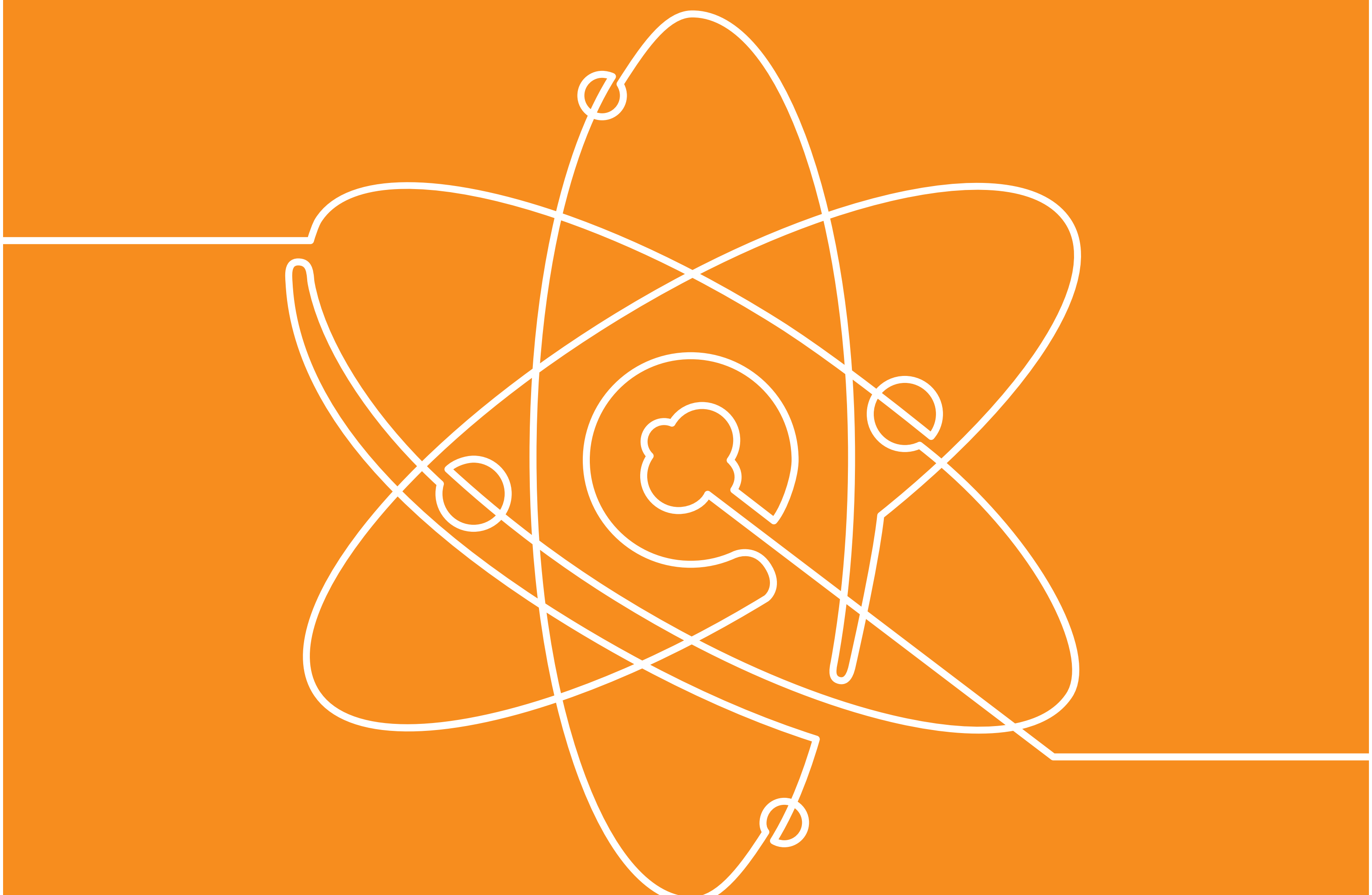
GOOD SCIENCE

VICTORIAN CURRICULUM

YEAR 9



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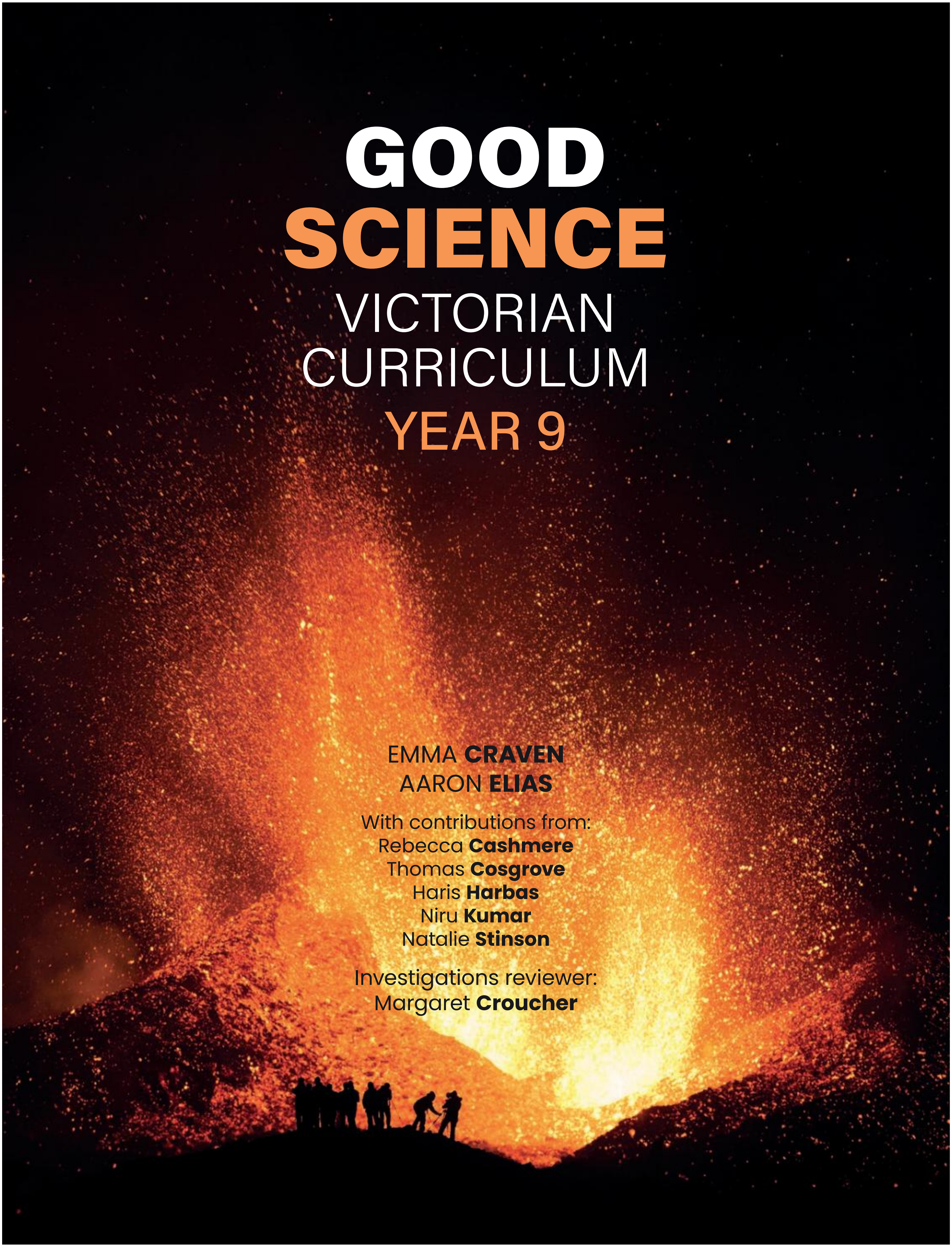

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VICTORIAN CURRICULUM

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MAKE EVERY LESSON A **GOOD** LESSON

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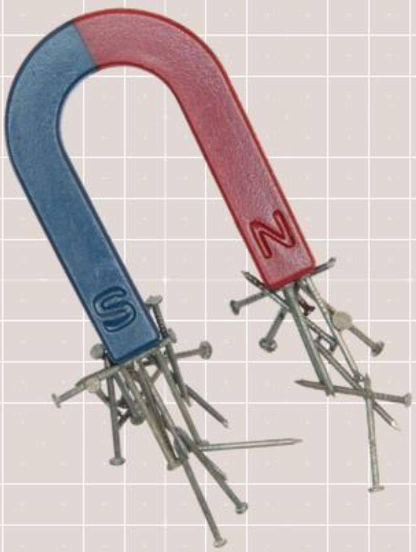

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CURRICULUM CORRELATION GRID

VICTORIAN CURRICULUM SCIENCE **LEVELS 9 AND 10**		
SCIENCE UNDERSTANDING: SCIENCE AS A HUMAN ENDEAVOUR		
VCSSU114	Scientific understanding, including models and theories, are contestable and are refined over time through a process of review by the scientific community	▪ Chapter 1: Coordination and control ▪ Chapter 2: Energy and matter in ecosystems ▪ Chapter 3: Atomic structure ▪ Chapter 5: Plate tectonics
VCSSU115	Advances in scientific understanding often rely on developments in technology and technological advances are often linked to scientific discoveries	▪ Chapter 1: Coordination and control ▪ Chapter 3: Atomic structure ▪ Chapter 6: Electricity
VCSSU116	The values and needs of contemporary society can influence the focus of scientific research	▪ Chapter 1: Coordination and control ▪ Chapter 5: Plate tectonics
SCIENCE UNDERSTANDING: BIOLOGICAL SCIENCES		
VCSSU117	Multicellular organisms rely on coordinated and interdependent internal systems to respond to changes to their environment	▪ Chapter 1: Coordination and control
VCSSU118	An animal's response to a stimulus is coordinated by its central nervous system (brain and spinal cord); neurons transmit electrical impulses and are connected by synapses	▪ Chapter 1: Coordination and control
VCSSU119	The transmission of heritable characteristics from one generation to the next involves DNA and genes	▪ Good Science 10
VCSSU120	The theory of evolution by natural selection explains the diversity of living things and is supported by a range of scientific evidence	▪ Good Science 10
VCSSU121	Ecosystems consist of communities of interdependent organisms and abiotic components of the environment; matter and energy flow through these systems	▪ Chapter 2: Energy and matter in ecosystems
SCIENCE UNDERSTANDING: CHEMICAL SCIENCES		
VCSSU122	All matter is made of atoms which are composed of protons, neutrons and electrons; natural radioactivity arises from the decay of nuclei in atoms	▪ Chapter 3: Atomic structure
VCSSU123	The atomic structure and properties of elements are used to organise them in the periodic table	▪ Good Science 10
VCSSU124	Chemical reactions involve rearranging atoms to form new substances; during a chemical reaction mass is not created or destroyed	▪ Chapter 4: Chemical reactions ▪ Good Science 10
VCSSU125	Different types of chemical reactions are used to produce a range of products and can occur at different rates; chemical reactions may be represented by balanced chemical equations	▪ Good Science 10
VCSSU126	Chemical reactions, including combustion and the reactions of acids, are important in both non-living and living systems and involve energy transfer	▪ Chapter 4: Chemical reactions
SCIENCE UNDERSTANDING: EARTH AND SPACE SCIENCES		
VCSSU127	The theory of plate tectonics explains global patterns of geological activity and continental movement	▪ Chapter 5: Plate tectonics
VCSSU128	Global systems, including the carbon cycle, rely on interactions involving the atmosphere, biosphere, hydrosphere and lithosphere	▪ Good Science 10
VCSSU129	The Universe contains features including galaxies, stars and solar systems; the Big Bang theory can be used to explain the origin of the Universe	▪ Good Science 10

SCIENCE UNDERSTANDING: PHYSICAL SCIENCES		
VCSSU130	Electric circuits can be designed for diverse purposes using different components; the operation of circuits can be explained by the concepts of voltage and current	▪ Chapter 6: Electricity
VCSSU131	The interaction of magnets can be explained by a field model; magnets are used in the generation of electricity and the operation of motors	▪ Chapter 7: Magnetism
VCSSU132	Energy flow in Earth's atmosphere can be explained by the processes of heat transfer	▪ Good Science 10
VCSSU133	The description and explanation of the motion of objects involves the interaction of forces and the exchange of energy and can be described and predicted using the laws of physics	▪ Good Science 10
SCIENCE INQUIRY SKILLS: QUESTIONING AND PREDICTING		
VCSIS34	Formulate questions or hypotheses that can be investigated scientifically, including identification of independent, dependent and controlled variables	▪ Skills and investigations ▪ Good Science 10
SCIENCE INQUIRY SKILLS: PLANNING AND CONDUCTING		
VCSIS135	Independently plan, select and use appropriate investigation types, including fieldwork and laboratory experimentation, to collect reliable data, assess risk and address ethical issues associated with these investigation types	▪ Skills and investigations ▪ Good Science 10
VCSIS136	Select and use appropriate equipment and technologies to systematically collect and record accurate and reliable data, and use repeat trials to improve accuracy, precision and reliability	▪ Skills and investigations ▪ Good Science 10
SCIENCE INQUIRY SKILLS: RECORDING AND PROCESSING		
VCSIS137	Construct and use a range of representations, including graphs, keys, models and formulas, to record and summarise data from students' own investigations and secondary sources, to represent qualitative and quantitative patterns or relationships, and distinguish between discrete and continuous data	▪ Skills and investigations ▪ Good Science 10
SCIENCE INQUIRY SKILLS: ANALYSING AND EVALUATING		
VCSIS138	Analyse patterns and trends in data, including describing relationships between variables, identifying inconsistencies in data and sources of uncertainty, and drawing conclusions that are consistent with evidence	▪ Skills and investigations ▪ Good Science 10
VCSIS139	Use knowledge of scientific concepts to evaluate investigation conclusions, including assessing the approaches used to solve problems, critically analysing the validity of information obtained from primary and secondary sources, suggesting possible alternative explanations and describing specific ways to improve the quality of data	▪ Skills and investigations ▪ Good Science 10
SCIENCE INQUIRY SKILLS: COMMUNICATING		
VCSIS140	Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations	▪ Skills and investigations ▪ Good Science 10

COORDINATION AND CONTROL

1

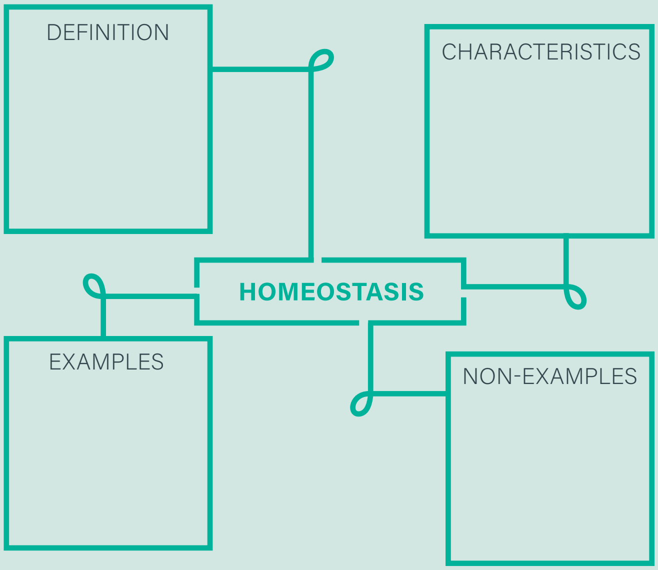
How is life maintained?

The human body can be thought of as a balanced machine, constantly working to stay stable in an ever-changing environment. Most humans can survive only three days without water, around three weeks without food, three minutes without oxygen and just over 10 days without sleep.

Keeping the body stable and meeting these needs is the function of different systems of organs. Each body system has its own specific purpose, but they all coordinate together so that the body works efficiently to ensure survival.

1 FRAYER MODEL

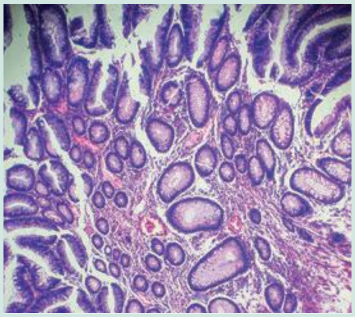
Copy and complete the below chart in your workbook.

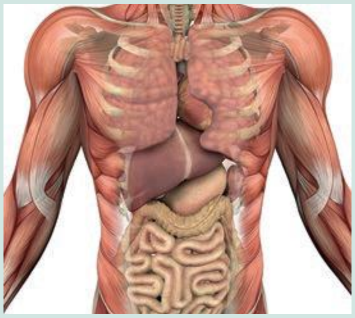


Complete two additional charts for the key terms *Stimulus* and *Disease*.

2 LEARNING LINKS

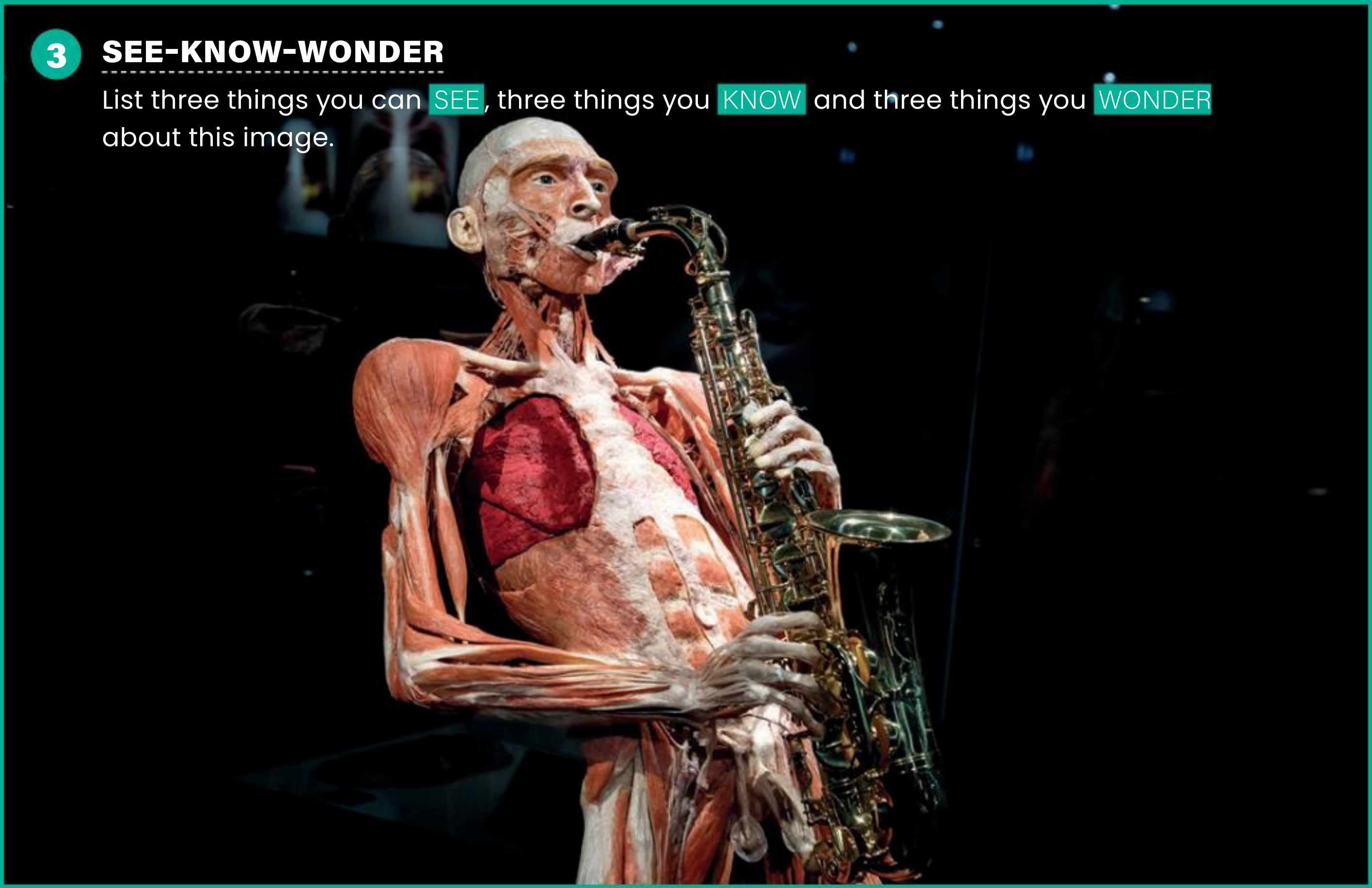
Brainstorm everything you already know about coordination and control.





3 SEE-KNOW-WONDER

List three things you can SEE, three things you KNOW and three things you WONDER about this image.



4 CRITICAL + CREATIVE THINKING

THE BAR: Think of one thing you would make **B**igger, one thing you would **A**dd and one thing you would **R**eplace in the human brain.

THE ALPHABET: Use the topic 'Human body' to write a list of words from A–Z.

WHAT IF ... Earth's gravitational pull were to decrease by 25 per cent? Suggest what might happen to the human body.

5 THE BIGGEST!

The blue whale has the biggest heart of any living creature. It is about 180 centimetres long and weighs about 200 kilograms, or about 1 per cent of the whale's body weight. It has the capacity to pump 220 litres of blood per beat! Adult human hearts are around 12 centimetres long and make up less than 0.5 per cent of their body weight – an average adult male heart weighs between 280 and 340 grams, and an average adult female heart weighs between 230 and 280 grams.

1.1 BODIES IN BALANCE

LEARNING INTENTION

At the end of this lesson I will be able to describe how multicellular organisms use internal systems to respond to changes in their environment.

KEY TERMS

homeostasis
maintaining a stable, balanced state within the body

negative feedback
a response that counteracts the stimulus

receptors
specialised cells and organs that detect changes

LITERACY LINK

VOCABULARY

Find the origin of the word 'homeostasis'. Think about how knowing its meaning can help you remember the definition of the word.

NUMERACY LINK

UNITS

A particular person sweats 0.8 litres per hour during exercise. Calculate how much sweat is produced per minute. Convert this value to millilitres.

Multicellular organisms tend to have complex bodies, consisting of multiple organs and systems that work together to maintain life and health. Whenever something changes in or around the organism, it has the potential to affect the organism's health and survival. Human bodies deal with these changes by working to keep all of the body systems in balance.

1 Many different types of changes affect the body

There are many types of changes within the environment that affect the body. Some of these are obvious, such as changes in temperature. If it gets hot, we sweat; if it gets cold, we shiver. Other changes are more subtle, but our bodies react to them all the same.

Physical changes affect the position of the body, such as balancing on a beam. As you move back and forth to keep your balance, your body reacts so that you stay in control. Movement is another physical change; not only does your body change position, but body parts such as your feet feel impacts as they push against surfaces.

Chemical changes involve your body's reaction to different chemicals. If the quality of the air you breathe changes, your body will react. Whenever you eat something, your body's systems react to it – and if it's something noxious or poisonous, that reaction could be extreme.

What are three changes in the environment that can affect the body?

2 Receptors detect changes and trigger feedback

Whenever something changes in the environment, the first step is for the body to actually detect that change. It does this thanks to different **receptors** – cells and organs that identify both internal and external changes.

Sensory receptors can be classified into four broad categories.

- *Photoreceptors* respond to changes in light. Human photoreceptors are located in the eye. Some other organisms, such as plants, have different types of photoreceptors.
- *Chemoreceptors* respond to different chemicals. The chemoreceptors in your tongue are what allow you to detect different flavours.
- *Thermoreceptors* respond to changes in temperature. Most of your thermoreceptors are on your skin; you also have a few on some organs.

- *Mechanoreceptors* respond to changes in pressure or position. Again, many of these are on your skin, but the ones in your inner ear are vital for maintaining balance.

Once a receptor detects a change, it sends a message to the brain, which can then target the appropriate body systems and organs. These systems then respond to compensate for that change. The process of stopping and reversing a process in the body is usually called **negative feedback**, because the body is acting to negate or reduce the effect of the change.

Sweating when the external temperature increases is an example of negative feedback. The thermoreceptors in your skin detect that your body temperature is increasing, triggering the excretory system to release sweat. The sweat evaporates once it's released, which reduces the skin's temperature.

What are some of the different types of receptors in the body?

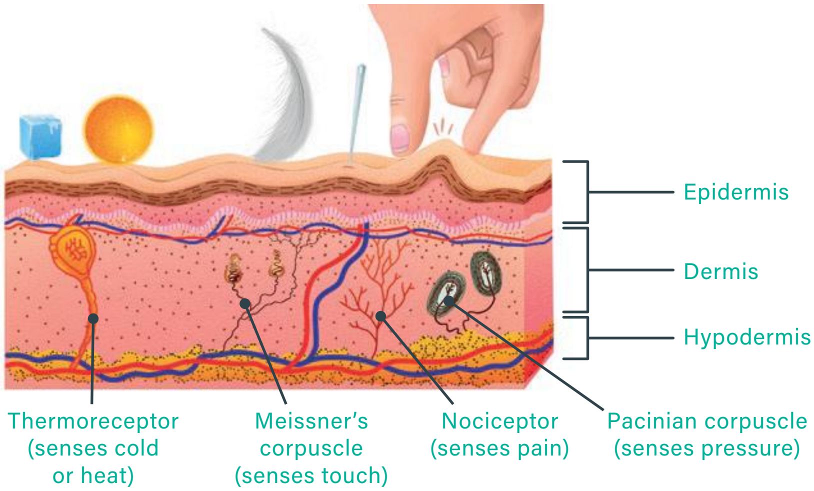


Figure 1.1 There are many different sensory receptors in the skin.

3 Homeostasis is the baseline state of the body

Whenever the body of a multicellular organism reacts to a change or stimulus with negative feedback, it is working to return to **homeostasis**. This is the 'normal' or baseline state of the body – the point at which every organ and system is working as it should.

When the human body is at homeostasis, vital body functions are maintained at the levels that sustain life and good health. These functions include body temperature, blood pressure, glucose and oxygen levels in the blood, brain activity and many more. If an organism's body did not work to achieve homeostasis at all times, these functions would quickly cease.

What is homeostasis?

INVESTIGATION 1.1A

Sensory receptors

KEY SKILL
Representing data to identify patterns and trends

▶ *Go to page* ***138***

INVESTIGATION 1.1B

Reaction time

KEY SKILL
Identifying the variables and formulating a hypothesis

▶ *Go to page* ***139***

CHECKPOINT 1.1

1 Explain homeostasis and why it is important to survival.

2 Identify a chemical and physical change that an organism may react to.

3 Identify which receptors would be responsible in the following situations.
   a Your hand jerks away after you touch a hot plate.
   b You feel pain when you step on a sharp stone in bare feet.
   c You taste some sour milk.
   d A flower turns towards the Sun during the day.

4 Explain what a negative feedback response is, using an example that is not in the text.

5 Sweating helps to lower body temperature. Propose how shivering helps to increase it.

INQUIRY

6 Brainstorm and create a list of ways that the human body responds to changes in temperature.

SUCCESS CRITERIA

- I can describe how physical and chemical changes can affect the body.
- I can identify the four types of sensory receptors.
- I can describe negative feedback and homeostasis.

1.2 THE ENDOCRINE AND NERVOUS SYSTEMS

LEARNING INTENTION

At the end of this lesson I will be able to describe the role of, and interaction between, the nervous and endocrine systems.

KEY TERMS

effector
a muscle, gland or organ that responds to a message sent by the nervous or endocrine system

gland
tissue that secretes hormones

hormone
a chemical secreted by a gland that triggers a response in certain cells

neuron
a specialised cell that makes up the nervous system

synapse
the gap between the axon and dendrite of two neighbouring neurons

NUMERACY LINK

DATA

Jesse performed an experiment to test his reflexes at different times of the day. He measured his response time in a single trial to be 0.58 s in the morning, 0.43 s in the afternoon, and 0.55 s in the evening. What conclusions can Jesse draw from this? What could he do to make his data more valid?

When receptors respond to stimuli, they send messages to different body systems to trigger changes. These 'messages' are complex chemical and electrical signals, and the different systems must interact in multiple ways to respond effectively. This complex interaction is governed by two vital body systems, which we refer to as the coordination systems: the nervous system and the endocrine system.

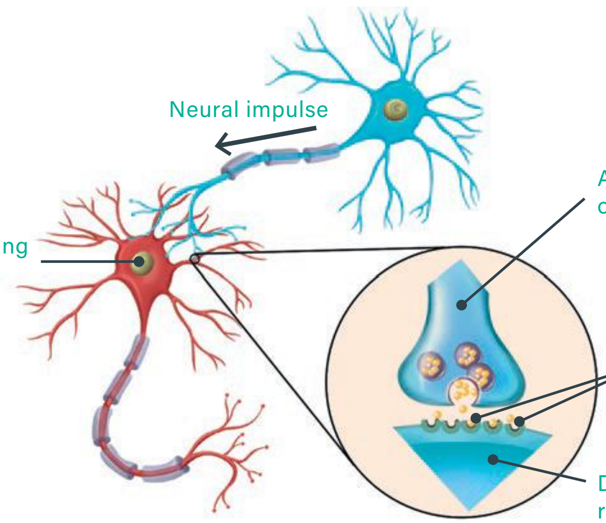


Figure 1.2 The axons and dendrites of neurons are separated by a gap called a synapse. The electrical impulse is translated into chemical neurotransmitters that cross the synapse and trigger the impulse to continue in the receiving neuron.

1 The nervous system transmits signals around the body

The nervous system is a network of cells and fibres that transmits fast messages between parts of the body. It consists of billions of cells called **neurons**, which form long nerve fibres. Those nerves connect the brain to muscles and organs by sending messages in the form of tiny electrical impulses.

The nervous system of vertebrates, such as human beings, has two parts. The *central nervous system* consists of the brain and the spinal cord. The *peripheral nervous system* is the network of nerves that runs through the rest of the body, connecting it to the central nervous system.

Neurons contain filaments called dendrites, which receive impulses, and long fibres called axons, which carry those impulses away from their cell body. Sensory neurons lead away from receptors, while motor neurons lead towards muscles, glands and other **effectors** that respond to signals.

Neurons do not actually connect to each other; they have tiny gaps between them, called **synapses**. When an electrical impulse reaches a synapse, it triggers the neuron to release chemical neurotransmitters. These cross the synapse and stimulate the next neuron, continuing the message.

How do signals pass along nerve cells?

2 The endocrine system releases hormones

The endocrine system consists of multiple **glands** – groups of cells that produce complex molecules called **hormones**. Once the gland is triggered, it secretes hormones into the bloodstream that travel to target cells and trigger a response. Endocrine responses are much slower than nervous system responses.

The pituitary gland is sometimes called the 'master gland' of the endocrine system. It sits at the base of the brain, just behind the bridge of the nose. While it's only the size of a pea, it secretes hormones that control many other endocrine glands. It also secretes hormones that regulate growth and reduce feelings of pain.

Hormones are often produced in pairs, one having the opposite effect to the other. For example, when blood sugar levels are too high, the pancreas produces insulin, which tells the liver to remove the excess glucose from the blood and store it. If blood sugar levels are too low, the pancreas releases glucagon, which tells the liver to return glucose into the blood.

How do hormones travel through the body?

3 The nervous and endocrine systems work together

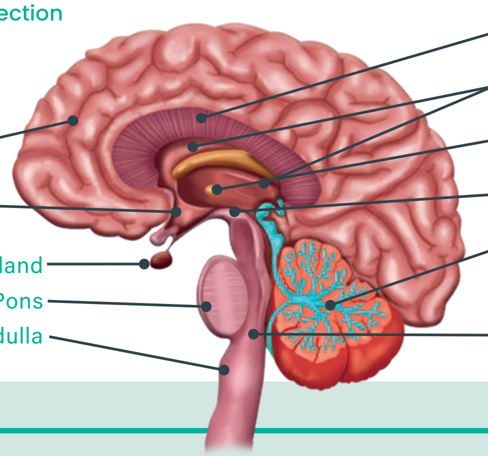
The nervous and endocrine systems coordinate the body's responses to changes to its internal and external environment. They do this thanks to the brain, which plays a key role in both systems.

The brain consists of three main sections. The *cerebrum* is the largest part, consisting of two wrinkled hemispheres; this is where conscious thought takes place. The *cerebellum*, at the back of the brain, controls movement and balance. Finally, the *brain stem* connects the brain to the spinal cord, as well as controls the automatic actions of the body.

The *hypothalamus* is a region in the centre of the brain that is responsible for interpreting signals from all over the body to ensure homeostasis. It does this through sending chemical signals to the pituitary gland, telling the gland to release hormones that will bring the body back into balance.

Which part of the brain coordinates the endocrine system?

Figure 1.3 A cross-section of the human brain



INVESTIGATION 1.2
Sheep brain dissection

KEY SKILL
Identifying and managing relevant risks

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CHECKPOINT 1.2

1 Identify the main types of neurons.
2 Distinguish between the central nervous system and the peripheral nervous system.
3 Describe how an impulse travels from one neuron to another, and identify the structures it passes through.
4 Suggest the benefit of hormones being produced in opposing pairs.
5 Identify the part of the brain that controls the endocrine system.
6 Suggest why it is important for the nervous and endocrine systems to work together.

CRITICAL AND CREATIVE THINKING

7 Create a labelled model of neurons that shows how a signal is passed from one to another.

SUCCESS CRITERIA

- I can describe the role of the nervous system.
- I can describe the role of the endocrine system.
- I can describe how the nervous and endocrine systems work together.

1.3 THE RESPIRATORY AND CIRCULATORY SYSTEMS

LEARNING INTENTION

At the end of this lesson I will be able to describe the role of, and interaction between, the respiratory and circulatory systems.

KEY TERMS

cellular respiration
the process that all living things use to produce cellular energy from glucose and oxygen

diffuse
to move from an area of high concentration to an area of low concentration

gas exchange
the exchange of oxygen and carbon dioxide between an organism and the environment

LITERACY LINK

WRITING

Create a mnemonic to remember the structures of the respiratory and circulatory systems.

NUMERACY LINK

CALCULATION

A person has a resting heart rate of 70 beats per minute. Each time their heart beats, it moves about 80 mL of blood through the heart. Calculate how much blood (in litres) is pumped through their body in 24 hours.

Every living thing needs energy to live, and that energy comes from **cellular respiration**: turning oxygen and glucose into energy for cells to use. In mammals, two body systems coordinate to support cellular respiration: the respiratory system, which exchanges oxygen and carbon dioxide, and the circulatory system, which transports these gases, along with nutrients and waste, around the body. These two systems are often considered together as the cardio-respiratory system.

1 The respiratory system is needed for gas exchange

The role of the mammalian respiratory system is to swap carbon dioxide from the blood with oxygen from the air. Its structure allows this **gas exchange** to happen very efficiently.

When you inhale, your diaphragm (a band of muscles under the lungs) moves down and your ribs move out, drawing air into the respiratory system through your nostrils or mouth. It goes through the trachea into two bronchi – one for each lung – before passing into smaller and smaller passages called bronchioles.

At the end of the bronchioles are tiny sacs called alveoli, which are surrounded by tiny capillaries. The oxygen in the air **diffuses** through the thin cell walls of the alveoli into the capillaries, where it bonds to haemoglobin, a protein carried in red blood cells. At the same time, the carbon dioxide in the blood plasma diffuses back out into the air within the alveoli. When you breathe out, your diaphragm moves up and your ribs move in, causing the air in your lungs to move back out.

In which structure does gas exchange take place?

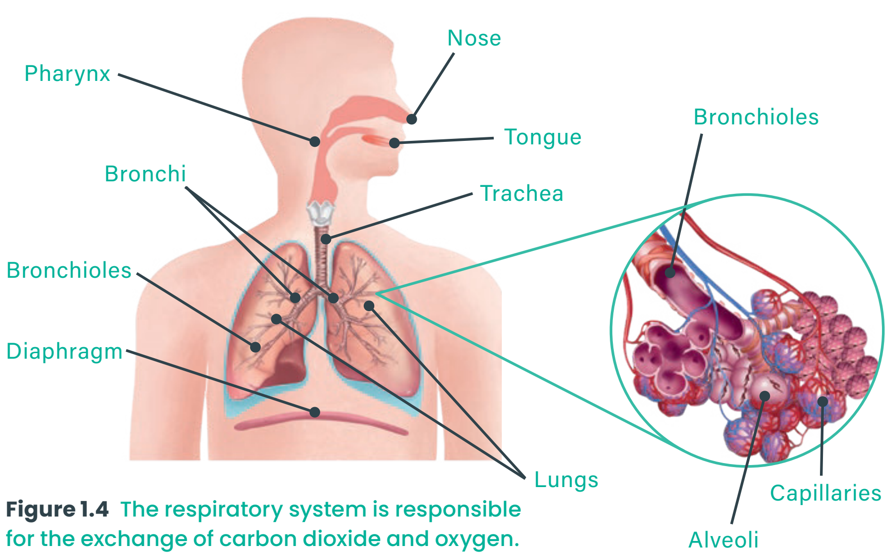


Figure 1.4 The respiratory system is responsible for the exchange of carbon dioxide and oxygen.

2 The circulatory system transports oxygen throughout the body

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

There are three main types of blood vessels. *Arteries* take blood from the heart to the body. They have thick muscular walls that expand and contract as the heart beats. *Veins* take blood from the body back to the heart. Their walls are not as thick as those of arteries, and they contain valves to keep the blood flowing in the right direction. *Capillaries* are the smallest blood vessels. They take blood right to the body's cells. They have walls that are just one cell thick – this allows nutrients and oxygen to easily move into the cells from the blood, and allows waste products to move out of the cells into the blood.

The heart is made up of four chambers. This structure allows oxygenated blood from the lungs to be pumped out to the body's cells, and deoxygenated blood returning from the body to be pumped to the lungs. Oxygenated blood comes from the pulmonary vein into the left atrium of the heart. It is then pumped into the left ventricle, before being pumped out of the heart through the aorta – the main artery that leads to the rest of the body. Deoxygenated blood from the body enters the right atrium of the heart from the vena cava – the main vein that leads from the body. It then moves into the right ventricle, before leaving the heart through the pulmonary artery to go to the lungs for gas exchange.

The circulatory system is not only important for transporting oxygen and carbon dioxide around the body, but for transporting nutrients from the digestive system (such as glucose) to the cells. It also moves waste products from the cells to the organs that process and remove them.

What are the three main types of blood vessel?

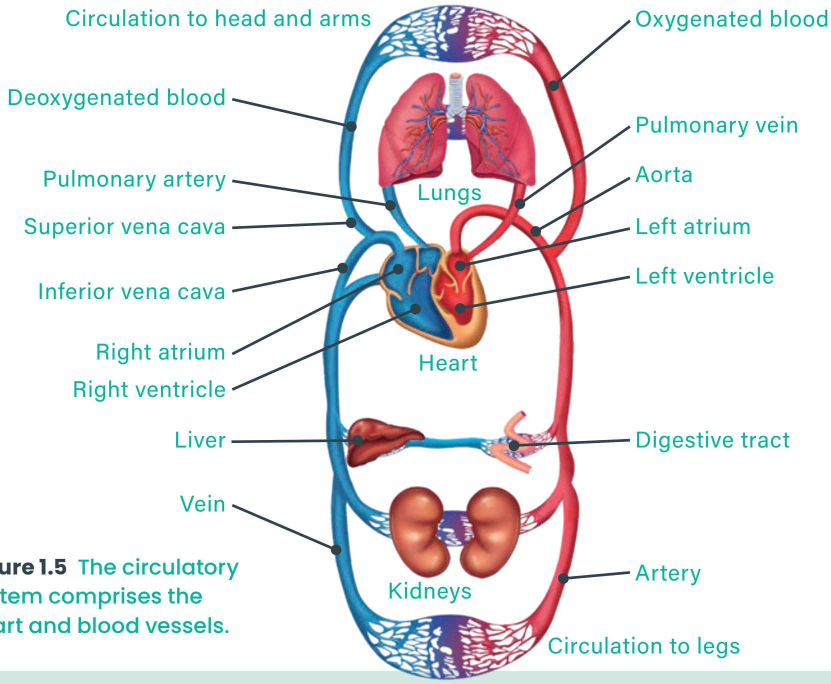


Figure 1.5 The circulatory system comprises the heart and blood vessels.

INVESTIGATION 1.3A

Heart dissection

KEY SKILL
Writing a research question

▶ *Go to page **142***

INVESTIGATION 1.3B

Heart rate, breathing rate and exercise

KEY SKILL
Representing data to identify patterns and trends

▶ *Go to page **144***

CHECKPOINT 1.3

1 What is the advantage of having lungs made up of thousands of tiny alveoli?
2 Explain why carbon dioxide in the blood needs to be exchanged with oxygen from the air.
3 Identify the structures of the circulatory system that a red blood cell moves through after it leaves the capillaries in the lungs, until it returns to the same position.
4 Identify which side of the heart contains oxygenated blood, and which side of the heart contains deoxygenated blood. What is the advantage of keeping them separated?

EXTENSION

5 Find out about the structures of the respiratory and circulatory systems in other animals such as fish and amphibians. Use a table to compare them with those of a mammal.

SUCCESS CRITERIA

- I can describe the structure and role of the respiratory and circulatory systems.
- I can describe how the respiratory system and the circulatory system work together.

1.4 THE DIGESTIVE AND EXCRETORY SYSTEMS

LEARNING INTENTION

At the end of this lesson I will be able to describe the role of, and interaction between, the digestive and excretory systems.

KEY TERMS

amino acid
a simple molecule that is the basic unit of a protein

digestive enzyme
a chemical that acts to break down large chemical structures in food into smaller forms

nitrogenous
containing nitrogen

LITERACY LINK

LISTENING

Describe the organs in the digestive system to a partner, including how the organs connect, what they look like and where they are located in the body. Your partner must try to draw a diagram from your description. Then swap roles and try to draw the excretory system from your partner's description.

NUMERACY LINK

UNITS

The volume of urine passed by a person varies from 0.250 to 0.400 L. Express these volumes in millilitres and then microlitres.

Mammals obtain nutrients and energy from the food that they eat. The nutrients in food are often not in the form required by the body's cells, so the body must process them. The digestive system breaks food down both physically and chemically so that the nutrients in it can be absorbed into the body.

Cellular activity, such as cellular respiration, creates waste products, and these must be removed from the body. The process that removes these wastes is known as excretion, and it is undertaken by organs in the excretory system such as the kidneys, liver and even the skin and lungs.

1 The digestive system breaks down food

All living organisms require nutrients and water to survive, grow and sustain cellular processes. These nutrients include vitamins, minerals, simple sugars, fatty acids and **amino acids** (organic compounds that combine to form proteins). The role of the digestive system is to break down food into small molecules that the body can absorb. This happens in two ways: mechanical digestion, where the food is broken down into smaller pieces (for example, chewing), and chemical digestion, where **digestive enzymes** break the molecules in the food down into smaller molecules that can be absorbed by the body's cells.

In the mouth, food is broken into small pieces by the teeth and mixed with saliva, which contains enzymes that break down carbohydrates. When you swallow, this mix of food and saliva moves down into the oesophagus and then to the stomach.

Within the stomach, the food is broken down further into a soupy mixture of very small pieces and it mixes with gastric juices that contain enzymes and hydrochloric acid. This mixture is slowly released into the top section of the small intestine. Here it mixes with pancreatic juices and chemicals that neutralise the stomach acid droplets.

As this mixture moves through the rest of the small intestine, the nutrients begin to be absorbed. The walls of the small intestine are lined with tiny projections called villi, which contain capillaries. In the same way that oxygen molecules pass through the lung's capillaries into the bloodstream, the nutrient molecules pass though the intestinal capillaries.

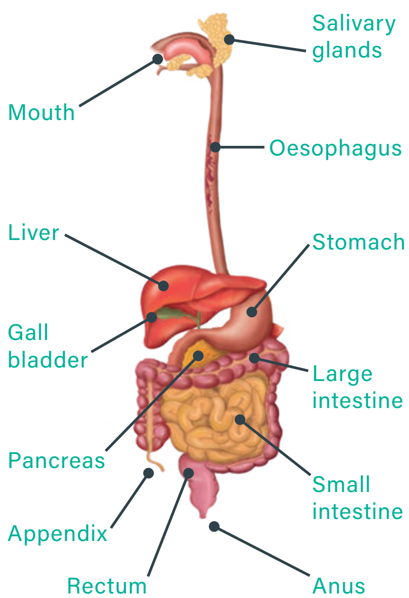


Figure 1.6 The role of the digestive system is to break down food into small molecules that the body can absorb.

The molecules enter the bloodstream, and the circulatory system moves them around the body to where they can be processed.

A lot of what we eat is left undigested as it passes through the small intestine; the nutrients are absorbed, but much material remains. This moves into the large intestine, also known as the bowel, where bacteria act on it, releasing some important vitamins and minerals that can be absorbed, producing gas as a by-product. Although water can be absorbed in the stomach and small intestine, the remaining absorption of water happens in the large intestine. The remaining solid waste collects in the rectum, and is finally expelled as faeces.

What is the role of the digestive system?

2 The excretory system removes waste

The chemical reactions in the body produce a variety of waste products that, if not removed, will build up in the body and cause harm. Excess carbon dioxide is removed by the lungs, and some excess salts and water are removed by the skin through sweat, but most water and other toxins are removed from the blood by the kidneys.

One major waste product is urea, a type of **nitrogenous** waste created by the liver. Urea is a by-product of reactions that break down proteins, amino acids and other molecules that contain nitrogen.

The kidneys are organs that remove waste products such as urea from the blood and ensure that the body retains the right amount of water. As blood moves into the kidneys through the renal arteries, microscopic structures called nephrons filter the blood, removing any waste products and excess water. The nephrons also make sure that substances the body needs, such as glucose, remain in the blood. The substances that have been removed from the blood are what we call urine, which leaves the kidneys through the ureters and is stored in the bladder until expelled through the urethra. The blood that has been filtered then returns to the circulatory system through the renal vein.

What is the structure in the kidney that filters blood?

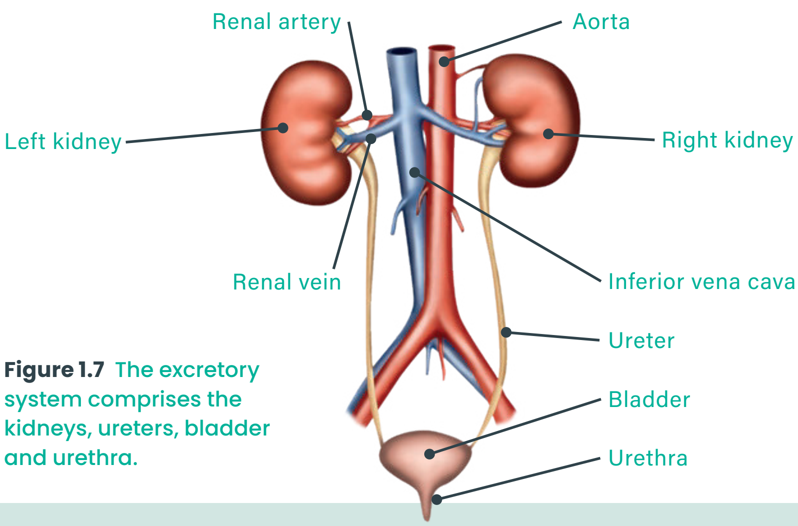


Figure 1.7 The excretory system comprises the kidneys, ureters, bladder and urethra.

CHECKPOINT 1.4

1 What is the difference between mechanical and chemical digestion?

2 State the function of a digestive enzyme.

3 Identify the location where most absorption of nutrients occurs.

4 Describe the role of the kidneys, ureters, bladder and urethra in removing waste from the body.

5 Describe the role of the circulatory system in removing waste from the body.

6 Explain why it is important that the circulatory system coordinates with the digestive system.

7 The villi increase the surface area of the small intestine. Explain why this is important.

CRITICAL AND CREATIVE THINKING

8 Consider the digestive systems of a carnivore (such as a wolf), a herbivore (such as a cow) and a human. Suggest how their diets might relate to the different structures in the digestive systems of these animals.

SUCCESS CRITERIA

- I can describe how the digestive system provides the body with nutrients.
- I can describe how the excretory system removes wastes from the body.
- I can describe how the digestive and excretory systems work together.

1.5 THE IMMUNE SYSTEM

LEARNING INTENTION

At the end of this lesson I will be able to describe the response of the body to changes as a result of the presence of microorganisms.

KEY TERMS

antibody
a protein that responds to a specific antigen

lymphocyte
a type of white blood cell that produces antibodies in response to a pathogen

pathogen
an agent that causes disease

phagocyte
a type of cell capable of engulfing and destroying bacteria

LITERACY LINK

READING

Choose five words in this lesson and write definitions that a younger student would be able to understand.

NUMERACY LINK

MEASUREMENT

The average red blood cell is 7.5 micrometres in diameter. A white blood cell is about 15 micrometres. Bacteria can vary from 0.5 to 2.0 micrometres. Draw a scale diagram of both types of blood cell plus a bacterial cell.

Our immune system is tasked with protecting us from disease. Unfortunately, sometimes things can go wrong. In some cases, **pathogens** such as viruses can even turn our own immune systems against us.

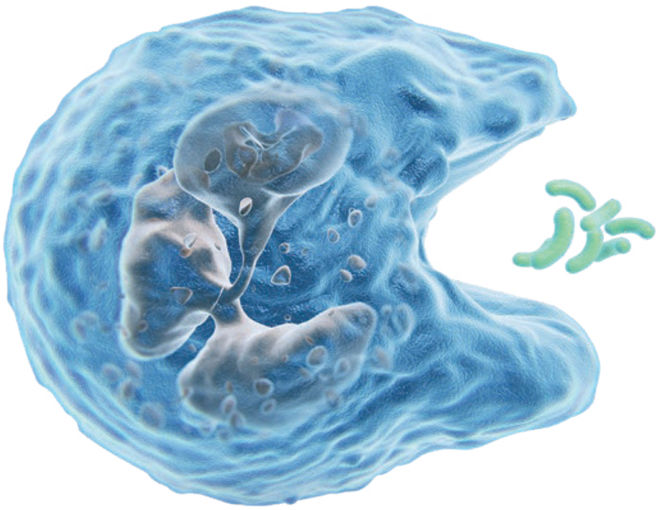


Figure 1.8 A white blood cell engulfing a bacterium in a process called phagocytosis. This is part of the body's second line of defence against disease.

1 Diseases may be infectious or non-infectious

Diseases cause damage to the body by preventing it from working as it should. Diseases can be classified as either infectious or non-infectious.

Infectious diseases can be transmitted (passed) from one person to another and are caused by agents called pathogens. Examples of pathogens are bacteria, viruses and fungi. Different pathogens can be transmitted in different ways, including skin-to-skin contact, breathing in droplets exhaled by an infected person, or the exchange of bodily fluids such as blood or saliva.

Non-infectious diseases aren't caused by pathogens and cannot be transmitted from one person to another. There are five main types of non-infectious diseases.

- Genetic diseases: conditions inherited from your parents, such as haemophilia (a disorder where blood doesn't clot)
- Lifestyle diseases: conditions caused by the way you live, such as dietary habits or smoking
- Parasitic diseases: conditions caused by parasitic organisms living on or inside your body. While these organisms do not spread an infectious disease, they may release toxins and their presence can still make you sick.
- Incorrect body function: conditions caused by organs or body systems not working the way that they should, such as diabetes or cancer
- Immunologic diseases: conditions caused by the immune system malfunctioning in some way

What is the difference between infectious and non-infectious diseases?

2 The first defence against pathogens is keeping them out

The first 'line of defence' that the body can use against pathogens is preventing them from entering the body in the first place.
Some examples of the first line of defence include the following.

- Your skin forms a barrier that keeps out pathogens. The circulatory system quickly seals any cuts by forming clots and then a scab.
- Mucous-coated membranes line the nasal passage and the airways leading to the lungs. This mucous traps dust and any pathogens. Microscopic hairs called cilia move any foreign debris away from the lungs, so that it is either coughed or sneezed out, or swallowed.
- Tears and saliva contain antimicrobial substances that can kill pathogens.
- Acidic gastric juices can kill pathogens that are on or in food we eat.

What is the first line of defence against pathogens?

3 The immune system fights pathogens and diseases

When pathogens make their way into the body, the immune system works to destroy them using the second and third lines of defence. These systems consist of a small number of organs and tissues, such as the thymus, lymph nodes and bone marrow, as well as the white cells in the blood.

The second line of defence involves cells called **phagocytes** that recognise foreign substances, engulf them and destroy them with the help of other cells. Fever and inflammation may occur when the second line of defence is active.

The third line of defence involves a specific, adaptive response of the immune system. When a foreign pathogen enters the body it is recognised by specialised white blood cells called **lymphocytes**. They produce **antibodies** as a response, which encourage cells of the immune system to kill off the pathogen. After the pathogen has been destroyed, special memory cells remain, ready for next time the body is infected by the same pathogen. The cells 'remember' the pathogen and fight it off quickly, making you immune to it. Vaccines take advantage of this adaptive immune system.

What is a lymphocyte?

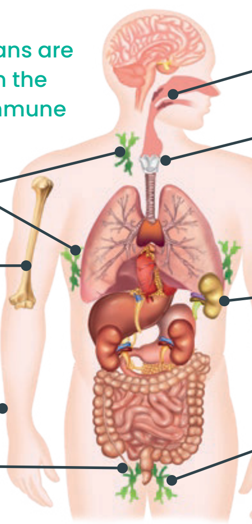


Figure 1.9 Many organs are involved in the human immune system

CHECKPOINT 1.5

1 What is a pathogen?
2 Identify two ways that pathogens can be transmitted from person to person.
3 Using evidence from the text, explain why it is important to wash your hands regularly if you have a cold.
4 Describe one way that pathogens can be prevented from entering the body in the first place.
5 Describe the second line of defence against pathogens.
6 Explain how the immune system adapts to fight specific pathogens.
7 Edward Jenner is credited with creating the first vaccine. Carry out research to find out about his contributions to medical science.

EXTENSION

8 Classify the following as infectious or non-infectious diseases.
  a Chicken pox
  b Haemophilia
  c Tapeworm
  d Influenza
  e Measles
  f HIV
  g Diabetes

SUCCESS CRITERIA

- I can describe the difference between infectious and non-infectious diseases.
- I can describe the immune system's response to microorganisms.

1.6 TREATING DISEASES

LEARNING INTENTION

At the end of this lesson I will be able to consider how ideas about disease transmission have changed over time as knowledge has developed.

KEY TERMS

bacteria
tiny, single-celled organisms that can live in a range of environments

immune
resistant to a particular illness or disease

transmissible
able to be passed from one person to another

virus
a tiny infectious agent that multiplies in its host

LITERACY LINK

SPEAKING

Write a short speech about whether you believe it was ethical for Edward Jenner to test his smallpox vaccine on an eight-year-old boy. Deliver your speech to a partner, then listen to their speech.

NUMERACY LINK

CALCULATION

Ten people are infected with a transmissible disease, with four more infected each day. Write an equation to model the spread of this disease. How many people have been infected after 17 days?

Nothing has caused more loss of human life than **transmissible** diseases. Historically, during some disease outbreaks, 10% of the world's population was wiped out.

Scientists have been vital in treating diseases, in some cases completely eliminating them. They have made vaccines and antibiotics, and educated people about how diseases spread, saving millions of people from suffering and death.

1 Transmissible diseases are passed from person to person

People in the Middle Ages had a life expectancy of around 30 years. Doctors had no idea what caused illness or disease, often blaming demons, sin, bad humours or even nasty smells! Fortunately we have learnt a lot since then and we now categorise diseases as either transmissible or non-transmissible.

Have you ever had to stay at home sick with `the flu'? Sometimes people use that word when they just have a cold, but the real flu is a disease called influenza. This is a transmissible disease – one that passes from person to person. There are many ways that diseases can be transmitted, including through skin contact and through tiny droplets in the air.

There are different types or strains of influenza, and some are stronger and more dangerous than others. In 1918, a strain called the Spanish flu killed 3–5% of people on Earth. That was between 50 and 100 million people! One of the reasons so many people tragically died was that there was no vaccine available to make people **immune** to influenza.

What is a transmissible disease?

