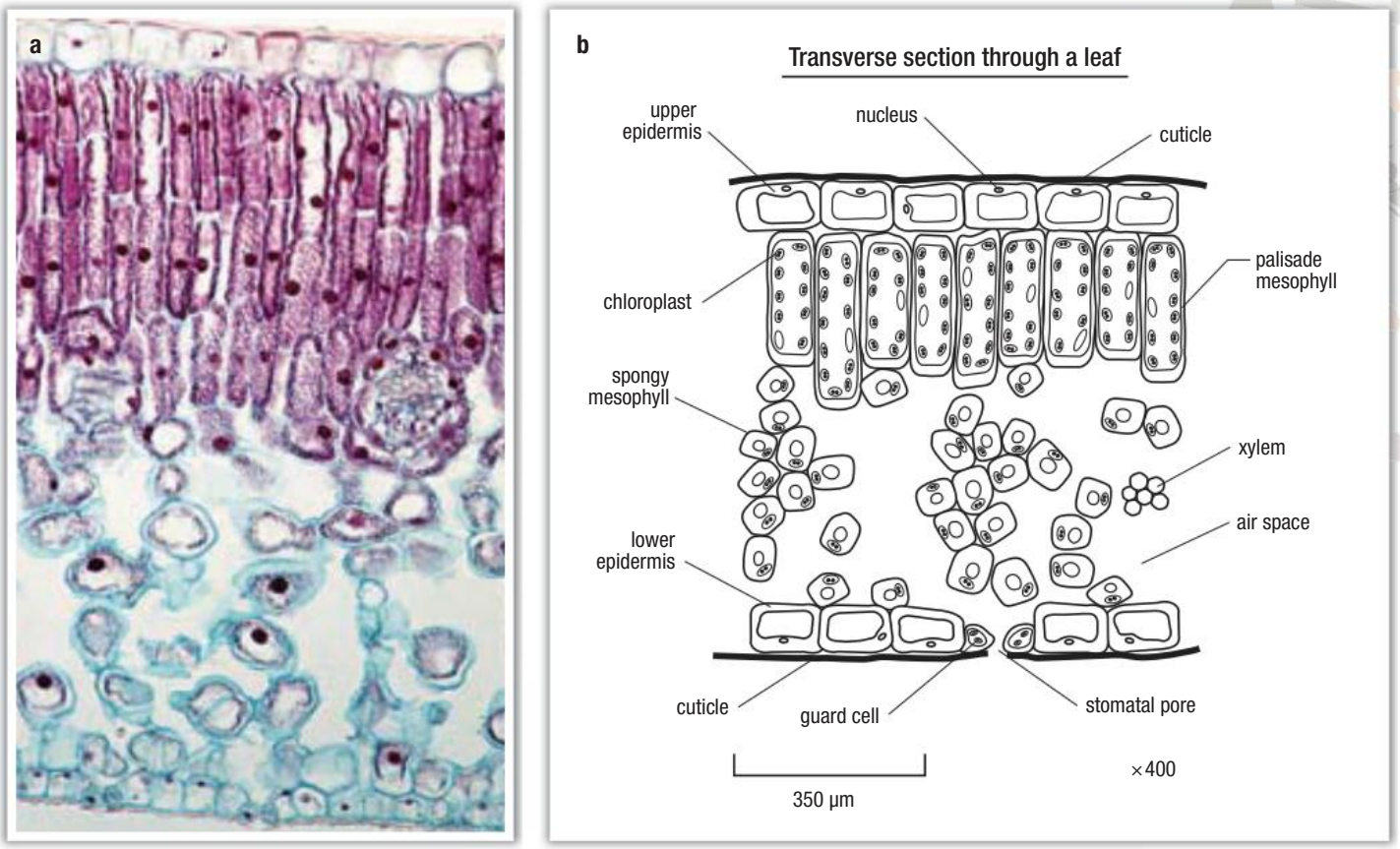


Figure 5.8 A photo (a) and map diagram (b) of a transverse section through a leaf.

Writing a scientific report

During the course of your studies, you will be expected to report on your investigations. The report should follow the scientific method outlined on page 315 and should include the following sections:

Title

Your report should have an appropriate title and be dated for easy reference.

Hypothesis

The report should have a hypothesis; a clear statement of prediction of the relationship between two variables.

Purpose

The purpose is a short statement of what you intend to find out. It is usually a rewording of the hypothesis, e.g. to see if light is required for photosynthesis.

Procedure

This is a list of steps involved in performing the activity. When writing formal scientific reports, the procedure should be written in the third person, past tense, to show what was done, e.g. a stick of celery was freshly cut at its base and placed in a beaker containing dye solution.

A procedural text, starting each instruction with a verb, is acceptable in the HSC as you are telling the examiner what should be done, e.g. 'Cut the base off a stick of celery and place the stem into a beaker containing dye solution.' The method should be able to be followed by someone else without any assistance or assumptions. Therefore, it needs to be in the correct sequence, allow for repetition and include instructions on how to observe, measure and record results. It must also identify the independent variable, the dependent variable and the controlled variables.

Results

The results section of your report is a record of your observations, in particular what happened to the dependent variable. Graphs, diagrams, tables and photographs are often a good way to present results. Do not interpret those observations in the results section.

Discussion

This is where you interpret and analyse your results, relating interpretations to your initial research. You should also mention any possible sources of error in your experiment. If the activity did not support your hypothesis, make suggestions here for recommended changes to the procedure, if appropriate. Future paths of investigation can also be suggested here.

Conclusion

This is a short statement about what you learned during your activity, relating to the aim. State whether your hypothesis was supported or not. It is important at a school level that you appreciate your limitations and the limitations of the school laboratory in performing research tasks. For instance, don't ever write 'we proved that…'. You can only really 'provide evidence for…'.

After the first-hand investigation and presentation of results, conclusions are drawn by identifying trends, patterns and relationships in the data. It is also important to acknowledge contradictions in data and information.

Magnification is how much bigger an object appears under the microscope. Resolution is the ability to distinguish two points.

Microscopes

Microscopes are an essential part of your studies in Biology. It is important that you learn how to use them with care and become competent in their use. Microscopes enable us to see beyond the limits of our vision. They magnify specimens so that we can see cellular detail. The light microscope is also called the 'high-power microscope' or 'compound microscope'. Images of specimens are magnified by the compounding effect of two magnifying lenses. An enlarged image of the specimen is achieved by the objective lens. This image is further magnified by the eyepiece lens.

The overall magnification is calculated by multiplying the degree of magnification of the objective lens by the degree of magnification of the eyepiece lens. The magnifying power of the lenses is clearly marked on the lens casing—for example, ×10, ×40.

Using the monocular compound microscope

Firstly, it is important to know the parts of the compound light microscope.

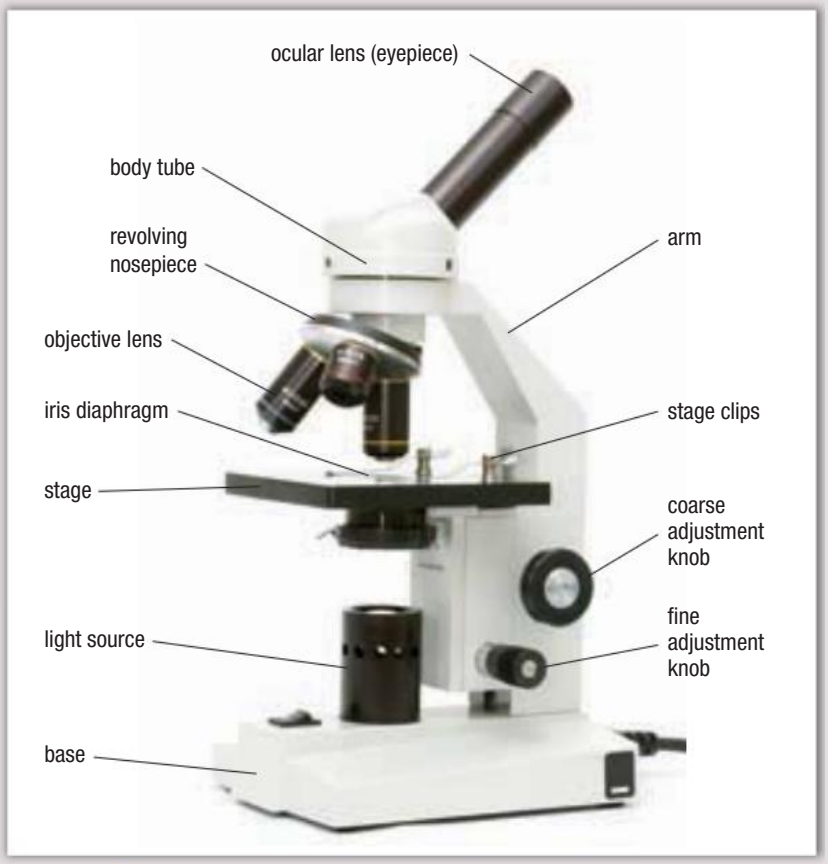


Figure 5.9 A monocular light microscope with in-built light.

Follow the instructions below every time you use a microscope.

- Carry your microscope upright with two hands (one under the base and the other on the arm).
- Place the microscope on the bench with the arm closest to you.
- Clean the lenses with a lens tissue.
- Turn on the light. If your microscope does not have a built-in light, focus a microscope lamp onto the mirror and adjust the iris diaphragm and condenser lens to obtain optimum light—it shouldn't be too bright.
- Place the slide on the stage so that the part of the specimen you want to magnify is in the small circle of light.
- Secure the slide with the stage clips.
- Turn the revolving nosepiece until the extra-low-power (ELP) lens (×4) is above the specimen.

- Looking from the side, across the stage, wind the stage up as far as you can so that the slide is nearly touching the lens. (In some microscopes, it is the tube that winds down and up, so wind it down as far as you can without it touching the specimen.)
- Looking into the ocular lens with one eye, and keeping the other eye open, wind the coarse focus knob slowly away from you to focus the image on the slide. (Keeping your other eye open will take some practice, but it is good if you can train yourself to do this as it is better for your eyes over extended viewing periods.)
- Adjust the light passing through the specimen using the iris diaphragm, so that you have good contrast in your view of the specimen.
- Rotate the revolving nosepiece so that the low-power (LP) lens (×10) is now above the specimen.
- Use the fine-focus knob to make small adjustments and focus the image. Your microscope should be parfocal, which means that whenever you move to the next lens, the image should be in focus and require only a small adjustment.
- Change to the high-power (HP) lens (×40) by rotating the revolving nose piece again, and use the fine-focus knob to focus the specimen. If you have lost the image, go back to the lowest power and focus through the different lenses again. Don't ever start with the highest power lens.
- To calculate your magnification, multiply the ocular lens magnification with the objective magnification. (The values are written on the side of the lens.)
- Finally, remember to remove the slide and return it before packing up the microscope.

Objects seen under the light microscope are inverted laterally and vertically. This means that when an object or slide moves in one direction, it is viewed as moving in the opposite direction. (See Investigation 5.1 Part B: Procedure 7 on page 337, and Questions 7 and 8 on the next page).

The magnifications that you will get from most microscopes in a school laboratory are shown in Table 5.8.

TABLE 5.8 How to calculate magnification

Ocular lens magnification	Objective lens magnification	Total magnification
×10	×4	×40
×10	×10	×100
×10	×40	×400

Questions

6 What does parfocal mean?

7 Construct a table showing the different lens combinations for your microscope. Calculate the overall magnification obtained from each combination.

8 Explain why the image observed using the compound microscope is inverted.

9 The lens that is closest to your eye when you look through a microscope is called the:

A ocular lens
B objective lens
C concave lens
D convex lens.

Using the binocular compound microscope

To use the binocular microscope, the same basic steps are used as for the monocular microscope. The image is essentially the same, except the viewer has a more comfortable view, using both eyes to see the image. The only extra step involved is moving the ocular lenses so that they fit your eyes. The distance between your eyes is unique. When viewing, you should see one image, not two, so keep adjusting the movable ocular lens until you have one clear picture.



