Summary Guides

Science 8

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Rachael Smith asserts the moral right to be identified as the author of this work.

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Please be aware this book contains images of Aboriginal and Torres Strait Islander people who may be deceased.

Contents

Introduction

The *Summary Guides – Science* series has been written by practising educators who are passionate about creating user-friendly, accessible guides for science.

The explanations and exercises in these guides develop core science knowledge and skills for personal, work and civic life, and provide the base knowledge to understand science comprehensively. Science will be part of your daily life no matter what you choose to do as an adult – understanding it will help you think critically and make sense of the world.

This book summarises key concepts clearly. It includes real-world examples, step-by-step explanations, and exercises for you to complete. The best way to use this book is to make a habit of it, regularly working through the material and questions, and comparing your answers with those provided. Whether you commit to a daily, weekly or fortnightly routine, consistent practice is the key to your success.

Rachael

About the author

Rachael Smith is a passionate educator and writer who is enthusiastic about making complex scientific concepts accessible to all learners.

With over 20 years of experience in teaching and curriculum development, Rachael has dedicated her career to inspiring curiosity and critical thinking in students.

Rachael has worked with teachers and students to develop engaging and effective learning materials that align with the Australian Curriculum. Her expertise spans multiple scientific disciplines, ensuring a well-rounded approach to science education.

Chapter 1 – Biology

1.1 What is biology?

Biology is a branch of science that studies living things. A biologist is a scientist who studies biology (from the Greek root word *bios*, which means 'life'). Biologists try to understand the natural world and everything that lives in it, including plants, animals, fungi, bacteria, viruses, algae and **protozoa**.

So why is biology important to you? Every living thing, including you, is made up of cells. Cells work together to help you function and produce new life!

Key term

protozoa	tiny living things made up of one cell; the word means 'first animals'

1.2 Cell theory

What are cells?

Cells are the basic building blocks of all **organisms**, from the smallest bacterium to the largest animal. All living things are made up of one or more cells, which carry out essential functions to support life.

Key term

organism	a living thing

Cells vary widely in size; most are too small to be seen with the naked eye, which is why biologists use microscopes to see cells. It is important to note that *all* cells come from pre-existing cells.

Types of living organisms

Unicellular organisms are made up of a single cell that performs all life processes within the one cell. They are often so small that you can only see them under a microscope. So, they are also referred to as microorganisms. Examples are bacteria, some algae, and protozoa.

Multicellular organisms are made up of more than one cell. In multicellular organisms, different types of cells perform special and unique functions. Examples of multicellular organisms are animals, plants, insects and humans. The human body consists of trillions of cells.

> **Fun fact**
>
> Many scientific words come from the ancient Roman language Latin. You probably already know that *uni* means one and *multi* means 'many'. 'Cell' comes from the root word *cella*, meaning 'small room' – like a prison cell!

Activity 1.2.1

1. List some things that contain cells.
2. Write two facts about cells. For example, a fact about cells is that cells are the basic building blocks of all living things.
3. Write a definition to explain the difference between unicellular organisms and multicellular organisms.

Science as a human endeavour: The light microscope

A microscope is a device that enables you to observe objects that are too small to be seen with the naked eye – such as cells.

Figure 1.1: Protozoa under a microscope

The microscope you use at school is called a light microscope. It is one of the most important inventions in biology. Light microscopes focus light through a specimen to magnify it.

The microscope allowed scientists to see that life exists on a cellular level and to view previously unseen microscopic things such as cells and bacteria. This led to many important discoveries about cells and microorganisms, and to the development of cell theory. Microscopes play a vital role in scientific research and innovation by helping us to understand the world around us.

Microscopes have developed since they were invented in 1590. Key inventors and developers of the microscope include Zacharias Janssen and his father Hans Janssen, Galileo Galilei, Robert Hooke, Antonie van Leeuwenhoek, Joseph Lister and Ernst Ruska.

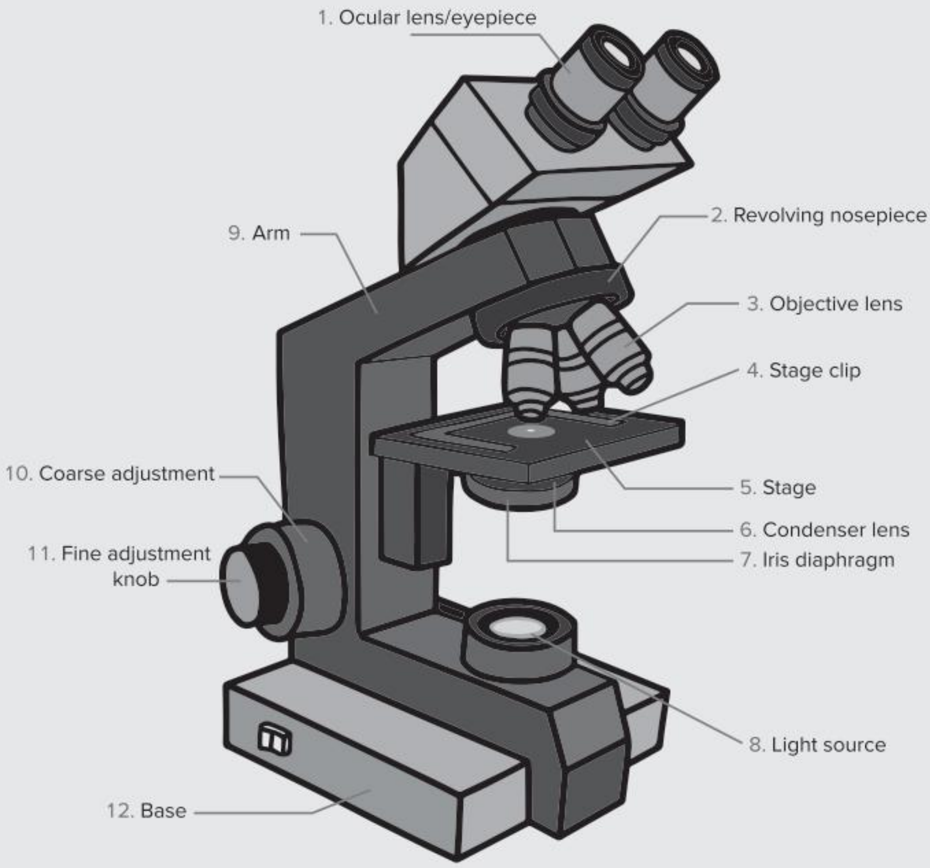


Figure 1.2: A light microscope

Table 1.1: The difference between stereo, compound and electron microscopes

Stereo	Compound	Electron
Magnifies by up to 300 times	Magnifies by up to 2000 times	Magnifies by up to 200 000 times
Can analyse whole parts	Can analyse whole parts	Can analyse thin slices
Can analyse living things	Can analyse living things	Can only analyse things that are dead or non-living
Can show outer details of specimens	Can show outer details of specimens and some structures inside cells	Can show outer details of specimens and some internal structures

1.3 Cell structures

Eukaryotic versus prokaryotic cells

Two main types of cells make up living organisms: **prokaryotic cells** and **eukaryotic cells**. The main difference between the cells is in their structure.

- Prokaryotic cells *do not* contain a **nucleus** or **membrane-bound organelles**.
- Eukaryotic cells *do* contain a nucleus and membrane-bound organelles.

Key terms

nucleus	in biology, the organelle in a eukaryotic cell that controls and regulates the activities of the cell and carries the genes
membrane-bound organelles	an organelle that is encased by a membrane, giving it a distinct internal environment
organelle	a small organ-like structure inside a cell that has a specific job; the word means 'very small organs'

Key fact

Classification means to sort things into groups based on similar features. The classification of the five kingdoms of life is based on differences in cell structure and on the presence or absence of different organelles.

Activity 1.3.1

On a piece of paper, brainstorm all the things you can see around you that are living organisms.

Eukaryotic cells

The living organisms that you see each day are most likely made up of eukaryotic cells – cells with a nucleus and membrane-bound organelles. These living organisms are mostly multicellular, but some are unicellular such as **protists** and some fungi. An example of a unicellular protist is green algae.

Key term

protist	a diverse group of eukaryotic organisms that are mostly unicellular; includes algae, amoeba and slime mould, among others

Eukaryotes are organisms that are made of eukaryotic cells and include all animals, plants, fungi and protists.

Animal and plant cells are eukaryotic cells.

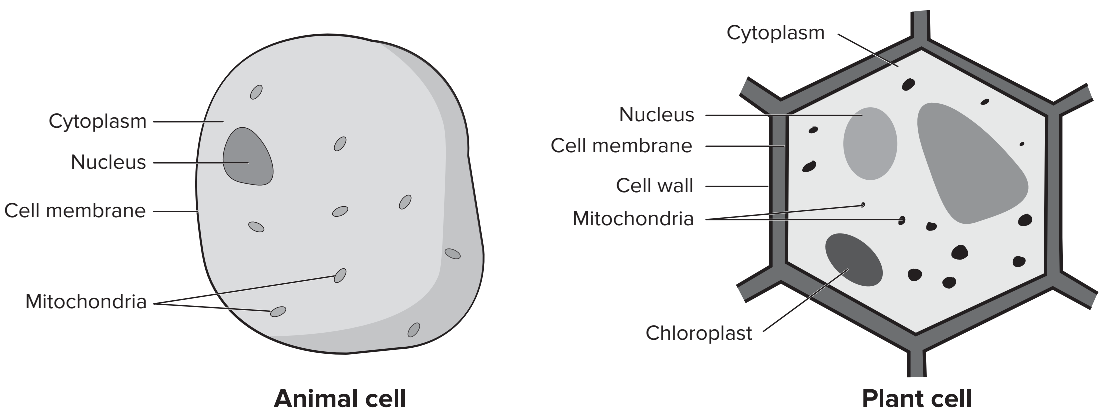


Figure 1.3: An animal and a plant cell

Eukaryotic cells are more complex and generally larger than prokaryotic cells. As well as the nucleus that contains **DNA**, eukaryotic cells have membrane-bound organelles – specialised compartments separated by membranes that act as a boundary. Examples are the nucleus, mitochondria (singular: mitochondrion), Golgi apparatus (or Golgi body), endoplasmic reticulum and vacuoles. We will learn more about these later.

Key term

DNA	(deoxyribonucleic acid) the molecule that carries genetic information so an organism can develop and function

Prokaryotic cells

Prokaryotic cells do not contain a nucleus or membrane-bound organelles. They have a specialised structure and their DNA is contained in the central area of the cell. Prokaryotic cells are simpler and generally smaller than eukaryotic cells.

Living organisms that are made of prokaryotic cells are unicellular.

Prokaryotes are living organisms that are made of prokaryotic cells. Examples are all bacteria.

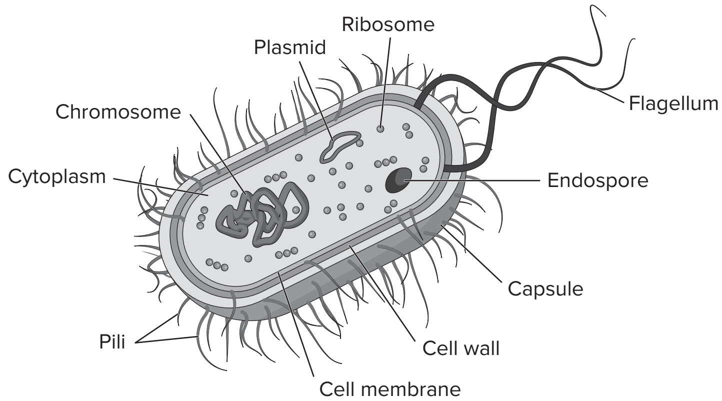


Figure 1.4: A prokaryotic cell

Activity 1.3.2

Write a definition to explain the difference between eukaryotic cells and prokaryotic cells.

1.4 Introduction to animal cells

Animal cells are the basic building blocks of animals. Humans are animals; therefore, we are made up of animal cells!

Animals are multicellular and built with various types of cells. Animal cells are eukaryotic cells (have a nucleus containing DNA and membrane-bound organelles).

Activity 1.4.1

Write two facts about animal cells.

Organelles within animal cells

All animal cells contain the same group of organelles inside the cell. Each organelle has a specific function or job to do inside the cell. Organelles are held inside the cell by a membrane called the cell membrane.

Figure 1.5 shows an animal cell with the organelles and other structures inside.

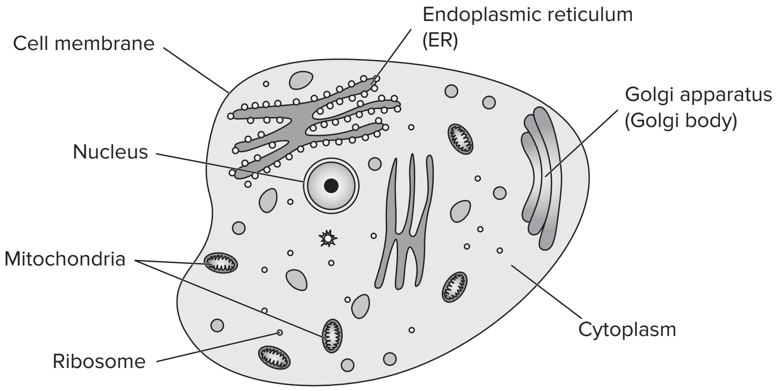


Figure 1.5: An animal cell and its organelles

Cross-check the following information about organelles and structures and their functions with Figure 1.5. You may like to colour code the information and the cell labels so that they match each other.

1. Cell membrane

Description: a thin, flexible layer that surrounds the cell.

Function: controls the entry and exit of different substances and provides protection and structure to the cell.

2. Cytoplasm (pronounced: SAI-tow-pla-zm)

Description: not strictly an organelle, but a jelly-like substance filling most of the cell. It maintains the shape of the cell.

Function: supports and protects the organelles.

3. Nucleus

Description: a large, round organelle.

Function: acts as the control centre of the cell. It contains and protects DNA that holds genetic information for cell growth, function and reproduction.

4. Ribosomes (pronounced: RAI-buh-sowms)

Description: a tiny, round structure floating in the cytoplasm or attached to the endoplasmic reticulum. Cells can have many of these.

Function: makes proteins for cell growth and repair.

5. Endoplasmic reticulum (ER) (pronounced: en-doh-PLAZ-mick re-TIK-yoo-lum)

Description: a network of tubules (tiny tubes) that can be rough or smooth. A rough endoplasmic reticulum (RER) has ribosomes on the surface, while a smooth endoplasmic reticulum (SER) does not.

Function: transports protein and other substances around the cell.

6. Golgi apparatus (Golgi body) (Golgi pronounced: gowl-jee)

Description: stacks of flattened membranes.

Function: processes, modifies and packages proteins.

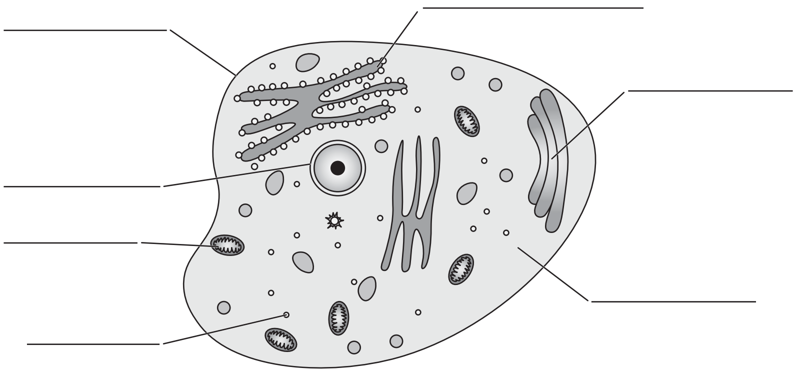
7. Mitochondria (pronounced: mai-tow-kon-dree-uh)

   Description: small bean-shaped organelles.

   Function: produces energy for the cell (often described as the powerhouse of the cell).

Activity 1.4.2

1. What surrounds the cell and controls the entry and exit of substances?
2. What protects the DNA in a cell?
3. What packages and processes proteins in a cell?
4. What produces energy for the cell?
5. What produces proteins in a cell?
6. Label the organelles in this cell.



1.5 Introduction to plant cells

Plant cells are the building blocks of plants. They have several structures that are specialised to help the plant grow, make food and survive. Plant cells have many of the same organelles as animal cells, but they also have some unique organelles.

Organelles within plant cells

In addition to the organelles common to all eukaryotic cells (see information on animal cells), plant cells contain the following structures and organelles.

1. Cell wall

   Description: a rigid structure that surrounds the cell membrane.

   Function: provides protection around the cell and allows substances to enter and exit the cell.

2. Chloroplast (pronounced: KLAW-roh-plast)

   Description: an oval-shaped organelle.

   Function: contains chlorophyll (green pigment). **Photosynthesis** takes place here.

3. Vacuole (pronounced: VA-kyoo-ole)

Description: a large organelle filled with sap (water, sugar, salt solution). Animal cells also contain vacuoles, but they are much bigger in plant cells and take up a large amount of space within the cell.

Function: helps to maintain water balance and shape.

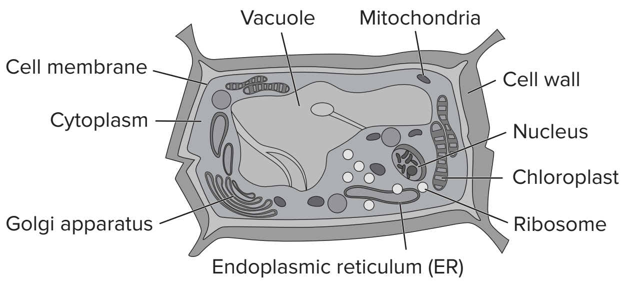
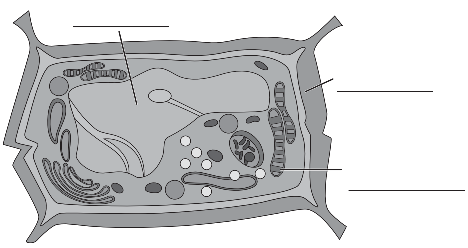


Figure 1.6: A plant cell and its organelles

> **Key fact**
>
> The word 'photosynthesis' can be split in two words, 'photo' and 'synthesis'. Think of a camera flash that creates light, and synthesis as a process that builds or makes something. Therefore, plants use the flash of sunlight (photo) to make (synthesise) energy.

Activity 1.5.1

1. What has a rigid structure, surrounds the cell and controls the entry and exit of substances?
2. Where does photosynthesis take place in a cell?
3. What is the name of the organelle that stores sap (water, sugars, salt solution)?
4. Label the three organelles indicated in the plant cell diagram below.



5. On a piece of paper, draw each of the organelles in plant cells and create a symbol to help you to remember what the function of the organelle is.

1.6 Specialised animal cells

Specialised cells are cells that have adapted to perform a specific function or job. These cells work together in tissues, organs and systems to ensure an organism's survival and growth. We will look at tissues and organs in more detail later.

Each specialised cell has a special function. They often have a distinctive structure and shape to perform their job effectively.

Animals have many specialised cells – more than 200 different types. Examples are blood cells, muscle cells and nerve cells.

Blood cells

Blood is constantly circulating around your body. It delivers oxygen and nutrients, and removes waste. Blood is mostly made up of a liquid called **plasma**. In the plasma, different cells carry out different functions.

- **Red blood cells** deliver oxygen to different parts of the body and remove waste such as carbon dioxide. They contain a protein called haemoglobin, which carries the oxygen. Red blood cells are disc shaped, or shaped like a donut without the hole in the middle. This increases their surface area, which allows more oxygen to attach to them. They do not have a nucleus and are very thin so they can pass through blood vessels.
- **White blood cells** protect the body against infections by destroying bacteria and viruses. They are part of the body's immune system. They are much larger than red blood cells and have a nucleus. Different types of white blood cells respond to different types of harmful bacteria and viruses.
- **Platelets** are small cell fragments that help the body form clots to stop bleeding. When you get a cut, the platelets receive a signal to move to the site of the cut and clot to prevent further blood loss.

Activity 1.6.1

Match the specialised blood cell to its function.

Red blood cell	Forms clots to prevent blood loss
White blood cell	Carries oxygen
Platelet	Fights infection

1.7 Specialised plant cells

As with specialised animal cells, specialised plant cells have special functions. They also often have a distinctive structure and shape so they can carry out their job effectively.

Specialised plant cells include:

- photosynthetic cells: they have stomata (singular: stoma), guard cells and chloroplasts. This group of photosynthetic cells is sometimes referred to as palisade cells
- root hair cells
- conducting cells.

Photosynthetic cells

Photosynthetic cells capture light energy and convert it into food for the plant. This process is called photosynthesis. We say that plants are **autotrophic**, which means they make their own food. Photosynthetic cells are in the leaves and sometimes the stems of the plant, where they can receive sunlight.

Plants use sunlight, water and carbon dioxide to produce oxygen and glucose (a sugar that plants use as a source of energy or food) in photosynthesis. Glucose is an energy source or food for plants. Photosynthesis takes place in the **chloroplast** organelles in plants. These contain the green pigment called **chlorophyll** that helps the plant to absorb sunlight.

There is a simple word equation for this process:

$$\text{water} + \text{carbon dioxide} \xrightarrow{\text{sunlight}} \text{glucose} + \text{oxygen}$$

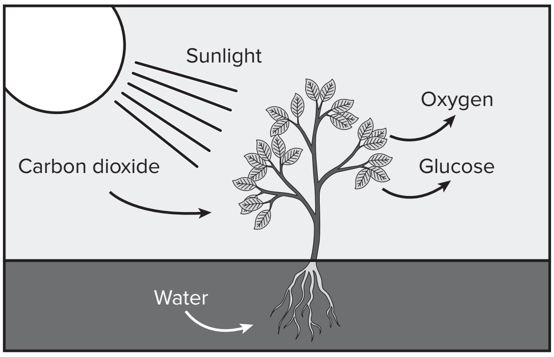


Figure 1.7: During photosynthesis, a plant converts water and carbon dioxide to glucose and oxygen.

Guard cells are photosynthetic cells on the surface of leaves and are responsible for opening and closing **stomata** (singular: **stoma**). A stoma is a small pore on the surface of the leaf that helps gas exchange between the plant and the atmosphere. Guard cells control the opening and closing of stomata depending on the needs of the plant. This controls gas exchange and water loss within the plant.

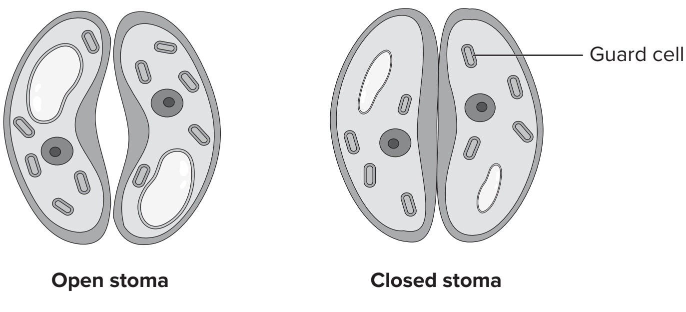


Figure 1.8: Stomata open and close to control the movement of gas and water in and out of the plant.

Gas exchange

- **Carbon dioxide** from the atmosphere enters the plant through stomata.
- **Oxygen leaves** the plant through stomata into the atmosphere.
- **Water vapour moves** through stomata and leaves the plant when the stomata are open.

- **Guard cells** control the opening and closing of stomata depending on the needs of the plant. They keep the stomata open during the day when the plant receives sunlight for photosynthesis to occur and closed during the night when there is no sunlight, to help conserve water.

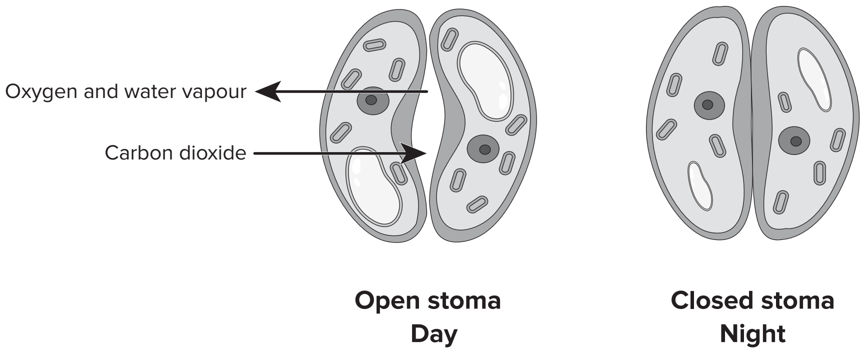


Figure 1.9: Stomata open during the day and close at night.

Activity 1.7.1

1. What do guard cells control?
2. Describe the process of photosynthesis. You may also like to write the word equation for it and draw a picture to help you understand the process.
3. When do guard cells open so that photosynthesis can occur?

Root hair cells

Root hair cells are on the outer layer of the roots of the plant. They help the plant to absorb water from the soil. Despite the name, root hairs are not hairs but narrow extensions of cells.

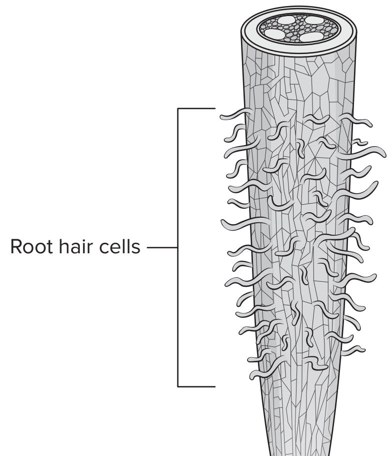


Figure 1.10: A root tip showing root hair cells

Conducting cells

Conducting cells form tubes that transport water and nutrients around the plant.

There are two types of conducting cells:

- **Xylem cells** transport water and nutrients from the roots to the leaves.
- **Phloem cells** transport food produced in the leaves to other parts of the plant.

Activity 1.7.2

1. On a piece of paper, draw a small plant showing the roots, stem and leaves. Label the different photosynthetic cells you are likely to find in this plant and explain the functions of each of the different cells.
2. Write the names of the two types of conducting cells.

1.8 Comparing animal and plant cells

Animal and plant cells have similarities and differences.

Similarities between animal and plant cells

Animal and plant cells are both eukaryotic cells, which have:

- a **cell membrane**, which is a thin, flexible layer surrounding the cell
- the **cytoplasm** – a jelly-like substance that fills most of the cell and maintains the shape of the cell
- a large round **nucleus** – the organelle containing DNA
- a network of tubules (tiny tubes) called the **endoplasmic reticulum (ER**), which can be rough or smooth
- **ribosomes** – tiny round structures that float in the cytoplasm or attach to the endoplasmic reticulum
- **Golgi apparatus** – stacks of flattened membranes
- **mitochondria** – small bean-shaped organelles that produce energy for the cell.

Differences between animal and plant cells

Although animal and plant cells have many of the same basic structures, plants need different organelles to carry out functions that animals cannot perform. For example, unlike animals, plants produce their own food through the process of photosynthesis. They therefore need different cellular structures to help them do this.

Table 1.2: Comparing animal and plant cells

Feature	Animal cells	Plant cells
Cell wall	✗ (only a cell membrane)	✓ (made of cellulose)
Chloroplasts	✗	✓ (with chlorophyll for photosynthesis)
Shape	Irregular or rounder shape	Regular, rectangle shape due to rigid cell wall
Vacuole	Small temporary vacuoles, if any	Large central vacuole
Food	Part of an organism that is heterotrophic (consumes other organisms)	Part of an organism that is autotrophic (makes their own food)

Activity 1.8.1

Draw a Venn diagram and compare animal and plant cells using the labels below to help you.

Mitochondria	Golgi apparatus	Nucleus	Large vacuole
Cell membrane	Cell wall	Small vacuole	Ribosome
Chloroplast	Chlorophyll	Autotrophic	Heterotrophic

1.9 Fungal cells

Fungi are eukaryotic: they have a nucleus and other membrane-bound organelles.

Fungi are a group of organisms that are different from plants and animals. They can be unicellular (e.g. yeast used in bread making and fermentation) or multicellular (e.g. mushrooms, toadstools and moulds).

In addition to the organelles common to all eukaryotic cells (animals and plants), fungal cells have a cell wall that is made of **chitin**, rather than cellulose.

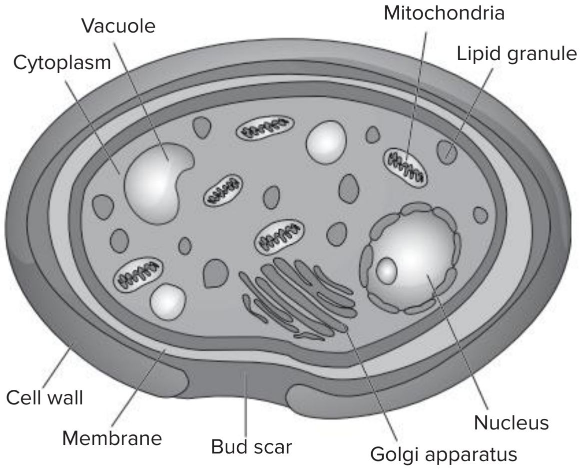


Figure 1.11: A fungal cell

- Fungi do not have chloroplasts so they cannot photosynthesise to make food. They are heterotrophic – they cannot make their own food. Humans and other animals are heterotrophic as we also cannot make our own food. We must eat other things such as plants and animals. Fungi absorb nutrients from their surroundings by breaking down dead or decaying organic material (**saprophytic**) or by feeding on living organisms (**parasitic**).

Fun facts

Think about a time when you saw mushrooms growing on a fallen tree in the bush or in a rainforest. This is an example of **saprophytic** nutrition. The mushroom is taking in nutrients from the decaying tree while also helping it to decompose.

Athlete's foot is a **parasitic** fungus that affects the skin of the feet. It makes the skin itchy with a scaly rash. This is a form of parasitic nutrition as the fungi feeds on the keratin proteins in the skin of the feet.

Fungi play an essential role in ecosystems by decomposing organic matter. They also provide us with food. Many types of fungi such as field and shiitake mushrooms are edible. If you have ever had a bacterial infection and needed to take penicillin (an antibiotic), then you have consumed a product made from fungi.

Key terms

saprophytic	living organisms obtain food by absorbing the products of organic break-down and decay
parasitic	living organisms obtain food by living off another organism
chitin	the primary component of cell walls in fungi (pronounced: KAI-tin)

Activity 1.9.1

1. Explain two key differences between a fungal cell and other eukaryotic cells.

2. State whether fungi is autotrophic or heterotrophic.

1.10 Comparing different cells – animal, plant, fungi

Animal, plant and fungal cells are all eukaryotic cells. They have some features in common but also have key differences based on their functions and the role of the organism within its ecosystem.

Similarities between animal, plant and fungal cells

All animal, plant and fungi cells have:

- a cell membrane
- a cytoplasm
- a nucleus
- ribosomes
- an endoplasmic reticulum (ER)
- a Golgi apparatus
- mitochondria.

Differences between animal, plant and fungal cells

Table 1.3: Comparing animal, plant and fungal cells

Feature	Animal cells	Plant cells	Fungal cells
Cell wall	✗	✓ (made of cellulose)	✓ (made of chitin)
Chloroplasts	✗	✓ (for photosynthesis)	✗
Shape	Irregular or round	Regular/rectangular	Irregular or tubular
Vacuole	Small and temporary if present	Large and central	Small or none
Food	Belong to an organism that is heterotrophic (consume other organisms)	Belong to an organism that is autotropic (make their own food)	Belong to an organism that is heterotrophic (absorb nutrients from other organisms)

Each of these living organisms has an important role to play within ecosystems.

- Animals are **consumers (heterotrophs)** – they depend on plants and other living organisms for food and energy.
- Plants are **producers (autotrophs)** – they convert sunlight to food (glucose) through the process of photosynthesis.
- Fungi are **decomposers (heterotrophs)** – they break down dead material and absorb the nutrients or live as parasites on other organisms.

In summary:

- Animal cells lack cell walls and chloroplasts, making them specialised for **movement** and **consuming** food.
- Plant cells have cell walls, providing them with structural support, and chloroplasts, allowing them to **produce** their own food.
- Fungal cells are unique because they have chitin cell walls; fungi are heterotrophic, absorbing nutrients and functioning as **decomposers** in ecosystems.

Activity 1.10.1

Write one fact each about animal, fungi and plant cells.

1.11 Bacteria

Bacteria are single-celled organisms that live everywhere on Earth, including in soil, water, air and inside and outside of living organisms. Unlike plant, fungi and animal cells, bacteria are **prokaryotic**, having no nucleus or membrane-bound organelles.

Bacteria are classified by their shape and how they obtain energy. They can be spherical, rod or spiral shaped. Bacteria can be autotrophic (make their own food by photosynthesis, e.g. blue-green algae) or heterotrophic (consume other organisms or organic matter, e.g. *Salmonella*).

Bacteria have:

- a capsule – a protective external coating that protects them from being damaged
- a cell wall
- a cell membrane
- a nucleoid area where genetic material (DNA) is stored.

Some also have:

- flagella (singular: flagellum) – tail-like structures to help the bacteria to move
- pili (singular: pilus) – hair-like structures used to attach to surfaces or other cells.

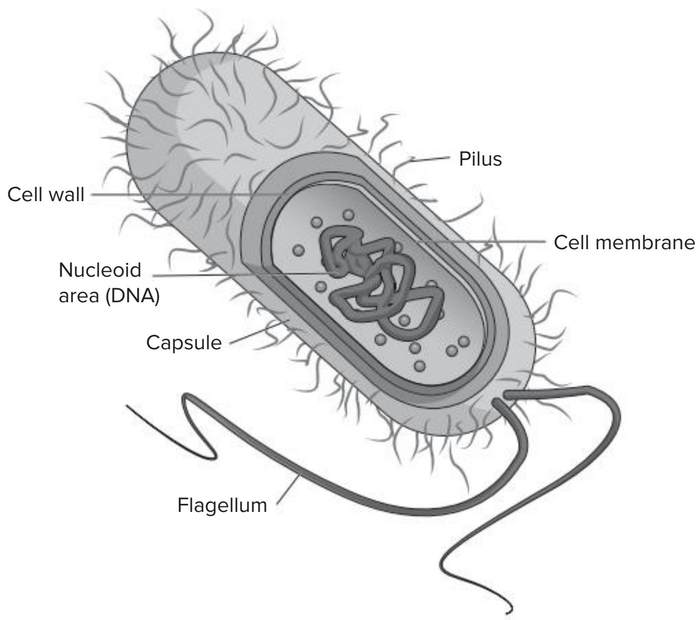


Figure 1.12: A bacterial cell

Fun facts

Bacteria are essential for life on Earth. They help maintain ecosystems, support agriculture and even play a crucial role in medicine. They can be beneficial when they break down dead organisms, recycling nutrients back into the environment.