Figure 1.10 During the 1918 Spanish flu epidemic, hundreds of patients were kept away from the public in tents, warehouses or hospital buildings.

2 Vaccines can prevent people from catching diseases

Vaccines are medicines that can prevent people from catching diseases in the first place. The vaccine is similar to the disease itself, so when a person is injected with it or swallows it, their immune system acts to fight it off. The person's body then usually 'remembers' the disease and becomes immune to it. If the person comes in contact with the disease again, they can remain healthy.

The first vaccine was discovered and developed at the end of the 18th century by English doctor Edward Jenner. He lived at a time where a disease called smallpox was killing millions of people all around the world.

Jenner noticed that people who had been exposed to cowpox – a very similar but much less dangerous disease – were immune to smallpox. One day he borrowed the eight-year-old son of his gardener and experimented on him. He rubbed pus from cowpox blisters into an open wound on the boy's arm. Jenner's experiment worked, and the boy became immune to smallpox!

How was the vaccine for smallpox developed?

3 Antibiotics treat diseases caused by bacteria

Have you have ever cut yourself and then noticed the wound is red and hot? It may have been infected with **bacteria**. Medicines called antibiotics can treat many infections like this. Antibiotics are also able to treat illnesses such as tuberculosis and pneumonia, which in the past have killed millions of people.

The earliest antibiotics used types of fungus, such as mould, to fight bacteria. There are records showing the use of mould in treating infections in Ancient Greece and Egypt. People at that time may not have known the science behind it, but they knew that it worked. British scientist Alexander Fleming was the first person to work out why moulds could treat infections, and he invented the first antibiotic medicine, penicillin from a fungus, in 1928. Australian scientist Howard Florey and British scientist Ernst Chain did more research to make this medicine in large amounts, so that it could treat many people.

Antibiotics have limitations, because they only work on bacteria. Diseases such as colds and influenza are caused by **viruses**, tiny infectious agents even smaller than bacteria, and antibiotics have no effect on them. Sometimes antibiotics are used too much or when they shouldn't be, which can cause them to lose their effectiveness. Many doctors suggest avoiding the use of antibiotics unless they are absolutely necessary.

Figure 1.11 The pale green bacteria cannot grow near the small discs of test antibiotics.

What can be treated with antibiotics?

INVESTIGATION 1.6

The contagion game

KEY SKILL
Explaining results using scientific knowledge

▶ *Go to page **146***

CHECKPOINT 1.6

1 What did doctors in the Middle Ages think caused disease?

2 Since the Middle Ages, scientific knowledge has led to many improvements in human health. Identify at least two of the ways that now exist to fight disease.

3 Explain in your own words how vaccines work.

4 There are many types of diseases that humans can have.
   a With a partner, list as many different diseases as you can.
   b Separate the diseases from part a into two columns: 'transmissible' (those you can catch from someone or something) and 'non-transmissible'.

5 Explain why antibiotics are not useful to treat influenza.

STUDENT VOICE AND AGENCY

6 Imagine you are the Prime Minister of Australia. Devise a plan to ensure the safety of all Australians in case of a disease outbreak. What are the three most important aspects of your plan?

SUCCESS CRITERIA

- I can describe some ways that scientific knowledge has contributed to how diseases are treated over time.

1.7 ANIMAL AND PLANT DISEASES

LEARNING INTENTION

At the end of this lesson I will be able to discuss how the values and needs of contemporary society can influence the focus of scientific research into diseases affecting plants and animals.

KEY TERMS

contagious
able to spread from one organism to another

pustule
a small blister

quarantine
the isolation of people, plants, animals or objects that may have been exposed to biosecurity threats

LITERACY LINK

WRITING

Write a short press release to inform the general public about the risks of FMD.

NUMERACY LINK

CALCULATION

A farmer discovers 23 of his sheep have symptoms of FMD. In total, he has 446 sheep on his farm. What percentage of his sheep have the disease?

Every organism has a different immune system, and is vulnerable to different pathogens. Many diseases that affect animals can also affect other animals and humans. The diseases that affect plants usually don't affect humans or animals, but there are a few exceptions. Scientists develop treatments to keep animals and plants healthy, and to protect the global economy and ecosystems.

1 Foot-and-mouth disease affects animals with cloven hoofs

Foot-and-mouth disease (FMD) is a highly **contagious** disease that affects animals with cloven (divided) hoofs, such as cattle, sheep, goats and pigs. The disease is caused by a virus that can be transmitted through droplets in the air, saliva, faeces and milk. As the name suggests, the disease causes blisters and ulcers on the feet and mouth of affected animals, leaving them unable to walk or eat properly. It does not affect humans.

FMD is found in many parts of the world, particularly in Asia, Africa, South America and the Middle East. There have also been outbreaks of the disease in other parts of the world, such as in the United Kingdom in 2001 and 2007. There is currently no cure for FMD, although vaccines can reduce the chance that animals become infected.

The greatest threat of FMD is economic rather than medical. Because it cannot be cured, and because it's so contagious, infected animals have to be destroyed and their carcasses burned. This has an enormous impact on farms and businesses that sell or export animals or their meat or milk. The 2001 outbreak in the United Kingdom caused a loss to the British economy of almost 20 billion dollars.

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) is undertaking research to help prevent the spread of FMD in our neighbouring countries. This includes developing better techniques to quickly diagnose the disease, as well as vaccines that are effective against new strains of the virus.

What are the symptoms of FMD?

Figure 1.12 Foot-and-mouth disease is a highly contagious disease that is a significant threat to the agricultural industry.

2 Guava rust affects many species of myrtle plants

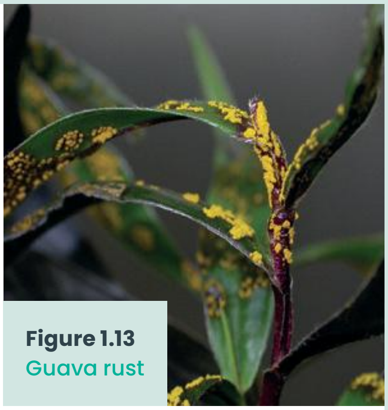


Figure 1.13
Guava rust

Guava rust is a plant disease caused by a fungus that only infects plants belonging to the *Myrtaceae* family. This is a large family of more than 100 different types of plants, including eucalyptus trees, which is why the disease is also known as eucalyptus rust.

Guava rust is primarily spread by spores of the fungus, which can be transported in the air or on the clothes and shoes of people working on trees. Spores can also survive on the surface of cut timber, wood packaging or infected plant material.

The disease attacks the leaves, stems and shoots of affected trees, and can also affect fruits and flowers. It causes tiny **pustules** to form, which erupt into yellow spores. As the infection spreads, it causes leaves to become deformed and stunts the plant's growth; it can even kill plants entirely and is a significant threat to ecosystems.

Scientists are undertaking research into what makes some plants resistant to guava rust and other similar diseases, in order to better understand the impact the fungus could have if released into the Australian ecosystem.

What kind of plants are affected by guava rust?

3 Biosecurity laws help control animal and plant diseases

Neither FMD nor guava rust are found in Australia, which is a very good thing! An outbreak of FMD would have a massive and terrible impact on Australia's sheep and cattle industry. Similarly, if guava rust infected Australia's eucalyptus forests, it could ruin our logging industry – not to mention the damage it could cause to the ecosystems that involve those forests; for example, to the koalas that eat eucalyptus leaves.

One vital protection we have against these diseases, and other dangerous plant and animal diseases, is that Australia is an island continent. Many diseases are airborne, travelling over national borders, but because Australia is surrounded by water, diseases cannot arrive that way.

We're also protected by Australia's biosecurity laws. These laws set strict guidelines on the types of animal and plant materials (including meat and wood as well as live organisms) that can be brought into the country. Any suspect materials are placed in **quarantine** when they reach Australia's ports. Quarantined materials are tested and, if they carry a risk, they may be destroyed or sent back to their point of origin.

Why does Australia have such strict biosecurity laws?

CHECKPOINT 1.7

1 Identify the pathogen that causes FMD and ways it can be transmitted.

2 Suggest why vaccines are useful for preventing FMD.

3 Explain how the CSIRO's research into FMD is of benefit to the agricultural industry in Australia and neighbouring countries.

4 Identify the pathogen that causes guava rust and ways it can be transmitted.

5 Explain why it is important to better understand the fungus that causes guava rust.

6 What is meant by biosecurity?

7 Use evidence from the text to explain Australia's advantageous position with regards to controlling the spread of diseases that can affect animals and plants.

INQUIRY

8 The CSIRO plays an important role in undertaking research to help tackle national and international health and biosecurity challenges. Conduct your own research to find some examples of the work the CSIRO is undertaking. Select one project and present a summary of it to your class.

SUCCESS CRITERIA

- I can describe how foot-and-mouth disease can impact the agricultural industry.
- I can describe how guava rust can impact native ecosystems and the forestry industry.
- I can describe the importance of biosecurity in Australia.

1.8 HUMAN DISEASES AND ILLNESSES

LEARNING INTENTION

At the end of this lesson I will be able to discuss how the values and needs of contemporary society can influence the focus of scientific research into diseases affecting humans.

KEY TERMS

dengue fever
a mosquito-borne viral disease occurring in tropical and subtropical areas

epidemic
the widespread occurrence of an infectious disease in a community

graft
a piece of living tissue that is transplanted surgically

pandemic
a disease occurring within a whole country or around the world

As well as protecting plants and animals, Australia's geography and our biosecurity laws also protect us from diseases that affect humans. There are many dangerous diseases, such as rabies and *Ebola*, that are not found in Australia because of these protections. However, many other diseases make their way here – and when there is a global pandemic, such as COVID-19, it's impossible for us to remain unaffected.

1 Diseases can spread in epidemics and pandemics

An **epidemic** is a major outbreak of a disease within one or more communities. Diseases spread very quickly during an epidemic, making it very difficult for doctors and medical officials to treat all sufferers. Australia's health system is effective in preventing epidemics. There were none recorded within Australia in the 20th century, and only one in the 21st century: a 2009 outbreak of **dengue fever** in Queensland.

Australia doesn't have the same level of protection against **pandemics** – disease outbreaks that affect global populations. The worst recorded pandemic in history was the Black Death, which killed millions of people in Europe during the 14th century. There have also been terrible pandemics of measles, smallpox, tuberculosis and other deadly diseases throughout history.

There are many pandemics currently affecting the world, and they're very hard to control when so many people travel internationally. Diseases such as COVID-19 (a coronavirus), influenza, measles and HIV are all global issues. During the COVID-19 pandemic we have seen first-hand the importance of practices such as social distancing, hand washing and quarantine.

What is the difference between an epidemic and a pandemic?

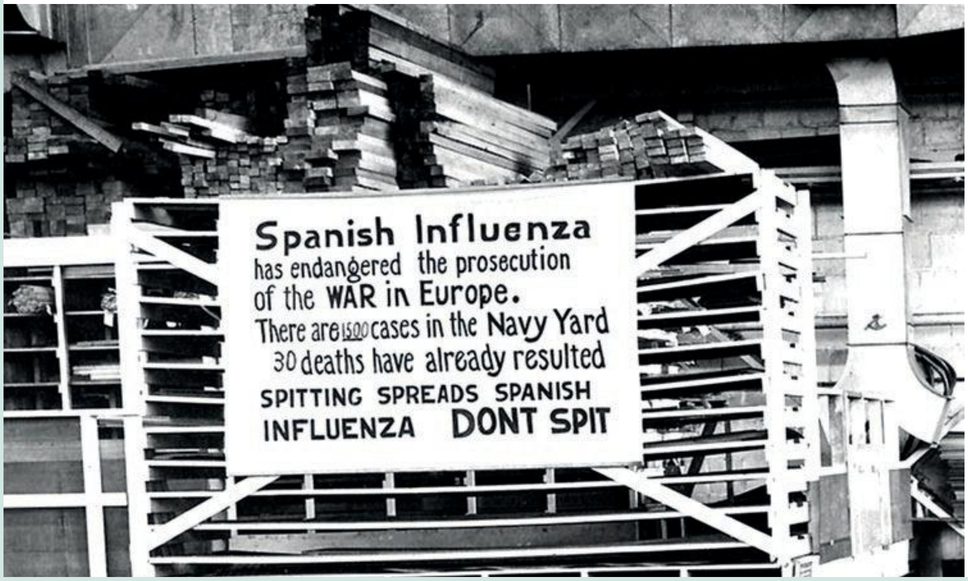


Figure 1.14 The 1918 H1N1 influenza virus was the deadliest pandemic of the 20th century. It was known as the 'Spanish flu' because it became more widely known after the disease spread from France to Spain.

2 Lifestyle diseases affect large numbers of Australians

While Australia has some protection against infectious diseases, Australians are just as vulnerable as people from other countries to non-infectious lifestyle diseases. A 2017 survey of records from Australian doctors and hospitals indicated that more than 12 per cent of Australians had hypertension, or high blood pressure, and more than 8 per cent had hyperlipidaemia, or high cholesterol. These are both diseases that can be caused or made worse by lifestyle factors, such as alcohol consumption and poor diet.

Diabetes is another non-infectious disease that is very prevalent in Australia – it's estimated that more than 1.7 million Australians suffer from some form of it. Diabetes is a disorder that affects the metabolism and is marked by high blood sugar levels. It can lead to cardiovascular disease, stroke, kidney disease, damage to the eyes and many other conditions.

Type 1 diabetes is a condition in which the pancreas no longer secretes insulin; it can be treated with regular insulin injections. Type 2 diabetes is a lifestyle disease, where insulin is still produced, but the target cells do not react to it. It is linked to obesity, high intake of sugar in the diet and lack of exercise.

What is a lifestyle disease?

Figure 1.15 Most people with diabetes must regularly check their blood sugar levels using a blood glucose meter.

3 Medical scientists research cures and treatments

Health and medical research is one of the largest and most active areas of scientific research in the world today. This research is conducted by scientists such as biologists, doctors and biotechnologists.

Early medical researchers provided us with cures and treatments that are still in use today. Vaccines were invented at the end of the 18th century. They work by introducing a small amount of disease antigens to a patient, prompting their immune systems to develop antibodies and making them immune to that disease in the future. Antibiotics kill bacteria that cause diseases. Penicillin, the first antibiotic medicine, was invented in 1928.

As diabetes is a major issue in Australia, it's also a major focus of medical research. The Australian Foundation for Diabetes Research is currently developing a form of insulin **graft** – an artificial device that creates insulin in the body. The graft is a network of microscopic bubbles, created from seaweed, that are filled with insulin. Devices like this could revolutionise the treatment of Type 1 diabetes. Type 2 diabetes is better treated with lifestyle changes; the CSIRO has developed diet and exercise plans to help sufferers change their lifestyle and improve their own health.

How could insulin grafts change how Type 1 diabetes is treated?

Figure 1.16 Social distancing (staying at least 1.5 m away from others) was a crucial part of slowing the spread of COVID-19 in Australia.

1.8 continued ...

… 1.8 continued

HUMAN DISEASES AND ILLNESSES

KEY TERMS

asymptomatic
displaying no symptoms of a disease

hygiene
ways of doing things that support health and prevent disease, often through cleanliness

sanitation
facilities and services to ensure safe treatment of human waste (urine and faeces)

LITERACY LINK

SPEAKING

SPEAKING

Read section **4** then, without looking at your book, explain to a partner what you have learnt. Swap roles and repeat for section **5**.

NUMERACY LINK

GRAPHING

Too much cholesterol in the bloodstream increases the risk of heart disease or stroke. In 2017–18, 3.1% of the Australian population aged 35–44 years had high cholesterol. This value increased to 6.8% for 45–54 years, 14.1% for 55–64 years and 21.2% for people aged over 65. Tabulate this data, then display it in a chart.

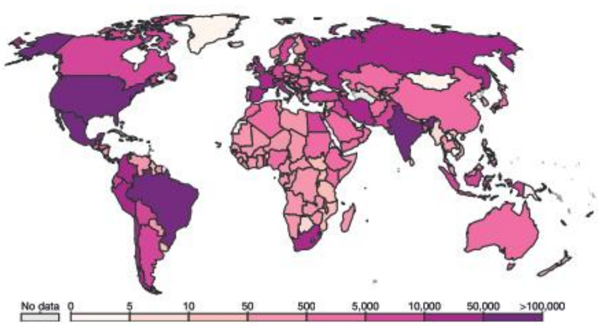
4 COVID-19 is a fast-spreading global pandemic

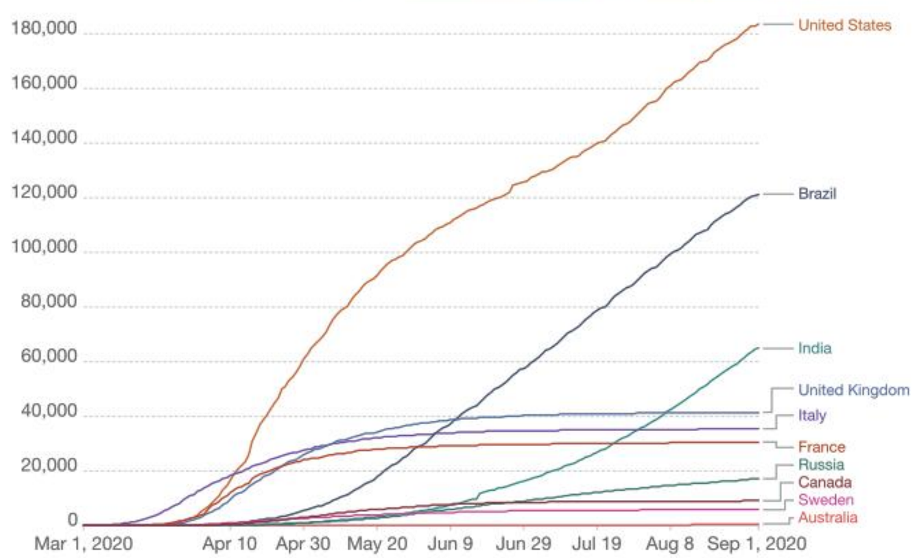
In December 2019, a new strain of a type of coronavirus was first identified in Wuhan, a city in central China that is home to 11 million people. Chinese officials began to warn the rest of the world – the virus was spreading quickly and multiplying extremely quickly. Many factors, including international travel and improper hygiene, caused the virus to spread within weeks to a large number of countries, and so the COVID-19 pandemic (also known as the coronavirus) was introduced to the world.

COVID-19 is the name of the disease, but the virus that causes the disease is called SARS-CoV-2. Preliminary research identified that SARS-CoV-2 has a zoonotic (animal) origin and genetic testing has found it to be similar to bat-borne viruses, which suggests that it originally came from bats (though may have spread to humans through another animal). The virus spreads from person to person in a number of ways, including through respiratory droplets such as those from coughs or sneezes. The virus can also be spread via surfaces and lasts for up to three days on shiny surfaces such as plastic. Symptoms include a cough, a fever and shortness of breath, but some people have shown no symptoms at all – this is called being **asymptomatic**. In those who do show symptoms, approximately 20% of people become seriously ill.

Why is COVID-19 classed as a pandemic and not an epidemic?

Figure 1.17
COVID-19 rapidly spread across the world in early 2020. The worst-affected countries at that time were the United States and Brazil.





Cumulative confirmed COVID-19 deaths, 1 September 2020

Source: European CDC

5 The virus infects host cells, turning them against themselves

A virus without a host cell is harmless because it can't reproduce by itself (which is also why we consider viruses to be non-living). SARS-CoV-2 attaches itself to a healthy host cell and then injects the cell with its genetic material (RNA). Once the virus has successfully infected a cell, it turns the cell against itself – forcing the cell to make virus particles that are then released to infect even more of the host's cells. The virus turns the cell into a virus-making factory! Soap is very effective in destroying SARS-CoV-2 because it breaks down the outside layer of the virus, which makes it unable to infect host cells.

How does the COVID-19 virus spread inside an individual?

6 Slowing the spread of the COVID-19 pandemic

The goal of slowing the spread of COVID-19 can be achieved in just two (easy-sounding) ways – not getting infected yourself and not infecting others. This is why special protective measures have been introduced all around the world, including measures such as social distancing (keeping at least 1.5 m apart from other people), coughing or sneezing into your elbow instead of your hand, using a contact tracking app like COVIDSafe, increased testing and, perhaps most importantly, washing your hands! **Sanitation** is about keeping the environment clean and free of disease. As well as including the removal and treatment of wastes such as sewage, sanitation also includes **hygiene**. Do you wash your hands after using the bathroom? Do you have regular showers or baths? Do you help your family by doing the dishes and wiping surfaces? All of these questions promote good hygiene, keeping people healthy and preventing the spread of disease.

What does sanitation involve?

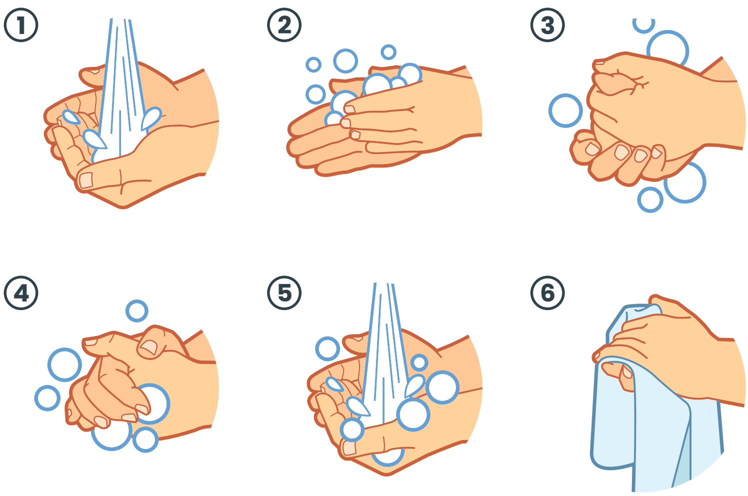


Figure 1.18 Washing your hands maintains health and hygiene, not just for yourself but for everyone and everything you come into contact with.

CHECKPOINT 1.8

1 Describe the difference between a pandemic and an epidemic.
2 Outline some measures used to protect against the spread of COVID-19.
3 The virus that causes COVID-19 is highly infectious. Suggest why.
4 Explain why hand washing, with soap in particular, is so effective against COVID-19.
5 Suggest why international travel could cause pandemics.
6 Identify three lifestyle diseases that are common in Australia.
7 Explain the difference between Type 1 and Type 2 diabetes.
8 Suggest why an artificial device that creates insulin would benefit someone with Type 1 diabetes and not someone with Type 2 diabetes.

STUDENT VOICE AND AGENCY

9 Funding for medical research is limited in Australia. Which diseases (both transmissible and non-transmissible) do you believe should be the focus of government spending? Justify your response.

SUCCESS CRITERIA

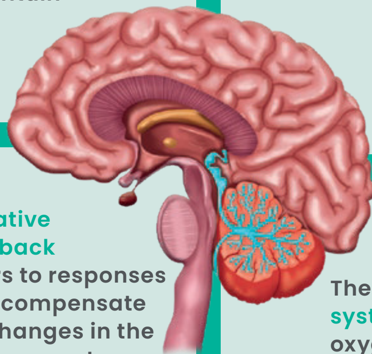
- I can describe the difference between an epidemic and a pandemic.
- I can describe some non-infectious diseases that cause problems in Australia.
- I can describe why diabetes is a major focus of medical research in Australia.

VISUAL SUMMARY

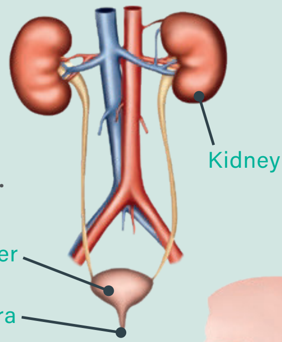
Body systems coordinate to sustain life.

Nervous and **endocrine systems** coordinate the body's responses to changes in the internal and external environment.

Hormones are chemicals produced by glands of the endocrine system; they trigger an effect in target cells to help maintain **homeostasis**.



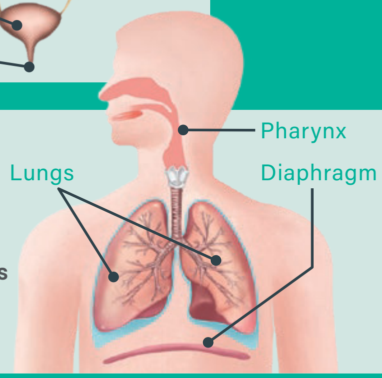
The **excretory system** is responsible for the removal of the waste from cellular processes.



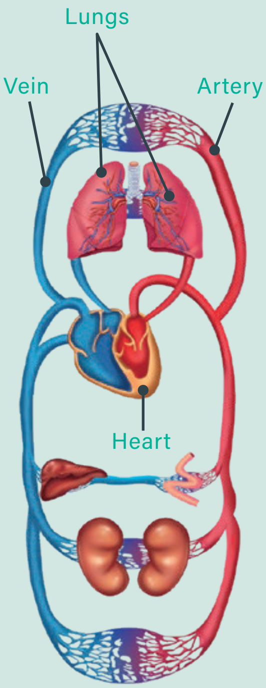
Homeostasis maintains bodily functions at levels that sustain life and good health.

Negative feedback refers to responses that compensate for changes in the environment.

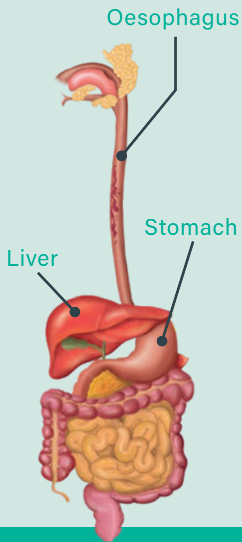
The **respiratory system** takes in oxygen and removes carbon dioxide.



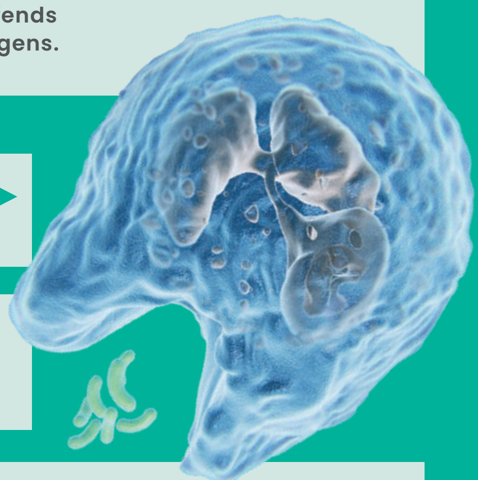
The **circulatory system** is responsible for the transport of nutrients and wastes around the body.



The **digestive system** is responsible for processing food into nutrients.



The **immune system** defends the body against pathogens.



Infectious diseases are caused by pathogens.

Non-infectious diseases are not caused by pathogens.

An **epidemic** is a major outbreak of a disease within one or more communities.

A **pandemic** is a major outbreak of a disease that affects global populations.

Guava rust and **foot-and-mouth disease**

Organisations such as the CSIRO undertake research to help prevent the spread of infectious diseases.

★ FINAL CHALLENGE ★

1. Match each receptor to its correct stimulus.

Photoreceptor	Chemicals
Chemoreceptor	Light
Thermoreceptor	Changes in pressure or position
Mechanoreceptor	Temperature changes

Level 1 — 50xp — LEVEL UP!

2. Identify which body system the following structures belong to.
   - **a** aorta
   - **b** bronchiole
   - **c** cerebrum
   - **d** kidney
   - **e** pituitary gland
   - **f** small intestine
3. Summarise the first, second and third lines of defence in the immune response to a bacterial infection.

Level 2 — 100xp — LEVEL UP!

4. Describe, using examples, the importance of biosecurity measures in Australia.
5. Explain what homeostasis is and give some examples of situations that require negative feedback in order for the body to remain in balance.
6. Outline how ideas about disease transmission have changed between the Middle Ages and the present.

Level 3 — 150xp — LEVEL UP!

7. Compare the endocrine and nervous systems with regard to:
   - **a** type of signal (chemical or electrical impulse)
   - **b** how the signal travels
   - **c** speed of the signal.
8. Explain the advantage of the respiratory system and circulatory system coordinating together.
9. Describe the COVID-19 virus and suggest why handwashing and social distancing are effective in battling the pandemic.

Level 4 — 200xp — LEVEL UP!

10. Explain why your heart rate and respiration rate increase during exercise.
11. Identify what the lungs, skin and kidneys have in common.
12. Explain why diabetes is a growing disease in Australia and justify why the disease should or should not be a focus for scientific research.

Level 5 — 300xp — LEVEL UP!

ENERGY AND MATTER IN ECOSYSTEMS

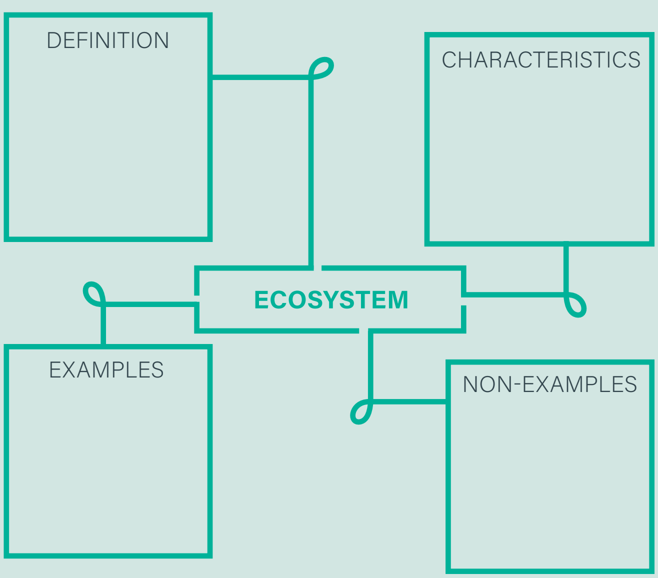
How is life maintained?

All living things and their environment are interconnected. If one thing changes so will everything else. The removal of wolves from Yellowstone National Park in the USA resulted in changes to the food web that affected how the rivers flowed – but this wasn't known until the wolves were returned.

By studying interactions between organisms and their environment as well as how matter and energy move through ecosystems, ecologists can help us learn how to manage and conserve ecosystems.

1 FRAYER MODEL

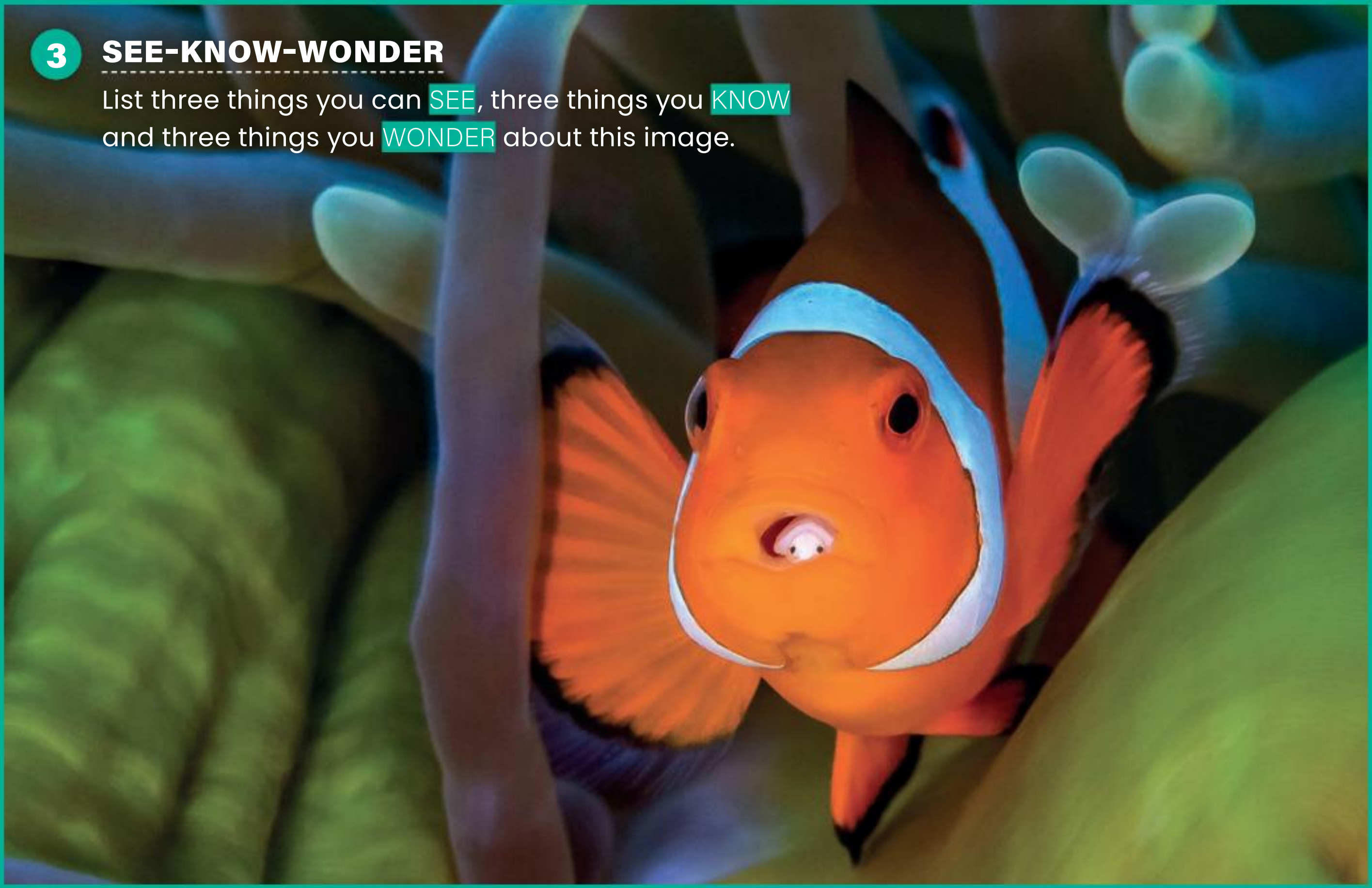
Copy and complete the below chart in your workbook.



Complete two additional charts for the key terms *Biotic* and *Abiotic*.

2 LEARNING LINKS

Brainstorm everything you already know about energy and matter in ecosystems.



3 SEE-KNOW-WONDER

List three things you can SEE, three things you KNOW and three things you WONDER about this image.

4 CRITICAL + CREATIVE THINKING

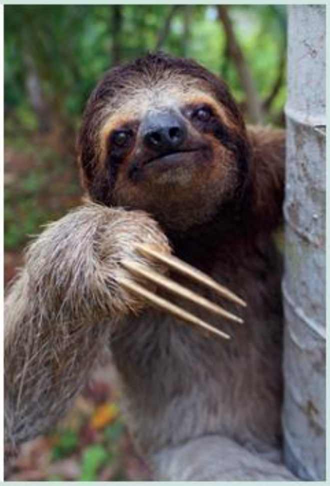
IN COMMON: List five things that a coral reef has in common with a rainforest.

FIVE FACTS: List five facts, thoughts or opinions about the use of zoos to preserve endangered species.

WHAT IF … a community of hippopotamuses were introduced to the Murray River? How would this affect the ecosystem?

5 THE MOST BIODIVERSE!

Biodiversity is the diversity of life in one particular place. The most biodiverse ecosystems are those close to the equator where there is high rainfall and it is warm all year round. On land, this means tropical rainforests; in the oceans, it means coral reefs. One in 10 species lives in the Amazon rainforest. It is home to more than 40 000 different plant species, more than 2000 species of birds, reptiles and mammals and more than 2.5 million species of insects.



2.1 COMMUNITIES IN ECOSYSTEMS

LEARNING INTENTION

At the end of this lesson I will understand that ecosystems include communities of interdependent organisms.

KEY TERMS

abiotic
non-living

biotic
living

community
a naturally occurring group of animals, plants and other organisms

consumer
an organism that gains energy by consuming other living organisms

ecosystem
a community of living things and their environment

habitat
the natural environment where a species or organism lives

photosynthesis
the chemical reaction, powered by sunlight, that plants use to change carbon dioxide and water into glucose and oxygen

producer
an organism that makes its own food using energy from the Sun

LITERACY LINK

VOCABULARY

List as many verbs as you can that describe interactions between different organisms in an ecosystem.

An **ecosystem** is an area that contains living things and their environment. Ecosystems can be very small (for example, a pond) or very large (for example, an island). A community refers to all of the living things in an ecosystem, which rely on each other to survive and interact in different ways.

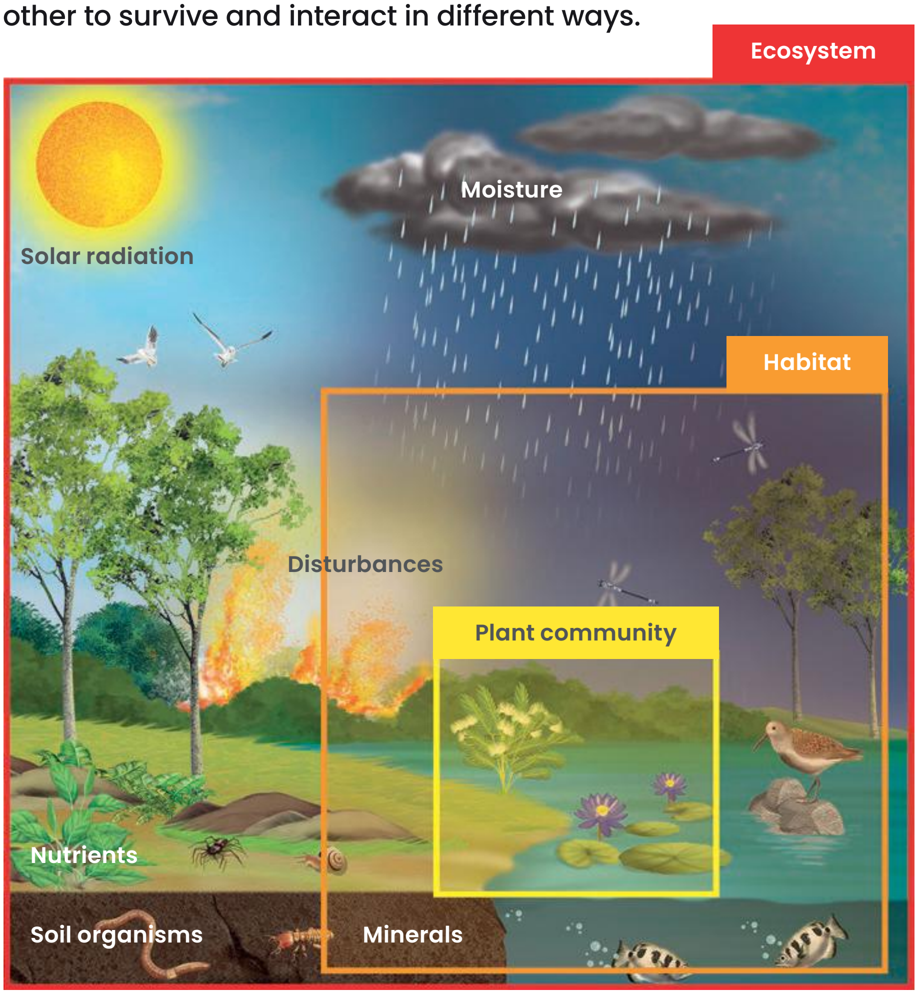


Figure 2.1 An ecosystem is an area that contains living things and their environment.

1 Communities are made up of different species

A **community** is made up of populations of all the different species that live in the ecosystem. All organisms within a community depend on each other for energy, nutrients and survival. Through the process of **photosynthesis**, **producers** convert the energy from the Sun into chemical energy that can then be used by other organisms. **Consumers** obtain their energy by eating other organisms.

Organisms such as bacteria and fungi are decomposers, recycling the nutrients from dead organisms and making these nutrients available to other species in the ecosystem.

The living things in an ecosystem are referred to as **biotic** factors. The non-living things, such as soil and water, are known as **abiotic** factors.

What is the difference between a consumer and a producer?

2 A habitat contains living and non-living factors

A **habitat** is the natural environment where a species or organism lives. A habitat is chosen carefully; it needs to have resources like food and water, shelter and protection, and mates to reproduce with. Every species has certain conditions that it needs in its habitat – a koala and a polar bear wouldn't live in the same place because they have different requirements. Habitats can and do change over time, which can result from a naturally occurring event like a volcanic eruption or from human causes like climate change or clearing land for building. The introduction of a new, non-native species can also have a major impact on native habitats and the organisms living there.

What should habitats contain?

3 Each organism has an ecological niche

Each organism has a particular job within the ecosystem – their ecological niche. An organism's niche includes the interactions it has with other organisms, the type of food it eats, where it lives and how it reproduces. Only one organism can fill a specific niche in an ecosystem. Many different species can co-exist within an ecosystem because no two species have exactly the same niche. Introduced species cause problems when they take over a niche – often they will out-compete the native animal, leading to localised extinction.

If organisms that fill a particular niche disappear, then there will be flow-on effects throughout the entire community. If a pollinator disappears, then plants cannot reproduce, which limits the amount of food available to the herbivores, which in turn limits the amount of food available for carnivores.

What is an ecological niche?

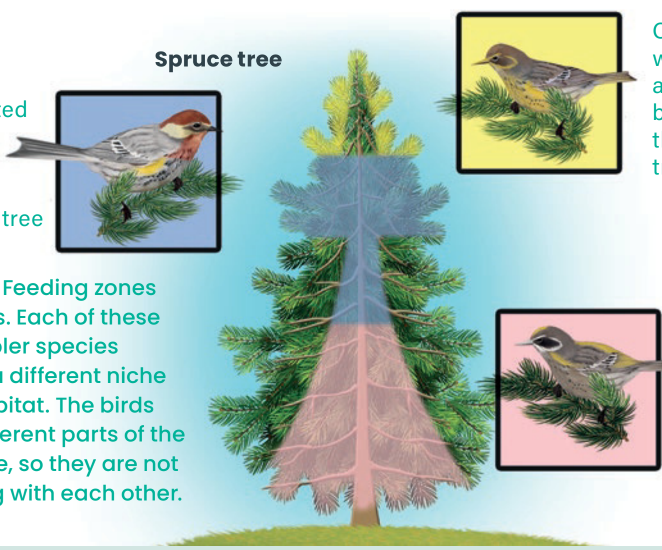


Figure 2.2 Feeding zones of warblers. Each of these three warbler species occupies a different niche in their habitat. The birds feed in different parts of the spruce tree, so they are not competing with each other.

INVESTIGATION 2.1

Identifying community members in a terrestrial ecosystem

KEY SKILL
Identifying and managing relevant risks

▶ *Go to page* ***147***

CHECKPOINT 2.1

1 Copy and complete.
A community is made up of ________ of all the different ________ that live in the ecosystem. All organisms within a community ________ on each other for ________ , ________ and ________.

2 Explain what a habitat is and what features are important.

3 Explain the difference between abiotic and biotic factors and give two examples of each.

4 What natural and human-made changes can affect habitats? Brainstorm as many as you can think of.

5 Explain, using an example, what an ecological niche is.

INQUIRY

6 Consider your favourite wild animal. Describe its habitat and suggest some features of its habitat that are important to the animal's survival.

SUCCESS CRITERIA

- I can define what an ecological community is.
- I can describe the difference between a habitat and a niche.

2.2 INTERACTIONS BETWEEN ORGANISMS

LEARNING INTENTION

At the end of this lesson I will be able to discuss key interactions between organisms including predators and prey, parasites, competitors and pollinators.

KEY TERMS

parasite
an organism that lives in or on another organism, causing it harm

pollinator
an organism that transfers pollen from the male to the female part of a plant

predator
an organism that kills and feeds on prey

prey
an organism killed by a predator

LITERACY LINK

READING

Summarise the three sections in this lesson in two dot points each.

NUMERACY LINK

CALCULATION

A male leopard in the wild will eat roughly 3 kg of meat per day. If a gazelle weighs 25 kg, how many gazelles would a leopard eat in one year?

There's more to interactions in an ecosystem than just who eats whom. Interactions between organisms can be helpful, such as the interaction between bees and flowers, or harmful, such as the interaction between a **parasite** and its host.

1 Competitors compete for resources

Competition often happens when organisms share the same limited resource in the same ecosystem; for example, when two organisms share a source of food. Competitors can be different species or members of the same species. Depending on the amount of food available, organisms may be harmed, may starve or may have to find a new food source. Some members of the same species will even compete for a mate; it's all part of trying to survive and thrive. Plants also compete for resources, but not food. Plants compete for space, light, water and nutrients – the things they need to produce energy. Some plants will grow and survive, while others will die.

What resources do plants compete for in an ecosystem?

Figure 2.3 Predators kill and feed on their prey.

2 Predators and prey keep each other in balance

Predators are organisms that kill and feed on another organism, their **prey**. An example of a predator is a fox and its prey, a rabbit. Predator–prey relationships might seem pretty ruthless, but their interaction plays a crucial role in an ecosystem – they stabilise the numbers of prey organisms and keep them under control. If the numbers of the prey species increase, then numbers of predators will increase too – keeping it all in balance. Predators have some special adaptations – they often have good vision and/or hearing, claws, sharp teeth and strong jaws to catch their prey.

Parasites are a type of predator that live on (or in) another organism, the host. Unlike other predators, parasites are usually much smaller than their prey and cause harm without killing the other organism. One example of a parasite is the hookworm, which lives in the intestines of its human host feeding on nutrients from digested food.

How does the predator–prey relationship benefit an ecosystem?

Figure 2.4 Parasites live on (or inside) their host organism.

Table 2.1 Ecological relationships

Interaction	Effects on population	Example
Mutualism	The interaction is beneficial to both species.	A cassowary eating the fruit of plants, and distributing the seeds in its dung
Commensalism	One species benefits but the other is unaffected.	A staghorn fern growing on the branch of a tree
Competition	Both species are negatively affected because they compete for the same resource.	Sugar gliders competing with superb parrots for nesting hollows
Predator–prey	The predator benefits and the prey is harmed/killed.	A bronze whaler shark eating sardines
Parasitism	The parasite benefits and the host is harmed.	Mistletoe taking nutrients from a host tree

3 Pollinators and plants help each other

Flowering plants have female and male sex organs. In order for fertilisation to occur they need a helping hand – a **pollinator**. A pollinator is an organism that moves pollen from the male sex organ of plants to the female. When you think of a pollinator, the first thing that comes to mind is probably bees, and importantly so – without bees a lot of plant life would cease to exist. The interaction is beneficial for the plant, which is able to reproduce, and the bee, which gets a meal of nectar to take back to its colony. Other organisms, including birds, some lizards and even monkeys, can also be pollinators, but bees are especially adapted to this very important job.

Why do flowers need pollinators?

CHECKPOINT 2.2

1 Brainstorm as many different predator–prey relationships as you can think of.

2 Describe the ecological importance of pollination in your own words.

3 Predators and prey keep each other in balance. Suggest how.

4 Why is a parasite considered a type of predator?

5 Competition occurs in every ecosystem.
   a Describe what competition is in your own words.
   b What are some resources that animals compete for?
   c What are some resources that plants compete for?

6 Use Table 2.1 to classify the following interactions.
   a Bandicoots feed on insects in your backyard.
   b Dung beetles feed on kangaroo dung. The kangaroos are unaffected.
   c A tick sucks blood from a wallaby.
   d A cleaner shrimp removes parasites from a sea turtle.

7 Explain the difference between mutualism and commensalism.

CONTEMPORARY ISSUES

8 You may have heard that there has been a decline in the number of bees globally. Why do you think this is occurring and what could be done to protect and grow our bee populations?

SUCCESS CRITERIA

- I can describe how predators and prey interact in an ecosystem.
- I can describe the interactions between competitors in an ecosystem.
- I can describe the role of pollinators in an ecosystem.

2.3 ABIOTIC FACTORS IN ECOSYSTEMS

LEARNING INTENTION

At the end of this lesson I will be able to discuss key abiotic components of the environment and their impact on ecosystems.

KEY TERMS

adaptation
a feature that enables an organism to survive in its environment

zone of tolerance
the range of an abiotic factor that an organism can survive in

LITERACY LINK

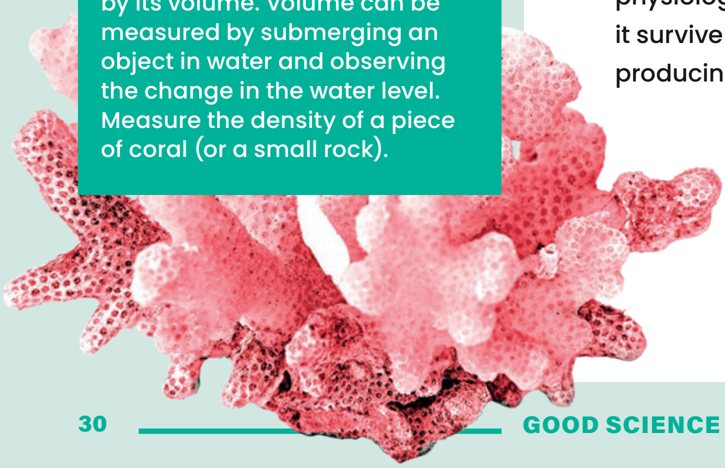
SPEAKING

Make a list of adjectives (describing words) to describe the photographs in Figure 2.6. With a partner, choose the best five words from your lists, then share your words with the class.

NUMERACY LINK

MEASUREMENT

The density of an object can be calculated by dividing its mass by its volume. Volume can be measured by submerging an object in water and observing the change in the water level. Measure the density of a piece of coral (or a small rock).



Abiotic factors are just as important as biotic or living factors in ecosystems. Factors such as water availability, soil type, temperature and availability of nutrients (for example, nitrogen) affect what living things will be in the ecosystem. If the abiotic factors change outside of their normal level, there can be major impacts on the rest of the ecosystem.

1 Abiotic factors affect what can live in an ecosystem

Abiotic factors are chemical and physical factors within an ecosystem. Abiotic factors include:

- rainfall and water availability
- soil type
- temperature
- pH of soil or water
- sunlight
- nutrient availability in soil or water
- gas (oxygen and carbon dioxide) availability
- salinity of soil or water.

The abiotic factors within an ecosystem will affect what can live there. Plants require a certain amount of sunlight, nutrients and water to grow, so these factors determine the types of plants that live in certain areas of an ecosystem. This, in turn, affects what consumers can live there.

What is an abiotic factor?

2 Organisms have adaptations to abiotic factors

Organisms have evolved **adaptations** to help them survive in their environment. The adaptations can be:

- structural – a feature of an organism's body that helps it survive (for example, the sharp claws of a koala help it climb trees)
- behavioural – the way an organism responds to its environment to help it survive (for example, the huddling of emperor penguins to stay warm)
- physiological – a process inside an organism's body that helps it survive (for example, the ability of a camel to retain water by producing very little urine).

Even though organisms have evolved to adapt to their ecosystems, they can still only tolerate specific levels of each abiotic factor. If the level of an abiotic factor moves out of this **zone of tolerance**, the organism will not survive.

What are the three types of adaptation?

3 Coral bleaching is caused by abiotic factors

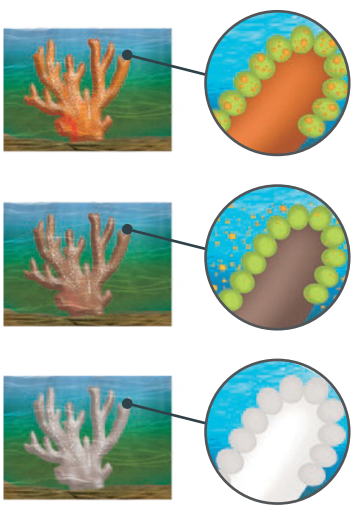
Coral bleaching is an example of what happens when abiotic factors move out of the zone of tolerance.

Coral live in a mutualistic relationship with an alga called zooxanthellae. The algae live inside the structure of the coral. The coral provides the algae with a home and the algae photosynthesise and provide the coral with 90% of its energy requirements. The algae are also responsible for the coral's colour.

If the water temperature or pollution levels increase to outside the coral's zone of tolerance, the coral expels the algae and becomes bleached. If temperatures and pollution levels return to normal, the coral allows the algae to return and so it will recover. If the levels remain too high for a long time, then the coral will die because it is not receiving the energy it needs.

The optimum water temperature range for most reef-building corals is 20–32°C, although different species have their own zones of tolerance. Increasing temperature levels in Australian waters have led to coral bleaching all along the Great Barrier Reef.

What is coral bleaching?



Healthy
Algae live inside the coral.
They depend on each other to survive.
Algae give the coral its colour.

Stressed
If the coral gets stressed by rising temperatures or pollution levels, the algae leave the coral.

Bleached
Without the algae, the coral does not receive enough food. It turns white and is more likely to get diseases and die.

Figure 2.5 The process of coral bleaching can be summarised in three stages.

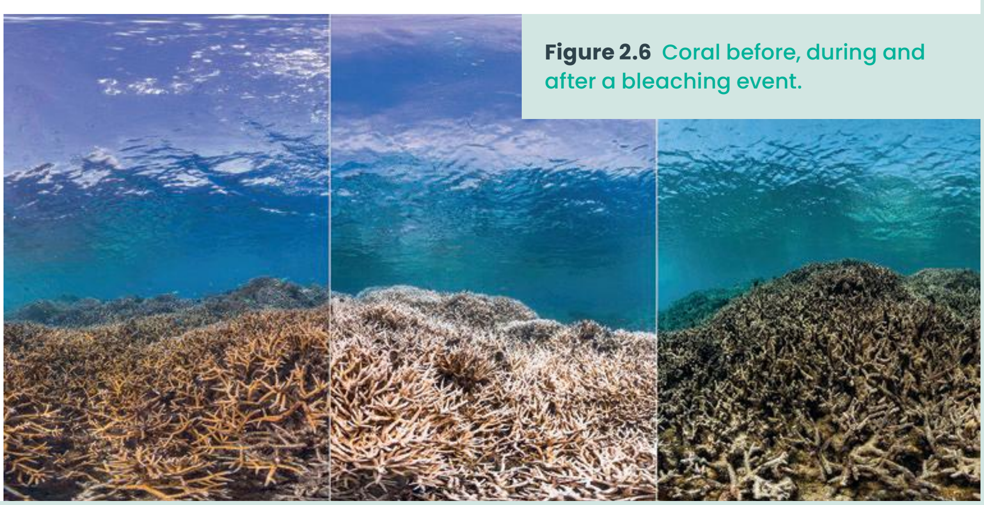


Figure 2.6 Coral before, during and after a bleaching event.

INVESTIGATION 2.3
Measuring abiotic factors

KEY SKILL
Writing a research question

▶ *Go to page **148***

CHECKPOINT 2.3

1 Explain the difference between abiotic and biotic factors.
2 Give five examples of abiotic factors.
3 Identify some abiotic factors that are important for a:
   a plant
   b saltwater fish.
4 Define *adaptation*.
5 Explain, using a specific example, what is meant by an organism's tolerance level to an abiotic factor.
6 Predict what would happen if pollution caused the salinity level of a freshwater pond to increase.

RESEARCH

7 Research to compare the abiotic factors in the Daintree Rainforest (Queensland) with those of the Simpson Desert (central Australia). Find out about rainfall (water availability), temperature range and nutrient availability in the soil. How do these factors influence what organisms live in these ecosystems?

SUCCESS CRITERIA

- I can explain what an abiotic factor is.
- I can identify at least three examples of abiotic factors.
- I can explain how abiotic factors can determine what organisms live in an ecosystem.

2.4 MATTER FLOWS THROUGH ECOSYSTEMS

LEARNING INTENTION

At the end of this lesson I will be able to outline, using examples, how matter such as nitrogen flows through ecosystems.

KEY TERMS

atmospheric nitrogen
nitrogen that is found in the atmosphere

mutualism
a relationship in which both organisms benefit

LITERACY LINK

WRITING

Write a story describing what happens to an atom of nitrogen as it cycles through the atmosphere, soil and living things.

NUMERACY LINK

GRAPHING

The nitrogen content of wheat is 1.68%; for barley, it's 1.62%; and for broad beans, it's 4.0%. Create a bar chart of this data.