Figure 5.10 Using the binocular microscope.

Using the stereo or dissecting microscope

The stereo microscope enables us to see a three-dimensional view of an object. Unlike the compound microscope, the stereo microscope does not use light transmitted through the specimen; rather it uses reflected light from the specimen. Stereo microscopes are used for observing small whole specimens such as insects, organs such as gills, or for dissecting organisms such as flowers and small fish.



Figure 5.11 The stereo microscope gives us a 3D view of specimens.

Follow the steps below to use the stereo microscope:

- Place the specimen to be observed in a petri dish.
- Select the white or black baseplate to give you the desired contrast and place the petri dish on the plate.
- Set up your microscope with ample light, or focus a microscope lamp onto the specimen.
- Looking sideways at the specimen, lower the tube using the focusing knob so that it is close to the specimen.
- Adjust the eyepiece (ocular lenses) so that they fit your eyes and you see one image in focus (i.e. one circle, not two overlapping circles).
- Place the extra low power (ELP) lens above the specimen.
- Turn the focus knob to focus the specimen.
- Change to the HP lens if required.

Question

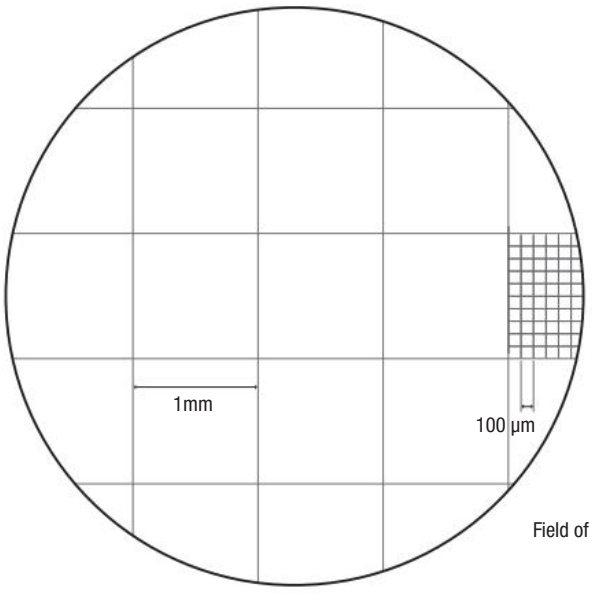
10 How does the view of a specimen using a stereo microscope compare with the view from the compound microscope?

Calculating field of view and size of specimens

Being able to calculate the field of view is essential in order to estimate the size of specimens you are looking at under the microscope. Also, all biological drawings require a scale. To calculate the field of view you use a minigrid. This is a 1 mm × 1 mm grid with a smaller 'microgrid' of 100 µm × 100 µm in the centre (used with the HP ×40 lens). If you don't have a minigrid, you can use a clear ruler marked in mm or a 1 mm × 1 mm grid on OHP plastic film.

To calculate the field of view:

- Place the minigrid on the microscope stage, but don't clip it down.
- Focus using the ELP lens so that you can see the grid clearly.
- Adjust the slide slightly, so that one line is on the edge of the field of view and the 100 µm x 100 µm part of the minigrid is on the other side.
- Count the grid lines across and estimate the diameter of the circle you see (on ELP, it should be about 4.5 mm or 4500 µm).
- Now change to the LP lens and estimate the size again (it should be around 1.5 mm (1500 µm). You should be able to use the 'microgrid' to measure an exact distance across the field of view.
- Move the 'microgrid' to the centre of the field of view.
- Focus on the 'microgrid' using the HP lens (remember the grid spaces for this grid are 100 µm). The field of view on HP should be around 450 µm.
- It is important that you measure field of view every time you use the microscope, as there are differences between microscopes and this will affect your estimates of the size of specimens.



Field of view = 4000 µm + 600 µm
= 4600 µm
= 4.6 mm

Figure 5.12 The field of view of this microscope under the ELP lens is 4.6 mm (or 4600 µm). You can work this out using the minigrid.

Now that you have calculated your field of view for each lens, it is possible to estimate the size of a whole specimen or the size of individual cells.

- Place the slide with specimen on the microscope stage and focus your microscope using the steps outlined on page 330.
- Knowing the field of view, you can estimate the size of the specimen. For example, if you are looking at a transverse section (TS) of a leaf and you can see exactly half of the leaf under ELP, then you can estimate that the size of the leaf is:

$$2 \times 4.5\,\text{mm} = 9\,\text{mm long}$$

- If you wish to calculate the size of the individual cells in the leaf, then a more accurate estimate will be achieved if you count the number of cells across the HP field of view. If, for example, there are 9 palisade mesophyll cells across the HP field of view, we can estimate that each cell is:

$$450/9 = 50\,\mu\text{m wide}$$

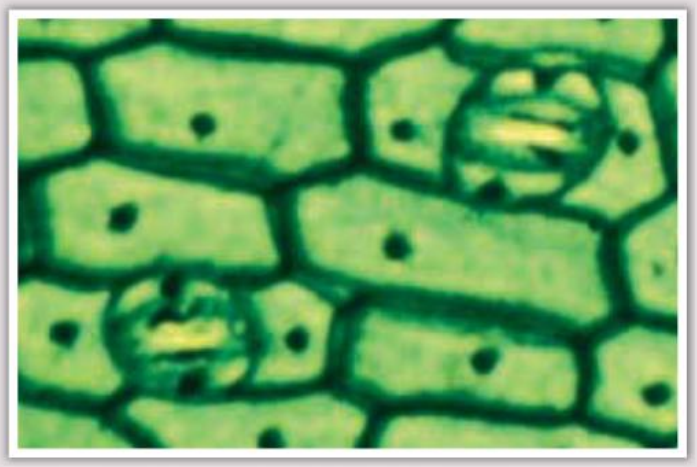


Figure 5.13 Leaf epidermis cells under the HP lens (×100).

The field of view for the photo of leaf epidermis above was 350 µm. There are two cells across the field of view, so the average width of a leaf epidermis cell is:

$$350/2 = 175\,\mu\text{m}$$

Question

11 Describe how to calculate the diameter of the field of view of a microscope under a low-power and a high-power lens.

Preparation of a wet mount

Many of the specimens you observe in your course will be on commercially prepared slides, such as leaf epidermis, striated muscle tissue and blood. It is also mandatory to create your own 'wet mount' slide. It is important that you follow the steps below to make sure your prepared slide is of a high quality.

Below is an example of how to prepare an onion epidermis wet mount, but the same technique can be used for lettuce leaves and other soft-leafed plants where the epidermis can be peeled to make one transparent layer of cells. The main trick is to ensure your specimen is extremely thin (1–2 cells thick only), so that light is transmitted through it.

- Peel the outer layers from an onion.
- Cut a small section of an inner layer and place it on the bench (outer side down).
- Using forceps, peel the inner epidermis from the thick piece of onion on the bench. Do this very carefully so you don't rip this layer. This will take some practice, so be patient; it may take many attempts.
- Place the transparent film of tissue on a clean microscope slide.
- Use the forceps and a dissecting needle to adjust the epidermis so that there are no folds in the layer and it is flat on the slide.
- Place a drop of iodine onto the specimen (staining increases contrast, making the cell components easier to see, and may selectively highlight certain organelles such as the nucleus).
- Using a dissecting needle and your fingers, carefully place a cover slip on one edge of the drop and gently lower it over the specimen (see Figure 5.14 below). Do not press the cover slip down.
- Use tissue to absorb any excess iodine by placing it near the cover slip and letting it absorb the liquid.
- View your specimen on ELP and look for air bubbles, which will appear as perfect spheres. If there are too many, make another wet mount.

Extra tips:

- Your wet mount will dry out after about 1 hour. You could try placing a layer of petroleum jelly around the edge of the coverslip; this will make it last for a day or two.
- If you are looking at pond organisms, draw a small amount of pond water into a dropper and drop it onto a slide, and then cover it in the same way as described above. If there are larger organisms swimming around, you should use a cavity slide. Again, cover with a cover slip and observe on ELP.

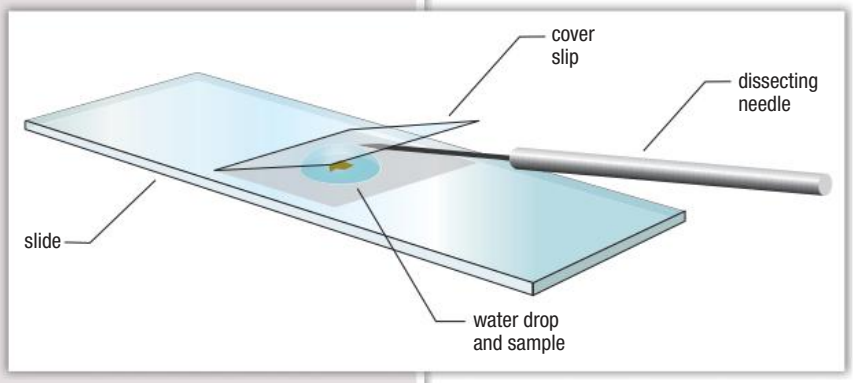


Figure 5.14 The correct technique for placing a cover slip on a specimen.

Question

12 Explain why specimens for viewing under the light microscope must be extremely thin.

13 Draw a large, labelled diagram of two or three cells as you see them under the microscope. Refer to the section 'Drawing scientific diagrams' on pp. 325–326 to help you.

INVESTIGATION 5.1

Using the light microscope

Skills and outcomes

P1, P3, P12, P14

Type of activity

First-hand investigation, second-hand data activity

Materials

Part B

- light microscope
- microscope slide
- minigrid slide or 1 cm^2 piece of 1 mm grid plastic film
- black and white newsprint

Part C

- light microscope
- microscope lamp
- onion
- scalpel
- forceps
- white tile
- iodine
- microscope slide
- coverslip

Introduction

The ability to use a light microscope is an essential skill in Biology because it enables us to observe objects that are too small to be seen with the naked eye, and to resolve structural details of very small objects such as cells.

Specimens viewed with the light microscope are normally illuminated with transmitted light. That is, light must be able to pass through the specimen to the eye of the observer. For this reason it is essential to have very thin specimens for successful observation.

Purpose

1. To become familiar with and use the light microscope.
2. To calculate the magnification of the microscope.
3. To calculate the field of view.
4. To prepare a wet mount for viewing using the light microscope.
5. To draw and label a diagram of onion epidermis.

A Examining the light microscope

Procedure

Use Figure 5.9 on page 329 to complete Table 5.9.

TABLE 5.9

Name of part	Function of part

B Using the light microscope

Procedure

1. Follow the procedures on pages 328–330 to set up and use your microscope.
2. Using a minigrid or a 1 cm^2 piece of 1 mm grid plastic film, calculate the field of view on each power (see pp. 333–334 for a guide on how to do this).

3 Complete Table 5.10 in your workbook.

TABLE 5.10

Magnification	Field of view (mm)	Field of view (µm)
×40		
×100		
×400		

4 Cut a 1 cm square of black-and-white newsprint containing a small letter 'e'. Fix the piece to a microscope slide using sticky-tape. Place the slide on the microscope stage with the letter 'e' facing the right way up and directly below the LP objective lens. Focus the microscope so that you have a clear image of the letter.

5 Observe the letter 'e' as it appears through the microscope.

6 Describe what happens to the orientation of an object when viewed under the microscope.

7 Which way does the image move when the object is moved
   a to your right?
   b away from you?

C Making and observing a slide

Procedure

1 Using the information on page 335, make a wet mount of a piece of onion epidermis.

2 Make a pencil drawing of the onion cells. Follow the instructions on pages 325–326 to draw your diagram accurately.

3 Using your observations of the size of a single onion cell in relation to the field of view and the information in Part B, calculate the size of an onion cell.

Discussion

1 Outline the way in which the light microscope works to obtain a clear image of an object.

2 Describe the steps you would take to obtain
   a adequate light
   b a clear focus using low power
   c a clear focus using high power.