Bacteria are used in making yoghurt, cheese and other fermented foods, and probiotics are a type of bacteria beneficial for gut health.

Activity 1.11.1

List the four structures that bacteria cells have that other cells do not.

1.12 Extension: Cell division

All cells are derived from pre-existing cells through the process of cell division. It is the process by which a **parent** cell divides into two or more **daughter** cells. This means that cells don't spontaneously come into life but are created through the replication of existing cells. This process is crucial to your body's functioning.

When you have a cut or even a broken bone, your body heals the wound by dividing and replicating the skin or bone cells to replace the parts of the skin or bone that were lost. We will look at an important Australian scientist who has done amazing work in this area a bit later.

Cell division is important for the:

- growth and development of organisms
- repair and replacement of damaged or dead cells
- reproduction of single-celled organisms.

There are two types of cell division:

- **Mitosis** produces identical cells.
- **Meiosis** produces different cells.

We will be focusing on mitosis in Year 8.

Activity 1.12.1

Imagine you get a small burn on your finger. Explain how your body uses cell division to heal your skin.

1.13 Extension: Genetic material and DNA

The nucleus of a eukaryotic cell contains the organism's genetic material. Genetic material contains information such as hair colour, eye colour and height. Your genetic material is what makes you, you.

The molecule that contains this information is DNA. Inside the nucleus, DNA is organised into **chromosomes**. Chromosomes are long, thread-like sections of DNA. Humans have 23 pairs of these in their cells. When cells replicate, it is important that the DNA is correctly copied and placed in the daughter cells. When DNA replication goes wrong, it can cause disorders that can lead to diseases or even death.

Variations in DNA replication can result in:

- cancer such as melanoma
- genetic conditions such as Down syndrome
- genetic diseases such as cystic fibrosis
- chromosome rearrangements, which means that pieces of chromosome are missing, duplicated or moved around.

The three main structures of a chromosome are the chromatid, telomere and centromere. These are labelled in Figure 1.13.

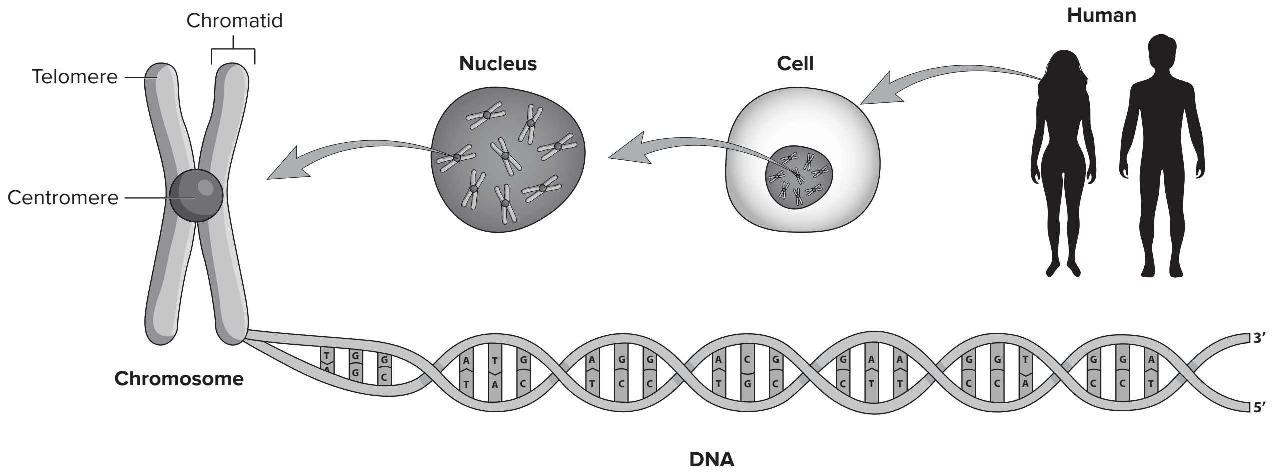


Figure 1.13: Chromosomes in the nucleus are made up of DNA

Activity 1.13.1

1. What could happen if DNA replication goes wrong?
2. Recreate Figure 1.13 to help you remember where DNA and genetic material are stored.

1.14 Extension: Disorders in cells or tissues

Disorders in cells and tissues occur when normal cellular functions are disrupted, leading to disease or damage in the body.

As we already know, cells are the building blocks of life Tissues are groups of cells working together. Damage or dysfunction in these can lead to organ failure and disease.

Types of disorders in cells and tissues

- **Cellular disorders** occur when cells fail to die when damaged, leading to abnormal growth. **Cancer** is a type of cellular disorder that occurs when cells divide uncontrollably to form tumours, which spread into surrounding tissues.
- **Degenerative disorders** occur when cells lose function over time, leading to diseases such as **arthritis**, which affects the tissues in the joints.
- **Infectious disorders** occur when cells and tissues are damaged by pathogens. **Malaria** is a disease that destroys red blood cells, and is spread by infected mosquitoes.

Activity 1.14.1

Explain what can happen when there are disorders in cells or tissues.

Science as a human endeavour: Adjuvant immunotherapy – cancer

Melanoma is a type of skin cancer that forms when abnormal cells in the skin grow out of control. Australia has the highest rate of melanoma in the world. Professor Georgina Long and Professor Richard Scolyer created a treatment that has saved thousands of people from succumbing to melanoma.

Less than a decade ago, advanced melanoma was fatal, but thanks to advances in immunotherapy (a type of treatment that uses a patient's own immune system), it has become a curable disease.

In 2009, the first human trials were conducted using immunotherapy drugs designed to stimulate the body's immune system to fight melanoma. The treatment worked, and the five-year survival rate jumped from 5 per cent to 50 per cent in patients with advanced melanoma.

Drug combinations are administered to prompt an immune response before surgery to remove the cancer. The cancer is then removed and more drugs are given to ensure the immune system is trained to continue to fight the cancer. This is called 'adjuvant immunotherapy'.

Both Georgina and Richard were named the 2024 Australians of the Year for their revolutionary and groundbreaking work in cancer research.

1.15 Tissues, organs and organ systems

Cells are the smallest functional unit of an organism and have a specific structure and function. Cells make up tissues, organs and organ systems.

Tissues

A **tissue** is a group of similar cells working together to perform a specific function. For example:

- **muscle** tissue contract to produce movement
- **nervous** tissue transmit signals for communication in the body
- **epithelial** tissue line the gastrointestinal tract and other hollow organs
- **connective** tissue support and bind other tissues.

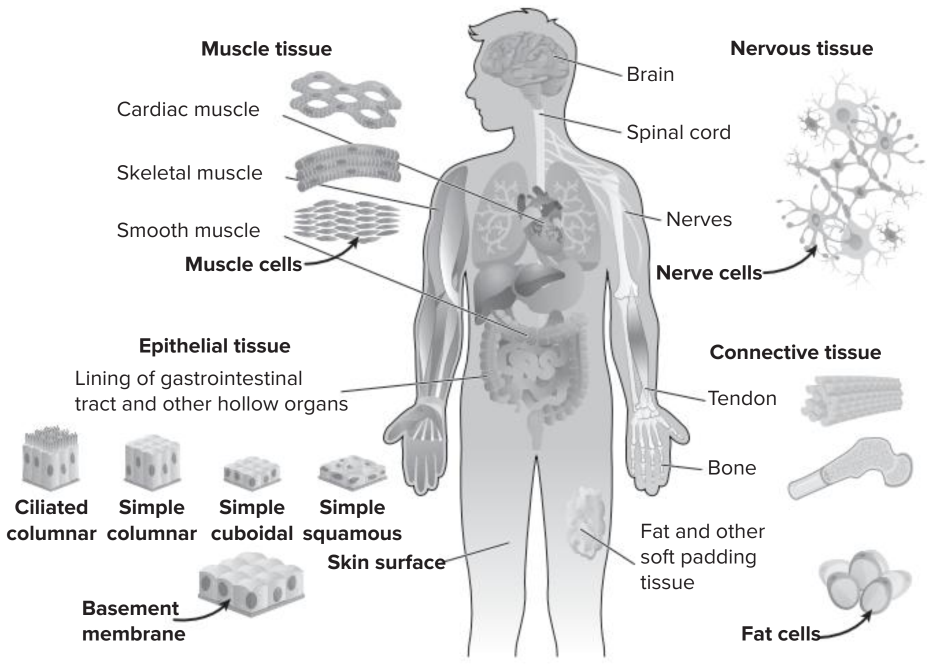


Figure 1.14 Types of tissues

Organs

An **organ** is a structure made up of two or more types of **tissue** that work together to perform a specific function. For example, the:

- **heart** is made of muscle tissue, connective tissue and nervous tissue. It pumps blood throughout the body
- **lungs** are made of a special sponge-like tissue that stretches easily to keep its shape without damage; it also has epithelial tissue to enable gas exchange
- **stomach** contains muscle tissue to churn food, epithelial tissue to secrete digestive enzymes, and nervous tissue to control its functions.

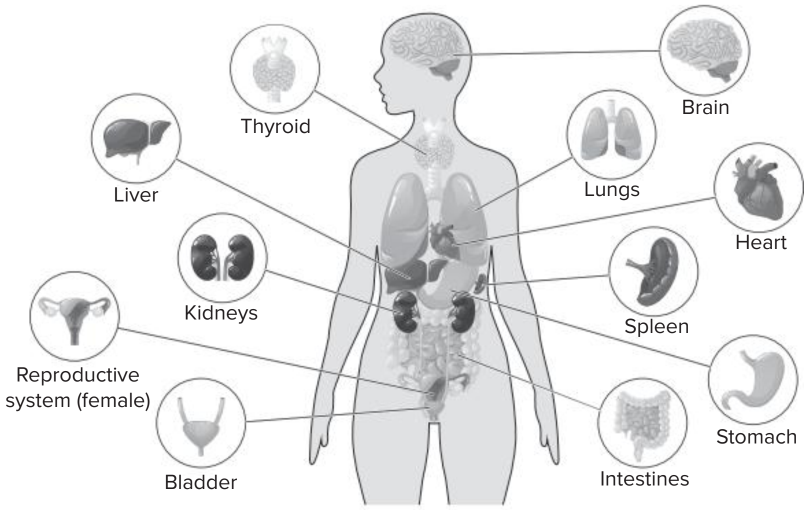


Figure 1.15 Human internal organs

Organ systems

An **organ system** is a group of organs working together to perform complex functions in the body.

Key organ systems include the:

- **digestive system**, which breaks down food to absorb nutrients.

  Key organs: mouth, oesophagus, stomach, intestines, liver, pancreas
- **circulatory system**, which transports oxygen, nutrients and waste products.

  Key organs: heart, blood vessels
- **respiratory system**, which facilitates breathing and gas exchange.

  Key organs: lungs, trachea, diaphragm
- **nervous system**, which sends signals and controls body functions.

  Key organs: brain, spinal cord, nerves

We will be examining each of these systems. It is important to note that these are not the only systems in the human body.

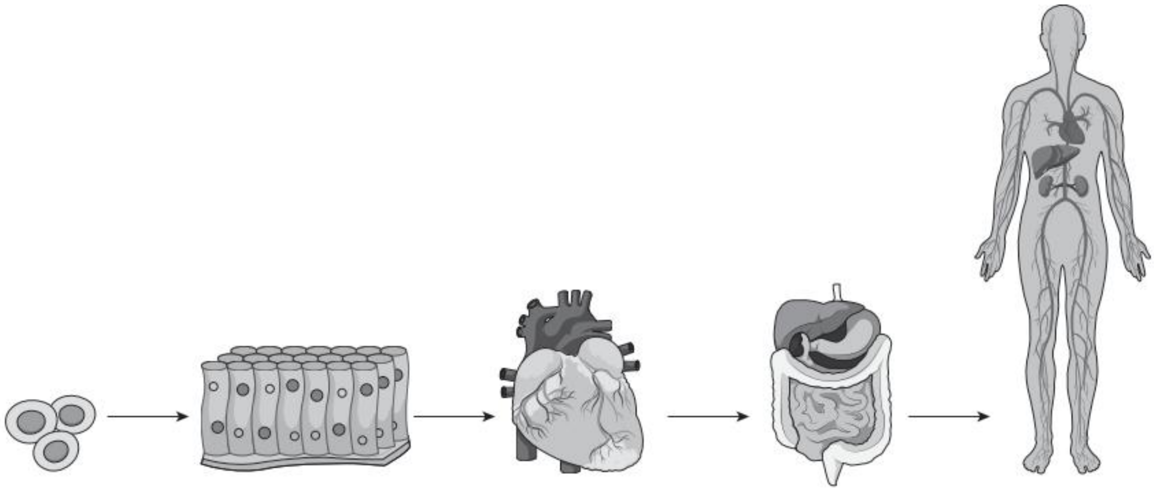


Figure 1.16 Levels of organisation

It is important to note that systems are **interdependent**. This means that they need each other to function properly. For example, the respiratory system and circulatory systems work together to deliver oxygen to cells.

Activity 1.15.1

Define the terms ‘tissue’, ‘organ’ and ‘organ system’.

Science as a human endeavour: Dr Fiona Wood – spray-on skin

Have you ever scalded your hand with boiling water, got sunburned or accidentally burnt your hand putting wood on a fire?

A burn is damage to the skin and underlying tissues. Burns can be on the outer layer of the skin, but severe burns can go down to the muscle and bone. Severe burns are called third- and fourth-degree burns; the skin may not be able to heal, and new skin must be applied to the burn area. This procedure is called a skin graft and involves surgically removing a layer of skin from elsewhere on the body and applying it to the burn site.

Enter Dr Fiona Wood, 2005 Australian of the Year. Fiona developed a spray-on skin in 1993. Skin cells are taken from the person, grown (cultured) in a laboratory and then sprayed onto the site of the burn. The new skin cells grow to replace the damaged skin cells.

There are many benefits to spray-on skin. Compared to ordinary skin grafts, spray-on skin:

- heals faster
- heals smoother and flatter
- has a more even colour.

1.16 The digestive system

The digestive system is a group of organs that work together to break down food into nutrients the body can use for energy, growth and repair.

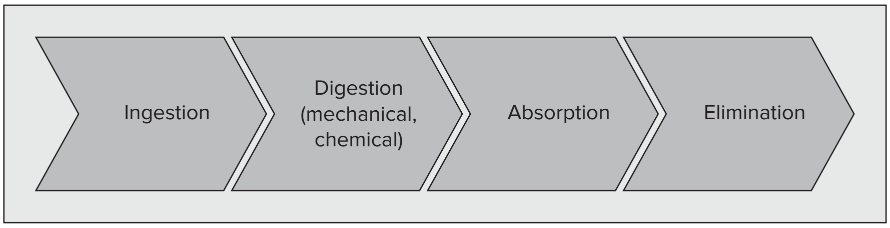
Humans and other animals are heterotrophs (consumers). We obtain food by consuming other organisms such as plants, animals and fungi. The food we consume is not directly usable by the body. It needs to be converted into a usable form by the process of digestion.

Key functions of the digestive system

- **Ingestion:** food is taken in via the mouth.
- **Digestion:** food is broken down into smaller, absorbable molecules. Digestion can occur through mechanical or chemical processes.

  Mechanical digestion: food is broken down physically by chewing in the mouth and churning in the stomach. This increases the surface area of food, which helps its chemical breakdown.

  Chemical digestion: food is broken down by **enzymes** and stomach acids. This occurs in the mouth, stomach and small intestine.
- **Absorption:** nutrients are absorbed into the bloodstream to be taken to cells.
- **Elimination:** undigested waste is removed through the rectum and anus.



Key term

enzyme	a protein that speeds up chemical reactions in living things

Main organs of the digestive system

1. **Mouth** – food enters the body here. Mechanical digestion occurs with the teeth chewing the food. Chemical digestion occurs when food mixes with saliva, which contains a special enzyme. This enzyme is called amylase and begins the process of breaking down carbohydrates.
2. **Oesophagus** – a muscular tube that transports food from the mouth to the stomach by **peristalsis**, which involves wave-like muscle contractions that push the food downwards.
3. **Stomach** – stores and breaks down food by using enzymes and stomach acid. In the stomach, proteins in the food begin to break down. Food is also physically broken down by strong muscle contractions in the stomach. Depending on the food, it will stay in the stomach for four to six hours before moving to the small intestine.
4. **Small intestine** – the main site of nutrient absorption. Enzymes from the pancreas continue digestion. The small intestine is lined with **villi** and **microvilli**, which increase the surface area of the small intestine, which helps it to absorb nutrients into the bloodstream. The small intestine can be up to 7 metres long and 2 cm in diameter.

5. **Large intestine (colon)** – absorbs water and minerals, and forms and stores faeces. Bacteria in the large intestine help break down any remaining food and produce vitamins such as vitamin K. The large intestine is about 1.5 metres long and 8 cm in diameter.
6. **Rectum and anus** – store and expel waste materials (faeces) from the body.

Other organs that are not part of the digestive pathway also help with digestion:

- Liver – cleans the blood, helps digest food by producing bile and stores energy.
- Gallbladder – releases bile into the small intestine to help break down fats.
- Pancreas – releases many enzymes that further break down fats, DNA and proteins.
- Saliva glands – release enzymes to break down starch.

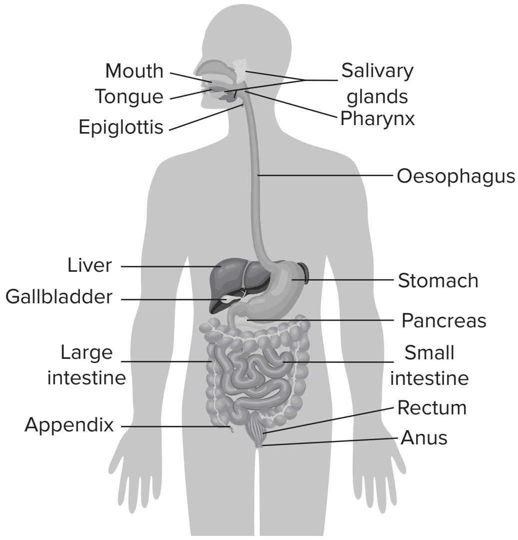


Figure 1.17 The human digestive system

Key terms

villi	tiny finger-like projections made of cells that line the small intestine to increase the surface area, which helps to maximise the absorption of nutrients (pronounced: VI-lee)
microvilli	extensions of villi, which help to maximise the absorption of nutrients

The digestive pathway

Mouth → oesophagus → stomach → small intestine → large intestine → rectum → anus

Why is the digestive system important?

The digestive system is important because it:

- enables the body to absorb nutrients such as carbohydrates, proteins, fats, vitamins and minerals needed for energy, cell repair and growth
- removes waste from the body
- works with other systems such as the circulatory system to distribute nutrients.

Activity 1.16.1

1. List the four key functions of the digestive system and explain why the digestive system is important.
2. Draw the digestive pathway, explaining the function of each of the organs.

1.17 Digestion in other animals

Animals need to be able to obtain nutrients from the environment and use them to create energy. Humans are omnivores, which means we can eat plants and animals. Other omnivores include pigs, black bears and seagulls, among many others. Some animals eat only plants (herbivores) or only animals (carnivores). In this section, we'll take a look at the digestive systems of these kinds of animals.

Digestive systems of herbivores

Herbivores only eat plants. Plants have a large amount of cellulose – the material that makes up their cell walls. Cellulose is hard to break down, but some herbivores can digest this material and have special enzymes to get the energy from the plants.

Herbivores must eat a large quantity of food and eat often to obtain the nutrients they require.

Fun fact

Since plant materials are more difficult to digest, herbivores often graze and chew food for many hours a day. Pandas, cows and koalas are all known for eating all day long.

Table 1.4: Features of herbivore digestive systems

Feature	Purpose
Teeth	Adapted for grinding and pulverising plant material (mechanical digestion). Teeth are large and flat to break down plant material between them. Jaws can move from side to side (think of a cow chewing grass).
Length	Generally, it is longer and more complex than the carnivore digestive system.
Enzymes	Special enzymes break down cellulose into smaller molecules such as glucose.

There are two major types of herbivore digestive systems: hindgut and foregut fermenters.

Hindgut fermenters (non-ruminants)

- Plant material moves from the mouth, down the oesophagus and into the stomach. The stomach does not do much digestion and is more of a storage area for the food.
- Food moves to the small intestine. This is where most of the chemicals and enzymes break down the food and nutrients are absorbed into the bloodstream.
- The main digestion of cellulose occurs in the **caecum**. This is a pouch-like extension of the large intestine, located where the small and large intestines join. Cellulose-digesting enzymes and bacteria live here.

- Any digested cellulose is then absorbed in the large intestine, which also absorbs water and forms faeces to be eliminated by the rectum.
- Examples are horses, koalas, mice and rabbits.

Foregut fermenters (ruminants)

- Food is chewed and then swallowed into the four-chambered stomach. The first chamber is called the **rumen**. The food sits here and is digested both mechanically by churning, and chemically by enzymes from bacteria. The animal will sometimes regurgitate chunks of food from the rumen as **cud**, which requires further chewing before being swallowed again for further digestion.
- Food moves to the second chamber in the stomach called the **reticulum** and the same process occurs.
- The food then moves to the **omasum**, the stomach's third chamber. The main purpose of the omasum is to remove water from the digested material.
- The final part of the stomach is the **abomasum**, which behaves like our stomachs. Additional enzymes here break down food further.
- Food moves into the small intestine and nutrients are absorbed. The food then moves into the caecum (less important than in non-ruminants) and some fibre is digested here.
- Food moves to the large intestine where more water is removed, and waste is ready to be eliminated from the rectum.
- Examples are cattle, deer and sheep.

Fun fact

'Hind' means 'behind or 'after' – digestion occurs after the stomach.

'Fore' means 'before' or 'in front of' – digestion occurs before the stomach.

Digestive systems of carnivores

Carnivores mostly eat meat. Meat is easier to digest than plants because there is no tough cell wall to break down.

Table 1.5: Features of carnivore digestive systems

Feature	Description
Teeth	Sharp canines and incisors to rip meat into small chunks. These chunks are then swallowed whole. Canine jaws can only move up and down.
Mouth	No enzymes in the mouth for breaking up food. Most digestive enzymes are in the stomach.
Stomach	Larger than herbivore stomachs. Most digestion occurs here. More acidic than human or herbivore stomachs.
Small intestine	Shorter than a herbivore's small intestine. Most absorption of nutrients takes place here.
Large intestine and rectum	Water is absorbed and faecal matter is eliminated.

Activity 1.17.1

1. Explain the main differences between the digestive system of a herbivore and a carnivore. Describe why they are different.
2. Discuss the main differences between a hindgut fermenter and a foregut fermenter.
3. Explain why some herbivores have large flat teeth and jaws that can move from side to side.

1.18 The respiratory system

The respiratory system is a group of organs that work together to take oxygen into the body and remove carbon dioxide from the body. This is essential for energy production in cells.

Key functions of the respiratory system

- **Gas exchange** – oxygen from inhaled air diffuses from **alveoli** into the blood and binds to red blood cells. Carbon dioxide is expelled from the blood into alveoli to be exhaled. This is done by the **physical** process of breathing and occurs between the alveoli and surrounding capillaries (microscopic blood vessels).
- **Energy production** – cells use glucose and oxygen to produce energy. This is called **cellular respiration** and is a **chemical** process.

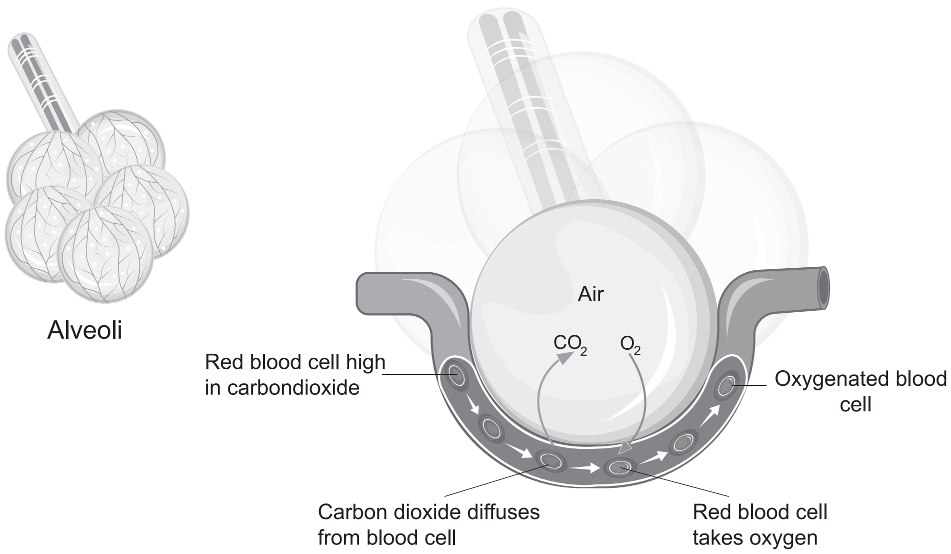


Figure 1.18: The process of gas exchange in the alveoli

Key terms

alveoli	tiny air sacs in the lungs (pronounced: al-vee-ow-lai)
diffusion	movement of molecules from an area of high concentration to one of low concentration

Cellular respiration

All cells need energy to perform the functions that keep us alive. Cellular respiration takes place in every cell, specifically, in the **mitochondria** where glucose and oxygen are turned into usable energy. Carbon dioxide is also produced, which we breath out as a waste product.

Cellular respiration can be represented by the following word equation:

Glucose + oxygen → carbon dioxide + water + energy

Main organs of the respiratory system

- **Mouth and nose** – air enters the body through the nose or mouth. The nasal cavity is warm and moist and filters air with tiny hairs called cilia, and mucus, which traps dust and **pathogens** (organisms that can cause diseases).
- **Pharynx** – the throat, which directs air from the nasal cavity to the larynx. The larynx is the voice box; it contains the vocal cords and protects the trachea. A small flap called the epiglottis closes off the larynx during swallowing to prevent food entering the respiratory pathway.
- **Trachea (windpipe)** – a tube that carries air from the throat to the lungs. It is made from C-shaped cartilage to keep it open, even when the neck is bent or turned.
- **Bronchi (singular: bronchus) and bronchioles** – the bronchi are two tubes (left and right) that each branch off the trachea and lead to a lung. The bronchioles are smaller airways that branch from the bronchi into the lungs.
- **Lungs** – the main organs (left and right) where gas exchange occurs. They contain millions of tiny air sacs called alveoli.
- **Alveoli (singular: alveolus)** – microscopic, sac-like structures that are one cell thick and the site of gas exchange. They give lungs their spongy texture.
- **Diaphragm** – a dome-shaped muscle beneath the lungs that contracts to inflate the lungs and relaxes to deflate the lungs.

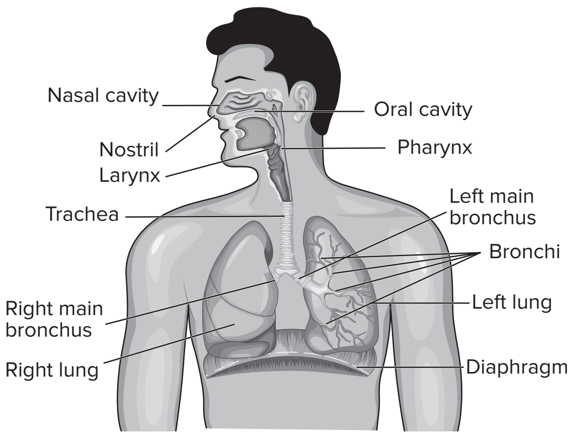


Figure 1.19: The respiratory pathway

The respiratory pathway

Mouth and nose → pharynx → larynx → trachea → bronchi → bronchioles → alveoli

Why is the respiratory system important?

The respiratory system provides oxygen for cellular respiration, which produces energy for the body.

It also removes carbon dioxide, which is a waste product, to prevent it from building up in the body.

The respiratory system works closely with the circulatory system to deliver oxygen to and remove carbon dioxide from the body.

Activity 1.18.1

1. Write the word equation to explain cellular respiration.
2. List the two key functions of the respiratory system and explain why it is important.
3. Draw the respiratory pathway and explain the function of each of the organs.

1.19 The circulatory system

Animals, including humans, require a system to move substances around the body. The circulatory system is a network of organs and blood vessels that transports oxygen, nutrients, hormones and waste products throughout the body.

Key functions of the circulatory system

- **Transportation** – delivers oxygen and nutrients to cells and removes waste products such as carbon dioxide.
- **Regulation** – helps to regulate body temperature and maintain **homeostasis**.
- **Protection** – circulates white blood cells and antibodies to fight infections.

Key term

homeostasis	the process through which a living thing maintains a stable internal environment, even when external conditions change (pronounced: ho-me-oh-STAY-sus)

Main components of the circulatory system

The circulatory system consists of the heart, blood vessels and blood.

Heart

The heart is a muscular organ that pumps blood to the lungs and then throughout the body. It is divided into four chambers. The **atria (singular: atrium)** are the **upper chambers** of the heart, and the **ventricles** are the **lower chambers** of the heart.

- The right atrium receives **deoxygenated** blood from the body.
- The right ventricle pumps **deoxygenated** blood to the lungs.
- The left atrium receives **oxygenated blood** from the lungs.
- The left ventricle pumps **oxygenated blood** to the rest of the body.

Oxygenated and deoxygenated blood do not mix. In a resting adult, the heart typically beats 70–100 times per minute to pump blood.

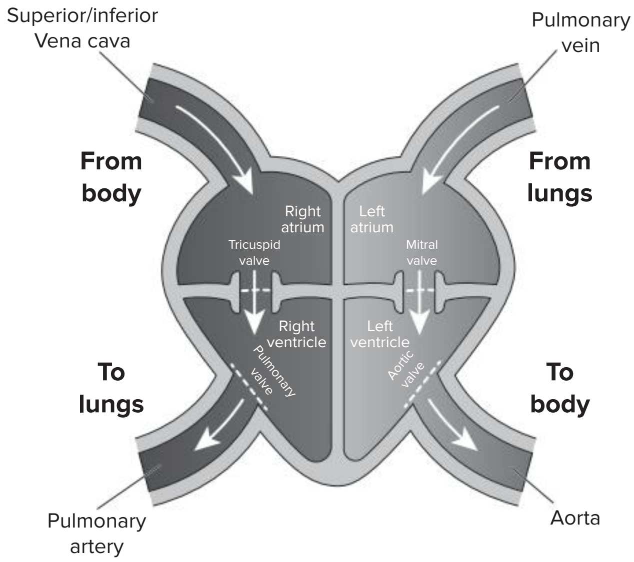


Figure 1.20: The heart

Blood vessels

Blood vessels are the arteries, veins and capillaries in the body.

- **Arteries** are made of thick muscle with elastic walls to handle high pressures. They carry oxygenated blood away from the heart (except for the pulmonary artery, which carries deoxygenated blood from the right side of the heart to the lungs).
- **Veins** have valves to prevent backflow. They carry deoxygenated blood back to the heart (except for the pulmonary vein, which carries oxygen-rich blood from the lungs to the heart).
- **Capillaries** are microscopic vessels where nutrients, oxygen and waste exchange occur between blood and tissues.

Blood

Blood contains red blood cells, white blood cells, platelets and plasma.

- **Red blood cells** make up about 99 per cent of the blood cells in our body. They contain haemoglobin, a protein that carries oxygen. Red blood cells transport oxygen from the lungs throughout the body. They are disc shaped for easier movement through narrow blood vessels and to maximise surface area for gas exchange.
- **White blood cells** form part of the body's immune system. They help to fight infections and protect the body.
- **Platelets** help the blood to clot to stop bleeding when the body is cut or injured.
- **Plasma** is the liquid part of blood and is mostly water. Plasma transports nutrients, hormones and waste products.

How does the circulatory system work?

Humans have a double circulatory system. This means that the blood flows through the heart twice in one cycle.

- **Pulmonary circulation** is a short loop from the heart to the lungs and back again. It carries deoxygenated blood from the heart to the lungs for oxygenation and back to the heart.

- **Systemic circulation** carries blood from the heart to all the other parts of the body and back again. It carries oxygenated blood from the heart to the rest of the body and returns deoxygenated blood to the heart.