Matter cannot be created or destroyed. On Earth, matter cycles through different parts of ecosystems, including the atmosphere, soil and different organisms. The atoms that make up your body were once part of the food that you consumed, and the air that you breathed.

If you eat a steak, the atoms in that steak have come from the plants that the cow has eaten, and before that from the carbon dioxide, water and nutrients that were used by the plants.

1 Nitrogen is an important element for life

Nitrogen (N) is an important element that cycles through ecosystems. Nitrogen is important because it is found in amino acids, the building blocks of proteins, which are essential for all life. Nitrogen is the most abundant element in Earth's atmosphere, making up approximately 78% of air. In the atmosphere, nitrogen is mostly found as molecular nitrogen (N_2).

Plants are a very important part of the nitrogen cycle because they can take up inorganic nitrogen (nitrogen from non-living sources) through their roots from the soil. Hence nitrogen enters the biosphere and cycles through living things. Bacteria are also vital to the nitrogen cycle and different species play different roles – converting nitrogen from one form into another.

Why is nitrogen important for living things?

2 Nitrogen cycles from the atmosphere

Although there is a lot of nitrogen in the air, plants cannot use this **atmospheric nitrogen**. Plants need to obtain nitrogen from the soil (through their roots) in the form of nitrate (NO_3^-). They use this nitrogen to make amino acids.

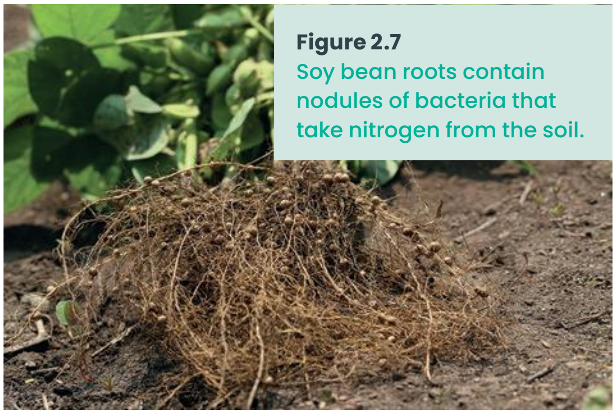


Figure 2.7
Soy bean roots contain nodules of bacteria that take nitrogen from the soil.

Most nitrogen is transformed by different species of bacteria into forms that plants can use. This usually happens in several steps, each involving a different species of bacteria. Some of these bacteria live in the roots of legumes (e.g. peas and beans). This relationship is an example of **mutualism** because both the bacteria and the plant benefit. Nitrogen-fixing bacteria convert nitrogen from the air in the soil into a form that the plant can use. There are also denitrifying bacteria, which release nitrogen back into the atmosphere.

Herbivores produce proteins from the amino acids in the plants they eat. When a herbivore is consumed by a higher-order predator, the amino acids are then taken in and used by the predator.

Decomposers such as bacteria and fungi play a key role in the nitrogen cycle. They break down the amino acids in dead matter, releasing nitrogen back into the soil so that it can be reused by plants.

How is nitrogen used by plants?

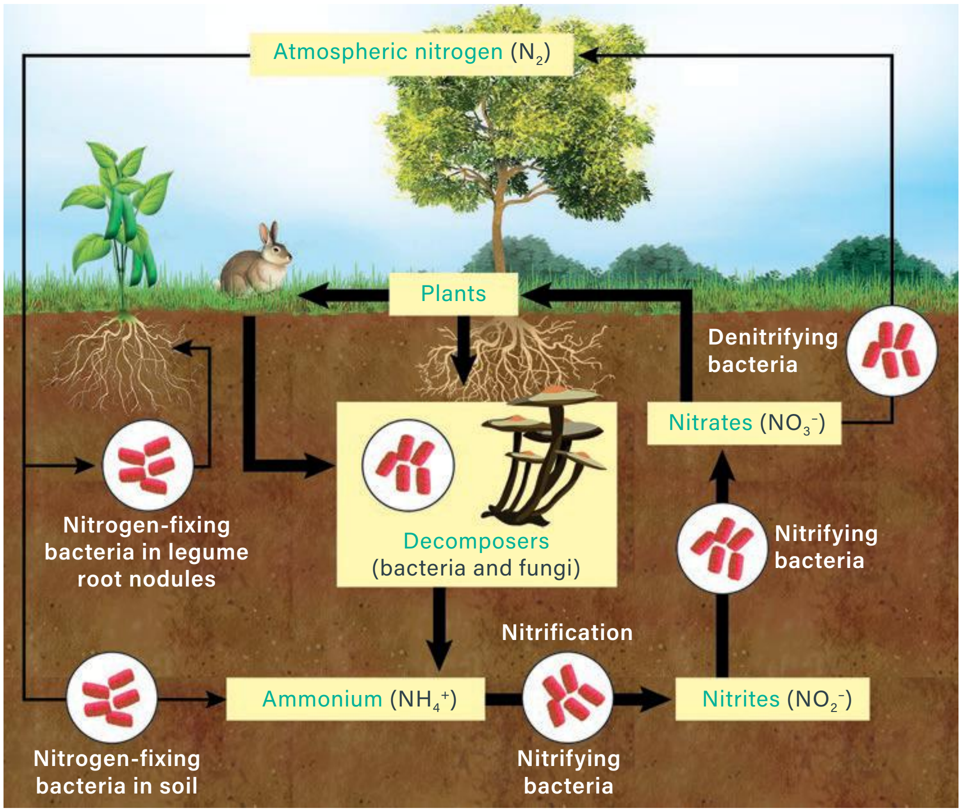


Figure 2.8 The nitrogen cycle is crucial for plants to grow.

❸ Other elements also cycle through ecosystems

Carbon, oxygen, hydrogen and phosphorus are other important elements that cycle through ecosystems. All of these elements are important for the formation of molecules that are vital for life.

Carbon, oxygen and hydrogen cycle through ecosystems through the processes of photosynthesis and cellular respiration. They move from inorganic molecules, such as carbon dioxide, molecular oxygen and water, into organic molecules, such as glucose and carbohydrates, which are then passed up through the food chain.

Phosphorus plays an important role in the formation of DNA. Plants take up phosphorus from soils and convert it into molecules that are then passed up through the food chain, returning to the inorganic forms through excrement and decomposition.

What other elements cycle through ecosystems?

CHECKPOINT 2.4

1 Explain what is meant by a *matter cycle*.

2 In what form is nitrogen found in the atmosphere?

3 Identify the two types of organisms that are important for the nitrogen cycle. What role do they play?

4 Predict what would happen to the nitrogen cycle in an ecosystem:
  a where there were no decomposers
  b that became too cold for the nitrogen-fixing and nitrifying bacteria to survive.

5 Carnivorous plants catch insects not to gain energy, but to extract nutrients such as nitrogen. Suggest what this means about the soils that they live in.

6 Identify two processes that allow carbon, oxygen and hydrogen to cycle through ecosystems.

EXTENSION

7 Compare the nitrogen cycle to the carbon cycle. In what ways are they similar and different?

SUCCESS CRITERIA

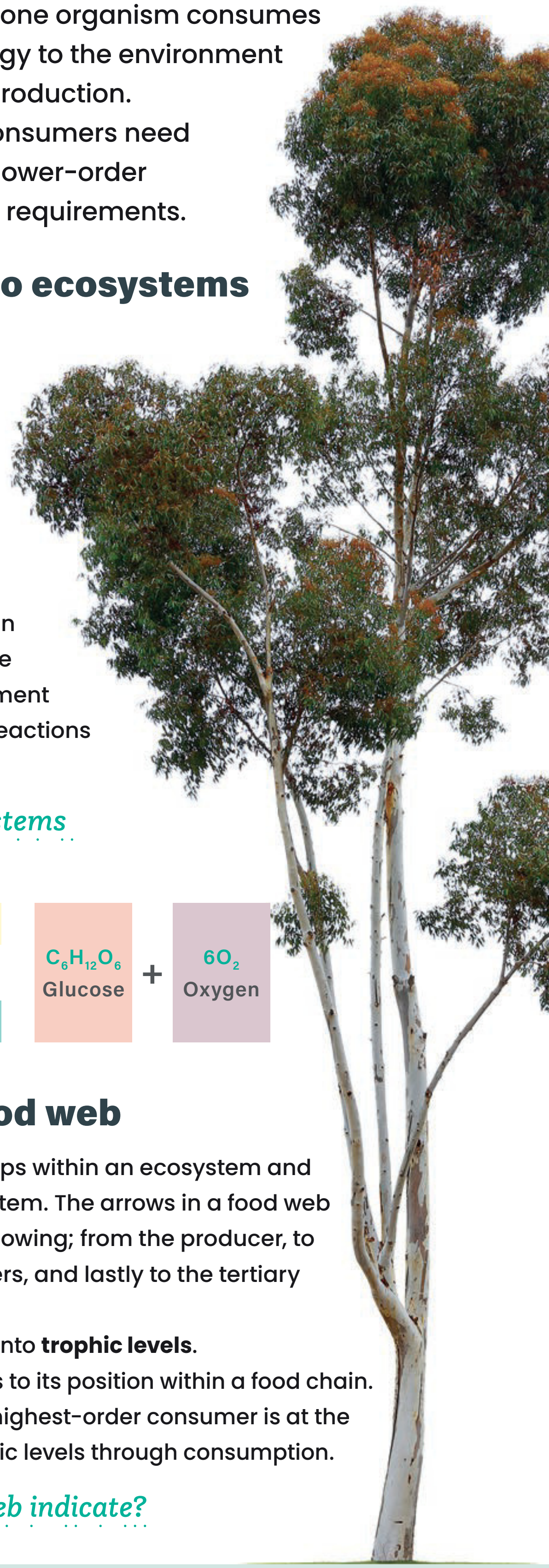
- I can outline the steps involved in the nitrogen cycle.
- I can explain the importance of the nitrogen cycle for living things.

2.5 ENERGY FLOWS THROUGH ECOSYSTEMS

LEARNING INTENTION

At the end of this lesson I will be able to outline, using examples, how energy flows through ecosystems.

Energy enters most ecosystems as solar energy from the Sun. Producers use this energy to make glucose. Glucose is then used as an energy source by all of the other living things in the ecosystem, being passed on as one organism consumes another. All organisms lose energy to the environment as heat, in excrement and in reproduction. This means that higher-order consumers need to consume a larger number of lower-order consumers to meet their energy requirements.



1 Plants bring energy into ecosystems

Energy enters most ecosystems as light energy from the Sun. Producers convert light energy into chemical energy during **photosynthesis**. In photosynthesis, plants use light energy to produce glucose ($C_6H_{12}O_6$) from carbon dioxide (CO_2) and water (H_2O).

In plants, photosynthesis happens in chloroplasts. These cell organelles are packed with chlorophyll, a green pigment that, when sunlight hits it, starts the reactions of photosynthesis.

Where does the energy in ecosystems originate?

$$\underset{\text{Carbon dioxide}}{6CO_2} + \underset{\text{Water}}{6H_2O} \xrightarrow[\text{Chlorophyll}]{\text{Light}} \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Oxygen}}{6O_2}$$

2 Energy flows up the food web

A food web shows feeding relationships within an ecosystem and how energy flows through the ecosystem. The arrows in a food web indicate the direction that energy is flowing; from the producer, to the primary and secondary consumers, and lastly to the tertiary consumers.

Food webs organise the organisms into **trophic levels**. The trophic level of an organism refers to its position within a food chain. Producers are at the bottom and the highest-order consumer is at the top. Energy passes to the higher trophic levels through consumption.

What do the arrows in a food web indicate?

KEY TERMS

photosynthesis
the chemical reaction, powered by sunlight, that plants use to change carbon dioxide and water into glucose and oxygen

trophic level
the position of an organism in a food chain

LITERACY LINK

VOCABULARY

Photosynthesis and chemosynthesis are processes used by organisms to convert energy from one form to another. Suggest what these words mean, then do some research to find out.

NUMERACY LINK

CALCULATION

If the energy content of the first trophic level is 140 000 joules and only 10% of energy is passed on to the next trophic level in a food chain, how much energy will an organism in the third trophic level consume? How much energy will have been lost?

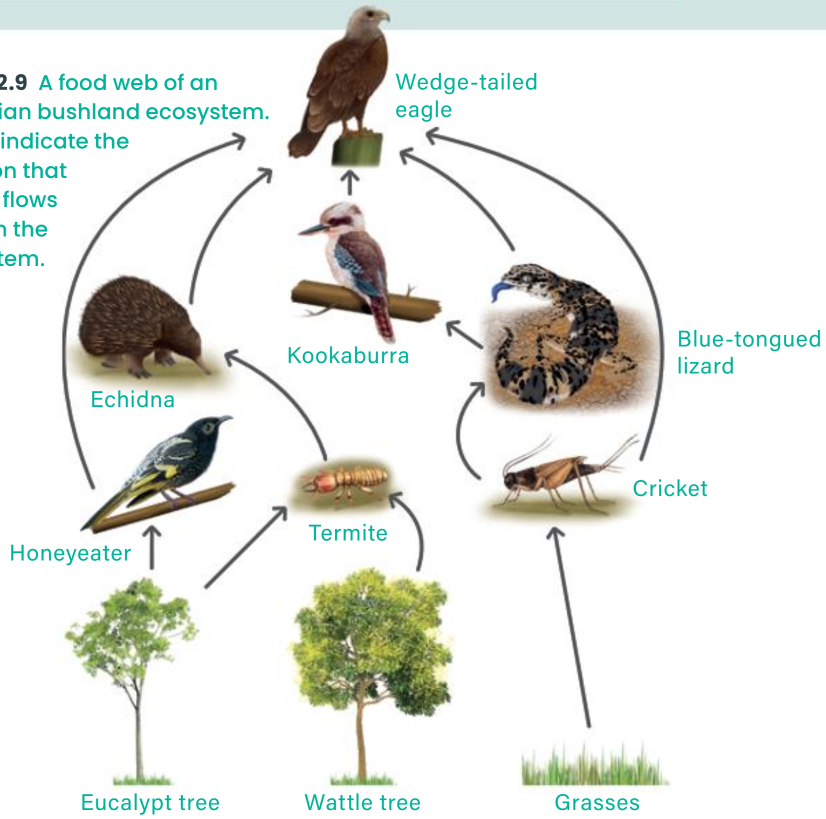


Figure 2.9 A food web of an Australian bushland ecosystem. Arrows indicate the direction that energy flows through the ecosystem.

❸ Energy is lost at each trophic level

Energy is lost at each trophic level. Every organism loses energy to the environment through metabolic heat loss. Energy is also used up through reproduction and in the production of waste such as faeces. Therefore, this energy is not available when that organism is consumed.

Only about 10% of the energy in a trophic level is passed onto the level above. This is why a high number of producers and lower-level consumers are required to support a small number of higher-order consumers. This relationship can be represented in an energy pyramid.

What percentage of energy is available to the next trophic level?

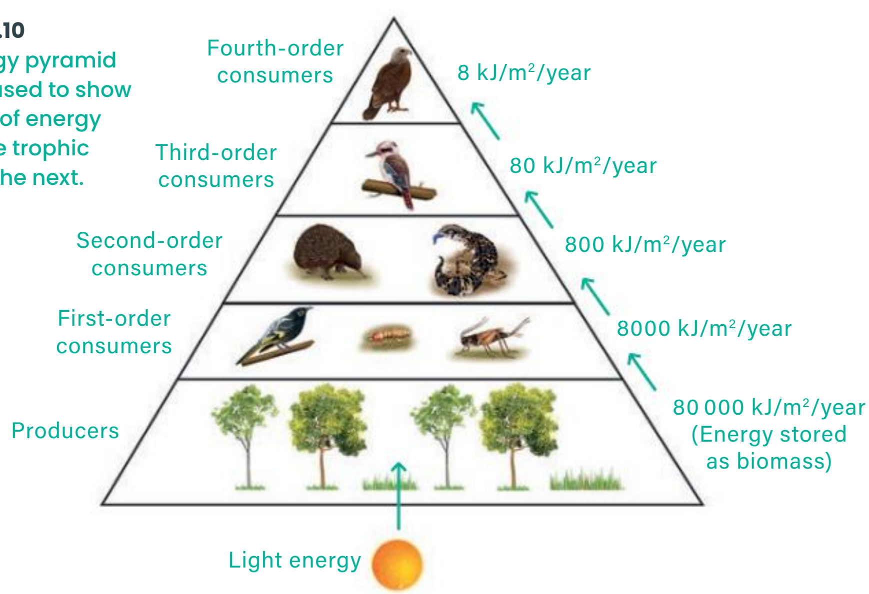


Figure 2.10 An energy pyramid can be used to show the flow of energy from one trophic level to the next.

INVESTIGATION 2.5

Algal balls

KEY SKILL
Identifying the variables and formulating a hypothesis

▶ *Go to page **149***

CHECKPOINT 2.5

1. Why are plants known as producers?
2. Approximately what percentage of energy is lost at each trophic level?
3. How is energy passed between organisms?
4. What can a food web be used to show?
5. Identify where most of the energy goes that an organism consumes.
6. Predict what would happen if a disease wiped out the major producer species in an ecosystem.
7. Predict what would happen if a large population of fourth-order consumers was released into an ecosystem.

CONNECTING IDEAS

8. Imagine what would happen if a new invasive species (such as cane toads) was introduced to a food web. Describe how you think the energy flow would be affected.

SUCCESS CRITERIA

- I can identify where energy in a food web originates.
- I can identify how energy is passed from one organism to another.
- I can describe how energy flows through an ecosystem.

2.6 CHANGES TO ECOSYSTEMS

LEARNING INTENTION

At the end of this lesson I will be able to analyse how changes in some biotic and abiotic components of an ecosystem affect populations and/or communities.

KEY TERMS

biodiversity
the variety of species in an ecosystem

eutrophication
the process in which nutrient levels increase in a waterway, resulting in increased algal growth and decreased dissolved oxygen levels

keystone species
a species that plays a crucial role in its ecosystem

LITERACY LINK

LISTENING

Think of a noun that has something to do with ecosystems. Your partner can ask you 20 questions to try to guess your word.

NUMERACY LINK

GRAPHING

The population of foxes in a particular ecosystem suddenly increases. Sketch a graph predicting what would happen to the population of rabbits and foxes in the area over a number of seasons. (Use a different colour for each.)

Within an ecosystem, everything is linked. Therefore, if one thing changes, so will others. Changes can happen to the biotic factors; for example, a species may be introduced or removed. Changes can also happen to the abiotic factors, such as a change in the nutrient availability or temperature. These changes can affect other abiotic factors as well as causing changes to the ecosystem's community if species cannot adapt to the changes.

1 Increased nutrient levels in waterways cause algal blooms

It is important that levels of nutrients, such as nitrogen, remain balanced in ecosystems. Producer organisms require these nutrients to grow. If there is too little of a nutrient, then the producers will be unable to grow. If too many nutrients flow into waterways from pollution or stormwater run-off, then it can cause other problems.

Eutrophication occurs when nutrient levels in a waterway increase so much that algae reproduce rapidly and algal blooms grow on the surface. This decreases the oxygen levels in the water. Different aquatic species require different oxygen levels. As the oxygen levels start to drop, those organisms that require the most oxygen die first.

Oxygen levels in the water decrease when:

- more algae use the oxygen dissolved in the water for cellular respiration – especially overnight when there is no photosynthesis to replace it
- algae block sunlight from reaching other producers deeper in the water and stop the producers from photosynthesising
- the increased numbers of algae die and decompose, so that more decomposers grow and increase their cellular respiration.

What is eutrophication?

Figure 2.11 This green water in the Condamine River in Queensland shows there is excessive algal growth and eutrophication.

2 Keystone species are essential to ecosystems

Keystone species are organisms that play essential roles in their ecosystems. No other species in the ecosystem can fill its niche. If a keystone species is removed, the whole ecosystem can collapse. The numbers of species decrease, causing a loss of **biodiversity** as more than just the keystone species becomes extinct.

Southern cassowaries (*Casuarius casuarius johnsonii*) are a keystone species in the north Queensland tropical rainforest ecosystem. They play a key role in the dispersal of the seeds of up to 150 plant species. Cassowaries eat fruit and then deposit the seeds in their dung throughout their territory.

The southern cassowaries are endangered because of habitat destruction and other human impacts. Without the cassowaries, some rainforest plants could also become extinct. If these plants were to disappear, the rainforest would, too, because more extinctions would follow at the different trophic levels.

What is a keystone species?

3 Introduced species compete with native species

The introduction of species into an ecosystem can have wide-ranging impacts on the community. Introduced species can compete with native species for the same resources, remove species through predation or toxins, and even damage soils and plant life through trampling, burrowing and digging.

In Australia, most ecosystems have been affected by the introduction of species. Foxes and cats are effective predators and have hunted many species to extinction. Rabbits out-compete small marsupials for food and other resources because they reproduce at a much faster rate. Brumbies (feral horses) and camels trample fragile soils and plants that have not evolved to cope with hard-hooved animals.

Why do rabbits out-compete native marsupials?

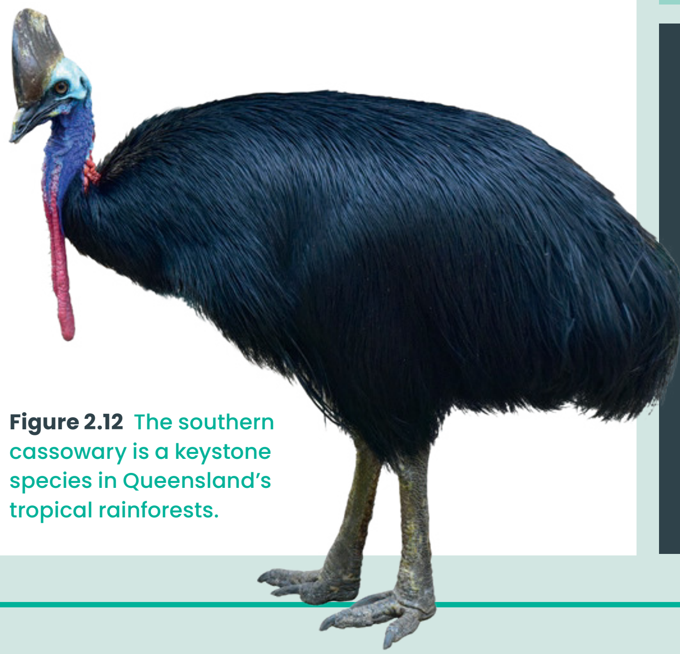


Figure 2.12 The southern cassowary is a keystone species in Queensland's tropical rainforests.

CHECKPOINT 2.6

1 Identify one way an ecosystem would be affected by a change to:
  a an abiotic factor
  b a biotic factor.

2 Explain why increasing levels of nutrients such as nitrogen in lakes and rivers can be detrimental for the organisms living there.

3 Explain why the loss of one species can lead to the loss of others.

4 Create a Daintree Rainforest food web that contains a cassowary, rainforest plants, an amethystine python, an estuarine crocodile, a white-tailed rat, a musky rat kangaroo and insects.

5 Identify three ways that an introduced species can impact an ecosystem.

CONTEMPORARY ISSUES

6 Climate change is having a significant impact on Australian ecosystems because it is changing abiotic factors such as temperature and water availability. Research and select one case study of an Australian ecosystem being affected by climate change and present your findings to your class.

SUCCESS CRITERIA

- I can identify some examples of changes that can occur to abiotic and biotic components of an ecosystem.
- I can give an example of how a change to an abiotic factor could affect a population or community.
- I can give an example of how a change to a biotic factor could affect a population or community.

2.7 THE EFFECT OF BUSHFIRES

LEARNING INTENTION

At the end of this lesson I will be able to explain how ecosystems change as a result of environmental events such as bushfires.

KEY TERMS

germinate
to grow and put out shoots

intensity
how much heat is released from a fire front

LITERACY LINK

READING

Find a newspaper article about Australia's 2019–20 bushfire season. Highlight any emotive words in the article.

Hint: Emotive words are words the author has used to make the reader feel a certain way.

NUMERACY LINK

UNITS

In March 2018, a bushfire in the South Coast region of NSW burned through approximately 1250 hectares of land. Convert 1250 hectares into square metres.

Hint: 1 hectare = 10 000 square metres

Australian ecosystems are often affected by unpredictable natural events that harm ecosystems and reduce biodiversity. These events include droughts, floods and bushfires.

Some natural events, such as low-intensity bushfires, can actually trigger new growth and cause a multitude of other changes in an ecosystem.

1 Bushfires happen every year in Australia

Bushfires are common natural events in Australia due to the hot, dry summer climates of many regions. Unfortunately, these conditions create the perfect environment for bushfires.

Lightning strikes are the most common natural cause of bushfires. When lightning hits a dry or dead tree, the heat of the strike makes the tree catch fire and break apart, scattering burning wood that then ignites other plants. Bushfires are also caused by human activity – often due to accidents, but sometimes deliberately.

The **intensity** and duration of a bushfire depend on the plants in the ecosystem, because they provide the fuel needed for the bushfire to burn.

What is the most common natural cause of bushfires?

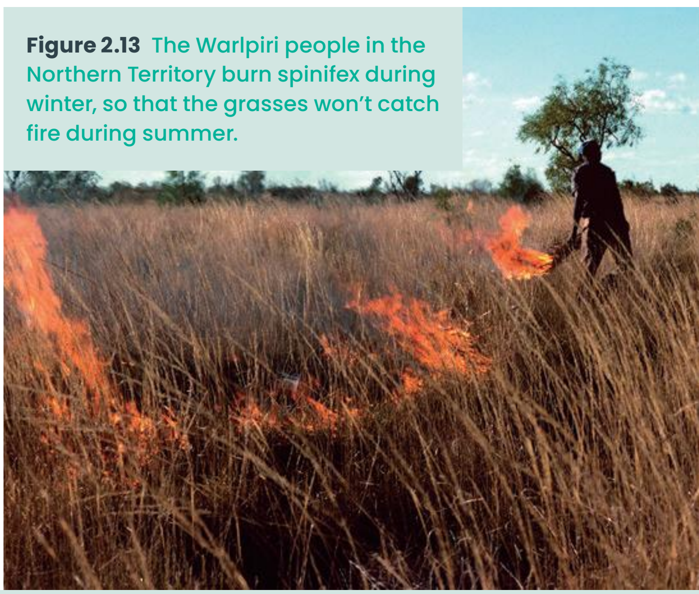
2 Low-intensity bushfires are helpful in some ecosystems

Low-intensity bushfires usually don't last very long and don't destroy many plants. In fact, they can be helpful for some ecosystems as a whole. These fires remove older or dead plants, making more space for seeds to **germinate** and grow. Fire can even trigger germination in some plants. The ash from the fire returns some nutrients to the soil, and the ecosystem recovers relatively quickly.

Lighting low-intensity bushfires has been an Indigenous Australian practice for thousands of years.

What is one advantage of a low-intensity bushfire to an ecosystem?

Figure 2.13 The Warlpiri people in the Northern Territory burn spinifex during winter, so that the grasses won't catch fire during summer.



3 High-intensity bushfires usually harm ecosystems

High-intensity bushfires cause a lot more damage to ecosystems. Tall, thick, compact grasses, and fallen leaves and branches, can provide a bushfire with a large fuel supply. They create high-intensity fires that take a long time to burn and can burn entire trees, right up to the top leaves.

High-intensity bushfires are more likely to happen in areas that haven't had a fire for many years. There is a large amount of dry plant material, such as fallen branches and dead trees at the ground layer. This provides the fire with fuel to burn for a long time.

Millions or even billions of animals can be killed in a high-intensity bushfire. The loss of such a huge number of plants and animals has a lasting impact on the entire food web and ecosystem.

What provides the fuel for a high-intensity fire?

4 Technology can help to understand bushfires

Technology can help scientists to understand bushfires by monitoring fires and learning from previous fires. They can then develop techniques and technology to better manage bushfires and better understand how they behave.

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) has a national bushfire research facility in Canberra called the Pyrotron. It is used to safely carry out bushfire experiments. The Pyrotron is a 25-metre-long wind tunnel with different sections and compartments. Fuel sources, such as different types of leaves, are placed in the tunnel and set on fire while a fan blows wind through the tunnel. Sensors and cameras measure how the fire spreads, while observers can watch through fireproof windows.

The Pyrotron improves our understanding of how bushfires spread in different conditions. It also helps firefighters train, be better prepared and make better decisions during a fire.

A computer model can also be used to predict the movement, intensity and duration of a bushfire. The CSIRO's bushfire modelling system, Spark, simulates a bushfire. It uses the information it receives to predict the direction, speed and intensity of a bushfire.

Figure 2.14 Dry eucalypt leaves are being used as a fuel source in this experiment at the Pyrotron.

How can technology help firefighters when they are in action?

CHECKPOINT 2.7

1 Explain how computer modelling systems can assist with understanding bushfires.

2 What are the benefits of a controlled burn?

3 Why does a fire need plant material to burn?

4 Suggest what plant characteristics you would see in an ecosystem that is prone to low-intensity bushfires.

5 Give two reasons why Indigenous Australian land management practices include regular burning of areas of vegetation.

6 Give an example of how technology is helping manage the impact of fires on Australian ecosystems.

CRITICAL AND CREATIVE THINKING

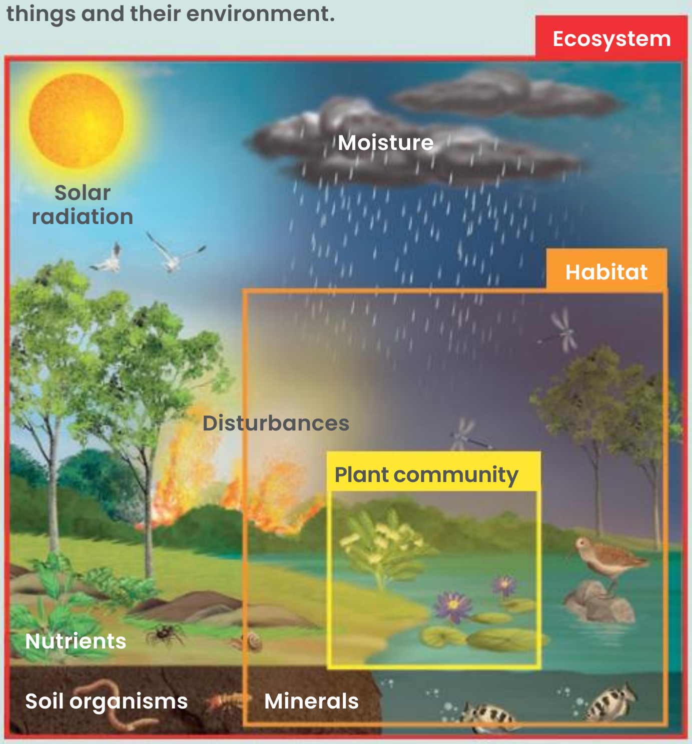
7 Outline how you would expect an ecosystem to change following a natural event such as a flood or a drought.

SUCCESS CRITERIA

- I can name at least three natural events that affect Australian ecosystems.
- I can suggest some changes that could be expected to occur in an ecosystem following a natural event such as a bushfire, flood or drought.

VISUAL SUMMARY

An **ecosystem** is an area that contains living things and their environment.



Biotic components of an ecosystem include:

- animals
- plants
- fungi
- bacteria.

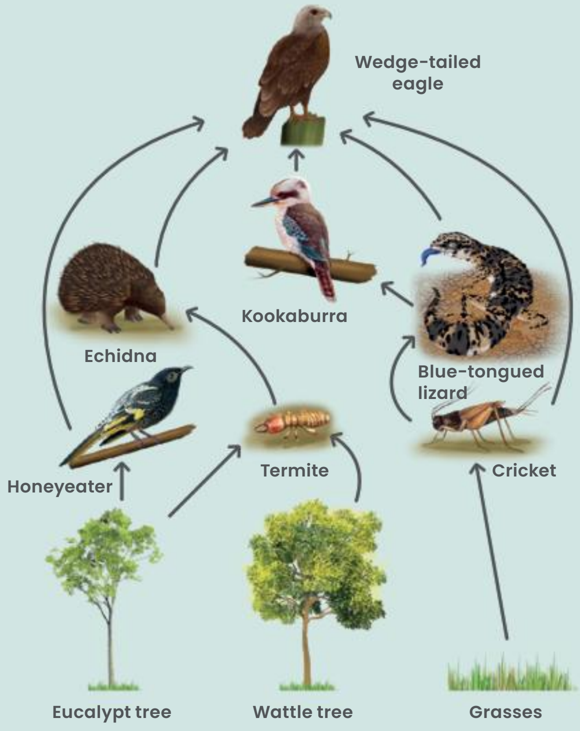
Abiotic factors include:

- water availability
- temperature
- soil.

A **community** is made up of populations of all the different species that live in an ecosystem.

All **organisms** within a community depend on each other.

Energy flows through ecosystems. Food webs can be used to describe how energy flows through ecosystems.



Keystone species play essential roles in their ecosystems. Extinction of keystone species will result in the extinction of other species.

Knowledge of the past distribution of endangered species helps to determine strategies to protect them from extinction.

★ FINAL CHALLENGE ★

1 Match these terms with their definitions.

abiotic	a naturally occurring group of animals, plants and other organisms
biotic	the number of a species in a particular area
community	non-living
ecological relationship	living
ecosystem	an interaction between two organisms
population	a community of living things and non-living things

LEVEL UP!

Level 1 ★☆☆☆☆☆ 50xp

2 Identify five different abiotic factors.

3 Explain the significance of the directions of the arrows in a food web.

4 What kinds of resources do plants and animals often have to compete for?

LEVEL UP!

Level 2 ★★☆☆☆☆ 100xp

5 Use a flow chart to show how energy flows through an ecosystem.

6 Abiotic factors can determine where an organism is able to live. Suggest why.

7 Explain how a naturally occurring event such as a bushfire can affect an ecosystem.

LEVEL UP!

Level 3 ★★★☆☆☆ 150xp

8 Describe three types of interactions that can occur in a community.

9 Explain why nitrogen is so important to living things.

10 Draw a labelled food web of an arctic ecosystem.

LEVEL UP!

Level 4 ★★★★☆☆ 200xp

11 Explain what is meant by a keystone species and justify their importance in ecosystems.

12 Outline the impact of an introduced species on an ecosystem. Suggest ways to control or manage introduced species.

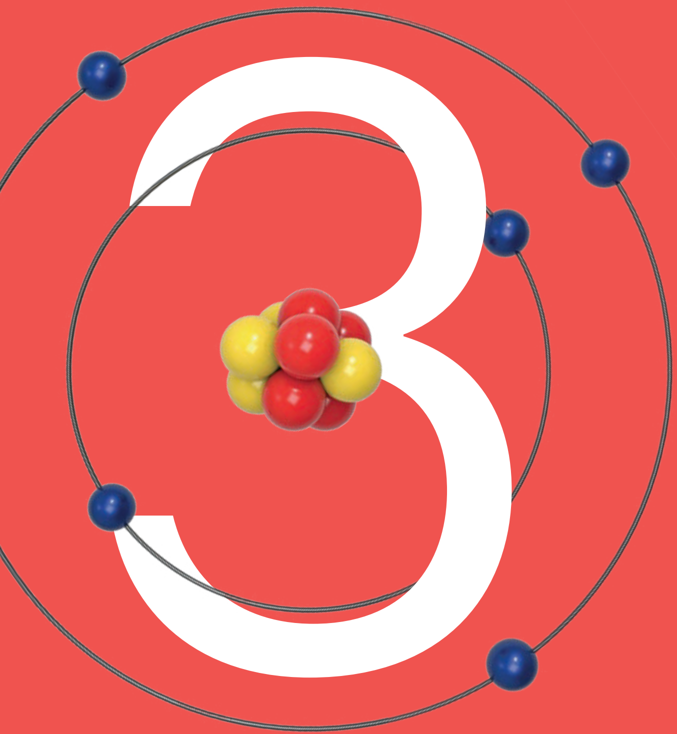
13 Without looking at your book, draw a diagram to explain what trophic levels are.

LEVEL UP!

Level 5 ★★★★★★ 300xp

ATOMIC STRUCTURE

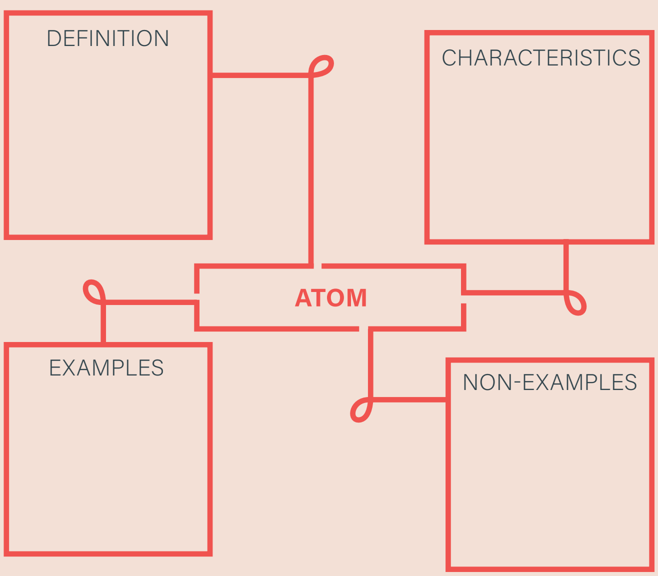
How does the structure of an atom influence its behaviour?



What are things made of? What is the smallest part of matter? Why do some elements have unique properties? These are all questions that, over many centuries, and through scientific collaboration, led scientists to discover tiny particles that eventually became known as 'atoms'. Through the ages, as technology progressed, different scientists discovered different parts of the atom, such as electrons, protons and neutrons. Recently, using a specialised tool called a scanning tunnelling microscope, scientists have been able to take an image of an atom.

1 FRAYER MODEL

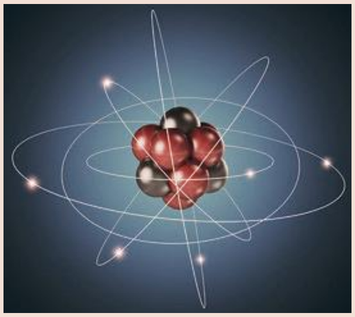
Copy and complete the below chart in your workbook.



Complete two additional charts for the key terms *Radiation* and *Nuclear power*.

2 LEARNING LINKS

Brainstorm everything you already know about atomic structure.



3 SEE-KNOW-WONDER

List three things you can SEE, three things you KNOW and three things you WONDER about this image.

4 CRITICAL + CREATIVE THINKING

WHAT IF ... 50% of all matter in the universe disappeared overnight?

THE REVERSE: Think of five things that are not made of atoms.

THE BAR: Think of one thing you would make **B**igger, one thing you would **A**dd and one thing you would **R**eplace in a nuclear power plant.

5 THE ENERGETIC DEBATE!

Scientists have been able to split the atom to release a large amount of nuclear energy. This energy can be used to generate electricity and for diagnosing and treating diseases. Although nuclear energy has many amazing benefits, some people are concerned about its safety because a nuclear accident could have catastrophic consequences. In 2011, the Fukushima nuclear reactor in Japan was damaged after an earthquake and tsunami. This led to dangerous radioactive material leaking into the environment.

3.1 MATTER IS MADE OF ATOMS

LEARNING INTENTION

At the end of this lesson I will be able to describe and model the structure of atoms and compare the mass and charge of protons, neutrons and electrons.

KEY TERMS

atom
the smallest particle of matter, made up of electrons orbiting a nucleus of protons and neutrons

compound
a substance made up of two or more types of atoms bonded together

electrically neutral
having an equal number of protons (positively charged) and electrons (negatively charged)

element
a pure substance made up of one type of atom

matter
particles that make up all physical substances

molecule
two or more atoms chemically bonded to each other

nucleus
the central part of an atom, containing protons and neutrons

LITERACY LINK

READING

Create a mind map using the key terms above and at least two additional terms of your choice.

Everything that you see around you is made of matter. Imagine you are sitting on a beach observing your surroundings. You observe three states of matter – liquid water, gas as air and clouds, and solid sand.

You feel the sand grains and wonder how tiny each grain is. You wonder if there is anything smaller than this. The answer is yes. The **atom** is the basic unit of matter, made up of tiny subatomic particles called protons, neutrons and electrons. In fact, there are more atoms in a single grain of sand than there are grains of sand on the whole beach!

1 Matter takes up space and has mass

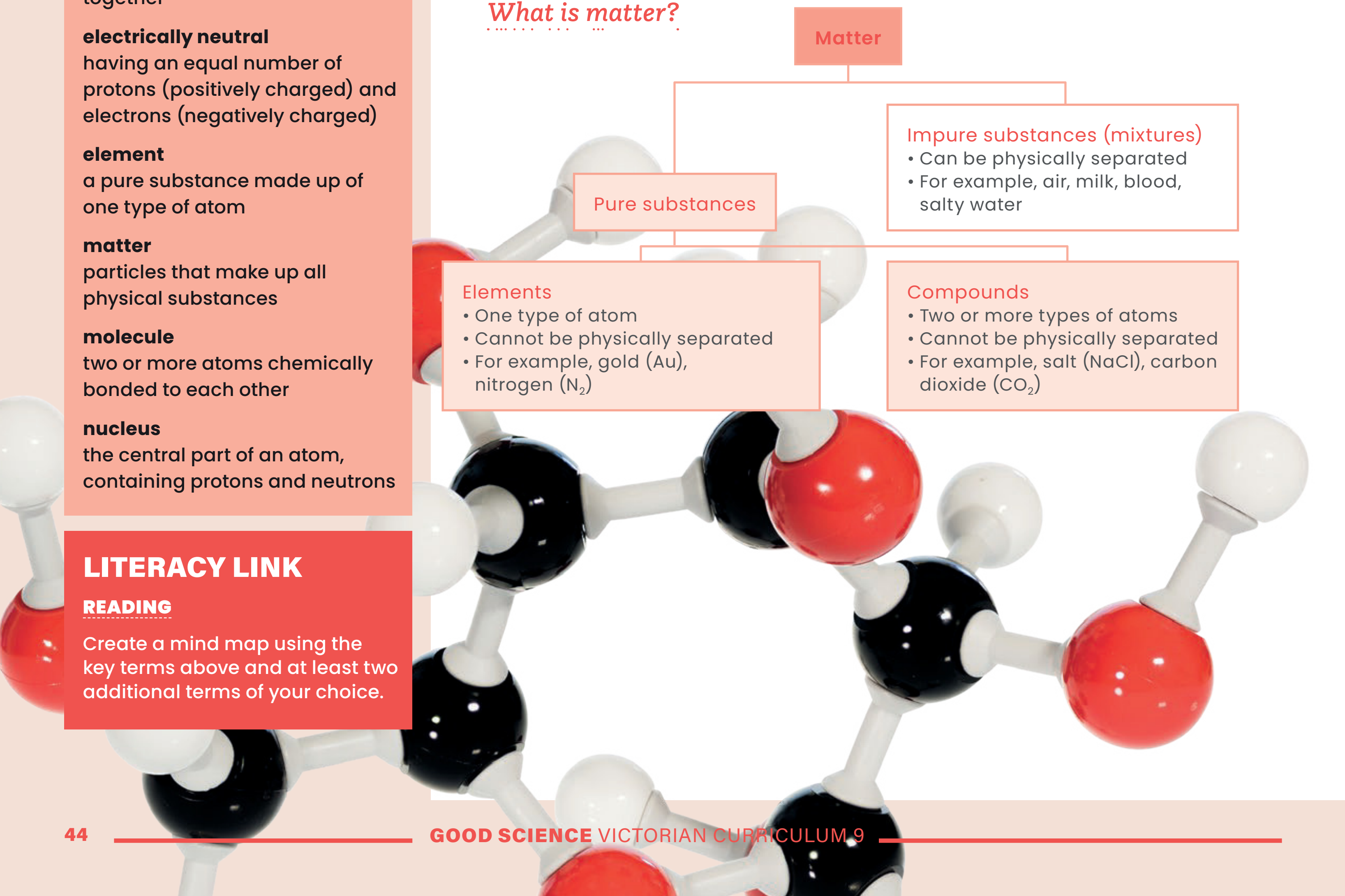
Matter is anything that takes up space and has mass.

Matter can be divided into pure substances and impure substances.

Pure substances include **elements** (made up of one type of atom) and **compounds**. Compounds are made of two or more types of elements chemically joined together into particles that cannot be physically separated.

Impure substances include mixtures, which can be physically separated into their different components. Air, milk and salt water are all mixtures.

What is matter?



2 Matter is made of atoms

All matter is made of atoms. Atoms are the basic building blocks of matter. There are more than 90 different elements that exist naturally and some that have been synthesised by scientists in the laboratory.

Atoms are **electrically neutral** and are made up of three small subatomic particles.

- Protons have a positive charge.
- Electrons have a negative charge.
- Neutrons have no charge.

Different atoms can bond to form **molecules**. For example, a glucose molecule is made up of 6 carbon atoms, 12 hydrogen atoms and 6 oxygen atoms, bonded together. Identical atoms can also bond to form molecules. For example, two oxygen atoms combine to form an oxygen (O_2) molecule.

What three subatomic particles is an atom made up of?

3 Atoms are made up of protons, neutrons and electrons

Scientific experiments in the 20th century proved the existence of atoms and their components – electrons and a **nucleus**, which contains protons and neutrons. The electrons are negatively charged and orbit the nucleus in clouds. Electrons are much smaller than protons and neutrons. An electron has only $\frac{1}{1840}$ the mass of a proton or neutron.

This means that almost all of the mass of the atom is in the nucleus, a tiny, dense core made up of positive protons and neutral neutrons. The protons and neutrons are held together by a strong nuclear force.

Atoms are held together by a strong attraction between the protons and electrons because they are oppositely charged, like opposite poles of a magnet. The electrical charge on a proton is exactly equal and opposite to the charge on an electron. An atom contains equal numbers of protons and electrons, so an atom has no overall charge.

What is the nucleus made up of?

	Electron	Proton	Neutron
Symbol:	e^-	p	n
Charge:	1^-	1^+	0
Relative mass:	$\frac{1}{1840}$	1	1
Location:	Electron cloud around the nucleus	Nucleus	Nucleus

Figure 3.2 Properties of the subatomic particles electrons, protons and neutrons

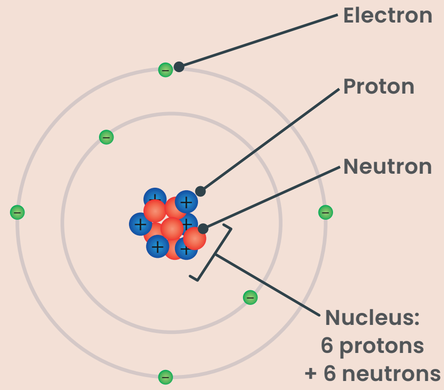


Figure 3.1 A carbon atom is made up of a nucleus – which contains six protons and six neutrons – and six electrons orbiting the nucleus.

CHECKPOINT 3.1

1 Describe matter.

2 Draw a simple diagram of an atom and label the three main parts.

3 Explain why protons and electrons must have opposite charges.

4 Describe the difference between atoms and molecules.

5 Elements and compounds are different. Explain how, using evidence from the text.

6 Describe how the particles in an atom are held together.

RESEARCH

7 Atoms are made up of protons, neutrons and electrons but protons and neutrons are made up of even smaller particles. Research to find out what these are.

SUCCESS CRITERIA

- I can describe what matter is and what it is made of.
- I can describe with diagrams or in words the structure of atoms, including the subatomic particles.

3.2 ATOMIC THEORIES

LEARNING INTENTION

At the end of this lesson I will be able to outline historical developments in atomic theory to demonstrate how models and theories have been contested and refined over time through a process of review by the scientific community.

KEY TERMS

alpha (α) particle
a positively charged particle that is four times larger than a proton

cathode ray
a stream of electrons observed in a high-vacuum tube

Dalton's atomic theory
the theory that states that all matter is made up of tiny particles

NUMERACY LINK

CALCULATION

Rutherford's experiment found that 0.8% of the alpha particles were deflected significantly. If 2125 alpha particles were used, how many were deflected?

Early ideas developed by scientists described atoms as tiny spheres that could not be split into anything simpler. This idea was difficult to test because atoms were not visible. Over time, many scientists have collaborated and devised clever experiments to develop the atomic model that we use today.

1 Democritus proposed that everything is made of atoms

Democritus was an ancient Greek philosopher who lived around 400 BCE. His greatest contribution to science was to suggest that all substances are made of small particles that are indivisible (cannot be divided) and indestructible. He called these particles *atomus*, meaning 'cannot be cut or divided'.

What did Democritus propose?

2 Dalton proposed that compounds are made of two or more different types of atoms

In 1803, English chemist John Dalton proposed his **atomic theory**. He proposed that all matter is made up of atoms, and atoms of a given element are identical in size, mass and other properties. For example, every carbon atom is exactly the same as every other carbon atom, in every way. Dalton concluded that each element has unique atoms and that atoms of different elements combine with each other in simple ratios to form new substances, called compounds.

What did John Dalton's atomic theory state?

3 Thomson discovered electrons

At the beginning of the 20th century, English physicist J.J. Thomson studied the effect of passing cathode rays through gases. A **cathode ray** tube is a glass tube that fires a beam of negatively charged particles. By observing how the cathode ray beam behaved, Thomson identified the particles as electrons.

Thomson proposed that if every atom contains negatively charged particles, then there must also be positively charged material in every atom to balance the electrical charge. His model was described as the plum pudding model in which the atom consists of a positively charged sphere with electrons embedded in it (Figure 3.3).

How did Thomson discover electrons?

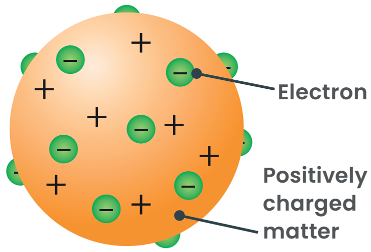


Figure 3.3 Thomson's plum pudding model describes the atom as a positively charged sphere (the 'pudding') with negatively charged electrons (the 'plums') embedded in it.

❹ Rutherford proposed the nuclear model of the atom

Ernest Rutherford was a New Zealand-born physicist. Working in England around 1910, he tested Thomson's plum pudding model by bombarding a piece of gold foil with **alpha (α) particles**, which are small, positively charged particles.

According to the plum pudding model, Rutherford would have expected all of the alpha particles to pass through the gold foil with little or no deflection. This is because the positive charge in the plum pudding model was assumed to be spread throughout the entire volume of the atom, so the overall charge would be too weak to significantly affect the path of the relatively massive and fast-moving alpha particles.

However, although most of the alpha particles went straight through the atoms, a small percentage were deflected at large angles. This led Rutherford to conclude that the atom is mostly empty space with a tiny, dense, positively charged nucleus and electrons orbiting the nucleus. Rutherford later identified that the positive components of the nucleus were protons.

What did Rutherford discover?

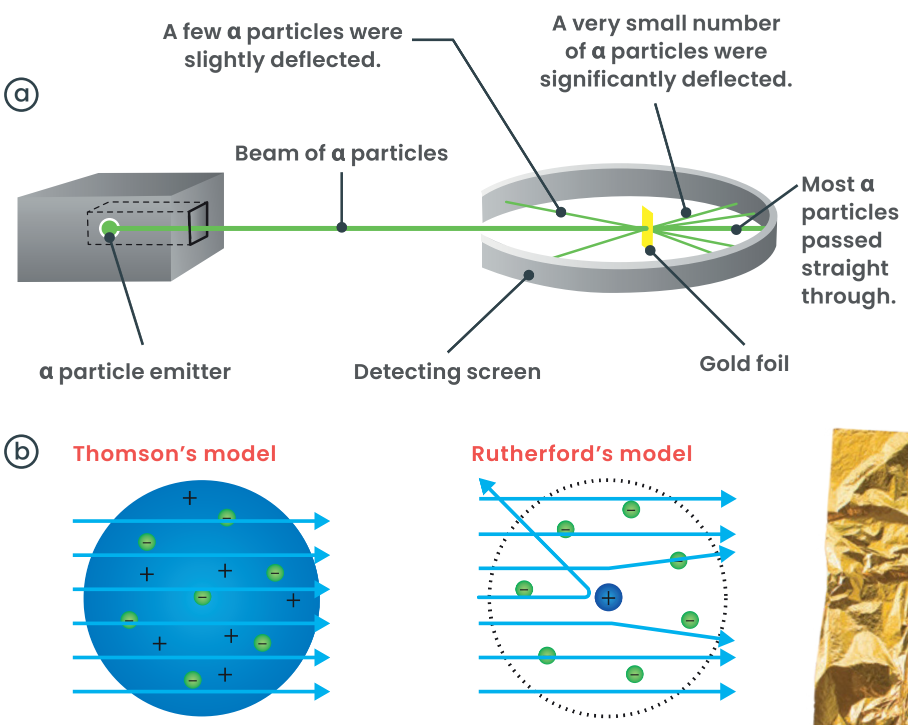


Figure 3.4 (a) Rutherford's famous experiment bombarded a sheet of gold foil with positively charged alpha particles. It showed that the atom is mostly empty space, with a small, dense, positively charged nucleus. **(b)** According to Thomson's plum pudding model, there was nothing dense or heavy enough in the atom to deflect the *α* particles. However, Rutherford's observations could only be explained by the presence of a dense, positively charged nucleus.

INVESTIGATION 3.2A
Making an atom
KEY SKILL
Using modelling and simulations
▶ *Go to page **150***

INVESTIGATION 3.2B
Flame test
KEY SKILL
Identifying the independent, dependent and controlled variables
▶ *Go to page **152***

3.2 continued ...

... 3.2 continued

ATOMIC THEORIES

KEY TERMS

electron shell
the space around the nucleus where electrons circulate

spectral line
a dark or bright line in an otherwise uniform spectrum

LITERACY LINK

SPEAKING

Choose one of the scientists in this lesson and read the section about their contribution to atomic theories. Explain what you have learnt to another student without looking at your book.

5 Bohr proposed the concept of electron orbits

In 1913, Danish physicist Niels Bohr worked out that the electrons in Rutherford's model must move around the nucleus in orbits of fixed sizes and energy levels, like planets orbiting the Sun. When an atom absorbs energy, it can then emit light of a specific colour. When this light is passed through a prism, **spectral lines** appear that are unique to each element. Bohr explained these lines by reasoning that electrons could only exist in specific **shells** (orbits), and that the spectral lines were the result of electrons moving between shells.

Bohr proposed that each orbit can only contain a certain number of electrons. The arrangement of electrons in different atoms explained how they can form bonds in chemical reactions.

What did Bohr discover? ....

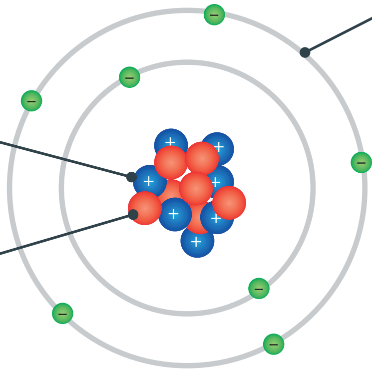


Figure 3.5 The Bohr model of the atom regards the atom as a small, dense nucleus surrounded by electrons in orbits of set size and energy.

6 Schrödinger took the Bohr model of the atom one step further

In 1926 an Austrian physicist named Erwin Schrödinger used mathematical equations to describe the probable location of an electron. Schrödinger worked out that electrons do not move in set paths (orbits) around the nucleus; instead, they move in clouds where their exact location is uncertain. Even though it is impossible to know the exact location of the electrons, Schrödinger's work shows that we are able to work out where they are likely to be found.

What did Schrödinger's work show? ....

Figure 3.6 Over time, many scientists have built on others' work to develop the atomic theory that we use today.


Democritus


John Dalton


J.J. Thomson


Ernest Rutherford

7 Chadwick discovered the neutron

James Chadwick was an English physicist who worked with Rutherford. In 1932, Chadwick bombarded beryllium atoms with alpha particles. He found that a new particle was ejected that had almost the same mass as the proton but no charge – the neutron. His finding revolutionised understanding of atomic structure and gained him a Nobel Prize in Physics in 1935.

During World War II, Chadwick was extensively involved in the Manhattan Project, a research project that studied nuclear fission reactions to produce nuclear weapons.