3 Explain why it is important to ensure that the objective lens is wound away from the stage during focusing.

4 Explain the terms 'magnification' and 'resolution'.

Caution

- Scalpel blades are very sharp. Take special care when using these instruments. Do not leave them close to the edge of your bench. Dispose of used scalpel blades in a sharps container.
- Take care with iodine. If you spill any on your skin, wipe it off and rinse the affected area well with water.

Analysing information

As independent learners, you will be expected to conduct your own research and gather information from secondary sources, such as books, journals and the Internet. All second-hand information has a bias, so you need to assess the accuracy, reliability and validity of the information gathered. It is best to use multiple sources of information when researching.

Interpreting graphs

Information is often displayed in pictorial form, such as graphs, flow charts, keys and models. It is important that you can interpret these representations in order to extract information from them.

The main purpose of graphs is to show trends. When data is plotted on graphs, any strange results become obvious as these points occur well away from the 'line of best fit'. These are called outliers and should not be included in your analysis.

When reading a graph, it is a good idea to mark on the graph the lines used to extract the information.

Interpolating occurs when you read data straight from the graph. Extrapolating occurs when you extend the graph following an already evident trend.

Question

14 Using the graph below, which shows the abundance of plants on Krakatoa after a volcanic eruption, estimate:

- **a** the abundance of ferns and the abundance of coconuts 5 years after the eruption
- **b** the abundance of ferns and the abundance of coconuts 8 years after the eruption.

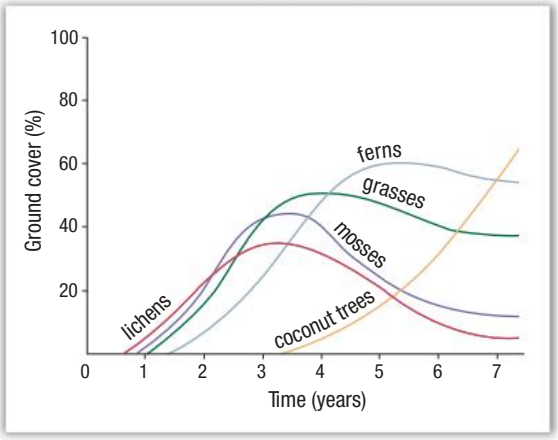


Figure 5.15 Abundance of plants on Krakatoa after a volcanic eruption.

Part (a) involves interpolating the graph to extract the appropriate information:

abundance of ferns = 60 % groundcover
abundance of coconuts = 15 % groundcover

Part (b) involves extrapolating the graph to estimate the appropriate information:

abundance of ferns = 51 % groundcover and
abundance of coconuts = 83 % groundcover.

Extrapolating graphs has more uncertainty than interpolating.

Interpreting and drawing flow charts

Series of complex processes can be simplified by organising them into flow charts.

To draw a flow chart, write down the first logical process and put a box around it. Then draw an arrow to the next process, also contained within a box, and continue in this way until the entire sequence of events is drawn. Many word processing packages have flow-chart options. There are conventions used in flowcharts as shown in Table 5.11.

TABLE 5.11 Common flowchart symbols

Symbol	Meaning
	process
	alternative process
	decision
	data
	terminator
	preparation

A feedback mechanism is a self-regulating cycle of events

To interpret flow charts, you basically run your finger from box to box along the arrows, asking yourself, 'Has the process been carried out?' until you reach a terminator or come back to the beginning, as in the case of a feedback mechanism.

On the right is a flow chart showing an example of how the nervous system can control the endocrine system. Note that each stage is contained in a single box and the path can be traced easily.

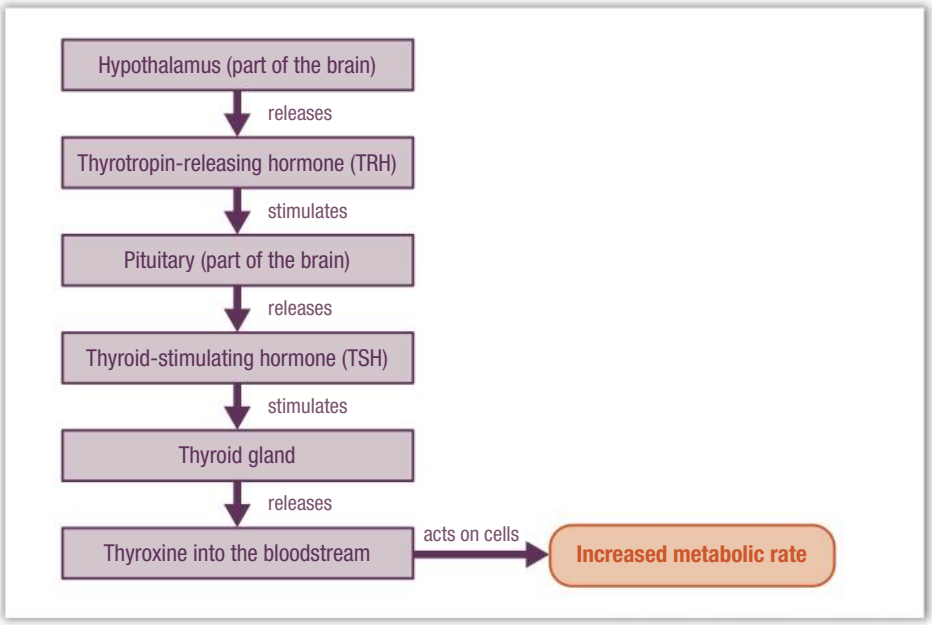


Figure 5.16 Flow chart showing how the nervous system can control the endocrine system.

Using biological keys

Keys are often used for classification of a large variety of things. Characteristics are arranged systematically, and it is important to follow the key point by point, eliminating those characteristics that do not match, while narrowing your options until you finally reach a decision. As you move through the key, the groups contain fewer types of organisms.

The most common key used in Biology is the dichotomous key, in which there are only two branches for each feature. It may be presented as a branching diagram or as a series of questions arranged in couplets. As each question is answered, you are directed to the number of a new question until, instead of a number, you are given the name of an organism. An example of plant classification is given below:

1a	Flowers arranged in globular heads	2
b	Flowers arranged in cylindrical spikes	*Acacia acuminata*
2a	Branchlets winged	3
b	Branchlets not winged	4
3a	Flowers cream coloured	*Acacia alata*
b	Flowers golden	*Acacia stenophylla*
4a	Phyllodes round in cross-section	*Acacia assimilis*
b	Phyllodes flat	*Acacia saligna*

Figure 5.17 Dichotomous key for identifying acacia species.

A dichotomous key is useful for classifying organisms in biology. Dichotomous means 'two branches'.

Sometimes the key is structured to show this branching and it looks like a tree, as shown below in the key used for identifying carbohydrates. Each stage of the key has two branches.

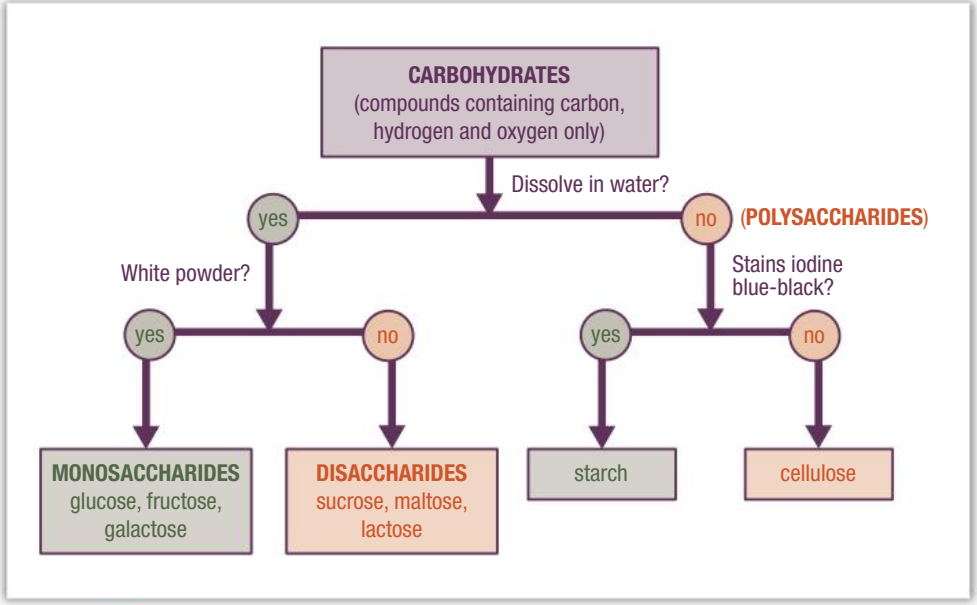


Figure 5.18 A dichotomous key for classifying carbohydrates.



Question

15 Using the key on p. 339, the species of acacia in the photo can be identified as:

- **A** *Acacia acuminata*
- **B** *Acacia alata*
- **C** *Acacia saligna*
- **D** *Acacia assimilis.*

Using models in Biology

A model is a representation of an actual object or phenomenon, and may be a diagram or a construction.

Models are useful tools in Biology and offer many advantages to help with your learning.

- Models allow you to 'see' something not visible to the naked eye (e.g. onion cells), or not accessible (e.g. how muscles work).
- Models allow non-destructive as opposed to destructive investigation (e.g. in dissections).
- A model can be a representation of a selected part of the whole, removing unnecessary detail and allowing you to understand a single concept (e.g. DNA in the nucleus of a cell).
- Interactive and simulated models on the computer allow you to slow down a process and observe an entire sequence of events (e.g. the various stages of mitosis).

Models cannot exactly represent the real situation, so there will be disadvantages and shortcomings of which you should be aware. For instance, you may use dialysis tubing to simulate a selectively permeable cell membrane, and this will give a clear demonstration of a phenomenon that is not visible to the naked eye. However, your model will not enable a full explanation of how a cell membrane functions under all conditions, so your information would be incomplete.

Accuracy, reliability and validity of second-hand data

Secondary sources of information include books, journals, magazines, newspapers, interviews, television programs and the Internet. You should aim to use a wide range of data sources when performing your second-hand data investigations. All secondary sources of information have a bias.

Accuracy is how close something is to the truth. Traditional sources such as books and encyclopedias require a lot of effort and expense in order to be published, so they are generally accurate in their content. Books can become outdated though, as new knowledge is gained and new technology developed, so check their date of publication.

The beauty of the Internet is that it can quickly provide specific and current information on your area of research. The downside of the Internet is that anyone can publish articles, so any information gathered from the Internet should be consistent with other information, especially that found in books. Quite often, people copy information from other sites for inclusion on their own site, so information will seem consistent; however, it has just been copied many times from the same original source (which could be incorrect). Again, find out how old the information is and how often a website is updated. If the information is too old, as with some books, it may not be accurate.

Articles published through journals represent the findings of current research, which may or may not be confirmed later, so be careful with these sources. Scientific journals are peer-reviewed (critically reviewed by other specialist scientists), which gives them greater credibility than other sources of media.

In all instances, check that the author has quoted their sources of information. Reliability is whether or not you can trust the information to be true or not.

Your textbook should be your first source of reliable information. Other information should agree with this. Here are some guidelines for using the Internet for research:

- Check the domain name of any websites:
  - .org is a non-profit organisation
  - .gov is a government agency
  - .edu is an educational institute.

  The last two domains are the most reliable sources.
- Those from .com (a commercial business) may have a bias towards selling a product.
- Websites for the popular media may not be reliable.
- A reliable website should include details of its author. Find out who wrote the information and check their qualifications.

Validity is an assessment of whether the information actually answers the question you are trying to research. Valid sources are those that have information about what they claim. The information gathered needs to be relevant to your topic of investigation.



Figure 5.19 This model of dialysis tubing in starch solution demonstrates diffusion, but does not give a complete picture of the process.

Second-hand data is information you have gathered from somewhere other than your own observations. It is important to use a range of different resources.

Plagiarism

Plagiarism means taking someone else's writing and using it as your own.

During the course of your studies, you will be expected to analyse information gained from secondary sources.