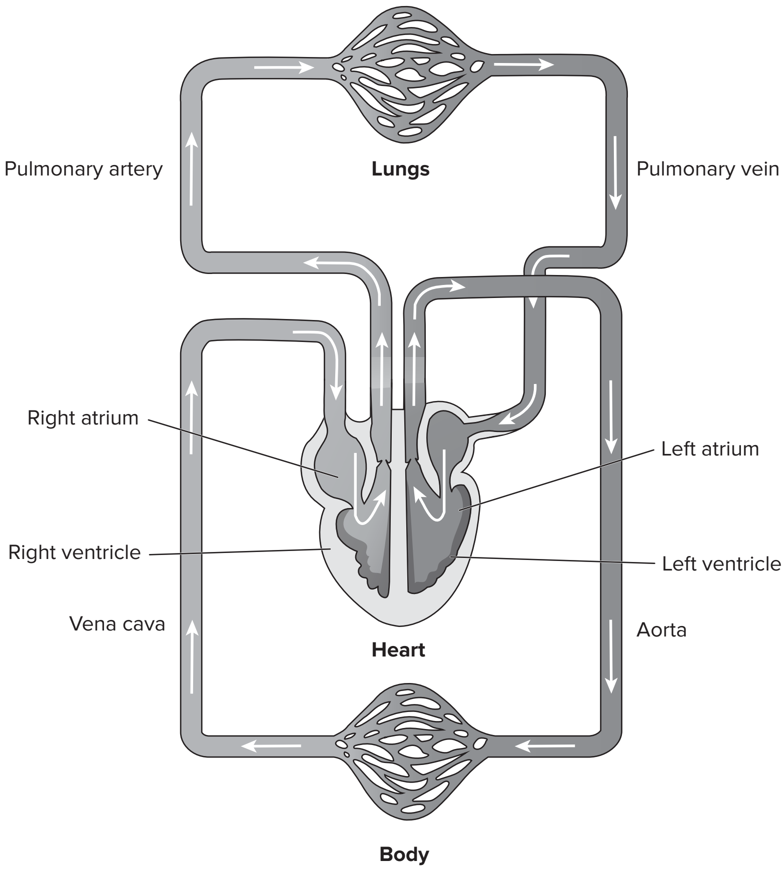


Figure 1.21: Blood circulation

Pathway of blood flow

- **Deoxygenated blood:**

  Body → veins → right atrium → right ventricle → lungs (to pick up oxygen)

- **Oxygenated blood:**

  Lungs → left atrium → left ventricle → arteries → body

Why is the circulatory system important?

The circulatory system ensures that all cells in the body receive the oxygen and nutrients they need to survive, while removing waste products such as carbon dioxide. The circulatory system works closely with the respiratory and digestive systems, and:

- fights disease – white blood cells and antibodies combat infections and pathogens
- regulates temperature by adjusting blood flow to maintain a stable body temperature

Activity 1.19.1

1. Draw a diagram of the heart, showing the four chambers, and the direction of blood flow.
2. Describe the differences between arteries and veins.

3. Describe the differences between red blood cells and white blood cells.
4. Draw a diagram to show pulmonary and systemic circulation.
5. Write the word equations to explain the pathways of blood flow.
6. List the three key functions of the circulatory system and explain why it is important.

Science as a human endeavour: Dr Daniel Timms

Australian scientists are developing an artificial heart. They hope that their invention is going to be an alternative to organ donation. Currently, the supply of donor organs does not meet the demand – there are not enough hearts being donated to supply the number of people who require a heart.

People need heart transplants for many reasons, including heart disease, heart failure and heart defects. Unfortunately, many people die while waiting for a heart transplant.

Bioscientist Dr Daniel Timms says his BiVACOR Total Artificial Heart, an artificial heart made of titanium, will be a durable long-term alternative to heart transplants. His invention began as a PhD project at the Queensland University of Technology more than 20 years ago. A handful of patients have had the titanium hearts implanted, with an Australian man the first to be able to go home from hospital. He had the heart in place for 100 days, which gave him enough time to finally receive a heart transplant. However, researchers hope this invention will provide an alternative to heart transplants and one day replace the need for donor hearts altogether.

1.20 The nervous system

The nervous system is a complex network of neurons that transmits signals between different parts of the body and the brain. It controls and coordinates all body activities, including voluntary (e.g. solving math puzzles) and involuntary (e.g. breathing) actions. Think of it as the control centre of your body!

Key functions of the nervous system

- **Sensation** – detects changes in the environment such as sound, light, heat and smell.
- **Integration** – processes and interprets sensory information.
- **Response** – triggers actions, such as muscle movement.

Main components of the nervous system

The nervous system is made up of two main parts: the central nervous system and the peripheral nervous system. Each of these parts contain special cells known as neurons.

Central nervous system (CNS)

The **central nervous system** is the control centre of the body. It consists of the brain and the spinal cord.

- The **brain** is an extremely complex organ that controls memory, emotions, motor skills, senses, speech, breathing, sleep, hunger and basically every single process that regulates the body!

  The brain receives information messages from the body, processes them and redirects them back out to the body.
- The **spinal cord** is a long, tube-like bundle of nerves that runs from the brain down the back, connecting the brain to the rest of the body, and transmitting signals to and from the brain.

Peripheral nervous system (PNS)

The **peripheral nervous system** is a long network of nerves that connects the central nervous system to the rest of the body. Messages are passed through the body to get a response or action from the central nervous system.

The peripheral nervous system is made up of two parts:

- The **somatic nervous system** controls voluntary actions or actions that you have control over (e.g. deciding to move) as well as the sensory signals you get from touching objects (e.g. feeling heat when touching a hot saucepan).
- The **autonomic nervous system** controls everything in your body that is automatic such as breathing, your heartbeat, digestion and blinking.

The autonomic nervous system has two more parts:

- The **sympathetic nervous system** prepares your body for 'fight or flight' when you encounter a stressful or scary situation. Fight or flight responses make you jump into action or run and hide.
- The **parasympathetic nervous system** promotes 'rest and digest' activities. This system helps us to return to a calm and relaxed state by reducing the heart rate and stimulating digestion so the body gets back to normal after experiencing stress.

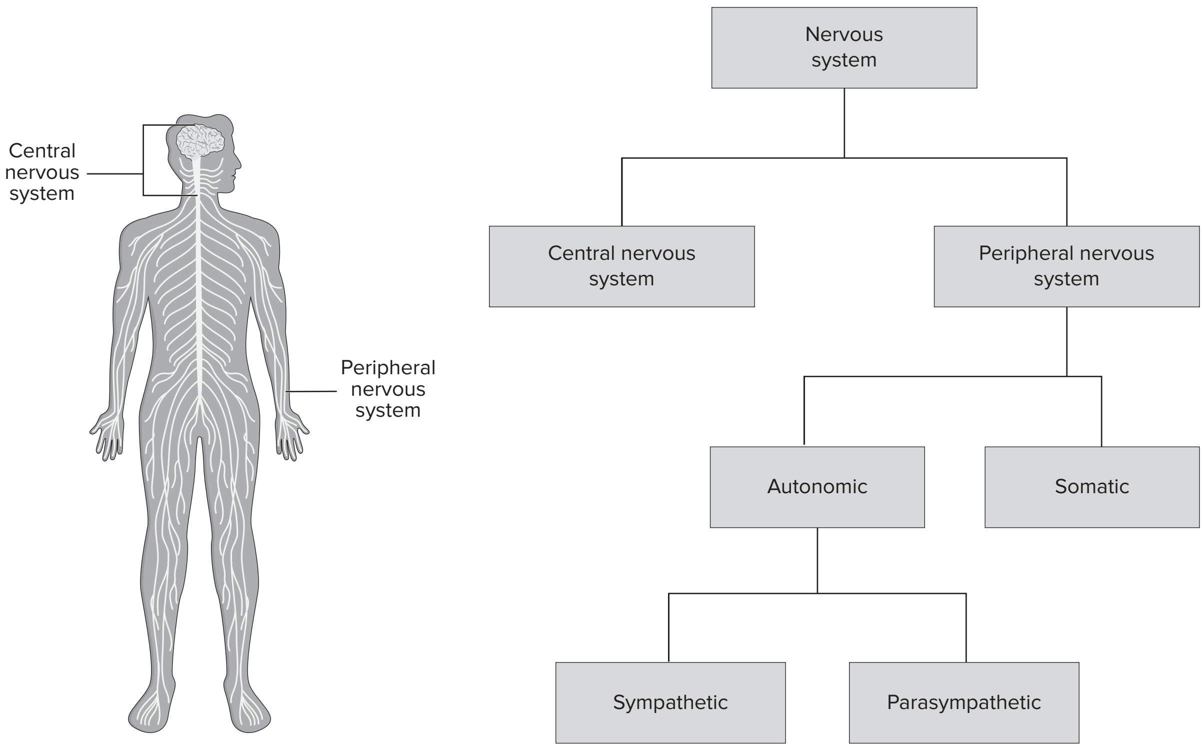


Figure 1.22: The parts of the nervous system

Neurons

The special cells that make up the nerves and brain tissue in the nervous system are called **neurons**. Neurons pass or transmit electrical signals to the neurons next to them until the signal reaches the target neuron.

Electrical signals travel rapidly, which means we can have very quick reactions. For example, when we touch something hot with our hand, we move our hand away quickly. For this, we can thank the sensory neurons in our skin!

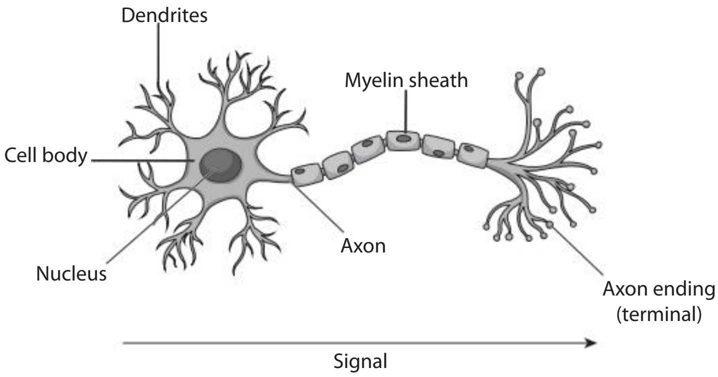


Figure 1.23: A neuron (nerve cell)

Parts of the neuron

- Dendrites: receives messages from neuron
- Cell body: holds nucleus
- Nucleus: controls and processes information
- Axon: carries impulse
- Axon ending (terminal): passes message to next neuron
- Myelin sheath: insulates axon and protects impulse

The three types of neuron

1. The sensory neuron transmits messages from sensory organs in the peripheral nervous system to the central nervous system; for example, taste or touch messages.
2. The interneuron transmits messages within the spinal cord and the brain.
3. The motor neuron transmits messages from the central nervous system to effectors in the peripheral nervous system to initiate a response; for example sending messages to a muscle to contract.

Receptors

Receptors are specialised cells that can convert phyiscal stimuli into electrical signals that the nervous system can interpret. When you smell the scent of a rose or bump your head on a shelf, your sensory receptors help your brain perceive what is happening to you.

Some receptors include:

- chemoreceptors – these are sensitive to chemicals, for example, the receptors in your nose that can detect the smell of sulfur
- mechanoreceptors – located in skin, muscles and the inner ear, these are sensitive to touch, pressure, sound and motion
- pain receptors – these are sensitive to chemical changes in damaged cells, mostly located in the skin
- thermoreceptors – these are sensitive to temperature changes and are mostly located in the skin
- photoreceptors – located in the eyes, these receptors are sensitive to light.

Figure 1.24 shows the stimulus–response model, a summary of how the body reacts to something.

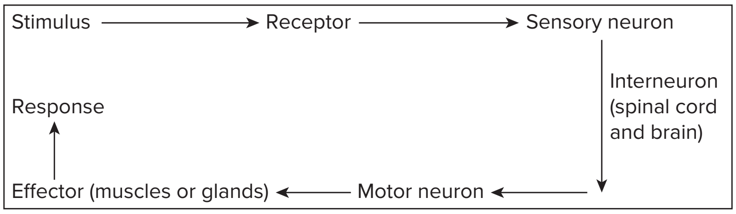


Figure 1.24: The stimulus–response model

There is another response model – the reflex arc. When you need to react quickly, this response skips the brain. For example, when you pick up something very hot, you will drop it immediately without even thinking.

Parts of the brain

As already discussed, the brain is an extremely complex part of the nervous system, and is the command centre for many different functions in the body.

The brain has four rounded parts, called lobes, that control different functions and actions (although some functions overlap). These are the frontal lobe, the parietal lobe, the occipital lobe and the temporal lobe. Their general functions are shown in Figure 1.25.

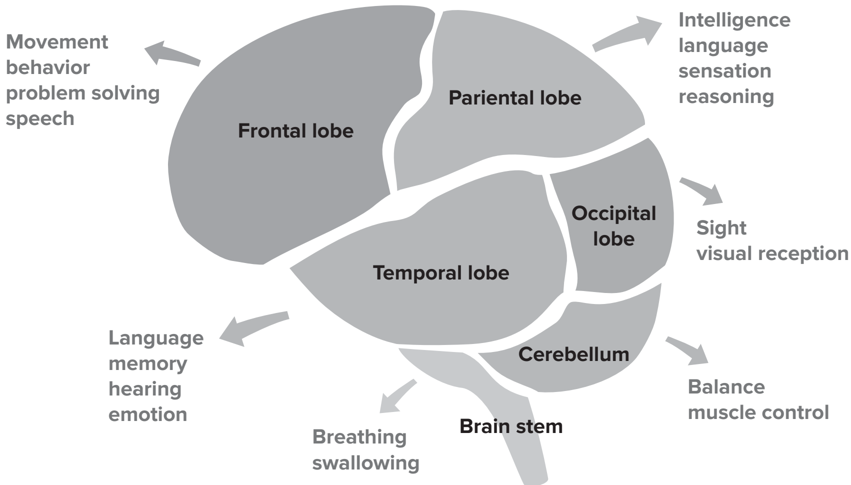


Figure 1.25: The four lobes of the brain, the brain stem and the cerebellum.

Other parts of the brain include:

- the brain stem, which controls basic life functions and reflexes
- the cerebellum, which controls movement, balance and posture
- the corpus callosum, which helps connect the left and right hemispheres of the brain
- the cerebrum, which is the area of higher-order functions such as thinking.

Activity 1.20.1

1. What are the two main parts of the nervous system?
2. What are the main components of the central nervous system?
3. Explain what the peripheral nervous system is.
4. Describe the differences between the autonomic nervous system and somatic nervous system.
5. The autonomic nervous system is made up of two parts. State what they are and describe their functions.
6. List the three key functions of the nervous system and explain why it is important.

Chapter 2 – Earth and space

2.1 What is Earth and space science?

Earth and space science is a branch of science that studies Earth's systems – such as geology, the weather and the oceans – as well as the universe beyond, including planets, stars and galaxies.

Studying Earth and space science is crucial for understanding and protecting our planet, preparing for natural disasters, managing resources and exploring the universe. It equips us to tackle global challenges and inspires us to learn more about Earth and beyond. In this chapter, we will learn about the rocks and layers that make up Earth, and about the processes that formed the continents as we know them today.

2.2 Rocks

Rocks aren't just lumps that look good in your garden or that you skim across the water. Rocks can tell us about the past in the form of fossils, and coal, a type of rock, provides us with a common source of electricity.

Rocks are solid masses made up of one or more **minerals** or mineral-like substances. They form Earth's crust and can vary in composition, texture and colour depending on how they are formed.

Properties of minerals

Minerals are a natural substance usually found as crystal within rocks. A common mineral you might have seen is the white mineral known as quartz.

The properties of minerals include:

- colour – different minerals are different colours but, on its own, this is not enough to identify a particular mineral as impurities can affect colour. For example, rose quartz is pink because of trace amounts of titanium, iron or mangnese in its crystal structure.
- hardness – we measure hardness on the Mohs scale. This scale tests the hardness of minerals based on their ability to scratch softer materials (Table 2.1).
- lustre – lustre means the way light interacts with the surface of a mineral; for example, shiny, dull, pearly, metallic or glossy.
- streak – this is the coloured trail of powder left behind after a scrape; for example, chalk leaves a clear white streak when you scrape it
- cleavage – this is how a mineral breaks along a plane of weakness.

Table 2.1: The Mohs hardness scale

Mineral	Hardness
Talc – easy to scratch with a fingernail	1
Gypsum	2
Calcite	3
Fluorite	4
Apatite	5
Orthoclase	6
Quartz	7
Topaz	8
Corundum	9
Diamond – can cut glass and other rock	10

Activity 2.2.1

Explain how rocks are significant in our lives.

2.3 Layers of Earth

Earth is not just one solid rock; it is made up of four main layers that all have different properties, forms and purposes. The four main layers are the crust, the mantle, the outer core and the inner core.

Crust

- It is the outermost layer of Earth and the thinnest. Think of it like the crust on a loaf of bread.
- It is made of rock, including underneath continents and ocean floors.
- The crust is thinner underneath oceans and thicker underneath continents. It is usually between 35 and 80 km thick but can be as thin as 5 km under the ocean.

Mantle

- It lies beneath the crust and is much thicker, about 2900 km thick. It is the thickest layer.
- It is made of superheated and softened rocks called semimolten rock. This creates **convection currents** (circular movements of liquid or air caused by differences in temperature). Hot melted rock comes up to the surface and then cools slightly before falling back towards the centre of Earth. This carries the crust on it like a boat being carried along the surface of water (see Figure 2.16 on page 56).

Outer core

- The outer core is a liquid layer of molten nickel and iron that mixes rapidly in convection currents. This is what creates Earth's magnetic field.
- It is extremely hot and very dense.

Inner core

- The inner core is solid. This is because it is being squeezed and placed under immense pressure by the rest of the planet and the atmosphere around it.

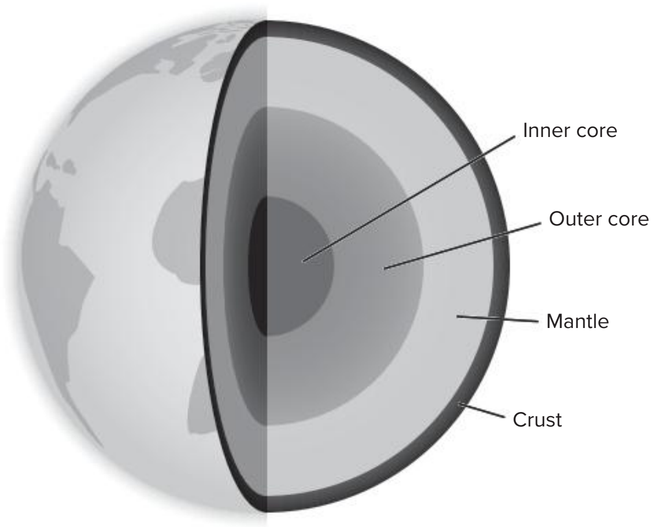


Figure 2.1: Earth's layers

Activity 2.3.1

On a piece of paper, draw and label the layers of Earth. Be careful to accurately show the varying thicknesses of the different layers. Describe some key facts about each of the layers.

2.4 Types of rocks

There are three main classifications of rock:

- sedimentary
- igneous
- metamorphic.

Their classifications depend on the processes used in making them.

Sedimentary rocks

Sedimentary rocks make up a large part of Earth's crust. They generally form close to Earth's surface. They act like a giant history book of our planet! These rocks are formed in layers with the oldest layers at the bottom and the youngest at the top. By studying these layers, geologists can learn about Earth's past climate, geography and life forms. Fossils, which are the preserved remains of ancient plants and animals, are mostly found in sedimentary rocks.

Sedimentary rocks can be categorised into two types depending on how they were formed: physical and chemical.

Physical

- These types of sedimentary rocks are formed over millions of years when **sediments** (e.g. rock pieces, sand, mineral grains, shell fragments) are compacted and cemented together. Essentially, they are rocks formed from other rocks.
- They can be shaped by weathering where they break down through contact with water, atmospheric gases, sunlight and biological organisms. This happens in place, with little or no movement. Or they can be broken down via the process of **erosion**, which involves pieces of the rock being transported by water, ice, snow, wind, waves and gravity.
- During erosion, the broken-down rock travels (**transportation**) away from the source and collect elsewhere (**deposition**). The broken-down rock collects over time in this location and the sediments on the bottom are compacted by the force of the weight on top of it. This begins to form layers of **compacted** rock matter.
- Pressure from the top layers compacts the lower layers and forces water out of the lower layers.
- **Cementation** occurs where minerals harden in the pores of the rock and 'glues' the rock together to form a solid.

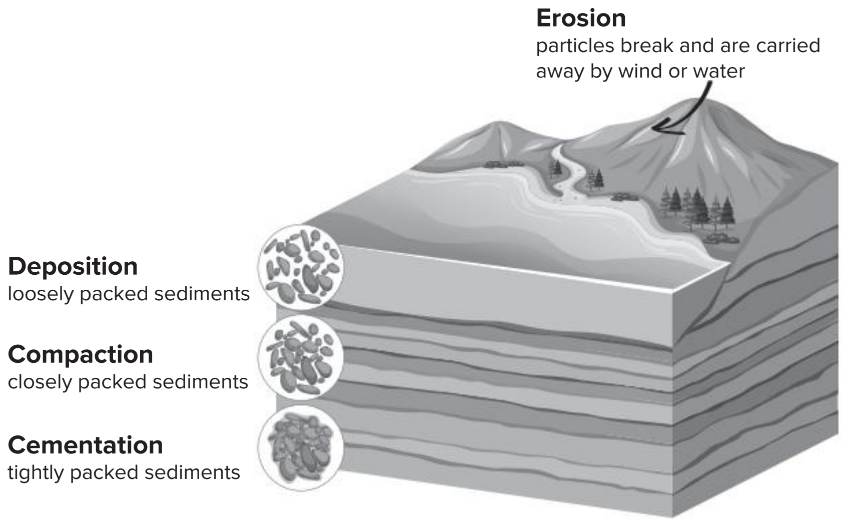


Figure 2.2: Formation of sedimentary rocks

Key term

erosion	the process of larger rocks breaking into smaller pieces and being carried away

Chemical

- In this process, chemical weathering dissolves the less stable minerals in rocks. These minerals end up as a solution (water + mineral) and the water evaporates into the atmosphere by the Sun's heat.
- The minerals that are left behind crystallise.
- Rock salt, also called halite, is an example, where the salty water evaporates, leaving behind concentrated salt rock crystals.

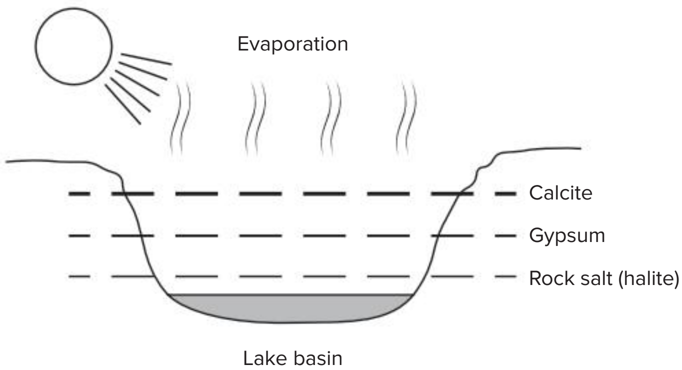


Figure 2.3: Rock salt is formed when salty water evaporates.

Examples of sedimentary rocks

Sedimentary rocks can be formed from inorganic or organic materials.

- Inorganic materials are not living, such as minerals and other rocks.
- Organic materials are formed from previously living organisms such as plants and animals. For example, coal is a sedimentary rock formed from the remains of plants that were buried and compressed over millions of years (Figure 2.4).

Table 2.2: Some sedimentary rocks, how they form, and their characteristics and uses

Example	How it forms	Characteristics	Uses
Sandstone (physical)	Forms from compacted and cemented sand particles, typically in riverbeds, deserts and beaches	Gritty texture, usually tan, brown, red or yellow, with visible sand grains	In gardens as landscaping; can be made into sturdy, heavy and durable outdoor furniture
Chalk (physical)	Forms from the calcium carbonate remains of microscopic marine organisms	Soft, powdery texture, can be scratched easily, white to light grey	For writing and drawing on blackboards; sometimes used in agriculture to adjust the acidity of the soil
Rock salt (chemical)	Forms from the evaporation of salt-rich water in shallow seas or salt lakes, leaving halite crystals	**Crystalline** texture, translucent to opaque, usually colourless, white, or shades of pink, grey or orange	In cooking; to melt ice on roads
Coal (physical)	Forms from compressed plant material in swampy environments over millions of years	Shiny or dull appearance, lightweight, often brittle, black or dark brown	Burnt in coal-fired power stations to create steam, which then spins a turbine to generate electricity

Key term

crystalline	having the characteristics or structure of crystals

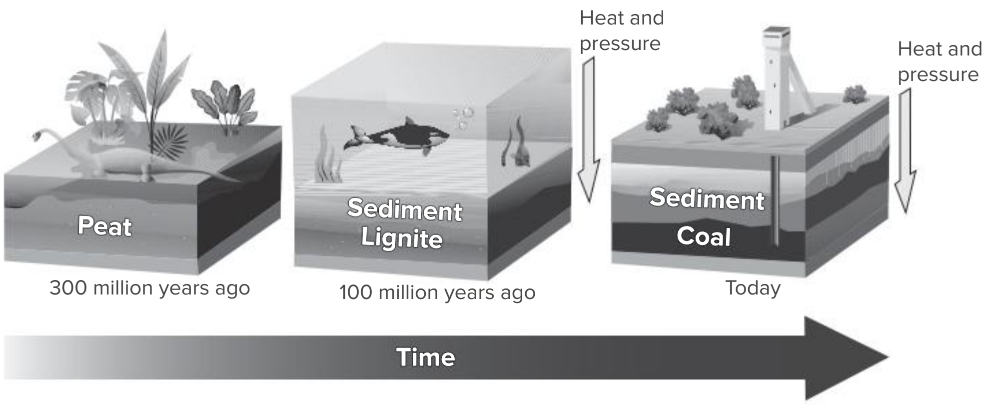


Figure 2.4: Coal formation – peat (partially decayed organic matter) is compressed under heat and pressure and becomes a type of coal called lignite. After further heat and pressure, it turns into different types of coal

Activity 2.4.1

1. Draw and label the process of the formation of physical sedimentary rocks. Write dot points to explain the process.
2. Write key words to describe the appearance of sedimentary rocks.

3. Describe the difference between organic and inorganic materials.
4. Name an example of an organic sedimentary rock and an inorganic sedimentary rock.
5. Name two examples of sedimentary rocks that are physically formed and one example of a sedimentary rock that is chemically formed.
6. Write some dot points explaining how we use sedimentary rocks in our daily life.

Science as a human endeavour: Coal

Coal is a controversial topic, mainly because when it is burnt, it produces carbon dioxide – a greenhouse gas.

Coal is the remains of plant material that has been covered in sediments and subjected to heat and pressure over millions of years.

Humans mine the coal and burn it to create steam to turn the turbines in power stations to create electricity. However, when coal burns, it releases large amounts of carbon dioxide gas into the atmosphere. This not only creates air pollution but also creates an effect that traps heat within Earth's atmosphere, causing warming beyond natural biological processes – global warming.

Unfortunately, this has led to climate change, which is affecting our planet at a rapid rate. Fortunately, there are cleaner options for many of us to now use to produce electricity.

Igneous rocks

Igneous rocks form from magma beneath Earth's surface. Magma is the semimolten material in Earth's mantle. The liquid is extremely hot, approximately 1000°C, and when it cools, it hardens to become igneous rock.

The type of igneous rock is determined by its location and the time it takes to cool. The formation of igneous rock can occur at the surface, around or in volcanoes, or within Earth's crust.

Fun fact

The word 'igneous' comes from the Latin word *ignis*, which means 'fire'.

There are two main types of igneous rocks: extrusive and intrusive.

Extrusive (volcanic rocks)

These rocks form when **magma** rises from the mantle, erupts on Earth's surface as **lava**, then cools and crystallises to form rocks.

The molten rock cools very quickly and crystallises (in minutes to months) on the surface of Earth's crust.

Key terms

magma	molten rock below the surface of Earth
lava	magma that rises to the surface and erupts from a volcano

Table 2.3: Some extrusive igneous rocks, how they form, and their characteristics and uses

Example	How it forms	Characteristics	Uses
Basalt	Forms from lava cooling quickly on Earth's surface	Fine-grained, dark-coloured (black to dark grey), with a smooth or vesicular texture	Crushed and used in concrete and asphalt
Obsidian	Forms when lava cools extremely quickly, preventing crystal growth	Glassy, shiny and often black, but can also appear reddish or greenish	Cutting tools
Pumice	Forms from gas-rich lava that cools rapidly, trapping gas bubbles	Light, porous and frothy, with a very low density; often light grey to white in colour	Polishes, toothpaste, concrete and even 'stone wash' jeans

Intrusive (plutonic rocks)

These rocks form when magma cools and solidifies beneath Earth's surface. This process occurs when magma from Earth's mantle rises into the crust but does not reach the surface.

The cooling time for intrusive rocks is thousands or millions of years. This means that generally the grains in these rocks are much larger.

Table 2.4: Some intrusive igneous rocks, how they form, and their characteristics and uses

Example	How it forms	Characteristics	Uses
Granite	Forms when magma cools slowly beneath Earth's surface	Coarse-grained, light-coloured with visible crystals of quartz, feldspar and mica	Monuments, flooring and kitchen benchtops
Diorite	Forms when magma cools slowly beneath Earth's surface	Coarse-grained, speckled black and white appearance with visible crystals	Curbing, cobblestones, base material for construction of roads, buildings and parking areas
Gabbro	Forms when magma cools slowly beneath Earth's surface	Coarse-grained, dark-coloured, often black or dark green, with visible crystals	Flooring, kitchen benchtops, construction projects and road base

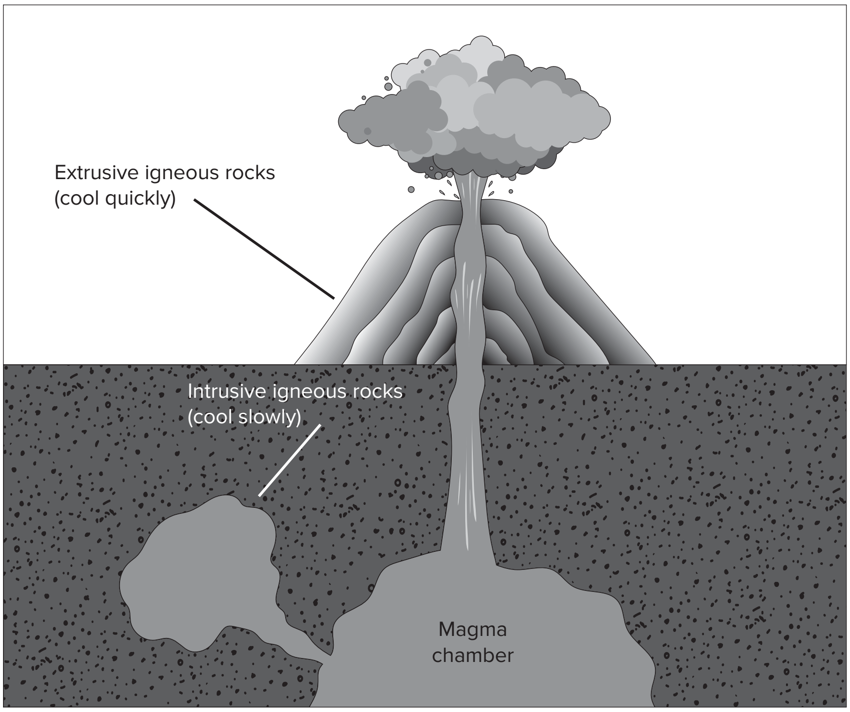


Figure 2.5: Formation of igneous rocks

Activity 2.4.2

1. Write key points for how extrusive igneous rocks are formed, then describe examples, including their characteristics and uses.
2. Write key points for how intrusive igneous rocks are formed, then describe examples, including their characteristics and uses.
3. Draw a diagram to show how igneous rocks form.

Metamorphic rocks

Metamorphic rocks are rocks that have changed (**metamorphosed**) from their original form because of heat, pressure or chemical processes.

They form deep within Earth's crust when sedimentary, igneous or other metamorphic rocks experience intense heat and pressure over time. (The original rocks they form from are known as parent rocks.)

Metamorphic rocks can be formed by pressure from the layers above them and from the extreme heat from magma as they are closer to the heat within the mantle.

They can also be made where Earth's crust rubs together as the tectonic plates move.

Key term

metamorphose	to change into a completely different form or type

Fun fact

The word 'metamorphic' comes from the Greek words *meta* (change) and *morph* (form), meaning 'to change form'.

Table 2.5: Some metamorphic rocks, the rock that they formed from, and their characteristics and uses

Example	Original rock	Characteristics	Uses
Marble	Limestone	Crystalline, often white, can be polished	Monuments, flooring and kitchen benchtops
Slate	Shale	Fine grained, splits into thin layers	Flooring, roof tiles
Quartzite	Sandstone	Hard, crystalline, often white or pink	Flooring, kitchen benchtops, construction projects

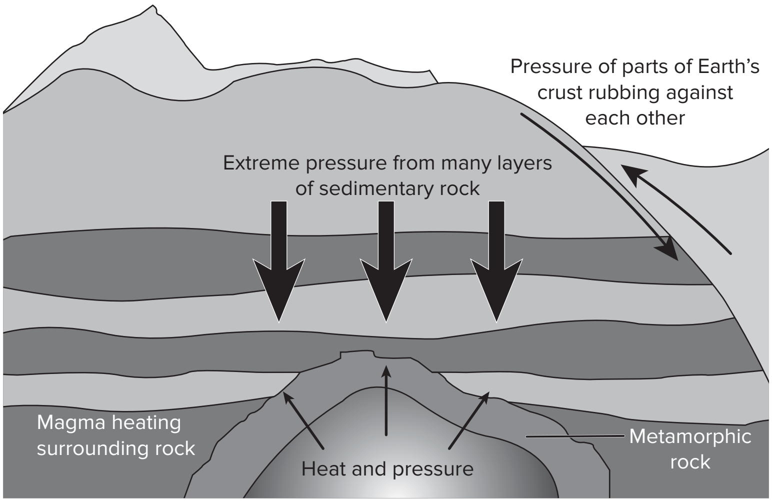


Figure 2.6: Formation of metamorphic rock

Activity 2.4.3

1. Write key points on how metamorphic rocks are formed, then describe examples, including their characteristics and uses.
2. Draw a diagram to show how metamorphic rocks form.
3. Using a trustworthy online resource of your choice, find examples of different types of rocks. Use the information in this chapter to identify the rocks as sedimentary, igneous or metamorphic.

2.5 First Nations peoples' knowledge and use of rocks

First Nations cultures tend to classify rocks on Country according to how they are used culturally, which is often connected to the natural properties of the rock. In some First Nations cultures, people believe that rocks are imbued with spiritual essence. First Nation peoples' knowledge of rocks is deeply rooted in a holistic understanding of Country, its resources and their significance to community life and cultural heritage.

The way rocks are classified varies among different groups and is often linked to the specific uses and symbolic meanings of the rocks.