How did Chadwick discover the neutron?

8 The evolution of atomic theories and models

Table 3.1 Summary of theories and models about the atom

Date	Name	Discoveries or theories
400 BCE	Democritus	All substances are made of atoms.
1803	John Dalton	Atoms are solid spheres and cannot be divided. Atoms of an element are identical. Atoms of different elements combine to form new substances called compounds.
1904	J.J. Thomson	Atoms are composed of electrons. An atom is a sphere of positive charge (the 'pudding') with negatively charged electrons (the 'plums') scattered through it.
1910	Ernest Rutherford	Atoms are mostly empty space, with a tiny, dense, positively charged nucleus in the centre.
1913	Niels Bohr	Electrons move around the nucleus in orbits of fixed sizes and energies (like planets orbiting the Sun).
1926	Erwin Schrödinger	Electrons do not move in set paths around the nucleus, but in waves or clouds.
1932	James Chadwick	The atom contains a neutral subatomic particle – the neutron.

How has atomic theory changed over time?


Niels Bohr


Erwin Schrödinger


James Chadwick

CHECKPOINT 3.2

1 Explain what atomic theory is.
2 List the concepts of the atomic theory proposed by Dalton.
3 According to Dalton, how do elements react to produce new elements?
4 Describe the atomic model proposed by Thomson.
5 Explain how a cathode ray tube works.
6 How did Rutherford discover the positively charged nucleus?
7 How was Rutherford's view of the atom similar to and different from that of Thomson?
8 How was the atomic model improved as a result of Bohr's discoveries?
9 Describe Bohr's evidence suggesting electrons orbit in shells.
10 Describe the experiment conducted by Chadwick.

CONNECTING IDEAS

11 Draw different models of atoms that have been developed to show how they have been refined over time.

SUCCESS CRITERIA

- I can define atomic theory.
- I can identify key scientists and outline their contribution to current atomic theory.

3.3 RADIATION

LEARNING INTENTION

At the end of this lesson I will be able to describe how alpha and beta particles and gamma radiation are released from unstable atoms.

KEY TERMS

atomic number
the number of protons in an atom

half-life
the time taken for half of a radioactive material to decay

ionise
to remove electrons from an atom or molecule

isotopes
atoms of the same element with the same number of protons but a different number of neutrons

penetrating power
how well radiation from radioactive materials can pass through matter

radioisotope
an isotope that emits radiation

NUMERACY LINK

GRAPHING

The activity of a radioactive sample was measured as follows:

Time (min)	35	50	80	150
Activity (counts)	120	100	80	60

Graph the above data and draw a curve of best fit. Determine the half-life of the sample.

Some atoms are unstable because their nucleus contains too many neutrons or protons. The nucleus breaks down and releases particles and energy. These emissions are known as radiation and can be either alpha or beta particles or gamma rays. Ultimately, the atom is transformed into a new element with the release of the particles.

1 Radioisotopes are unstable atoms that decay

Atoms of different elements have different numbers of protons in the nucleus. Atoms of the same element always have the same number of protons but can have different numbers of neutrons.

Isotopes are atoms of the same element with the same **atomic number** but a different atomic mass. For example, carbon-12 has six protons and six neutrons. Its isotope carbon-14 also has six protons, but it has eight neutrons. An isotope of an element has the same number of protons, but a different number of neutrons.

Most atoms have stable nuclei, which contain enough neutrons to balance out the protons. These stable atoms do not break down. Atoms that are unstable have either too many protons or too many neutrons. **Radioisotopes** are radioactive isotopes of an element – unstable atoms that break down and release particles and energy from their nucleus.

When a sample of radioisotope breaks down (or decays), it emits radiation. Over time, the level of radioactivity falls as the amount of radioisotope in the sample decreases. The **half-life** of a radioactive substance is the time it takes for a given amount of the substance to reduce by half. Half-lives range from a fraction of a second to thousands of years.

What are radioisotopes?

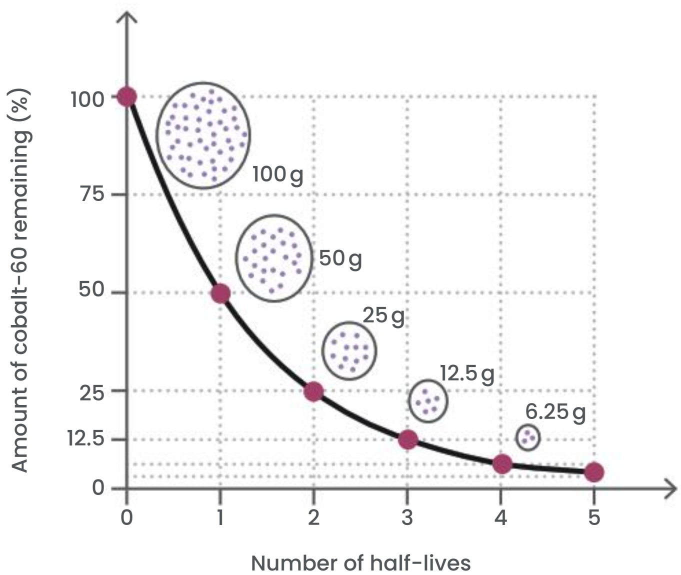


Figure 3.7 The decay curve for cobalt-60, which has a half-life of 5.27 years

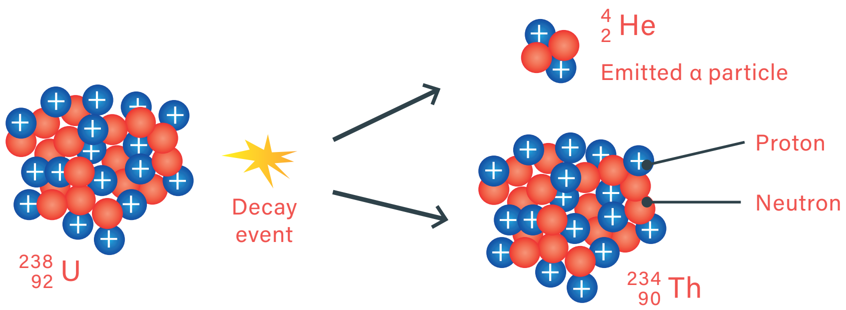


Figure 3.8 Uranium-238 has too many protons and is unstable. Therefore, it decays by emitting alpha radiation to become a new element, thorium.

2 An unstable nucleus may emit α or β particles

When a nucleus has too many protons, the like charges of the protons repel each other. This causes the nucleus to break down and release a particle made up of two protons and two neutrons. This is called an alpha (α) particle or alpha radiation. A new element is also formed, one that has an atomic number two less than the original element.

When a nucleus has too many neutrons, a neutron breaks down into a proton and an electron. The proton is retained and the electron is emitted as beta (β) radiation. Because the element now has an additional proton, the atomic number increases by one, producing a new element.

Because they have a large charge, α particles **ionise** other atoms strongly. However, they have a low **penetrating power** because they lose energy each time they ionise an atom. Beta particles ionise atoms that they pass through, but not as strongly as **alpha** particles do; however, they are more likely to penetrate other atoms.

What is the difference between α and β radiation?

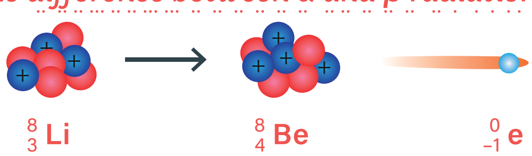


Figure 3.9 Lithium-8 is an unstable isotope of lithium. It decays by emitting beta radiation to form a new element, beryllium-8.

3 Different types of radiation have different properties

Another type of radiation that is produced when a nucleus decays is gamma (γ) radiation. Gamma rays are high-energy radiation and are more penetrating than α or β radiation. Gamma rays are emitted when the protons and neutrons in an unstable nucleus rearrange and emit energy instead of a particle.

Gamma rays are energy, not particles. This means that they have no mass and no charge.

What is gamma radiation?

INVESTIGATION 3.3

Half-life coin experiment

KEY SKILL
Representing data to identify patterns and trends

▶ *Go to page **154***

CHECKPOINT 3.3

1 Explain what radioactivity is.

2 Explain what is meant by half-life and give an example.

3 Explain why some nuclei are unstable.

4 Describe why these radiation types occur.
- a Alpha
- b Beta
- c Gamma

5 Explain the difference between nuclear decay by α and β radiation in terms of the new elements that are formed.

6 Strontium-90 has a half-life of 28.9 years. It emits β particles, which can be dangerous for human health. How many years must pass before its activity falls to one-eighth of its original value?

EXTENSION

7 Research the carbon-14 radioisotope and how scientists have used it to estimate the ages of many of the mummified bodies that have been discovered in the past century.

SUCCESS CRITERIA

- I can explain what radiation is and what happens during nuclear decay.
- I can identify the different particles and energy released when an atom's nucleus breaks down.

3.4 NUCLEAR ENERGY

LEARNING INTENTION

At the end of this lesson I will be able to evaluate the benefits and problems associated with medical and industrial uses of nuclear energy.

KEY TERMS

dosimeter
a device used to measure an absorbed dose of ionising radiation

ionising radiation
radiation, made up of particles, X-rays or gamma rays, that has sufficient energy to cause cancer

radiotherapy
a therapy that uses radiation to kill cancerous cells

LITERACY LINK

WRITING

Write a letter to the editor of a newspaper arguing either for or against the use of nuclear power.

NUMERACY LINK

CALCULATION

The amount of energy that can be generated from 1 kg of uranium is equivalent to 10 000 kg of mineral oil or 14 000 kg of coal. If the fission of 1 kg uranium produces 8×10^{10} kJ of energy, calculate how much energy is produced by 1 kg of mineral oil and 1 kg of coal.

Nuclear reactions release huge amounts of energy. This energy, which is in the form of radiation, can be used to generate electricity at nuclear power plants. In medicine, nuclear radiation can be used to treat and diagnose medical conditions.

There are many benefits associated with the use of nuclear energy. However, with these benefits there have also been the problems of nuclear disasters and nuclear waste.

1 Nuclear energy is used to detect and treat cancer

Radiation in medicine is used to diagnose medical problems and treat cancer. One major use is in medical imaging, where technologies such as PET scans use radiation to detect cancer sites. During a PET scan, diagnostic isotopes are injected in liquid form into the bloodstream. The scanner can then locate tumours and blood clots by detecting the radiation as it passes through body tissues.

The use of radiation to treat cancer is known as **radiotherapy**. Radiation can destroy the tumour and eliminate the cancer. The use of radiotherapy to destroy a tumour can also destroy the surrounding healthy cells. Although radiation may stop a tumour from growing, it can also cause side effects, such as nausea, swelling, skin irritation, ulcers, loss of hair and secondary cancers.

What are some uses of radiation in medicine?

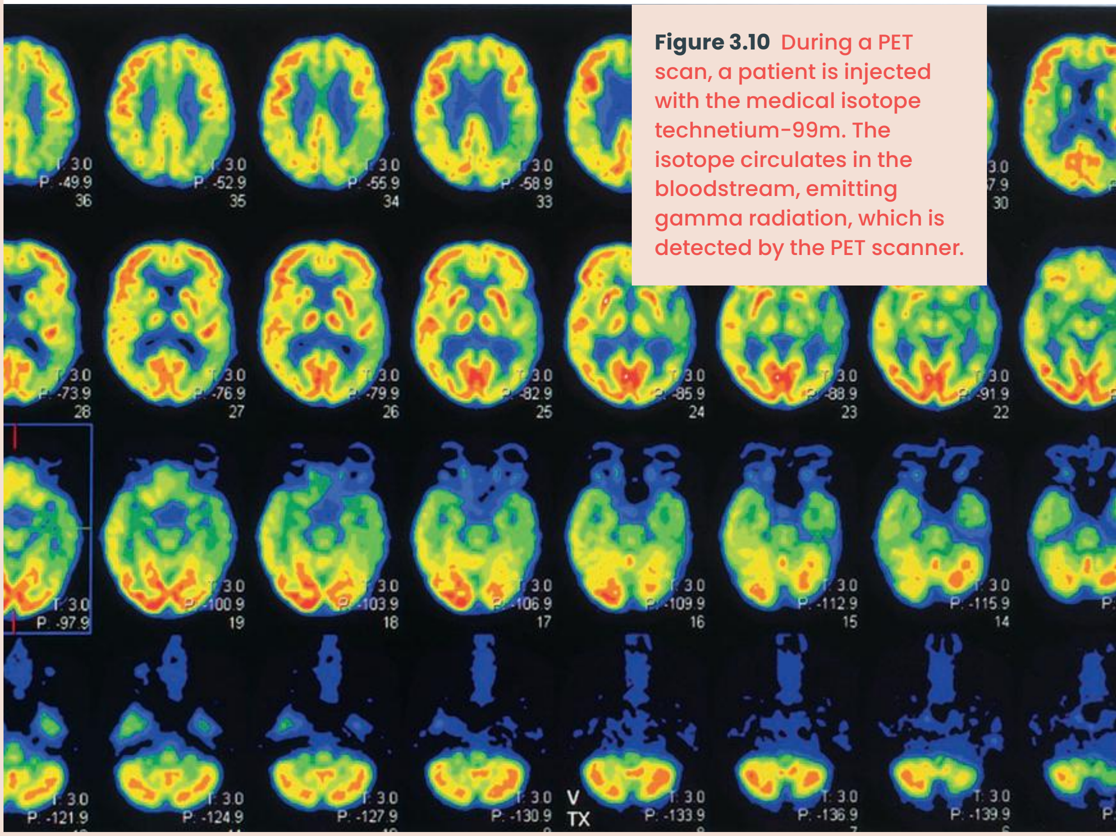


Figure 3.10 During a PET scan, a patient is injected with the medical isotope technetium-99m. The isotope circulates in the bloodstream, emitting gamma radiation, which is detected by the PET scanner.

2 Nuclear energy has many industrial uses

Some common uses of radiation in industry are to sterilise food to extend its shelf life, check for cracks in underground pipes, and check the thickness of paper during manufacturing.

Nuclear energy can also be used to generate electricity instead of conventional methods that use fossil fuels. Nuclear power plants have low emissions of CO_2 and SO_2 gases and don't rely on coal, which is a non-renewable resource. Nuclear power uses much less fuel (in the form of uranium) than a coal-powered station does. Nuclear power plants produce far less background radiation than coal-powered plants and are far more effective at producing energy.

What are some uses of radiation in industry?

3 Nuclear energy has safety concerns

Prolonged exposure to radiation damages living cells and can lead to diseases such as leukaemia and cancer. It can also damage DNA and lead to birth defects. In the past, scientists such as Marie Curie (1867–1934) have died as a result of exposure to dangerous radiation.

There are now guidelines that protect hospital staff and people who work in nuclear power stations. Workers wear special detectors called **dosimeters**, which monitor their exposure to radiation. They can also wear protective suits or work behind thick glass screens to shield them from radiation.

One of the main issues in the nuclear industry is nuclear waste. Nuclear waste contains radioactive elements such as plutonium, which has a half-life of 24 000 years. Workers handling such radioactive materials are exposed to dangerous **ionising radiation**, which causes cancer. Dangerous radioactive waste must be treated and then stored safely; for example, in concrete cylinders or by burying it deep underground.

In the past, there have been disasters at nuclear power plants. In 1986, a nuclear reactor at Chernobyl, Ukraine, exploded. This caused deaths and cancers in the surrounding area, and spread radioactive products as far as Europe. In 2011, a tsunami off the coast of Japan resulted in the meltdown of the Fukushima nuclear power plant, and release of radioactive contamination.

Other disadvantages of nuclear energy include the expense of constructing a safe nuclear power plant, which can operate for only 40 years and then has to be safely dismantled and removed.

What is the main safety concern when dealing with nuclear energy?

INVESTIGATION 3.4

Nuclear energy debate

KEY SKILL
Referencing sources of information

▶ *Go to page **156***

CHECKPOINT 3.4

1 Describe how a PET scan works.
2 What are some of the side effects of using radiotherapy?
3 Outline some advantages and disadvantages regarding the use of nuclear energy.
4 The use of nuclear energy has resulted in some large scale catastrophes. Suggest why it continues to be used.
5 Outline some safety precautions that can be used when working with nuclear energy and radiation.
6 Write a list of pros and cons for the use of nuclear energy.
7 Describe the benefits and dangers of using radiation to treat cancer.

RESEARCH

8 Research a disaster related to the use of nuclear energy. Prepare a short report and include how it happened and what effects it had.

SUCCESS CRITERIA

- I can describe some benefits of nuclear energy in medicine and industry.
- I can describe some problems with the use of nuclear energy in medicine and industry.

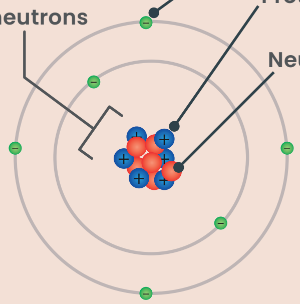
VISUAL SUMMARY

Matter is made up of atoms.

Matter

- Pure substances
  - Elements
    - One type of atom
    - Cannot be physically separated
    - For example, gold (Au), nitrogen (N_2)
  - Compounds
    - Two or more types of atoms
    - Cannot be physically separated
    - For example, salt (NaCl), carbon dioxide (CO_2)
- Impure substances (mixtures)
  - Can be physically separated
  - For example, air, milk, blood, salty water

Properties of subatomic particles



Nuclear energy

Pros:

- generates fewer emissions than CO_2
- can be used to treat cancer
- can extend the shelf life of food

Cons:

- risk of environmental disaster
- can lead to illness and disease
- disposal of nuclear waste

Properties of alpha, beta and gamma radiation

Radiation	Symbol	Composition	Charge	Relative penetrating power	Ionising power
Alpha	α	Alpha particles (proton–neutron pairs)	2+	Low	Strong
Beta	β	Beta particles (electrons)	1–	Medium	Medium
Gamma	γ	High-energy radiation (photons)	0	High	Very weak

Atomic theory – key thinkers

Democritus

John Dalton

J.J. Thomson

Ernest Rutherford

Niels Bohr

Erwin Schrödinger

James Chadwick

★ FINAL CHALLENGE ★

1. Match each scientist to the description of their contribution.

Democritus	Proposed that atoms are positively charged spheres with electrons embedded like plums in a plum pudding
Bohr	Proposed that substances consist of tiny particles called atoms
Thomson	Proposed the atomic theory that all matter is made up of atoms
Dalton	Discovered that electrons orbit the nucleus in energy levels
Rutherford	Discovered the existence of neutrons in the nucleus
Chadwick	Proposed that the atom is mostly empty space, with a dense, positively charged nucleus in the centre

Level 1 ★☆☆☆☆☆ 50xp LEVEL UP!

2. Describe the three parts of the atom.
3. What holds the parts of an atom together?
4. Identify four concepts of the atomic theory proposed by John Dalton.

Level 2 ★★☆☆☆☆ 100xp LEVEL UP!

5. Describe how Rutherford proved that the atom is mostly empty space.
6. Describe the two situations when an isotope would become unstable.
7. Compare the three types of radiation in terms of penetrating ability and ionising power. (Hint: Refer to the table on page 54.)

Level 3 ★★★☆☆☆ 150xp LEVEL UP!

8. Create a table that summarises the main points under the headings of 'Uses of radiation in medicine' and 'Problems of radiation in medicine'.
9. Using your understanding of nuclear power to generate electricity, propose reasons for moving away from using fossil fuels towards using nuclear power.

Level 4 ★★★★☆☆ 200xp LEVEL UP!

10. Research the consequences of the nuclear disasters at Chernobyl, Ukraine, in 1986 and Fukushima, Japan, in 2011.
11. Nuclear power plants produce nuclear waste. Make some suggestions as to how to best address this problem.

Level 5 ★★★★★★ 300xp LEVEL UP!

CHEMICAL REACTIONS

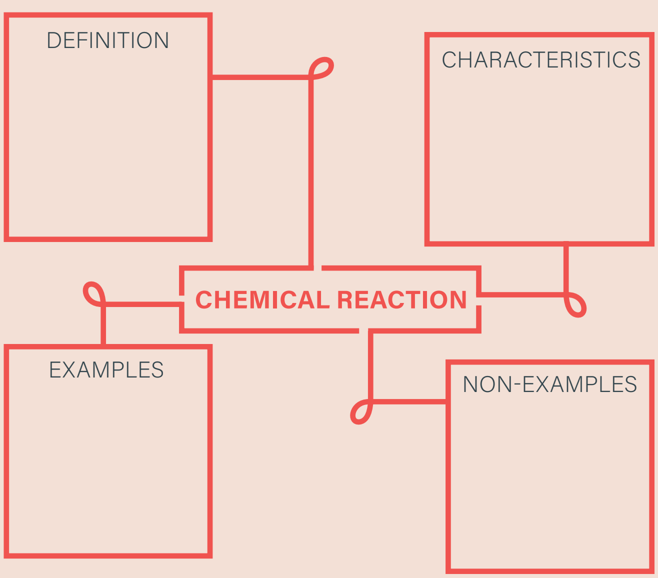
How does the structure of an atom influence its behaviour?

4

Have you ever heard the saying 'your eyes are bigger than your stomach'? Well, the world's largest burger costs $8000 and weighs a whopping 813 kilograms. That's a lot of burger! Sometimes we eat things that are much bigger than our stomachs, so how is that even possible? The answer is chemical reactions. These reactions can be fast or slow, and are involved in our digestion and the processes we use to obtain energy. Chemical reactions for digestion begin straight away, in our mouths, starting to break the food down before it even gets to our stomach. In our stomach, strong acids break down the food even more, so we can eat more of that burger!

1 FRAYER MODEL

Copy and complete the below chart in your workbook.



Complete two additional charts for the key terms *Combustion* and *Acid*.

2 LEARNING LINKS

Brainstorm everything you already know about chemical reactions.

3 SEE-KNOW-WONDER

List three things you can SEE, three things you KNOW and three things you WONDER about this image.

4 CRITICAL + CREATIVE THINKING

THE REVERSE: List things that can never be involved in a chemical reaction.

THE BRAINSTORM: Brainstorm a list of ways to prevent cars from rusting.

DIFFERENT USES: How many different uses can you think of for a very strong acid?

5 THE GREENEST!

The Statue of Liberty, one of the most iconic landmarks in the world, is found in New York. The statue is famous for its green colour – however, it was originally brown! The Statue of Liberty is made of copper, and over the years the copper in the statue reacted with the oxygen in the air to form a coating of copper oxide. It is this copper oxide that gives the statue its familiar green colour. This is an example of a chemical reaction, one that happened very slowly and in front of our very eyes.

4.1 REPRESENTING CHEMICAL REACTIONS

LEARNING INTENTION

At the end of this lesson I will be able to describe a chemical reaction in terms of reactants and products.

KEY TERMS

chemical reaction
a reaction that involves the creation of new substances

conservation of mass
the scientific law that mass cannot be created or destroyed

product
a substance formed in a chemical reaction

reactant
a substance that starts a chemical reaction

word equation
a representation of a chemical reaction using words

LITERACY LINK

WRITING

Write some non-scientific word equations from your own life. Be as funny or creative as you like.

NUMERACY LINK

CALCULATION

How many oxygen gas and hydrogen gas molecules are required to create 20 molecules of water?

Human beings need several things to be able to survive, including oxygen to breathe, water to drink and food to eat. Have you ever wondered why this is? All of these substances are involved in **chemical reactions** that give us the energy we need to grow, move and survive.

1 A chemical reaction is a rearrangement of atoms

A chemical reaction occurs when two substances combine in such a way that the atoms rearrange themselves. Consider water. The formula for water is H_2O, because each molecule of water contains two hydrogen atoms and one oxygen atom. We can form water by combining hydrogen and oxygen gas and adding some energy to get the reaction going. This will cause the hydrogen and oxygen molecules to split apart into atoms and recombine into water molecules.

What substances are combined to form water?

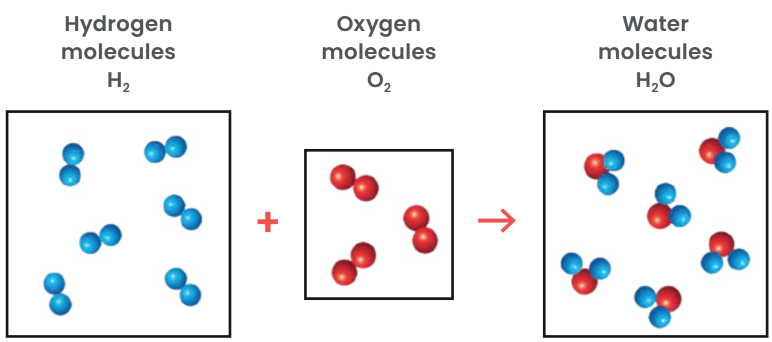


Figure 4.1 Hydrogen (H_2) and oxygen (O_2) molecules split apart and recombine to form water molecules (H_2O).

2 Writing word equations

In the reaction in Figure 4.1, the oxygen gas and hydrogen gas were the initial substances before the reaction – these are known as the **reactants**. Water is the substance created in the reaction, known as the **product**. We can represent this process as a **word equation**.

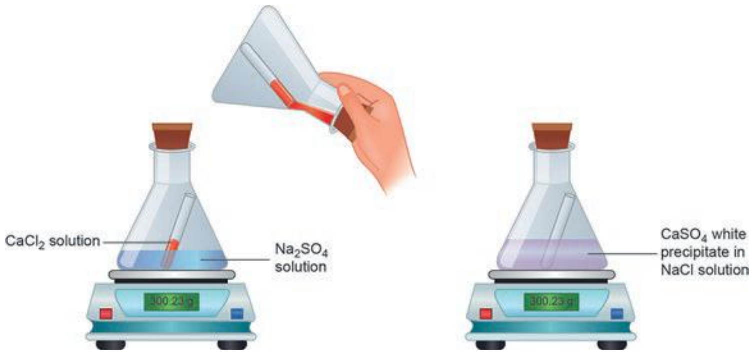
Oxygen gas + hydrogen gas → water

The arrow (→) represents the reaction. The reactants are always on the left of the arrow with plus (+) signs between them. The products are always on the right of the arrow.

What are reactants and products?

3 Conservation of mass

During a chemical reaction, the atoms of the reactants recombine to form new substances. It is important to realise that no new atoms are created, and no atoms are destroyed. This means that however many atoms there were in our reactants, we must have exactly the same number and type of atoms in our products, just arranged differently. The total mass of our products must be the same as the mass of our reactants. This is known as the law of **conservation of mass**.



$CaCl_2$	+	Na_2SO_4	→	$CaSO_4$	+	2NaCl
Calcium chloride solution	+	sodium sulfate solution	→	calcium sulfate precipitate	+	sodium chloride solution

Figure 4.2 If a reaction occurs in a sealed container, the mass will not change.

Sometimes, the law of conservation of mass might seem wrong. Think about a piece of wood burning in a fireplace. The wood is undergoing a chemical reaction – combustion. After the reaction has finished, the ash left over is much lighter than the wood was originally. It is important to realise that the ash is not the only product of the reaction. Carbon dioxide and water have also been formed, but drifted away. If we were to gather up all of the ash, carbon dioxide and water and weigh them, they'd be equal to the mass of the original block of wood.

Can atoms be created or destroyed in a chemical reaction?

Figure 4.3 Wood burning in a fireplace is an example of the conservation of mass.

CHECKPOINT 4.1

1 State the law of conservation of mass.

2 Identify the reactants and products in the following word equations.
 a Zinc + hydrochloric acid → zinc chloride + hydrogen gas
 b Oxygen gas + magnesium → magnesium oxide
 c Hydrogen peroxide → oxygen gas + hydrogen gas

3 Write a word equation for photosynthesis, where carbon dioxide and water combine to form glucose and oxygen gas.

4 Explain why an arrow (→) is used in chemical equations, and not an equals (=) sign.

5 Dissolving salt in water is not an example of a chemical reaction. Explain why.

6 A piece of wood is burned in air. The wood forms ash, which is lighter than the original wood. What happens to the rest of the mass of the wood?

CONNECTING IDEAS

7 Write a brief paragraph explaining the law of conservation of mass in terms of protons, neutrons and electrons.

SUCCESS CRITERIA

- I can identify the reactants and products in a chemical reaction.
- I can use word equations to represent chemical reactions.

4.2 EXOTHERMIC AND ENDOTHERMIC REACTIONS

LEARNING INTENTION

At the end of this lesson I will be able to explain that chemical reactions involve energy transfer and can be exothermic or endothermic.

KEY TERMS

electrolysis
a decomposition reaction using electricity

endothermic
a reaction that absorbs energy in the form of heat

exothermic
a reaction that releases energy in the form of heat

LITERACY LINK

VOCABULARY

The prefix *ex-* or *exo-* means 'outside of'. Think of five words that start with this prefix and explain how they relate to being 'outside of' something.

NUMERACY LINK

DATA

A sample of sodium hydroxide was dissolved in a test tube of water at 19 °C. The temperature increased to 28 °C. A sample of potassium nitrate was dissolved in a test tube of water at 20 °C. The final temperature was 11 °C. Which reaction was endothermic and which was exothermic?

Chemical reactions involve more than just elements and compounds – they also involve energy. This energy usually takes the form of heat. Some reactions release heat, such as burning a candle. Others require heat to be added, such as cooking an egg. Without energy being transferred, chemical reactions simply would not happen.

1 Exothermic reactions release heat, while endothermic reactions absorb heat

In **exothermic** reactions, the reactants have more energy than the products. This extra energy is released as heat. Exothermic reactions include:

- respiration
- combustion reactions
- corrosion
- neutralisation reactions
- burning magnesium.

In **endothermic** reactions, the products have more energy than the reactants. This energy has to be added or absorbed, mainly in the form of heat. Endothermic reactions include:

- photosynthesis
- bread baking
- an egg cooking
- **electrolysis** of water
- thermal decomposition reactions.

What are two differences between exothermic and endothermic reactions?

Figure 4.4 Fuel being burnt in a rocket launch is an example of an exothermic reaction.

2 Bonds break and form during chemical reactions

Why do chemical reactions involve energy? It's because of the bonds between the atoms within the molecules. These bonds, which hold molecules together, contain chemical potential energy. During a chemical reaction, bonds in the reactants break, and new bonds form to make the products.

In all chemical reactions, energy is needed to break the bonds of the reactants, and energy is released when new bonds form in the products. For example, methane reacts with oxygen to form carbon dioxide and water:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

Methane + oxygen → carbon dioxide + water

As bonds within methane and oxygen break, new bonds form between carbon, hydrogen and oxygen to form carbon dioxide and water.

Why is energy needed in chemical reactions?

3 Chemical reactions produce or absorb heat

To see whether a reaction is exothermic or endothermic, we need to look at the overall energy of the reaction – whether energy was required to make the reaction proceed or whether energy was released.

In an endothermic reaction, the energy required to break the bonds in the reactants is greater than the energy released when the products are formed. This means that the reaction takes in more energy overall, so the temperature decreases around the reaction container or surroundings. Endothermic reactions give rise to cold surroundings.

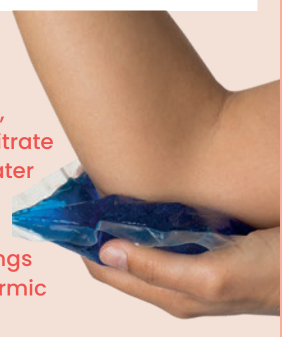


Figure 4.5 In a cold pack, ammonium nitrate reacts with water and absorbs energy from the surroundings in an endothermic reaction.

Chemical equations for endothermic reactions can be written like this:

Reactants + ENERGY → products

An exothermic reaction occurs when the energy used to break the bonds in the reactants is less than the energy released when new bonds are made in the products. This extra energy is given off as heat and the temperature of the surroundings increases. Exothermic reactions give rise to hot surroundings.

Chemical equations for exothermic reactions can be written like this:

Reactants → products + ENERGY

Why is energy released in an exothermic reaction?

INVESTIGATION 4.2

Exothermic and endothermic reactions

KEY SKILL

Explaining results using scientific knowledge

▶ *Go to page* ***158***

CHECKPOINT 4.2

1 How is an endothermic reaction different from an exothermic reaction?

2 Give two examples of endothermic reactions and two examples of exothermic reactions.

3 Compare the energy required to break and form bonds in both endothermic and exothermic reactions.

4 Which of the following reactions are exothermic and which are endothermic? Give reasons for your choice.
  a Baking biscuits
  b Burning a piece of paper
  c Lighting a candle
  d Using a cold pack on an injured leg

5 Bonds break during chemical reactions. Explain why.

RESEARCH

6 Research how endothermic and exothermic reactions are used in everyday life. Give at least three examples of each.

SUCCESS CRITERIA

- I can explain why chemical reactions involve energy transfer.
- I can explain what endothermic and exothermic reactions are.

4.3 ACIDS AND BASES

LEARNING INTENTION

At the end of this lesson I will be able to describe what acids and bases are and how they are measured.

KEY TERMS

alkali
a base that is dissolved in water

caustic
able to burn or corrode organic tissue through chemical action

concentration
the amount of a substance in a volume of solution

corrosive
highly reactive and damaging or destructive to another substance

neutralise
to make something chemically neutral

pH
a figure expressing the acidity or alkalinity of a solution

LITERACY LINK

READING

Create a Venn diagram to compare and contrast the characteristics of acids and bases.

NUMERACY LINK

UNITS

a How much more acidic is pH 5 than 7?

b Compare the acidity levels of pH 9 and 6.

Chemical compounds can be grouped according to their common characteristics. Two of the most common groups are acids and bases. They are used in cleaning products, swimming pools and kitchens. Many of the foods we eat are either acidic or basic, and acids and bases help digest food.

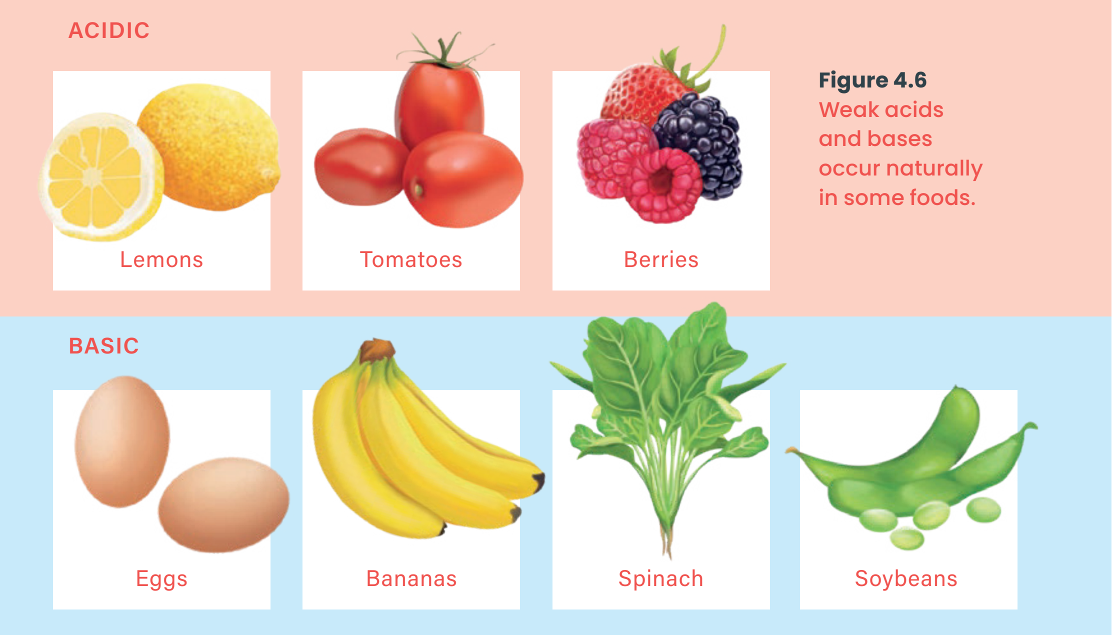


Figure 4.6 Weak acids and bases occur naturally in some foods.

1 Acids produce large amounts of hydrogen ions

An acid is a **corrosive** chemical substance that produces hydrogen ions (H^+) when mixed with water. The hydrogen ions can react with the other substances to produce salts (ionic substances) and other substances such as water and hydrogen gas.

The higher the **concentration** of hydrogen ions produced by an acid, the higher its acidity. Strong acids are very dangerous, especially when they contact skin and eyes. That's why you must always wear protective clothing and eyewear when working with acids in the lab.

Weak acids are much safer to use, and are important in our diet. Citrus fruits such as oranges and lemons contain a weak acid, called citric acid, which contributes to their sour flavour. Soft drinks also contain weak acids, as does coffee. There's even some very, very weak acid in milk.

What happens when an acid is mixed with water?

2 Bases produce large amounts of hydroxide ions

A base is a substance that reacts with an acid to **neutralise** it. Bases that dissolve in water are called **alkalis**. When mixed with water, bases produce hydroxide ions (OH^-), which are one atom of oxygen bonded to one atom of hydrogen, with a negative charge.

Although bases are not acidic, they are **caustic**, and can be just as dangerous as acids. Household cleaning products are strong bases. Bases such as sodium hydroxide and ammonia react with oils and fats, which is why they are used in many household cleaners. Weak bases are found in toothpaste, conditioners, antacid tablets and baking powder.

There are three types of bases.

- Metal hydroxides (e.g. potassium hydroxide) contain metals bonded with hydroxide (OH^-).
- Metal oxides (e.g. zinc oxide) contain metals bonded with oxide (O_2^-).
- Metal carbonates (e.g. copper carbonate) contain metals bonded with carbonate (CO_3^{2-}).

What are alkalis?

3 The pH scale measures acidity

The acidity of a solution is measured on a scale called the **pH** scale. Acids have a low pH, while bases have a high pH. A solution with a pH of 7 is neutral, while a solution with a pH below 7 is an acid and a solution with a pH above 7 is a base.

The pH scale goes from 1 to 14, where each number differs by a factor of 10. For example, pH 2 is 10 times more acidic than pH 3.

You can measure pH by adding an indicator to a solution and matching its colour to a chart or using a pH meter. Indicators are substances that change to different colours depending on whether they're mixed with an acid or a base. One of the most common indicators is litmus, which turns red when mixed with acids and blue when mixed with bases.

What is the pH of a neutral substance?

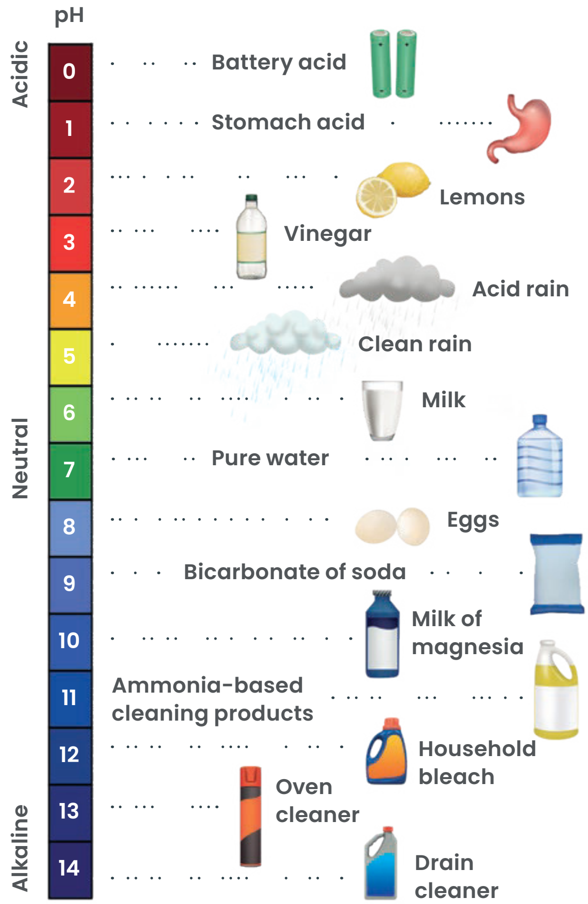


Figure 4.7 The pH scale measures acidity.

INVESTIGATION 4.3A

Action of acids and bases – cleaning coins

KEY SKILL
Identifying the independent, dependent and controlled variables

▶ *Go to page **160***

INVESTIGATION 4.3B

Acid or base?

KEY SKILL
Evaluating results for reliability and validity

▶ *Go to page **161***

INVESTIGATION 4.3C

The effect of indicators on acids and bases

KEY SKILL
Identifying and managing relevant risks

▶ *Go to page **162***

CHECKPOINT 4.3

1 List three properties of acids.
2 Identify three acids.
3 List two properties of bases.
4 Identify three bases.
5 Describe the pH scale in your own words.
6 Identify the pH of water.
7 Explain why strong acids and bases can be dangerous.

CONNECTING IDEAS

8 Make a list of five liquids you can find at home that aren't listed in Figure 4.7. Estimate where on the pH scale you expect them to be, then research to find out if you are correct.

SUCCESS CRITERIA

- I can explain what acids and bases are and give examples of each.
- I can describe the pH scale, including the range for acids and bases.

4.4 ACID REACTIONS

LEARNING INTENTION

At the end of this lesson I will be able to investigate reactions of acids with metals, bases and carbonates.

KEY TERMS

carbonate
a substance containing the elements carbon and oxygen

neutralisation reaction
a reaction involving an acid and a base to produce water and a salt

strong acid
an acid that ionises completely in water

weak acid
an acid that partially ionises (loses or gains electrons) in water

LITERACY LINK

LISTENING

Read section 1 aloud to a partner, who must then summarise what you read in three dot points. Repeat for section 2, swapping roles.

NUMERACY LINK

GRAPHING

Magnesium was added to hydrochloric acid at different temperatures and the time of reaction recorded:

Temp (°C)	0	15	25	40
Time to react (s)	36	21	15	14

Construct a line graph for this data.

Acid reactions are very important to life. Your stomach contains a very corrosive acid that breaks down and allows the digestion of food. Without stomach acid, we wouldn't be able to eat! Acids also react with many other substances in a variety of ways.

1 Acids and bases neutralise each other

In a **neutralisation reaction**, an acid and a base react to form a salt and water. This happens because acids are a source of hydrogen ions (H^+), while bases are a source of hydroxide ions (OH^-).

In an acid–base neutralisation reaction, the H^+ from the acid and the OH^- from the base combine to form pure water, which is neutral and has a pH of 7:

$$\text{Hydrogen} + \text{hydroxide} \rightarrow \text{water}$$
$$H^+ + OH^- \rightarrow H_2O$$

The other parts of the acid and base combine to produce a salt.

The reaction of a **strong acid** with a strong base results in a neutral solution with a pH of 7 and a neutral salt. For example, hydrochloric acid reacts with sodium hydroxide to form water and the neutral salt sodium chloride (NaCl):

$$\text{Hydrochloric acid} + \text{sodium hydroxide} \rightarrow \text{water} + \text{salt}$$
$$HCl + NaOH \rightarrow H_2O + NaCl$$

The reaction of a strong acid with a weak base produces a solution with pH < 7, containing water and an acidic salt. The reaction of a strong base with a **weak acid** produces a solution with pH > 7, containing water and a basic salt.

What is a neutralisation reaction?

2 Acids react with metals to produce salts and hydrogen

Some metals are more reactive with acids than others. You can see this in the reactivity series of metals in Table 4.1.

The metals at the top of the reactivity series react violently, while those at the bottom react very little. This is one reason why gold and silver are used to make jewellery, rather than iron and zinc. Gold and silver are chemically very unreactive, and they keep their shiny surface even when exposed to acids and oils in the air or on your skin.

Table 4.1 Metals can be arranged from most to least reactive with acids.

Metal	Reactivity
Potassium (K)	Most reactive
Sodium (Na)	
Calcium (Ca)	
Magnesium (Mg)	
Aluminium (Al)	
Zinc (Zn)	
Iron (Fe)	
Tin (Sn)	
Lead (Pb)	
Copper (Cu)	
Silver (Ag)	
Gold (Au)	Least reactive

Acids react with metals to form a salt and hydrogen gas. More reactive metals react faster, which you can see by how fast the hydrogen gas bubbles are released.

Acid + metal → salt + hydrogen

The salt formed depends on the acid the metal reacts with. For example, magnesium reacts with hydrochloric acid to produce magnesium chloride and hydrogen gas:

Hydrochloric acid	+	magnesium	→	magnesium chloride	+	hydrogen
2HCl	+	Mg	→	$MgCl_2$	+	H_2

Which metals are more reactive than magnesium?

3 Acids react strongly with metal carbonates

A metal **carbonate** is a compound containing metal, carbon and oxygen. Acids react with metal carbonates to form salts, carbon dioxide and water.

Acid + metal carbonate → salt + carbon dioxide + water

For example, calcium carbonate (a compound used to settle an upset stomach) reacts with hydrochloric acid to produce calcium chloride, carbon dioxide gas and water:

Hydrochloric acid	+	calcium carbonate	→	calcium chloride	+	carbon dioxide	+	water
2HCl	+	$CaCO_3$	→	$CaCl_2$	+	CO_2	+	H_2O

Carbonates give off the gas carbon dioxide when they react with acids. This is why people burp when they take calcium carbonate to settle an upset stomach. The carbonate reacts with the stomach acids to produce carbon dioxide, which fills up the stomach and has to be released by burping.

To test if the gas released in a reaction is carbon dioxide, bubble the gas through limewater. Carbon dioxide turns limewater milky or cloudy.

How can we test if a gas is carbon dioxide?

Figure 4.8 Calcium carbonate reacts with hydrochloric acid to produce calcium chloride and carbon dioxide, which you can see as bubbles.

INVESTIGATION 4.4A

Reactions of acids with metals

KEY SKILL
Explaining results using scientific knowledge

▶ *Go to page **163***

INVESTIGATION 4.4B

Reactions of acids with carbonate

KEY SKILL
Identifying and managing relevant risks

▶ *Go to page **164***

CHECKPOINT 4.4

1 Write the general neutralisation equation.

2 Identify the salt formed when sulfuric acid reacts with zinc.

3 Describe what happens when an acid reacts with a metal.

4 a Which metal is more reactive – magnesium or aluminium?
b How could you show your answer to part a was true?

5 Identify the gas formed when a metal carbonate reacts with an acid.

6 Identify the salt formed when nitric acid reacts with magnesium carbonate.

7 Explain how calcium carbonate can help an upset stomach.

CRITICAL AND CREATIVE THINKING

8 Design an experiment to see if increasing the concentration of hydrochloric acid affects the rate of its reaction with zinc metal. In your answer, include the controlled, independent and dependent variables.

SUCCESS CRITERIA

- I can describe what happens when an acid reacts with a base, a metal and a metal carbonate.

4.5 COMBUSTION REACTIONS

LEARNING INTENTION

At the end of this lesson I will be able to describe combustion as a chemical reaction that involves energy transfer.

KEY TERMS

combustion
a reaction that involves burning in the presence of oxygen to release heat

hydrocarbon
a compound made up of only hydrogen and carbon

oxidation
a reaction taking place in the presence of oxygen

soot
a black form of carbon formed by incomplete combustion

transform
to change from one form to another

LITERACY LINK

READING

Summarise this lesson in a postcard addressed to your teacher.

NUMERACY LINK

MEASUREMENT

In real life, the space shuttle shown in Figure 4.11 is 37 metres long. Use a ruler to measure the length of the shuttle pictured to work out the scale of the photograph.

Energy is essential for life. Biological reactions and chemical reactions involve energy transfer. Some chemical reactions need energy to start them and others release energy in the form of heat, light and sound. **Combustion**, the reaction of acids with metals and neutralisation reactions are some reactions that release energy.

Figure 4.9 Energy transformation occurs when a match is struck.

1 Combustion reactions involve oxygen

An **oxidation** reaction is a reaction that occurs in the presence of oxygen. There are two types of oxidation reactions – combustion and corrosion. A combustion reaction takes place between a compound and oxygen to produce heat and a new product. The most obvious example of a combustion reaction is the burning of wood in a fire; another example is the respiration that happens within your cells.

All of the products formed in combustion reactions are oxides. When a metal is burnt in oxygen, a metal oxide is formed and energy is released. For example, burning magnesium in oxygen produces heat and light energy and a white solid product called magnesium oxide.

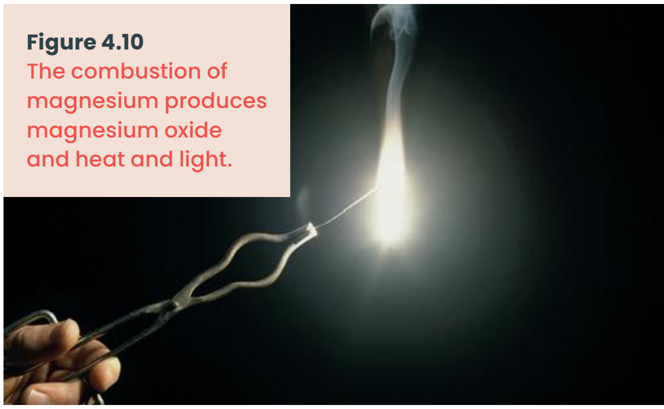


Figure 4.10 The combustion of magnesium produces magnesium oxide and heat and light.

Magnesium + oxygen → magnesium oxide

When a **hydrocarbon** such as natural gas or methane is burnt, the products are usually carbon dioxide and water. This is because hydrocarbons only contain carbon and hydrogen. Methane undergoes a combustion reaction in the presence of oxygen to form carbon dioxide and water:

Methane + oxygen → carbon dioxide + water

We use combustion reactions to provide energy for our daily activities. Power plants burn coal to provide us with electricity. The combustion of petrol in cars provides the energy to make them move. In a combustion reaction, most of the energy is **transformed** from chemical energy to heat energy.

What is an example of a combustion reaction?

2 Incomplete combustion reactions produce carbon monoxide and carbon

If there is plentiful oxygen, complete combustion of hydrocarbons occurs. But if there is a limited supply of oxygen, incomplete combustion may occur. Instead of producing carbon dioxide and water, incomplete combustion produces carbon monoxide and water or carbon (**soot**) and water.

For example, the complete combustion reaction of propane (C_3H_8) requires five molecules of oxygen for every molecule of propane:

Propane	+	oxygen	→	carbon dioxide	+	water
C_3H_8	+	$5O_2$	→	$3CO_2$	+	$4H_2O$

If there are only 3.5 oxygen molecules for every molecule of propane, incomplete combustion will produce carbon monoxide and water:

Propane	+	oxygen	→	carbon monoxide	+	water
C_3H_8	+	$3.5O_2$	→	$3CO$	+	$4H_2O$

If there are only two oxygen molecules for every molecule of propane, the reaction will produce carbon and water:

Propane	+	oxygen	→	carbon	+	water
C_3H_8	+	$2O_2$	→	$3C$	+	$4H_2O$

Soot is black, powdery carbon, and not very useful. Carbon monoxide is a toxic gas, so it is important to ensure that combustion reactions, like those in a car engine, take place in enough oxygen.

What is the difference between combustion and incomplete combustion?

Figure 4.11
The combustion of rocket fuel powers this shuttle into space.

INVESTIGATION 4.5A
Combustion of fuels

KEY SKILL
Evaluating results for reliability and validity

▶ *Go to page **166***

INVESTIGATION 4.5B
Complete and incomplete combustion reactions

KEY SKILL
Identifying the controlled variables

▶ *Go to page **167***

CHECKPOINT 4.5

1 Explain what combustion is.
2 Why is combustion an important chemical reaction?
3 When a metal is burnt in oxygen, what is formed?
4 Identify the products of a complete combustion reaction.
5 When does incomplete combustion occur?
6 Identify the possible products of an incomplete combustion reaction.
7 What is needed for a combustion reaction to start?
8 What is the energy transformation taking place in a combustion reaction?

RESEARCH

9 Research and provide a summary of the major combustion reactions currently used on Earth and what they are used for.

SUCCESS CRITERIA

- I can explain what combustion reactions are.
- I can give two examples of combustion reactions.

4.6 RESPIRATION AND PHOTOSYNTHESIS

LEARNING INTENTION

At the end of this lesson I will be able to compare respiration and photosynthesis and their roles in biological processes.

KEY TERMS

photosynthesis
the chemical reaction, powered by sunlight, that plants use to change carbon dioxide and water into glucose and oxygen

respiration
the chemical reaction that occurs in cells to release energy

LITERACY LINK

SPEAKING

Write a short speech explaining the consequences of cutting down too many trees. You must mention photosynthesis and respiration in your speech. Perform your speech for another student.

NUMERACY LINK

CALCULATION

An average human will consume 550 L of oxygen per day. Plants will create 15 L of oxygen for every 100 g of growth. How much plant growth is required to provide the oxygen for one person for a day?

In order for living things to survive, they require energy. The source of this energy depends upon the organism – plants get their energy from sunlight, while animals eat food to get energy. Chemical reactions occurring inside the cells of organisms release this energy.

1 Respiration is essential for energy

Respiration is a form of combustion reaction – it requires oxygen and results in the release of energy. In fact, this need for energy is the reason that humans need to eat and breathe! All cells in your body require energy in order to be able to move and grow. This energy comes from respiration, which occurs in the mitochondria of cells.

Glucose + oxygen gas → carbon dioxide + water + ENERGY

Glucose is a chemical that we get from the food we eat, and oxygen is obtained by breathing in. These two substances react in the cells to create carbon dioxide and water, but the important part is that the reaction releases energy, making it exothermic. The carbon dioxide and water are simply breathed out (which is why you can fog a window with your breath), and the important energy is used by the cells for a variety of processes.

Where does the energy to power our cells come from?

Figure 4.12
Your breath will fog a window because your breath contains water, a by-product of respiration.

❷ Photosynthesis is how plants grow

The exact opposite equation of respiration is **photosynthesis**. Photosynthesis is an endothermic reaction, meaning that it requires energy to work. It occurs in the chloroplasts in plant cells.

Carbon dioxide + water + ENERGY → oxygen + glucose

Plants get their energy from the light and heat of the sun. They take in carbon dioxide through little holes in their leaves called stomata, and water comes from the rain or other sources. The products of the reaction are oxygen, which is not used by the plant, and glucose either fuels the respiration of the plant cells or is stored until it is needed later.

Where do plants get their energy from?

❸ Complementary reactions

As you can see, the equations for photosynthesis and respiration are opposites. The reactants of one are the products of the other. It is a beautiful balance – the oxygen needed for respiration is largely created by photosynthesis, and the carbon dioxide needed for photosynthesis is largely created by respiration. It is worth remembering that both plants and animals (as well as all other living organisms) need energy and so respire. Animals require food for this purpose, whereas plants will make their own food during photosynthesis.

What sort of organisms respire?

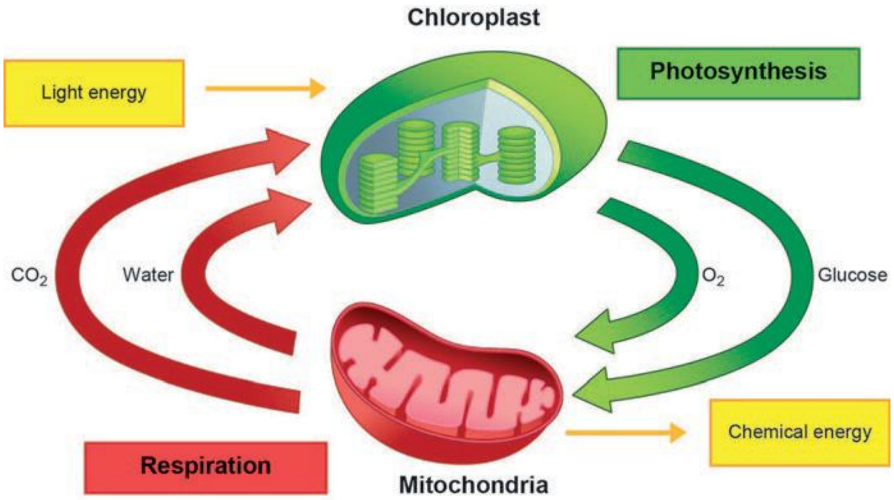


Figure 4.13 Photosynthesis and respiration are complementary reactions, because the reactants of one are the products of the other.