Plagiarism is a breach of intellectual copyright. In order to prevent this, it is advisable to read through any information gathered, form your own ideas and opinions, and then write those down. Be careful when you are rewording secondary information that the meaning is not lost. Jotting down points as you read through an article might help. Of course, Biology is such a factual subject that information will remain constant, but it is unacceptable to copy large sections of literature from the Internet or books.

You must reference your secondary sources of information; first, to acknowledge those sources, and second, to enable anyone else to continue your research.

Preparing a bibliography

A bibliography is an alphabetical list of the resources used in research tasks.

A bibliography is an alphabetical list of the resources you use in research tasks. It includes books, journal articles, newspapers, interviews, television programs, websites, etc. In your Biology course, you will be required to write scientific reports, essays and research assignments. Most tasks that you submit for marking will require a detailed bibliography, and it is important that you follow a protocol similar to the one below to reference your research materials correctly and avoid plagiarism. Also, it is important for the reader to be able to verify information in your report.

If you do further study in science, you will be required to cite the work of other authors, but at a school level all that is required is a bibliography placed at the end of your assignment.

There are a number of systems such as the Harvard, Oxford and MLA that are acceptable. However, the APA system is used in Australian science teaching journals, so this is the one we have suggested you follow. (Check with your teacher or librarian as to the guidelines for your school.) The guidelines below can help to create your bibliography. Be sure to include commas, full stops, italics and brackets in the right places.

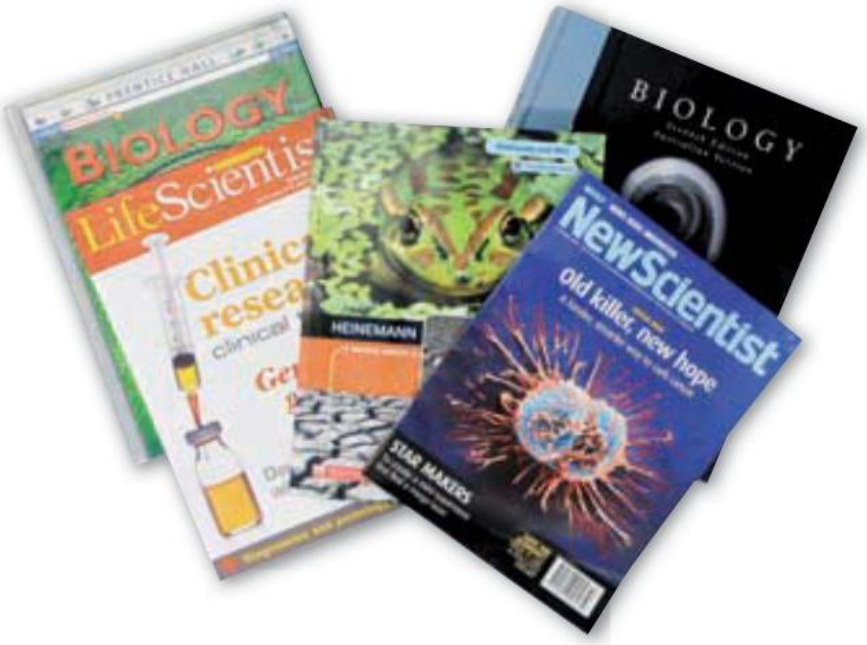


Figure 5.20 There are many sources available to you when you are doing research.

Book

Surname(s) of author(s) (as they appear on the book), first name initial (followed by full stop), (date of publication), *Book title*. City of publication: name of the publisher.

For example: White, M. E. (1994), *The Greening of Gondwana*. Sydney: Reed.
Mudie, K. & Brotherton, J. (2003), *Biology*. Melbourne: Heinemann.

Encyclopedia or dictionary

Author, first name initial (date of publication), *Book title* (volume number). Place of publication: publisher.

For example: Makins, M. (1993), *Collins English Dictionary and Thesaurus* (vol. 5). Glasgow: HarperCollins.

Journal article

Surname(s) of author(s), initials (date of publication). Title of article. *Name of journal*, volume, page number(s).

For example: Grayling, A. C. (2008). The importance of knowing how. *New Scientist*, vol. 199, p. 46.

Newspaper article

Author's surname, initials (year, month, date of publication). Title of article. *Name of newspaper*, page number.

For example: Fawcett, A. (2008, October 11). How Kermit can save the world. *Sydney Morning Herald*, p. 35.

Interview

According to APA conventions, an interview is not considered recoverable data. You may, however, list the interview as a personal communication. For example: (R. Fogerty, personal communication, 15 August, 2007)

Internet sites

Electronic sources include databases, online books and journals, websites or webpages, newsgroups and email discussion groups. Outlining the rule for each is unnecessary for use at school level, so follow this as a general guide:

Author(s) surname(s), initials. *Title of article*. Retrieval date and URL.

For example: Sullivan, J. *Animal cell mitosis*. Retrieved 29 September, 2008 from http://www.cellsalive.com/mitosis.htm

CD-ROM

Author(s) surname(s), initials (date of publication). *Title of article*, name of CD-ROM [CD-ROM]. City of publication: name of publisher.

Cunningham, F. (2001). *Cell division*, GeneISSUES, Medical Miracles, Ethical Dilemmas [CD-ROM]. Sydney: GeneCRC and the Department of Education and Training.

DVD, video, radio or television program

Writer/director's surname, initials (date of program). *Title of programme*. [DVD, video, television or radio program]. City of viewing: channel.

Eagle, R. (2002). *Darwin's evolution*. [Video recording]. London: Channel 4.

UNIT REVIEW 5.1

Biology skills

Summary

- First-hand investigations are investigations where you gather the raw data for yourself.
- The scientific method is an accepted procedure for conducting experiments.
- Plan an experiment by carrying out background research and forming a hypothesis: a predictive statement based on sound scientific knowledge. Variables are the things that can change or be changed during an experiment.
- Identify the independent variable and the dependent variable; keep all other variables constant.
- Set up a control, that is, apparatus that does not contain the independent variable.
- Accuracy is how close your results are to the truth.
- Reliability is how dependable your results are.
- Validity is whether the experiment tests your hypothesis.
- Non-destructive testing means equipment can be reused, while destructive testing means equipment has been changed so much it can't be reused.
- A risk assessment is a means of identifying and reducing hazards.
- Choose equipment suitable for the experiment and list it, or draw a labelled scientific diagram.
- Data collected in investigations may be quantitative (numbers) or qualitative (description).
- SI units should always be used for measurements.
- Results may be presented as text, as a table or in a graph.
- Scientific reports are written according to the scientific method.
- Microscopes are complex tools of biology that work best when they are set up following the correct procedure.
- Making a wet mount requires a procedure producing a very thin specimen for microscope viewing.
- Processing information from secondary sources requires interpretation of graphs, flow charts, biological keys, models and text.
- Accuracy, reliability and validity of second-hand data must be ascertained.
- Plagiarism is a breach of copyright, and a bibliography must be included in scientific reports.
- Ethics are your reasoned moral position and should be included in your studies.

Questions

The following questions are in the HSC format. Remember, both knowledge and the application of skills may be examined in the HSC Biology exam.

1 Complete the following table by converting the lengths to millimetres (mm).

TABLE 5.12 Average length of some animals

Animal	Average length (m)	Average length (mm)
lobster	0.3	
earthworm	0.15	
amoeba	0.00025	

2 In 1590, Thomas Maufet was trying to sort the grasshoppers and locusts he had collected.

> *'Now all locusts are either winged or without wings…some fly with one pair of wings, others more, those that cannot fly, they walk; some have longer shanks, some shorter.'*

Maufet, T. *Theatre of Insects*, quoted in *Focus on Life*, Rosen, G. and Kelly, N. (1981), McGraw-Hill: Sydney.

a Based on the description above, construct a key that might have been useful for Maufet.

b Give an example of how quantitative data would have improved his classification system.

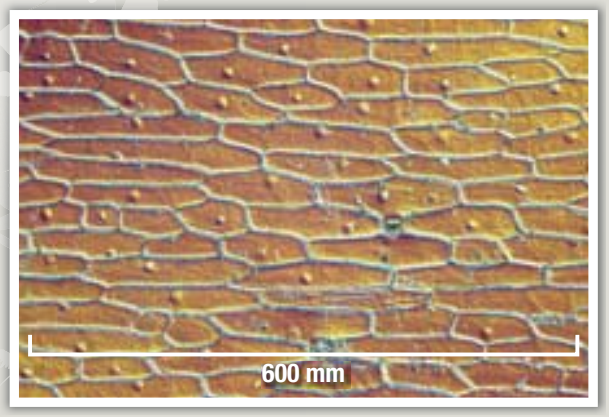
3 While performing a first-hand investigation, a group of students found that glucose reacted with Benedict's solution, but not iodine solution or Sudan III; starch reacted with iodine solution, but not Benedict's solution or Sudan III; and olive oil gave a positive result with Sudan III, but not with Benedict's solution or iodine solution. Arrange the students' results into a table.

4 Outline the difference between a binocular compound microscope and a stereo microscope.

5 Construct a graph to illustrate the data in the table below.

TABLE 5.13 Heart rate measured over 10 minutes of exercise

Time (minutes)	Heart rate (beats per minute)
0	60
1	65
2	80
3	100
4	120
5	148
6	135
7	120
8	115
9	110
10	90



6 a Draw a fully labelled diagram of the cells in the photo viewed at ×100 magnification.

b Using the scale at the bottom, calculate the average width of the cells.

c Explain why a specimen must be thin when making a wet mount.

d Evaluate the use of stains in cytology.

7 Design a first-hand investigation to test the following hypothesis: 'The rate of water loss via transpiration decreases if petroleum jelly is applied to the surface of leaves.'

a Name the independent variable.

b Name the dependent variable.

c List the controlled variables.

d List the equipment required.

e Write a procedure (including a control).

f How will you plan to achieve accuracy in your experiment?

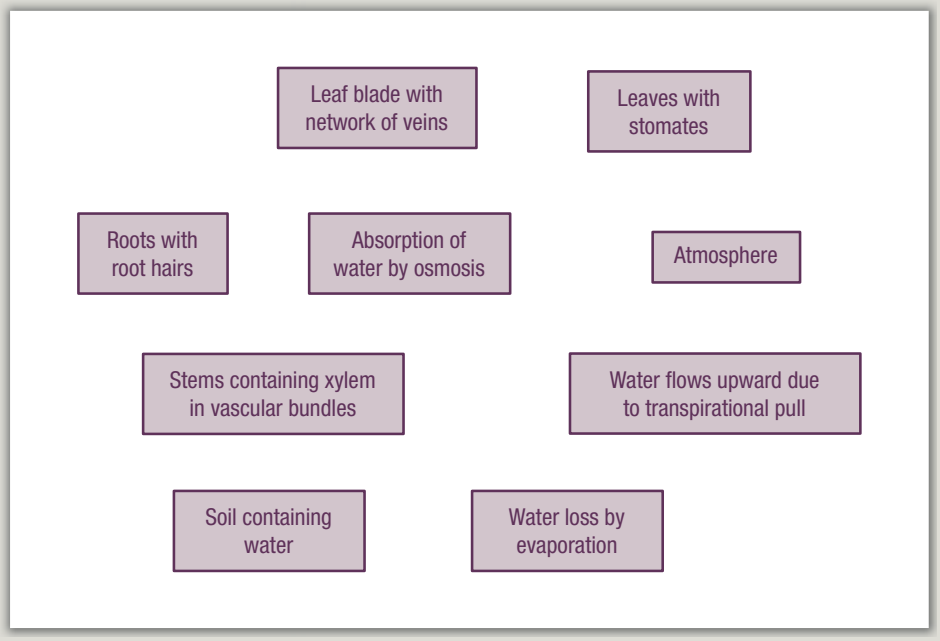
g How will you plan to achieve reliability in your results?

h What would be the best way to present your results?

8 In Australia in 1995, in the 15- to 34-year-old age group, 62% of drug deaths were related to alcohol use and 34% were due to the use of illicit drugs. Draw a pie chart to show the types of drugs causing death in the 15- to 34-year-old age group.