Practical use

Some rocks are valued for making tools.

- Greenstone (dolerite) is used for making axe heads.
- Silcrete and quartzite are used for making sharp-edged tools such as knives.
- Ochre is used for ceremonies as a pigment for body painting and in rock art.

Physical properties

The characteristics of rocks, such as hardness, colour and texture, are used for classification.

- Hardness and durability: rocks that are harder and more durable are preferred for toolmaking.
- Texture: the texture of a rock can determine its purpose; for example, sandstone was often used for making grindstones and millstones because it provides a rough surface for grinding food.
- Colour: these properties can determine the use of the rock in art and for ceremony.

Cultural and spiritual significance

Rocks are sometimes classified according to their cultural and spiritual meanings.

- Certain rocks may be considered sacred and associated with Dreaming stories and songlines.
- Rocks were once used as currency.

Activity 2.5.1

Write dot points about how some First Nations people categorise rocks and what they use the different rocks for.

First Nations quarries

First Nations quarries included rocky outcrops that First Nations people took stone from to make stone tools. Rocks that were quarried for tools included greenstone, silcrete, basalt and quartzite. These rocky outcrops have scars from where the rock was flaked, crushed or bashed out.

Pigments were made from quarried ochre, and grinding tools were made from quarried sandstone.

These quarries are usually on slopes where erosion has exposed the stone; for example, the slopes above creeks and rivers, on the sides of old volcanoes and on ridges.

First Nations people used two main methods to quarry the stone:

- striking the surface of the outcrop with a hammerstone
- digging around and under the outcrops to find buried stone.

2.6 The rock cycle

All rocks are part of a continuous natural process called the rock cycle. The rock cycle describes how rocks change from one type to another over time, breaking down (erosion), changing through heat and pressure, and re-forming into different rocks.

Temperature, pressure and changes in environmental conditions at and beneath Earth's surface drive the rock cycle.

Processes in the rock cycle

The rock cycle involves several key processes that drive the transformation of rocks.

Melting

Rocks are melted into magma because of intense heat in Earth's mantle.

Cooling and solidification

Magma and lava cool to form igneous rocks.

Weathering and erosion

Rocks are broken down by wind, water and other natural forces, creating sediment.

Transportation and deposition

Sediments are moved (transportation) by rivers, wind or ice and deposited in new locations (deposition).

Compaction and cementation

Layers of sediments are pressed together (compaction) and hardened (cementation) into sedimentary rocks.

Heat and pressure

Rocks are transformed into metamorphic rocks as a result of the high temperatures and pressures within Earth.

Uplift and exposure

Rocks are pushed to the surface by tectonic forces (we will discuss this later), exposing them to weathering and erosion. And so the cycle continues.

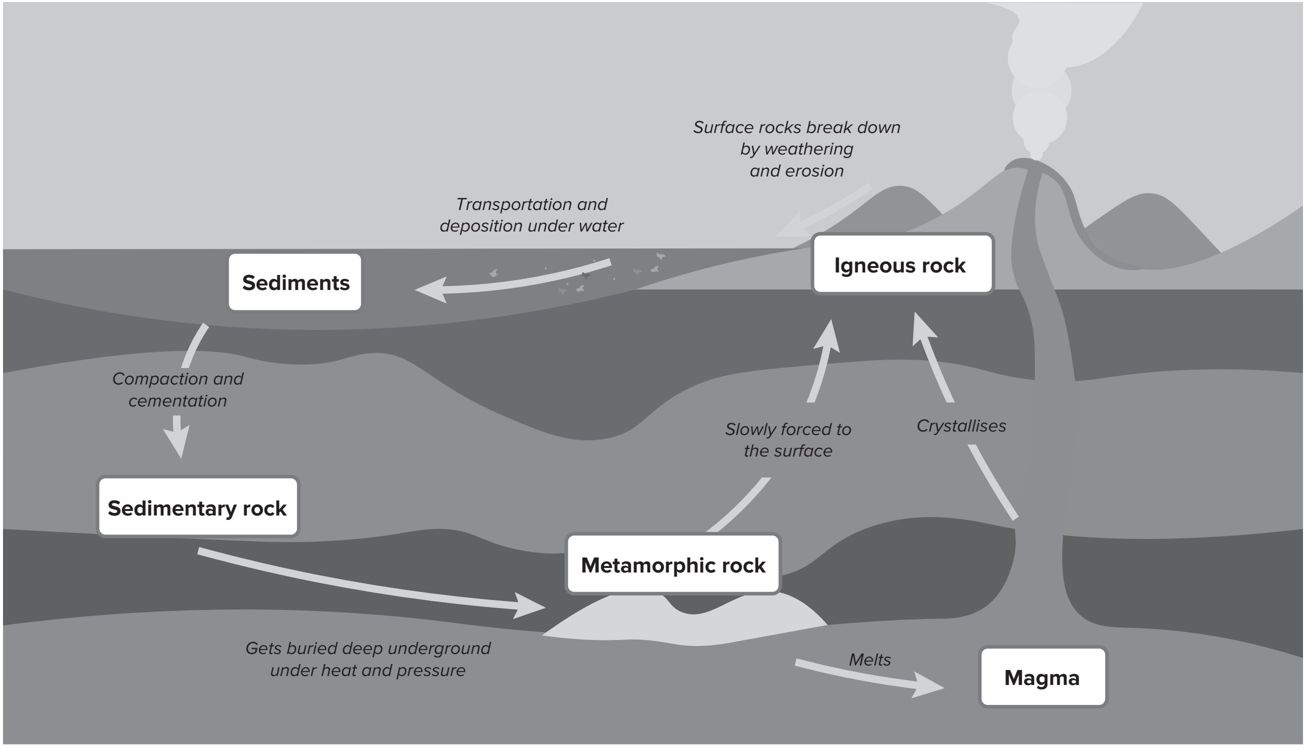


Figure 2.7: The rock cycle

You can also remember the rock cycle this way:

Igneous rock → weathering → sediments → sedimentary rock → heat and pressure → metamorphic rock → melting → magma → cooling → igneous rock

The rock cycle is important to the Earth because:

- it ensures that Earth's materials are reused and reshaped
- the weathering creates soil for plants
- it provides us with useful minerals and fossil fuels.

Activity 2.6.1

1. Draw and label the rock cycle. Add dot points to remind yourself of each process.
2. Explain why the rock cycle is important.

Science as a human endeavour: James Hutton

James Hutton (1726–1797) was a Scottish geologist, sometimes referred to as the 'father of modern geology'. His work and ideas helped to revolutionise our understanding of Earth's processes and its history.

One of his main contributions to geology was developing the theory of uniformitarianism. He proposed that the processes shaping Earth in modern times – erosion, sedimentation and volcanic activity – have been occurring in the same way throughout Earth's history. This idea is summed up as 'the present is the key to the past'. He laid the foundation for modern geology and our understanding of the rock cycle and Earth's processes.

Science as a human endeavour: Mining

Mining is the process of extracting minerals and **ores** from Earth so we can use them. Extracting them from Earth often requires skilled geologists, ecologists and engineers because these resources are normally found deep under the ground or under an ocean. This requires drilling and large-scale removal of earth and rocks.

The many reasons we use ores and minerals include, for:

- building materials (limestone and cement)
- energy sources (coal and uranium)
- manufacturing (metals for electronics and cars).

There are two main types of mining: surface and underground.

Although mining is important and necessary, it does significantly affect the environment, including by:

- destroying habitats
- eroding soil
- producing water and air pollution
- creating waste.

In Australia, after all the ores or minerals have been taken from a mine, some mining companies rehabilitate the area to try to get it back to its original state, creating wetlands, farmlands, bushlands and semi-arid ecosystems. Or they may reuse the land for something completely different, such as solar farms or parks.

Mining is essential for modern life but can harm the environment. To balance economic benefits with environmental care, rehabilitation programs and sustainable practices are crucial.

Key term

ore	a mineral that contains a more valuable mineral, such as gold or coal, inside it

2.7 Continental drift theory

Have you ever noticed that on a map of the world, some of the continents such as South America and Africa could fit back together like a jigsaw puzzle?

More than 100 years ago, the German scientist Alfred Wegener made a bold suggestion. He suggested that Earth's continents were once joined together in a single landmass and have drifted apart over millions of years. This is known as continental drift theory. Wegener suggested that the continents broke apart from each other and drifted about like giant ships, moving around the surface of the earth.

Key ideas of the theory

- Pangaea – Wegener proposed that all continents were once part of a supercontinent called Pangaea, meaning 'all Earth', which existed 250 million years ago and broke apart over time.
- Continental movement – continents slowly drifted to their current positions by forces in Earth.

Evidence supporting continental drift theory

- Fit of the continents – some coastlines fit together like puzzle pieces.
- Fossil evidence – identical fossils of ancient plants and animals have been found on continents separated by oceans, which suggests the land was once connected (e.g. *Mesosaurus* and *Glossopteris fossils*).
- Rock and mountain correlation – similar rock formations and mountain ranges are found on different continents (e.g. the Appalachian Mountains in North America and the Scottish Highlands in Scotland).
- Climate evidence – fossils of tropical plants found in Antarctica and evidence of glaciers in now warm regions suggest the continents were once in different locations.

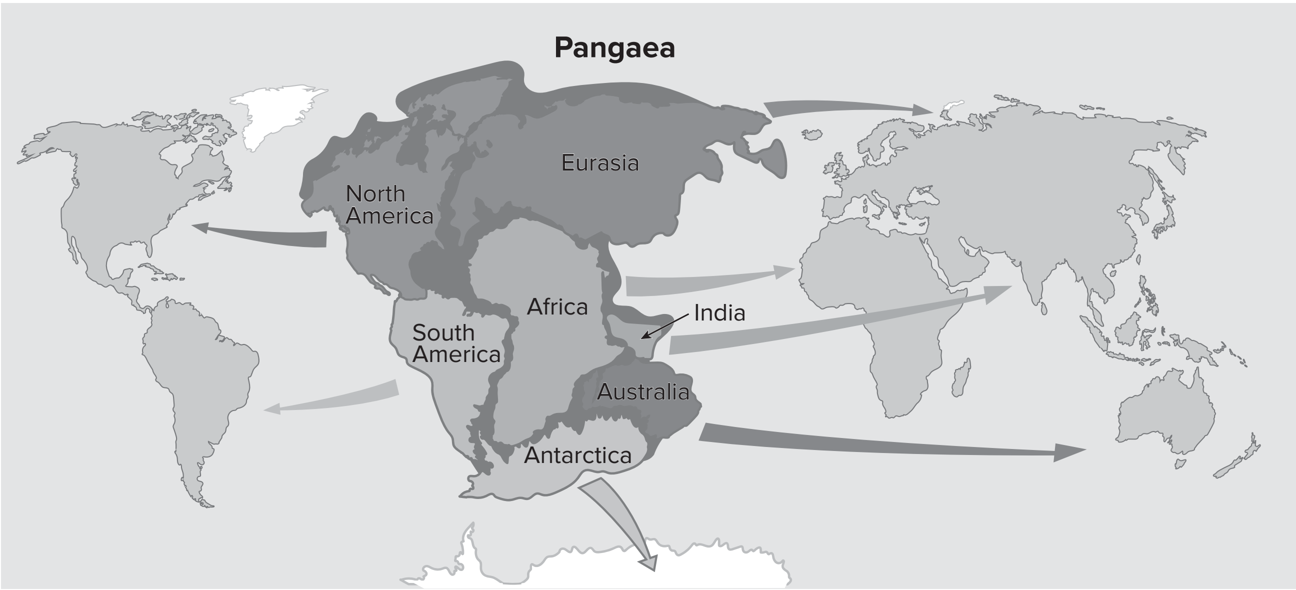


Figure 2.8: The theory of continental drift

Early challenges to continental drift theory

Although Wegener's theory revolutionised our understanding of Earth's history, Wegener could not explain how or why the continents moved.

Activity 2.7.1

1. Explain the evidence supporting continental drift.
2. What was Wegener's biggest challenge with proving continental drift?

2.8 Plate tectonics

Wegener's continental drift theory was initially considered controversial; however, his work became more accepted following the development of the plate tectonics theory, which answered the question of how and why the continents moved.

Plate tectonics explains that Earth's outer shell – the **lithosphere** – is divided into large pieces called tectonic plates. The tectonic plates move over the semi-fluid layer – the **asthenosphere**.

Key terms

lithosphere	Earth's rigid outer layer, composed of the crust and the uppermost part of the mantle
asthenosphere	a partially molten layer of the upper mantle that lies beneath the litho-sphere and behaves like a viscous fluid

This movement results in earthquakes, volcanoes and mountains, and is responsible for shaping Earth's surface. This is where your knowledge of the layers of Earth is useful (Table 2.6).

Table 2.6: Earth's layers revisited

Layer	Description
Crust	Thin, outer layer where all life lives; includes continents and ocean floors
Mantle	Semi-solid layer beneath the crust; convection currents here drive plate movement
Core (outer)	A liquid layer
Core (inner)	Solid composed mostly of iron and nickel

Figure 2.9 is a map of most of the tectonic plates.

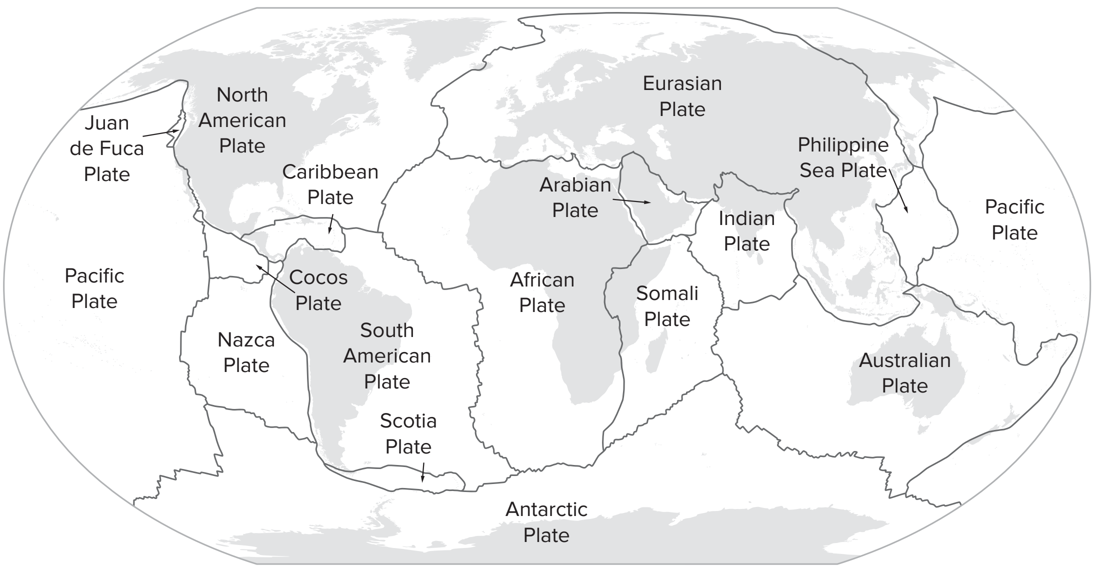


Figure 2.9: Tectonic plates

> **Fun fact**
>
> There are seven major and eight minor tectonic plates.

How tectonic plates create earthquakes, volcanoes and mountain ranges

Figure 2.10 shows the direction of movement at some plate boundaries or edges. This is where the action happens! These are regions of intense geological activity.

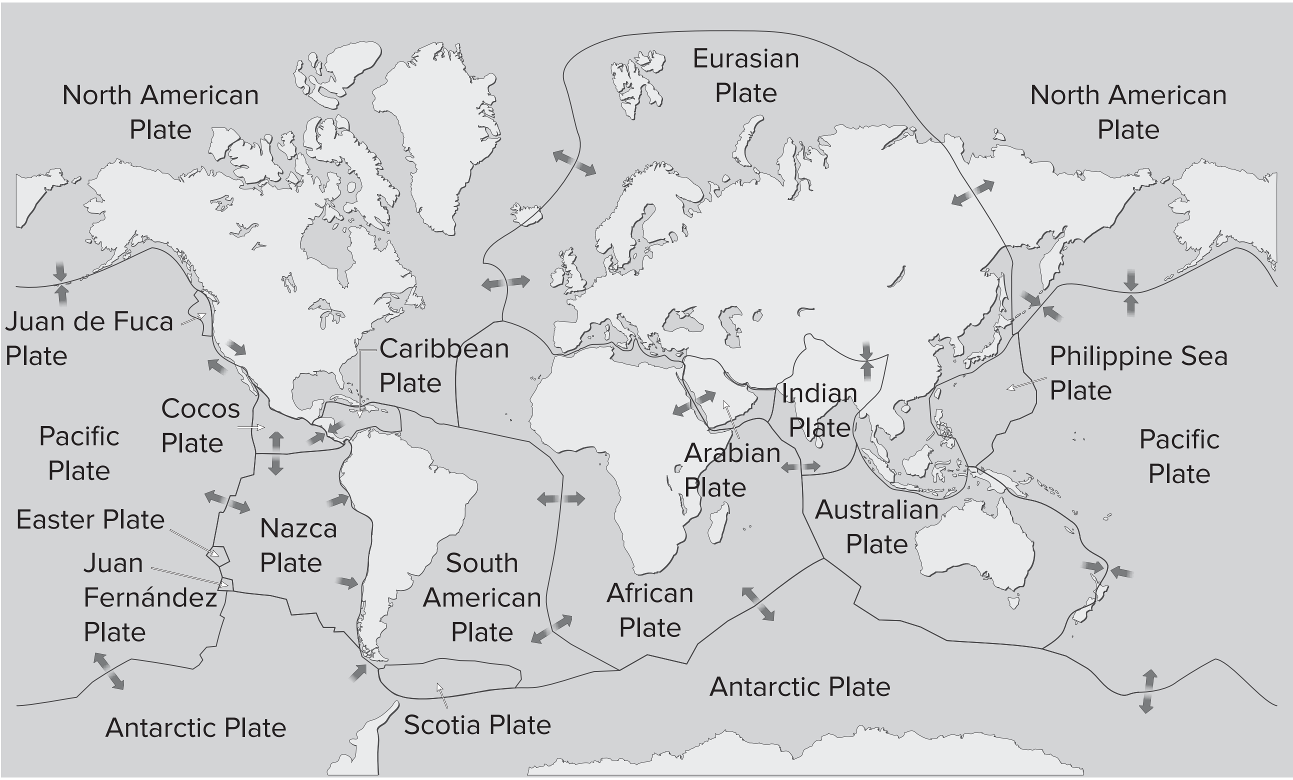


Figure 2.10: Movement of tectonic plates

There are three main types of plate boundaries.

- Divergent boundaries
- Convergent boundaries
- Transform boundaries

Activity 2.8.1

1. What is plate tectonics?
2. How many major plates are there?
3. Which plate is Australia on?
4. What are the names of the three main types of plate boundaries?

2.9 Divergent boundaries

At divergent boundaries, plates move *away* from each other. Magma rises from Earth's mantle to the surface and solidifies, forming new crust. Divergent boundaries often occur under oceans, forming **mid-ocean ridges** (underwater mountains caused by divergent boundaries). There is significant geological activity at divergent plate boundaries.

Divergent boundaries are sometimes called constructive boundaries because new crust is 'constructed' where the two tectonic plates move apart from one another.

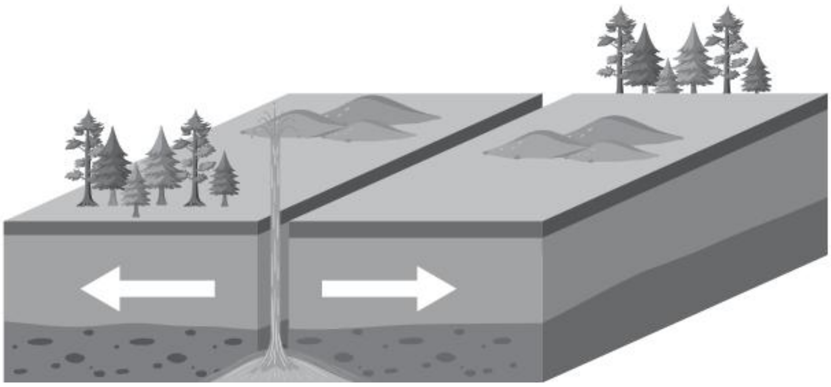


Figure 2.11: Movement of tectonic plates at a divergent boundary

Divergent boundary case study – the Mid-Atlantic Ridge

Iceland is a place where you can see part of a mid-ocean ridge on land. The Mid-Atlantic Ridge is a divergent boundary that runs through the island. This ridge separates the North American Plate and the Eurasian Plate.

This geological feature produces:

- rift valleys – the plates are pulling Iceland apart by about 2 cm each year, creating a rift valley (a valley caused by tectonic plates moving apart)
- volcanoes – which allow magma to rise to Earth's surface where the lava cools to form new crust
- earthquakes
- geothermal activity such as hot springs and geysers – these are caused by heat from magma close to Earth's surface.

This geological activity shapes Iceland's unique landscape.

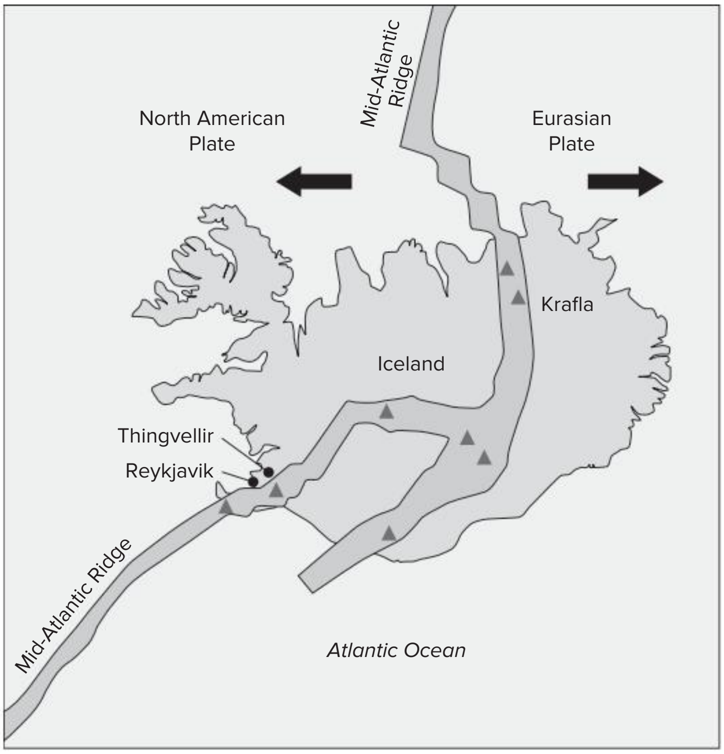


Figure 2.12: The Mid-Atlantic Ridge runs through Iceland

Activity 2.9.1

1. Draw a diagram to show how the plates move at divergent boundaries.
2. Why are divergent boundaries sometimes called constructive boundaries?
3. What geological features and activity does the Mid-Atlantic Ridge (a divergent boundary) cause in Iceland?

2.10 Convergent boundaries

At convergent boundaries, plates move *towards* each other. One plate may sink under another (subduction), or the plates may collide (compression). This geological activity causes features such as mountains, volcanoes and deep ocean trenches. Sometimes, convergent boundaries are called destructive boundaries because the process destroys crust. There is significant geological activity at convergent boundaries.

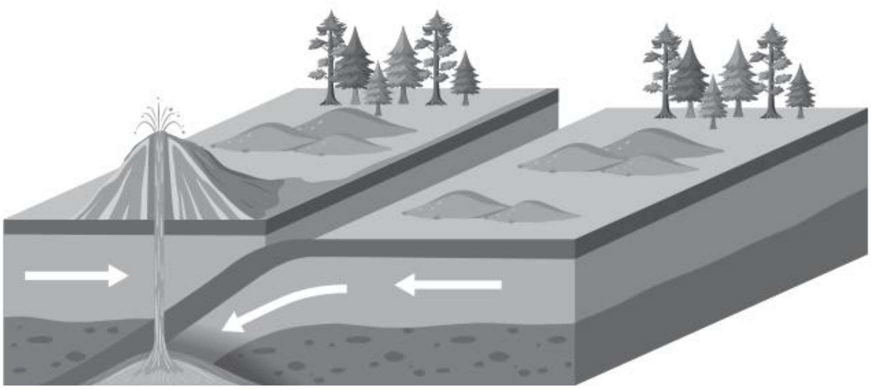


Figure 2.13: Movement of tectonic plates at a convergent boundary

Convergent boundary case study – the Himalayas

The Himalayas is the tallest mountain range in the world and is in Asia, spanning across five countries. The range is home to the tallest mountain in the world – Mount Everest. These mountains were formed at a convergent boundary.

The mountain range was formed by the collision of the Indian Plate and the Eurasian Plate millions of years ago. The compression of the two plates pushed up layers of rock and formed the mountains we see today. This process is called **orogeny** and is ongoing. The Himalayan range is still rising by about 1 cm a year.

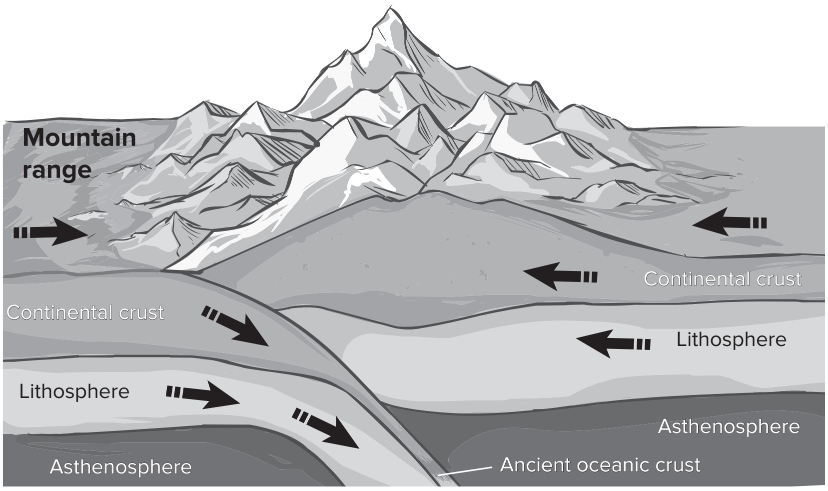


Figure 2.14: The Himalayas was formed by the collision of the Indian Plate and the Eurasian Plate millions of years ago

Activity 2.10.1

1. Draw a diagram to show how the plates move at convergent boundaries.
2. Why are convergent boundaries sometimes called destructive boundaries?
3. Explain how the Himalayas was formed.

2.11 Transform boundaries

A transform boundary is where two tectonic plates slide past each other horizontally. Unlike at convergent and divergent boundaries, no crust is formed or destroyed. The plates grind against each other as they move in opposite directions or at different speeds. This creates earthquakes. Frequent and severe earthquakes are associated with transform boundaries. Transform boundaries do not involve magma rising to the surface so there is no volcanic activity. The place where the two plates meet is called a **fault line**.

Examples of transform boundaries are the:

- San Andreas Fault in the USA
- Alpine Fault in New Zealand
- North Anatolian Fault in Türkiye.

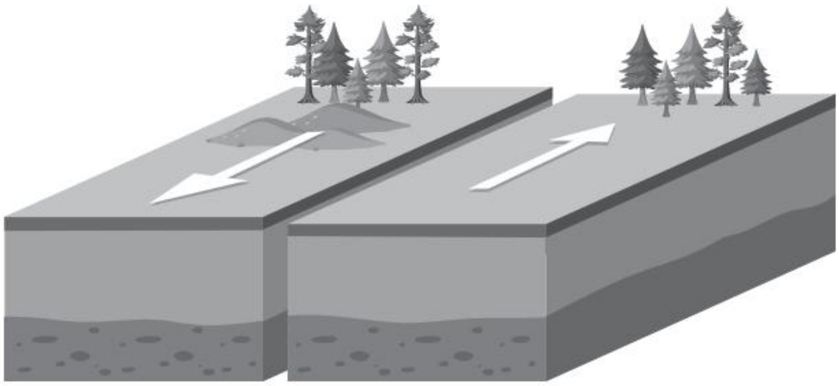


Figure 2.15: Movement of tectonic plates at a transform boundary

Transform boundary case study – the Alpine Fault

The Alpine Fault is major geological feature in New Zealand's South Island and marks the boundary between the Australian Plate and the Pacific Plate.

The fault is approximately 600 km long and moves horizontally at a rate of about 30 metres every 1000 years, which is considered very fast! It also moves vertically, lifting the Southern Alps, New Zealand's largest mountain range. The last major earthquake on the Alpine Fault was in 1717. However, pressure has been building up over the past 300 years and geologists predict that there is a 75 per cent chance of an Alpine Fault earthquake with a predicted magnitude of more than 8 in the next 50 years. An earthquake of this magnitude will be a major earthquake causing serious damage over large areas.

It is important to note that New Zealand has a lot of geological activity because of its position in relation to tectonic plates, including regular earthquakes, volcanoes, glaciers and geothermal areas such as hot springs, mud pools and geysers, shaping New Zealand's unique landscape.

Activity 2.11.1

1. Draw a diagram to show how the plates move at transform boundaries.
2. What is the name of the place where the two plates meet at a transform boundary?
3. What is different at a transform boundary compared with a divergent and convergent boundary?
4. Explain how the Alpine Fault was formed.

Stable Australia

Find Australia on the map in Figure 2.10. What do you notice about where Australia is relative to tectonic plates?

Australia is situated in the centre of its tectonic plate, well away from active regions. Because of this, Australia has a very stable geological environment. Its earthquakes are usually minor, and it has had no volcanic eruptions for thousands of years.

2.12 What causes tectonic plates to move?

Think back to Alfred Wegener. The challenge to his continental drift theory was that he couldn't work out how the continents moved. Scientists since Wegener have worked this out by understanding the movement of tectonic plates.

Tectonic plates move because of currents. There is a lot of heat energy in the mantle. The heat rises, cools slightly and sinks, creating circular movements called convection currents. You will learn about these in Chapter 3. These currents cause the plates to move.

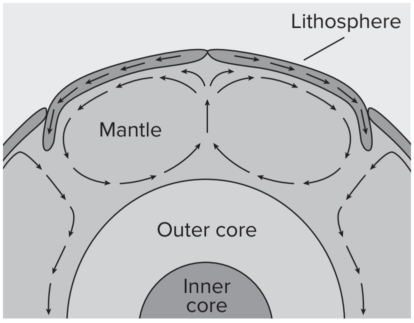


Figure 2.16: Convection currents cause the tectonic plates to move.

Activity 2.12.1

Draw a labelled image to show how tectonic plates move.

2.13 First Nations peoples' knowledge of geological sites

First Nations people have a deep understanding of the geological history of the land and Country. This knowledge has been passed down orally. The following extract from The Conversation website discusses First Nations peoples' knowledge, understanding and connection to a geological site.

When the Bullin shrieked: Aboriginal memories of volcanic eruptions thousands of years ago

Figure 2.17: Mount Gambier's Blue Lake is in a volcanic crater.

… The shrieks of the bullin (a bird) were heard by a person named Craitbul and his family as they wandered the area of volcanic activity clustered around the southernmost part of the border between South Australia and Victoria. Settling first on Mount Muirhead, they buried their food overnight in the earth to cook – which tells us the ground here was unusually hot. In the middle of the night, the bullin shrieked, something that can be interpreted as a sign of a volcanic eruption.

> Craitbul's family fled to Mount Schank, where eventually the same thing happened, so they shifted to Mount Gambier. Here the bullin was silent, but the earth ovens in which they had placed their food flooded – water rose up from below – so they abandoned this area as well.
>
> Many volcanoes of this area like Mount Gambier are maars, places where superhot magma from the Earth's interior rises until it encounters cold groundwater, whereupon there is an almighty explosion. Rocks are thrown out into the air from a single point on the ground. These often settle in a ring around this point, forming a natural circular basin that invariably fills with rainwater – a maar lake.
>
> Key details of this process are contained in First Nations stories of volcanism such as that about Craitbul: the heat below the surface in which food could be cooked; the alarming shrieks of the bullin bird of eruption; and the water filling the crater-ovens. Given that the most recent volcanic activity at Gambier and Schank occurred 4300 years or so ago, this gives us an approximate length of time for the Craitbul story to have endured, largely as an oral tradition …
>
> **Credit:** Patrick D. Nunn, Professor of Geography, University of the Sunshine Coast. Published 23 August 2017.

Oral stories such as this can provide a way of helping to date and describe natural events. As well as their cultural significance, oral histories and the practices of First Nations people can be used to verify scientific information.

Activity 2.13.1

Using trustworthy online resources, research other oral stories that have been passed down about First Nations peoples' knowledge and understanding of geological activity in Australia. Create a comic or a poster to retell one of the stories you researched.

Chapter 3 – Physics

3.1 What is physics?

Physics is a branch of science that studies matter, energy, motion and force. People who work in physics are called physicists.

So why is physics important to you? Every action you perform in daily life has a direct or indirect connection to the concepts of physics. Walking, drinking, jumping and using your electronic devices are just a few examples of activities that follow the laws of physics. Think about a time you went on a roller coaster; physics plays a very important role in rides and roller coasters.

3.2 Energy

What is energy?

Energy is a tricky concept, but it is everywhere around us. Your computer works because of electrical energy, your food gets hot because of thermal energy and, as we have learned already in Chapter 1, you get energy from the food that you eat so that your body can function.

Put simply, energy is the ability to do work or cause change. Or, energy is the potential to perform an action through some force.

Energy exists in many forms and can be transferred or transformed but never created or destroyed. This is called the **law of conservation of energy**.

Activity 3.2.1

Define the term 'energy'.

3.3 Law of conservation of energy

The law of conservation of energy is a scientific law and is an important concept to help us understand how energy works. Keep this law in your mind as you read further into this chapter. It underpins how we understand energy in every aspect of science.

When you toast your bread in the morning, electrical energy in the toaster is changed into heat energy, which cooks the bread to make it toast. This shows the law in action. The electrical energy becomes heat energy to toast the bread – the energy was not created or destroyed, just transformed (converted or changed).