CHECKPOINT 4.6

1 Define these terms in your own words.
  a Respiration
  b Combustion
2 Identify the vital ingredient required for combustion to occur.
3 Explain the purpose of photosynthesis.
4 True or false? Combustion and respiration are both exothermic.
5 What do you think would happen to the animals on Earth if all of the plants died? Explain your answer.
6 What are the waste products of respiration? How do they relate to photosynthesis?
7 Where does the energy needed to start respiration come from?
8 Draw a Venn diagram to illustrate the similarities and differences between photosynthesis and combustion.

RESEARCH

9 Research cellular respiration. Write a half-page report, using the following prompts.
  - Where does it take place?
  - Which organisms and types of cells use cellular respiration?
  - What is the chemical equation for respiration?

SUCCESS CRITERIA

- I can explain what respiration and photosynthesis are and give the equations of both.

4.7 CORROSION AND DECOMPOSITION

LEARNING INTENTION

At the end of this lesson I will be able to describe corrosion and decomposition as chemical reactions that involve energy transfer.

KEY TERMS

alloy
a mixture of two or more metals

degrade
to wear down a substance

LITERACY LINK

WRITING

Write a short guide for boat owners showing the different ways to prevent their boats from rusting.

NUMERACY LINK

CALCULATION

A scientist analysed an 8.5 g piece of metal and recorded that there was 3.4 g of iron oxide (rust) on it. Calculate the percentage of the metal that had rusted.

Figure 4.14 The iron in this old car has corroded to produce orange-brown rust.

Corrosion is a natural process. It is the gradual **degradation** of metals by chemical reactions with their environment. When metals react with oxygen, compounds form on the surface of metals. The oxygen can be in the air, water or salt water. Most metals corrode, some faster than others. Corrosion affects the properties of a metal structure, such as its strength and appearance.

1 Iron corrodes to create rust

Rusting is the corrosion of iron. The scientific name for rust is iron oxide (Fe_2O_3), and it forms so easily that pure iron is rarely found in nature. Rust forms as a flaky red-brown solid on iron structures. For rusting of iron to occur, you need water and oxygen:

$$\text{Iron} + \text{oxygen} \rightarrow \text{iron oxide}$$
$$4Fe + 3O_2 \rightarrow 2Fe_2O_3$$

Rust causes a lot of damage to buildings, cars and ships because it does not form a protective layer on the metal's surface. Water can get through to the metal underneath, leading to corrosion. Little bits of rust flake off, leaving the rest of the metal exposed to oxygen. Eventually all of the metal corrodes.

Corrosion and combustion reactions are very similar. They are both oxidation reactions, involving oxygen, and they both give off heat. However, combustion is a fast reaction that gives off a lot of heat, while corrosion may take years and gives off very small amounts of heat.

How is corrosion different from combustion?

2 Corrosion can be prevented in various ways

To prevent corrosion, you need a barrier between the metal surface and the water and oxygen. Some ways to prevent corrosion are:

- painting the metal
- coating the metal with plastic
- coating iron with a protective layer of zinc – galvanising
- coating the metal with another metal – electroplating
- attaching the metal to a more reactive metal, which will be 'sacrificed', leaving the less reactive metal intact – sacrificial protection
- forming an **alloy**, which is a substance made up of two or more metals that is often stronger and more resistant to corrosion. For example, stainless steel is an alloy of iron and chromium or nickel. Stainless steel is slower to corrode than iron, which is why it is used to make pots, pans and utensils
- use passivating metals, which are metals that form inactive surface layers that prevent further corrosion. For example, aluminium reacts with oxygen in the air to form a protective coating of aluminium oxide (Al_2O_3), which acts as a barrier to prevent rust.

What are three ways in which iron can be prevented from rusting?

3 Decomposition reactions break down substances

In decomposition reactions, one substance breaks down into two or more simpler substances. Most decomposition reactions require energy to get them started.

Thermal decomposition is started by heat energy. This is an easy reaction to see in the laboratory, if you heat a reactive substance over a Bunsen burner. For example, if you heat copper carbonate, it decomposes into copper oxide and carbon dioxide gas:

Copper carbonate	→	copper oxide	+	carbon dioxide
$CuCO_3$	→	CuO	+	CO_2

The carbon dioxide released can be tested by bubbling it through limewater. The limewater should go milky in the presence of carbon dioxide.

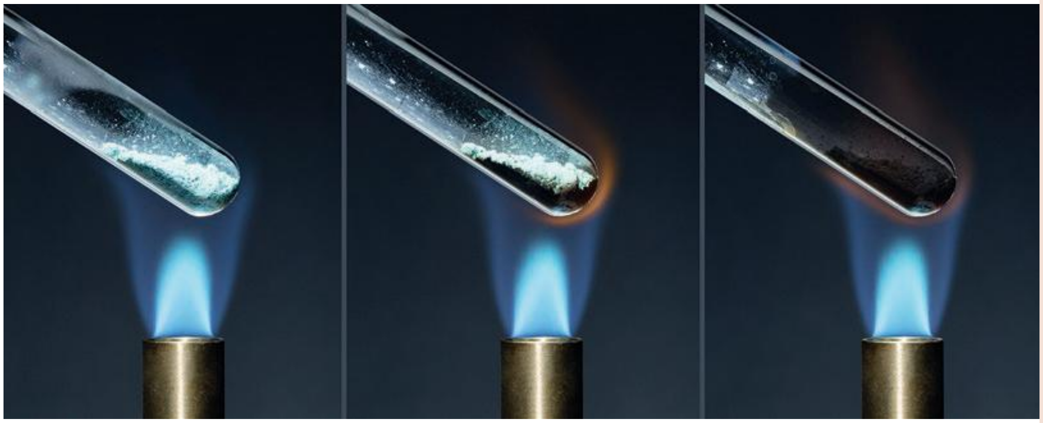


Figure 4.15 Heating a metal carbonate causes it to decompose and produce the metal oxide and carbon dioxide gas.

Electrical decomposition is better known as electrolysis. It is usually performed by passing an electrical current through a liquid reactant. For example, if you apply electricity to water, it decomposes into hydrogen and oxygen:

Water	→	hydrogen	+	oxygen
$2H_2O$	→	$2H_2$	+	O_2

Photochemical decomposition is triggered by light energy. This can often be a very slow reaction, so we don't notice it much in our everyday lives. For example, when silver chloride is exposed to light, it slowly decomposes into silver and chlorine ions:

Silver chloride	→	silver ions	+	chlorine ions
$AgCl$	→	Ag^+	+	Cl^-

What is corrosion?

INVESTIGATION 4.7A

Corrosion of iron

KEY SKILL
Drawing conclusions consistent with evidence

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INVESTIGATION 4.7B

Preventing corrosion

KEY SKILL
Identifying limitations to the method and suggesting improvements

▶ *Go to page **169***

CHECKPOINT 4.7

1 What is corrosion?
2 When is corrosion also known as rusting?
3 What is necessary for rusting to occur?
4 List two methods of preventing corrosion.
5 List three types of decomposition reaction.
6 Give an example for each type of decomposition reaction you listed in question 5 and write the word equation for each.
7 Explain what a passivating metal is and give an example of one.
8 Explain what happens when water undergoes electrolysis.

CONNECTING IDEAS

9 You are given four items – a gold coin, an iron nail, a piece of copper plate and some aluminium foil. Which do you think will corrode faster and why? Write a method to test your hypothesis.

SUCCESS CRITERIA

- I can explain what corrosion and decomposition reactions are and give some examples of each.

4.8 PRECIPITATION REACTIONS

LEARNING INTENTION

At the end of this lesson I will be able to describe precipitation as a chemical reaction that involves energy transfer.

KEY TERMS

dissociate
to split apart into ions

insoluble
unable to be dissolved

ionic compound
a compound made up of metal and non-metal ions

precipitate
an insoluble product

LITERACY LINK

VOCABULARY

Identify some other words you could use instead of *soluble*, *precipitate* and *reaction*.

NUMERACY LINK

DATA

Anu conducted a precipitation reaction four times and measured the quantity of lead iodide that formed. Her results were 0.234 g, 0.247 g, 0.238 g and 0.241 g. Calculate the average mass (in milligrams) of the lead iodide for this experiment. Why was the reaction conducted four times?

A precipitation reaction is a chemical reaction in which two liquids are combined to produce a solid (called a **precipitate**) floating in a liquid. These reactions will often involve colour changes and can be very visually striking. Precipitation reactions can be used to identify the presence of certain compounds or ions.

Figure 4.16 In a precipitation reaction, a solid is formed from the combination of two solutions.

1 Precipitates are solids formed from solutions

Regular table salt is made of sodium chloride: metal ions (sodium) and non-metal ions (chloride). There are many other salts that exist too – and like sodium chloride they always contain one metal and one non-metal. These are called ionic **compounds**.

When an ionic compound is placed in water, the water molecules pull the compound apart and it **dissociates** into its parts (ions). The ions are then free to form new compounds with other ions. When you mix two ionic compounds they sometimes form a solid **insoluble** substance called a precipitate. A precipitate is insoluble, which means it can't dissolve in water.

Consider what happens when solutions of potassium iodide and lead nitrate are combined, as shown in Figures 4.17 and 4.18. When these ions are mixed together, a precipitation reaction occurs, and the insoluble lead and iodide ions combine to form a solid. This produces a solution of potassium nitrate, with a precipitate of insoluble yellow lead iodide floating in it.

Potassium iodide	+	lead nitrate	→	lead iodide	+	potassium nitrate
$2KI$	+	$Pb(NO_3)_2$	→	PbI_2	+	$2KNO_3$

What are precipitation reactions?

Figure 4.17 When a solution of potassium iodide is added to a solution of lead nitrate, a yellow precipitate of lead iodide is formed.

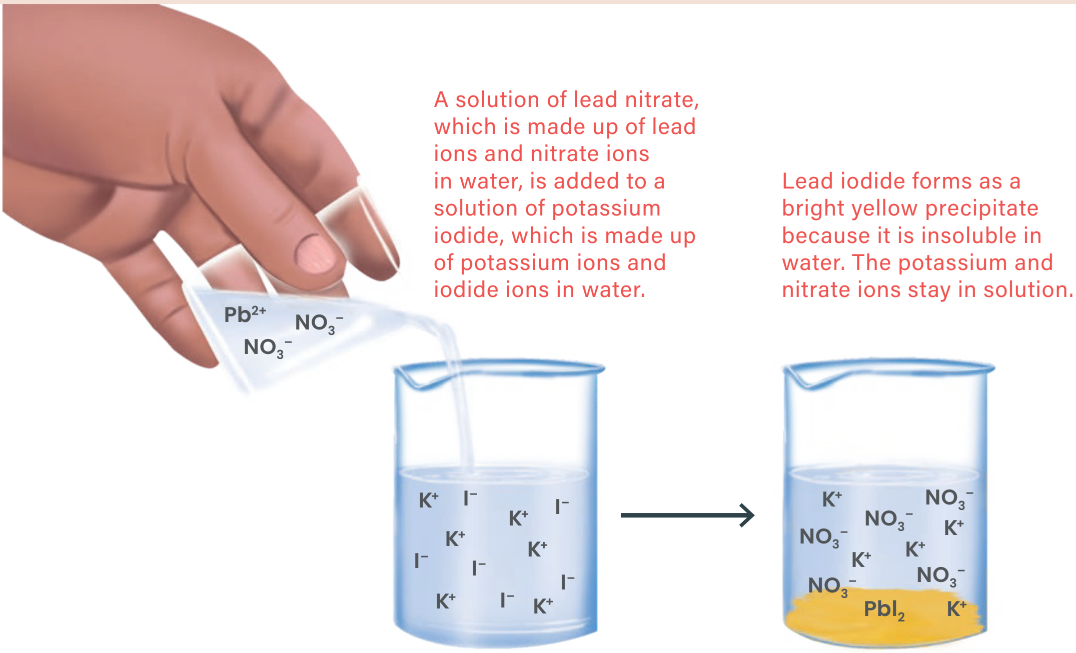


Figure 4.18 The lead and iodide ions combine to form a solid, while the potassium and nitrate ions stay in solution.

2 Solubility rules help to identify precipitates

If a reaction produces a precipitate, you may want to identify it. You can use solubility rules to help identify a precipitate. The solubility rules are a list of rules for ionic compounds that tell you whether certain ions will form precipitates with other ions or stay in solution. Table 4.2 is a list of solubility rules. As well as these rules, all salts containing group 1 metals and all ammonium (NH_4^+) salts are soluble and do not form precipitates.

For example, the rules tell you that in the previous reaction of potassium iodide with lead nitrate, all nitrates are soluble but lead iodide is insoluble. This helps identify the yellow precipitate as lead iodide. Similarly, you can see that sodium chloride (table salt) is soluble but silver chloride is not soluble.

Table 4.2 The solubility rules

Ions	Solubility
Nitrates (NO_3^-)	All soluble
Chlorides (Cl^-)	All soluble except for AgCl, $PbCl_2$ and $HgCl_2$
Iodides (I^-)	All soluble except for AgI, PbI_2 and HgI_2
Sulfates (SO_4^{2-})	All soluble except for $PbSO_4$, $CaSO_4$ and $BaSO_4$
Carbonates (CO_3^{2-})	All insoluble except for group 1 carbonates (e.g. Na_2CO_3, K_2CO_3) and $(NH_4)_2CO_3$
Hydroxides (OH^-)	All insoluble, except for group 1 hydroxides (e.g. NaOH, KOH), $Ca(OH)_2$, $Ba(OH)_2$ and NH_4OH

What is an example of a solubility rule?

INVESTIGATION 4.8

Precipitation reactions

KEY SKILL
Identifying the independent, dependent and controlled variables

▶ *Go to page* ***170***

CHECKPOINT 4.8

1 What is a precipitation reaction?

2 How can you tell if a precipitation reaction occurs?

3 How would you describe potassium iodide and lead nitrate solutions?

4 State whether each of the following salts would be soluble or insoluble.
  a $Pb(NO_3)_2$
  b K_2SO_4
  c LiOH
  d $CuCO_3$

5 True or false? All nitrates and solutions of group 1 compounds are soluble.

EXTENSION

6 What would be the precipitate formed in the following reactions?
  a $NaCl + AgNO_3 \rightarrow NaNO_3 + AgCl$
  b $BaCl_2 + K_2SO_4 \rightarrow BaSO_4 + 2KCl$
  c $FeI_2 + 2KOH \rightarrow 2KI + Fe(OH)_2$

SUCCESS CRITERIA

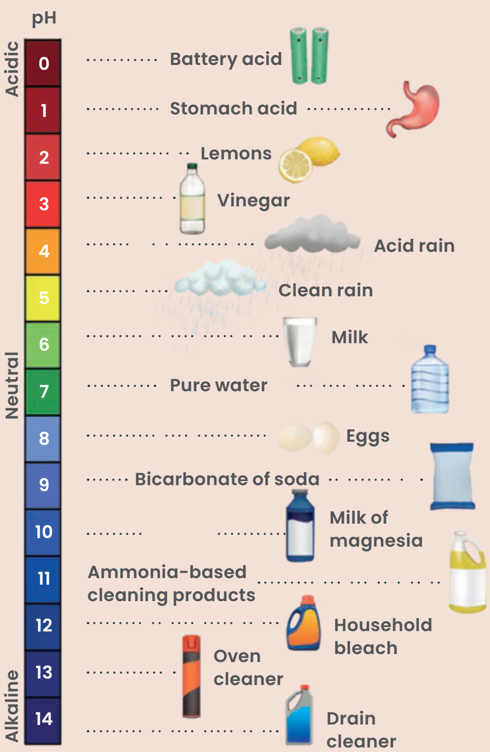
- I can explain what a precipitate is and how they are formed.
- I can use the solubility table to predict which compounds form a precipitate.

VISUAL SUMMARY

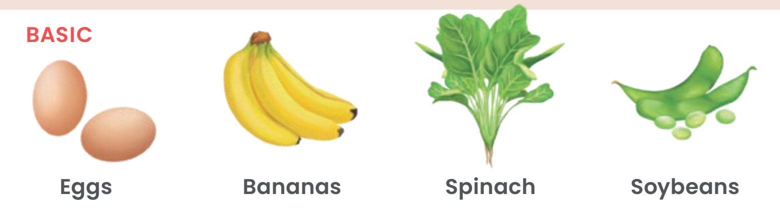
Exothermic reactions release heat. Endothermic reactions absorb heat.

Combustion and respiration are exothermic reactions that release energy.

The pH scale measures acidity.



Two common groups of chemical compounds are acids and bases.



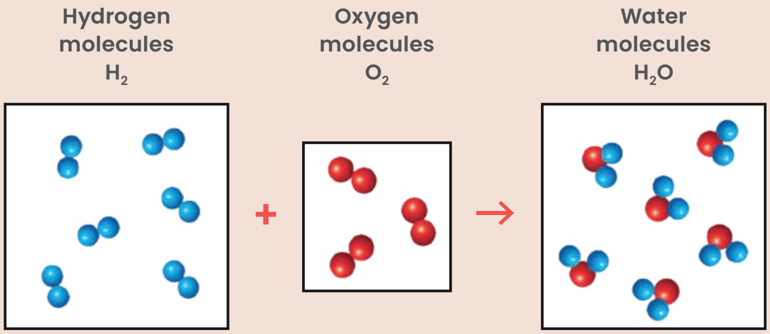
Corrosion is the degradation of metals when they bond with oxygen.

Precipitation reactions create a solid precipitate from two mixed salt solutions.

Combustion reactions occur rapidly to release heat and light.

Incomplete combustions are a result of limited oxygen supply.

The number of reactant atoms must equal the number of product atoms.



★ FINAL CHALLENGE ★

1. Explain the difference between exothermic and endothermic reactions.
2. Draw and annotate the pH scale.
3. Suggest why corrosion occurs and how to prevent it.

Level 1 ★☆☆ ☆☆☆ 50xp

LEVEL UP!

4. Where does respiration occur and why is it important?
5. Identify the products and reactants in the following chemical reaction:

   $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

6. How many carbon, hydrogen and oxygen atoms can be found in the products and reactants of the reaction in question 5?

Level 2 ★★☆ ☆☆☆ 100xp

LEVEL UP!

7. Explain the following statement.
   Photosynthesis and respiration are complementary reactions.
8. What is a decomposition reaction?
9. What are precipitates and how are they formed?

Level 3 ★★★ ☆☆☆ 150xp

LEVEL UP!

10. Would you be able to light a match in space? Explain why or why not. (Hint: What sort of reaction is lighting a match? What does this type of reaction need?)
11. Describe what a combustion reaction is and what the products of combustion are.
12. Explain how neutralisation reactions work and give an example using a chemical equation.

Level 4 ★★★ ★☆☆ 200xp

LEVEL UP!

13. Describe what happens to the chemical bonds in molecules during a chemical reaction.
14. Give an example of an important chemical reaction that takes place in the body. Describe the reaction and suggest why it is so important.

Level 5 ★★★ ★★★ 300xp

LEVEL UP!

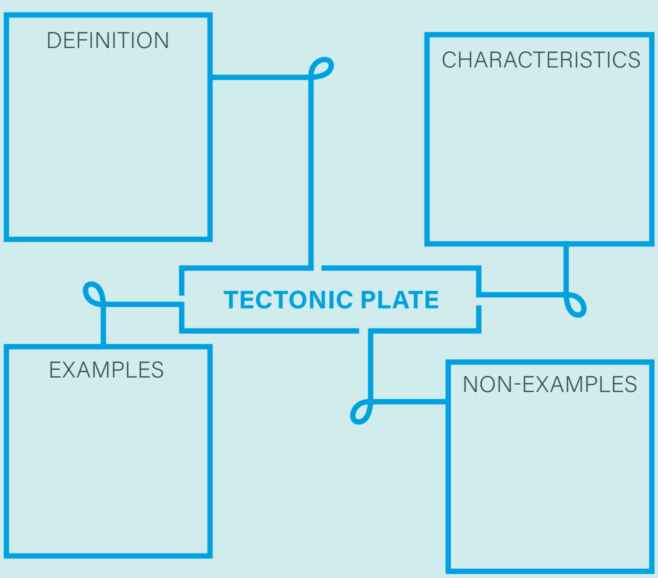
5 PLATE TECTONICS

Do we have any control over major changes to the surface of Earth?

The theory of plate tectonics explains how Earth functions from a geological point of view. This one theory accounts for why mountain ranges have formed where they are, why volcanoes erupt, why earthquakes occur, why we observe certain patterns in the fossil record and why animals and plants on one continent can be related to those on the other side of the planet.

1 FRAYER MODEL

Copy and complete the below chart in your workbook.



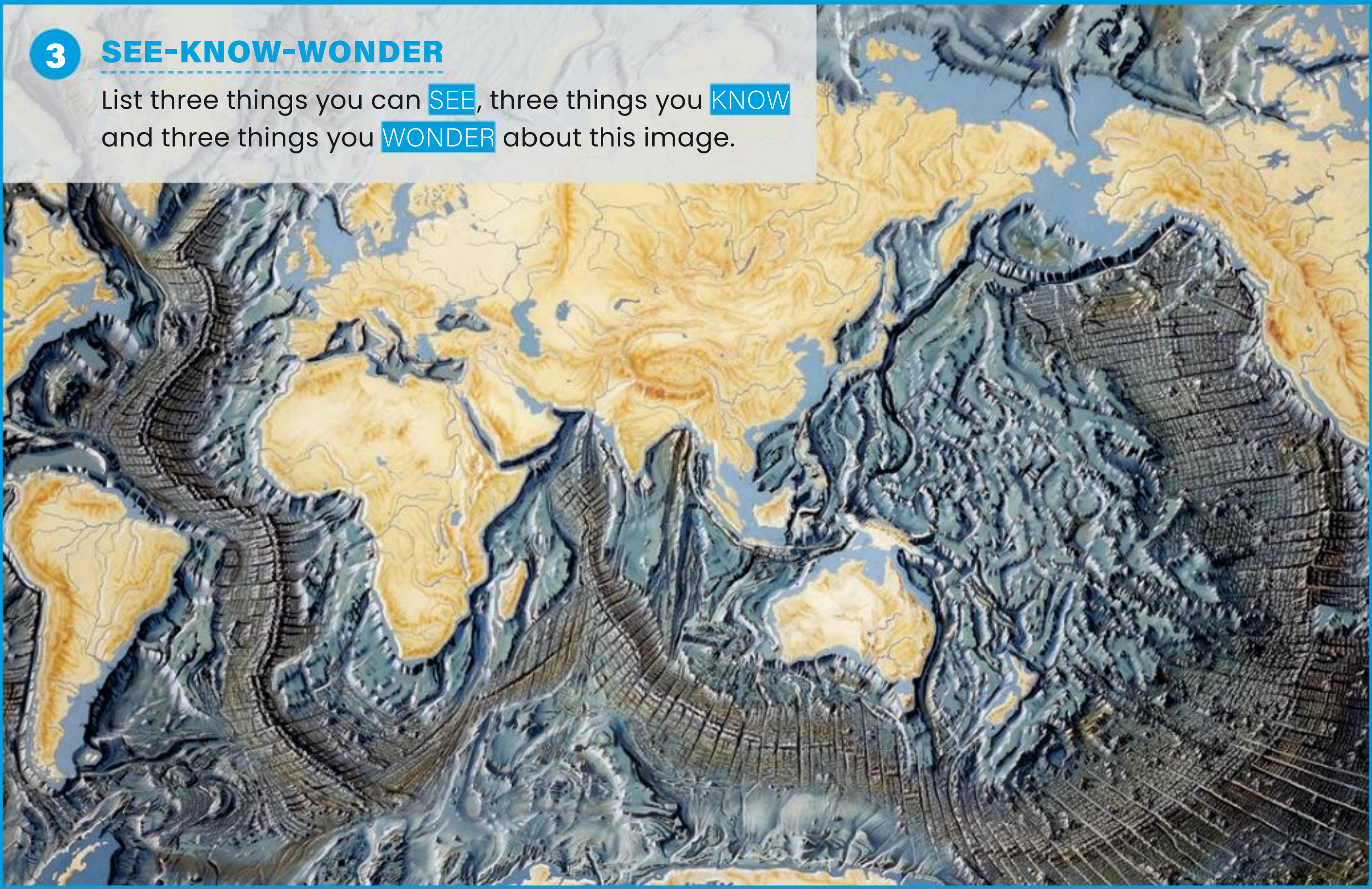
Complete two additional charts for the key terms *Continents* and *Lithosphere*.

2 LEARNING LINKS

Brainstorm everything you already know about plate tectonics.

3 SEE-KNOW-WONDER

List three things you can SEE, three things you KNOW and three things you WONDER about this image.



4 CRITICAL + CREATIVE THINKING

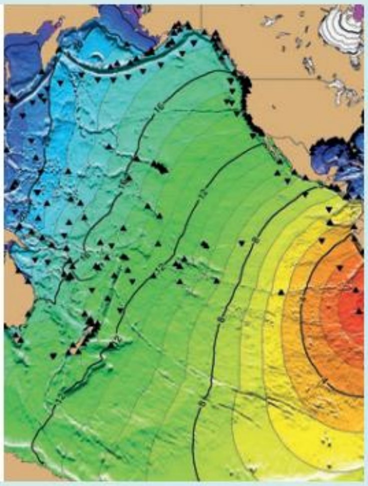
WHAT IF ... earthquakes hit Victoria every day?

FIVE QUESTIONS: Write five questions that have the answer 'plate'.

PREDICTION: What will the surface of Earth look like in 250 million years?

5 THE BIGGEST!

The most powerful earthquake ever recorded was the 1960 earthquake in Valdivia, Chile, which geologists think measured 9.5 on the moment magnitude scale. The energy released was large enough to shift Earth's axis and shorten the length of a day by 1.26 microseconds. The earthquake also caused a tsunami that hit the coastline of Chile and travelled across the Pacific Ocean at more than 300 km/h. The tsunami killed people in Hawaii, Japan and the Philippines, and damaged infrastructure in many other countries.



5.1 EVIDENCE FOR PLATE TECTONICS

LEARNING INTENTION

At the end of this lesson I will be able to outline how the theory of plate tectonics was developed over time based on evidence.

KEY TERMS

asthenosphere
the portion of Earth's mantle underneath the lithosphere that can flow

continental drift
the theory that the continents have moved position over time

lithosphere
Earth's rigid outer zone (crust and uppermost part of the mantle), made up of tectonic plates

tectonic plate
a section of Earth's lithosphere

LITERACY LINK

WRITING

Write a status update or tweet from Alfred Wegener that summarises the evidence for his theory of continental drift.

NUMERACY LINK

MEASUREMENT

The diameter of Earth is 12 742 km. If Figure 5.1 were to scale, what would be the actual thicknesses of the crust, asthenosphere, and outer core?

Hint: You will need a ruler to help you.

The theory of plate tectonics states that Earth's outer layer – the **lithosphere** – is divided into more than 15 massive pieces called **tectonic plates**. These plates move around on the **asthenosphere** (part of the upper mantle), interacting at boundaries, shifting the continents and producing new landforms.

For a long time, people thought that the continents were in the same place as when Earth first formed. However, evidence gathered in the first half of the 20th century indicated that the continents are moving.

1 The continents move over time

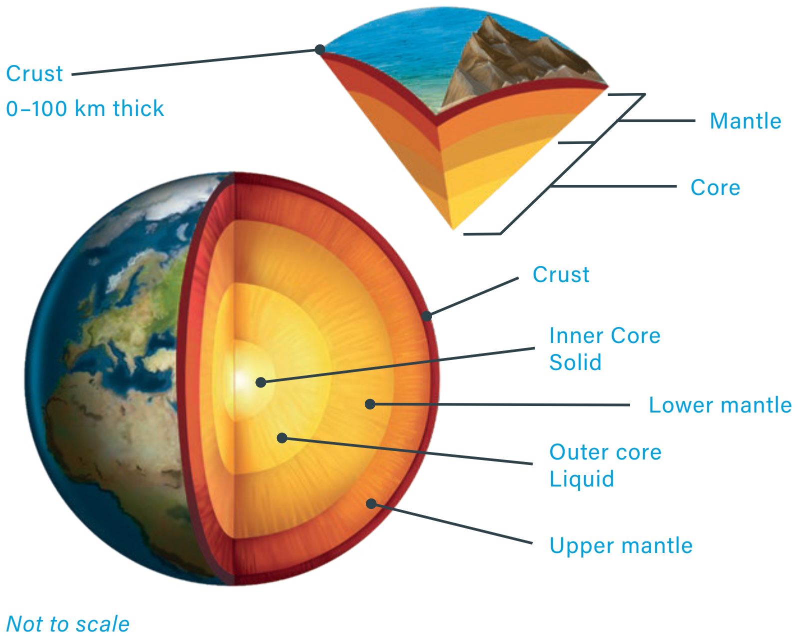


Figure 5.1 The lithosphere comprises the crust and uppermost part of the mantle, which moves around on the liquid asthenophere.

In 1912, German meteorologist Alfred Wegener published his theory on **continental drift**. He proposed that the continents had once been joined in one large landmass that he called Pangaea. Over time, this landmass split apart and the continents moved to their current positions.

Wegener found evidence for past glacial climates in equatorial Africa and tropical climates in northwestern Europe. The only way to explain this was that the continents had moved.

Further evidence to support Wegener's theory includes:

- how the continental shelves of continents fit together like pieces of a jigsaw
- identical rock formations on either side of the Atlantic Ocean
- identical plant and animal fossils on different continents separated by oceans.

Figure 5.2 Wegener proposed that the continents had once been joined in one large landmass called Pangaea. Over time, the continents split into two supercontinents (Gondwana and Laurasia) and then into the continents of today.

INVESTIGATION 5.1

Modelling seafloor spreading

KEY SKILL

Referencing sources of information

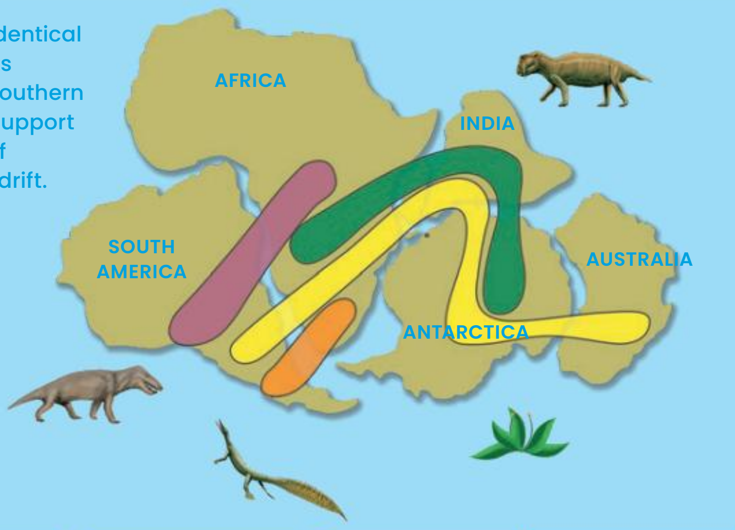
▶ *Go to page **172***

Wegener reasoned that it was unlikely that identical rocks would have formed and identical species would have evolved so far apart. Therefore, the continents must have once been joined together and drifted apart over time to their current positions.

Wegener could not suggest how the continents moved, and so his theory was not supported by most of the scientific community. He continually refined and published his ideas as new evidence came to light. Modern geologists accept his theory as correct.

What three pieces of evidence support Wegener's theory of continental drift?

Figure 5.3 Identical fossil records across the southern continents support the theory of continental drift.



Fossil evidence of freshwater reptile Mesosaurus has been found in Brazil and Africa.	Fossil evidence of the land reptile *Lystrosaurus* has been found in Africa, Antarctica and India.	Fossils of the fern *Glossopteris* have been found in all southern continents.	Fossil evidence of land reptile *Cynognathus* has been found in Argentina and southern Africa.

5.1 continued ...

... 5.1 continued

EVIDENCE FOR PLATE TECTONICS

KEY TERMS

mantle
Earth's middle layer, made up of two layers

mid-ocean ridge
a long chain of mountains under the ocean formed by plate tectonics

rift valley
a valley formed when a continent is being pulled apart

subduction
when one tectonic plate moves underneath another

2 The sea floor is spreading apart

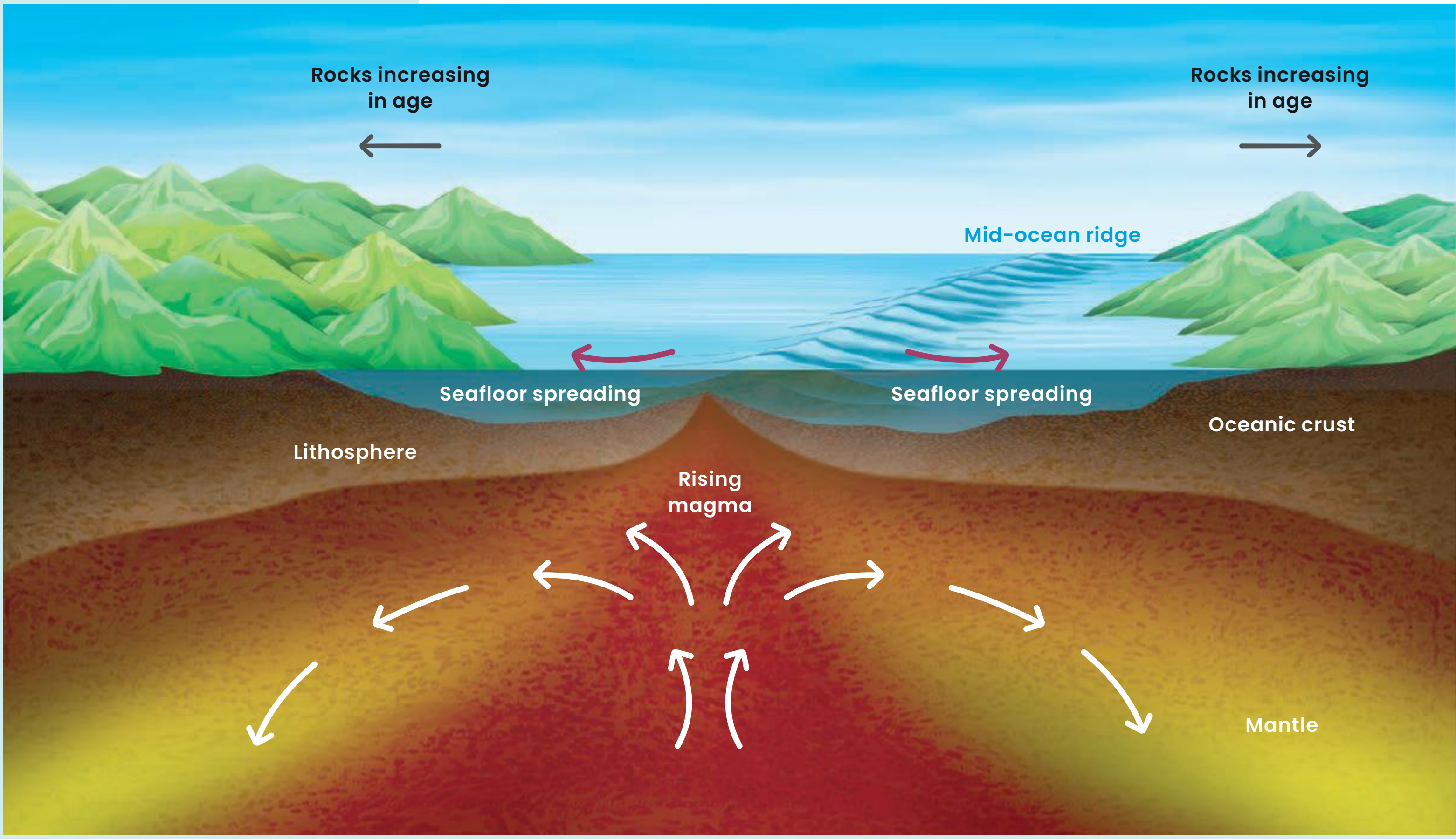
Seafloor spreading happens when molten rock rises up from the **mantle** at the **mid-ocean ridges** and solidifies to form new oceanic lithosphere.

There are four major pieces of evidence to show that the sea floor is spreading.

- *Rift valleys along mid-ocean ridges*: In 1952, US geologist Marie Tharp found that there was a V-shaped valley running along the bottom of the Atlantic Ocean. This **rift valley** is where the new lithosphere is formed.
- *Magnetic striping*: As lava cools, the magnetic minerals in it align with Earth's magnetic poles, just like a compass needle does. The positions of the magnetic poles have changed over time, even reversed, and so in rocks formed at different times, the minerals are aligned differently.
- *Depth of sediments*: The depth of sediments on the oceanic crust are deeper closer to the continents. This implies that those rocks are older because there has been more time for the sediment to accumulate.
- *Age of the sea floor*: Radiometric dating shows that the oceanic crust closer to the continents is much older than the rock closer to the mid-ocean ridges.

What is a rift valley?

Figure 5.4 Molten rock rises up from the mantle at the mid-ocean ridges and solidifies to form new oceanic lithosphere.



3 Old lithosphere is subducted

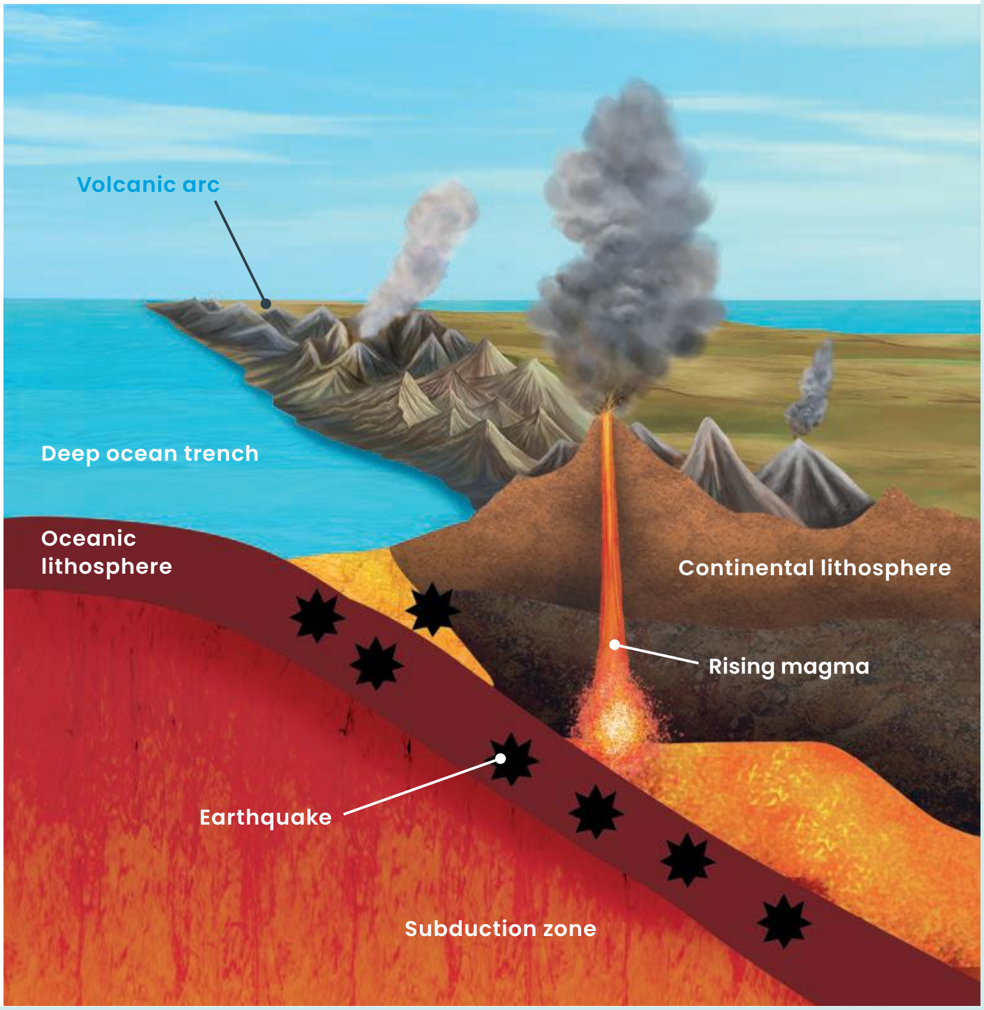
If new lithosphere is being formed at mid-ocean ridges, why isn't Earth getting larger? Scientists discovered that this is because of **subduction** – where the edge of one tectonic plate is pushed under the one next to it.

Geologists use three main pieces of evidence to show that the lithosphere is being subducted.

- *Ocean trenches*: Seafloor mapping shows the existence of deep ocean trenches. We now know this is where two tectonic plates are colliding.
- *Earthquake locations*: Earthquakes get deeper further away from ocean trenches. This is evidence that one plate is moving down under the other. Regions where this happens are called Wadati–Benioff zones, after the scientists who discovered them.
- *Volcano chains above such zones*: The formation of chains of volcanoes above a Wadati–Benioff zone shows that one plate is moving under another. When a plate subducts, the subducting lithosphere starts to melt and the molten rock rises to the surface to form volcanoes.

What is subduction?

Figure 5.5 Denser crust subducts underneath less-dense crust. This forms a deep ocean trench, causes deep earthquakes and forms a chain of volcanoes.



CHECKPOINT 5.1

1 Copy and complete.
The theory of ______ ________ states that Earth's continents were once ________ together and moved ________ over time.

2 Outline why the discovery of seafloor spreading was important for the development of the theory of plate tectonics.

3 The discovery of subduction was important for the development of plate tectonics. Suggest why.

4 Explain why Wegener's theory of continental drift was not supported by the scientific community.

5 If plate tectonics did not exist and the continents had not moved, what would Wegener have observed in the geological record instead? How would this have been different from what he actually observed?

RESEARCH

6 Research and learn more about Wegener, Tharp, Harry Hess or John Tuzo Wilson. Find out about their contribution, why it was important for our understanding of Earth and any challenges they faced.

SUCCESS CRITERIA

- I can explain the theory of plate tectonics.
- I can explain some of the evidence that was used to support the theory of plate tectonics.

5.2 PLATE BOUNDARIES

LEARNING INTENTION

At the end of this lesson I will be able to recognise the major plates on a world map and describe how tectonic plates interact with each other.

KEY TERMS

convergent boundary
where two tectonic plates are moving towards each other, also referred to as a destructive boundary

divergent boundary
where two tectonic plates are moving away from each other, also referred to as a constructive boundary

fault
a break in Earth's surface where blocks of rock slide past each other

fold mountain
a mountain formed by the folding of continental crust when tectonic plates collide

transform boundary
where two tectonic plates are sliding past one another

LITERACY LINK

VOCABULARY

Convergent boundaries are often called destructive, divergent are called constructive and transform are called conservative. Can you think of any other adjectives to describe how the plates are moving at the three different boundary types?

As tectonic plates move on the flowing, semi-molten asthenosphere, they slowly transform Earth's surface. Violent geological changes can occur when plates collide, move apart or grind past each other.

Figure 5.6 The major tectonic plates and their boundaries

1 Divergent boundaries are where plates move apart

Divergent boundaries exist where two plates are moving away from each other. Magma rises up in the gap between the two plates and solidifies to form new lithosphere.

When this happens between two oceanic plates, it forms a mid-ocean ridge. When this happens on a continent, it forms a rift valley and volcanoes. A divergent boundary is sometimes referred to as a constructive boundary because new lithosphere is being made.

In what direction do plates move at a divergent boundary?

2 Convergent boundaries are where plates collide

Convergent boundaries are where two plates are moving towards each other and colliding. A convergent boundary is sometimes referred to as a destructive boundary because the lithosphere is destroyed.

If two continental plates collide, the crust buckles and pushes together to form **fold mountains**.

In what direction do the plates move at a convergent boundary?

3 Transform boundaries are where two plates slide past each other

Transform boundaries are where two plates slide past each other. This causes a break in Earth's surface called a **fault**. As the plates slowly move, they cause earthquakes.

Transform boundaries are also called conservative boundaries because lithosphere is neither created nor destroyed.

The San Andreas Fault near San Francisco in the USA is the most famous transform fault. It has caused many destructive earthquakes.

In what direction do tectonic plates move at a transform boundary?

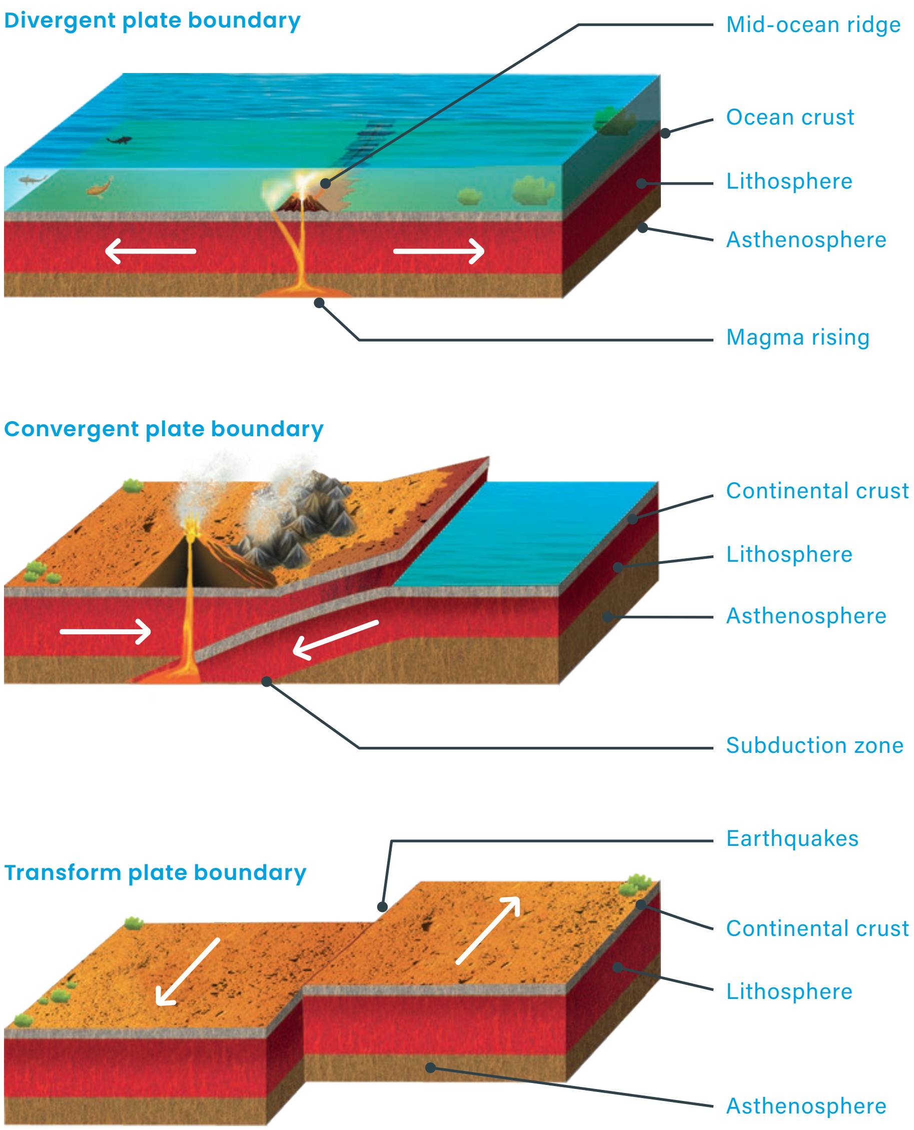


Figure 5.7 At a divergent boundary, two plates move apart. At a convergent boundary, two plates collide and the denser plate subducts. At a transform plate boundary, two plates slide past each other.

INVESTIGATION 5.2

Modelling plate boundaries

KEY SKILL
Identifying and managing relevant risks

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CHECKPOINT 5.2

1 Describe subduction.

2 A convergent boundary is sometimes called a destructive boundary. Explain why.

3 Draw a diagram to illustrate what you would expect to occur in these situations.
   a Plate A is moving towards plate B. Plate A is denser than plate B.
   b Plates C and D are both continental plates. They are moving towards each other.

4 The African continent is beginning to split apart along the East African Rift Valley. What type of crust would you expect to be forming in the rift? Justify your response.

5 What type of plate boundaries are needed to:
   a bring continents together?
   b break continents apart?

CONNECTING IDEAS

6 The Australian and Pacific plates interact in New Zealand. Explain why active volcanoes are found on the North Island, while a long mountain range is found on the South Island.

SUCCESS CRITERIA

- I can describe the three types of movement that can happen at tectonic plate boundaries.
- I can describe how tectonic plates interact.
- I can recognise the major tectonic plates on a map.

5.3 WHAT CAUSES THE PLATES TO MOVE?

LEARNING INTENTION

At the end of this lesson I will be able to describe the forces that move tectonic plates, including the roles of heat energy and convection currents.

KEY TERMS

convection
the transfer of heat by movement of a liquid or a gas

LITERACY LINK

SPEAKING

After reading this lesson, explain the process of convection to a partner, then listen to their explanation.

NUMERACY LINK

DATA

Density is a physical property determined by the amount of mass in a given volume. The density of metals is greater than non-metals. If the amount of iron is doubled in the crust and the oxygen is decreased, how would the density of the crust be affected? How would the density of the crust change if silicon replaced the iron in the crust?

Most geologists currently think that three factors cause tectonic plates to move on top of the asthenosphere. Gravity is an important force, pulling subducting plates down into the mantle and pushing newly formed lithosphere along at mid-ocean ridges. Convection currents in the asthenosphere play a minor role as they bring hot rock up towards the crust. Most plates have a convergent boundary on one side and a divergent boundary on the other. These three factors work together to move the plates along like a conveyor belt.

1 Big plates can pull each other down

When a denser plate moves under another plate (subduction) at a convergent plate boundary, it will start to pull the rest of the plate along with it. This is known as slab pull.

Slab pull is thought to be the major cause of the movement of tectonic plates. As a subducting plate is cooler and denser than the warmer mantle, gravity causes it to sink towards Earth's core, pulling the rest of the plate along behind it. Plates with long subduction zones often move faster than plates with shorter subduction zones.

What is slab pull?

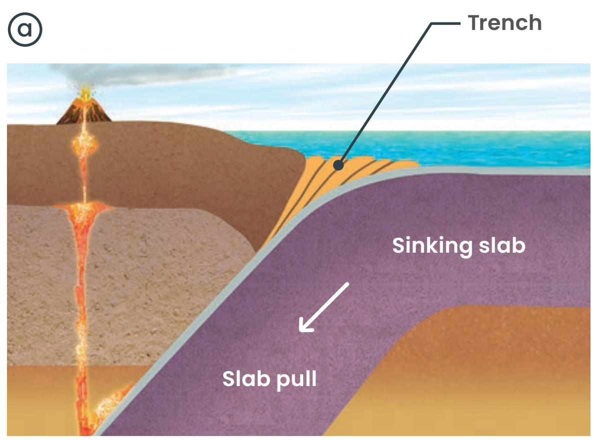
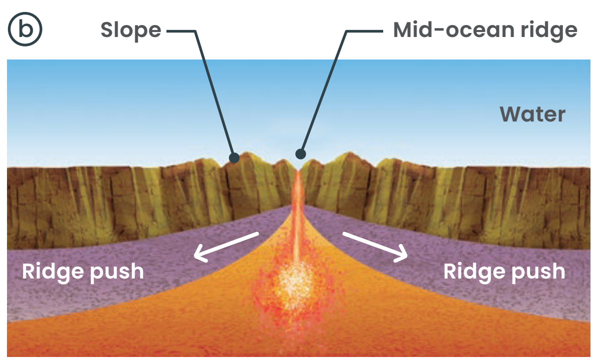


Figure 5.8
(a) Slab pull happens when the denser lithosphere slowly sinks underneath the less dense asthenosphere. This is like a rock slowly sinking in water.



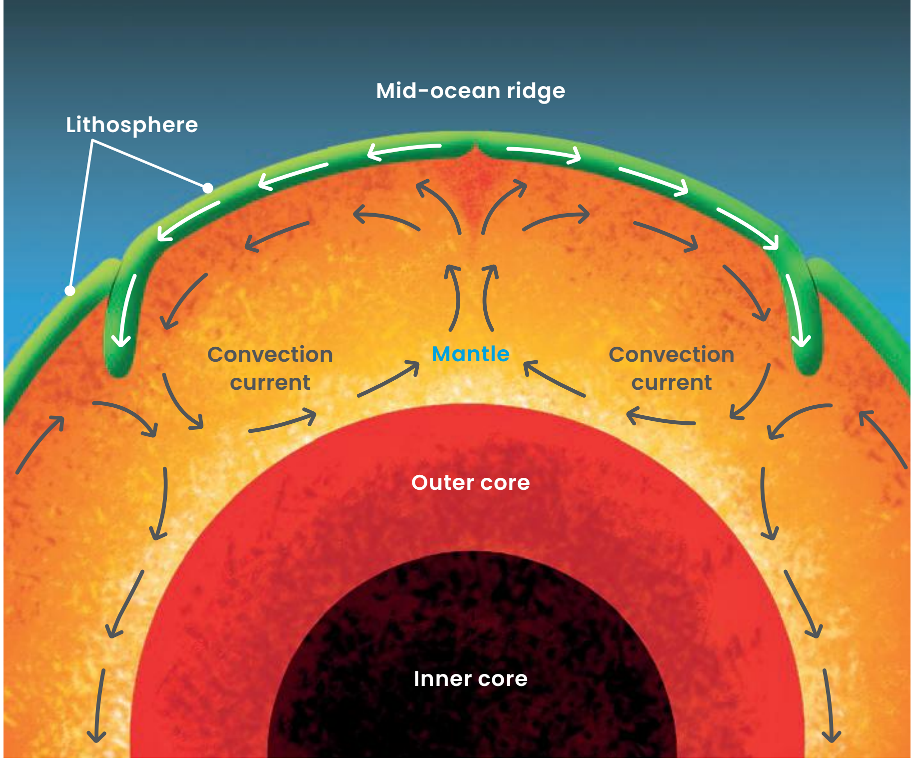
(b) Ridge push happens when the region of a rift is lifted up and the mass of the ridge pushes sideways. This is like a wedge of honey with a sloping surface.

2 Ridge push is caused by gravity

Ridge push happens at mid-ocean ridges. When magma rises up at a mid-ocean ridge, it forms new lithosphere. This new lithosphere sits higher than the old one and so gravity causes it to slide downhill, pushing the old lithosphere in front of it. This push helps to move the tectonic plate along, away from the mid-ocean ridge towards the subduction zone, similar to the movement of a conveyor belt.

Where does ridge push happen?

Figure 5.9 Convection currents form because the centre of Earth is hotter than the crust. The less dense hot material rises and the denser cool material falls down to the heat source.



3 Convection causes hot rock to rise and cooler rock to sink

Convection is a way of transferring heat. A convection current is the movement of material from a hot area to a cool area and back again.

In the mantle, rock in the asthenosphere moves slowly in convection currents formed by hot rock near the core rising up, cooling and falling back down again. This brings molten material up to the mid-ocean ridges. As the rock in the asthenosphere slowly moves, it drags the plate along like a conveyor belt moving out and away from the mid-ocean ridges towards the subduction zones.

What is a convection current?

INVESTIGATION 5.3A

Modelling slab pull

KEY SKILL
Writing a research question

▶ *Go to page **175***

INVESTIGATION 5.3B

Observing convection currents

KEY SKILL
Explaining results using scientific knowledge

▶ *Go to page **176***

CHECKPOINT 5.3

1 Copy and complete.
Tectonic plates are thought to be able to move around on the ________ due to three ________: ________ pull, ridge ________ and mantle ________.

2 Describe the forces that move plate tectonics.

3 Outline the difference between ridge push and mantle convection.

4 Explain how density is important for the movement of the tectonic plates.

CONNECTING IDEAS

5 Use the map of the tectonic plates in Figure 5.6 in lesson 5.2 to put these plates in order from longest subduction zone to smallest subduction zone.
- Australian Plate
- Nazca Plate
- Pacific Plate
- Philippine Sea Plate
- Arabian Plate

SUCCESS CRITERIA

- I can describe how tectonic plates move
- I can explain the forces that move tectonic plates.

5.4 EARTHQUAKES

LEARNING INTENTION

At the end of this lesson I will be able to outline how earthquakes can be explained by the theory of plate tectonics.