9 A student made a model of an animal cell using lollies. He placed a large marshmallow in a clear plastic bag to represent the nucleus. Long pieces of thin licorice (with Smarties®) attached using icing) represented the endoplasmic reticulum and ribosomes. He used Licorice All Sorts® for the mitochondria, Maltesers® for the lysosomes, Bullets for the centrioles and a Flake® for the Golgi body.
Evaluate the use of the student's model in helping to understand the components of a cell.

10 Use the following boxes to construct a flow-chart of the movement of water through plants.



5.2 UNDERSTANDING AND USING THE BOS KEY TERMS



Verbs in action

This glossary of terms has been put together by the Board of Studies to make sure the questions that you will encounter in the HSC examination are consistent in meaning, and to specify the type of answers that are required of you. There are many other terms that could be used, but for this chapter we will concentrate on those outlined by the Board of Studies.

Knowing the definitions of these words is only the first step. What depth is required in an answer for each verb? How many marks is the question worth? This chapter is designed to help you answer these questions in the HSC exams with ease.

Keywords

Account	Account for, state reasons for, report on. 'Give an account of': narrate a series of events or transactions.
Analyse	Identify components and the relationship between them; draw out and relate implications.
Apply	Use, utilise, employ in a particular situation.
Appreciate	Make a judgement about the value of.
Assess	Make a judgement of value, quality, outcomes, results or size.
Calculate	Ascertain/determine from given facts, figures or information.
Clarify	Make clear or plain.
Classify	Arrange or include in classes/categories.
Compare	Show how things are similar or different.
Construct	Make, build, put together items or arguments.
Contrast	Show how things are different or opposite.
Critically (analyse/evaluate)	Add a degree or level of accuracy, depth, knowledge and understanding, logic, questioning, reflection or quality to (analysis/evaluation).
Deduce	Draw conclusions.
Define	State meaning and identify essential qualities.
Demonstrate	Show by example.
Describe	Provide characteristics and features.
Discuss	Identify issues and provide points for and/or against.
Distinguish	Recognise or note/indicate as being distinct or different from; to note differences between.
Evaluate	Make a judgement based on criteria; determine the value of.
Examine	Enquire into.
Explain	Relate cause and effect; make the relationships between things evident; provide why and/or how.
Extract	Choose relevant and/or appropriate details.
Extrapolate	Infer from what is known.
Identify	Recognise and name.
Interpret	Draw meaning from.
Investigate	Plan, enquire into and draw conclusions about.
Justify	Support an argument or conclusion.
Outline	Sketch in general terms; indicate the main features of.
Predict	Suggest what may happen based on available information.
Propose	Put forward (for example a point of view, idea, argument, suggestion) for consideration or action.
Recall	Present remembered ideas, facts or experiences.
Recommend	Provide reasons in favour.
Recount	Retell a series of events.
Summarise	Express the relevant details concisely.
Synthesise	Put together various elements to make a whole.

Grouping the verbs

We can make small groups within the list of verbs to help us structure answers. Each group contains verbs that require a similar manner of thinking, and therefore the same approach to answering the question.

Group	Action	Verbs
1	Knowledge	Define, Extract, Identify, Outline, Recall, Recount
2	Comprehension	Account, Clarify, Compare, Contrast, Describe, Discuss, Distinguish, Extrapolate, Interpret, Predict
3	Application	Apply, Calculate, Classify, Demonstrate, Examine
4	Analysis	Analyse, Explain, Investigate
5	Synthesis	Construct, Propose, Summarise, Synthesise
6	Evaluation	Appreciate, Assess, Deduce, Evaluate, Justify, Recommend

Each group builds on the next and can be approached by following a series of steps. This is reflected in the scaffold below. You will only need to use the part of the scaffold that relates to the group your verb falls into, and the points above.

Answer scaffold

Group	Action	Hints
Group 1 Knowledge	Outline the specifics of a topic	List what you know about the topic. Include definitions, formula and diagrams.
Group 2 Comprehension	Give your interpretation of the information	Look through your information, highlight, interpret it and state it in your words.
Group 3 Application	Applications/example	Link concepts you have learnt to an example or application.
Group 4 Analysis	Relate concepts to application	Interpret the information and the relationships. Determine the reliability and quality of the components of your topic.
Group 5 Synthesis	Build/create your answer	Use your creative thinking to put the information that you have gathered together in a format that shows your understanding of the concepts in the question.
Group 6 Evaluation	Make a judgement Draw conclusion	Give your opinion based on the facts you have gathered and any criteria that you have been asked to assess against. What can be concluded from the information?

In some situations, you will find that some steps are redundant as you will be repeating yourself. In any case, you need to work through them in order to make sure you are developing your answer fully. As you get more familiar with the verbs, you will find that you can do this without the scaffold.

When answering any question, the following steps should always be followed:

- **Read the entire question.**
- **Highlight the verb(s) in the question.**
- **Recall the definition of the verb(s).**
- **Identify what topic the verb(s) is/are relating to; highlight this.**
- **Read the question a second time to make sure you have not missed anything.**

Marks

The number of marks allocated to a question is the first indication of the depth of answer that is required of you. A question may be straightforward in its answer, but have several marks allocated. This is a signal that the markers want more than a brief statement. Each group of verbs outlined below will include a range of marks that could be expected when answering these questions.

Using the scaffold

Group 1: Knowledge

The Group 1 keywords are: **Define**, **Extract**, **Identify**, **Outline**, **Recall**, **Recount**.

These verbs require specifics. List all the information about the topic in question; this includes using diagrams and definitions.

Possible marks allocated for Group 1 verbs: 1–2.

Using the scaffold, follow the steps as outlined on page 349.

Steps to add when answering questions in this group:

- List specifics of the topic in the question.

Worked example 1

Question

Identify the materials required for photosynthesis. (1 mark)

Solution

Group	Action	Your answer
All	Verb	Identify
	Definition	Recognise and name
	Topic related to	Photosynthesis
Group 1	Specifics of topic	• Used by plants. • Requires carbon dioxide and water, radiant energy from the Sun and chlorophyll.

Recognise and name material required

Answer

Photosynthesis requires carbon dioxide, water, radiant energy from the Sun and the pigment chlorophyll.

Group 2: Comprehension

Group 2 keywords: **Account**, **Clarify**, **Compare**, **Contrast**, **Describe**, **Discuss**, **Distinguish**, **Extrapolate**, **Interpret**, **Predict**.

This group of verbs requires you to show understanding. This is a little more difficult than Group 1, so it will require greater depth. To answer these questions properly, you need to define and describe the concepts or topic, as well as restating it in your own words, giving your interpretation.

Possible marks allocated for Group 2 verbs: 2–4.

Using the scaffold, follow the steps outlined on p. 349.

Steps to add when answering questions in this group:

- List specifics of the topic in the question.
- Restate the information in your own words.

Worked example 2

Question

Compare internal and external fertilisation. (4 marks)

Solution

Group	Action	Your answer
All	Verb	Compare
	Definition	Show how things are similar and/or different.
	Topic related to	Internal and external fertilisation
Group 1	Specifics of topic	• Internal fertilisation: occurs mainly in terrestrial animals, sperm is deposited within the female, requires few gametes, produces few offspring. • External fertilisation: occurs mainly in aquatic organisms, gametes are released and fertilised outside the body, requires many gametes, produces numerous offspring.
Group 2	Your interpretation of the information	• Similar: union of male and female gametes to reproduce the population of organisms, successful methods of fertilisation. • Different: environment, number of gametes, number of offspring.

Answer

Internal fertilisation	External fertilisation	
Successful method for reproducing species	Successful method for reproducing species	Similarities
Fusing of male and female gametes	Fusing of male and female gametes	
Occurs mainly in terrestrial organisms	Occurs mainly in aquatic organisms	Differences
Few gametes required	Many gametes required	
Limited offspring produced as a result, e.g. birds may only lay 1–2 eggs per year.	Numerous offspring produced as a result, e.g. frogs hatch numerous tadpoles.	

Group 3: Application

The Group 3 keywords are: **Apply**, **Calculate**, **Classify**, **Demonstrate**, **Examine**.

This group requires you to apply the knowledge that you have learnt to a situation that you may not have encountered before.

Possible marks allocated for Group 3 verbs: 2–4

Using the scaffold, follow the steps outlined on page 349.

Steps to add when answering questions in this group:

- Recall the material learnt.
- Identify the specifics of the topic in the question.
- Use your knowledge (i.e. the specifics you list) to answer the situation.

Worked Example 3

Question

In a study on the abundance of koalas in the Port Stephens area, Jenny captured 20 koalas, tagged and released them. Six months later, Jenny recaptured 30 koalas and found that 5 of them had been tagged previously. **Calculate** the abundance of koalas in the Port Stephens area. (2 marks)

Solution

Group	Action	Your answer
All	Verb	Calculate
	Definition	Ascertain/determine from given facts, figures or information
	Topic related to	Capture–recapture
Group 1	Specifics of topic	$\frac{\text{number captured} \times \text{number recaptured}}{\text{number tagged in the recaptured group}}$ = abundance
Group 2	Your interpretation of the information	Number captured = 20 Number recaptured = 30 Number tagged in the recaptured group = 5
Group 3	Application/ Example	$\frac{20 \times 30}{5}$

Answer

$$\frac{\text{number captured} \times \text{number recaptured}}{\text{number tagged in the recaptured group}} = \text{abundance}$$

Number captured = 20

Number recaptured = 30

Number tagged in the recaptured group = 5

Therefore:

Abundance of koalas = $\frac{20 \times 30}{5}$ = 120 koalas

Show how this answer is achieved

Group 4: Analysis

The Group 4 keywords are: **Analyse**, **Explain**, **Investigate.**

Relationships between concepts need to be shown in order to fully answer this type of question. This will require information to be organised into categories in a manner that most clearly shows the relationships, i.e. tables, charts or graphs.

Possible marks allocated for Group 4 verbs: 2–4

Using the scaffold, follow the steps outlined on page 349.

Steps to add when answering questions in this group:

- Recall the material learnt.
- List specifics in the form asked for.

- Show the relationship between concept and application.
- Summarise your findings.

Worked Example 4

Question

Analyse the effect Urey and Miller's findings had on the debate about the origin of life. (4 marks)

Solution

Group	Action	Your answer
All	Verb	Analyse
	Definition	Identify components and the relationship between them; draw out and relate implications.
	Topic related to	• Chemical evolution • Debate on the origin of life
Group 1	Specifics of topic	• Urey and Miller tested Oparin and Haldane's theory that organic molecules, required for life processes, originated from inorganic molecules in conditions present on primordial Earth. • Origin of life: – creationism and the Church widely believed – cosmos theory—molecules for life originated from outer space.
Group 2	Your interpretation of the information	• Results of the experiment provided evidence to support the idea of chemical evolution and Oparin and Haldane's theory. • Created the need for further research by many other scientists.
Group 3	Application/ Example	Disagreed with both cosmos theory and creationism, causing widespread conflict about the origin of life.
Group 4	Relate concepts to application	• Urey and Miller's results provided evidence for the evolution of life on Earth. • These results created a great deal of controversy because there were many other 'unproven' theories for the origin of life. • Their results highlighted the need for further research and experimentation to consolidate their findings. • Example of how our understanding changes as more knowledge is made available.

Answer

Urey and Miller were responsible for providing evidence that organic molecules could have arisen from inorganic molecules in the conditions present on primordial Earth. — Identify components

Their results contradicted traditional religious views of creationism, causing a great deal of controversy between religion and science. Their findings also disagreed with the theory that organic molecules originated from outer space, as there was no evidence supporting this theory at the time of their discoveries. — Relating information

Urey and Miller's findings stimulated further research and a transformation in our understanding of how life on Earth may have evolved. — Implications

Group 5: Synthesis

The Group 5 keywords are: **Construct**, **Propose**, **Summarise**, **Synthesise**.

This requires you to put together ideas that you have learnt to form a new answer.

Possible marks allocated for Group 5 verbs: 2–4

Using the scaffold, follow the steps outlined on p. 349.