Activity 3.3.1

Using coloured markers, write the law of conservation of energy – 'Energy cannot be created or destroyed only transferred and transformed'. You can add images to help you to remember.

3.4 Kinetic and potential energy

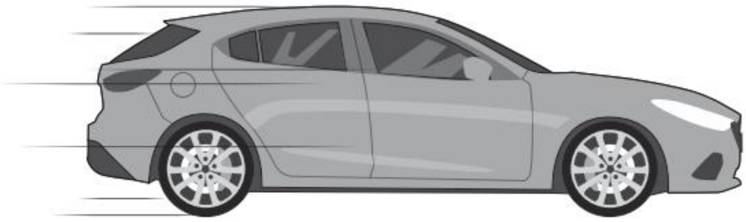
There are two main types of energy: **kinetic energy** and **potential energy**.

Kinetic energy

Kinetic energy is **active energy**. It includes any form of energy where work is being done. Kinetic energy involves movement, which could be the movement of whole objects or the movement of particles within objects or waves (a disturbance through space and matter, e.g. sound waves).

It is a form of energy that is **directly usable** and **measurable**.

Walking is a form of kinetic energy.



A moving car is kinetic energy.

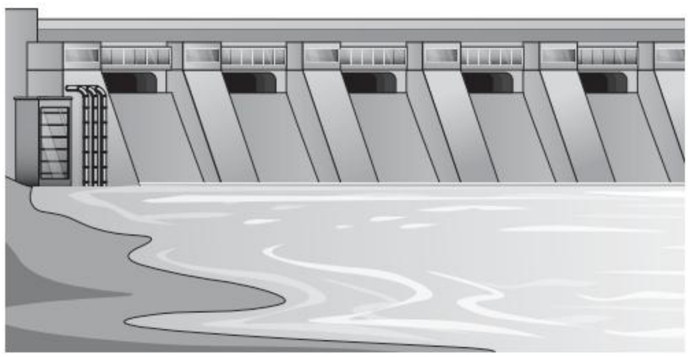
Figure 3.1: Forms of kinetic energy

Potential energy

Potential energy is **inactive energy**. It includes any form of energy where work is not being done but the capacity to do work exists. Potential energy involves energy storage. It is a form of energy that is **not directly usable** or **measurable**.

Potential energy only becomes usable and measurable when it is converted into kinetic energy.

A stretched bow and arrow is potential energy.



A dam wall holding back water is potential energy.

Figure 3.2: Forms of potential energy

Activity 3.4.1

Draw a Venn diagram and compare kinetic energy and potential energy. You can add images to help you to remember.

3.5 Types of energy

Some types of energy are more complicated than others to understand, so read the information in Table 3.1 a few times if necessary.

Table 3.1: Different types of energy

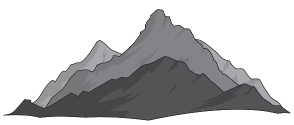
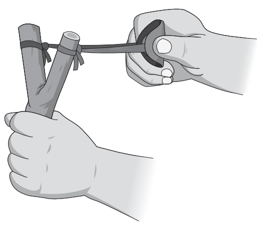
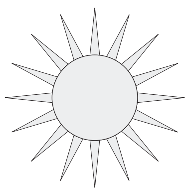
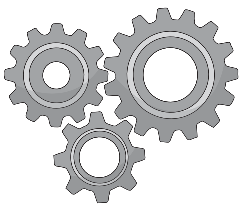
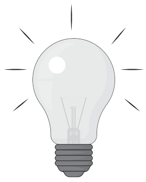
Energy	Description	Potential or kinetic	Example
Gravitational 	Gravitational energy is associated with gravity. It is the potential energy stored by an object because of its higher position compared to a lower position.	Potential	A ball sitting on top of a mountain has a higher gravitational potential energy than a ball sitting at sea level.
Elastic 	Elastic energy is energy stored in an object when there is a temporary strain on it, such as a stretched elastic band.	Potential	Stretching a rubber band gives it elastic potential energy, as its shape temporarily changes and is strained.
Light 	Light energy is the energy of electromagnetic waves. These waves can travel through space.	Kinetic	Light energy can be visible waves such as light rays or invisible waves such as X-rays and radio waves.
Thermal 	Thermal energy (also called heat energy) is energy that comes from a substance whose molecules and atoms are vibrating faster because of a rise in temperature.	Kinetic	When you boil a pot of hot water, the flame makes the particles in the metal pot move faster. This then makes the particles in the water move faster, heating it up to boiling point.
Mechanical 	Mechanical energy (sometimes called motion energy) is energy stored in moving objects.	Potential and kinetic	When your foot is extended back to kick a ball, your foot has potential energy. When you kick your foot forward, this becomes kinetic energy, which drives the ball forwards.

Table 3.1: Continued

Energy	Description	Potential or kinetic	Example
Electrical 	Electrical energy is caused by moving electric charges. These charged particles are called electrons.	Potential and kinetic	Electricity is a type of energy that comes from electrical energy.
Chemical 	Chemical energy is energy that is stored in the bonds in chemical compounds. It holds atoms in a molecule and molecules in a substance together.	Potential and kinetic	Dry wood contains chemical energy. When the wood is burnt, the chemical energy is released and converted into thermal (heat) energy.
Sound 	Sound energy is the movement of energy through a substance such as air and is caused by vibrations. It moves as waves.	Potential and kinetic	Music is a form of sound energy. When the strings on a guitar are plucked, the strings vibrate and transmit energy.

The mind map in Figure 3.3 may help you to remember the different forms and types of energy.

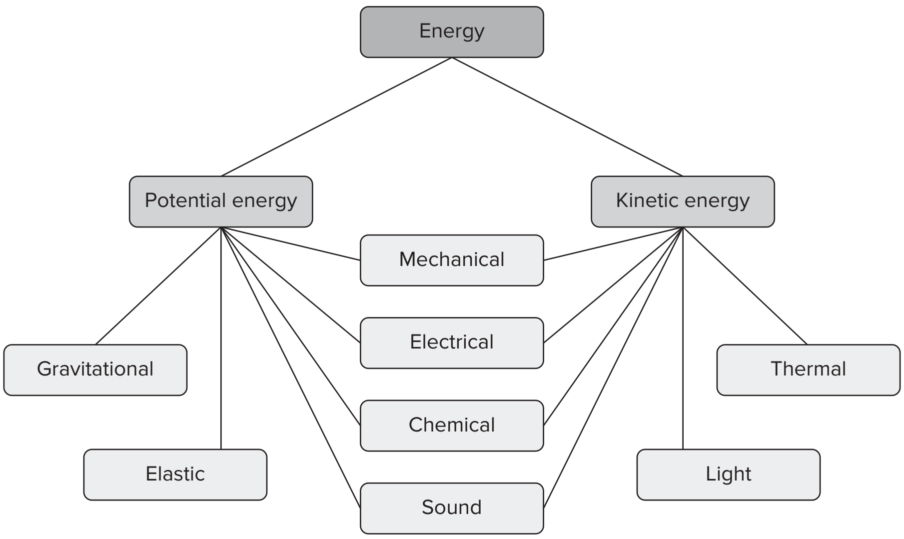


Figure 3.3: Forms and types of energy

Activity 3.5.1

Using coloured markers, draw a mind map of the different types of energy with some examples. You can add diagrams to help you remember.

Science as a human endeavour: Sir Isaac Newton

Sir Isaac Newton was born in 1643 in England. He was a mathematician, physicist, astronomer and author, and is known as one of the most influential scientists in history.

According to popular accounts, Newton saw an apple fall from a tree and began thinking about why objects fall to the ground. This led him to wonder if the same force that made the apple fall could also explain the motion of the Moon and planets.

From here, Newton formulated the idea that gravity is a force of attraction between two objects that depends on the:

- mass of the objects (larger masses exert stronger gravitational pulls)
- distance between them (the closer they are, the stronger the pull).

He described gravity as a universal force, meaning it works everywhere in the universe. The impact of his work is amazing. Newton developed the **theory of gravity**, which explained:

- the orbits of planets around the Sun
- the tides caused by the Moon's gravitational pull on Earth
- why objects fall on Earth.

Newton's work on gravity marked the beginning of modern physics and transformed how we understand the universe.

3.6 Energy conversion: transfer and transform

We know that energy cannot be created or destroyed, only transferred and transformed. With that in mind, let's take a closer look at energy transfer and transformation.

Energy transfer

Energy transfer is the **movement** of energy from one place to another without changing form; for example, when electricity from a power point charges a phone. The energy is being transferred from the power point, through the charger and into the phone battery. The energy is moving from one place to another. Or when a soccer player kicks a ball, they transfer kinetic energy from their foot to the ball.

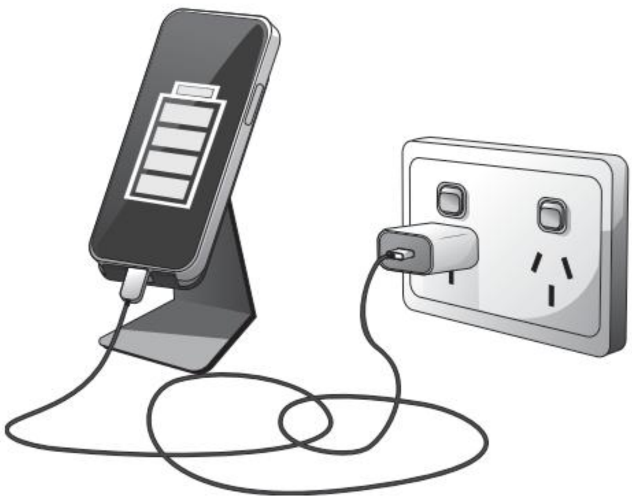


Figure 3.4: Charging a mobile phone involves the transfer of energy from the power point, through the charger and into the phone battery.

Energy transformation

Energy transformation is when energy **changes** from one form to another; for example, when the body converts the chemical energy in food into mechanical (motion) energy. The energy is being changed or converted into another form of energy.

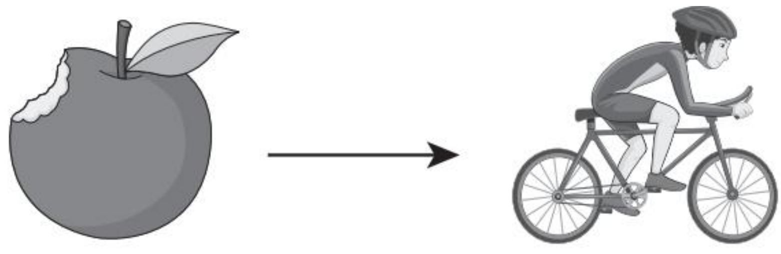


Figure 3.5: The chemical energy in food is converted into mechanical energy.

These examples demonstrate the law of conservation of energy. Remember that although energy can be transferred and transformed, the total amount of energy does not change. This is called energy conservation.

In Figure 3.6, you can see more examples of energy transformation.

- The chemical energy from the battery is transformed into light energy (and a little bit of heat, but more about that later).
- The light energy from the Sun is turned into chemical energy for the plant to use as food through the process of photosynthesis (see Chapter 1).

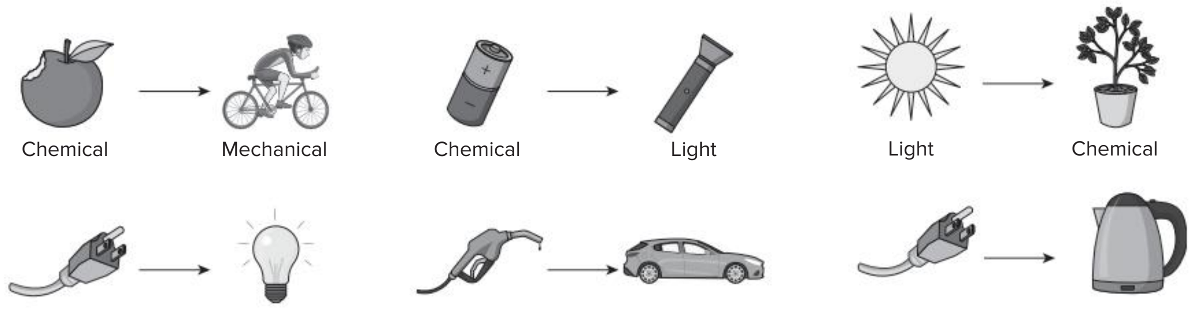


Figure 3.6: Energy transformations

Activity 3.6.1

Define the terms 'energy transfer' and 'energy transformation'. You can draw examples to help you to remember.

3.7 Thermal (heat) energy

We use heat every day. Thermal energy, or heat energy, is the energy that is produced from the movement of particles (molecules and atoms) in a substance. When a substance heats up, the rise in temperature makes these particles move faster and bump into each other.

Thermal energy comes from heating up a substance. The hotter the substance, the more the particles move, and the more thermal energy the substance has.

Examples of thermal energy are the:

- warmth of the Sun
- heat from a heater or fire.

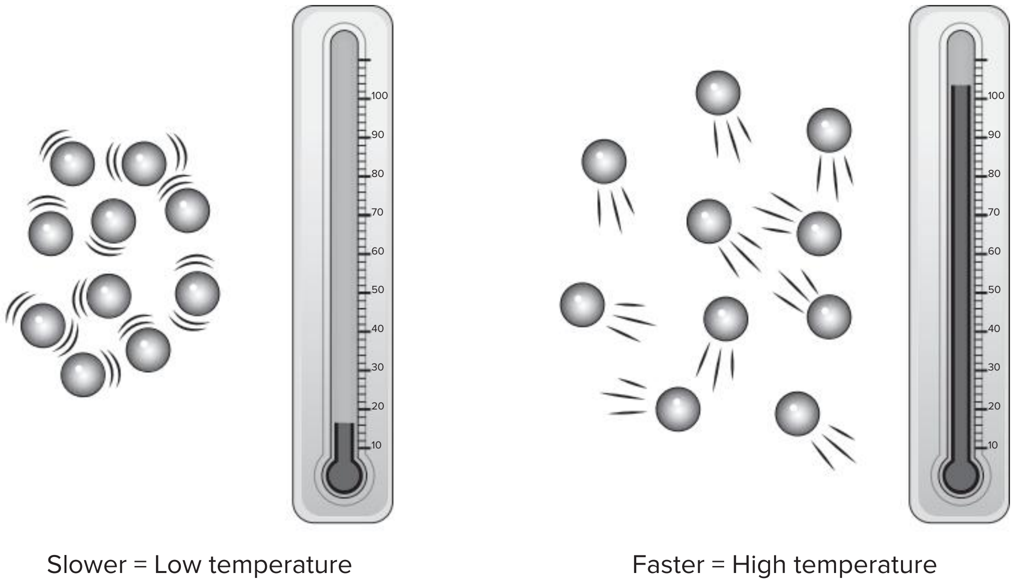


Figure 3.7: The speed of particles depends on their thermal energy.

Activity 3.7.1

Define the term 'thermal energy'. You can draw examples and add key words to help you to remember.

Transferring heat energy

Heat can be transferred (moved from one place to another) in three main ways:

- conduction
- convection
- radiation.

Conduction

Conduction is the movement of heat energy in a substance through direct contact between particles. The particles collide, forcing energy along an object. Conduction usually only happens in solids and liquids because their particles are closer together than in gases. Heat is always transferred from areas of higher temperature to areas of lower temperature.

Conduction is when heat moves from one object to another through direct touch. For example, one piece of metal could conduct heat to another piece of metal if the two are touching. Think about a saucepan on a cooktop. As the saucepan heats up, the handle can also heat up because the base of the saucepan and the handle are connected. The particles in the metal transfer heat from one particle to the next. Heat can then be conducted from the handle to your hand (see Figure 3.8).

Convection

Convection is the transfer of heat energy through indirect means from a warmer area to a cooler area. Like with conduction, the heat transfer occurs because of the movement of the particles, which move more quickly as they heat up. Convection only happens in liquids and gases.

Think about the water in the saucepan on the cooktop. You turn on the heat source and begin heating the water. The water at the bottom of the pot, which is close to the heat source, heats first. As this layer of water heats, it expands slightly and becomes less dense, causing it to rise. As the warmer water moves up, the cooler water at the top of the pot sinks down to take its place and is then also heated. The cyclic process of rising warm water and sinking cooler water creates **convection currents** that effectively distribute the heat throughout the pot.

Convection currents are also discussed in Chapter 2. This process also happens with air, which is a gas. As the hot air rises, it cools and falls back to Earth. This helps to drive the weather patterns on Earth.

Radiation

Radiation is different from the other types of heat transfer. Rather than heat being transferred through particles, radiation involves the transfer of energy through electromagnetic waves. Heat waves radiate out from the hot object in every direction.

Examples of radiation are:

- feeling the warmth of the Sun – you don't need to be touching the Sun to feel its warmth.
- feeling the heat from a campfire – you don't need to touch the fire to feel the heat.

Figure 3.8 illustrates the three types of heat transfer.

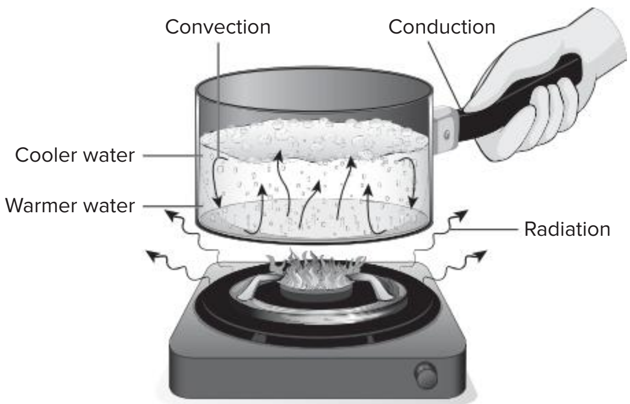


Figure 3.8: Heat transfer by conduction, convection and radiation

Activity 3.7.2

Write key points and draw diagrams to show your understanding of the three main types of heat transfer. Use examples to help you to remember.

3.8 Heat as a by-product of energy transfer and transformation

When energy is transferred or transformed, some energy is converted into heat energy. In some cases, light energy or sound energy may also be produced. This means that the transfer and transformation of energy is not 100 per cent efficient.

Light bulbs

In a light bulb, electrical energy is transformed into light energy, which is what creates the visible light you can see when you turn it on. When you leave the light on for a while and go to touch the light bulb, it is hot. The light bulb is losing energy as heat.

Remember the law of conservation? Energy cannot be destroyed, only transferred and transformed. Many of these energy transfers have some energy lost as heat in the process.

Friction

Rub your hands together as fast as you can. You may notice that your hands got warm or even hot. Friction is a force that produces thermal energy when two surfaces rub together. The friction converts the kinetic energy of motion into thermal energy, which causes the surfaces to heat up. By rubbing your hands together, the particles in that area gain energy, thereby causing heat.

Activity 3.8.1

Have a member of your family or a friend rub their hands together. Explain to them why their hands are warming up.

3.9 First Nations peoples' knowledge of fire-starting methods

First Nations people have used fire for thousands of years to shape the landscape and support ecosystems. They have also used it in everyday life for making tools and cooking food.

First Nations fire making is based on the science of friction. Think back to when you rubbed your hands together and they warmed up; they warmed up because of friction.

First Nations people used many different methods to make fire by using friction. One method is the fire drill. A flat piece of wood is used as a base and a thin but strong stick is used as a drill. The drill stick is pushed into the base piece and twirled between the palms of the hands. The friction creates sawdust and converts the kinetic energy of motion into thermal energy, which causes the objects to heat up to a temperature where the sawdust that is produced gets so hot that it ignites. Eventually a glowing ember is produced, which is placed onto a tinder bundle and gently blown until a flame appears.

Sometimes a pinch of sand would be placed between the two pieces of wood to increase friction and hence speed up the formation of the glowing ember.

Activity 3.9.1

On a piece of paper, draw and label the fire drill method of making fire.

Science as a human endeavour: Energy efficiency

Energy efficiency is the process of reducing the energy wasted when we do work. Heat is a common by-product of energy transfers, such as in light bulbs. When lots of energy is wasted on by-products, it is inefficient energy.

Energy efficiency means using less energy to produce the same product or service. For example, using a low-energy light bulb will still provide you with light but it is more energy efficient than using a high-energy light bulb.

Much of the energy that we use is electrical energy produced by burning coal. Coal is a fossil fuel and **non-renewable**. It will eventually run out. Also, burning coal causes harmful carbon emissions (the release of carbon compounds such as carbon dioxide), which contribute to climate change.

Earth depends on us to be energy efficient. Climate change is causing extreme weather events, rising sea levels and the acidification of our oceans. If we can be more energy efficient, we can create a more sustainable future for our planet.

We can be more energy efficient by reducing our energy consumption and choosing **renewable** sources of energy such as solar, hydro, wind and even geothermal power for our homes, businesses and cars. This helps reduce greenhouse gas emissions and potentially slows climate change.

Consider conducting an 'energy audit' at your house to determine how efficient it is. Are there particular appliances that use a lot of energy? Do your appliances have energy star ratings? Research those ratings. How are they determined?

What other ways could you help to reduce to energy demand of your household now and in the future? Look up how different housing designs can reduce energy bills and how using energy at different times of day can help with efficiency.

Key terms

non-renewable energy	energy from a source that will eventually run out; most non-renewable energy sources are fossil fuels that release harmful carbon compounds
renewable energy	energy from a source that will never run out; renewable sources of energy are more environmentally friendly

3.10 Energy flow diagrams

Most devices involve more than one type of energy. A light bulb uses electrical energy and converts this to light energy; when we touch the bulb, it is hot, so there is also some heat energy.

An energy flow diagram is a visual way to show how energy changes into different forms within a system. These are also called energy transfer diagrams.

Table 3.1 on pages 60–1, which lists the types of energy, is useful here.

Consider a bouncing ball. We hold a ball at a height and drop it. Gravitational potential energy is transferred to kinetic energy when the ball is dropped and in motion. When the ball hits the ground, it squishes slightly, and at the moment it is stationary it has elastic potential energy but no kinetic energy. The ball also releases sound energy when it hits the ground, and even a little heat (thermal) energy.

This can be drawn as the energy flow diagram in Figure 3.9.

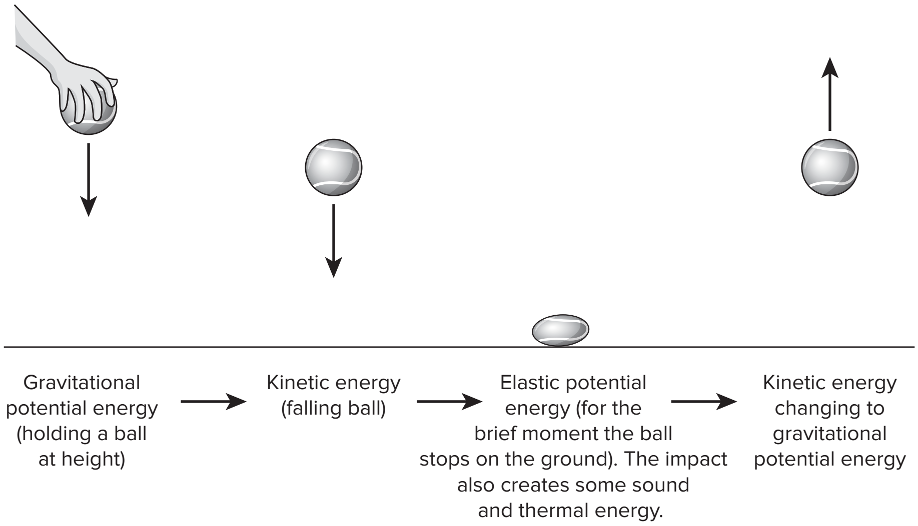


Figure 3.9: An energy flow diagram for a bouncing ball

For another example, consider an electric toothbrush. Electricity is generally produced by coal, which is a form of chemical energy. The electrical energy charges the battery of the toothbrush, which makes the toothbrush move to help clean your teeth. This produces sound and a small bit of heat.

This can be drawn as the energy flow diagram in Figure 3.10.

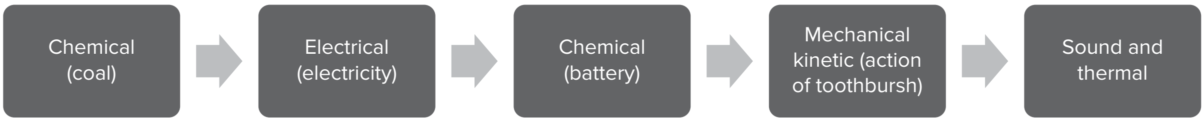


Figure 3.10: An energy flow diagram for an electric toothbrush

Activity 3.10.1

On a piece of paper, draw an energy flow diagram for an object such as a computer, or a hat being dropped. You may need to do some research to find out all the different kinds of energy involved.

Chapter 4 – Chemistry

4.1 What is chemistry?

Chemistry is a branch of science that studies matter, its properties, how it changes and the energy involved in these changes. It explains how substances interact, combine and transform into new substances.

Chemistry helps us understand the composition and behaviour of matter, and how it's used in everyday life. It explains how materials are formed and helps us to develop new materials and substances such as medicines to improve our lives. We see chemistry in action every day – when we cook food, wash dishes, use sunscreen, shed tears when we cut onions, and eat!

> **Fun fact**
>
> Chemistry is regarded as the central science because it connects physics, biology and Earth and space science.

4.2 Matter refresher

What is matter?

Matter is anything that has mass and takes up space (volume). Everything around you, including yourself, is made of matter! The concept of matter can be a little confusing because it is about huge objects such as Earth and the smallest units, atoms.

Matter has mass and takes up space (volume). Key characteristics of matter are:

- **mass** – the amount of material in an object, measured in units such as grams (g) and kilograms (kg)
- **volume** – the amount of space an object takes up, measured in units such as litres (L), millilitres (mL) and cubic metres (m^3)
- **particles** – tiny units called atoms and molecules, which make up matter; they are too small to see with the naked eye.

Non-matter does not have mass and does not take up space. It includes:

- energy – light (sunlight, laser beams), heat (thermal energy), sound (strumming a guitar), electricity (flow of electrons), kinetic energy (active energy), potential energy (stored energy)
- forces – gravity, magnetism, friction
- thoughts and feelings
- time
- waves – radio waves, microwaves, X-rays.

Activity 4.2.1

1. Explain what matter is.
2. Define the term 'non-matter' with examples. You may like to draw some diagrams to help you.

The building blocks of matter

Particles are the building blocks of matter and consist of atoms and molecules.

Atoms:

- are the smallest unit of matter
- can be different types, which are called elements (e.g. hydrogen, oxygen).

Molecules:

- are groups of two or more atoms bonded together. For example, a water molecule (H_2O) consists of two hydrogen atoms and one oxygen atom bonded together.

We will explain these concepts in more detail later in the chapter.

Activity 4.2.2

Explain the difference between atoms and molecules.

States of matter and their properties

Matter can only exist in a few states. The three main states of matter are solid, liquid and gas.

Solids:

- have a fixed shape
- have a fixed volume
- have particles that are closely packed together and strongly attracted to each other, and which move by vibrating
- are not easily **compressed**
- have a high to very high **density**.

Key terms

compress	to press or squeeze
density	how heavy something is relative to its volume

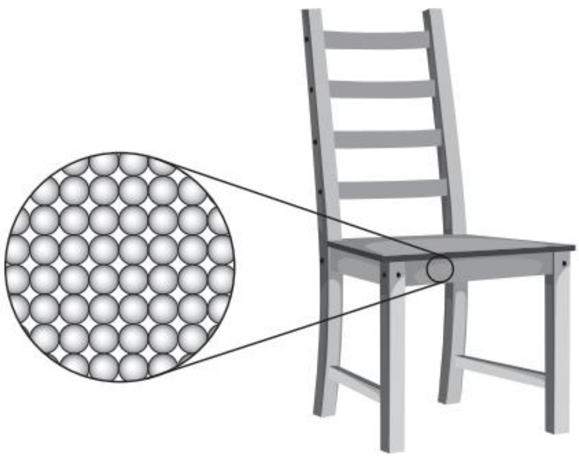


Figure 4.1: Solid particles

Liquids:

- have a variable shape
- have a fixed volume
- have particles that are attracted to each other strongly enough to stay close together, but weakly enough to be able to move by sliding around each other
- are not easily compressed
- are usually less dense than solids.

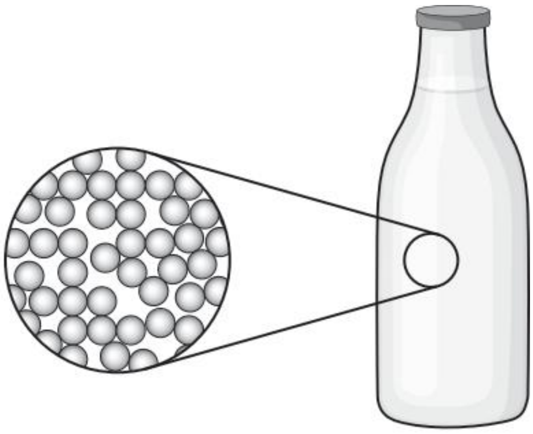


Figure 4.2: Liquid particles

Gases:

- have a variable shape
- have a variable volume
- are easily compressed
- have particles that move freely in all directions and are not attracted to each other
- have a low density.

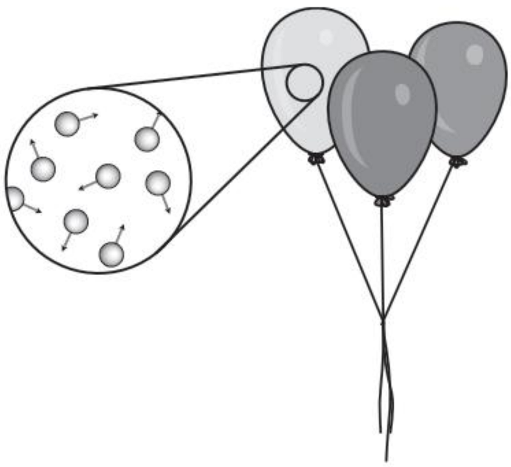


Figure 4.3: Gas particles

Activity 4.2.3

1. Describe the three main states of matter and their properties.
2. Explain how the particles behave differently in each of the states of matter.

4.3 Models

In science, a model is a representation of an idea, object, process or system that helps scientists understand and explain phenomena that are difficult to observe directly.

Models can be **physical**, **mathematical**, **conceptual** or a combination of these:

- Physical: a model that has been drawn, a computerised representation, a built model
- Mathematical: a mathematical equation formed to represent a system and predict possible outcomes
- Conceptual: a complex idea represented in a simple format. Examples are the water cycle and the DNA double helix model.

Models are used to:

- represent complicated ideas; for example, how we think of an abstract idea such as atoms
- represent complicated ideas expressed by one person through action, speech or images such as a diagram
- help scientists to reach a consensus; for example, scientists might test a model and agree that the model has merit, such as the Big Bang model.

Models are central to how scientists communicate. Over time, they can be used to advance the ideas of how something works, with different scientists proposing new models as new information is discovered. They are also used to make predictions; for example, about the weather and weather patterns.

Modelling is valuable for the topic of matter, because matter is made up of particles that are too small to be visible to the human eye.

Activity 4.3.1

Describe each of the different ways scientists model ideas, objects, processes and systems.

4.4 The particle theory of matter

This topic links in nicely with this section on models! The particle theory of matter is a scientific model. This theory helps us to understand how matter behaves.

The key ideas are listed below.

- All matter is made up of tiny particles. These particles are either individual atoms or groups of atoms called molecules.
- Atoms of the same element are the same. Atoms of different elements are different. So, all the atoms in carbon are the same. But the atoms in nitrogen and oxygen are different from carbon atoms.
- Particles are attracted to each other by forces. In some kinds of matter such as diamonds, these forces are very strong. In other kinds of matter such as milk, these forces are weaker.
- Particles are always moving at temperatures above –273.15°C.
- Particle speed increases with temperature; the higher the temperature, the faster the particles move.

- Particles of matter have spaces between them. The space varies depending on the state of matter.

Figures 4.4 and 4.5 show visual representations of some of these ideas. Figure 4.4 shows how a particle model or diagram can represent a solid element, a liquid element or a gaseous element.

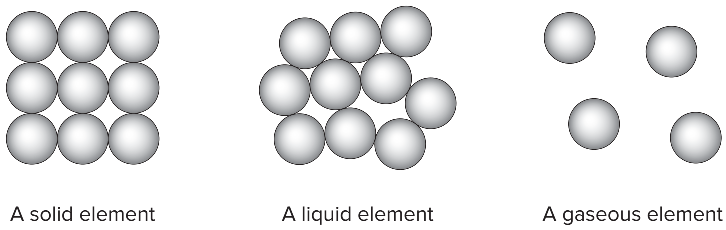


Figure 4.4: Particle diagrams of solid, liquid and gaseous elements

Figure 4.5 shows a particle diagram for hydrogen and oxygen gases. Both elements exist as molecules made up of two atoms. A hydrogen molecule is made up of two hydrogen atoms and an oxygen molecule is made up of two oxygen atoms.

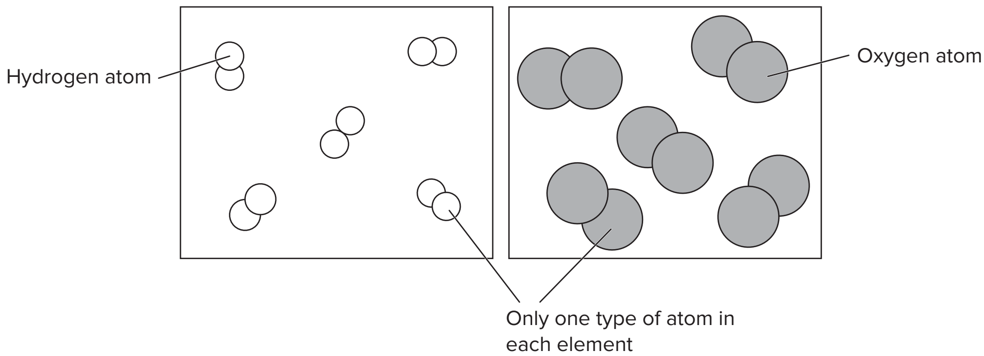


Figure 4.5: Hydrogen and oxygen are both elements. They are each made up of only one type of atom.