KEY TERMS

epicentre
the point on Earth's surface directly above the focus of an earthquake

focus
the origin of an earthquake

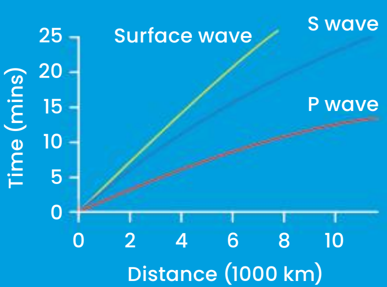
seismic wave
a wave of energy that passes through Earth's layers and is caused by an earthquake

seismometer
a scientific instrument that detects seismic waves

NUMERACY LINK

GRAPHING

How long would it take a P wave to travel from the epicentre to a location 6000 km away? How long for an S wave?



Earthquakes are caused by a build-up of pressure and the release of energy in Earth's crust. Most earthquakes happen along the boundaries of the tectonic plates, but they can also happen within a plate. A fault is the name given to a part of Earth's surface where blocks of rock slide past each other. Faults can be as large as a tectonic plate boundary or much smaller.

1 Earthquakes happen when tectonic plates move

Blocks of rocks don't slide smoothly past each other. They catch and lock together, almost like Velcro. As they catch, pressure builds up until the rock is forced to move, releasing energy. The energy passes through Earth as **seismic waves** that move and shake the crust. This is an earthquake.

The point where an earthquake starts is called the **focus**. This is where the pressure has built up and been released, often causing rocks to rupture (break) and move along the fault. The point on the surface directly above the focus is called the **epicentre**.

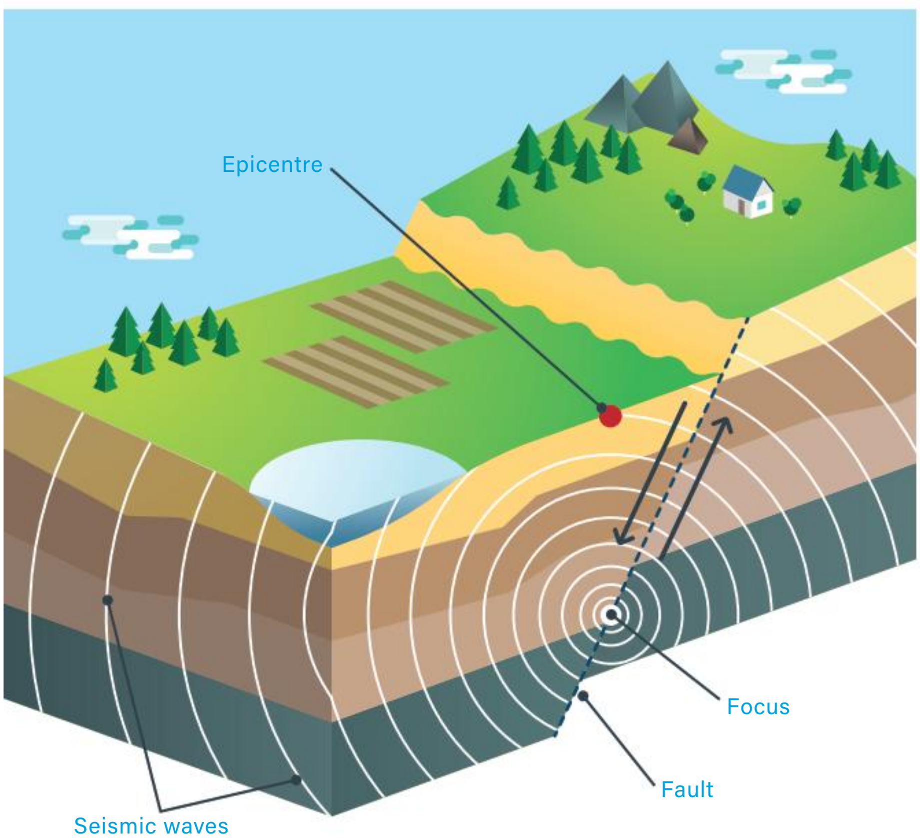


Figure 5.10 The focus is the point where an earthquake starts, and the epicentre is the point on the surface above it.

Epicentres are usually located along plate boundaries. This is because this is where most movement happens. Shallow earthquakes happen at divergent (constructive) boundaries as the plates move apart. Shallow earthquakes also happen at transform boundaries because the plates are sliding past each other. Most earthquakes occur at convergent (destructive) boundaries where plates collide. The deepest earthquakes happen at subduction zones because the subducting plate is moving down into the asthenosphere. Earthquakes that take place within plates are called intraplate earthquakes. Intraplate earthquakes happen along fault lines and are caused by the build-up of pressure within the plate.

What causes earthquakes?

INVESTIGATION 5.4
Slinky waves

KEY SKILL
Using modelling and simulations

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Plate movement relative to the African plate

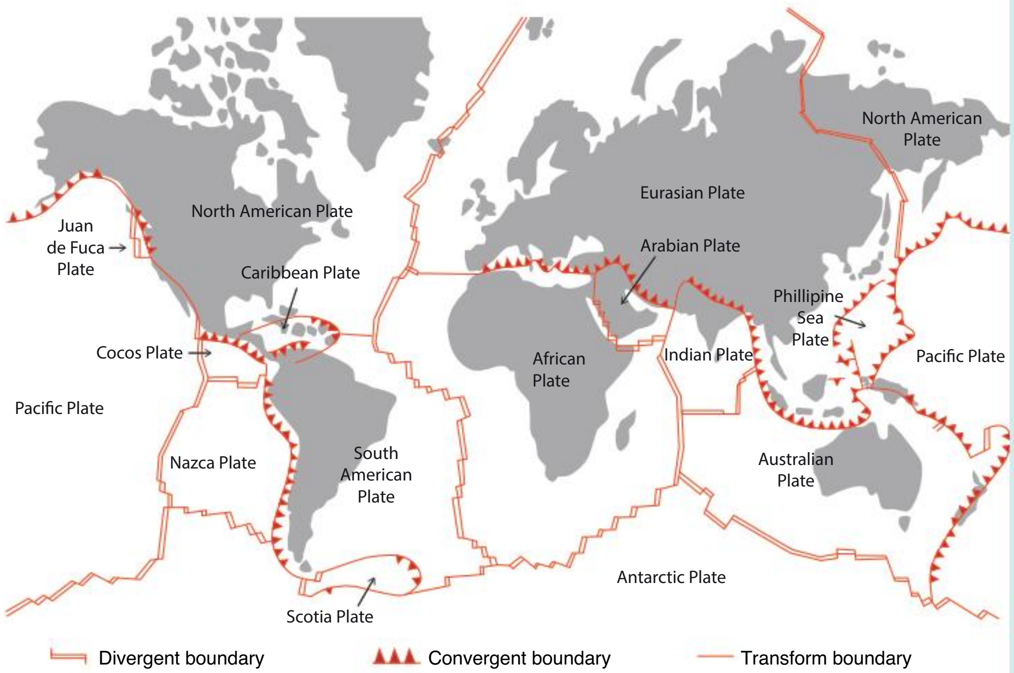


Figure 5.11 Most earthquake epicentres are located on plate boundaries and are caused by the movement of the plates.

2 Earthquakes produce seismic waves

Seismologists are scientists who study earthquakes. They use sensitive equipment called **seismometers** to measure how much and how often Earth's outer layers move as a result of a seismic wave.

There are two main types of seismic wave. Body waves travel through Earth and surface waves travel around Earth's surface.

There are two main types of body wave – primary (P) waves and secondary (S) waves. Primary waves travel faster and are longitudinal waves. Secondary waves are transverse waves.

There are also two types of surface waves, known as Rayleigh and Love waves. They can move across the surface in all directions, like a rolling ocean wave. These waves travel slower than P and S waves, but their surface motion causes more destruction.

What are the two main types of seismic wave?

5.4 continued ...

... 5.4 continued

EARTHQUAKES

KEY TERMS

intensity
a measure of the amount of destruction caused by an earthquake

magnitude
a measure of the energy released by an earthquake

moment magnitude scale
a logarithmic scale used to compare the amount of energy released by earthquakes

LITERACY LINK

LISTENING

Read section 3 aloud to a partner, then ask each other true-or-false questions about what you read.

Figure 5.13 This road near Christchurch in New Zealand was damaged by a magnitude 7.1 earthquake.

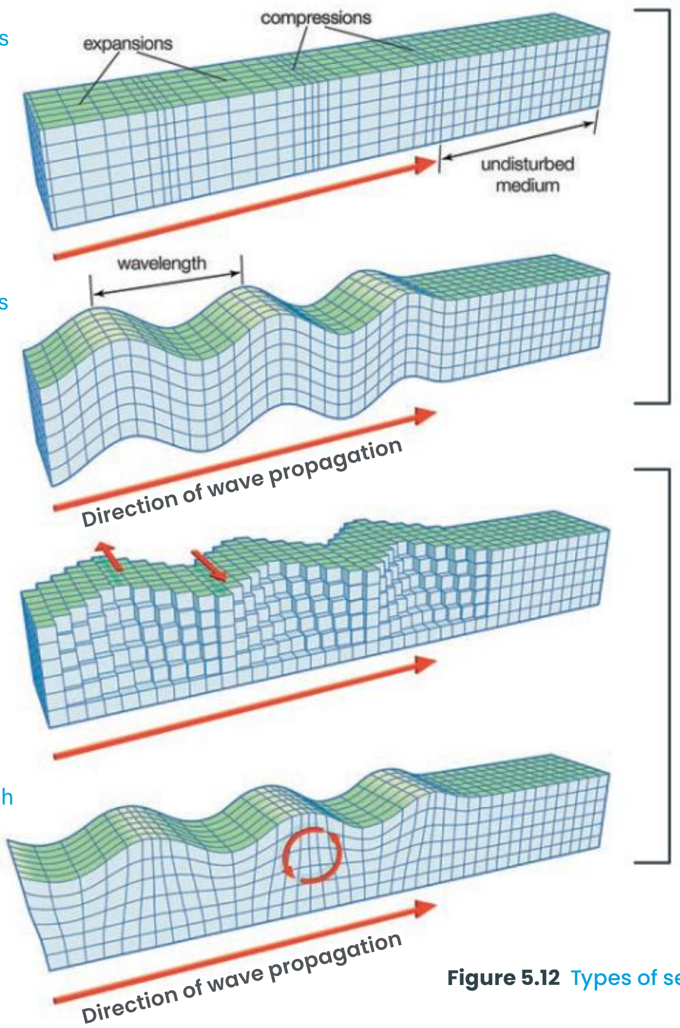


Figure 5.12 Types of seismic waves

3 Earthquakes are measured by magnitude and intensity

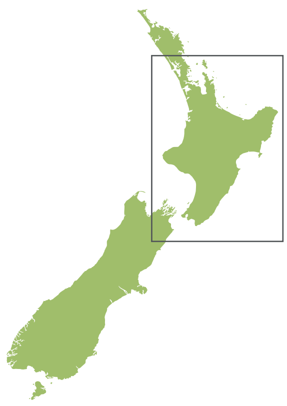
Scientists describe the size of the earthquake in terms of its magnitude and intensity.

The **magnitude** of an earthquake depends on how much energy it releases, and is related to the area of the fault that ruptured and how far it moved.

The **moment magnitude scale** is used to compare earthquakes. On the moment magnitude scale, a magnitude of 10 is equivalent to the energy released by 100 000 atomic bombs. Seismologists now use the moment magnitude scale instead of the Richter scale because it allows them to more accurately compare the sizes of earthquakes all over the world.

An earthquake's **intensity** refers to the amount of damage it causes and is measured by the modified Mercalli intensity scale (Table 5.1). The intensity of an earthquake is influenced by the magnitude of the earthquake, the distance from the epicentre, the local geology, and any buildings and other structures in the area.

How is the size of an earthquake usually described?



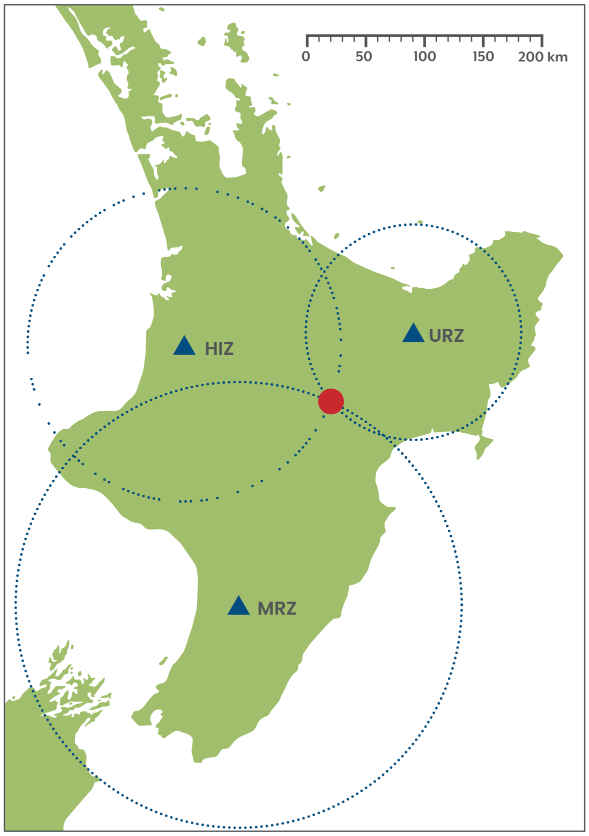


Figure 5.14 Triangulation is used to locate the epicentre of an earthquake in New Zealand. If you draw a circle around each seismic monitoring station (HIZ, URZ and MRZ) with the radius being the distance to the epicentre, then the epicentre is where the three circles overlap.

Table 5.1 The modified Mercalli intensity scale refers to the amount of damage caused by an earthquake.

Intensity	Shaking	Common observations
I	Not felt	Detected only by instruments
II	Weak	Noticed only by people at rest
III	Weak	Noticed by people indoors. Vibrations similar to a passing truck
IV	Light	Felt by people indoors and some people outdoors. Loose objects disturbed
V	Moderate	Felt by most people. Unstable objects overturned. Pendulum clocks stopped
VI	Strong	Felt by everyone. Slight structural damage
VII	Very strong	Felt by people in vehicles. Damage to poorly designed structures
VIII	Severe	Slight damage to well-designed structures. Much damage to other buildings
IX	Violent	Much damage to substantial structures
X	Extreme	Many buildings destroyed
XI	Disastrous	Few structures left standing
XII	Catastrophic	Total destruction

CHECKPOINT 5.4

1 Describe what causes earthquakes.

2 Earthquakes are much more common near convergent (destructive) boundaries. Suggest why.

3 Describe the difference between primary and secondary waves.

4 Which waves would cause more destruction to buildings – body waves or surface waves? Justify your response.

5 What information do seismologists need to know to determine how far an earthquake epicentre is from a seismic station?

6 Explain why a high-magnitude earthquake in an unpopulated area could have a lower value on the intensity scale than a lower magnitude earthquake in a populated area.

7 Explain why Australia has fewer earthquakes than New Zealand.

CONNECTING IDEAS

8 Research the five largest earthquakes that have been recorded. Plot their locations on a map that shows tectonic plate boundaries. What do their locations have in common?

SUCCESS CRITERIA

- I can explain what causes earthquakes and how this is linked to plate tectonics.
- I can discuss the occurrence of earthquakes in terms of constructive and destructive plate boundaries.

5.5 VOLCANOES

LEARNING INTENTION

At the end of this lesson I will be able to outline how volcanoes can be explained by the theory of plate tectonics.

KEY TERMS

lava
molten rock above Earth's surface

magma
molten rock below Earth's surface

strato volcano
a volcano formed at a subduction zone

volcano
a point in Earth's crust where lava erupts

LITERACY LINK

READING

Choose any 10 words on this page, and think of a definition for each in your own words.

NUMERACY LINK

UNITS

The VEI (volcanic explosivity index) is a logarithmic scale used to measure the intensity of an eruption. For example, an eruption classified as 3 is ten times more explosive than an eruption classified as 2. Compare the explosivity of a volcano that is 5 on the VEI scale with one that is 8.

A **volcano** is where molten rock erupts at Earth's surface. Most volcanoes are found along the boundaries of tectonic plates, which helps explain how they formed and their behaviour.

Volcanoes along diverging boundaries have runny lava that spreads out over large areas. Volcanoes formed along subduction zones have thicker lava and tend to be more explosive. Hot spot volcanoes are formed in the middle of a plate, rather than at a boundary.

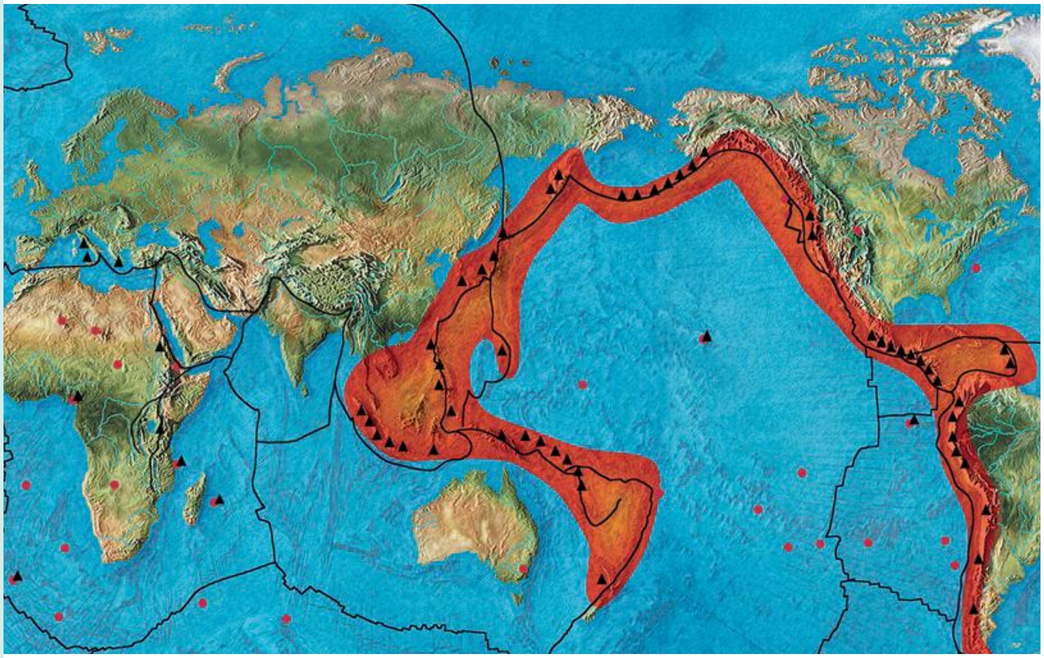


Figure 5.15 The Ring of Fire is a chain of volcanoes around the north, east and western edges of the Pacific Ocean.

1 Some volcanoes form at divergent plate boundaries

Figure 5.16 Basalt is an igneous rock that is formed from the fast cooling of lava from volcanoes at divergent boundaries. It makes up oceanic crust.

At divergent (constructive) plate boundaries, volcanoes form when **magma** (molten underground rock) rises up to fill the gap between the two diverging plates.

Most volcanoes on divergent plate boundaries form as fissure volcanoes – long fractures in the crust from which the **lava** erupts – and can be many kilometres long. Because the lava has come from the asthenosphere, it contains a lot of dark minerals and is very hot and runny, so spreads out over large areas. When it cools and solidifies, the lava forms an igneous rock called basalt.

What causes volcanoes to form along divergent plates?

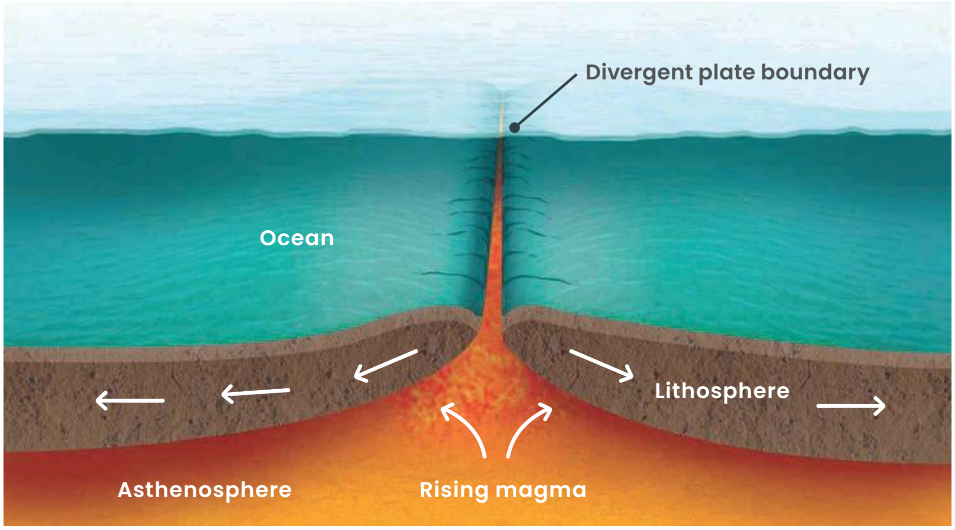


Figure 5.17 Formation of a volcano on a divergent plate boundary under the ocean. As magma rises up in the asthenosphere, it forms a fissure volcano many kilometres long.

2 Volcano arcs form at subduction zones

Volcanoes also form in chains known as arcs along the length of subduction zones.

Subduction zone volcanoes erupt violently because the pressure of gases moving up to the surface can build up and cause explosive eruptions. Because the lava is sticky, it doesn't spread out very far. Instead, volcanoes build up with steep sides.

Volcanoes along subduction zones are known as **strato volcanoes**.

Where do strato volcanoes form?

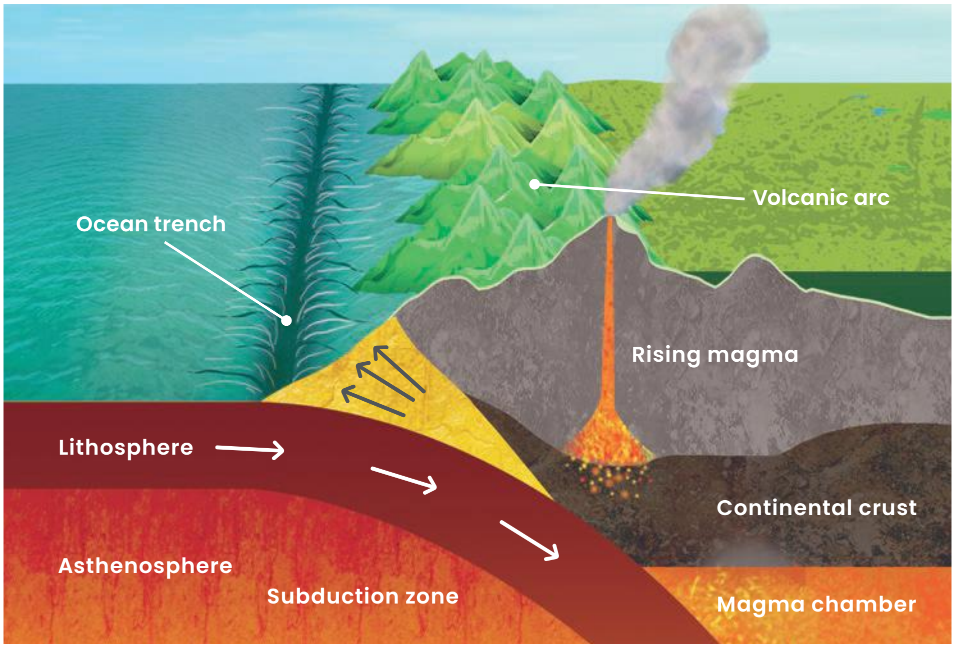


Figure 5.18 Strato volcanoes form as one plate subducts under the other. This causes magma to form and move up towards the surface.

INVESTIGATION 5.5A
Viscosity of lava

KEY SKILL
Evaluating results for reliability and validity

▶ *Go to page **178***

INVESTIGATION 5.5B
Wax volcano

KEY SKILL
Identifying and managing relevant risks

▶ *Go to page **179***

Figure 5.19 Rhyolite is an igneous rock formed from the rapid cooling of lava from a strato volcano.

5.5 continued ...

... 5.5 continued

VOLCANOES

KEY TERMS

hot spot volcano
a volcano formed by magma upwelling underneath a tectonic plate

3 Some volcanoes form in the middle of plates

Some volcanoes are not on plate boundaries, but are in the middle of the tectonic plates. These volcanoes are formed when there is an upwelling of magma (a hot spot) in a single location, so they are known as **hot spot volcanoes** or shield volcanoes. The lava that erupts out of hot spot volcanoes is similar to that of volcanoes at divergent boundaries because it comes from the asthenosphere. It is made of dark minerals, is very runny and forms the igneous rock basalt when it solidifies. The lava spreads out over large areas and over time forms volcanoes that are wide at the base compared to their height.

The hot spot in the mantle does not move, but the tectonic plates do and over time new volcanoes form in a chain (Figure 5.21). Unlike volcanoes that form along a subduction zone, only the volcano over the hot spot is active and erupts. The volcanoes that have moved away from the hot spot no longer have a magma source and so are said to be extinct.

Where on the tectonic plates do hot spot volcanoes form?

Figure 5.20 A fissure eruption at Iceland's Eyjafjallajökull volcano. This volcano has formed as the North American and European Plates move apart.

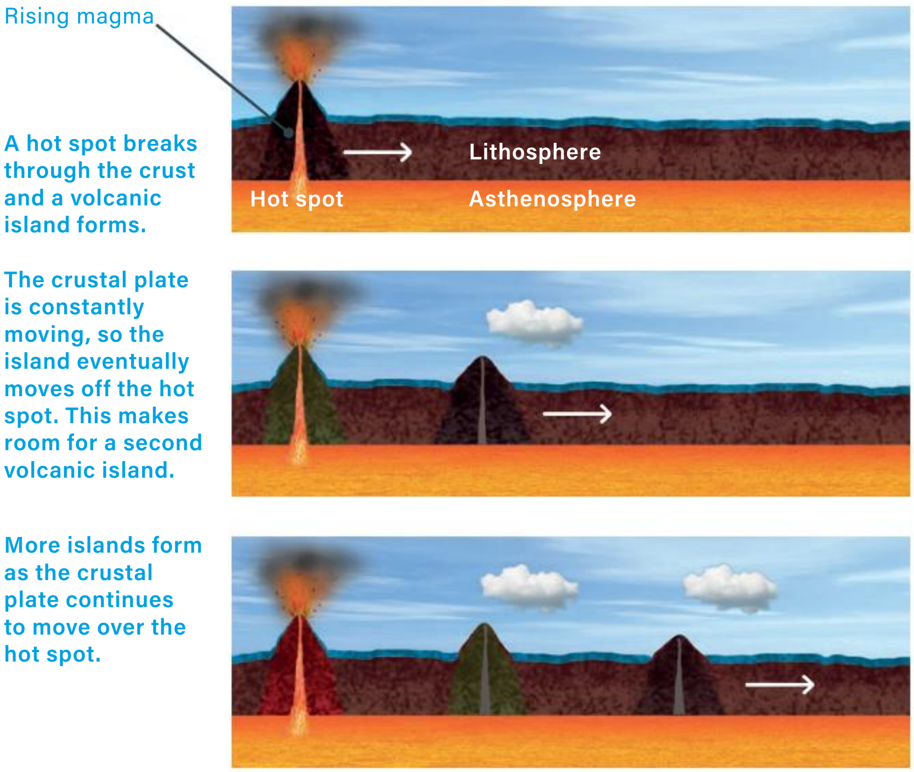


Figure 5.21 Steps in the formation of a volcanic island chain as a result of hot spot volcanism

4 Volcanoes create new landforms

We often think of volcanoes as destructive, but they are actually the main way in which landforms, especially islands, are created.

The Hawaiian Islands and Galapagos Islands have been formed by hot spot volcanism, and the positions of the islands in the chain can provide evidence for the direction and speed at which the plate is moving. Volcanoes in eastern Australia are part of a chain of hotspot volcanoes that formed as the continent moved north away from Antarctica. The oldest Australian volcanoes are in Queensland, and the youngest is Mount Gambier in South Australia, which was last active about 10 000 years ago.

What kind of volcanoes formed the Hawaiian Islands?

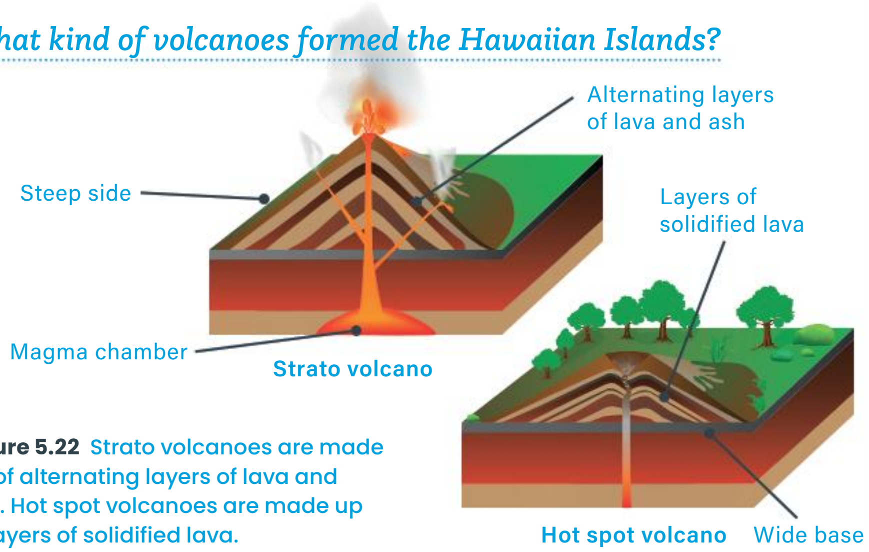


Figure 5.22 Strato volcanoes are made up of alternating layers of lava and ash. Hot spot volcanoes are made up of layers of solidified lava.

CHECKPOINT 5.5

1 State the type of volcano that is under the ocean and is many kilometres long.
2 State the type of volcano that forms chains of volcanoes in the middle of tectonic plates.
3 State the type of volcano that is made up of alternating layers of ash and lava flows.
4 Describe the relationship between the theory of plate tectonics and volcanoes.
5 How is the lava that erupts from strato volcanoes formed?
6 Compare and contrast a chain of islands formed by a hot spot with a chain of islands formed by a subduction zone.

EXTENSION

7 You observe some volcanoes on a continent. What evidence do you need to look for to determine how they were formed? Justify your reasoning.

SUCCESS CRITERIA

- I can explain how volcanoes are formed.
- I can name and describe at least two types of volcanoes.
- I can discuss the occurrence of volcanic activity in terms of constructive and destructive plate boundaries.

5.6 MONITORING OUR EARTH

LEARNING INTENTION

At the end of this lesson I will be able to describe how computer modelling and imaging technologies have improved knowledge and predictability of plate tectonic movement.

KEY TERMS

GPS
global positioning system

tsunami
a sea wave caused by the displacement of water as a result of an earthquake or other disturbance

LITERACY LINK

WRITING

Create a quick-reference guide that tells residents what to do in case of an earthquake.

NUMERACY LINK

CALCULATION

Use the formula below to determine the speed (in m/s) of a tsunami wave at a depth of 4,500 m:

$$\text{speed} = \sqrt{g \times d}$$

Where g = acceleration due to gravity (9.81 m/s^2) and d = water depth in metres.

Convert your answer to km/h.

As technology has improved, scientists have been able to collect more data and develop our understanding about Earth. In the 20th century, new technologies enabled scientists to discover evidence for plate tectonics. More recently, very precise instruments, satellites and internet communication technologies have allowed us to collect even more data and information about Earth.

Some countries have technologies to warn citizens about geological hazards such as earthquakes and tsunamis.

1 Geologists use seismic data to predict the size of earthquakes

Computer analysis of seismic data can help geologists build better models of local geology, such as how plates move at subduction zones. As one plate subducts under another, it causes many earthquakes to occur. Scientists can plot this information to produce a three-dimensional image of the subduction zone. The data can also identify if the plate tends to move down at a steady rate, causing many smaller earthquakes, or if it tends to get stuck and move suddenly, causing fewer but larger earthquakes.

Seismologists can determine patterns and predict the possible magnitudes and intensities of earthquakes in a particular region, but they can't predict exactly when an earthquake is going to occur.

How can earthquakes be predicted?

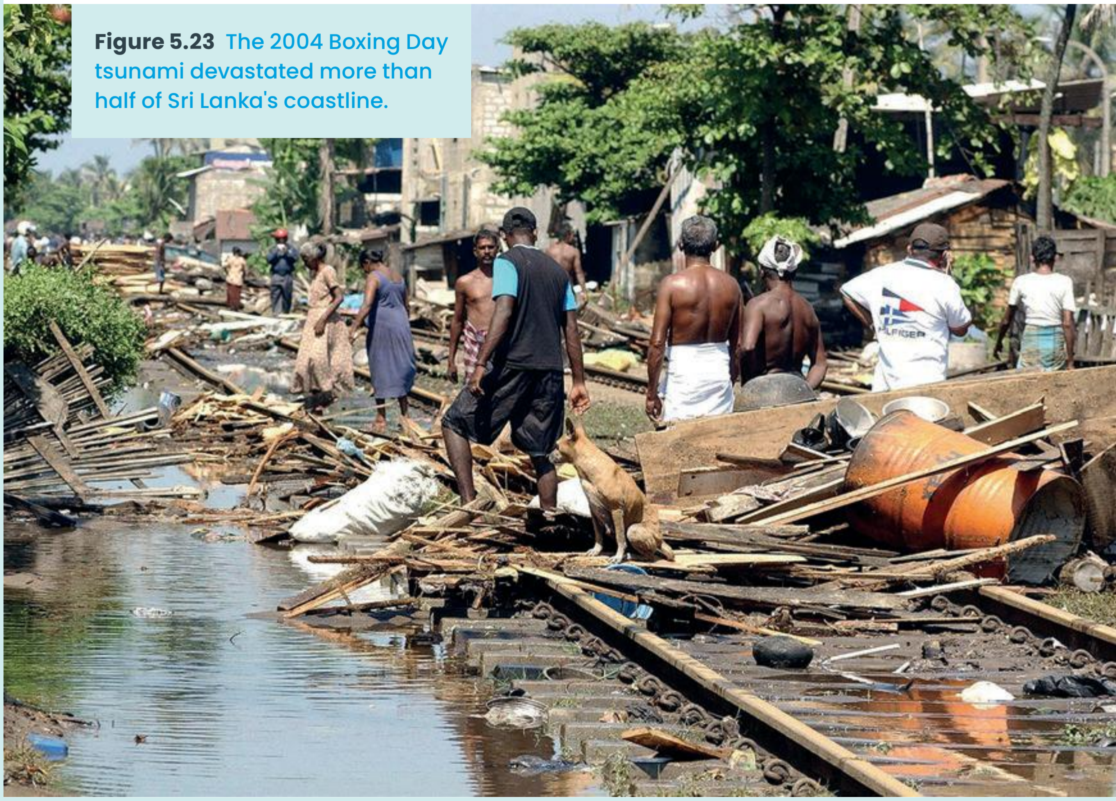


Figure 5.23 The 2004 Boxing Day tsunami devastated more than half of Sri Lanka's coastline.

2 Warning systems can detect tsunamis

Tsunamis are fast-moving waves generated from a sudden massive movement of water. Most tsunamis are caused by earthquakes, but they can also be caused by undersea volcanoes or even a meteorite impact. Tsunamis can result in mass destruction and loss of life in populated areas.

Earthquakes that cause tsunamis happen along subduction zones because when one plate moves under during an earthquake, it pushes the other plate upwards suddenly, displacing the water above it.

After the Boxing Day tsunami hit Indonesia in 2004, the Australian Government funded the Joint Australian Tsunami Warning System, which uses various technologies to detect tsunamis. The system involves a network of seismic sensors that measure earthquakes and send out warnings when an earthquake occurs that could cause a tsunami.

Deep ocean detection buoys have also been deployed near the subduction zones that surround Australia to monitor sea level changes. The buoys will send out an alert via satellites if they detect a change in sea level that could have been caused by a tsunami, providing the warning centre with further information.

How can tsunamis be detected?

Figure 5.24 A deep ocean detection buoy is deployed in the Tasman Sea to monitor changes in sea levels that may have been caused by a tsunami.

3 Australia is slowly moving

Geologists know from **GPS** (global positioning system) satellite and laser technology that Australia is moving north at about 7 cm a year.

As the continent moves, the latitude and longitude coordinates change. GPS navigation systems rely on reference sets of data to determine location. If the longitude and latitude of the continents are not kept up to date, systems that rely on GPS for navigation and positioning will be incorrect.

Geoscience Australia recently updated the data set that was being used by GPS navigation systems because it was out by about 1.5 m!

What technologies are used to measure the movement of the Australian continent?

CHECKPOINT 5.6

1 Technology has led to greater scientific understanding of geological activity. Explain how.

2 Explain why seismic data can help us understand what is happening at subduction zones.

3 Explain why it is better for tsunami warning centres to use data from both earthquakes and sea level changes to determine if a tsunami could affect the Australian coastline.

4 If Australia is moving north at 7 cm a year, when will the continent be 1.5 m further north than it is today?

5 Explain why it is important to be able to know exactly where continents are located when using GPS and other satellite navigation technologies.

RESEARCH

6 Research tsunami warning systems and prepare a short report about which countries have them and how they work.

SUCCESS CRITERIA

- I can describe how technology has improved knowledge and predictability of plate tectonic movement.
- I can name at least two pieces of technology that have led to improved knowledge and predictability of plate tectonic movement.

VISUAL SUMMARY

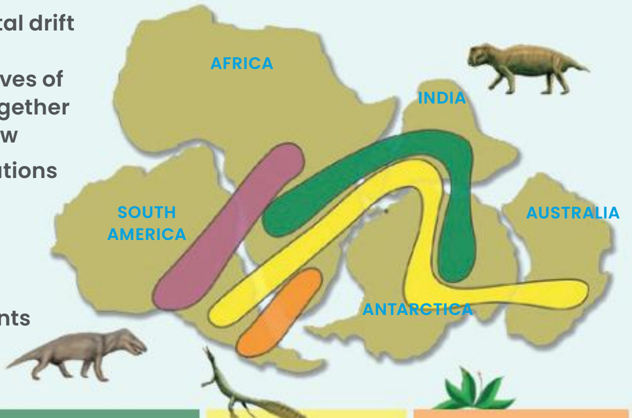
The theory of **continental drift** states that the continents have moved over time.

▲ **GPS** data can be used to track the movement of the continents.

The theory of **plate tectonics** explains how the continents move.

Evidence for continental drift includes:

- the continental shelves of continents fitting together like pieces of a jigsaw
- identical rock formations on either side of the Atlantic Ocean
- identical plant and animal fossils on different continents now separated by oceans.



Fossil evidence of freshwater reptile Mesosaurus has been found in Brazil and Africa.

Fossil evidence of the land reptile *Lystrosaurus* has been found in Africa, Antarctica and India.

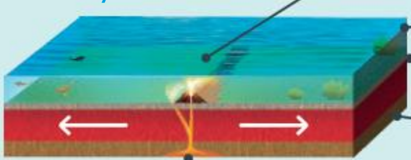
Fossils of the fern *Glossopteris* have been found in all southern continents.

Fossil evidence of land reptile *Cynognathus* has been found in Argentina and southern Africa.

Tectonic plates interact in three different ways:

- divergent – plates move away from each other
- convergent – plates move towards each other
- transform – plates slide past each other.

Divergent plate boundary

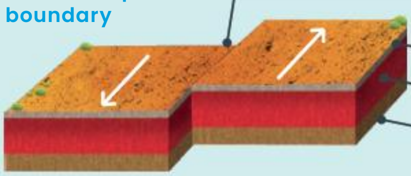


Mid-ocean ridge
Ocean crust
Lithosphere
Asthenosphere
Magma rising

Convergent plate boundary

Continental crust
Lithosphere
Asthenosphere
Subduction zone

Transform plate boundary

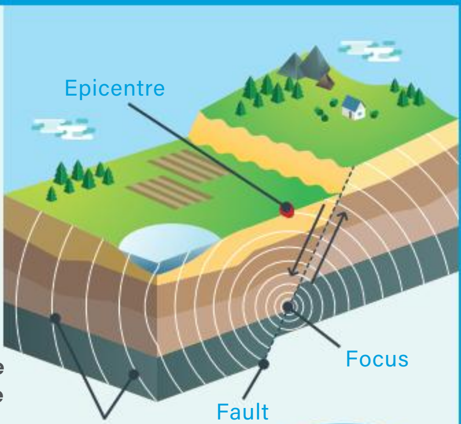


Earthquakes
Continental crust
Lithosphere
Asthenosphere

Most **earthquakes** happen when tectonic plates move.

The **epicentre** is the point on the surface directly above the focus.

The **focus** is the point where the earthquake starts.



◄ Earthquake data can be used to warn about **tsunami** risks.

★ FINAL CHALLENGE ★

1. Identify this statement as true or false. The theory of continental drift is the same as the theory of plate tectonics.
2. List three observations that Alfred Wegener identified as evidence that the continents have drifted over time.

Level 1 ★☆☆☆☆☆ 50xp

LEVEL UP!

3. What layer of Earth do tectonic plates 'float' on?
4. Identify three pieces of evidence for the theory of plate tectonics.
5. Match the following plate boundaries with the types of plate movement.

Divergent	Plates slide past each other
Convergent	Plates move apart
Transform	Plates move together

Level 2 ★★☆☆☆☆ 100xp

LEVEL UP!

6. Copy and complete these sentences.
   - **a** Earthquakes produce ________ waves. ________ waves travel through Earth, and ________ travel along the surface of Earth.
   - **b** There are two main types of body waves: ________ or P waves travel fastest; ________ or S waves travel ________.
   - **c** Surface waves cause the ________ damage.

Level 3 ★★★☆☆☆ 150xp

LEVEL UP!

7. What is subduction? Use a labelled diagram to help you describe the process.
8. About 85 million years ago the continents of Australia and Antarctica began to separate. The continents were completely separated 30 million years ago.
   - **a** Identify the type of plate boundary that would have formed to separate the continents.
   - **b** Draw a series of labelled diagrams that illustrate two continents separating and the features that would be observed.

Level 4 ★★★★☆☆ 200xp

LEVEL UP!

9. Identify two ways that earthquake data can be used to tell us more about patterns of geological activity.
10. Explain why more earthquakes and volcanic eruptions are experienced in Indonesia than in Australia.

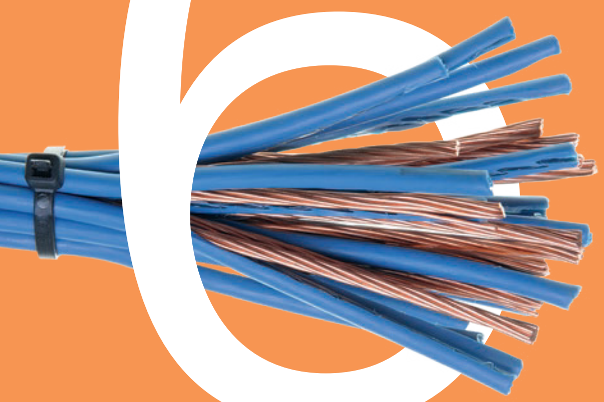
Level 5 ★★★★★★ 300xp

LEVEL UP!

ELECTRICITY

Why can't electricity and magnetism exist without each other?

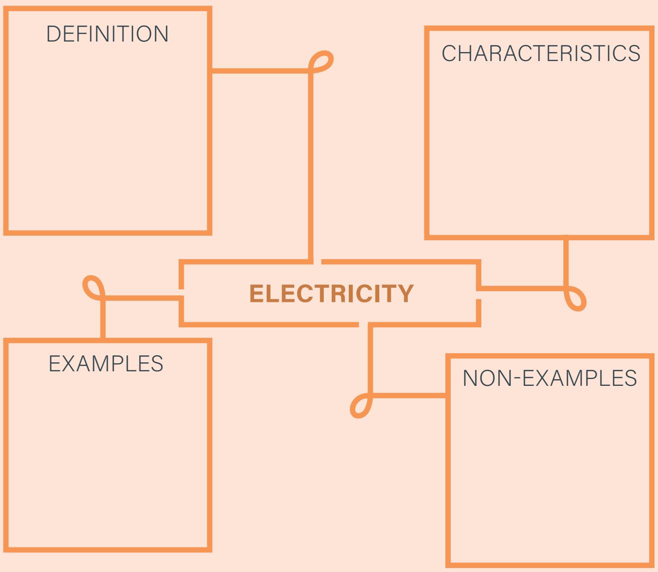
6



Electricity is a form of energy that can flow from one place to another. When you think about electricity you might automatically think of wires, light bulbs and how your television is powered, but electricity existed before all those things. Electricity, the flow of electrons, occurs in nature – in lightning, in the synapses in our bodies and even in the shock of an electrostatic 'zap'. In the 19th century, there were huge leaps forward in our understanding and use of electricity. Famous scientists such as Edison, Einstein and Tesla all joined the race to power the world. Power plants and wires spread out across Earth at an incredible rate, powering lights, and heating and cooling homes.

1 FRAYER MODEL

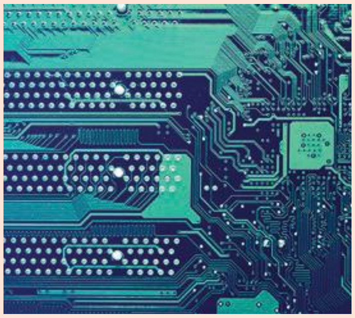
Copy and complete the below chart in your workbook.

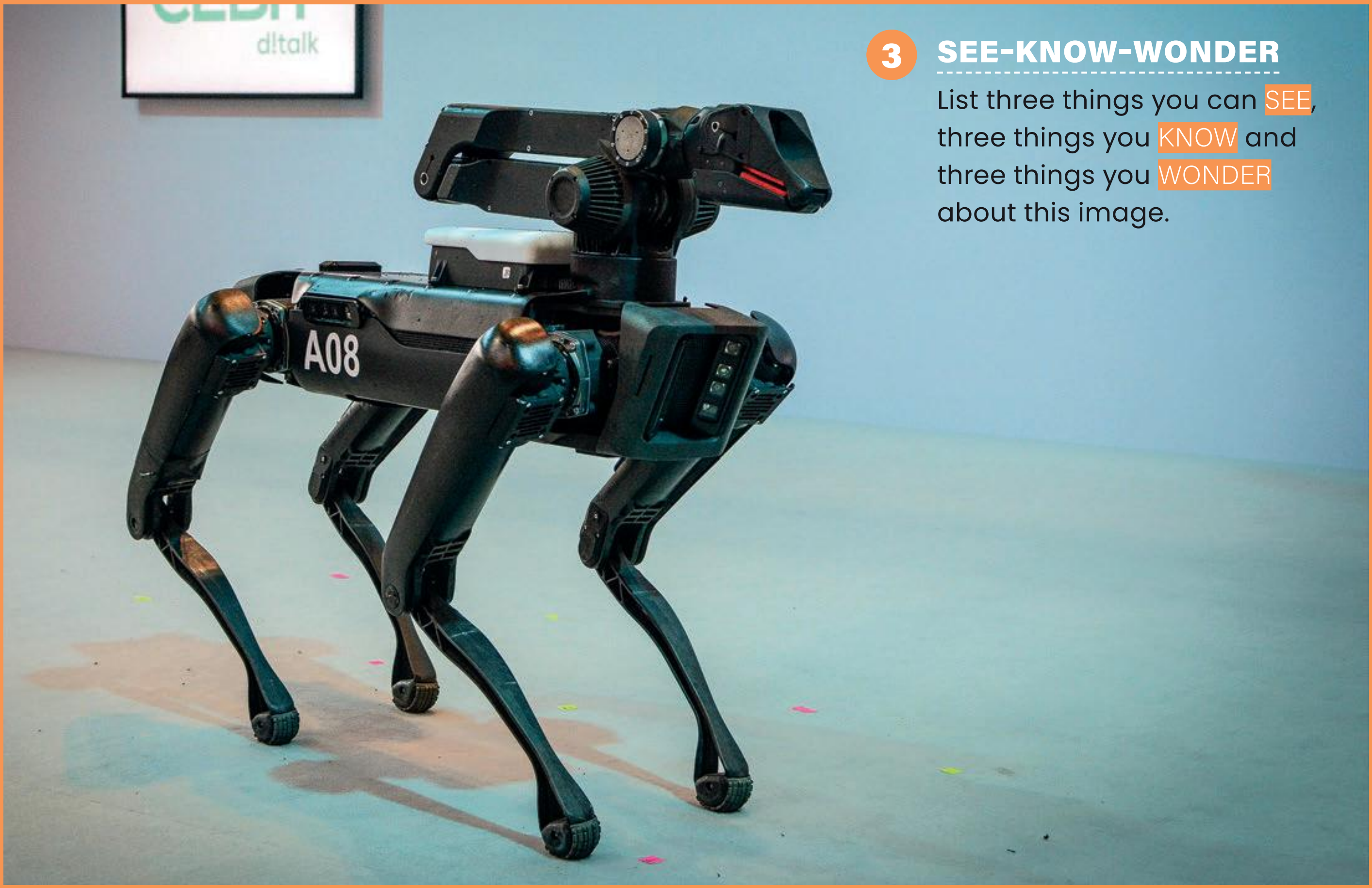


Complete two additional charts for the key terms *Circuit* and *Conductor*.

2 LEARNING LINKS

Brainstorm everything you already know about electricity.





3 SEE-KNOW-WONDER

List three things you can SEE, three things you KNOW and three things you WONDER about this image.

4 CRITICAL + CREATIVE THINKING

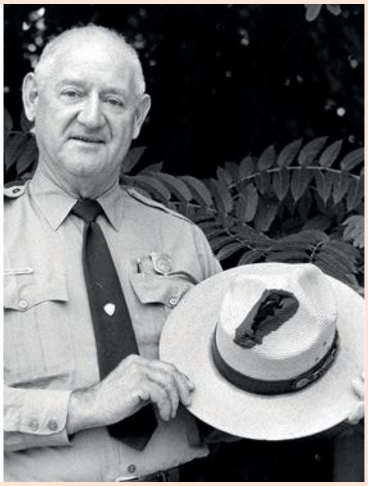
COMMONALITIES: How many points of commonality between an electrical circuit and a race track can you think of?

ALTERNATIVES: List as many things as you can think of that cannot be done without modern technology.

THE REVERSE: List things that cannot be powered by electricity.

5 THE LUCKIEST UNLUCKY GUY!

Roy Sullivan was a park ranger in the United States when he was first struck by lightning in 1942. Roy went on to be struck six more times, miraculously surviving every time. He currently holds the Guinness World Record for being struck by lightning the most times. The probability of being struck by lightning more than once is ***extremely*** low; however, due to the nature and location of Roy's job he was more exposed to storms than the average person.



6.1 ELECTRICAL ENERGY

LEARNING INTENTION

At the end of this lesson I will be able to relate electricity with energy transfer in a simple circuit.

KEY TERMS

circuit
a closed path containing a collection of components connected to a power source that allows current to flow

component
a part of an electric circuit in an electrical device

current
a measure of how fast electrons move in a circuit

load
any part in a circuit that receives power

resistance
how much a substance opposes an electric current moving through it

NUMERACY LINK

DATA

Amy measured the resistance of some substances.

Material	Resistance (ohms)
Copper	0.003
Silver	0.002
Iron	0.007
Rubber	0.006
Wood	120.6
Glass	250.3

She suspects an error in one of the measurements. Which one do you think it is? Why?

Figure 6.1 Batteries are a convenient and portable way to store chemical potential energy. They come in many sizes and are made of a variety of materials.

We can see the transfer of energy in circuits every time we push a button or flick a switch. We can see the light energy and feel the heat energy from a light bulb.

What is happening inside the wires? Is it something we can see through a microscope, or is it invisible? Will we need a model to describe this science?

1 Circuits transform chemical energy into electricity

An electric **circuit** is an energy converter. The stored chemical energy in a battery is transformed into electric potential energy by the circuit.

In an electric circuit, electrons move through the wires and **components** of the circuit. The electrons receive electrical potential energy from a battery. They then carry this energy around the circuit, but give away the energy when they reach a **load**. The load could be a light bulb, a motor or a heater coil. The electrons transfer their energy to the component, which will convert that electrical energy into another type. For example, a light bulb will convert electrical potential energy into heat and light energy. The electrons then continue through the circuit, returning to the battery, where they will receive more energy, and repeat the cycle again.

Figure 6.2 Electrons move through the the electric circuit via the electrical wires in a smoke detector.

What type of energy is stored in a battery?

2 Energy and current are different

A battery gives electrical potential energy to the electrons in a circuit, but this is not the same as the **current** of the circuit. The current is how fast the energy moves through the circuit. A battery might hold a lot of potential energy, but the circuit may deliver it slowly, so the current is small.

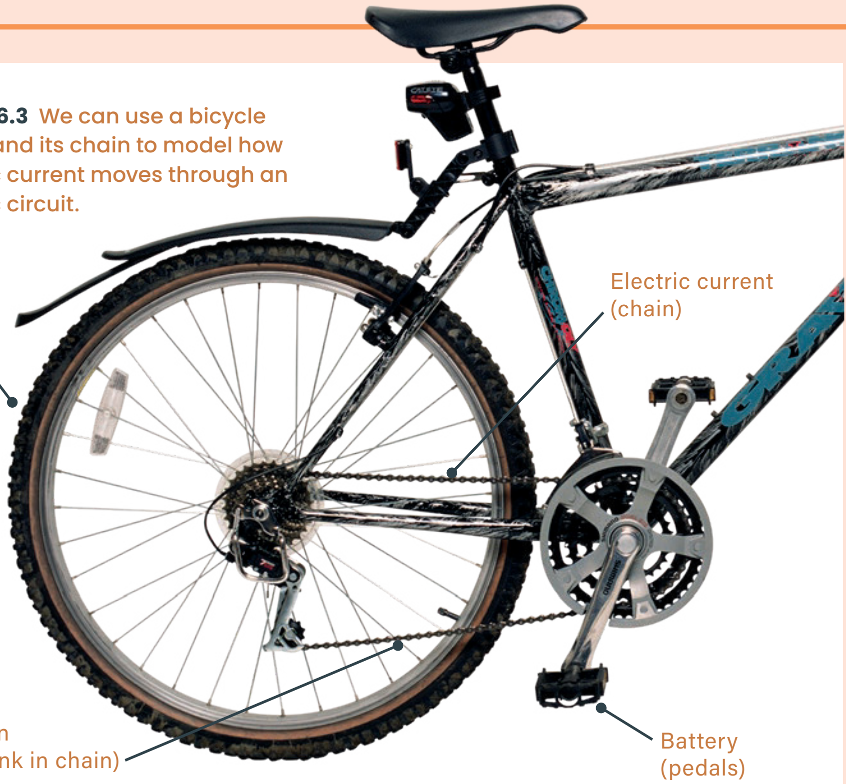


Figure 6.3 We can use a bicycle wheel and its chain to model how electric current moves through an electric circuit.

A bicycle wheel and chain can be used to model an electric circuit. The current is the entire chain, and each link of the chain represents an electron. The pedals are the battery pushing the electron around the circuit, while the wheel is the load in the circuit, such as a light bulb. As soon as you push the pedals and they start to turn, the back wheel begins to move. A link in the chain might take a long time to go all the way around, but the wheel will turn immediately and for as long as the pedals do.

Does a circuit transfer energy quickly or slowly?

3 Materials provide resistance to electric currents

Something else that affects the speed of a current is the **resistance** of the circuit. Some materials allow electrons to move easily through them, while others stop or slow the current.

A material that contains movable electrons (or other charged particles) is called an electrical conductor. These substances have the lowest resistance to current moving through them. Pure silver, gold and copper are good electric conductors. Most wiring is made of copper because it's cheaper than gold and silver, and easier to get.

A material that doesn't contain movable electrons is an insulator. These substances have the greatest resistance to current moving through them. Plastic, ceramic and rubber tend to be good insulators.