Steps to add when answering questions in this group:

- Recall what you have learnt in the topic.
- List specifics in the form asked for.
- Show the relationship between concepts.
- Use the relationship(s) to determine the answer.

Worked Example 5

Question

Summarise the effects of a named human impact on the environment. (4 marks)

Solution

Group	Action	Your answer
All	Verb	Summarise
	Definition	Express, concisely, the relevant details.
	Topic related to	• Human impact—activities carried out by humans. • Environment—all the biotic and abiotic factors that act on an organism.
Group 1	Specifics of topic	• Human impact—introduced species. • Effects—damage to habitats from introduced species, loss of biodiversity, impact on agriculture.
Group 2	Your interpretation of the information	The rate of habitat loss has increased, environmental pressures have changed the evolutionary path of a number of organisms, including extinctions.
Group 3	Application/ example	The cane toad was introduced in the 1930s to stop the cane beetle from destroying sugar cane crops. Only 101 cane toads were released and the population was controlled, but then they reproduced and spread rapidly.
Group 4	Relate concepts to application	Cane toads compete for the food that native animals need to survive. Cane toads produce a toxin that is stored in a gland on their back. It may kill animals such as the quoll and snakes that eat cane toads.
Group 5	Build/create your answer	*As below*

Answer

Humans have transformed their environment to suit their own needs. This involves actions that affect the biotic and abiotic factors in an environment, and these changes are often irreversible. An example of this is the introduction of a species such as the cane toad to control aspects of the environment.

Defining and naming human impact

Cane toads were introduced to control the cane beetle population, which was destroying sugar cane crops in Queensland. Only 101 cane toads were released and they did control the beetle population. However, they began to compete with other native species, and they have the ability to survive in the harshest of conditions.

Application and example

The cane toad has few predators, and will eat anything that will fit into its mouth, thereby competing for food sources with native species such as native frogs. Cane toads produce a toxin, which may kill animals that ingest them; this has led to a depletion in the quoll, snake and native frog populations. Cane toads also prey on native insects, birds and mice, thereby decreasing Australia's biodiversity.

Effects of cane toad on the environment

Group 6: Evaluation

The Group 6 keywords are: **Appreciate**, **Assess**, **Deduce**, **Evaluate**, **Justify**, **Recommend**, **Critically analyse/evaluate**.

Here is where your opinion counts. To evaluate a subject, it is important to objectively list facts for and against. But it doesn't stop here. You must then use these facts to conclude an answer on the subject. It is very important to spend time planning your answer to these types of questions.

Possible marks allocated for Group 6 verbs: 4–6

Using the scaffold, follow the steps outlined on p. 349.

Steps to add when answering questions in this group:

- Recall the material learnt.
- List specifics for and against the concept.
- Make judgements on the topic.
- Draw a conclusion.

Worked Example 6

Question

Evaluate the impact that technology has had on the development of the cell theory. (6 marks)

Solution

Group	Action	Your answer
All	Verb	Evaluate
	Definition	Make a judgement based on criteria; determine the value of.
	Topic related to	• Cell theory • Technology—light microscope, staining techniques and the electron microscope.
Group 1	Specifics of topic	• Cells are the smallest unit of life. • All living things are made up of cells. • All cells come from pre-existing cells.

Group	Action	Your answer
Group 2	Your interpretation of the information	• Light microscope—allowed cells to be observed. • Staining and improved preparation techniques—allowed for better examination of organelles. • Electron microscope—allowed for more powerful magnification and resolution of organelles.
Group 3	Application/ example	• Light microscope—identified cell membrane, cell wall, nucleus, cytoplasm, chloroplasts and vacuoles. • Electron microscope—identified mitochondria, ribosomes, endoplasmic reticulum, Golgi apparatus and lysosomes. • Staining techniques—allowed for observation of cell division and chromosomes in the nucleus.
Group 4	Relate concepts to application	Relate each point of cell theory to the evidence provided by the technology.
Group 5	Build/create your answer	• Light microscope allowed scientists to view cells as the smallest unit of life, and learn that they are found in all living things. • Electron microscopes allowed scientists to view the intracellular organelles that make up the cell. • Staining techniques revealed that all cells come from pre-existing cells by the process of cell division. • Technology provided the evidence needed for cell theory to develop.
Group 6	Make a judgement	Technology has had a very significant impact on understanding the cell theory, for the reasons above.

Answer

Defining cell theory

The cell theory was developed to argue that all living organisms have fundamental similarities at the cellular level and to disprove the notion that living matter could arise from non-living matter. Schleiden and Schwann stated that cells are the smallest unit of life, all living things are composed of cells, and all cells originate from pre-existing cells.

Link the relationship between the two

Our understanding of the cell theory was dependent upon the development of technologies such as the microscope and staining techniques.

When the light microscope was developed, it enabled scientists to view the cells that made up all living organisms, and also allowed them to see fundamental similarities in cell structure, such as the cell membrane, nucleus and cytoplasm. The development of the electron microscope allowed for much more powerful magnification and resolution of the structures within the cell, and allowed the observation and recognition of many other organelles, including the mitochondria and ribosomes. Staining techniques informed the cell theory by showing coloured threads in the nucleus (chromosomes) replicating and dividing, demonstrating that all cells come from pre-existing ones through the process of cell division.

Judgement

Technologies such as the light and electron microscopes, as well as staining techniques, have had a very significant impact on the development of the cell theory.

Conclusion

Without these technologies, we would have a very limited understanding of the cell, its functioning and reproduction.

5.2 UNIT REVIEW

Understanding and using the BOS key terms

Summary

- The definitions of verbs used by the Board of Studies.
- How to apply the answer scaffold to each group of verbs.
- The depth of knowledge required for answering exam questions.

Questions

1 Explain the difference in your answer for Worked Example 1 on page 350, if the verb was changed to 'Outline the roles of the materials required for photosynthesis.' Do you think the allocated marks would change? (2 marks)

2 How will your answer change for Worked Example 2 on page 351, if the verb 'compare' is replaced with 'contrast'? (4 marks)

3 Account for the accuracy of the capture–recapture calculation. (2 marks)

4 Calculate the surface area to volume ratio of a cube with sides measuring 2.5 mm. (4 marks)

5 Classify whether the following organelles are found in animal or plant cells (or both): mitochondria, nucleus, cell membrane, cell wall, ribosomes, chloroplasts, vacuole. (4 marks)

6 Match the verb to its meaning. (7 marks)

Verb	Meaning
Assess	Infer from what is known.
Distinguish	Express, concisely, the relevant details.
Evaluate	Make a judgement of value, quality, outcomes, results or size.
Extrapolate	Recognise or note/indicate as being distinct or different from; to note differences between.
Interpret	Sketch in general terms; indicate the main features of.
Outline	Make a judgement based on criteria; determine the value of.
Summarise	Draw meaning from.

7 Contrast the two processes of meiosis and mitosis. (4 marks)

8 Assess the reliability and accuracy of the secondary sources you used in your studies of Australian fossils. (5 marks)

9 Explain why multicellular organisms require specialised transport systems. (4 marks)

10 _____ the role of teeth in digestion.
The question above has the verb missing.

a Write answers to this question using each of the following verbs: identify (1 mark), explain; (3 marks).

b Compare the two answers. (2 marks)

11 In each sample answer below, deduce which verb was used in the question and give reasons for your answer.

a Pollination involves the transfer of pollen from the anther to the stigma, while fertilisation is the union of the pollen with the ovum. (3 marks)

b The observations made during the experiment show that the larger the surface area to volume ratio, the faster the rate of diffusion. (3 marks)

12 Evaluate the impact of fossils on our understanding of the development of life on Earth. (6 marks)

Glossary

abiotic Relating to the physical parts of the environment, as opposed to the biological (biotic) parts.

abundance The number of individuals of a species that occur in a particular area.

acidic Relating to a substance that releases hydrogen ions in water. Acidity is measured on the pH scale; acids have a pH below 7.

active transport Movement of substances across membranes, requiring the expenditure of energy; occurs through selective protein channels.

adaptation A feature of an organism that makes the organism suited to its environment and helps it to survive and reproduce. An adaptation can be physiological, structural or behavioural.

adaptive radiation The evolution of a species from its original form to a variety of new forms or species that are adapted to different environments or ways of life.

alkaline Relating to a substance that releases hydroxide ions in water; on the pH scale, alkalis have a pH above 7.

allelopathy The production of specific biomolecules by one plant that can harm or benefit another plant.

alveoli (sing. alveolus) Terminal air sacs of lungs, where gas exchange takes place.

amino acid An organic compound containing an amino group ($–NH_2$) and a carboxyl group (–COOH) at opposite ends of the molecule. Amino acids linked together form the peptide chains in protein molecules.

anoxic Without oxygen.

anther Structure at the tip of the stamen that contains chambers called pollen sacs in which pollen grains develop following meiosis.

aquatic environments Water environments—may be saltwater or freshwater.

archaea Type of procaryote with no murein in its cell wall, containing branched lipids in the cell membrane and not sensitive to common antibiotics.

astrobiology The study of life in the universe.

ATP (adenosine triphosphate) Molecules of ATP provide energy for immediate use by the cell; produced during glycolysis and cellular respiration.

autotroph An organism that uses simple inorganic materials from the environment for its nutrition (e.g. green plant).

bacteria A type of procaryote with murein in its cell walls.

binomial system The standard system for naming species, in which each name consists of two parts. The first is the name of the genus, and the second is the name of the particular species. For example, *Eucalyptus regnans*.

biodiversity The variety of all living things on Earth.

biomass Amount of plant and animal tissue that accumulates in an ecosystem; usually measured as mass per unit area (g/m^2) or the equivalent amount of chemical energy bound in the mass of tissue (kJ/m^2).

biomass pyramid The biomass of plants eaten is much greater than the biomass of animals it produces at each level in a food chain, causing a pyramid shape.

biotic Relating to the biological parts of the environment, as opposed to the abiotic (physical) parts.

blood Specialised fluid, often containing cells, which is circulated to provide internal transport in animals.

buds Regions of potential growth, containing meristematic cells, found in leaf axils. They may not develop.

caecum The region of hindgut that lies after the small intestine in some herbivores, e.g. rabbits, koalas. It contains bacteria that help digest cellulose.

cambium Region of rapidly dividing cells (vascular cambium and cork cambium), which produces secondary growth in woody plants.

cancer A disease resulting from uncontrolled cell division of abnormal cells.

capillary Tiny blood vessel, with a wall only one cell thick and across which exchange occurs between blood and tissues.

capture–recapture A method of estimating the size of a population of animals by capturing some, tagging and releasing them, and then capturing another sample. The proportion of tagged animals in the second sample can be used to estimate the total population size.

carnivore Animal that catches live prey for food; also called a predator.

carpel Found inside the reproductive system of female flowering plants (the pistil), each carpel is made up of a stigma, a style and an ovary.

catalyst A substance that increases the rate of a reaction, without being consumed in the reaction, e.g. enzymes.

cell The smallest structural and organisational unit of which all living things are built.

cell growth The increase in size and number of cells.

cell membrane Phospholipid bi-layer that encloses the contents of a cell and controls the movement of substances into and out of the cell.

cell sap The fluid inside a plant cell vacuole. It is mostly water, with dissolved sugars, salts and sometimes pigments.

cell theory The theory that states that all living things are made of cells, cells are the smallest units of life and all cells come from pre-existing cells.

cell wall Cellulose wall outside the cell membrane of plant cells.

cellulose Complex carbohydrate molecule that is very strong; forms plant cell walls.

centrioles A pair of organelles found in animal cells; consisting of hollow cylinders of fibres used in spindle formation in mitosis.

centromere Part of the chromosome that attaches to the spindle during cell division, and where the two chromatids of a double-stranded chromosome are joined.

chloroplast Green organelle containing chlorophyll, present in some plant cells, in which photosynthesis takes place. Composed of many folded layers of membrane.

chromatid One of the two daughter strands of a replicated chromosome, which are joined by a single centromere; separates and becomes a daughter chromosome.