Activity 4.4.1

1. Define the particle theory of matter and summarise the key ideas.
2. Draw a particle diagram for a solid, a liquid and a gas.
3. Draw the particle diagram for hydrogen and oxygen.

Science as a human endeavour: Democritus to John Dalton

Democritus was an ancient Greek philosopher who proposed the idea that all matter is made up of tiny, invisible particles. He called these particles *atomos*, meaning 'uncuttable' or 'indivisible'. You can see the word 'atom' in the word *atomos*.

His theories laid the foundation for modern atomic science but were largely ignored during his time because Aristotle's idea that matter is composed of earth, air, fire and water was far more influential.

Around two thousand years later, chemist John Dalton picked up where Democritus left off. Dalton became known as the 'father of atomic theory' because of his groundbreaking work with matter. He developed one of the first scientific atomic models in the early 1800s.

His key ideas included:

- Atoms are the building blocks of matter – each element is made up of unique atoms.
- Chemical reactions involve the rearrangement of atoms.
- Atoms are not created or destroyed in chemical reactions.
- Compounds are formed when atoms of different elements combine in fixed ratios (this is important to remember for later in the chapter).

4.5 Changing state

Matter can change from one state to another. Look at Figure 4.6, which shows the changing states of water.

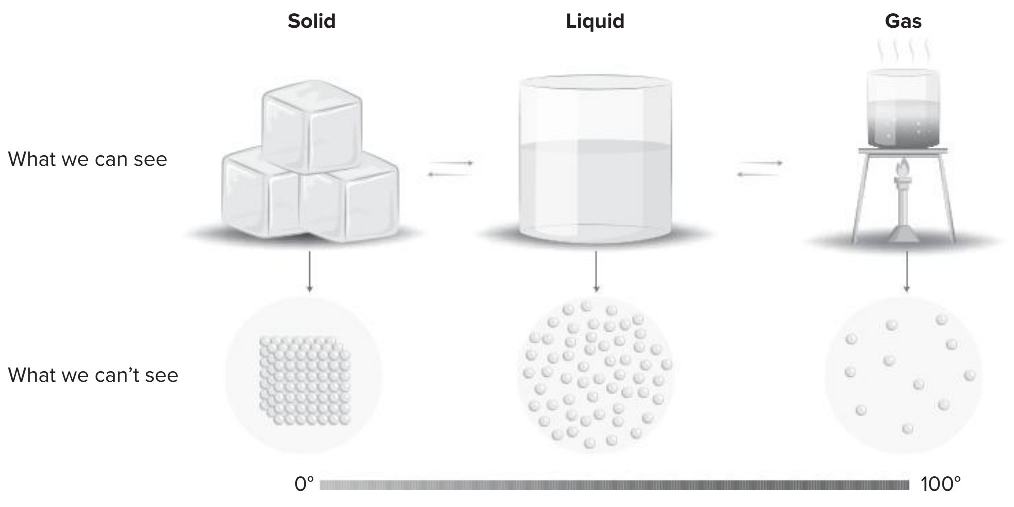


Figure 4.6: The changing states of matter

Water moves through the three states as the **temperature** changes. The temperature of a substance increases due to the introduction of thermal energy (heat), which gets transferred between particles. We can add thermal energy to increase temperature and remove it to decrease temperature.

A change in state happens because the particles vibrate faster or slower. For example, when the temperature of a liquid decreases, the particles lose thermal energy and vibrate more slowly. So, when you put liquid water into an ice cube tray and place it into a freezer, the temperature decreases, the particles slow down and solid ice forms.

Similarly, if the temperature in a solid increases, the particles begin to move faster and the strong connections between the particles start to break down. The substance moves into a liquid state and the particles move more freely. So, as ice is heated, its particles start to vibrate faster and the solid ice melts into liquid water.

If we continue to add thermal energy (heat), the particles will move even faster, the connections between the particles break completely and the individual particles are released from the liquid to form a gas.

Figure 4.7 shows the names for the changes of state.

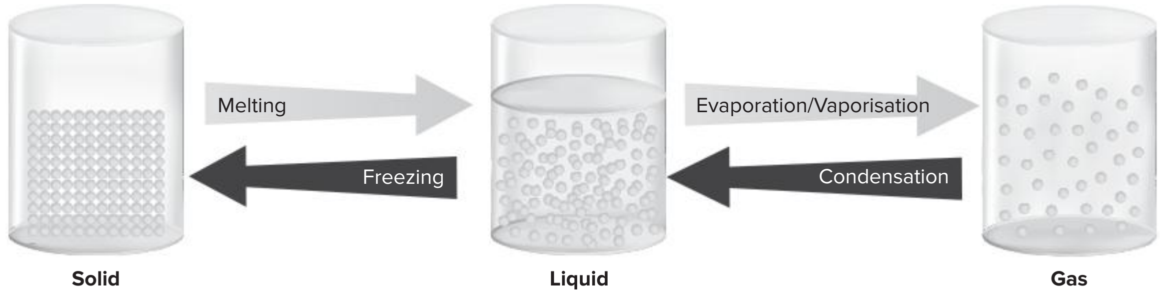


Figure 4.7: Names for different types of state changes

Activity 4.5.1

Explain how changes in temperature can change matter from one state to another.

Melting – thermal (heat) energy is increased

Melting is when a solid becomes a liquid. The point at which something melts is called its **melting point**. Water has a melting point of 0˚C. This is the point where ice melts to form liquid water. Different substances have different melting points. When a solid is heated, the thermal (heat) energy gets transferred to the particles, which start to vibrate because of the added energy. This kinetic energy loosens the connections between the particles. The particles have weaker connections to each other and move about faster in a more free-flowing way (liquid state).

Vaporisation/evaporation – thermal (heat) energy is increased

Evaporation, or vaporisation, is when liquid becomes a gas. The point where all of a liquid will evaporate is called the **boiling point**. Water has a boiling point of 100˚C; each substance has a different boiling point.

Evaporation happens when heat is applied to the liquid. The liquid particles start to move about faster. This weakens the connections between the particles to the point where individual particles are released into the air from the surface of the liquid.

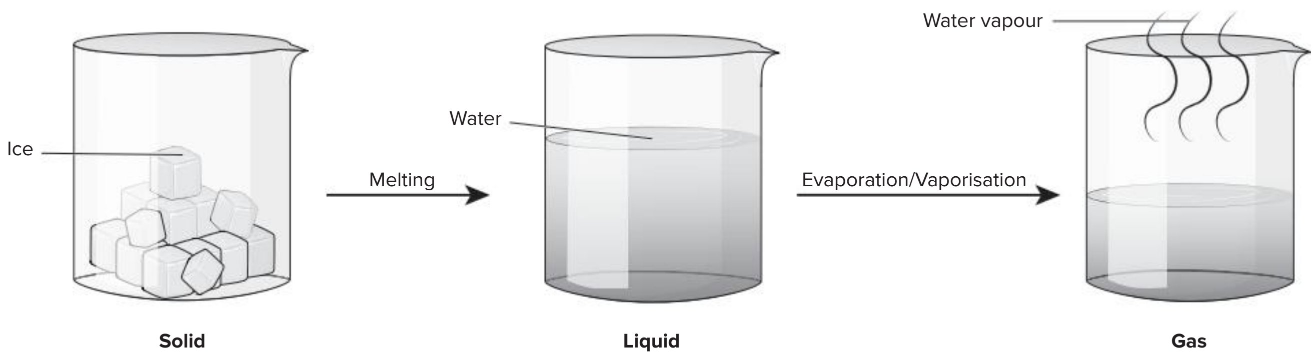


Figure 4.8: The changing states of matter: melting and evaporation/vaporisation

Activity 4.5.2

Explain how an increase in thermal energy changes matter from one state to another.

Condensation – thermal (heat) energy is reduced

Condensation is when a gas becomes a liquid. The heat energy is reduced. The gas particles lose energy and vibrate more slowly, and the connections between the particles re-form. When you have a hot shower, the bathroom mirror might get fogged up. This is because the heat vaporises some of the liquid water to a gas, and the gas moves around the bathroom and condenses on the cooler mirror to form liquid water droplets.

Evaporation and condensation are opposite processes.

Freezing – thermal (heat) energy is reduced

Freezing is when a liquid becomes a solid. When enough heat is removed from a substance, the particles move more slowly. This allows the connections between the particles to re-form, creating a solid.

Melting and freezing are opposite processes.

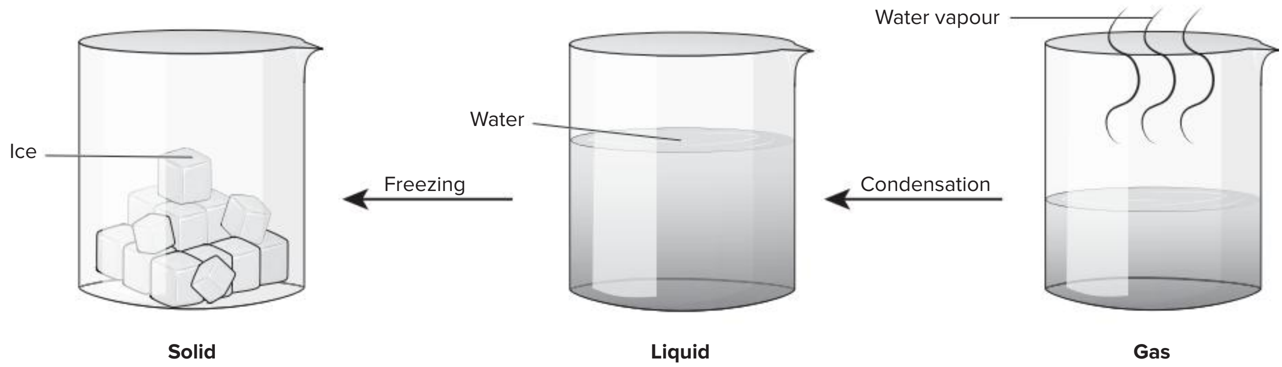


Figure 4.9: The changing states of matter: freezing and condensation

Activity 4.5.3

Explain how decreasing thermal energy changes matter from one state to another.

Some substances don't need to pass through the liquid state, when their state of matter changes. Dry ice changes from a solid straight to a gas, and from a gas straight to a solid.

- Changing from a solid to a gas is called **sublimation**.
- Changing from a gas to a solid is called **deposition**.

Sublimation and deposition are opposite processes.

Figure 4.10: Dry ice

In summary, there are six different types of state changes:

- melting
- freezing
- evaporation
- condensation
- sublimation
- deposition.

Melting, evaporation and sublimation involve an *increase* in heat. Condensation, freezing and deposition involve a *decrease* in heat.

4.6 Elements, compounds and mixtures

All matter is made up of two types of particles: atoms and molecules.

- **Atoms** are the basic unit of matter. There are 118 different types of atoms. These atoms can come together in different combinations to form different types of matter.
- **Molecules** are chemical structures made up of two or more atoms held in a fixed arrangement. They can consist of just one type of atom, but more often they consist of more than one type of atom. Molecules can contain as little as two atoms, or they can contain thousands of atoms.

Matter can be divided into pure substances and mixtures.

Pure substances

Pure substances are made up of one type of particle, an atom or a molecule.

They can be divided into elements and compounds.

Elements

An element is a pure substance that cannot be broken down into any other substance. Elements are made up of only *one* type of atom.

Examples are:

- oxygen (O)
- hydrogen (H)
- iron (Fe)
- gold (Au).

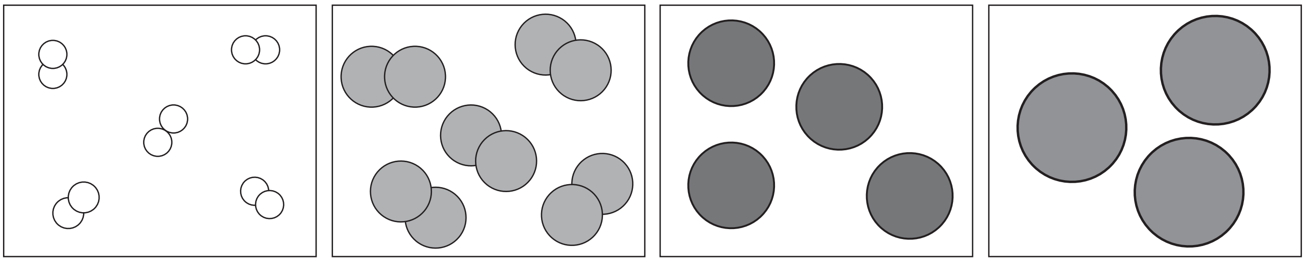


Figure 4.11: Elements are made up of only one type of atom

✎ Activity 4.6.1

1. Explain what a pure substance is.
2. Define the term 'element' and give three examples.

The **periodic table** is a chart that organises all the known elements. We will discuss this in more detail later.

Each element has a unique symbol, usually one or two letters. Examples of chemical symbols are O for oxygen, H for hydrogen and Fe for iron.

On the periodic table, the elements are organised into groups of elements with similar properties.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 **H** Hydrogen																	2 **He** Helium
2	3 **Li** Lithium	4 **Be** Beryllium											5 **B** Boron	6 **C** Carbon	7 **N** Nitrogen	8 **O** Oxygen	9 **F** Fluorine	10 **Ne** Neon
3	11 **Na** Sodium	12 **Mg** Magnesium											13 **Al** Aluminium	14 **Si** Silicon	15 **P** Phosphorus	16 **S** Sulfur	17 **Cl** Chlorine	18 **Ar** Argon
4	19 **K** Potassium	20 **Ca** Calcium	21 **Sc** Scandium	22 **Ti** Titanium	23 **V** Vanadium	24 **Cr** Chromium	25 **Mn** Manganese	26 **Fe** Iron	27 **Co** Cobalt	28 **Ni** Nickel	29 **Cu** Copper	30 **Zn** Zinc	31 **Ga** Gallium	32 **Ge** Germanium	33 **As** Arsenic	34 **Se** Selenium	35 **Br** Bromine	36 **Kr** Krypton
5	37 **Rb** Rubidium	38 **Sr** Strontium	39 **Y** Yttrium	40 **Zr** Zirconium	41 **Nb** Niobium	42 **Mo** Molybdenum	43 **Tc** Technetium	44 **Ru** Ruthenium	45 **Rh** Rhodium	46 **Pd** Palladium	47 **Ag** Silver	48 **Cd** Cadmium	49 **In** Indium	50 **Sn** Tin	51 **Sb** Antimony	52 **Te** Tellurium	53 **I** Iodine	54 **Xe** Xenon
6	55 **Cs** Caesium	56 **Ba** Barium	57–71	72 **Hf** Hafnium	73 **Ta** Tantalum	74 **W** Tungsten	75 **Re** Rhenium	76 **Os** Osmium	77 **Ir** Iridium	78 **Pt** Platinum	79 **Au** Gold	80 **Hg** Mercury	81 **Tl** Thallium	82 **Pb** Lead	83 **Bi** Bismuth	84 **Po** Polonium	85 **At** Astatine	86 **Rn** Radon
7	87 **Fr** Francium	88 **Ra** Radium	89–103	104 **Rf** Rutherfordium	105 **Db** Dubnium	106 **Sg** Seaborgium	107 **Bh** Bohrium	108 **Hs** Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

57 **La** Lanthanum	58 **Ce** Cerium	59 **Pr** Praseodymium	60 **Nd** Neodymium	61 **Pm** Promethium	62 **Sm** Samarium	63 **Eu** Europium	64 **Gd** Gadolinium	65 **Tb** Terbium	66 **Dy** Dysprosium	67 **Ho** Holmium	68 **Er** Erbium	69 **Tm** Thulium	70 **Yb** Ytterbium	71 **Lu** Lutetium
89 **Ac** Actinium	90 **Th** Thorium	91 **Pa** Protactinium	92 **U** Uranium	93 **Np** Neptunium	94 **Pu** Plutonium	95 **Am** Americium	96 **Cm** Curium	97 **Bk** Berkelium	98 **Cf** Californium	99 **Es** Einsteinium	100 **Fm** Fermium	101 **Md** Mendelevium	102 **No** Nobelium	103 **Lr** Lawrencium

Figure 4.12: The periodic table

Compounds

A compound is a pure substance made from more than one element. In a compound, elements are chemically bonded together, which makes it very hard to separate them. They can only be separated into their elements through chemical reactions.

When a compound is made, the atoms of the elements bond together in a fixed ratio. Therefore, each compound is represented by a chemical formula.

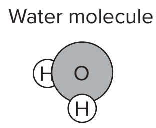
Examples are:

- water (H_2O) – made of hydrogen and oxygen
- carbon dioxide (CO_2) – made of carbon and oxygen

A water molecule (H_2O) consists of two hydrogen atoms and one oxygen atom. A carbon dioxide molecule (CO_2) consists of one carbon atom and two oxygen atoms. H_2O and CO_2 are chemical formulas. Compounds are always represented by a chemical formula.

Compounds often have different properties from the elements they are made of. For example, hydrogen and oxygen are gases, but together they form water, a liquid.

Compounds are not included on the periodic table. A diagram of a water molecule is shown below.



Activity 4.6.2

Define the term 'compound' and provide two examples.

Table 4.1: The differences between elements and compounds

Element	Compound
Made up of one type of atom	Made up of two or more elements
Represented by a symbol (e.g. Fe)	Represented by a formula (e.g. H_2O)
Cannot be separated into other substances	Can be separated chemically into their component elements

The difference between a molecule and a compound is that a molecule is any two or more atoms bonded together. It can be made of different elements or the same elements. However, compounds are always made of two or more different types of elements.

Activity 4.6.3

Explain the differences between an element and a compound. What is a similarity?

A particle model or diagram for a compound shows more than one type of atom. In Figure 4.13, you can see water molecules made up of two elements – hydrogen (small white atoms) and oxygen (grey atoms). Water has a fixed ratio of two hydrogen atoms to one oxygen atom.

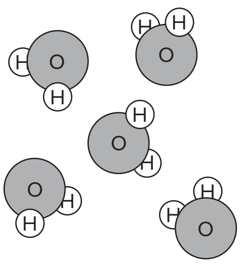


Figure 4.13: A particle diagram of water, H_2O

In Figure 4.14, you can see each particle in the water is made up of a molecule that has three atoms of two different types: two hydrogen atoms and one oxygen atom.

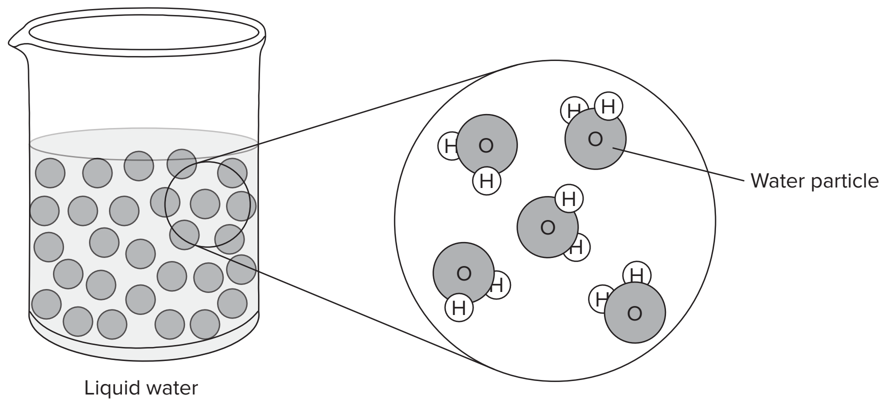


Figure 4.14: Each molecule of water is made up of two hydrogen atoms and one oxygen atom.

Figure 4.15 shows the compound carbon dioxide (CO_2). Carbon dioxide is made up of two elements – carbon (black atoms) and oxygen (grey atoms). Carbon dioxide has a fixed ratio of one carbon atom to two oxygen atoms.

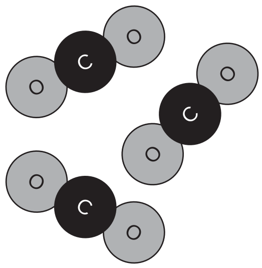


Figure 4.15: A particle diagram of carbon dioxide, CO_2

Mixtures

Mixtures are not pure substances. A mixture is formed when two or more elements or compounds/molecules are present without being chemically bonded together. Mixtures can be solids, liquids or gases.

The substances that have been mixed are not present in fixed ratios as they are in a compound. They can be in any combination. For example, when you mix cordial with water, you can have any amount of cordial or water depending on how strong or weak you want your cordial drink to be.

Mixtures can be separated by physical methods such as filtration (removing solid particles from a liquid or gas by using a filter) or distillation (heating a substance to boiling point then condensing the vapour back to liquid form).

Examples of mixtures:

- Saltwater – a mix of water and salt
- Cement – a mix of sand, water and gravel
- Air – a mix of various gases such as oxygen and carbon dioxide

Mixtures are the product of the combination of compounds and elements without chemical change. Each substance retains its original properties.

Mixtures can be either heterogeneous or homogeneous.

Activity 4.6.4

Define the term 'mixture' and provide two examples.

Heterogeneous mixtures

- The components of the mixture can be easily separated, and the substances are not evenly distributed.
- Examples: trail mix, pizza, fruit salad, salad dressing and chocolate chip biscuits.

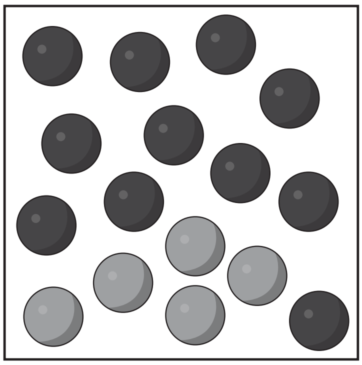


Figure 4.16: A particle diagram of a heterogeneous mixture

Homogeneous mixtures

- The components of the mixture cannot be easily separated, and the substances are evenly distributed throughout.
- Examples: lemonade, coffee, wine, vinegar, steel, brass and air.

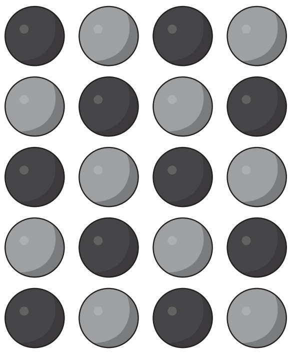


Figure 4.17: A particle diagram of a homogeneous mixture

Activity 4.6.5

Explain the difference between a heterogeneous mixture and a homogeneous mixture. List two examples of each type of mixture.

Types of mixtures

Let's take a closer look at three different types of mixtures.

A **solution** is a homogeneous mixture in which one substance dissolves into another. An example is sugar water.

A solution has two components:

- The **solvent** is the substance (e.g. water) that dissolves the other substance.
- The **solute** is the substance being dissolved (e.g. sugar).

A **suspension** is a heterogeneous mixture in which particles are dispersed but settle over time. An example is muddy water.

A **colloid** is a heterogeneous mixture in which the particles are evenly dispersed and do not settle over time. An example is milk.

Activity 4.6.6

Summarise the three types of mixtures and give an example for each.

Table 4.2: The differences between elements, compounds and mixtures

Element	Compound	Mixture
Made up of one type of atom	Made up of two or more elements	Made up of one or more pure substances
Represented by symbols (e.g. O), diagrams and models	Represented by formulas (e.g. H_2O), diagrams and models	Represented by percentages, particle diagrams and models
Cannot be separated into other substances	Can be **chemically** separated into their component elements	Can be **physically** separated into their component substances

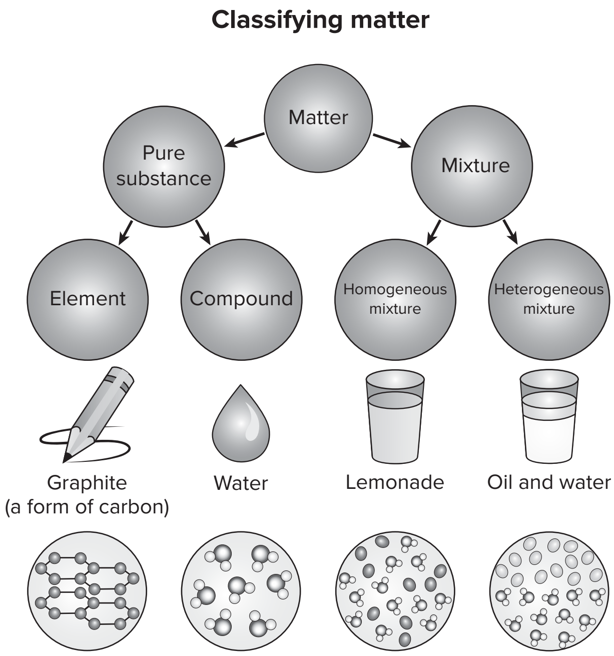


Figure 4.18: Classifying matter

Activity 4.6.7

Summarise the similarities and differences between elements, compounds and mixtures.

4.7 The periodic table of elements

So far, scientists have discovered 118 elements. The periodic table of elements is a way to summarise and simplify a lot of information about each of these elements on one simple table, including their symbol, state and mass.

Each element is given a symbol based on its name (e.g. the symbol for hydrogen is H). Sometimes the link between an element's name and its symbol is not immediately clear. In these cases, the symbol is often based on the name in a different language (e.g. the symbol for iron is Fe, which comes from the Latin name, *ferrum*).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 **H** Hydrogen																	2 **He** Helium
2	3 **Li** Lithium	4 **Be** Beryllium											5 **B** Boron	6 **C** Carbon	7 **N** Nitrogen	8 **O** Oxygen	9 **F** Fluorine	10 **Ne** Neon
3	11 **Na** Sodium	12 **Mg** Magnesium											13 **Al** Aluminium	14 **Si** Silicon	15 **P** Phosphorus	16 **S** Sulfur	17 **Cl** Chlorine	18 **Ar** Argon
4	19 **K** Potassium	20 **Ca** Calcium	21 **Sc** Scandium	22 **Ti** Titanium	23 **V** Vanadium	24 **Cr** Chromium	25 **Mn** Manganese	26 **Fe** Iron	27 **Co** Cobalt	28 **Ni** Nickel	29 **Cu** Copper	30 **Zn** Zinc	31 **Ga** Gallium	32 **Ge** Germanium	33 **As** Arsenic	34 **Se** Selenium	35 **Br** Bromine	36 **Kr** Krypton
5	37 **Rb** Rubidium	38 **Sr** Strontium	39 **Y** Yttrium	40 **Zr** Zirconium	41 **Nb** Niobium	42 **Mo** Molybdenum	43 **Tc** Technetium	44 **Ru** Ruthenium	45 **Rh** Rhodium	46 **Pd** Palladium	47 **Ag** Silver	48 **Cd** Cadmium	49 **In** Indium	50 **Sn** Tin	51 **Sb** Antimony	52 **Te** Tellurium	53 **I** Iodine	54 **Xe** Xenon
6	55 **Cs** Caesium	56 **Ba** Barium	57–71	72 **Hf** Hafnium	73 **Ta** Tantalum	74 **W** Tungsten	75 **Re** Rhenium	76 **Os** Osmium	77 **Ir** Iridium	78 **Pt** Platinum	79 **Au** Gold	80 **Hg** Mercury	81 **Tl** Thallium	82 **Pb** Lead	83 **Bi** Bismuth	84 **Po** Polonium	85 **At** Astatine	86 **Rn** Radon
7	87 **Fr** Francium	88 **Ra** Radium	89–103	104 **Rf** Rutherfordium	105 **Db** Dubnium	106 **Sg** Seaborgium	107 **Bh** Bohrium	108 **Hs** Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

57 **La** Lanthanum	58 **Ce** Cerium	59 **Pr** Praseodymium	60 **Nd** Neodymium	61 **Pm** Promethium	62 **Sm** Samarium	63 **Eu** Europium	64 **Gd** Gadolinium	65 **Tb** Terbium	66 **Dy** Dysprosium	67 **Ho** Holmium	68 **Er** Erbium	69 **Tm** Thulium	70 **Yb** Ytterbium	71 **Lu** Lutetium
89 **Ac** Actinium	90 **Th** Thorium	91 **Pa** Protactinium	92 **U** Uranium	93 **Np** Neptunium	94 **Pu** Plutonium	95 **Am** Americium	96 **Cm** Curium	97 **Bk** Berkelium	98 **Cf** Californium	99 **Es** Einsteinium	100 **Fm** Fermium	101 **Md** Mendelevium	102 **No** Nobelium	103 **Lr** Lawrencium

Figure 4.19: The periodic table

The layout of the periodic table can already provide us with some information about the different elements.

The elements are arranged in order of increasing atomic number (the top number of each square). Atomic numbers are the number of protons in the nucleus of an atom.

The elements are also organised into columns (vertical) and rows (horizontal).

The columns are called groups and are numbered 1–18. Groups contain elements with similar physical and chemical properties.

The rows are called periods and are numbered 1–7. Rows contain elements with varying physical and chemical properties.

Fun fact

The periodic table was created by Dmitri Mendeleev in 1869 and has been updated as new elements were discovered. An element discovered in 1955 was named mendelevium!

Elements can be classified according to whether they are solids, liquids or gases at room temperature. Most elements are solids. There are only two liquids – bromine and mercury. There are 11 gases, which mostly occupy the top right section of the periodic table.

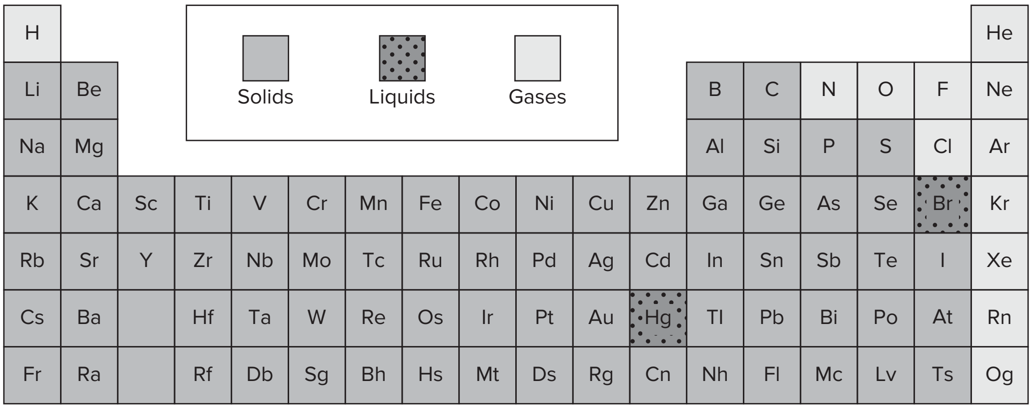


Figure 4.20: Solids, liquids and gases on the first six rows of periodic table

Elements can also be classified according to whether they are metals, metalloids (semi-metals) or non-metals. Most elements are metals, and these occupy the left and middle sections of the periodic table.

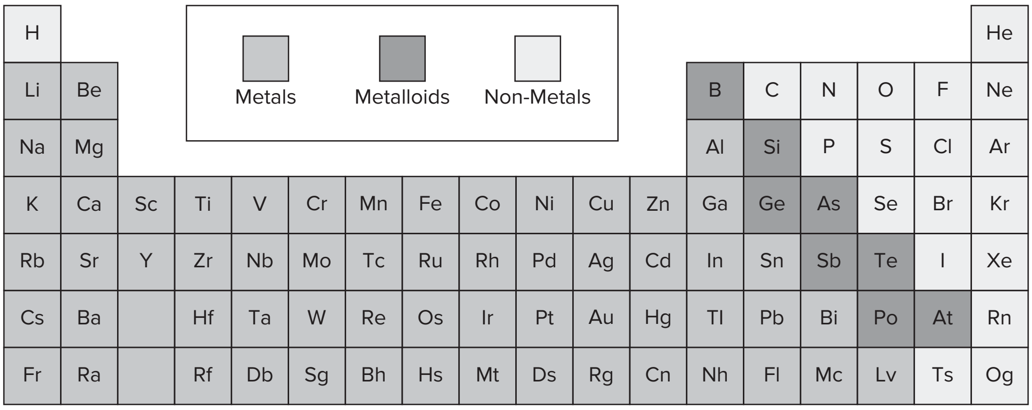


Figure 4.21: Metals, metalloids and non-metals on the first six rows of the periodic table

Properties of metals, non-metals and metalloids

- Metals are generally shiny, good conductors of heat and electricity, malleable (flexible), ductile (can bend without breaking), and have high melting and boiling points.
- Nonmetals are usually dull, poor conductors of heat and electricity, brittle when solid, and often have lower melting and boiling points.
- Metalloids have properties that are intermediate between metals and nonmetals. They often look like metals but behave like nonmetals.

Activity 4.7.1

Write five key points about the periodic table of elements.

Science as a human endeavour: Mendeleev

Dmitri Mendeleev was a Russian scientist. He is known as the 'father of the periodic table' for organising elements into a systematic table. His work helped to shape modern chemistry and made him one of the most influential figures in chemistry.

Mendeleev published his version of the periodic table in 1869. He also predicted the existence and properties of elements that had not yet been discovered. He observed that elements with similar properties appear at regular intervals when arranged by atomic mass (the mass of an atom), leading to the development of the periodic law: 'The properties of elements are periodic functions of their atomic mass'.

Key features of Mendeleev's periodic table:

- Rows (periods) – elements were arranged by increasing atomic mass.
- Columns (groups) – elements with similar properties were placed in columns.
- Gaps were left to indicate undiscovered elements.

Mendeleev's work provided a logical system for organising elements. His table was later modified to arrange elements by atomic number (number of protons) instead of atomic mass, but the structure remains similar.