Electric wiring is covered in insulation, which acts as a barrier. The current can't pass through the insulation, and so the wires are much less dangerous to people and other electrical objects.

What is electrical resistance?

CHECKPOINT 6.1

1 Match the electrical objects to their energy types.

speaker	light energy
toaster	chemical energy
light	sound energy
battery	kinetic energy
fan	heat energy

2 The model of a bicycle chain has been used to describe energy transfer in an electric circuit.
   a Describe what the pedal, chain and wheel of a bicycle represent in an electric circuit.
   b What does this model explain well and what does it leave out? Suggest improvements.

3 Electrical tape is made of a flexible plastic with sticky adhesive on one side.
   a What do you think electrical tape might be used for?
   b Give reasons why plastic is a suitable material for electrical tape.

INQUIRY

4 Investigate different types of batteries and their uses. List some strengths and weaknesses for each type of battery.

SUCCESS CRITERIA

- I can describe how a circuit demonstrates energy transfer.
- I can explain the difference between a conductor and an insulator.

6.2 ENERGY IN CIRCUITS

LEARNING INTENTION

At the end of this lesson I will be able to describe how the operation of circuits can be explained by the concepts of voltage, current and resistance.

KEY TERMS

conductor
a material that allows the flow of current

insulator
a material that resists the flow of current

voltage
the difference in potential energy between two points in a circuit

LITERACY LINK

READING

Summarise the information in this lesson in a postcard addressed to your teacher.

NUMERACY LINK

GRAPHING

Plot a graph of the following data:

I (amps)	0.12	0.29	0.51	0.67
V (volts)	0.65	1.41	2.55	3.28

Draw a line of best fit and calculate the resistance of the circuit by determining the gradient of the line.

Electricity is created by the flow of electrons and is a form of energy that can be transported from one place to another. For example, for your television to work, electrical energy must be transported from the power plant where it is generated, into your home, and finally into your television.

There are three important quantities involved in the transport of electricity. These are current (how quickly electrons move through a circuit), voltage (how much energy the electrons contain) and resistance (how much energy is used to get through a certain point in the circuit).

1 Voltage is a measure of potential difference

An electric circuit is a closed path that current flows through. **Voltage**, which is also called potential difference, is the difference in potential energy between two points in the circuit. Voltage has the symbol *V* and the unit of voltage is the volt (V).

The bigger the potential difference between two points in an electric circuit, the bigger the voltage. This is like the difference in height between two points on a rollercoaster (Figure 6.4). Higher voltages have more energy and can do more work, just as higher points on a rollercoaster have more energy or potential than lower points. The difference between these points on the circuit is the voltage or potential difference. The battery causes an increase in voltage because it is an energy source. Each of the components in the circuit causes a drop in voltage when they use energy in the circuit.

If a higher voltage battery is used in a circuit, light bulbs glow more brightly. However, there is a limit to how much voltage a bulb can cope with. A bulb will fail or 'blow' if there is too much voltage in the circuit.

What is voltage?

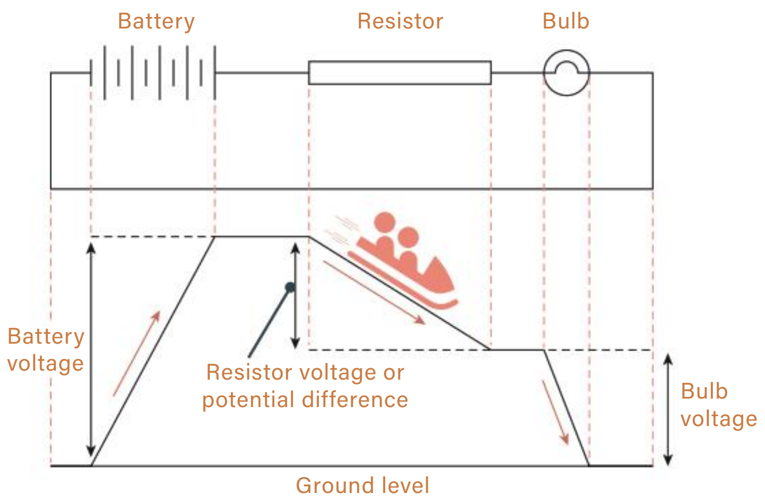


Figure 6.4 Voltage or potential difference is like the difference in height between two points on a rollercoaster.

2 Current is the rate of movement of electrons

Current is the rate of movement of electrons in a circuit. Current has the symbol *I* and the unit of current is the ampere (or amp) (A).

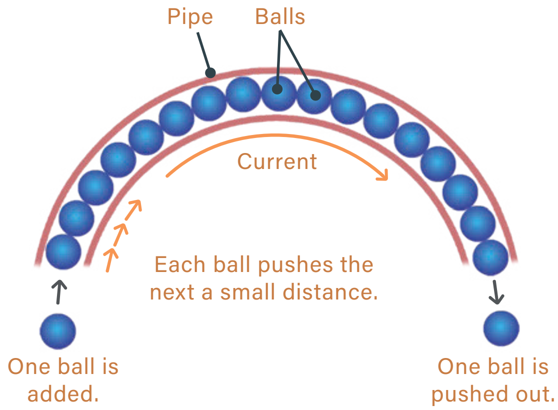
In a circuit, electrons can move in either direction, depending on which way the power source 'pushes' the electrons. If you changed the direction of the battery in a simple circuit, you would change the direction of current.

You can visualise current as a pipe filled with small balls. When a ball is pushed into the end of the pipe, a ball at the other end is pushed out. So, a small movement of one ball can cause an action a long distance away. In this model, the balls are the electrons, you are the battery pushing the charges and the current is how fast you push the balls.

Some circuit components are sensitive to current direction while others are not. Complicated or delicate components can be damaged by current flowing in the wrong direction.

What unit is current measured in?

Figure 6.5 Current can be visualised as a pipe filled with small balls.



3 Resistance opposes voltage

Circuits are made up of wires and components that conduct electrical energy. Some materials, such as copper, allow current to flow more easily and are known as **conductors**. Other materials, such as rubber, resist the flow of current and are called **insulators**. Resistance has the symbol *R*. The unit of resistance is the ohm (Ω).

If voltage is the amount of 'push' given to a charge, then resistance is the opposing force. A component with resistance consumes electrical energy and converts it into other forms of energy, such as heat.

While each component in a circuit has resistance that 'slows' the flow of current in a circuit, special components called resistors let you introduce exact amounts of resistance into circuits.

What is a resistor?

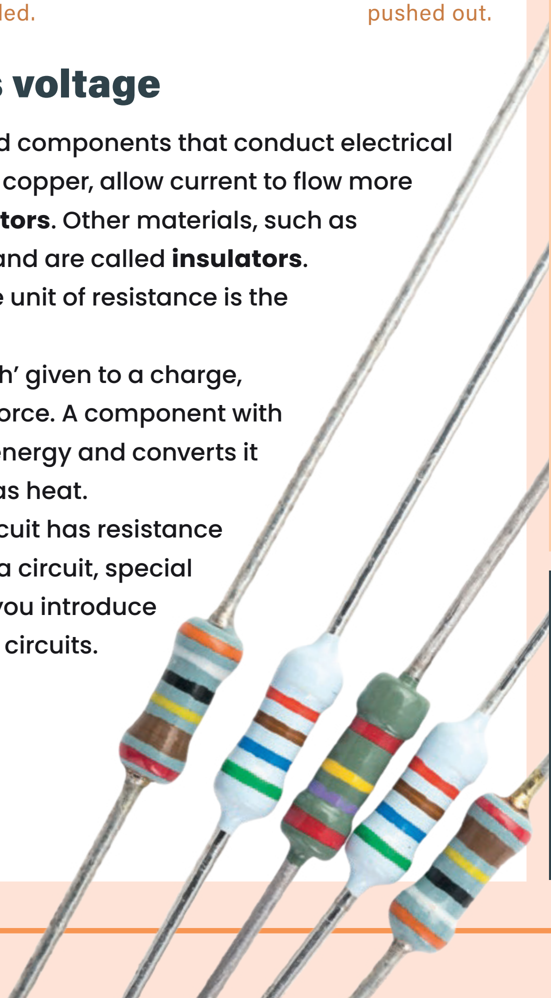


Figure 6.6 The coloured bands on these resistors indicate the value of the resistance in ohms.

INVESTIGATION 6.2
Modelling a simple circuit

KEY SKILL
Using modelling and simulations

▶ *Go to page* ***180***

CHECKPOINT 6.2

1 Outline the difference between voltage, current and resistance.
2 Identify these statements as true or false.
   a Voltage is supplied by a resistor.
   b Too much voltage will cause a bulb to fail.
   c Current always flows clockwise.
   d Current gets used up as it goes around a circuit.
   e Resistance is measured in ohms.
   f Conductors have zero resistance.
3 What are the units for current, voltage and resistance?
4 Explain what conductors and insulators are and provide an example of each.

CONNECTING IDEAS

5 Create a cartoon strip or series explaining voltage, current and resistance.

SUCCESS CRITERIA

- I can explain what is meant by voltage, current and resistance.
- I can describe how voltage, current and resistance affect energy in a circuit.

6.3 OHM'S LAW

LEARNING INTENTION

At the end of this lesson I will be able to describe the relationship between voltage, resistance and current.

KEY TERMS

ammeter
a device that measures electric current

diode
an electrical component that allows electric current to flow in only one direction

Ohm's law
a law that states that the current through a conductor between two points is directly proportional to the voltage across the two points

voltmeter
a device that measures potential difference (voltage)

LITERACY LINK

WRITING

Create a how-to guide for using an ammeter. Using dot points, explain how to connect it, what it measures and how to read it.

NUMERACY LINK

MEASUREMENT

What is the reading on the voltmeter above?

The German physicist Georg Ohm (1789–1854) discovered the relationship between voltage, current and resistance in an electric circuit. This relationship became known as Ohm's law.

Ohm's law states that the current flowing between two points in a circuit is directly proportional to the voltage difference between the two points. Ohm's law forms the basis for understanding electric circuits, and helped pave the way for the electrical devices we enjoy using today.

1 Electrical current is proportional to voltage

Ohm discovered that the relationship between current (I), voltage (V) and resistance (R) can be summarised in the formula:

voltage (V) in volts = current (I) in amperes × resistance (R) in ohms

This means that if you have a fixed resistor (one whose resistance doesn't change), then increasing the current through the resistor will increase the voltage across the resistor. Likewise, reducing the voltage across the resistor will reduce the current flowing through it.

If you know any two of the values for voltage, current or resistance, then you can use **Ohm's law** to calculate the third one. A useful way to remember Ohm's law is to use an Ohm's law triangle (Figure 6.4). To use this triangle, place a finger over the value being calculated and the remaining two values will complete the calculation.

Conductors with a fixed resistance are known as ohmic resistors. Some conductors, such as light-emitting **diodes**, change their resistance depending on the current passing through them; they are referred to as non-ohmic resistors.

What is Ohm's law used to calculate?

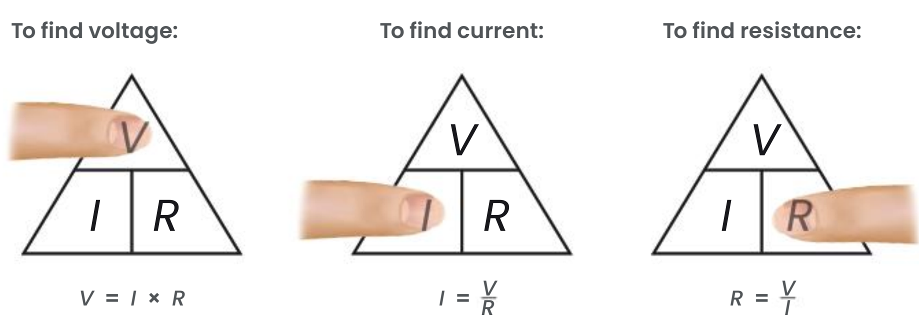


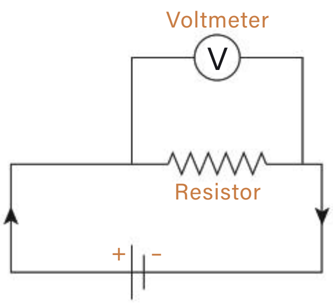
Figure 6.7 An Ohm's law triangle allows you to calculate voltage, current or resistance. Cover the value you need to know and use the other two values to complete the calculation.

2 Voltmeters measure potential difference

Ohm's law is more than just an equation. The tools we use to check and repair electric circuits are based on the relationship between current and resistance.

A **voltmeter** is a device that measures the potential difference or voltage across two points in a circuit. Before you can measure voltage, the circuit must be completed. Then, add the voltmeter so that the two probes are at the two points that the voltage will be measured across.

What does a voltmeter measure?



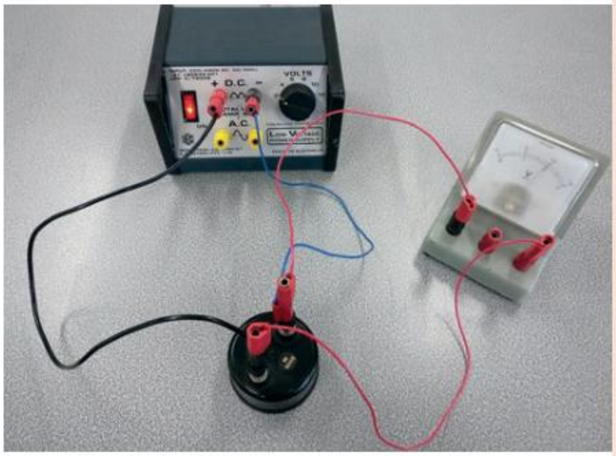
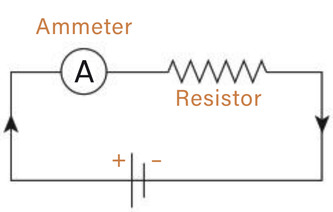


Figure 6.8 How to connect a voltmeter in parallel to take a measurement.

3 Ammeters measure current

An **ammeter** is a device that measures current. To correctly measure the current at a certain point in a circuit, the ammeter needs to be connected as a part of the circuit. That is, the current must have no other path but to go through the ammeter.

What does an ammeter measure?



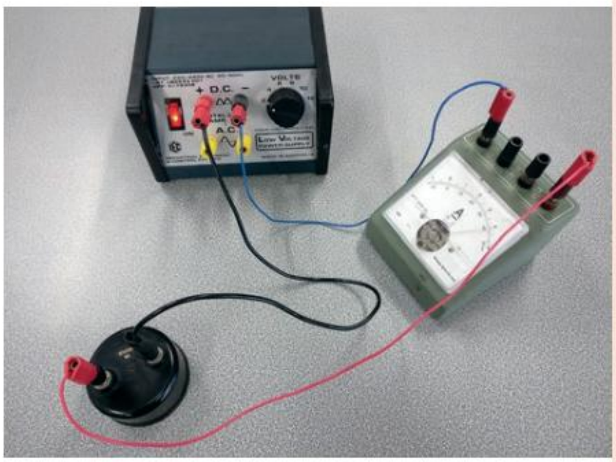


Figure 6.9 How to connect an ammeter in series to take a measurement.

INVESTIGATION 6.3

Exploring Ohm's law

KEY SKILL
Identifying the variables and formulating a hypothesis

▶ *Go to page **181***

CHECKPOINT 6.3

1 Explain Ohm's law.

2 Use the Ohm's law triangle to give the equations for measuring:
 a current
 b voltage
 c resistance.

3 Outline the difference between an ammeter and a voltmeter.

4 Explain what is meant by a non-ohmic resistor.

5 Given a voltage of 110 V and a current of 7 A, calculate the resistance.

6 If the current is 8 A and the resistance is 2 Ω, calculate the voltage.

7 If a battery in a circuit is 24 V and the resistance is 14 Ω, calculate the current.

INQUIRY

8 Carry out research to make a list of substances that have low resistance. Suggest why these substances are not used in circuits in homes.

SUCCESS CRITERIA

- I can describe the relationship between voltage, resistance and current.
- I can calculate voltage, current and resistance using Ohm's law.

6.4 MAKING ELECTRIC CIRCUITS

LEARNING INTENTION

At the end of this lesson I will be able to construct and draw circuits containing a number of components to show a transfer of electricity.

KEY TERMS

circuit
a closed path containing a collection of components connected to a power source that allows current to flow

component
a part of an electric circuit in an electrical device

LITERACY LINK

WRITING

Write a short guide to explain to younger students how to create a simple circuit.

NUMERACY LINK

UNITS

The unit for electrical resistance, the ohm (Ω), is proportional to the number of joules multiplied by the number of seconds. Which quantities are measured in joules and seconds? How do you think this relates to resistance?

Have you ever wondered what is going on inside your electronic devices? Every device you own, from the simplest torch to the most sophisticated computer, works because of the electrical **components**.

Electrical components are part of electric **circuits**, which can be shown using circuit diagrams.

1 Electricity will only flow through a complete circuit

Electric circuits can be open or closed. A closed circuit is also known as a complete circuit.

A closed or complete circuit allows electricity to flow. An open or incomplete circuit is like a hose that has been cut, so water cannot flow to the sprayer or sprinkler. Any gaps will cause an incomplete circuit and stop the current from flowing through the circuit.

Many circuits contain switches, which are used to open and close circuits. When you turn on a light, the switch changes the open circuit to a closed circuit and allows energy to flow through the wires to operate the light bulb.

What is another name for a closed circuit?

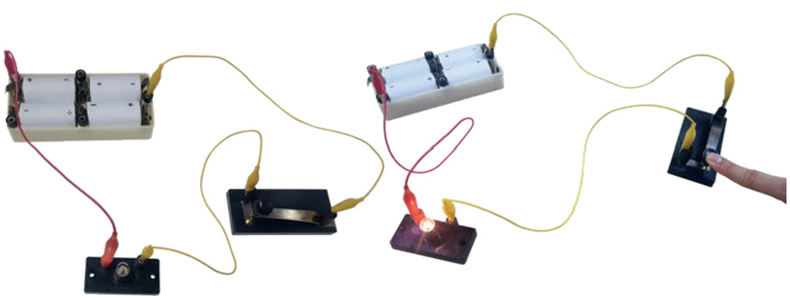


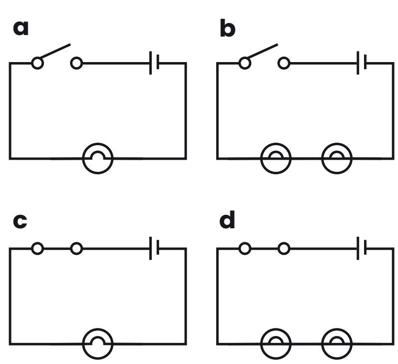
Figure 6.10 Turning on a switch changes an open circuit (left) to a closed circuit (right).

2 Electric circuits can be planned and drawn using diagrams

An electric circuit can be recorded as a picture called a circuit diagram. Circuit diagrams use symbols to show how the different electrical components are connected.

Diagrams are used to record circuits that would be too confusing to show as pictures of each component. They are efficient to draw and easy to read, so circuits can be built quickly from them.

Figure 6.11 Circuit diagrams show the components of electric circuits in a simple and standard way.

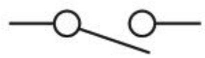
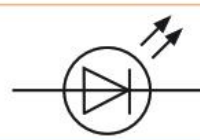


How is an electric circuit recorded?

3 Circuit components are shown using standard symbols

Component symbols are nearly always shown the same way. This means that anyone who knows these symbols can read a circuit diagram. Table 6.1 shows symbols for the most common components, and what each component looks like.

Table 6.1 Common electrical components and their symbols

Component	Picture	Symbol
Open switch		
Closed switch		
Lamp (e.g. light globe)		
Light-emitting diode (LED)		
Cell		
Battery (multiple cells)		
Wire		

Follow these steps when drawing circuit diagrams:

1 Use a sharp pencil and a ruler.
2 Draw the symbols in the correct places. Symbols should not be drawn at corners.
3 Use a ruler to connect the symbols with wires. Wires should generally only change angles at 90°.
4 Make sure that the wires don't cross.
5 Check the circuit by tracing around from the battery through each component and back to the battery.

How is a closed switch drawn?

INVESTIGATION 6.4
Investigating conductors and insulators

KEY SKILL
Identifying the variables and formulating a hypothesis

▶ *Go to page* ***182***

CHECKPOINT 6.4

1 **a** Identify each of the circuits in Figure 6.11 as open or closed.
b In which of the circuits will the bulbs light up?

2 Draw these components in a simple circuit: battery, open switch, bulb.

3 Draw the components in question 2 in a closed circuit and add arrows to show the direction of the flow of energy.

4 Electricity will only flow through a complete circuit. Explain why.

5 Give some advice about how to draw an accurate circuit diagram.

CRITICAL AND CREATIVE THINKING

6 Design and create a card for a special occasion that will light up using LEDs, wires and a switch. Draft the circuit diagram and check with your teacher before building your circuit. Be creative!

SUCCESS CRITERIA

- I can draw a simple closed circuit that shows wires, a switch, lamp and battery.
- I can identify the different components of a circuit from their symbols.
- I can create a circuit from a circuit diagram.

6.5 SERIES AND PARALLEL CIRCUITS

LEARNING INTENTION

At the end of this lesson I will be able to compare the features of series and parallel circuits.

KEY TERMS

parallel circuit
a circuit in which all components are connected between the same points, so the current has more than one path to take

reciprocal
the reciprocal of a number is 1 divided by that number

series circuit
a circuit in which components are arranged in a chain, so the current has only one path to take

LITERACY LINK

LISTENING

Design a simple circuit containing three light bulbs. Describe your circuit to a partner while they try to draw it from your description.

NUMERACY LINK

CALCULATION

Three resistors (3 Ω, 4 Ω and 6 Ω) are connected in parallel and then connected to a 4 V battery.

a What is the resistance of the parallel combination?

b What is the current through each resistor?

Have you ever plugged in a string of Christmas lights, only to find they won't turn on because a single bulb is out? You have to test every single globe in the string to find the faulty one. This is because the lights are part of a series circuit, and a single bulb will stop the flow of electricity through the whole circuit.

A parallel circuit allows components to work independently of each other. A string of Christmas lights that are connected in parallel would still work if one of the bulbs was broken.

1 In series circuits, components are connected one after another

When components in a circuit are arranged one after another, this is called a **series circuit**. If you trace your finger over the circuit or diagram, you will be able to pass through every component back to the start without having to retrace your path. There is only one path for the current to flow.

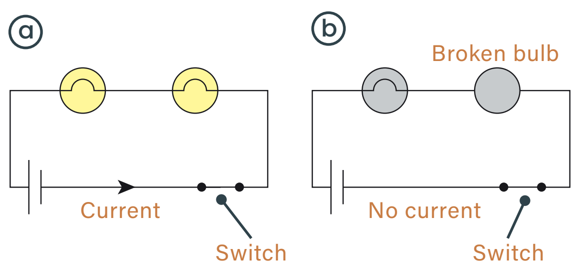


Figure 6.12
(a) In a complete series circuit, the bulbs light up.
(b) A broken bulb causes an incomplete circuit and no bulbs light up.

The circuit needs to be complete for current to flow. If one of the components breaks or is removed, then the circuit is incomplete and no current can flow (Figure 6.12b).

What is a series circuit?

2 In parallel circuits, components are on different branches

In a **parallel circuit**, each component is connected on a different branch of the circuit. To check if components are connected in parallel, trace around the circuit. If you come to a point where you must choose between two or more branches, then this circuit is parallel.

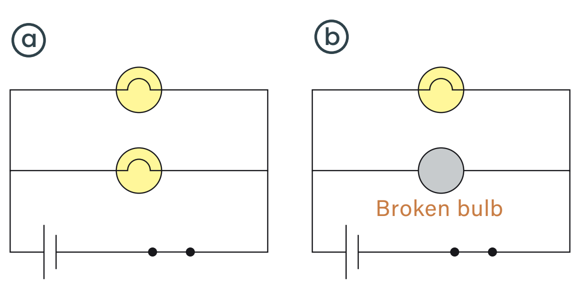
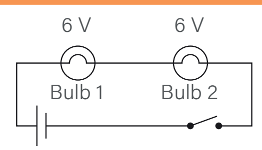
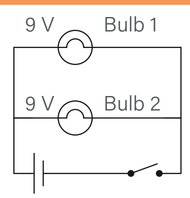
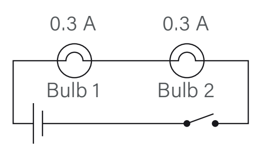
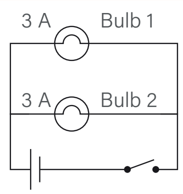
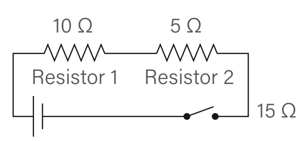
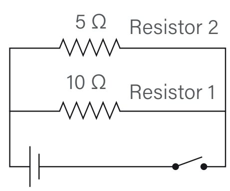


Figure 6.13
(a) In the complete parallel circuit, the bulbs light up.
(b) A broken bulb does not cause an incomplete circuit and the other bulbs remain lit.

The branches in a parallel circuit mean that if a component breaks, the circuit can still be complete through the connections in the other branches. A bulb in this part of the circuit stays on even when a bulb in the other branch breaks.

House wiring is an example of parallel circuits. Parallel circuits require more wiring, but if one light bulb breaks or is removed, then the rest of the house lights can still work even if they are controlled by the same switch.

Table 6.2 Summary of voltage, current and resistance in series and parallel circuits

	Series circuit	Parallel circuit
Voltage	 12 V 6 V + 6 V = 12 V Bulb 1 + bulb 2 = total The voltages across components add up to the total voltage supplied by the battery.	 9 V = 9 V = 9 V Bulb 1 = bulb 2 = total The voltage across each component is the same.
Current	 0.3 A = 0.3 A = 0.3 A Bulb 1 = bulb 2 = total The current is the same everywhere in the circuit.	 3 A + 3 A = 6 A Bulb 1 + bulb 2 = total The current in each component adds up to the total current in the main branch containing the battery.
Resistance	 10 Ω + 5 Ω = 15 Ω Resistor 1 + resistor 2 = total The resistances of components add up to the total resistance of the circuit. The total resistance in the circuit is *more* than the resistance of each component.	 $\frac{1}{10\ \Omega} + \frac{1}{5\ \Omega} = \frac{1}{\text{TOTAL}}$ $0.1\ \Omega + 0.2\ \Omega = \frac{1}{\text{TOTAL}}$ $0.3\ \Omega = \frac{1}{\text{TOTAL}}$ TOTAL = 3.33 Ω The **reciprocal** of the total resistance is found by adding the reciprocal of the resistance of each component. The total resistance of the circuit is *less* than the resistance of each component.

What is a parallel circuit?

INVESTIGATION 6.5

Series and parallel circuits

KEY SKILL
Explaining results using scientific knowledge

▶ *Go to page* ***184***

CHECKPOINT 6.5

1 Explain the difference between series and parallel circuits.

2 Draw a simple labelled diagram of a series and a parallel circuit.

3 Describe the placement of components in series and parallel circuits.

4 Give an example of a product that may contain a:
  a series circuit
  b parallel circuit.

5 Calculate the total resistance in a circuit in which two 10 Ω resistors are connected in:
  a series
  b parallel.

CRITICAL AND CREATIVE THINKING

6 Design a circuit that contains two light bulbs that can operate independently. If possible, set up your circuit and test it in class.

SUCCESS CRITERIA

- I can compare the features of series and parallel circuits.
- I can calculate voltage, current and resistance in series and parallel circuits.
- I can give examples of how series and parallel circuits are used.

6.6 MODERN ELECTRONICS

LEARNING INTENTION

At the end of this lesson I will be able to outline some examples of technological advances that are linked to scientific discoveries.

KEY TERMS

amplifier
an electronic component that boosts electrical current

transistor
an electronic component that can act as a switch or an amplifier

LITERACY LINK

SPEAKING

Read section 2, then explain to a partner what you have learnt. Then listen to your partner explain what they learnt from reading section 3.

NUMERACY LINK

CALCULATION

A carbon atom has a diameter of about 0.33 nanometres (0.33×10^{-9} m). Calculate the number of graphene layers that exist in 1 mm of graphite.

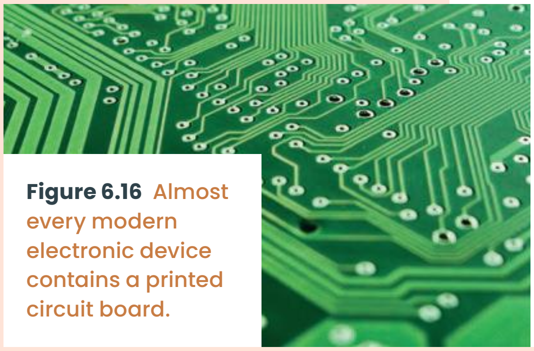


Figure 6.16 Almost every modern electronic device contains a printed circuit board.

One of the earliest ways of storing electrical energy was to use a Leyden jar. This was a glass jar coated inside and out in foil, with a metal bar touching the inside surface. This allowed scientists to store electrical energy to create sparks.

Our understanding of electricity has come a very long way since then, and today it is hard to imagine life without electricity. How did we come to this point, and what is likely to be the future of electric energy?

1 Advances in digital circuits opened up many possibilities in electronics

Transistor

The transistor was invented in 1947 at Bell Labs in the USA. A **transistor** is a small electronic device that can be used as a switch (can be turned on or off by current) or as an **amplifier** (can boost current). The transistor is the basis of all modern digital circuitry and opened up many new possibilities in electronics.

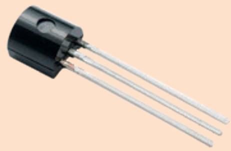


Figure 6.14 The transistor has three terminals and is made of semiconducting materials such as silicon and germanium.

Integrated circuit

The integrated circuit is also known as the microchip. It is a small chip that can contain hundreds or even millions of tiny transistors. There are many different types of microchip that can do a variety of jobs. The invention of the microchip is responsible for the digital explosion in the late 20th century, giving people access to more compact personal electronic devices for the first time.

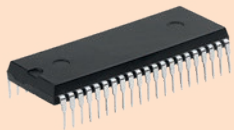


Figure 6.15 The microchip has many terminals that can be connected in a circuit to perform many different tasks.

Printed circuit board

The printed circuit board is a mass-producible base of fibreglass or reinforced plastic with thin strips of conductor to connect components such as microchips. The invention of the printed circuit board contributed to advances in robotics, automation and industry.

What is another name for an integrated circuit?

2 Graphene is used to make small 2D circuits

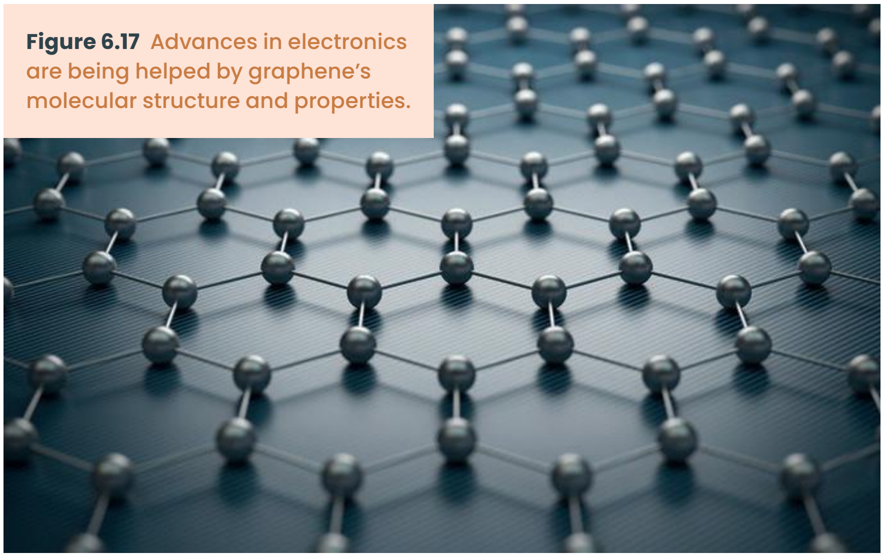
In recent years, scientists have begun developing incredibly flat circuits known as 2D circuits. These are so flat that you could stack 400 000 of them on top of each other, and the stack would still be thinner than a sheet of paper.

2D circuits are usually made of graphene, which is a sheet of carbon that is only a single atom thick. Graphene has incredible properties in terms of strength and flexibility, and is an excellent conductor of electricity.

Graphene may have started the 2D revolution in electronics, but that's just the start. Silicene, phosphorene and stanene (atom-thick forms of silicon, phosphorus and tin, respectively) have a similar honeycomb structure with different properties, allowing for different applications. All four materials could change electronics to allow for miniaturisation, higher performance and lower costs. Several companies, including Samsung and Apple, are developing applications based on graphene.

What is the benefit of a 2D circuit?

Figure 6.17 Advances in electronics are being helped by graphene's molecular structure and properties.



3 Electronic sensors have many applications

A sensor is a device that measures some sort of physical data and converts it to something readable. An example of a sensor is a thermometer, which measures and displays temperature. As technology becomes more advanced, the need for accurate sensors increases. In a regular car, the driver will notice someone crossing the road in front of them and slow down. A self-driving car must have some sort of sensor to detect this same pedestrian. Sensors of this type typically work by sending out some sort of beam and measuring the time it takes for the beam to bounce back, indicating how far away an object is. Sonar and radar are sensors that work in this way.

What is a sensor?

CHECKPOINT 6.6

1 Describe the function of a transistor.

2 What properties of graphene make it so useful for emerging technology?

3 Explain why microchips were a huge technological breakthrough.

4 Describe some applications of electronic sensors.

5 What do you think are some of the benefits of using a printed circuit board (such as in Figure 6.16) instead of wires?

RESEARCH

6 ENIAC was the first general-use computer and was made before microchips were invented. Use the internet to find out how big ENIAC was and how much it weighed, and compare this to a modern-day computer.

SUCCESS CRITERIA

- I can outline at least one recent scientific development in the field of electricity.

VISUAL SUMMARY

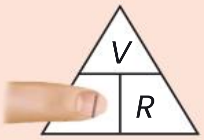
Electricity is a form of energy that can flow from one place to another.

Qualities involved in transporting electricity: Current, Voltage, Resistance

Ohm's law states that current is proportional to voltage.

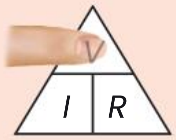
voltage (V) in volts = current (I) in amperes × resistance (R) in ohms

To find current:



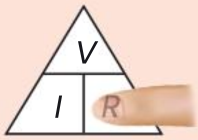
$I = \frac{V}{R}$

To find voltage:

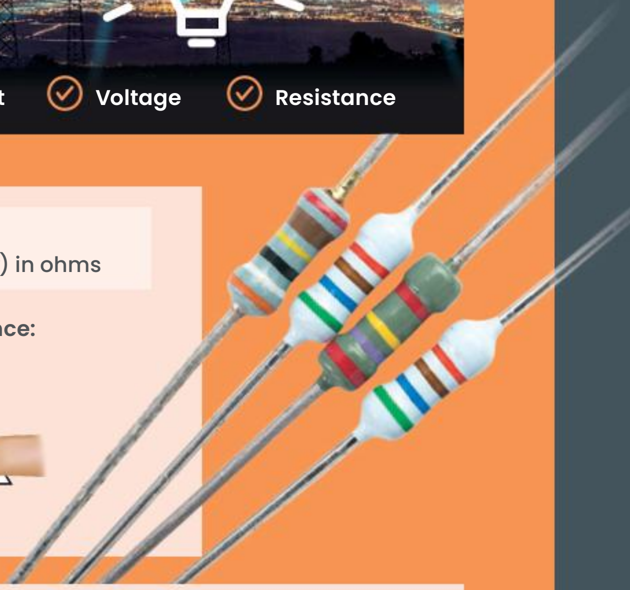


$V = I \times R$

To find resistance:

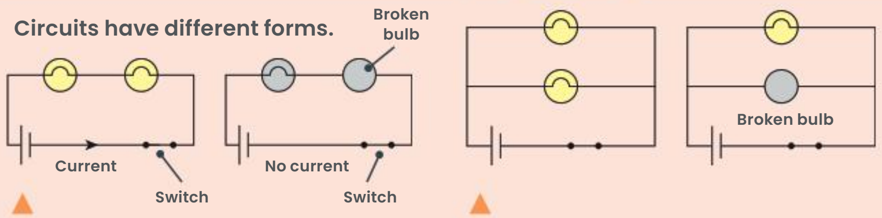


$R = \frac{V}{I}$



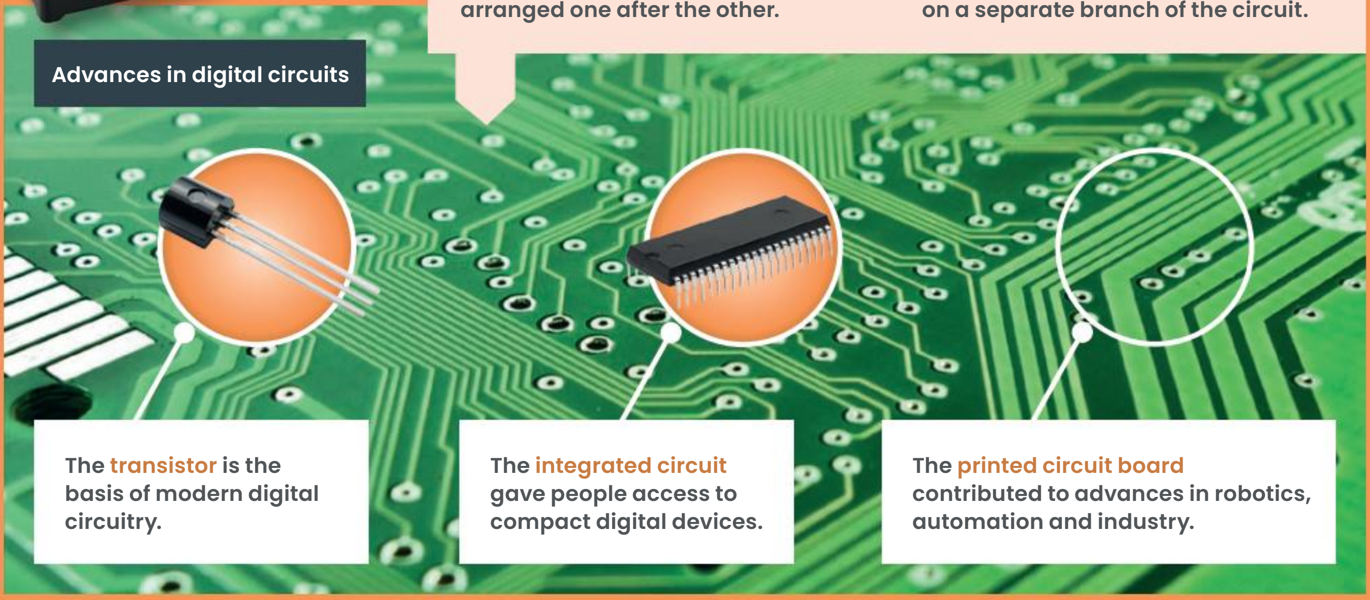
Ammeters measure current.

Circuits have different forms.



Series: Components are arranged one after the other.

Parallel: Each component is connected on a separate branch of the circuit.



Advances in digital circuits

The **transistor** is the basis of modern digital circuitry.

The **integrated circuit** gave people access to compact digital devices.

The **printed circuit board** contributed to advances in robotics, automation and industry.

★ FINAL CHALLENGE ★

1. Match these terms to their definitions.

conductor	the difference in potential energy between two points in a circuit
current	an electronic component that can act as a switch or an amplifier
amplifier	a material that resists the flow of current
transistor	a measure of how fast electrons move in a circuit
insulator	a material that allows the flow of current
voltage	an electronic component that boosts electrical current

Level 1 50xp LEVEL UP!

2. Give the symbols for current, voltage and resistance.
3. Explain what Ohm's law is in your own words.
4. Explain the difference between an amplifier and a transistor.

Level 2 100xp LEVEL UP!

5. Give an example of a new development or technology in relation to the use of electricity.
6. Describe what an ammeter is, how it is used and what it measures.
7. Explain the difference between current and voltage in your own words.

Level 3 150xp LEVEL UP!

8. Calculate the:
   - **a** resistance of the resistor in a circuit that has a voltage of 6 V and a current of 0.7 A
   - **b** current in an electrical component that has a resistance of 12 Ω and a voltage of 16 V
   - **c** voltage in an electrical component that has a resistance of 12 Ω and a current of 24 A.

Level 4 200xp LEVEL UP!

9. If you adjust the current but keep the resistance the same, will this affect the voltage? Give evidence for your answer.
10. Draw and label a diagram of a series circuit and a parallel circuit. Annotate the diagrams to highlight how they are different (in red pen) and how they are similar (in blue pen).

Level 5 300xp LEVEL UP!

MAGNETISM

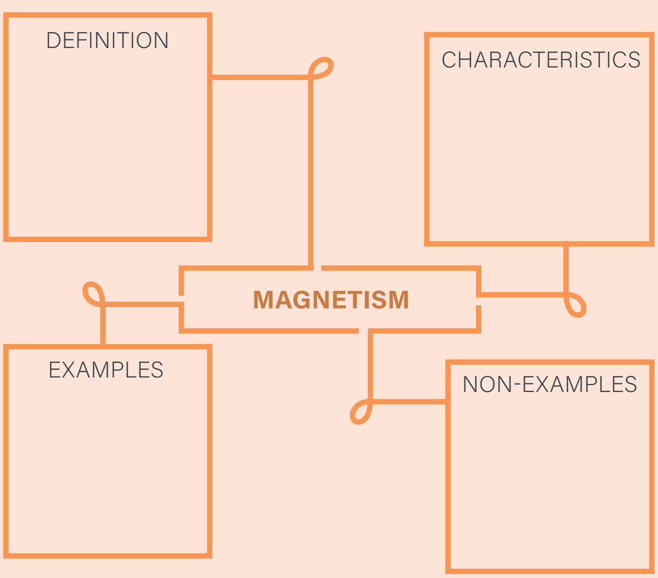
Why can't electricity and magnetism exist without each other?

When you think of forces, you might think of physical actions such as dragging a box along a floor, or the thrust from a car's engine. These are called contact forces because objects are physically interacting (coming into contact) with each other.

Some forces, called non-contact forces, have no physical interactions. Gravity can pull things towards Earth without touching them, and magnets attract pieces of metal without contact. A place where a non-contact force is acting is called a field. Right now, you're being acted on by gravity from Earth – you're in Earth's gravitational field.

1 FRAYER MODEL

Copy and complete the below chart in your workbook.



Complete two additional charts for the key terms *Field* and *Motor*.

2 LEARNING LINKS

Brainstorm everything you already know about magnetism.

3 SEE-KNOW-WONDER

List three things you can SEE, three things you KNOW and three things you WONDER about this image.

4 CRITICAL + CREATIVE THINKING

WHAT IF ... Earth suddenly swapped gravitational fields with the Moon?

MISMATCHES: How could you lift a piano using a coathanger, a magnet and a box of matches?

THE BAR: Think of one thing you would make **B**igger, one thing you would **A**dd and one thing you would **R**eplace on an electric car.

5 THE PRETTIEST!

Auroras are beautiful displays of light seen in the night sky in areas near or at Earth's poles (such as in the Arctic or Antarctica). They happen when charged particles drawn into Earth's magnetic field excite atoms in the air, causing patterns of green, red and blue light.

Due to their rarity in some parts of the world, auroras are part of several myths and legends about Greek, Roman and Norse gods, and even Chinese dragons.

7.1 INTRODUCTION TO FIELDS

LEARNING INTENTION

At the end of this lesson I will be able to use the term 'field' in describing forces acting at a distance.

KEY TERMS

electrostatic force
a non-contact force between any objects with an electric charge

field
an area of space where objects are affected by a non-contact force

field line
a line used to show the direction of a force within a field

gravitational force
a non-contact force that affects all matter

magnetic force
a non-contact force that affects any object made of certain metals, such as iron

NUMERACY LINK

GRAPHING

The field strength of a magnet was measured at several different distances.

Distance (cm)	Field strength (T)
10	18
20	4.5
30	2
40	1.125

Display this data in a line graph.

Most forces are contact forces. This means that objects need to touch for one object to exert force on another. You can't lift a box just by pointing at it or thinking about it – you need to use the force generated by your muscles.

A non-contact force can act on an object without having any physical contact. This happens when the object is within an area of influence, called a **field**, and has properties affected by that field.

1 Non-contact forces can be gravitational, magnetic or electrostatic

Non-contact forces can work at a distance, without contact. Only a few of these forces exist in the universe, and they only affect certain objects in their fields.

- **Gravitational forces** are the most common, and they affect any objects containing matter.
- **Magnetic forces** affect any object made of certain metals, such as iron, nickel or cobalt.
- **Electrostatic forces** affect any object that has an electrical charge, even very weak charges.

Why are gravitational, magnetic and electrostatic forces called non-contact forces?

2 Fields are the areas where non-contact forces act

Any area where non-contact forces act on objects is a field. For example, any object in space that is affected by a gravitational force from Earth is said to be within Earth's gravitational field. This is the same for magnetic and electrostatic fields.

If something is outside the field of a non-contact force, it's not affected by that force. The limits of a field can be hard to measure.

How can you tell if an object is within a field?

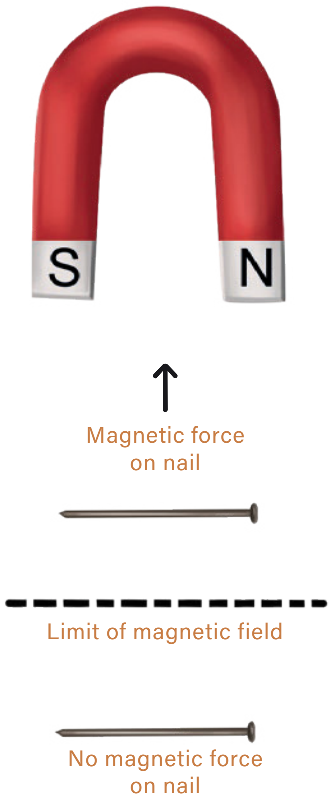


Figure 7.1 The nail within the magnetic field is attracted to the magnet, but the one outside the field is not.

3 The strength of a force varies within a field

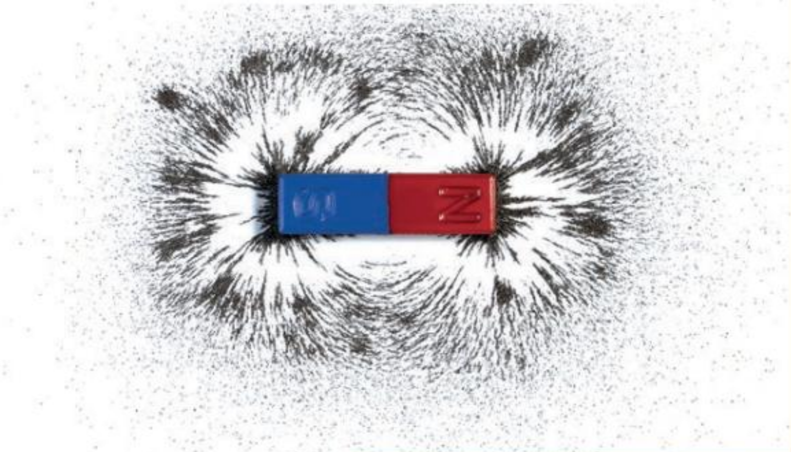
Have you ever seen an image of iron shavings around a bar magnet, or observed them in class? One thing you may have noticed is that the iron filings are thickest at the ends of the bar magnet, but are less thick in other areas. This is evidence that the non-contact forces within fields are not always the same.

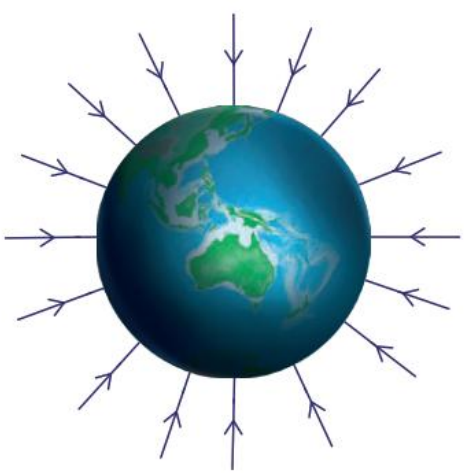
Field lines can help to locate the source of a force. For example, the field lines around a bar magnet show that the ends of the magnet generate the force, not the whole magnet.

An object that is close to the source of a field will be under a larger force than an object that is further away. This is shown by drawing field lines that are closer together.

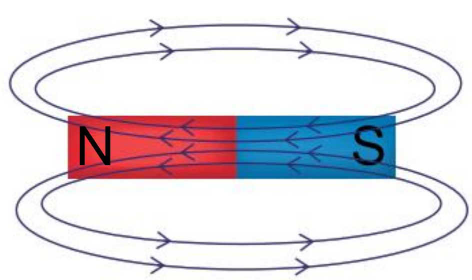
How can you tell where a non-contact force is the strongest?

Figure 7.2 Iron filings gather in the areas around a magnet where the magnetic field is strongest.



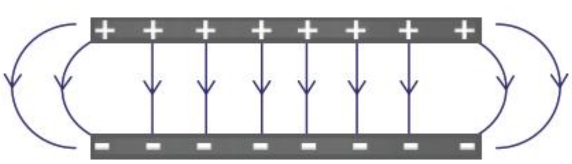


Gravitational field lines



Magnetic field lines

Figure 7.3 Field lines show how the different non-contact forces operate within fields.



Electrostatic field lines

CHECKPOINT 7.1

1 What is a non-contact force?

2 What are three examples of non-contact forces?

3 What is the name of the area that non-contact forces act in?

4 Outline the evidence that suggests that fields generate forces of different sizes in certain areas.

5 What is something that reduces the force on an object and is common between the three types of non-contact forces?

6 Using the diagram of the field lines around the bar magnet in Figure 7.3 to help you, draw how you think field lines would look around a horseshoe magnet.

CONNECTING IDEAS

7 Suggest how you could use a compass to find the magnetic field direction at different points around a magnet.

SUCCESS CRITERIA

- I can explain what fields are and how they work.
- I can describe the difference between contact and non-contact forces and give examples of each.

7.2 HOW MAGNETS BEHAVE

LEARNING INTENTION

At the end of this lesson I will be able to describe the behaviour of magnetic poles when they are brought close together.

KEY TERMS

attractive force
a force that pulls objects towards each other

like poles
magnetic poles that are the same (both north or both south); they repel each other

magnetic pole
one of the two ends of a magnet

repulsive force
a force that pushes objects away from each other

unlike poles
magnetic poles that are different (south-north or north-south); they attract each other

LITERACY LINK

WRITING

Write a two-part statement to describe the general rules of behaviour between two magnets.

NUMERACY LINK

CALCULATION

A magnet exerts a force of 0.07 N on a piece of iron. If that force becomes 100 times stronger, what will it be now?

A magnet is made of a material that has two **magnetic poles**, north and south. The direction of magnetic force in a magnet is from the north pole to the south pole.

When poles are brought together, the lines of force interact, pulling them together or pushing them apart. **Like poles** repel each other and **unlike poles** attract.

1 Magnetic field lines show the direction of magnetic forces

Each field line around a magnet shows the magnetic forces of the magnet's poles at that place. These lines can also show the direction of the magnetic force, and how that affects objects within the magnetic field.

One way to examine the field lines around a magnet is to use a compass. When you put a compass in a magnetic field, the compass needle lines up with the direction of the field lines around the magnet. The needle will always point from the magnet's north pole to its south pole. This shows that the direction of a magnetic force around a magnet is from north to south.

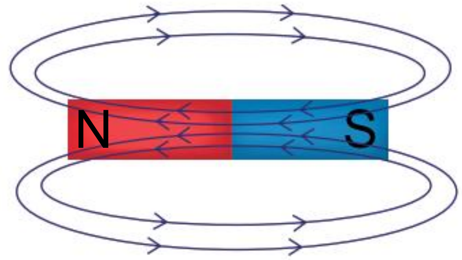


Figure 7.4 The direction of magnetic forces in a bar magnet is in a loop from the north pole to the south pole.

Here are some other things to remember about magnetic field lines:

- The distance between field lines represents the strength of a field in any given area.
- Field lines can never cross one another.
- Field lines continue through the magnets.

In which direction do the arrows point on magnetic field lines?

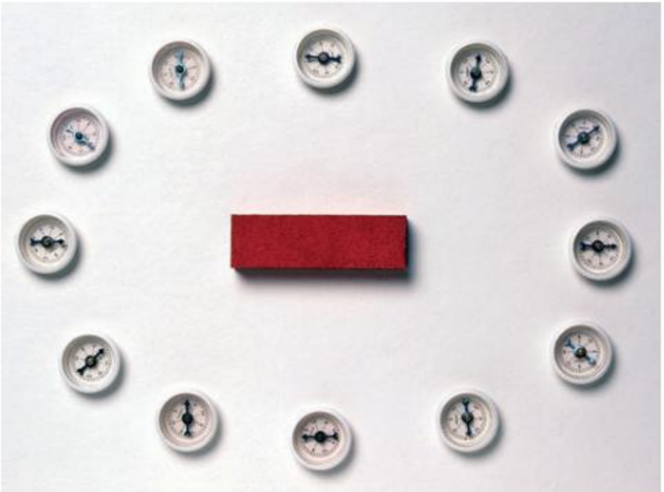


Figure 7.5 A compass can be used to show the direction of magnetic field lines.

2 Like magnetic poles repel each other

When the north poles of two magnets are moved close together, a **repulsive force** is made and pushes them away from each other. This is because the field from one north pole cannot enter or cross the field of the other north pole. Instead, the fields move away from each other and the field lines become more tightly packed.

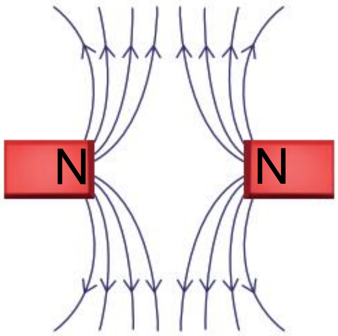


Figure 7.6 When two like poles are put together, the repulsive force can be strong enough to cause one object to hover over the other.

Although the fields between two north poles have been squeezed into a smaller area, the distance between field lines still shows the strength of the field. The force pushing the two poles apart becomes stronger.

A repulsive force also happens between the south poles of two magnets. This means we can say that, for all magnets, like poles repel.

When two like poles are moved closer together, what happens to their magnetic fields?

3 Unlike poles attract each other

When the opposite poles of two magnets are brought close together, an **attractive force** is made. This is because the field lines from the north pole of one magnet can flow easily into the south pole of the other magnet. In other words, unlike poles attract.

When two magnets get close enough to each other, they act as one big magnet rather than two joined magnets.

What type of force happens between the north pole of one magnet and the south pole of another?

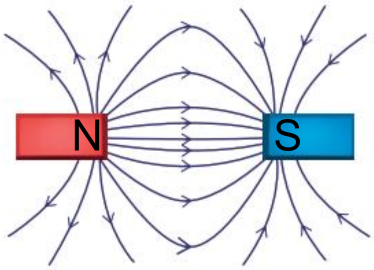


Figure 7.7 When two unlike poles are put together, the forces pull the north pole of one magnet towards the south pole of the other.

INVESTIGATION 7.2

Magnets and Matchbox cars

KEY SKILL
Writing a research question

▶ *Go to page* ***186***

CHECKPOINT 7.2

1 Which pole on a magnet does a compass needle point towards?

2 What happens when the like poles of two magnets are pushed closer together?

3 Draw a diagram that shows the field lines of a magnet that is attracted to another magnet.

4 How could you map the direction of the field lines between two magnets?

5 Write a use for both the attractive force and the repulsive force between two magnets.

EXTENSION

6 Some trains use magnets to move incredibly quickly. Suggest how you could use both attractive and repulsive forces to move a train, then research 'maglev trains' and see if your suggestion is correct.