chromatin Darkly staining material in the nucleus of cells that is a combination of DNA, RNA and protein.

chromoplast A cell organelle in plants that contains coloured pigments.

chromosomes Darkly staining structures in the nucleus that are composed of DNA and protein, which carry the hereditary information of the cell in the form of genes. Found in constant numbers in body cells of a particular species.

cilia (sing. cilium) The hair-like structures on the surfaces of some eucaryotic cells, consisting of a '9 + 2' arrangement of microtubules enclosed by an extension of the cell membrane. Cilia move with an oar-like motion and are usually shorter and more numerous than flagella.

classification Grouping organisms on the basis of features they have in common and naming these groups in a hierarchical system of kingdoms, phyla or divisions, classes, orders, families, genera and species. See also *taxonomy*.

cleavage In mitosis in animal cells, this refers to the process of separation of the cytoplasm following chromosome separation to form two daughter cells.

climate change Long-term significant changes in the expected patterns of average weather of a region.

clone A cell, group of cells or organism produced from ordinary body cells of an organism and containing identical genetic information to the parent organism.

closed circulatory system A circulation system in which a specialised fluid carrying nutrients, such as blood, is circulated through the body in a closed system of vessels.

colon The region of the digestive system that moves material from the small intestine to the rectum.

commensalism A relationship between two organisms that benefits one, but does not harm the other, e.g. epiphytes growing on rainforest trees.

community All the living organisms in a habitat; the living part of an ecosystem.

companion cells In flowering plants, the small cells that occur next to sieve-tube cells in phloem, and arise from the same parent cell.

competition The struggle between organisms for an environmental resource that is in limited supply, e.g. water.

condensation A reaction in which two organic molecules combine to form a larger molecule and a smaller molecule (often water).

conservation In ecology, the protection and management of biodiversity.

continental drift The movement of continents as they are carried along on the large segments of the Earth's crust called tectonic plates.

continental margins The outer edges of the continents that are submerged under water.

cortex In plants—the outer part of the stem or root below the epidermis.

creation myths Explanations by ancient cultures of the origins of the universe and everything in it.

cross-pollination The transfer of pollen from the stamen of one flower to the stigma of another flower.

cuticle A waterproof layer secreted by the epidermis.

cyanobacteria Microscopic single-celled procaryotic organisms containing chlorophyll; found in wet and damp situations.

cytokinesis The division of cytoplasm during mitosis or meiosis, as distinct from the division of the nucleus.

cytoplasm The fluid content of a cell, made up mostly of water; includes ions, enzymes, food molecules and organelles other than the nucleus.

cytosol The fluid component of cytoplasm in a cell.

daughter cells The new cells created when a cell divides.

decomposer Bacteria and fungi that consume and break down dead plants, animals and their waste products (organic matter) into soluble organic molecules such as sugars, and eventually into inorganic nutrients (e.g. phosphates, carbon dioxide).

denaturing An irreversible change in a protein's structure, usually as a result of heating above a certain critical temperature.

deoxribose A 5-carbon sugar that is a component of the nucleic acid DNA (deoxyribonucleic acid).

detritus Dead organic matter derived from plants, animals or other organisms.

differentiation The process of change from an unspecialised cell to a specialised cell.

diffusion The passive movement of molecules from where they are more concentrated to where they are less concentrated.

digestion The breakdown of food into a form that can be used by an organism for metabolism; involves mechanical digestion and chemical digestion.

digestive system The system in an animal used to process food.

diploid Containing the full set of chromosome pairs, as in body cells.

diploid cell Cell containing two of each type of chromosome found in a species (2n); e.g. the diploid number in humans is 46.

disaccharides Simple carbohydrates consisting of double units of sugar.

distribution The area or range of locations in which a species can be found.

divergent evolution The evolution in a species from its original form to a variety of new forms or species that are adopted to different environments or ways of life.

DNA (deoxyribonucleic acid) Molecule that is the carrier of genetic information in the cell; found in chromosomes.

dominant In ecology, an individual having greater access to resources than other individuals in the group.

ecology The study of the interrelationships between living things, and between living things and their environment.

ecosystem System formed by organisms interacting with one another and their physical environment.

electron microscope A microscope in which a beam of electrons is used to form an image of an object.

embryo A developing plant or animal formed from a fertilised egg.

emigration The movement of organisms out of a population.

endocytosis Active transport of large molecules across a membrane using temporary vacuoles (pouches) formed by the membrane.

endoplasmic reticulum Layers of intracellular membranes; may be rough endoplasmic reticulum (associated with ribosomes) or smooth endoplasmic reticulum (lacking ribosomes).

environment The non-living and living surroundings of an organism.

enzyme Protein molecule that acts as a biological catalyst. Enzymes usually speed up the rates of reactions that would otherwise have taken place much more slowly. Their action is specific: they catalyse only one type of reaction.

epidermis Outermost layer of cells in plants and animals.

eucaryote An organism with cells containing membrane-bound organelles.

evolution Change over time. In living organisms this occurs through natural selection.

excretory system The organ system involved in the removal of waste products, e.g. the products of metabolism.

extant species A living species with a long fossil history, e.g. the Wollemi pine.

external fertilisation Fertilisation that takes place outside the body, in the external environment.

extremophile A type of microorganism that lives in extreme environments where most organisms would not survive, for example in extremes of temperature, salinity or pH.

facilitated diffusion A type of passive diffusion across cell membranes involving carrier proteins.

faeces The solid waste material evacuated from the digestive system through the anus.

fertilisation Penetration of the egg by a sperm, and fusion of the egg and sperm nuclei to form a zygote.

fibres In plants, long, narrow cells, with thick lignified cell walls but no cytoplasm or nucleus, which provide strength and support.

filament The stalk of the stamen, which bears the anther.

flagellum (pl. flagella) Relatively long, fine, motile organelle; often there are only one or two per cell. In eucaryotic cells it is composed of a '9 + 2' arrangement of microtubules enclosed by an extension of the cell membrane. In procaryotic cells, it is composed of three protein fibrils.

flower In many plants, the structure that contains the reproductive organs.

fluid mosaic model The model that proposes that cell membranes are dynamic structures made up of a phospholipid bilayer with integral and peripheral proteins attached.

food chain A representation of the flow of energy from one organism to another, for example producers to consumers.

food vacuoles Vesicles containing reserves of food (starch, oils, etc.) in the cytoplasm of cells.

food web A series of interacting food chains link up to form a food web.

fruit The mature fertilised ovary of a plant, containing the seeds.

fungi (sing. fungus) Heterotrophic organisms with eucaryotic cells. The cells have cell walls but never contain chlorophyll, e.g. mushrooms, mould, yeast. They help bring about the decay of organic matter.

gamete A haploid sex cell; egg or sperm.

genes Parts of DNA molecules that contain the instructions to make proteins. Particular genes have specific locations on chromosomes. Genes are copied and passed from one generation to the next during reproduction.

gene tree A branching diagram that shows the relationship between groups of genes. This can suggest relationships between different groups of organisms.

genome All the genetic information (DNA) possessed by an organism.

gill An organ of gas exchange in aquatic animals, consisting of a surface whose area is increased by folds, lamellae or filaments. Gases are exchanged when water flows over the surface.

Golgi body (also called the Golgi apparatus or Golgi complex) A cell organelle involved in the secretion of cellular products.

Gondwana Previously existing super continent of the southern landmasses and the Indian subcontinent, which began to break apart about 135 million years ago.

guard cells Pairs of specialised epidermal leaf cells bordering stomates. Stomates are open when the guard cells are turgid.

habitat Place where an organism lives.

haemolymph In insects, the body fluid circulated by a simple pumping system using one or more hearts.

halophiles Aerobic archaea found in very salty lakes or ponds.

halophyte Plant that is adapted to salty conditions and has specialised mechanisms for handling excess salt.

haploid Containing only half the normal number of chromosomes (one of each pair), as in gametes.

heart Muscular pumping organ that moves internal fluids (usually blood) in animals.

herbivore A plant eater, such as the kangaroo or rabbit.

heterotroph An organism that obtains organic nutrients from other living things (e.g. an animal).

homologous chromosomes Matching pairs of chromosomes in a diploid organism.

immigration The movement of organisms into a population.

inorganic compounds All chemical compounds other than organic compounds (see organic compounds); for example, water, carbon dioxide, calcium carbonate (lime).

internal fertilisation Fertilisation that occurs inside the body of the female (in animals), or inside the female part of the plant (in sexually reproducing plants).

iris diaphragm An adjustable aperture in a light microscope that controls the amount of light passing through the specimen from the light source.

lamina The blade (wide part) of a leaf.

lenticel Group of loosely packed cells that allow gas exchange across the otherwise airtight waterproof cork layer covering the stems of plants.

leucoplast A colourless membrane-bound organelle (plastid) in a plant cell, which stores nutrients such as starch.

lignin A complex organic compound deposited in the cell walls in the xylem vessels, tracheids and sclerenchyma of many plants; gives strength to the stem and other plant parts.

liposome A spherical structure covered with a selectively permeable membrane, which absorbs organic molecules from water. Formed from complex organic molecules called phospholipids.

lungs Organs in which gas exchange takes place.

lymph Fluid collected from the tissues, transported in lymph vessels.

lymphatic system System of vessels, emptying into veins near the heart, that collects and returns tissue proteins and fluid to the blood circulation.

lysosomes Membrane-bound vesicles, found in most animal cells, in which powerful enzymes break down debris and foreign microorganisms.

maltose A simple carbohydrate, consisting of two linked molecules of glucose.

marsupial A mammal with a specialised pouch in which the young are carried after being born in an immature state. The young are usually carried until weaned.

megafauna The giant animals known from fossil evidence to have once inhabited Australia; ancestors of many present-day Australian species.

meiosis A cell division which reduces the number of chromosomes in the parent cell by half and produces four daughter cells. Gametes are the products of meiosis.

meristem A type of plant tissue where mitosis occurs, resulting in growth; found in the tips of stems and roots and in apical buds and cambium.

mesophyll Thin-walled, loosely packed photosynthetic plant tissue that forms most of the interior of leaves.

metabolism The total of the chemical processes in an organism.

meteorite A rock or rock fragment from space that has penetrated the Earth's atmosphere and struck the surface.

methanogen Archaea found in bogs and deep, wet soils, in the guts of herbivores and in sewage treatment plants. Exposure to oxygen will kill them.

microfilaments Solid threads of protein that help to support cell walls and movement (e.g. in muscle fibres).

microfossil A type of fossil that can only be seen with microscopes. They may be microorganisms, such as protista, or microsopic evidence of multicellular organisms, such as pollen or spores.

microtome An instrument that cuts thin sections of tissue for microscopic examination.

microtubules Long protein polymers in cells; involved in intracellular movement of organelles, motility of cilia and flagella, and spindle formation during cell division.

microvilli Microscopic folds of the inner surface of intestinal epithelial cells which increase the surface area for absorption.

mid-ocean ridge Underwater mountain range formed where molten material has welled up as tectonic plates move apart.

migration The movement of an animal from one area to another in response to a change in the availability of resources. Migration may be cyclic (e.g. in response to the availability of food resources in another area) or spontaneous (e.g. when all nesting sites have been filled).

mineral Naturally occurring inorganic compound produced by the weathering of rocks. All inorganic nutrients required by plants, except nitrogen, are derived from this process.

mitochondria (sing. mitochondrion) Organelles in which cellular respiration occurs; composed of many layers of folded membrane.

mitosis Division of the nucleus, which leads to identical copies of each chromosome being passed from a mother cell to two daughter cells.

monera Single-celled organisms whose cells are procaryotic (e.g. bacteria, cyanobacteria).

monosaccharide The simplest type of carbohydrate; single units of water-soluble sugar. They include glucose, fructose and ribose.

monotreme A mammal that lays eggs in which the embryo develops until hatching. The only three known monotremes are the platypus, short-beaked echidna and long-beaked echidna.

mucigel Slimy coating on the sheath of a young root.

mutualism Partnership between two organisms in which both of them benefit, e.g. an alga and fungus living together as a lichen.