Fun fact

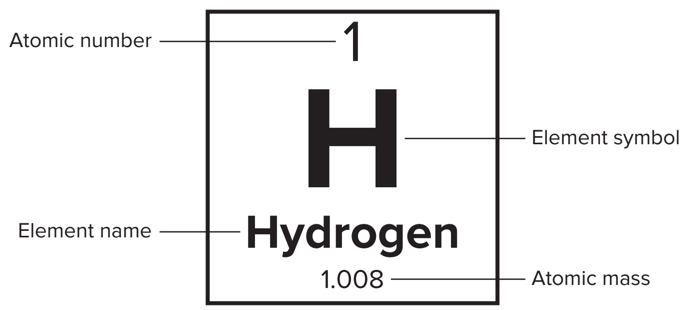
Mendeleev created a version of the periodic table on a deck of playing cards to help him to visualise it.

4.8 Symbols and formulas

Symbols

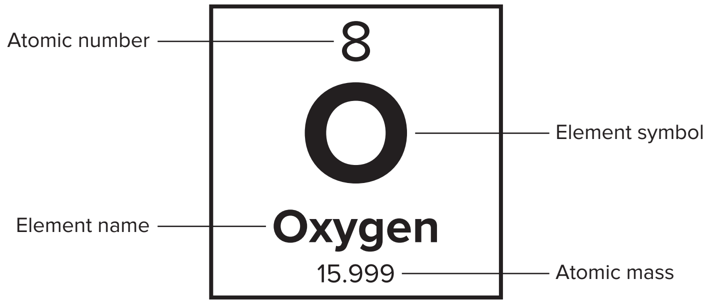
The symbols used to represent the elements on the periodic table are important to learn. They are what we use to represent all the elements, molecules and compounds in chemistry.

Let's look at the element hydrogen.



The symbol for hydrogen is a capital H. Hydrogen is the first element of the periodic table and has the smallest atomic number; hence, the number 1 above the symbol 'H'. The number below the element name is the mass number. Hydrogen has an approximate mass of 1.

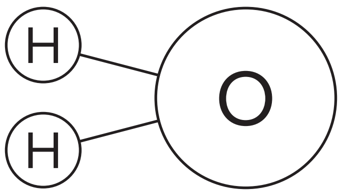
Let’s look at the element oxygen.



The symbol for oxygen is a capital O. Find the element oxygen on the periodic table in Figure 4.19. It is the eighth element and has an approximate mass of 16 (its official atomic mass is 15.999).

A water molecule is made up of two hydrogen atoms and one oxygen atom, H_2O.

We could draw it like this:



Two hydrogen atoms are connected to one oxygen atom. The lines joining the atoms are called **bonds**.

Activity 4.8.1

On a piece of paper, draw and label the elements hydrogen and oxygen as represented on the periodic table.

It is not necessary to memorise all the elements because you can refer to a periodic table, but it will be useful to try to learn the names and symbols for the first 20 elements, and some other common elements, as you will come across these a lot in chemistry.

Table 4.3: The first 20 elements

Atomic number	Element name	Element symbol
1	Hydrogen	H
2	Helium	He
3	Lithium	Li
4	Beryllium	Be
5	Boron	B
6	Carbon	C
7	Nitrogen	N
8	Oxygen	O

Table 4.3: Continued

Atomic number	Element name	Element symbol
9	Fluorine	F
10	Neon	Ne
11	Sodium	Na
12	Magnesium	Mg
13	Aluminium	Al
14	Silicon	Si
15	Phosphorus	P
16	Sulfur	S
17	Chlorine	Cl
18	Argon	Ar
19	Potassium	K
20	Calcium	Ca

Table 4.4: Common metal elements other than the first 20 elements

Atomic number	Element name	Element symbol
26	Iron	Fe
29	Copper	Cu
30	Zinc	Zn
47	Silver	Ag
50	Tin	Sn
79	Gold	Au
82	Lead	Pb

Table 4.5: Common non-metal elements other than the first 20 elements

Atomic number	Element name	Element symbol
35	Bromine	Br
53	Iodine	I

Formulas

A chemical formula is a shorthand way to represent a substance with symbols and numbers. It shows the types of elements present in a substance and the number of atoms of each element in a molecule or compound.

A formula includes:

- chemical symbols of each type of atom; for example, H (hydrogen), O (oxygen)
- small numbers (subscripts) that indicate how many of each atom is in a molecule (e.g. H_2O).

To write a chemical formula:

1. Identify the elements in the molecule (e.g. hydrogen, oxygen, carbon).
2. Count how many atoms of each element are in the molecule.
3. Write the chemical symbols of the elements from the periodic table.
4. Write the number of atoms as a small number (subscript) after the element symbol. If there's only one atom, no subscript is needed.

Examples of chemical formulas are listed below.

- Water (H_2O):

  2 hydrogen atoms

  1 oxygen atom.
- Carbon dioxide (CO_2):

  1 carbon atom

  2 oxygen atoms.
- Methane (CH_4):

  1 carbon atom

  4 hydrogen atoms.
- Oxygen molecule (O_2):

  2 oxygen atoms.

The best way to learn is to practise writing them!

Order of elements:

- Hydrogen is written last, except when combined with oxygen or a halogen (Group 17 on the periodic table: Fluorine, Chlorine, Bromine, Iodine, Astatine, Tennessine).
- In organic molecules (those containing carbon), write C first, then H, followed by other elements.
- Example: CH_4 (methane).

Subscripts show the ratio of atoms:

- Subscripts are always whole numbers.
- Example: In CO_2, the ratio of carbon to oxygen atoms is 1:2.

Brackets are used for groups:

- If a group of atoms repeats, use brackets and a subscript.
- Example: Calcium hydroxide is $Ca(OH)_2$:

  1 calcium atom

  2 oxygen atoms

  2 hydrogen atoms.

When you have a compound with a metal and a non-metal, always write the metal first.

When a compound has two non-metals, write the element further to the left of the periodic table first.

If both non-metals are in the same group (the same column) write the one with the larger atomic number first.

Table 4.6: Common compounds and their chemical formulas

Compound name	Formula
Water	H_2O
Carbon dioxide	CO_2
Carbon monoxide	CO
Hydrochloric acid	HCl
Sulfuric acid	H_2SO_4
Nitric acid	HNO_3
Sodium hydroxide	$NaOH$
Ammonia	NH_3
Sodium chloride	$NaCl$
Copper sulfate	$CuSO_4$
Calcium carbonate	$CaCO_3$

Activity 4.8.2

Write the formulas for the following compounds.

Compound	Number of atoms	Formula
Hydrochloric acid	One hydrogen and one chlorine atom	
Ethene	Two carbon and four hydrogen atoms	
Aluminium oxide	Two aluminium and three oxygen atoms	
Sodium hydroxide	One sodium, one oxygen and one hydrogen atom	

4.9 Reactions

Have you baked a cake or lit a match? Or have you ever left something metal out in the rain, and it went rusty? These all involve reactions.

There are two types of reactions: physical reactions and chemical reactions. We call these reactions changes – physical changes or chemical changes.

Physical change

A physical change is when changes occur to the appearance of a substance, but the type of substance does not change. The substance may change shape, size, colour, texture or state of matter, but the same substance is present before and after the change. It could be melting ice to water (solid to a liquid) or crushing a rock into smaller parts. It is also the formation of mixtures such as whisking eggs with milk, preparing a salad or creating a potting mix. The formation of a mixture is a physical process.

An other example is chopping wood. When we chop or cut wood, we are physically changing it to a smaller size, but it is still wood.

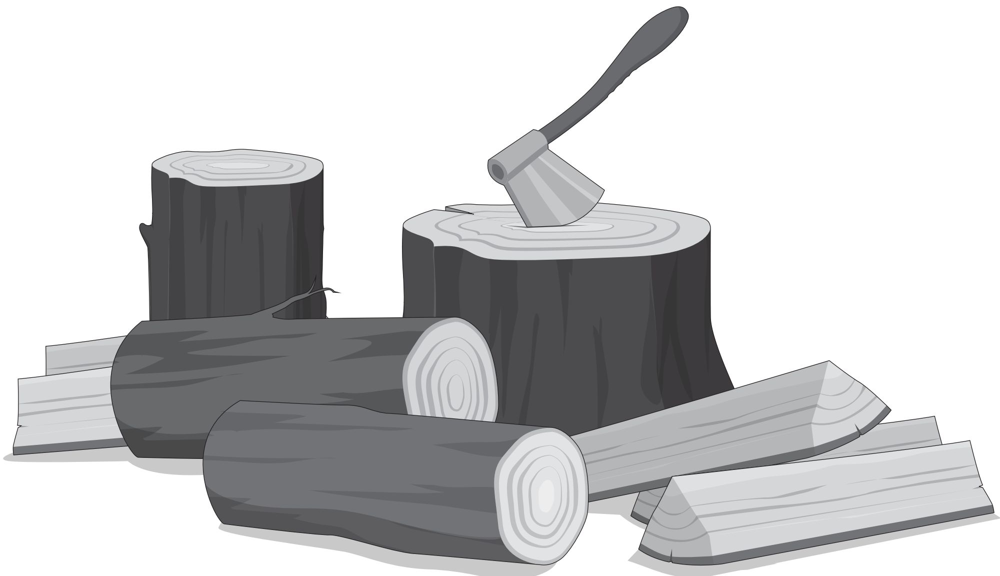


Figure 4.22: Chopping wood involves a physical change.

Chemical change

There are many types of chemical changes. However, it is important to remember that it is not always easy to determine if a chemical change has occurred or whether a change in appearance is purely physical. This is because often a chemical change involves a physical change as well.

A chemical change is where the chemical nature of the matter has changed, and a new substance is formed. The atoms in the matter have rearranged to form something new.

There are certain signs to look for that indicate that a chemical change has taken place. These include:

- colour change – for example, rusting iron, ripening fruit, bleaching hair and burning toast. However, not all colour changes are chemical changes
- formation of bubbles or odours – for example, the smell of rotting rubbish, the fumes from car exhaust, and fizzing when acid contacts a metal. However, not all bubbles and odours are chemical changes

- disappearance or formation of a new solid
- formation of a solid substance – also known as a precipitate
- temperature change (release or absorption of heat) – chemical changes involve the transfer of heat energy, which is sometimes accompanied by light and occasionally sound. Burning coal in a steam engine, igniting fireworks and activating instant cold packs are examples where you would see a temperature change. However, not all changes in temperature are caused by chemical changes.

When we burn wood, it is a chemical change or reaction called combustion. When wood is burnt, it is transformed to ash, which has a different chemical composition, and carbon dioxide is released into the atmosphere. Water vapour is also produced. We can't see the gas produced, but it is there.

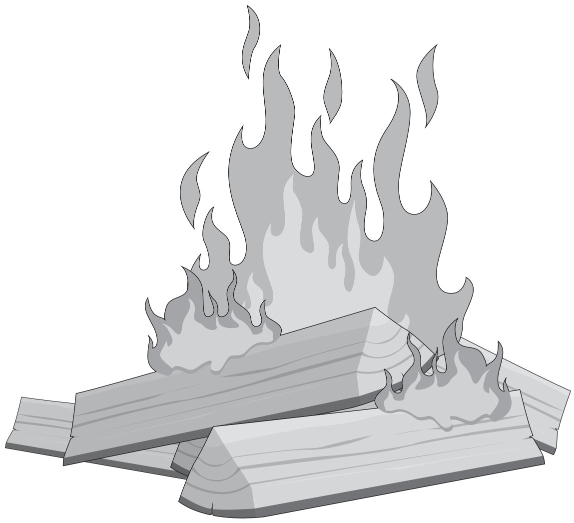


Figure 4.23: Burning wood involves a chemical change.

Activity 4.9.1

1. Summarise the differences between a physical change and a chemical change.
2. List some of the main indicators of a chemical change.
3. Use the wood example to explain a physical and a chemical change.

A chemical change involves breaking and forming chemical bonds between atoms. Atoms and molecules are rearranged, but the number and types of atoms remains the same. In other words, there is a conservation of mass (the total mass stays the same).

All chemical changes involve energy changes and the transfer of heat energy. Depending on the change, energy can be released or absorbed.

When energy is released in a reaction, it is called an **exothermic** chemical change – energy is released in the form of heat and sometimes light and sound. Examples are combustion (burning wood), burning a candle and lighting a match.

When energy is absorbed in a reaction, it is called an **endothermic** chemical change – heat energy is absorbed from the surrounding environment. Examples are cooking an egg and photosynthesis.

Activity 4.9.2

Summarise the differences between an exothermic chemical change and an endothermic chemical change, and provide an example of each.

Chemical equations

Chemical reactions can be described in an abbreviated form, known as a chemical equation. A chemical reaction involves two or more substances, known as **reactants**, interacting to form one or more new substances, known as **products**.

There are two ways to write chemical equations, with words or with formulas.

Word equations contain the chemical names of all reactants and products.

The word equation for the chemical reaction between baking soda and vinegar is:

sodium hydrogen carbonate + acetic acid ⟶ sodium acetate + carbon dioxide + water

The arrow represents the process occurring that results in the change. The words on the left-hand side of the arrow are called the reactants, which are what react together. The words on the right-hand side are called products, which are produced as a result of the reaction.

Formula equations contain the chemical symbols for all reactants and products.

The formula equation for carbon dioxide is:

$$C + O_2 \longrightarrow CO_2$$

The formula equation for the reaction between baking soda and vinegar is:

$$NaHCO_3 + CH_3COOH \longrightarrow NaCH_3COO + CO_2 + H_2O$$

Activity 4.9.3

1. What is the purpose of a chemical equation?
2. What is the difference between a word equation and a formula equation?
3. Write the word equation and the formula equation for the reaction between baking soda and vinegar.

Reversibility of physical and chemical changes

Most physical and chemical changes are reversible, and generally physical changes are easier to reverse than chemical changes. This is because physical processes do not require as much energy as chemical processes because they do not involve the breaking of chemical bonds.

If a car has dents in it, the dents in the metal can be beaten out, but rust on the car is a chemical change that requires more energy and complex chemical processes to reverse.

4.10 Types of chemical reactions

Chemical reactions involve the rearrangement of atoms to form new substances. They can be categorised according to how the atoms and molecules are rearranged. Chemical reactions can also be classified according to the energy changes that take place.

Combination reactions

Combination reactions involve two or more reactants combining to form a single product.

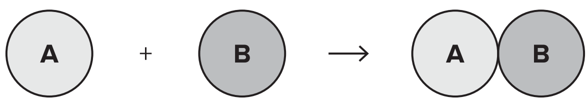


Figure 4.24: A combination reaction

Some examples of combination reactions are:

hydrogen + oxygen ⟶ water

$H_2 + O_2 \longrightarrow H_2O$

carbon monoxide + oxygen ⟶ carbon dioxide

$CO + O_2 \longrightarrow CO_2$

Decomposition reactions

Decomposition reactions involve a single reactant breaking down to form two or more products.

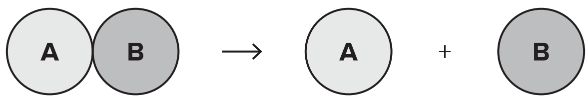


Figure 4.25: A decomposition reaction

An example of a decomposition reaction is:

magnesium nitride ⟶ magnesium + nitrogen

$Mg_3N_2 \longrightarrow Mg + N_2$

Activity 4.10.1

Explain the main difference between a combination reaction and a decomposition reaction.

4.11 Chemical properties

Chemical substances have different properties. These properties can be physical or chemical. Table 4.7 shows some of the many types of physical and chemical properties.

Table 4.7: Common properties of chemical substances

Property	Description	Example
Toxicity 	This refers to whether the chemical substance can cause harm to humans, animals or environmental health. The substance can cause a toxic reaction.	Mercury is a toxic substance. It can harm the body and even cause death.
Flammability 	This refers to how easily a substance will burn.	Petrol is highly flammable.

Table 4.7: Continued

Property	Description	Example
Corrosion 	This refers to when a substance deteriorates due to chemical reactions with the environment. Some parts of the substance will be chemically changed.	Many metals corrode when they are left in the environment. Rust is a form of corrosion.
Heat of combustion 	This refers to how much thermal or heat energy is released when a substance is burnt in the presence of oxygen.	When we burn a substance (e.g. ethanol, coal, methane and butane), we can measure how much heat is released to determine the heat of combustion.
Reactivity 	This refers to how likely it is that a substance will react with another to form a new substance. We can predict how reactive a substance will be based on its atoms.	Elements in Group 1 of the periodic table (e.g. lithium, sodium and potassium) are reactive.

We can use the periodic table to help us understand the physical and chemical properties of elements because they are arranged and grouped according to their properties.

It is important to understand the properties of substances so that we can use them safely and correctly. For example, a substance's flammability will affect when, how and under what conditions we should use it. We also need to know if a substance is toxic, so that people can be warned with appropriate labels and instructions.

Activity 4.11.1

1. Why is it important to understand the properties of chemicals?
2. List five properties of chemicals with examples.

4.12 First Nations peoples' knowledge of chemistry – pigments and dyes

First Nations people have been sourcing and using natural pigments and dyes for tens of thousands of years for cultural, artistic and ceremonial purposes. These natural pigments and dyes are sourced from the environment.

Pigments are intensely coloured molecules that impart colour to other materials. They are generally insoluble (can't be dissolved), and are ground into a powder and mixed with a liquid to make a mixture, specifically a suspension mixture. They usually need a binder, sometimes called a binding agent, to bind the pigment particles together. First Nations people mix pigments with animal fat or water to create body paints, and paint for rock art and tool and weapon decoration.

Examples of pigments:

- Black pigments are primarily created from particles of carbon (charcoal).
- Ochre is a clay-rich component made of iron and oxygen that comes in colours of red (haematite, Fe_2O_3), yellow (limonite, $FeO(OH){\cdot}nH_2O$), white (kaolin) and brown. Limonite can turn red when heated.

Dyes are soluble (can be dissolved) substances that stain or colour materials such as skin, fabric or hair. Dyes are mixtures, more specifically, solutions. First Nations people use natural materials such as bark, berries and roots to create dyes to dye natural string for weaving and as well as other useful objects.

First Nations peoples' use of pigments and dyes not only highlights their connection to Country, but also their early application of chemistry. These practices also reflect a sustainable approach to the use of natural resources.

Science as a human endeavour: The development of rapid chemical tests

Rapid chemical tests are important tools in science and everyday life. Over time, scientists have developed faster and more reliable ways to detect substances and identify materials. Rapid chemical tests are portable, easy to use, save time, improve safety, and allow quick decision-making in many fields.

The purpose of a rapid chemical test is to provide results quickly, without the need for complex equipment. One of the more recent and common rapid chemical tests is the COVID-19 Rapid Antigen Test (RAT). This test helped save many lives!

Other examples of rapid chemical tests are:

- food safety tests that can detect harmful bacteria such as *Salmonella* and *E. coli* in food
- environmental tests that can check water or air quality for pollution, such as carbon monoxide detectors
- medical tests that can check blood sugar levels and detect the presence of infections
- forensic tests that are used at crime scenes to identify substances such as drugs or blood.

Many of these tests rely on chemical reactions that produce observable changes such as colour changes or the release of gas.

Rapid chemical tests are a vital part of modern science, providing quick and reliable results that affect medicine, the environment and everyday life. These innovations highlight how chemistry continues to improve our world.

Chapter 5 – Science inquiry skills

5.1 Conducting an investigation

Scientists conduct investigations to test their ideas about the world. All the facts you have read in this book have been investigated!

We can be scientists too. We may have an idea that something is true, but if we want to be sure about it, we need to test our guess – the **hypothesis** – and gather evidence to prove our idea is correct.

For example, a friend tells you that a long, narrow paper plane will fly further than a short, wide paper plane. You are not sure if they are correct. The best way to find out is to conduct an investigation to determine whether the claim is true.

Key term

hypothesis	an educated guess or idea about something that has not yet been proven

5.2 Asking and framing your question

The first part of any investigation is deciding what we want to find out. Scientists ask questions about the world around them to try to understand the universe. We need to ask a specific question about what we want to find out. In addition to that, we need to frame the question so that we can investigate it. This initial framework involves defining our aim and stating our hypothesis.

Aim

The aim is the end goal for your investigation. In the paper plane example, some aims could be to make a paper plane that flies the highest, stays up the longest or does the most loops. Your aim is to find the design that will enable the paper plane to fly the furthest distance.

Start an aim with 'To' and follow with words such as 'investigate', 'observe', 'determine' or 'measure'. For example, Aim: To investigate how the design of a paper plane affects the distance it can fly.

Hypothesis

The next step is to write your hypothesis. The hypothesis should be an **educated guess** about the result of your investigation. It should be based on knowledge you already have about the subject. So your hypothesis might be that a long, narrow paper plane would fly further than a short, wide paper plane. This is based on the design of regular aeroplanes you have seen.

You would not say your hypothesis is that your paper plane will fly to the Moon! That is not an educated guess, as we know from experience throwing paper planes that it is not likely to happen.

Write your hypothesis as an 'If, then' statement. For example, 'If a paper plane is long and narrow, then it will fly further'. Your hypothesis could be wrong – and this is okay. What matters is that you can test it. Putting everything together gives us the following:

- Aim: To investigate how the design of a paper plane affects the distance it can fly
- Hypothesis: If a paper plane is long and narrow, then it will fly further than one that is short and wide.

5.3 Planning your investigation

The next step is to plan your investigation. This means you need to think about how you will conduct your investigation to get the best evidence, what equipment you might need and how you will conduct the investigation safely and ethically.

To ensure you get the best evidence, you need to identify your variables.

Variables

There are three types of variables: the independent variable, the dependent variable and the controlled variables.

- The **independent variable** (IV) is the thing we test – the thing we change in the investigation.
- The **dependent variable** (DV) is the thing we measure. This will give us results from our investigation.
- **Controlled variables** are the things we keep the same. There can be lots of these!

> **Remember it!**
>
> The independent variable is just that – Miss Independent! It gets to **change**.
>
> The dependent variable **depends** on its buddy. It will only change if Miss Independent changes. Then you get to **measure** it.

For example, imagine you want to investigate whether the design of a paper plane affects how far it can travel. For any investigation, you can find the variables by going back to your hypothesis: A paper plane that is long and narrow will fly further than one that is short and wide.

- The independent variable would be the different designs of paper planes. You **change** this.
- The dependent variable would be how far each plane travels. You **measure** this.
- Some controlled variables would be the type of paper used, the throwing location and the person throwing the plane. Keep these the same.

Going back to our hypothesis, the 'If, then' statement helps us identify our variables.

If a paper plane is *long and narrow* (IV), then it will *fly further* (DV).

Materials

Next, consider what equipment you might need – your materials. In the case of a paper plane investigation, the equipment needed should be straightforward, but other investigations are far more complex and require specialised scientific equipment.

The materials list would be:

- sheets of paper (A4 size)
- tape measure (at least 4 metres long)
- chalk or tape to create a throwing line
- notebook and pen/pencil for recording results
- a large, open area, such as a hallway or playground, without wind or obstacles.

Determining the method

Now you can decide on the procedure – the **method** – you will follow for the investigation. First, choose the two designs for the planes.

Long and narrow design – Plane A

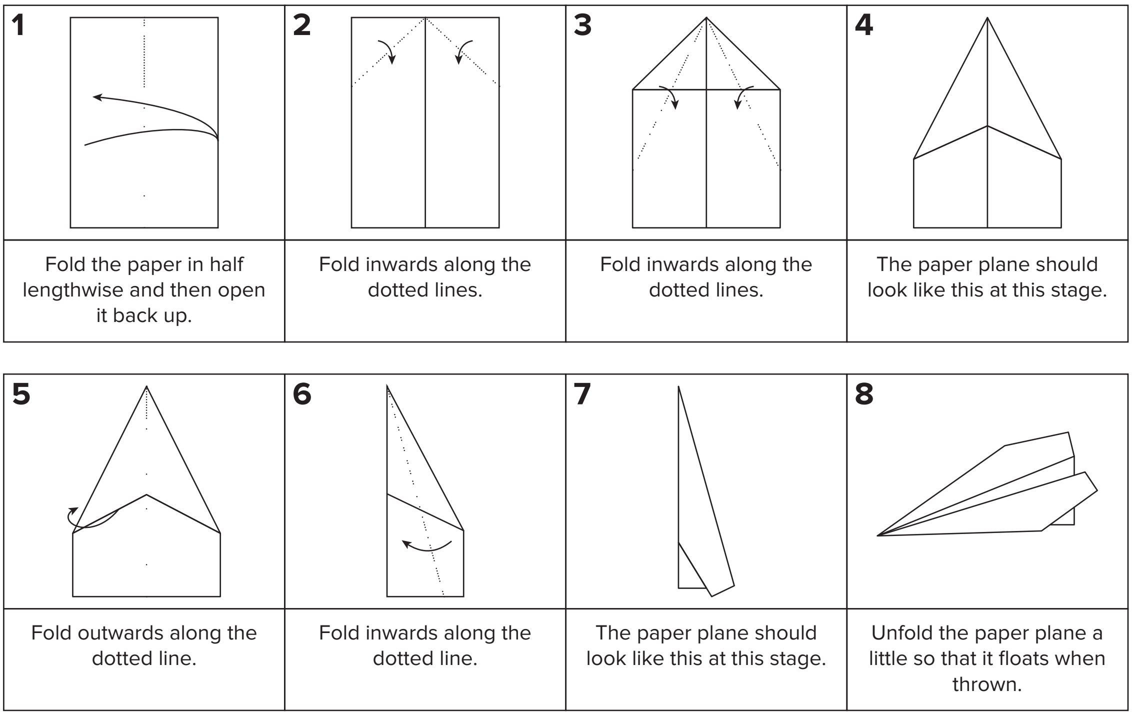


Figure 5.1: Follow the steps to make Plane A.

Wide and short design – Plane B

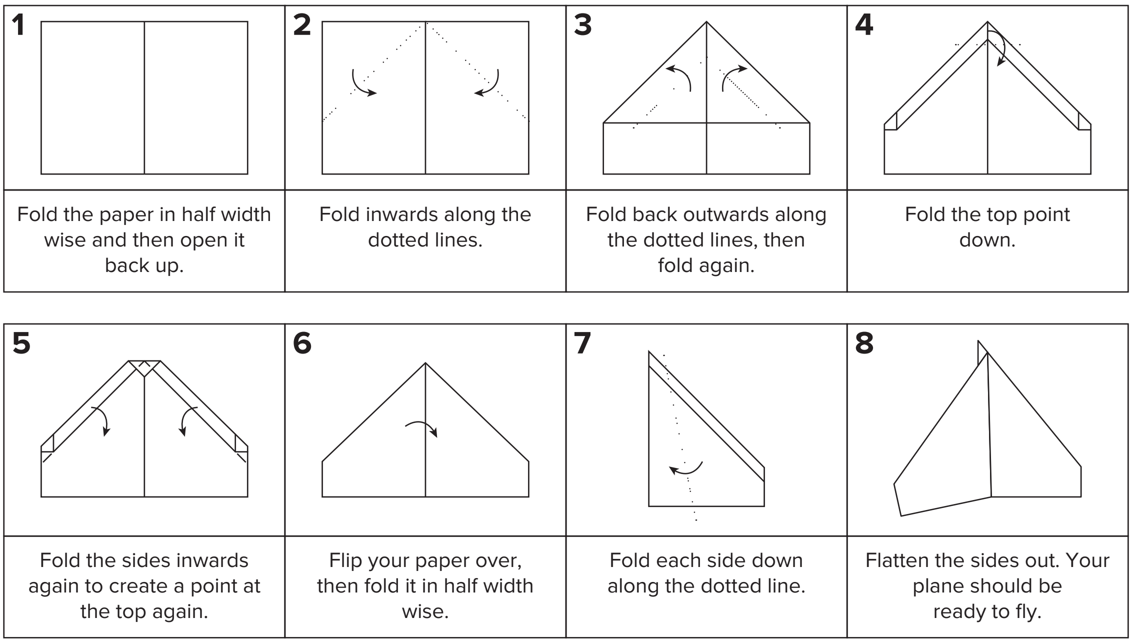


Figure 5.2: Follow the steps to make Plane B.

Then you can make the two planes.

Next, decide how to measure the flight distance. You will need to mark a throwing line and use a tape measure to measure from that line to the plane once it lands. You will also need to find a location protected from the wind so that it doesn't affect the results.

You can now write your method. Make each step clear and concise to help you achieve your aim.

Method

1. Fold a sheet of A4 paper, into the long and narrow design (Plane A, Figure 5.1).
2. Fold a second sheet of A4 paper, into the short and wide design (Plane B, Figure 5.2).
3. In a hall or other large, sheltered space, mark a throwing line at one end with chalk or tape.
4. Throw Plane A and measure the distance it travels. Record this in your notebook.
5. Throw Plane B and measure the distance it travels. Record this in your notebook.
6. Repeat steps 4 and 5 two more times. (Make sure the same person throws the planes, and they use the same throwing technique every time.)

5.4 Risk assessment

Being safe is crucial when you perform investigations, and in the science laboratory in general. The safety part of science is not exciting – you just need to accept that it is one of the most important factors in any investigation. You must work to minimise hazards, identify materials that could be dangerous and wear safety equipment.

Safety tips

Most of these tips are common sense things you already know, but a reminder never hurts!

- Wear safety goggles to protect your eyes.
- Tie back long hair to avoid it getting caught in anything. Avoid dangling jewellery.
- Wear close-toed shoes to protect your feet.
- If you are using hazardous material, find and follow the safety information for that material.
- Take care with anything hot or heated, such as Bunsen burners, or substances and equipment heated in an investigation.
- Never run in the science lab.
- And finally, follow all instructions from your teacher.

Extension

Make your own lab safety poster highlighting a rule not already on this list. Make sure your poster says why the rule is important.

The paper plane investigation is very safe. The only precaution you need to take is ensure no one is standing where the planes are being thrown. (And try to avoid getting a paper cut when folding!)

Ethics

Another thing to consider is whether an investigation is **ethical**. This is particularly important when performing investigations involving animals or people. We must balance the need to find an answer to our question with what is best for the participants and the researchers. For example, while it may not be illegal to investigate ways to make high-school students cry, it certainly wouldn't be ethical, particularly if the students didn't know that was the aim of your investigation.

Key term

ethical	following principles to guide you in doing what is morally right

Luckily, there are no ethical concerns for the paper plane investigation.

5.5 Displaying your results

Once you have conducted your investigation, it is time to display your results. Each measurement you have taken is one point of data. You can put these points in a table, called a results table.

Results table

Table 5.1 shows the distance of each plane throw in centimetres. It is important to include the unit of measurement (centimetres) in case someone else wants to compare or **replicate** your results.

Key term

replicate	reproduce by repeating a process or procedure

Table 5.1: Results table for throw distance of paper planes

Plane design	Throw distance (cm)		
	Throw 1	Throw 2	Throw 3
Plane A (long, narrow)	269	358	333
Plane B (short, wide)	273	255	285

You should throw your paper planes multiple times to make the results more accurate. If you threw the plane once, a freak gust of wind or a trip-up when throwing might distort the data. It is better to perform the test a few times and then take an average of your results.

Graphing

Another way to display your results is as a graph. This can make your results easier to interpret, particularly if they are complex. Some people understand numbers better if they are shown visually.

The most common graphs used in science are column (bar) graphs and line graphs. A couple of examples are shown in Figures 5.3 and 5.4. Figure 5.3 shows a bar graph created, using the results of our investigation. The graph is annotated to show you the important features.

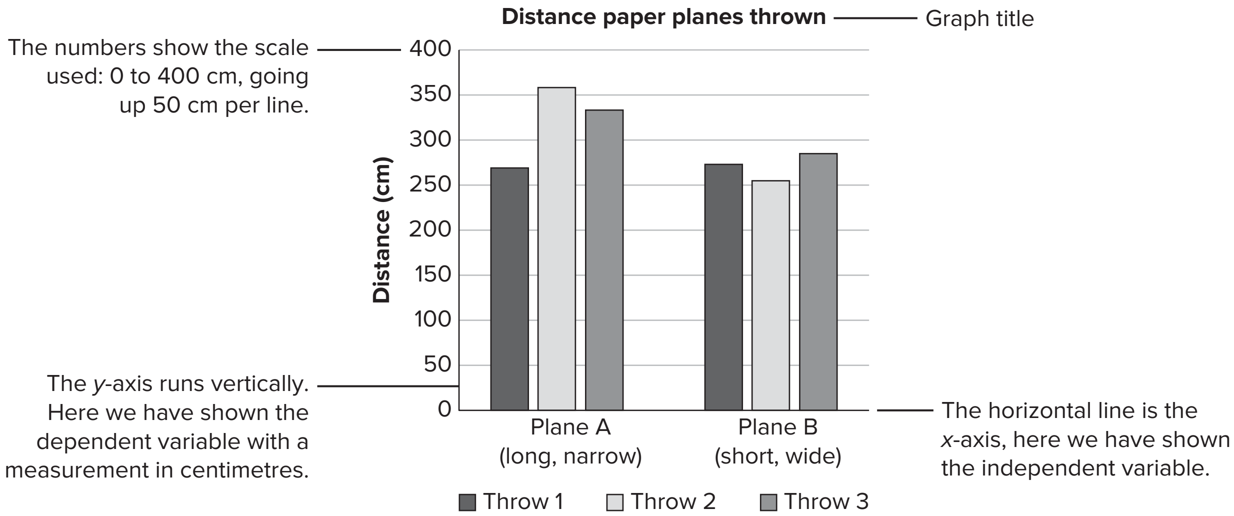


Figure 5.3: A column graph showing the results of the paper plane investigation

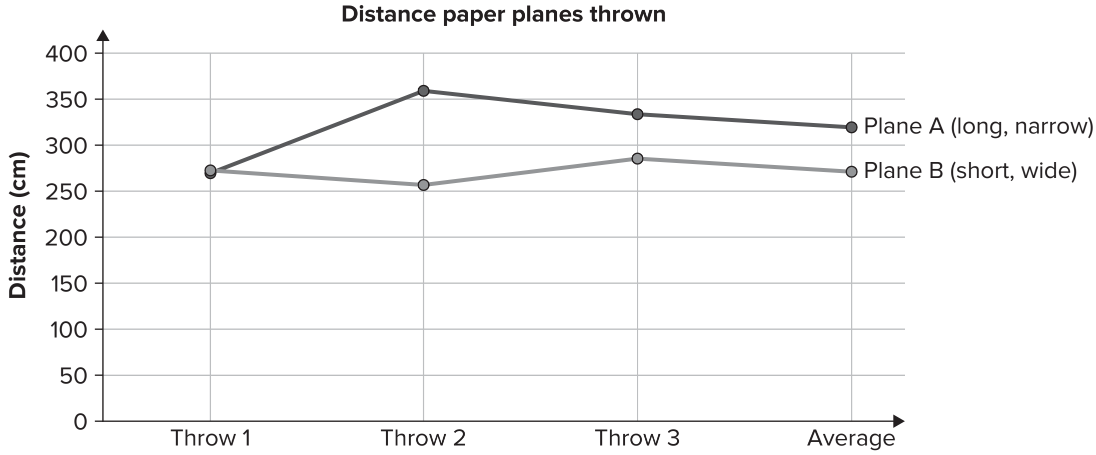


Figure 5.4: A line graph showing the results of the paper plane investigation.

Think about it

Another common type of graph is a pie chart. It is usually used to show parts of a whole. Why wouldn't a pie chart be the best way to display the results of your paper plane investigation?

Analysing your data

You can now analyse your results to find out if your hypothesis was correct. First, find the average (the mean) of the data.

Add up the three distances for Plane A and divide it by 3:

$$269 + 358 + 333 = 960$$

$$960 \div 3 = 320$$

The average distance for Plane A is 320 cm.

Add up the three distances for Plane B and divide it by 3:

$$273 + 255 + 285$$

$$813 \div 3 = 271$$

Add this information to your results table.

Table 5.2: Results table for throw distance of paper planes, including average distance

Plane design	Throw distance (cm)			
	Throw 1	Throw 2	Throw 3	Average
Plane A	269	358	333	320
Plane B	273	255	285	271

It is clear the paper plane that was long and narrow flew further than the plane that was short and wide. Your hypothesis was correct!

5.6 Reporting your findings

The final step of any investigation is to report what you have discovered. In your investigation report, this part is called the discussion. You need to summarise your findings and draw a conclusion about what you have learned. You could also discuss anything that went wrong or anything you might like to improve on.

In your report, you should state the following.

- What you know about aeroplane design generally.
- What you discovered (Which plane flew furthest?) and what that might mean. For example, you could explain what the differences in flight distance might mean. Other factors to consider are air resistance, weight distribution and the shape of the wings.
- Was your hypothesis correct? Why or why not?
- Was your investigation accurate and precise? Were your results reliable?
- What could you do to improve your experiment?

You could also look at ways to make the investigation results **accurate** and **precise**. These terms have specific meanings in an investigation.

Key facts

An investigation can be accurate, precise, neither or both!

Something is **accurate** if it is as close to the correct value as possible. For example, if you shoot three arrows and they all land around the centre circle of a target, your shots are accurate.

Something is **precise** if its measurements are very close together. For example, if you shoot three arrows and they all land next to each other on one side of the target, your shots are precise.

When measuring, you need to be careful that your equipment is working properly, and you are using it correctly. For example, if you measured the length of your paper plane flights but didn't place the tape measure exactly on the throwing line, your measurements might be precise, but they would not be accurate.

If you shoot three arrows and they land all over the target, with none in the centre circle, then you are neither accurate or precise.

You want to be both accurate and precise: you want your arrows to land close together in the centre circle.

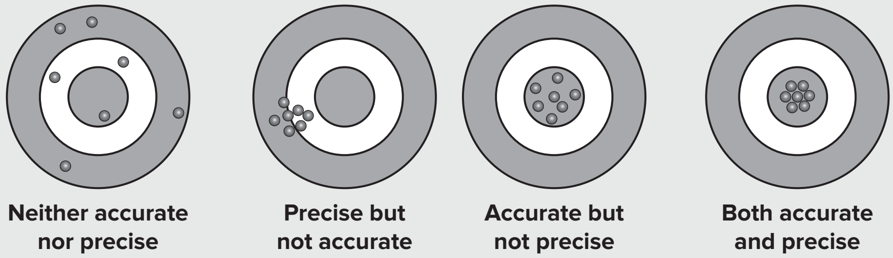


Figure 5.5: Examples of precision and accuracy

If your results are accurate and precise, and particularly if you have conducted your test multiple times, your results can be said to be **reliable**.

To make sure the paper plane investigation is reliable, you should do multiple throws of each paper plane to gather more results and ensure that you measure the distance travelled from the throwing line precisely. You could even use a laser measuring tool instead of a tape measure, if one was available, to increase the precision of your measurements.

For example, you could do six throws for each plane instead of three to collect more data, or two people could throw each plane three times, to make sure one person's throwing technique wasn't influencing the experiment.

Your discussion might look something like the following.

Discussion

Aerodynamics is the way objects move through air. The rules of aerodynamics explain how a paper plane can fly. Anything that moves through air is affected by aerodynamics.

The results show that Plane A, the long and narrow design, flew the furthest on average. This supports my hypothesis that a longer and narrower design would perform best. It is more aerodynamic. Plane B, the wide and short design, had a shorter average flight distance, which was probably due to the increased **air resistance** caused by its wider shape.

One factor that could have influenced the results is variations in the throwing technique. Repeating the experiment with two people throwing each plane three times each might help by providing more data and varying how the planes are thrown.

Key terms

aerodynamics	the study of air and how it moves, and the interaction between the air and objects moving through it.
air resistance	a force that slows down objects as they move through the air

Conclusion

Write a conclusion to sum up your investigation and results. For example:

'In conclusion, the design of a paper plane significantly affects its flight distance. The long and narrow Plane A flew furthest, demonstrating the importance of aerodynamics in paper plane design. This experiment highlights how small changes in design can lead to big differences in performance.'

Tell the world

Although discovery is the most vital element of science, communication comes a very close second. It is important to share your discoveries so people can learn from and build on your work. Scientists use information reports and scientific posters to clearly communicate their investigations and results. Figure 5.6 shows an example of a scientific poster. Note the use of clear headings, diagrams and tables, and snappily written text.

Scientific research poster

Authors: Adbi, Miranda and Tran

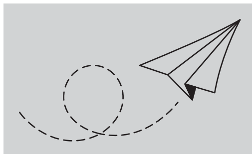
Say who you are.

Introduction

A poster is a popular way to present research findings visually. Posters are commonly used at science conferences. Start by introducing the subject of your research, the questions you were asking, your aim and your hypothesis.

Materials

List the equipment you used. You can include one or two pictures.



Method

Outline your procedure to let people know how you did your study. It helps to list each step in a list.

- Step 1:
- Step 2:
- Step 3: and so on

Include diagrams, pictures or photos to make your poster more engaging. For example, include an image of the thrower about to toss a plane.

Results

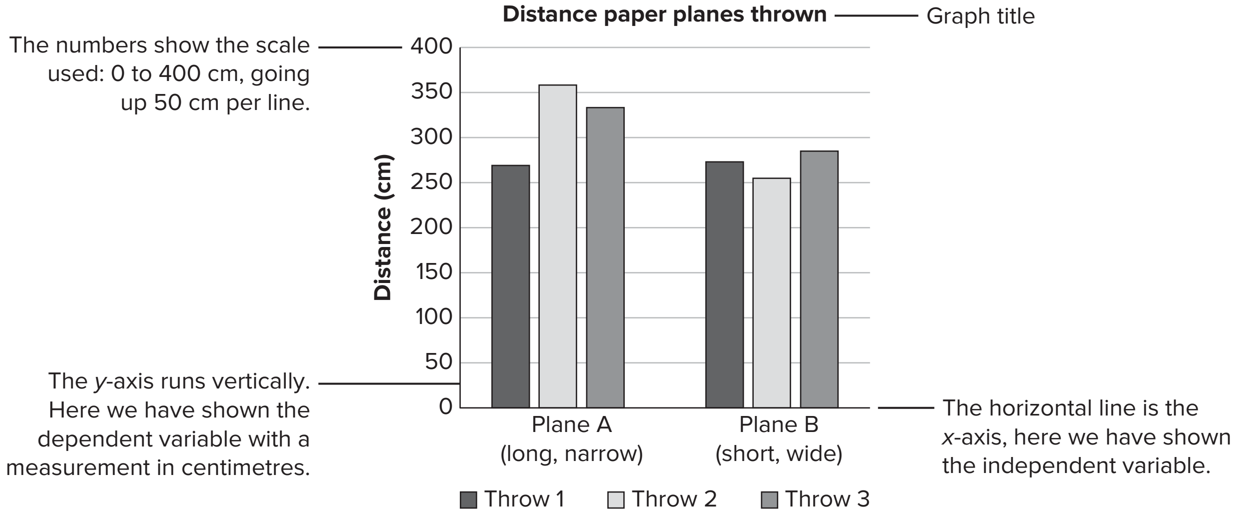
Here you can show your results table, or just the final averages.

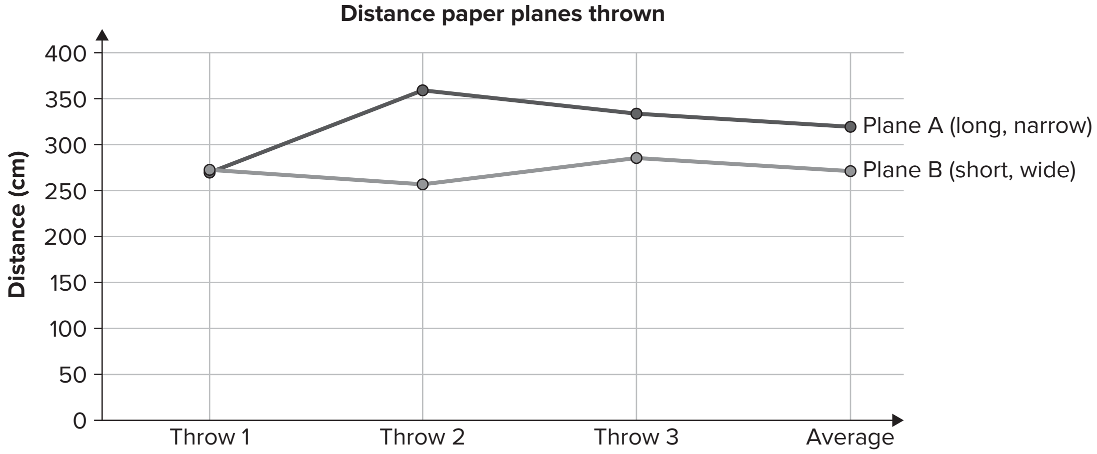
Results table for throw distance of paper planes, including average distance

Plane design	Throw distance (cm)			
	Throw 1	Throw 2	Throw 3	Average
Plane A	269	358	333	320
Plane B	273	255	285	271

Discussion

Expand on your findings by discussing how you analysed your data. Keep it simple and direct. Use bullets for emphasis. Include key graphs, tables, illustrations, and other images that support the study and show a visual analysis of the data. Make sure they are large enough to be seen from a distance but not clutter the poster.





Conclusion

Summarise your study and let the readers know the key findings.

Figure 5.6: A sample scientific poster

More often, you will put your findings in a scientific report. It will be similar to a poster, but you can write more in depth. Remember to include clear headings to guide the reader, label all your tables and graphs and write clearly and concisely.

Chapter 6 – Study and test preparation

6.1 Studying science in Year 8

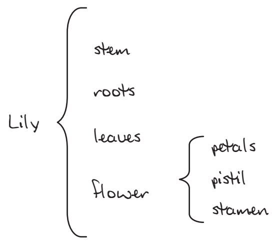
Ways to learn

Learning by doing

A lot of us need to get our hands dirty to really understand something. And while it's not always practical to run investigations for every concept, you can apply science to real life to learn through experience. For example, you could look into the paper plane investigation and ask more questions:

- What forces affect the flight of a paper plane?
- What other designs might fly further?
- How do things that fly, such as birds, insects and helicopters, use aerodynamics in different ways?

Other ways to learn by doing include creating diagrams and pictures. Draw diagrams of processes like photosynthesis or the water cycle, or create mind maps of particular concepts.



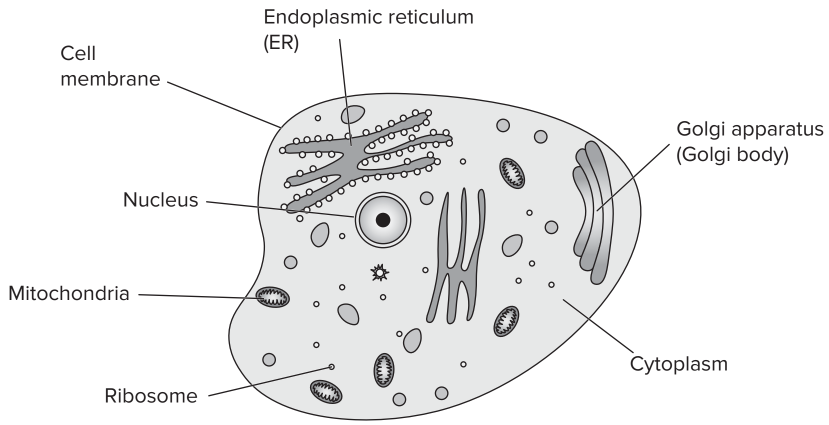


Figure 6.1: Creating diagrams and mind maps are great ways to learn by doing. They can be as simple or complex as you like.

Remember, it is okay to make mistakes and sometimes it is the best way to learn. Keep trying new things.

Social learning

Talking over a concept can help fix it in your mind. Of course, if you don't understand something, ask your teacher. But sometimes they might not explain something in a way you understand. Other social ways to learn about a new concept are:

- form a study group with some friends
- watch a web video explaining the concept (e.g. Khan Academy) and post follow-up questions in an online community
- talk to an older student or sibling. Often someone close to your own age can explain something in a way you'll understand.

The other part of social learning is that you can really reinforce your understanding by teaching others. This helps you learn to explain concepts clearly and think about them in different ways.

Focused learning

Sometimes you need to really focus on your studies. Focused learning involves setting a particular goal, such as learning all the parts of a cell, and then reading deeply, asking questions and testing yourself until you feel confident in your knowledge. People often use the 'Pomodoro technique', which involves studying solidly for 25 minutes and then taking a break for 5 minutes.

> **Fun fact**
>
> 'Pomodoro' means tomato in Italian! The technique was named after a timer that looked like a tomato.

Sometimes it can be hard to get started but try to study for a few minutes and see how you go. Often, once you start you can keep going.

Learning by rote

Rote learning refers to memorising basic facts. Often, people learn by rote by repeating things and testing themselves. Although deeper, focused learning is often preferable, rote learning has a place. For example, it is good to understand how different multiplication problems can be applied, but it is also useful to memorise that $7 \times 9 = 63$ and not have to work it out every time.

> **Key fact**
>
> Setting a study schedule will pay off in the future – not just with the knowledge you gain, but with the habits you are creating.
>
> Set aside regular time for science study each week and break your study sessions into manageable chunks, ideally 25 minutes or so, but even 10 minutes of going over your notes in the afternoon will help.

Apply science to your life

Ultimately, science is about understanding the world around us. Look for ways you can connect what you are studying with your own life.

For example:

- Chemistry: Baking a cake or making a sauce involves mixing substances and applying heat.
- Biology: Get out into the garden and study your own ecosystem.
- Physics: Think about travel. How do you stay up on a bike? How does a plane stay in the sky?
- Geology (Earth science): Think about your local area. What are the rocks in your area made of? Has the land in your area been affected by erosion?

This helps make science more engaging and easier to understand.

6.2 Preparing for a test

Your teacher has announced a test on what you have just covered in class. What is the best way to prepare for it?

- Do example questions or a practice test – see how you go at the start and then test yourself again after you have worked to memorise the material.
- Summarise your class notes. In particular, note any tricky words or formulas you might need to remember.
- From memory, try to draw a diagram about the scientific concept you need to know. Then go back and study the parts you couldn't remember.
- Get together with a friend to quiz each other, explain concepts and motivate yourselves.
- Use **mnemonics**. For example, if you need to learn 'Domain, Kingdom, Phylum, Class, Order, Family, Genus, Species' the mnemonic is: 'Dear King Phillip, Come Over For Good Soup'.

Key term

mnemonic	a short saying to help you remember something. The first 'm' is silent – it's pronounced 'nem-onic' neh-MON-ic. A common one helps us remember the order of the compass points, north, east, south and west, is 'Never Eat Soggy Weetbix'.

The night before

- Eat a nutritious meal and drink enough water – a healthy body will help your brain function.
- Try to get enough sleep. Go to bed on time.
- If you can't sleep, do some box breathing to relax. Or try to think about the most boring things you can. Rate boring things from 10 to 1!

Box breathing

This is a tried-and-true method to help your body and mind de-stress.

- Inhale through your nose for four counts; expand your ribs to take a full breath.
- Hold for four counts.
- Exhale gently through your mouth for four counts, emptying your lungs.
- Hold with empty lungs for four counts, then repeat the steps until you feel more calm.

During the test

- Don't worry about being nervous. It is natural. If your mind goes blank, take a deep breath and remind yourself that you have studied the material.
- Read the questions carefully. Circle key words to ensure you understand what is being asked. Watch out for negatives such as 'not' that require you to give an opposite answer.
- If you don't know the answer to a question, skip it and come back to it later if you have time. Don't waste time getting bogged down.

- If you only know part of the answer, write that down to show your teacher what you do know. You will still get some marks.
- If you get the time, go back and review your answers. Check that your answers match what the key words of the question have asked you to do.

If you don't get the marks you were hoping for, try not to become discouraged. Focus on **what you are learning** about the topic rather than on how much you know. For example, you could ask yourself, 'What did I understand about aerodynamics before my paper plane investigation? What did I learn by conducting the investigation?' rather than 'Who got the highest mark in the aerodynamics and forces test?'

Remember, science is about discovery. As long as you stay curious, you can be a scientist!

Answers

Chapter 1 Biology

Activity 1.2.1

1. Answers will vary but should include living things.
2. Answers will vary.
3. Unicellular organisms are made up of one cell that performs all life processes within the one cell. They are often so small that you can only see them under a microscope.

   Multicellular organisms are made up of more than one cell, with cells that perform special and unique functions. The human body consists of trillions of cells.

Activity 1.3.1

Answers will vary.

Activity 1.3.2

Eukaryotic cells are cells with a nucleus and membrane-bound organelles. Eukaryotic cells are more complex and generally larger than prokaryotic cells. Prokaryotic cells do not contain a nucleus or membrane-bound organelles. They have a specialised cellular structure but with DNA contained in the central area of the cell. Prokaryotic cells are simpler and generally smaller than eukaryotic cells.

Activity 1.4.1

Answers will vary.

Activity 1.4.2

1. Cell membrane
2. Nucleus
3. Golgi apparatus
4. Mitochondria
5. Ribosome
6. Refer to Figure 1.5 to check your answers.

Activity 1.5.1

1. Cell wall
2. Chloroplast
3. Vacuole
4. Refer to Figure 1.6 to check your answers.
5. Drawings will vary.

Activity 1.6.1

Red blood cells carry oxygen. White blood cells fight infection. Platelets form clots to prevent blood loss.

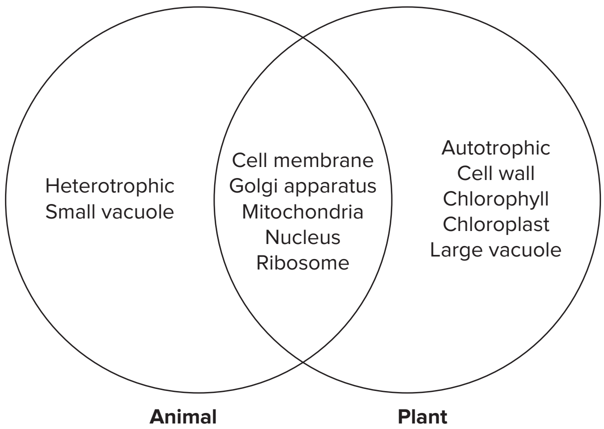
Activity 1.7.1

1. Guard cells control stomata.
2. Carbon dioxide + water + (light energy) → glucose + oxygen
3. Guard cells open during the day, allowing carbon dioxide to enter the cell while the plant is receiving sunlight, so that photosynthesis can occur.

Activity 1.7.2

1. Answers will vary.
2. Xylem, phloem

Activity 1.8.1



Activity 1.9.1

1. Answers will vary.
2. Heterotrophic

Activity 1.10.1

Animal cells lack cell walls and chloroplasts, or animals are consumers (heterotrophs).

Plants have cell walls and chloroplasts, or they can produce their own food.

Fungal cells have unique chitin cell walls, or fungi are decomposers in ecosystems.

Activity 1.11.1

Capsule, nucleoid area, flagella, pili

Activity 1.12.1

Your body heals the wound by dividing and replicating skin cells to replace the skin cells that have been damaged by the burn.

Activity 1.13.1

1. When a cell is replicated, the DNA is being copied. If DNA replication goes wrong, this could result in consequences such as cancer, genetic conditions and cystic fibrosis.
2. Answers will vary.

Activity 1.14.1

Answers will vary.

Activity 1.15.1

- A tissue is a group of similar cells working together to perform a specific function.
- An organ is a structure that is made up of two or more types of tissue working together to perform a specific function.
- An organ system is a group of organs working together to perform complex functions in the body.

Activity 1.16.1

1. Ingestion, digestion, absorption and elimination. The digestive system is important because it breaks down the food we eat, so our bodies can use the nutrients to function properly and stay healthy.
2. Answers will vary.

Activity 1.17.1

1. A herbivore's digestive system is longer and more complex, and is adapted to break down cellulose using mechanical digestion and special enzymes. A carnivore's digestive system is simpler. Most of the digestion takes place in the stomach. The differences are mainly because cellulose is harder to digest as it involves breaking down the cell wall.
2. Hindgut fermenters have a shorter passage time than foregut fermenters, and hence are less efficient in cellulose digestion, for which they compensate with a higher intake of food.
3. To break down plant material more easily

Activity 1.18.1

1. Glucose + oxygen → carbon dioxide + water + energy released
2. Gas exchange and energy production. It is important because it provides oxygen for cellular respiration, which produces energy for the body. It also removes carbon dioxide, which is a waste product, to prevent it from building up in the body.
3. Refer to Figure 1.19 to check your answers. Explanations will vary.

Activity 1.19.1

1. Refer to Figure 1.20 to check your answers.
2. Arteries are made of thick muscle with elastic walls to handle high pressures. They carry oxygenated blood away from the heart. Veins have valves to prevent backflow. They carry deoxygenated blood back to the heart.
3. Red blood cells make up 99 per cent of the blood cells in our body. They contain haemoglobin, a protein that carries oxygen. Red blood cells transport oxygen throughout the body.

   White blood cells form part of the body's immune system. They help to fight infections and protect the body.
4. Drawings will vary. Refer to Figure 1.21.
5. Deoxygenated blood: body → veins → right atrium → right ventricle → lungs

   Oxygenated blood: lungs → left atrium → left ventricle → arteries → body
6. Transportation, regulation, protection. The circulatory system is important because it transports oxygen, nutrients, hormones and waste products throughout the body.

Activity 1.20.1

1. The central nervous system and the peripheral nervous system
2. The brain and the spinal cord
3. The peripheral nervous system is a long network of nerves that connects the central nervous system to the rest of the body.
4. The somatic nervous system controls voluntary movements; the autonomic nervous system regulates involuntary functions such as heart rate and digestion.
5. The autonomic nervous system is made up of the sympathetic nervous system, which prepares the body for fight or flight responses, and the parasympathetic nervous system, which promotes rest and digest activities.
6. Sensation, integration and response. The nervous system helps you move and feel, and it regulates the things you do automatically such as digestion.

Chapter 2 Earth and space

Activity 2.2.1

They can tell us about the past and they provide us with a common source of electricity.

Activity 2.3.1

Answers will vary.

Activity 2.4.1

1. Answers will vary but should mention sediments being compacted and cemented together.
2. Answers will vary but should mention grains that are cemented together, often with visible layers.
3. Organic materials are formed from previously living things. Inorganic materials are formed from things that are not living and never were living.

4. Answers will vary.
5. Answers will vary.
6. Answers will vary.

Activity 2.4.2

1. Answers will vary.
2. Answers will vary.
3. Refer to Figure 2.5 to check your answer.

Activity 2.4.3

1. Answers will vary.
2. Refer to Figure 2.6 to check your answer.
3. Answers will vary.

Activity 2.5.1

Answers will vary.

Activity 2.6.1

1. Refer to Figure 2.7 to check your answer. Dot points will vary.
2. The rock cycle is important because it ensures that Earth's materials are reused and reshaped, weathering creates soil for plants, and it provides important minerals and fossil fuels that we use.

Activity 2.7.1

1. Fit of the continents, identical fossils of ancient plants and animals found on continents separated by oceans, similar rock formations and mountain ranges found on different continents, and climate evidence such as evidence of glaciers in now warm regions.
2. Wegener's challenge was explaining how and why the continents moved.

Activity 2.8.1

1. Plate tectonics is the theory that explains that Earth's outer shell – the lithosphere – is divided into large pieces called tectonic plates. The tectonic plates move over the semi-fluid layer – the asthenosphere.
2. Seven
3. Australian Plate
4. Divergent, convergent, transform

Activity 2.9.1

1. Refer to Figure 2.11 to check your answer.
2. Because new crust is 'constructed' where the two tectonic plates move apart from one another.
3. Rift valleys, volcanoes, earthquakes, hot springs and geysers

Activity 2.10.1

1. Refer to Figure 2.13 to check your answer.
2. Convergent boundaries are sometimes called destructive boundaries because the process destroys crust.
3. By the process of orogeny – the Indian Plate and the Eurasian Plate collided millions of years ago. The resulting compression of the two plates pushed up layers of rock and formed the mountain range.

Activity 2.11.1

1. Refer to Figure 2.15 to check your answer.
2. Fault line
3. There is no volcanic activity. No crust is formed or destroyed.
4. The Australian Plate and Pacific Plate move against one another to create the Alpine Fault.

Activity 2.12.1

Refer to Figure 2.16 to check your answer.

Activity 2.13.1

Answers will vary.

Chapter 3 Physics

Activity 3.2.1

Energy is the ability to do work or cause change, or it is the potential to perform an action through some force.

Activity 3.3.1

Answers will vary.

Activity 3.4.1

Answers will vary.

Activity 3.5.1

Answers will vary.

Activity 3.6.1

Energy transfer is the movement of energy from one place to another. Energy transformation is when energy changes from one form to another. Drawings will vary.

Activity 3.7.1

Thermal energy, or heat energy, is the energy that comes from the movement of particles (molecules and atoms) in a substance. When a substance heats up, the rise in temperature makes these particles move faster and bump into each other. Drawings will vary.

Activity 3.7.2

Answers will vary.

Activity 3.8.1

Their hands warm up because of the thermal energy produced by friction – the particles on their hands have gained energy.

Activity 3.9.1

Drawings will vary.

Activity 3.10.1

Drawings will vary.

Chapter 4 Chemistry

Activity 4.2.1

1. Matter is anything that has mass and takes up space (volume).
2. Non-matter does not have mass or take up space. It includes energy, forces, thoughts and feelings, time, and waves (radio waves, microwaves, X-rays). Drawings will vary.

Activity 4.2.2

Atoms are the smallest unit of matter and can be different types, called elements. Molecules are groups of two or more atoms bonded together.

Activity 4.2.3

1. Solids have a fixed shape and volume, are not easily compressed and are dense; liquids have a variable shape but a fixed volume, are not easily compressed and are less dense; and gases have a variable shape and volume, are easily compressed and are not dense.
2. Particles in a solid are closely packed together, strongly attracted to each other and move by vibrating. Particles in a liquid are packed less densely than in a solid. They are attracted strongly enough to stay close together, but weakly enough to be able to move around each other. Particles in a gas move freely and are not attracted to each other.

Activity 4.3.1

Answers will vary.

Activity 4.4.1

1. All matter is made up of tiny particles. These particles are either individual atoms or groups of atoms called molecules. Atoms of the same element are the same. Atoms of different elements are different. Particles are attracted to each other by forces. Particles are always moving at temperatures above −273.15°C. Particle speed increases with temperature; the higher the temperature, the faster the particles move. Particles of matter have spaces between them. The space varies depending on the state of matter.
2. Drawings should be similar to Figure 4.4.
3. Drawings should be similar to Figure 4.5.

Activity 4.5.1

Changes in temperature can change matter from one state to another because a change in state occurs when particles vibrate faster or slower. At higher temperatures, the particles vibrate faster, and at lower temperatures, the particles move more slowly.

Activity 4.5.2

When thermal (heat) energy is added, the particles of a solid substance start to vibrate faster. A change in state happens because the connections between the particles start to break down. The substance changes from a solid to a liquid state. If more thermal energy is added, the particles will move even faster, the connections between the particles break completely and the individual particles are released from the liquid to form a gas.

Activity 4.5.3

When temperature decreases, the particles lose thermal energy and vibrate more slowly. Gas particles begin to re-form in a liquid state. When enough heat is removed from a substance, the connections between the particles strengthen even more and a liquid will become a solid.

Activity 4.6.1

1. Pure substances are made up of one type of particle (atom or molecule).
2. An element is a pure substance that cannot be broken down into any other substance. Elements are made up of only one type of atom. Examples will vary.

Activity 4.6.2

A compound is a pure substance made from more than one element. Examples will vary.

Activity 4.6.3

An element is made up of one type of atom, and it cannot be separated into other substances. It is represented by a symbol. A compound is made up of two or more elements, and can be separated into its component elements. It is represented by a formula.

A similarity is that they are both pure substances.

Activity 4.6.4

Mixtures are not pure substances. A mixture is formed when two or more elements or compounds are present without being chemically bonded together. Examples will vary.

Activity 4.6.5

A heterogeneous mixture is where the components of the mixture can be separated easily, and the substances are not evenly distributed. A homogeneous mixture is where the components of the mixture cannot be separated easily, and the substances are evenly distributed throughout. Examples will vary.

Activity 4.6.6

A solution is a homogeneous mixture in which one substance (the solute) dissolves in another (the solvent). A suspension is a heterogeneous mixture in which particles are dispersed but settle over time. A colloid is a heterogeneous mixture in which the particles are evenly dispersed and do not settle over time. Examples will vary.

Activity 4.6.7

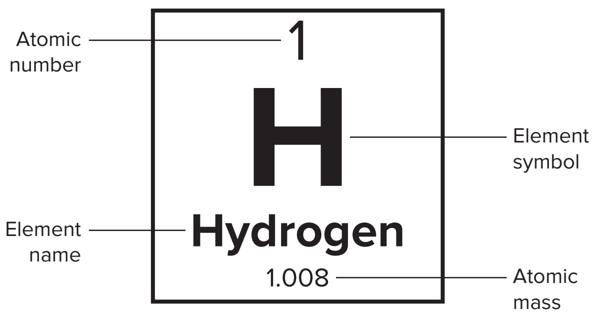
Differences: An element is made up of one type of atom, is represented by symbols, diagrams and models and cannot be separated into other substances. A compound is made up of two or more elements, is represented by formulas, diagrams and models and can be separated chemically into component elements. A mixture is made up of one or more pure substances, is represented by particle diagrams and models and can be physically separated into component substances by processes such as filtration and distillation

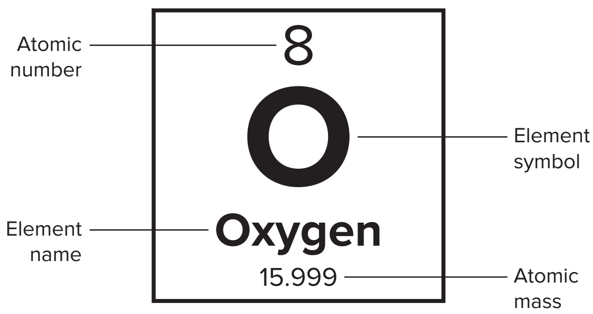
A similarity is that they are all made up of atoms.

Activity 4.7.1

Answers will vary.

Activity 4.8.1





Activity 4.8.2

- Hydrochloric acid: HCl
- Ethene: C_2H_4
- Aluminium oxide: Al_2O_3
- Sodium hydroxide: $NaOH$

Activity 4.9.1

1. A physical change is where changes occur to the appearance of a substance, but the type of substance does not change. A chemical change is where the chemical nature of the matter has changed, and a new substance is formed. The atoms in the matter have rearranged to form something new.
2. Colour change, formation of bubbles or odours, formation of a solid substance, temperature change
3. A physical change to wood is cutting it. We have changed the appearance of it, but what it is has not changed. A chemical change is burning wood, where the wood changes to ashes and has a different chemical composition.

Activity 4.9.2

When energy is released in a reaction, it is called an exothermic chemical change – energy is released in the form of heat and sometimes light and sound. When energy is absorbed in a reaction, it is called an endothermic chemical change – heat energy is absorbed from the surrounding environment. Examples will vary.

Activity 4.9.3

1. To represent the changes in a chemical reaction.
2. A word equation uses the chemical names, whereas a formula equation uses chemical formulas.
3. sodium hydrogen carbonate + acetic acid → sodium acetate + carbon dioxide + water

$$NaHCO_3 + CH_3COOH \rightarrow NaCH_3COO + CO_2 + H_2O$$

Activity 4.10.1

Combination reactions involve two or more reactants combining to form a single product, whereas decomposition reactions involve a single reactant breaking down to form two or more products.

Activity 4.11.1

1. It is important to understand the properties of chemicals so that we can use them safely and correctly.
2. Toxicity, flammability, corrosion, heat of combustion, reactivity. Examples will vary.

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Text

Extract from *The Conversation* article, Professor Patrick D. Nunn, 23 August 2017, https://theconversation.com/when-the-bullin-shrieked-aboriginal-memories-of-volcanic-eruptions-thousands-of-years-ago-81986. Text licensed under Creative Commons, CC BY 4.0, p.56.

Images

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Curriculum correlation

While this book has been written to follow the Australian curriculum: Science, its content also covers specific state curricula. Go to the Insight Publications website for curriculum correlation charts.