nanotechnology The research, development and manufacture of substances at the molecular level.

natural selection The process by which favourable variations in a population accumulate over time in a particular environment.

niche In ecology, the function or role of an organism in its community.

nitrogen fixation The conversion of atmospheric nitrogen into nitrogenous compounds that can be used by plants. Nitrogen fixation is brought about by specialised bacteria and cyanobacteria, especially Rhizobium bacteria that live symbiotically in the roots of legumes.

node A point on the plant stem that contains buds from which new stems or leaves can grow.

nucleic acids (DNA and RNA) The genetic material of all organisms; determine features of an organism and control cellular activities.

nucleolus Dark-staining body in the nucleus; site of synthesis of ribosomal RNA.

nucleotide A molecule consisting of a 5-carbon sugar (ribose or deoxyribose), a nitrogenous base (purine or pyrimidine) and a phosphate group; the main building blocks of nucleic acids.

nucleus (pl. nuclei) The cell organelle that contains the genetic material (in the chromosomes) and controls the activities of the cell.

omnivore Animal that eats both plant and animal foods.

open circulatory system A system for circulation of the transport fluid in many invertebrate animals. The fluid moves from the simple heart and around the body cavity as the animal moves its muscles.

organ A structure made of groups of tissues, e.g. the stomach.

organelle Any of the specialised structures in a cell, such as the Golgi apparatus, mitochondria and vacuoles.

organic compounds Chemical substances containing carbon that were once thought to come from living organisms, e.g. proteins, carbohydrates and lipids. Nowadays, organic compounds include all carbon compounds, except oxides, carbonates and bicarbonates.

osmosis Passive diffusion of free water molecules across a selectively permeable membrane from a solution in which there are more free water molecules (a dilute solution) to a solution in which there is less free water (a more concentrated solution).

ovary Female organ into which precursor egg cells migrate and develop into ripe eggs.

ovoviviparity Reproduction where the fertilised egg continues to develop inside the mother and the young are born alive.

ovum (pl. ova) The female gamete or egg produced after meiosis in sexual reproduction.

oxic Containing oxygen.

oxidised rocks Ancient rocks which became oxidised by absorbing oxygen from the atmosphere.

ozone layer The region of the Earth's atmosphere in which there is a high concentration of ozone.

palaeontology The study of fossils.

palisade mesophyll The regularly arranged rectangular cells beneath the epidermis of a leaf.

Pangaea The original single landmass on the Earth, which separated into the northern landmass of Laurasia and the southern landmass of Gondwana.

panspermia Meaning 'seeds everywhere'. The theory that life on Earth originated from bacterial spores that drifted in from outer space.

parasitism A relationship between two organisms in which one benefits and one is harmed.

passive transport Movement of liquid or gas through cell membranes without using any energy, e.g. diffusion and osmosis.

peptide bond The bond that links amino acids.

peroxisome A small organelle that contains enzymes which use oxygen to break down toxic materials in plant and animal cells.

petals Parts of a flower, located inside the sepals and arranged in a circle around the reproductive organs; often colourful.

petiole The 'stalk' of a leaf, which joins it to the stem.

pH A way of describing acidity; pH 7 is neutral; a pH of less than 7 is acidic; a pH of more than 7 is alkaline.

phloem Plant tissue through which sugars and other organic compounds are distributed to different parts of a plant. In flowering plants, phloem consists of sieve tubes, companion cells and fibres.

phospholipid A molecule containing a lipid and a phosphate group. Phospholipids are components of cell membranes.

photosynthesis A process in plants involving the use of light energy to combine carbon dioxide and water to make glucose.

pili Protein rods projecting from the outside cell wall of procaryotes. They help the cell stick to other cells.

pistil Female reproductive organs of the flower; composed of stigma, style and ovary.

placenta Specialised organ in placental mammals that provides for the nutrition of the developing embryo and removal of its wastes by exchange with maternal blood.

plan sketch A diagram showing the top or horizontal view of the distribution of a species.

plasma membrane The membrane that encloses the internal contents of a cell. Also called the cell membrane.

plasmid A genetic element within the cell cytoplasm, consisting of DNA, that exists and replicates independently of the chromosomes. In genetic engineering, bacterial plasmids can be used to produce recombinant DNA.

plasmodesma (pl. plasmodesmata) In plant cells, an intercellular connection composed of a fine strand of cytoplasm passing through channels in cell walls.

plastid Large organelle with a double membrane found in plant cells. Involved in either storage or photosynthesis.

plate tectonics The theory that the Earth's crust is divided into separate plates, which move on a layer of semi-liquid rock in the mantle. Collisions of plates form mountain ranges or deep-sea trenches, and the separation of plates widens oceans and forms new sea floors.

pollen Tiny grains produced in the anthers of flowers that contain the haploid male gametes. Each flowering plant species has pollen of a characteristic shape, size and surface patterning.

pollination Transfer of pollen from one flower to another by wind and animals such as insects, birds and small mammals (called pollinators).

polypeptide A polypeptide is a chain of linked amino acids.

population A group of organisms of the same species living in a defined geographic area.

population explosion A sudden, rapid increase in the abundance of a species in a particular area, usually caused by a sudden increase in the availability of resources or a decrease in predators.

predator An organism that obtains its food by killing another organism.

prey Animals captured, killed and consumed by other animals.

procaryote A unicellular organism whose cells lack membrane-bound organelles. Procaryotes include archaea, bacteria and cyanobacteria.

profile sketch A diagram showing the side view of the distribution of a species.

protist Single-celled eucaryotic organism, e.g. protozoans, some algae.

protoplasm The internal contents of a cell.

protozoans Single-celled eucaryotic organisms.

quadrat Square, rectangular or circular patch of vegetation of any size, used to sample an area of an ecosystem.

radioactive isotope Isotopes are alternative forms of the same chemical element, e.g. carbon-12 and carbon-14. Radioactive isotopes have unstable nuclei, which spontaneously emit radiation.

random segregation The process by which pairs of homologous chromosomes are divided between separate gametes during meiosis.

regeneration The regrowth of parts of an organism which have been cut off or lost. Used in plant propagation, and by some animals.

reliability The extent to which a set of measurements remains consistent over identical repeated tests under the same conditions. Reliability is increased when repeated testing gives consistent results. For example, using a control can increase reliability, using a large population sample can increase reliability.

reproduction The production of offspring.

respiration The process that provides energy to cells (as ATP) by the oxidation of organic molecules such as glucose. It also releases carbon dioxide and water.

respiratory surfaces The surfaces of an organism over which exchange of gases occurs.

rhizoid Hair-like structure in some plants that anchors the plant, but does not conduct water or nutrients.

ribosomes Tiny organelles often attached to the endoplasmic reticulum; composed of protein and RNA; the site of protein synthesis.

RNA (ribonucleic acid) Nucleic acids involved in protein synthesis.

root hairs Extensions of root epidermal cells into the soil. They greatly increase the surface area over which water can be absorbed into the root.

rumen The region of foregut that lies before the stomach in some herbivores, e.g. cattle, kangaroos. It contains bacteria that help digest cellulose.

sampling method Technique used to estimate the distribution and abundance of a species in an area.

scavenger Animal that eats other dead animals, e.g. the Tasmanian devil.

secondary tissue Sites of secondary growth in a plant, which increases the plant's thickness or diameter.

seed A fertilised mature ovule containing a new plant embryo.

selectively permeable Allowing the passage of some substances but not others.

self-pollination The transfer of pollen from the stamen to the stigma of the same flower, or another flower on the same plant.

sepals Outer parts of a flower that are usually small and green; they enclose and protect the other parts of a flower during the bud stage.

sieve tube cell Elongated living cell found in phloem tissue, through which fluids and dissolved sugars are transported throughout the plant.

species A group of similar organisms that can interbreed and produce fertile offspring under natural conditions.

sperm The male gamete produced after meiosis in sexual reproduction.

spongy mesophyll The irregularly arranged cells with large air spaces between them in a leaf.

spontaneous generation The idea that living things could spring into life from non-living matter.

spreading zone Region of new ocean floor that forms from molten rock material in mid-ocean ridges as two tectonic plates move apart.

stamen Male reproductive organ of a flower, composed of filament and anther.

starch Complex carbohydrate compound, made up from glucose subunits. It is the main energy storage component in plants.

stele A central cylinder of vascular tissue in roots.

stigma Receptive surface for pollen, found at the tip of the style.

stomate Tiny epidermal pore bounded by two highly specialised guard cells; stomates are the main route through which gas exchange and water loss occurs in plants.

stromatolites Colonial cyanobacteria first discovered in fossils from more than 3000 million years ago.

style Organ in flower that bears the stigma and through which, after pollination, pollen tubes grow down towards the ovules.

sucrose Table sugar; a glucose and a fructose molecule joined together; a simple carbohydrate.

symbiosis Relationship where two quite different organisms live and function together in a close association, to the benefit of at least one of them. See also *mutualism* and *parasitism*.

synchrotron A large facility that produces beams of high-energy electrons or protons that can be used to examine matter at an atomic level.

systematics The study of taxonomy, the systematic classification of life forms on Earth, past and present, and the relationships between them. These relationships are often represented as evolutionary trees.

taphonomy The study of the processes by which dead organisms become fossils.

taxonomy Naming groups recognised in a classification system of organisms. See also *classification*.

telomere The protective non-coding terminal ends of chromosomes.

terrestrial environments Environments on land.

thermophiles Archaea which require high temperatures; found near volcanic activity: in hot springs, geysers, thermal vents and cracks in the ocean floor.

threatened species Species whose population numbers are falling and are at risk of extinction in the near future. The degree of threat may be classified as vulnerable, endangered, critically endangered and extinct.

thylakoid In plants, a structure containing photosynthetic pigments, forming part of the chloroplast in green plants.

tissue A group of cells similar in structure and function, e.g. muscle.

trachea (pl. tracheae) Airway leading from the pharynx into the bronchi in mammals.

tracheal system The system of interconnecting tubes, called tracheae and tracheoles, in insects that bring air from the external environment to the body cells.

transect In ecology, a narrow strip through an area to study the distribution of species.

translocation Transport of sugars in solution through sieve tubes from leaves to other parts of the plant. Translocation is driven by active transport of sugars, and so requires energy expenditure by the plant.

transpiration Evaporation of water from the leaves of plants due to heat from the Sun; causes suction, which draws water up xylem vessels from roots.

transpiration stream The constant upward flow of water through a plant.

transport vesicle Membrane-enclosed material that is moved around the cell. Specifically, transport vesicles move materials from the endoplasmic reticulum to the Golgi apparatus.

trophic interactions Feeding relationships.

tumour A mass of abnormal cells produced as a result of uncontrolled cell division. Tumours may be benign or malignant.

vacuoles Membrane-bound structures found in most cells; may contain food, enzymes or fluid. In plants, typically large and fluid-filled.

valid How well an investigation tests what it is intended to test. Validity can be achieved by well-controlled experiments with only one dependent variable.

variation The natural differences between individuals of a species as a result of inherited (genetic) or environmental factors.

vascular tissue Xylem and phloem tissues in a plant.

vein In vertebrates—a blood vessel that returns blood to the heart. In plants—a tube of vascular tissue in a leaf.

virus A very small non-cellular structure consisting of nucleic acids enclosed in a protein coat. Viruses can reproduce only inside a living cell.

vitamin Any organic compound required in small amounts for cell processes; in humans, any of 13 such compounds, called vitamins A, B group (eight vitamins), C, D, E and K.

viviparity Reproduction where the developing young receive nutrients from the mother and the young are born alive.

X-ray microscopy Microscopes that use X-rays to produce detailed 2-dimensional images showing internal structure. When combined with computers using sections from CAT (computed axial tomography) scans, 3-dimensional images can be produced.

xylem Tissue composed of vessels, tracheids, supporting fibres and parenchyma. Responsible for the transport of water and minerals from the soil to leaves of plants.

zygote Diploid cell resulting from the fusion of an egg and sperm; the first stage of a unique new organism.

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