SUCCESS CRITERIA

- I can describe the behaviour of like and unlike poles when they are brought close together.
- I can draw a diagram that shows magnetic field lines.

7.3 USES OF MAGNETS AND ELECTRO-MAGNETS

LEARNING INTENTION

At the end of this lesson I will be able to investigate how magnets and electromagnets are used in some devices and technologies that are used in everyday life.

KEY TERMS

electromagnet
a device that uses electricity to make a magnetic field

polarity
the direction of a force, such as a magnetic force

LITERACY LINK

READING

Choose 10 words from this lesson and write a brief definition in your own words for each.

NUMERACY LINK

DATA

Tran is designing an experiment to test the strength of a magnet. What is one type of qualitative and one type of quantitative data he could obtain?

Ordinary magnets have a magnetic field that is always on – they don't need a supply of electricity. **Electromagnets** make magnetic fields using the flow of electricity.

Electromagnets are very useful because the strength and direction of their field can be easily changed. They are important parts of devices such as speakers, electric motors, medical equipment and computers.

1 Electromagnets use electricity to make a magnetic field

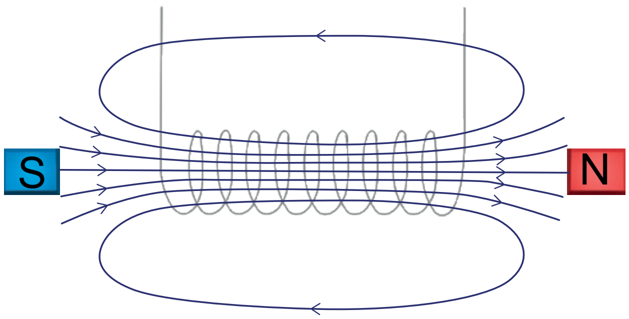
An electromagnet uses the flow of electricity to produce a magnetic field. The movement of electricity through a wire makes a circular magnetic field around the wire. If the wire is coiled into a spiral and electricity flows through it, then the field around the wire builds into one large field that's like the field around a bar magnet.

The field in the spiral can be strengthened by:

- placing an iron core in the middle
- increasing the amount of electricity
- making electricity flow faster
- using more wire to create more coils or loops in the spiral.

What is an electromagnet?

Figure 7.8 The magnetic field around an electromagnet's core has a north and a south pole, like a bar magnet.



2 Magnets can hold objects together

Ordinary magnets are sometimes called permanent magnets, because they constantly have magnetic force. The most common use of magnets is to hold objects together. The constant attractive force acts on certain metals or the opposite pole of another magnet.

Magnets used to hold objects together are on cabinet and fridge doors, wallet and purse clasps, and even some charger cords. Some tools, such as screwdrivers, have magnetic heads, which allows screws to 'stick' to the tool without needing to be held.

How are magnets commonly used?

Figure 7.9 A magnetic screwdriver head allows you to hold screws in place or pick them up more easily if you drop them.

INVESTIGATION 7.3

Building an electric motor

KEY SKILL
Identifying and managing relevant risks

▶ *Go to page* ***187***

3 Electromagnets are used in devices such as speakers and medical equipment

Electromagnets are used in an enormous number of devices and technologies. This is because they can change the strength of their magnetic field very precisely. They can also change the direction, or **polarity**, of their magnetic field.

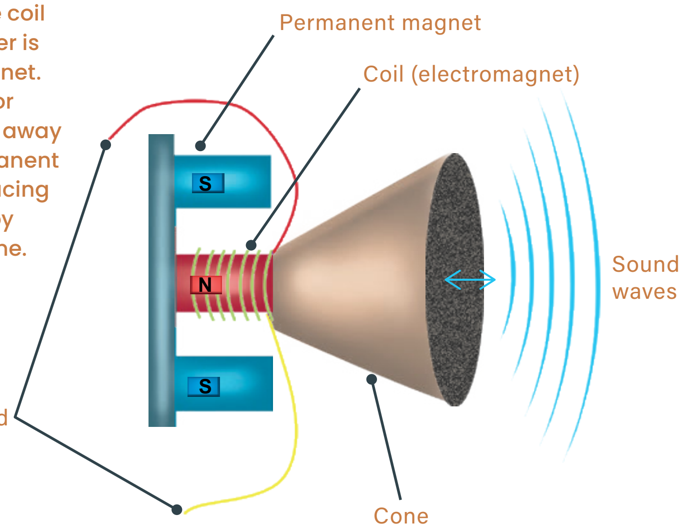
When a speaker is connected to a powered device playing music, the electricity changes the coil in the speaker into an electromagnet. The electromagnet can rapidly flip its field direction. This attracts and then repels a permanent magnet inside the speaker. The electro-magnetic coil moves back and forth, pushing sound waves through the 'skin' of the speaker cone.

Computers contain very sensitive electromagnets. They're used in hard drives to read information stored on metallic strips.

Another major use of electromagnets is in medical equipment. Magnetic resonance imaging (MRI) scanners generate magnetic fields that can be used to create images of the inside of the human body.

What is one common use of electromagnets?

Figure 7.10 The coil inside a speaker is an electromagnet. It pulls closer or pushes further away from the permanent magnet, producing sound waves by moving the cone.



CHECKPOINT 7.3

1 What does the flow of electricity make in an electromagnet?

2 How can you increase the strength of an electromagnet?

3 What is the most common way that magnets are used in everyday life?

4 What can electromagnets do that permanent magnets cannot?

5 How does an electromagnet create a magnetic field?

6 List the magnets you can find either around your classroom or around your home. For each one, describe the purpose they serve and why they are used.

INQUIRY

7 One common use of electromagnets is as a transformer. Research what a transformer is, and give some examples of how it is used in modern devices.

SUCCESS CRITERIA

- I can describe how magnets are used in everyday life.
- I can describe what an electromagnet is and how electromagnets are used in everyday life.

7.4 MOTORS AND GENERATORS

LEARNING INTENTION

At the end of this lesson I will be able to explain how magnets can be used to generate electricity and motion.

KEY TERMS

generator
a device that converts kinetic energy into electricity

Lorentz force
a force created by a current flowing through a magnetic field

motor
a device that converts electricity into kinetic energy

solenoid
a tight coil of wire

LITERACY LINK

SPEAKING

After reading this lesson, explain how a generator works to a partner. Then listen to your partner explain how a motor works.

NUMERACY LINK

UNITS

The frequency of rotation of a coil in a motor is measured in hertz (Hz). 10 Hz means the coil rotates 10 times per second. How long would it take a 50 Hz coil to rotate once?

Electricity and magnetism are very closely linked. This is why 'electromagnetism' is considered a single phenomenon. In fact, you can generate an electric current by using a magnetic field, and you can generate a magnetic field by using an electric current. This close relationship between electricity and magnetism is used in several modern devices.

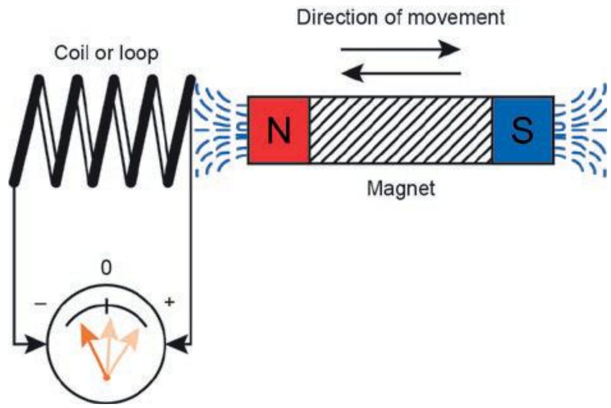
1 A magnetic field can create a current

Any electric current running through a wire will generate a magnetic field. If the current is running in a straight line, the magnetic field will be circular. If the current is travelling in a circle, the magnetic field will be straight. This is the basis of electromagnets – running a current through a coil of wire will generate a magnetic field that can be used to lift very heavy metal objects.

Likewise, a magnetic field can also be used to generate a current. Moving a magnet into a **solenoid** will cause a current to flow in it. However, if the magnet stops moving, the current will also stop. The wire and the magnetic field must move relative to one another in order to keep the current flowing.

What must a magnet do to generate a current?

Figure 7.11
Moving a magnet into a coil or loop will cause a current to flow in it.



2 Generators generate electricity from motion

Some people with unreliable access to electricity may use a **generator**. A generator is a machine that can burn fuel to generate electricity. A simple generator consists of a coil of wire inside a magnetic field. The fuel is burned, causing the coil to spin. As the wire is moving relative to the magnetic field, a current will be induced in it. We can use the electricity from a generator to power electrical appliances when not connected to main power lines.

What type of energy does a generator convert?

Figure 7.12 Research stations in Antarctica require generators to provide them with electricity.

CHECKPOINT 7.4

1 Describe one way in which electricity and magnetism are related to one another.

2 Susie holds a magnet inside a coil of wire connected to an ammeter, but no current flows. What must she do to generate a current?

3 Explain the difference between a generator and a motor in your own words.

4 Name three devices at your house that contain an electric motor. (Hint: Think of things that need to be plugged in to move.)

5 All hospitals have a generator on the premises. Suggest why.

STUDENT VOICE AND AGENCY

6 Design an experiment that will allow you to measure the size of the Lorentz force acting on a wire.

❸ Motors generate motion from electricity

While a generator will turn kinetic energy into electricity, a **motor** will turn electricity into kinetic energy. This works in a very similar way to how a generator operates. Like in a generator, an electric motor consists of a wire coil in a magnetic field. This coil is connected to some sort of power source so that current flows through it. When an electric current flows through a magnetic field, a force (called the **Lorentz force**) is generated that pushes against the wire. This force causes the wire coil to spin around, and this spinning motion can be used to power all sorts of things, from power tools to electric cars.

What type of energy does a motor convert?

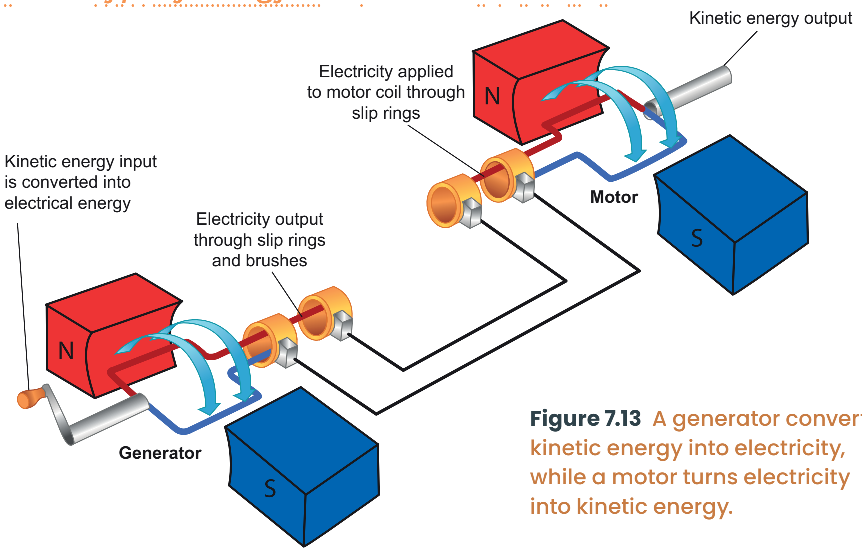


Figure 7.13 A generator converts kinetic energy into electricity, while a motor turns electricity into kinetic energy.

SUCCESS CRITERIA

- I can describe how a magnet can create an electric current.
- I can explain the difference between a motor and a generator.

VISUAL SUMMARY

Forces are the result of objects interacting with each other or with a field.

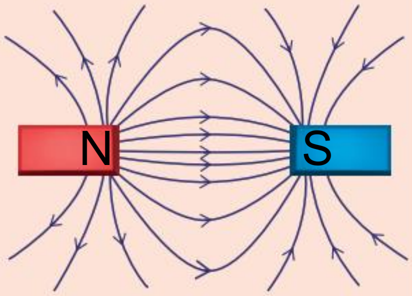
Magnetic forces affect any objects that contain certain metals.

Fields are areas in which non-contact forces act on certain objects

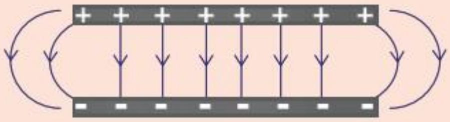
Electrostatic forces affect any objects with a positive or negative charge.

Gravitational forces affect all objects made of matter.

Like magnetic poles repel and unlike poles attract.



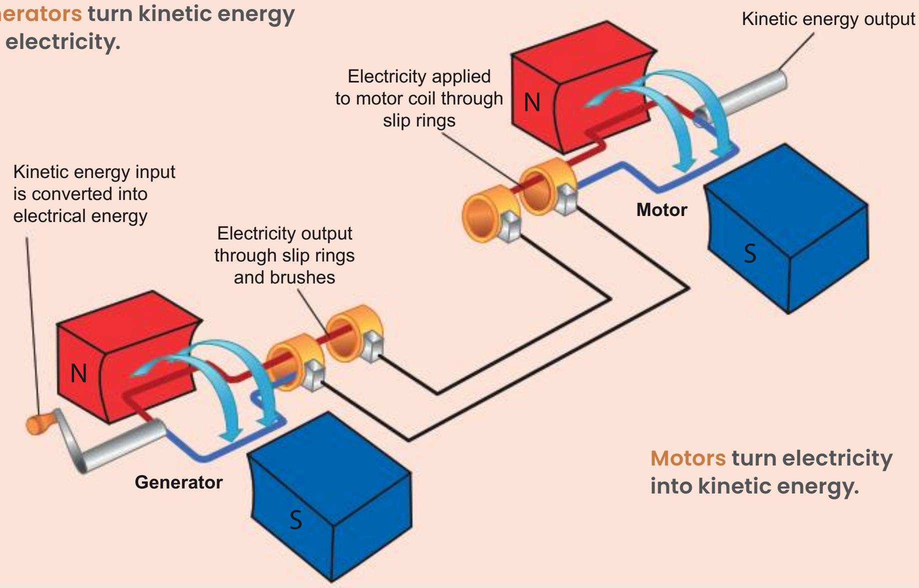
Like electrostatic charges repel and unlike charges attract.



Objects with high mass gravitationally attract objects with lower mass.

Electromagnets are used in devices such as speakers and medical equipment.

Generators turn kinetic energy into electricity.



Motors turn electricity into kinetic energy.

★ FINAL CHALLENGE ★

1. In your own words, provide a definition of the word 'field'.
2. Copy and complete the following sentence: Like poles _________ each other, while unlike poles _________ each other.
3. Explain what an electrostatic charge is.

Level 1 ★☆☆☆☆☆ 50xp — LEVEL UP!

4. Draw a diagram showing the magnetic field lines of:
   a two like poles close to one another
   b two unlike poles close to one another.
5. Draw a diagram showing how gravity acts for two people standing on opposite sides of Earth.

Level 2 ★★☆☆☆☆ 100xp — LEVEL UP!

6. List three everyday devices or technologies that use either magnets or electromagnets.
7. You have two positively charged objects and you bring them close together. Describe what will happen.
8. An object that has been dropped will speed up as it falls. Explain why.

Level 3 ★★★☆☆☆ 150xp — LEVEL UP!

9. Describe the conditions that must be present in order for lightning to occur.
10. Using your understanding of gravity, explain why your weight would be different on different planets.

Level 4 ★★★★☆☆ 200xp — LEVEL UP!

11. Rubbing a balloon on your hair causes an electrostatic charge to form. Describe what is happening to the atoms of the balloon and your hair when this occurs.
12. Design a device that could be used to protect cars from lightning strikes. Draw a diagram and show all required materials.

Level 5 ★★★★★★ 300xp — LEVEL UP!

SKILLS AND INVESTIGATIONS

SCIENCE SKILLS

Questioning, predicting and planning

Collecting and using data

Analysing and visualising data

Uncertainty, errors and mistakes

Science in the media

Writing investigation reports

INVESTIGATIONS

BIOLOGICAL SCIENCES

1.1A Sensory receptors

1.1B Reaction time

1.2 Sheep brain dissection

1.3A Heart dissection

1.3B Heart rate, breathing rate and exercise

1.6 The contagion game

2.1 Identifying community members in a terrestrial ecosystem

2.3 Measuring abiotic factors

2.5 Algal balls

CHEMICAL SCIENCES

3.2A Making an atom

3.2B Flame test

3.3 Half-life coin experiment

3.4 Nuclear energy debate

4.2 Exothermic and endothermic reactions

4.3A Action of acids and bases – cleaning coins

4.3B Acid or base?

4.3C The effect of indicators on acids and bases

4.4A Reactions of acids with metals

4.4B Reactions of acids with carbonate

4.5A Combustion of fuels

4.5B Complete and incomplete combustion reactions

4.7A Corrosion of iron

4.7B Preventing corrosion

4.8 Precipitation reactions

EARTH AND SPACE SCIENCES

5.1 Modelling seafloor spreading

5.2 Modelling plate boundaries

5.3A Modelling slab pull

5.3B Observing convection currents

5.4 Slinky waves

5.5A Viscosity of lava

5.5B Wax volcano

PHYSICAL SCIENCES

6.2 Modelling a simple circuit

6.3 Exploring Ohm's law

6.4 Investigation conductors and insulators

6.5 Series and parallel circuits

7.2 Magnets and Matchbox cars

7.3 Building an electric motor

KEY SKILLS

Representing data to identify patterns and trends	Investigation 1.1A Investigation 1.3B Investigation 3.3
Identifying the variables and formulating a hypothesis	Investigation 1.1B Investigation 2.5 Investigation 6.3 Investigation 6.4
Identifying and managing relevant risks	Investigation 1.2 Investigation 2.1 Investigation 4.3C Investigation 4.4B Investigation 5.2 Investigation 5.5B Investigation 7.3
Writing a research question	Investigation 1.3A Investigation 2.3 Investigation 5.3A Investigation 7.2
Explaining results using scientific knowledge	Investigation 1.6 Investigation 4.2 Investigation 4.4A Investigation 5.3B Investigation 6.5
Using modelling and simulations	Investigation 3.2A Investigation 5.4 Investigation 6.2
Identifying the independent, dependent and controlled variables	Investigation 3.2B Investigation 4.3A Investigation 4.8
Referencing sources of information	Investigation 3.4 Investigation 5.1
Evaluating results for reliability and validity	Investigation 4.3B Investigation 4.5A Investigation 5.5A
Identifying the controlled variables	Investigation 4.5B
Drawing conclusions consistent with evidence	Investigation 4.7A
Identifying limitations to the method and suggesting improvements	Investigation 4.7B

QUESTIONING, PREDICTING AND PLANNING

KEY TERMS

controlled variables
all the things that need to stay the same during an investigation

dependent variable
the thing that will be measured and is altered by the independent variable

experiment
an investigation carried out under controlled conditions, to test a hypothesis

fair test
an investigation in which only one factor is changed and all other variables are kept the same

fieldwork
an investigation conducted in the natural environment, not a laboratory

hypothesis
a scientific statement that can be tested

independent variable
the thing that is purposefully changed during an investigation

reliable
provides consistent results when repeated

research
to gather data and information in an organised way to inform a hypothesis or an investigation

valid
measures what is intended to be measured

Science is all about investigating – asking questions, looking at data and drawing conclusions about how things work. A scientist is like a detective, but instead of investigating a crime, they're investigating the world. To be useful, a good scientific test needs to follow certain principles.

1 Good science needs to be valid and reliable

When scientists design investigations, they ask themselves 'is this *good science*?'

To figure out if something is good science, you need to check that it's both **valid** and **reliable**. If a test is reliable, you can do the test over and over again and get very similar results. If a test is valid, it measures what it is supposed to measure.

Imagine you design a catapult that launches marshmallows and decide to test it against a friend's design. Just as your friend is firing the catapult, a massive gust of wind blows their marshmallow further than yours – that's not fair, right? It's not a valid outcome because the wind caused the increased distance, not the catapult. The test didn't measure what you wanted it to measure (the power of the catapult); it measured the power of the catapult *and* the power of the wind. It's not reliable because, if you did the test again, the wind might be weaker, stronger or not there at all.

Why does good science need to be valid and reliable?

2 A fair test needs to be controlled

Fair tests are essential for good science. A **fair test** is one in which only one variable is changed and all other variables are kept the same. Variables are the things that can be controlled, changed or measured during an investigation or experiment. There are three main types of variables: independent, dependent and controlled variables.

The **independent variable** is the one thing you want to change in an investigation. If you change more than one thing, the investigation probably won't be a fair test. The **dependent variable** is what you are measuring in an investigation, and is what is altered by the independent variables. Examples include time in seconds or mass in grams.


Experiments are carried out in order to test a hypothesis.

The **controlled variables** are all the things you will keep the same. Examples of controlled variables are temperature, mass, equipment, location and volume.

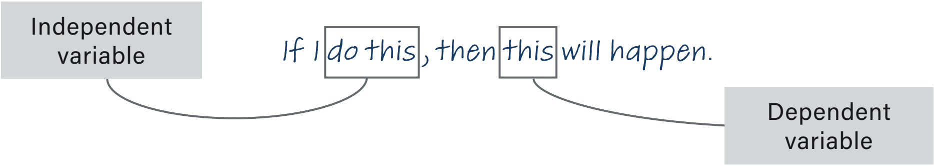
Let's say you decide to put three plants in three different amounts of sunlight to see which plant grows the most. You would make sure the plants were the same size, health and species, and only change the amount of sunlight the plant is getting – this is the independent variable. The dependent variable would be your measurement of the plants' growth (which could be their weight or their size) and the controlled variables are all the other factors.

What are the three types of scientific variable?

3 A hypothesis is a prediction of the outcome

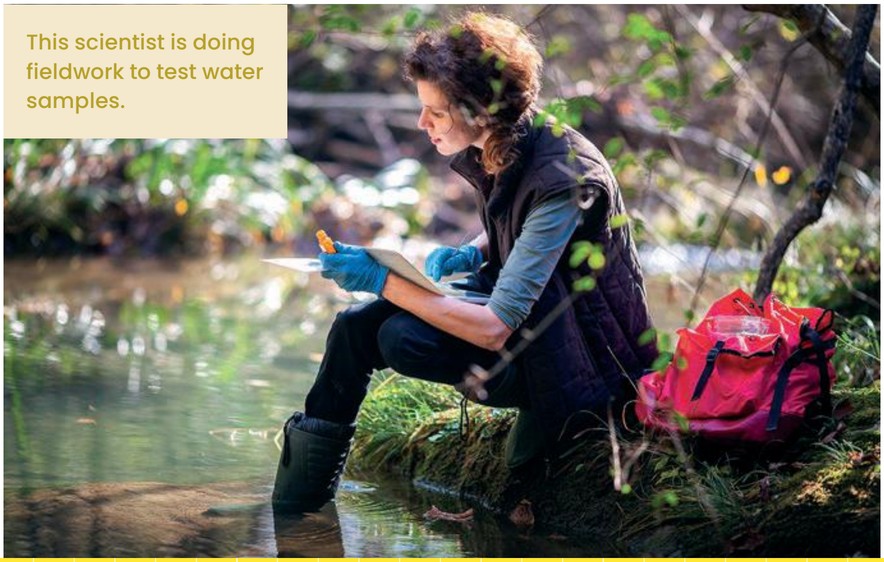
A **hypothesis** is a prediction made to test something. A good hypothesis involves some reading and research so that scientists can make an informed decision about what they think will happen, before testing it in an investigation. A hypothesis can be supported (found to be correct) or rejected (found to be incorrect).

You use the independent and dependent variables when writing a hypothesis, so the first step is always to identify these. The general rule to use when writing a hypothesis is:



Even though this rule has the word 'I' in it, that's not how you write the hypothesis! You should always write it formally and in the third person (don't use *I*, *we*, *you* etc.).

What is a hypothesis?


This scientist is doing fieldwork to test water samples.

ELEMENTS OF AN INVESTIGATION

Think again about the investigation that involves plants in different amounts of sunlight to see which plant grows the most. The elements of this investigation are:

- *hypothesis*: If a plant is placed in direct sunlight, then it will grow more than a plant in indirect or no light.
- *independent variable*: amount of direct sunlight (one plant is put in a dark cupboard, one is put outside in direct sunlight and one is put near a window)
- *dependent variable*: growth of the plant, in millimetres
- *controlled variables*: species of plant, starting size of plant, health of plant, amount of water given to plant.

TYPES OF INVESTIGATIONS

Scientists do many different types of investigations, depending on their area of science and the information they need to gather.

Fieldwork happens when information and data are collected outside of the laboratory or usual setting. Environmental scientists often do fieldwork, such as collecting water samples from streams to study the water quality or counting the numbers of species of plants and animals in an area.

Experiments are usually carried out to test a hypothesis. Experiments in science include (among other things) those undertaken in chemistry, physics, earth science, and with living things in biology.

Research informs a hypothesis before it is created. Scientists often share their research so they can build scientific understanding and discoveries over time.

COLLECTING AND USING DATA

KEY TERMS

accuracy
how close the results are to the true values

inference
an educated guess or judgement based on observations

observation
something you see and know to be true

prediction
a statement about the future based on observation and evidence

primary data
first-hand data, from your own investigation

qualitative
written descriptions and observations

quantitative
numerical information and data

sample size
the number of participants in a survey or samples tested in an experiment

secondary data
second-hand data, from someone else

CALCULATING THE MEAN

To calculate the mean (also known as the average) of a group of numbers, add all the numbers together and then divide them by how many numbers you added together.

For example, to calculate the average temperature change in Table 1, you would add 12, 2, 5, 40 and 9, then divide by 5.

The mean would be (12 +2 + 5 + 40 + 9) ÷ 5 = 13.6 °C

Data is like evidence – you need it to draw your conclusion. Scientists collect and analyse data to test their hypotheses.

1 Scientists collect different types of data

One way to describe data is that it can be **qualitative** or **quantitative**. Quantitative data relates to quantities – that is, numbers. Quantitative data can include the number of something, the volume, the length, time, or anything that scientists can physically measure or count. Qualitative data relates to the qualities of something – that is, written descriptions or observations about data.

Another way to describe data is as **primary data** or **secondary data**. Primary data is first-hand data that you collect yourself through scientific investigation. Secondary data is second-hand data, gathered by someone else and given to or accessed by you.

To make sure secondary data is valid and reliable (see page 128), you need to check that it comes from a reliable source. It's also important to make sure the data is **accurate**. If it is a survey, was the **sample size** large enough or did it only involve a small number of people? Are the results from just one country or population group?

How are qualitative and quantitative data different?

2 Data needs to be carefully collected and recorded

To ensure that their data is valid, scientists record observations and measurements very carefully. They might do this in a logbook or table for quantitative data. Qualitative data might be recorded in a journal or workbook. Sometimes data is visual and can be recorded with a camera.

When taking measurements and recording quantitative data, use the appropriate units for physical quantities. This table shows some common metric units for physical quantities.

Physical quantity	Measurement and unit	Conversion
Length	Millimetre (mm)	10 mm = 1 cm
	Centimetre (cm)	100 cm = 1 m
	Metre (m)	1000 m = 1 km
	Kilometre (km)	
Mass	Milligram (mg)	1000 mg = 1 g
	Gram (g)	1000 g = 1 kg
	Kilogram (kg)	
Volume	Millilitre (mL)	1000 mL = 1 L
	Litre (L)	
Temperature	Celsius (°C)	

Why is it important to use the correct units when measuring?

❸ Organising data makes it easier to understand

Collecting data isn't the end of the process – the data needs to be analysed and considered. That means it must be well organised and clearly presented, or else it will be difficult to understand.

One of the best ways to arrange and present scientific data is in a table. Always design and rule out your table before you start your investigation – this ensures you are ready and organised to collect the correct data, and that you don't forget to collect important data.

MAKING A GOOD SCIENTIFIC DATA TABLE

1 Use a ruler so that your table is clear and easy to read.
2 Give your table a descriptive and useful title and include a table number, in case you want to refer to it in your investigation report.
3 Include the units in the column headings where needed (e.g. mm).

Clear descriptions in titles

Table has a number and title

Units are given at the top of each column

Lines are ruled and easy to follow

TABLE 1: TEMPERATURE CHANGE OF VARIOUS METALS

Metal	Initial temperature (°C)	Final temperature (°C)	Change in temperature (°C)
Aluminium	20	32	12
Copper	20	22	2
Iron	20	25	5
Magnesium	20	60	40
Zinc	20	29	9

Another way to present data is to illustrate it using a chart or graph. This is an excellent visual way to show the data from your table.

Why are tables used to organise data?

Charts, graphs and other visual tools can be used to present and explain data.

Recording your observations is a great way to gather first-hand data.

INFERENCES, OBSERVATIONS AND PREDICTIONS

An **inference** is something you think might be the case, but you don't know for sure. An **observation** is something you see and know is definitely true. A **prediction** is what you think will happen in the future.

In science, an observation can often lead to an inference. You could observe that your cactus is dying, and then infer that this was because it was overwatered. You could then stop watering it and observe it again – this could re-inform and change your inference.

ANALYSING AND VISUALISING DATA

KEY TERMS

mean
the values of a data set added together and divided by the number of values

median
the middle result in a set of data

precision
how close the results of repeated trials are to each other

range
the largest value in a data set minus the smallest value

trend
a consistent change in the values of a data set

TYPES OF DATA

Discrete data is data that can only have certain values. For example, the number of seeds that sprouted in a week. You can't have half a seed sprouting, so our data here can only have the value of whole numbers.

Continuous data is data that can have any value, including decimal points. For example, the time taken for a ball to roll a certain distance. The time could be in seconds, or tenths of seconds, or hundredths or thousandths of seconds. Any data that can take any possible value is continuous data.

After completing an experiment, you now most likely have a table showing the raw data that you collected. But a table full of numbers might not tell you much about what your results mean, so now it's time for some analysis.

1 Raw data needs to be analysed

There are many ways that data collected from an experiment can be analysed. Let's say you performed an experiment to measure how far a catapult will launch a ball. The results are shown in the table on the right. What can we tell from this data?

Trial	Distance (cm)
1	235
2	244
3	242
4	238
5	133

The **mean** is the average of a data set. To calculate the mean, simply add up the values and divide by the number of values. In the case of this data set, the mean is:

$$(235 + 244 + 242 + 238 + 133) \div 5 = 218.4 \text{ cm}$$

The mean is a useful way of determining a predicted value if the experiment were to be repeated.

The **median** is the middle result in a set of data. Using the median rather than the mean offsets the effect of extreme outliers. In the catapult results, the fifth trial clearly travelled a much shorter distance than the others. It appears that something may have gone wrong during this trial – perhaps a misalignment of the catapult or a strong wind affecting the distance. This means that the mean (218.4 cm) is smaller than four out of the five measurements – not ideal when talking about expected values! In this case, it may be better to use the median result. To determine the median, arrange the values in order from smallest to largest (133, 235, 238, 242, 244) and the middle value (238) is the median. 238 cm for this data set is probably much closer to the expected value than our mean of 218.4 cm would be. If there had been an even number of trials, then the median would be calculated by finding the mean of the two middle values.

The **range** of values is the difference between the largest and smallest value. In this example, our range is:

$$244 - 133 = 111 \text{ cm}$$

The range can tell you a lot about the **precision** of the experiment – the smaller the range, the more precise our experiment is. In this case, we have a very large range, and so a very low precision.

The fifth result in this data set is an outlier – a result that is a long way from the other results. If you notice an outlier while performing the experiment, the best approach would be to disregard that particular result and redo it. Hopefully, redoing the trial will give you a result closer to what was expected. If you can't redo the trial (for example, if you've already packed away your equipment before noticing the outlier), it can be either included (if it won't affect the outcome too badly) or excluded from your results. In this case, the outlier is so far from our other results that it makes sense to exclude it – it is clearly an incorrect value. If we removed the fifth trial, we would have a mean of 239.75 cm, a median of 240 cm (the mean of the two middle values) and a range of 6 cm. In short, our data would become much more precise and accurate. However, we cannot just pretend that the fifth trial didn't happen – someone reading your report might understandably wonder why you have five trials for most data points and only four for that point. If you choose to disregard a trial, you must address it in your discussion. You need to explain what the result was, and why you have chosen to remove it.

What is the difference between the mean and the median?

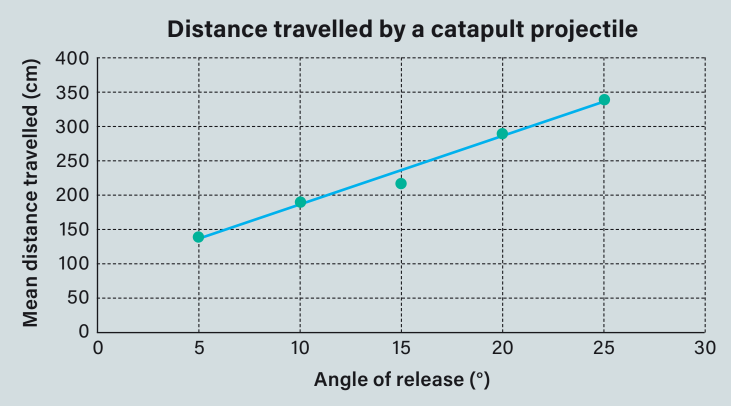
2 Visualising data can show patterns and relationships

In an experiment, we need to have an independent variable that we change and a dependent variable that we measure. In this example, we have performed an experiment where we changed the angle of the catapult (independent) and measured the distance a ball was thrown (dependent). A good experiment will use repeat trials for each value of the independent variable. The data table for this experiment might look like this:

	Distance travelled (cm)					
Angle (°)	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Mean**
5	135	142	138	145	140	140.0
10	195	188	193	188	192	191.2
15	235	244	242	238	133	218.4
20	287	295	290	289	286	289.4
25	340	339	344	339	335	339.4

It can be difficult to analyse data that is just raw numbers such as above. To help us see patterns, it is usually a good idea to display the data in a graph or chart. A line graph of the above data looks like that shown at the right.

This graph now makes it much easier to see the pattern (or **trend**) in our data – as the angle of release is increased, the distance travelled will increase as well. A strong analysis will then describe the relationship between the independent and dependent variables.



How do graphs help us to understand data?

DRAWING A LINE GRAPH

A scientific line graph should have:

- a title
- a consistent scale and axis label on both the *x*-axis and the *y*-axis: usually, the *x*-axis is the independent variable and the *y*-axis is the dependent variable. Make sure to include units in your axis labels
- a line of best fit: this is a straight line that shows the pattern of your results. Your line of best fit doesn't have to go through every data point, but should show the general direction of your data. Your line of best fit should never change direction or zig-zag – it should just be a single straight line.

UNCERTAINTY, ERRORS AND MISTAKES

KEY TERMS

error
the difference between the measured value and the actual value

mistake
something that has been done incorrectly in an experiment

uncertainty
the margin of error of a measurement

EXPERIMENTAL ERRORS

There are two categories of errors that could occur in an experiment.

Systematic errors are errors that will give consistent, incorrect results. Systematic errors can include things like incorrectly calibrated equipment or a flawed experimental design. These errors can be difficult to detect, as repeated measurements may yield the same results. Experiments must be carefully designed to avoid systematic errors. Comparing your results to expected results may also help identify systematic errors.

Random errors give inconsistent results, and repeated measurements will give different values. Examples of random errors include human reflexes when using a stopwatch or fluctuating values on a measuring instrument. The easiest way to reduce the impact of random errors is to take repeated measurements and then average them out.

Three things that can lead to problems in a set of data are **uncertainty**, **errors** and **mistakes**. While they all sound very similar, in a scientific experiment, these three terms have important different meanings.

1 Uncertainty depends on the measuring device

Uncertainty is the limit to how accurate a measurement can be due to the measuring device. The scale on the right shows that the chocolate weighs 100 g. However, as the scale only measures to the nearest whole number of grams, it doesn't tell us the whole story. The chocolate could weigh anywhere from 99.5 g to 100.4 g and the scale will round it to 100 g. There are a range of possible values of the mass of the chocolate and so there is uncertainty about its true mass.

In a scientific report, we would say the value of the mass is 100 ± 0.5 g. That is, the true value is within 0.5 g of 100 g. We call this ± 0.5 the uncertainty of the measurement. What if the scale showed 100.0 g? The chocolate would still have a possible range of values from 99.95 g to 100.04 g, and our recorded value would be 100.0 ± 0.05 g. In general, the uncertainty of a measurement is ± half of the smallest reading on the measuring device. If your device measures to the nearest gram, then the uncertainty is ± half a gram.

What determines the uncertainty of a measurement?

2 Errors can be systematic or random

Experimental error is how far away your measured value is from the actual value. There are two categories of errors: systematic errors, which give consistently incorrect results, and random errors, which give inconsistently incorrect results.

What is the difference between a systematic error and a random error?

3 Mistakes are caused by humans

Mistakes are things that you have done incorrectly in your experiment; for example, reading a thermometer incorrectly or adding too much of a certain chemical. Mistakes may invalidate your results, depending on how severe they are. Mistakes should not be written up as a part of your error analysis, and instead the experiment (or the part of it that contained the mistake) should be redone and the mistake avoided.

What is the difference between a mistake and an error?

SCIENCE IN THE MEDIA

Today in the digital era, there is an unimaginably large amount of scientific information available to be interpreted (correctly or not!) by anyone with internet access. How can we tell what is true or false, or, in more scientific terms, what is valid or invalid? How does the general public interpret science in the media and how can we ensure we critically evaluate all that we read and watch online?

1 Media reporting of science is not always reliable

When considering whether a science report in the media is trustworthy, asking yourself some questions can help.

- Is the headline **sensationalised**? Is the author just trying to get people's attention no matter what?
- Have the results been misinterpreted – possibly by someone without scientific understanding?
- Is the sample size small? (This could lead to invalid interpretations of data.)
- Does the article have **speculative** language – or is it written with the facts only?
- Are reputable scientists quoted in the article?

If the article references other information or research, you can follow up on its sources to see if they are trustworthy, valid and reliable.

Why is trustworthy science reporting important?

News media is an important method for science to be communicated to the public, but sometimes the science is overtaken by the story.

KEY TERMS

sensationalised
language that aims to shock or produce an emotional reaction in the reader

speculative
relying on theories or opinions rather than facts

ETHICAL CONDUCT

In general terms, ethics is the consideration of what is right or wrong so that the best possible choice can be made. Scientists can further ensure ethical conduct by reporting all scientific research honestly and accurately, by following safety standards and by ensuring their investigations are valid and reliable – acting to reduce and eliminate errors. If any activity includes experimental investigations using human or animal subjects, a legal and moral responsibility exists to follow ethical principles. If animals are used, further research to ensure that all legislation is being followed is important. Students can read more in the *Prevention of Cruelty to Animals Act 1986* and its *Regulations 2019* as well as the *Australian Code of Practice for the Care and Use of Animals for Scientific Purposes 2014*.

WRITING INVESTIGATION REPORTS

Writing an investigation report is a key skill in science, and one you will use many times during scientific study. By writing a clear, consistent report at the end of your investigation, you ensure that other people will understand your work.

1 An investigation report has a consistent structure

Your investigation reports should typically have a similar structure to the one shown here.

The title should be clear and in plain language. Many scientists write their title as a research question.

HOW DO DIFFERENT METALS REACT WITH HYDROCHLORIC ACID?

Use your research question/title to write your aim. You can start the aim with 'To investigate …'

AIM

To investigate the reactivity of a range of metals in hydrochloric acid

It is a good idea to include the variables in an investigation report. They can help you to write your hypothesis.

- Independent variable: type of metal
- Dependent variable: change in temperature (reactivity)
- Controlled variables: amount and concentration of hydrochloric acid, size of metal pieces, time

If your investigation is an experiment, then you should include a hypothesis. It should refer to your independent variable and your dependent variable. Remember to write in the third person.

HYPOTHESIS

If a more reactive metal is placed in hydrochloric acid, then a greater temperature change will occur.

List all materials and equipment with amounts and sizes as simple bullet points.

MATERIALS

- similar-sized pieces of metals: aluminium, copper, iron, magnesium and zinc
- 50 mL of 2 mol/L hydrochloric acid
- 10 mL measuring cylinder
- 5 test tubes
- test-tube rack
- thermometer
- 5 rubber stoppers
- sandpaper

The method provides clear, step-by-step instructions.

Remember to number the steps of your method, and that traditionally methods are written in the past tense and third person. Methods should be written like a cooking recipe – very simple, clear and detailed. A good idea is to imagine that a younger student has to follow your method.

METHOD

1. The pieces of metal were all cleaned with sandpaper.
2. 5 mL of hydrochloric acid was added to each test tube and the initial temperature of the acid in each test tube was recorded.
3. The piece of aluminium was added to one test tube, and the test tube was stoppered until the reaction stopped.
4. The final temperature of the test tube was recorded.
5. Steps 3 and 4 were repeated for the rest of the metals.

RESULTS

TABLE 1: TEMPERATURE CHANGE OF VARIOUS METALS

Metal	Initial temperature °C	Final temperature (°C)	Change in temperature (°C)
Aluminium	20	32	12
Copper	20	22	2
Iron	20	25	5
Magnesium	20	60	40
Zinc	20	29	9

DISCUSSION

As the results in Table 1 show, the most reactive metal was magnesium and the least reactive metal was copper. The addition of copper to hydrochloric acid increased the temperature by only 2 degrees, whereas magnesium increased the temperature by 40 degrees.

Use exact figures from your table and compare them to others, to show you have analysed the data.

The results make sense because metals like magnesium are more reactive, which is supported by their position on the periodic table.

Describe your results (referring to the table or figures) in the discussion and link them to your understanding of science.

One error that may have occurred is that the thermometer may not have been correctly calibrated (an example of a systematic error). Another example of an error is that the size of the metals may not have all been exactly the same (random error). The experiment could be improved by improving the accuracy of the size of each metal by using a more precise cutting instrument. The validity and reliability could be improved by repeating the experiment another two times.

Identify any potential errors here and suggest improvements to the method to try to control these. Discussion questions can be answered here too.

CONCLUSION

The results of this investigation show that the type of metal does affect how reactive it is in hydrochloric acid. The investigation supported the hypothesis that a more reactive metal will produce more heat (increased temperature change) when placed in hydrochloric acid. This is due to the reactivity of the metal, as illustrated by its position in the periodic table.

Your conclusion summarises the investigation by responding to the aim.

Mention whether the results support or reject your hypothesis, and briefly summarise the investigation, but don't introduce any new information.

REFERENCES

Compound Interest, 2020. The Metal Reactivity Series – Compound Interest. [online] Available at: https://www.compoundchem.com/2015/03/10/reactivity-series/ [Accessed 14 June 2020].

References show the source of any information you used that was not your own.

This is particularly important when you use secondary data.

Many investigation reports also include a background information section at the beginning, and it is important to identify in your references where you found that information.

Investigation **1.1A**

Sensory receptors

30 min | Level 1

KEY SKILL
REPRESENTING DATA TO IDENTIFY PATTERNS AND TRENDS

When you write a formal investigation report, there is always a results section that includes your data, often as a table, chart or image. Choosing how to represent your data so that it can be clearly communicated to someone reading your investigation report is an important skill. In this investigation, after you have collected and recorded your data in the results table, turn your data into a chart or a graph. Identify any patterns or trends in your data and include this in your discussion.

Hint #1: *There are many ways to visualise your data, such as bar charts, line graphs and pie charts. Make sure you choose the best one for your data set.*

AIM

To determine which of three areas of the body has the highest concentration of pressure receptors

MATERIALS

- ruler
- 3 lengths of copper wire approximately 10 cm long

METHOD

NOTE: You will be testing three different areas to determine if the subject can tell the difference between being poked with one wire tip, or a bent wire with the tips close together (5 mm apart), or further apart (15 mm). You will need to be consistent with where you poke the subject (and be gentle!).

1 Copy the results table into your notebook, adding a title and rows as needed.
2 The test subject closes their eyes and holds out their dominant hand with the fingers together, palm up.
3 The tester GENTLY pokes the subject's forefinger with the wires. You need to poke the subject 10 times with each wire (a total of 30 times), but don't do it in order. Mix up which wires you use and do it randomly so the tester can't guess which wire you are using.
4 Each time they are poked, the subject must say which wire was used. The tester records the subject's results in the table, using a tick for a correct statement and a cross if they were wrong. Do not tell the subject whether they were right or wrong.
5 Repeat steps 3 and 4 for the forearm and the back of the neck.

QUESTIONS

1 Which part of the body had the highest concentration of receptors (i.e. the subject got the most correct)? Why do you think this is?
2 Which part of the body was the least sensitive (i.e. the subject got the most incorrect)? Why do you think this is?
3 Compare your results with those of the rest of the class. Were they consistent?
4 Suggest two ways that you could improve this investigation in order to eliminate sources of error.

CONCLUSION

Copy and complete:
'The results show that: (*respond to the aim*).'

RESULTS **TABLE I1.1A**

Trial	Finger			Forearm			Back of neck		
	1 point	2 points 5 mm apart	2 points 15 mm apart	1 point	2 points 5 mm apart	2 points 15 mm apart	1 point	2 points 5 mm apart	2 points 15 mm apart
1									
2									
…									
10									
Total correct									

Investigation **1.1B**

Reaction time

15 min · Level 1

KEY SKILL

IDENTIFYING THE VARIABLES AND FORMULATING A HYPOTHESIS

Before you formulate a hypothesis, identify your independent, dependent and controlled variables.
The independent variable is the one thing that you purposefully want to change in an investigation.
The dependent variable is what you will be measuring.
The controlled variables are all the things you need to keep the same throughout the investigation.
To formulate your hypothesis, use the following sentence stem: It can be hypothesised that if (something to do with your independent variable), then (something to do with your dependent variable).
***Hint #1:** If you get stuck, use the prompts on page 129 to help you.*
***Hint #2:** In your conclusion, state whether your hypothesis was supported (correct) or rejected (incorrect).*

AIM

To determine whether a person's dominant or non-dominant hand has a faster reaction time

MATERIALS

- 30 cm ruler

METHOD

1 Copy the results table into your workbook, adding a title and rows as needed.
2 Have a partner sit at a table, with their arm resting on the table and their hand resting over the edge. Get them to hold their thumb and forefinger about 2 cm apart, so that they can catch the ruler in a pincer grip.
3 Hold the ruler upside down between their open thumb and forefinger but just above it, so that the 0 cm-mark on the ruler is aligned with the top of their thumb.
4 Without any obvious warning, drop the ruler for your partner to catch. Record the distance that they caught it at in the results table.
5 Repeat another 9 times for that hand. Then repeat the 10 trials for their other hand.
6 Calculate the average distance in centimetres that the ruler was caught in.
7 Use this value to calculate their reaction speed for each trial using the following formula:

$$t = \sqrt{\frac{d}{50g}}$$

where t = time to react in seconds
d = distance ruler dropped in cm
g = acceleration due to gravity, or 9.8 m/s^2.

8 Calculate the average reaction time.

QUESTIONS

1 Which hand had the faster reaction time? Was this what you expected? Explain why/why not.
2 Compare your results with those of the rest of the class.
3 Propose the series of actions and reactions that must occur in your body for you to react and catch the ruler.

CONCLUSION

Copy and complete.
'The results show that: (*respond to the aim*).'

RESULTS **TABLE I1.1B**

Trial	Distance dropped before ruler caught (cm)	
	Dominant hand	Non-dominant hand
1		
2		
...		
10		
Average reaction distance (cm)		
Average reaction time (s)		

Investigation **1.2**

Sheep brain dissection

KEY SKILL

IDENTIFYING AND MANAGING RELEVANT RISKS

Brainstorm with a partner to identify three possible hazards or risks that may be involved in this investigation. Suggest one way that each hazard or risk could be reduced.

AIM

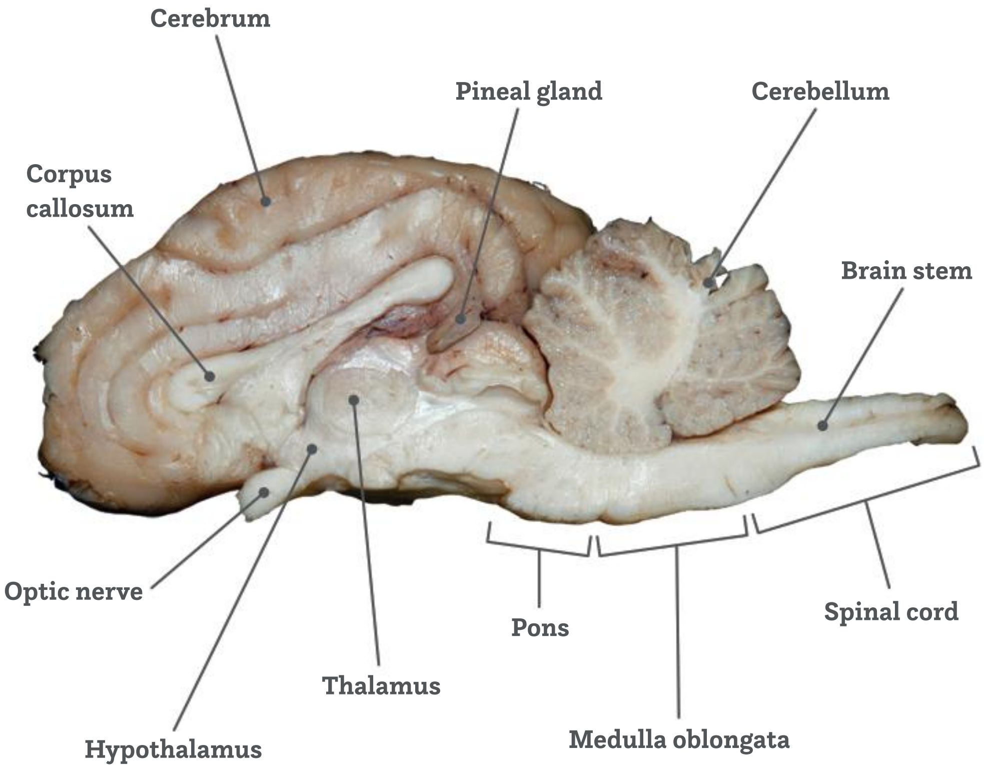
To investigate the structure of a mammalian brain

MATERIALS

- sheep brain
- dissection kit
- gloves
- dissecting board
- newspaper
- paper towel
- disinfectant

METHOD

1. Place some newspaper on the bench and the dissecting board on top of it.
2. Carefully place the sheep brain on the dissecting board. Identify the cerebrum, cerebellum and brain stem.
3. Draw a diagram of the brain, labelling these structures. (Alternatively, take a photograph.)
4. Notice that the cerebrum is made up of two halves, called hemispheres. Use the scalpel to carefully cut the brain in half, so that these hemispheres are separated.
5. Use the photograph below to help you identify the major structures of the brain. Draw a diagram of this cross section of the brain, labelling as many structures as you can identify.



30 min Level 2

6 Take one of the hemispheres and cut it across, perpendicular to the corpus callosum.
7 Notice that some parts of the cerebrum are white, whereas others are more pinky-grey. The white area is known as 'white matter', and the pinky-grey is the 'grey matter'.
8 Draw a diagram of this cross section, labelling the grey and the white matter.
9 When you have completed your dissection, carefully clean up and disinfect your work area.

QUESTIONS

Research to help you answer the following questions.

1 Find images that will allow you to compare the size and shape of a sheep brain and a human brain. What do you think influences these differences?
2 Find out more about the functions of the following brain structures.

Brain structure	Function
Cerebrum	
Cerebellum	
Brain stem (spinal cord, medulla oblongata, pons)	
Corpus callosum	
Hypothalamus	
Thalamus	

3 What is the difference between 'white matter' and 'grey matter'?

CONCLUSION

Copy and complete:
'The results show that: (*respond to the aim*)'.

WEAR EYE AND HAND PROTECTION. TAKE CAUTION WITH CUTTING IMPLEMENTS. DISPOSE OF ALL MATERIALS AS DIRECTED BY YOUR TEACHER. WASH YOUR HANDS AFTERWARDS.

Investigation **1.3A**

Heart dissection

KEY SKILL

WRITING A RESEARCH QUESTION

Turn the aim of this investigation into a question that asks what you are trying to discover. This is called a research question.

Hint #1: *Make sure that your research question has a question mark at the end.*

Hint #2: *Your research question can also be used as a title for an experiment report.*

AIM

To investigate the structure of the mammalian heart

MATERIALS

- sheep or cow heart
- dissection kit
- dissecting board
- newspaper
- disinfectant
- pins
- labels
- gloves

METHOD

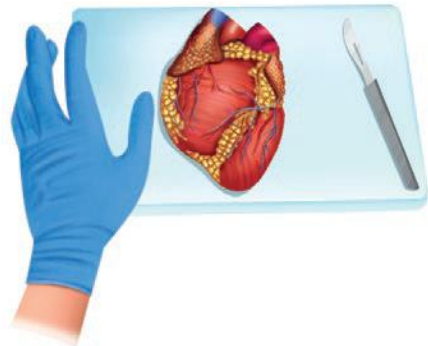
1 Place some newspaper on the bench and the dissecting board on top of it.

2 Carefully examine the heart. The blood vessels around the outside are the coronary arteries and veins – those that take blood to and from the heart muscle.

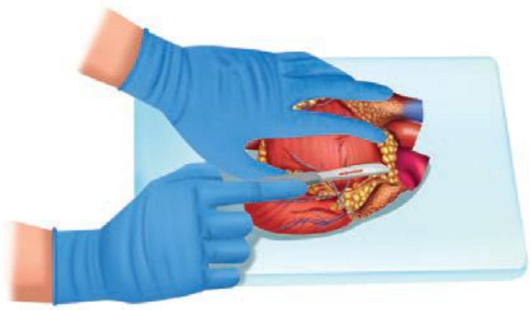
3 Feel either side of the heart. One should feel thicker than the other. The thicker side is the left, and the smaller and thinner side is the right.

4 Look for the blood vessels on the top of the heart. Can you stick your fingers in to see where they lead to?

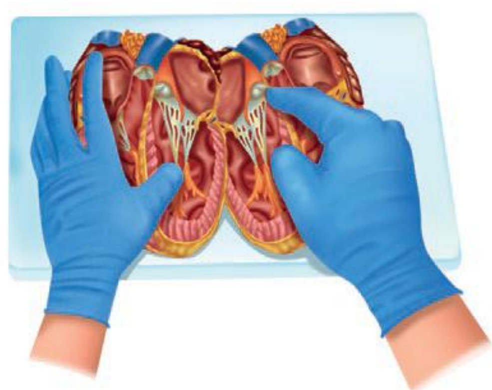
5 Place the heart on the dissecting board with the apex (pointed end) towards you, and the right side of the heart to your left.



6 Carefully make a cut around the outside of the heart.



7 You should now be able to open the heart and see inside both the right and left sides.



30 min · Level 2

8 Carefully examine the inside of the heart. You should be able to identify the valves between the atrium and ventricles of each side. These are controlled by tendons – try pulling these.
9 Identify the septum – it is the structure that separates the left and right sides of the heart.
10 Use the pins and labels to label your heart with the correct structures.
11 Take a photo of your labelled, dissected heart.
12 When you have completed your dissection, carefully clean up and disinfect your work area.

QUESTIONS

1 Compare the size of the left and the right sides of the heart. Propose why there is such a size difference.
2 Compare the size of the atria and the ventricles. Propose why there is such a size difference.
3 What is the function of valves within the heart? What might occur if they did not function properly?
4 What is the function of the septum in the heart?

CONCLUSION

Copy and complete:
'The results show that: (*respond to the aim*)'.

WEAR EYE AND HAND PROTECTION. TAKE CAUTION WITH CUTTING IMPLEMENTS. DISPOSE OF ALL MATERIALS AS DIRECTED BY YOUR TEACHER. WASH YOUR HANDS AFTERWARDS.

Investigation **1.3B**

Heart rate, breathing rate and exercise

KEY SKILL

REPRESENTING DATA TO IDENTIFY PATTERNS AND TRENDS

When you write a formal investigation report, there is always a results section that includes your data, often as a table, chart or image. Choosing how to represent your data so that it can be clearly communicated to someone reading your investigation report is an important skill. In this investigation, after you have collected and recorded your data in the results table, turn your data into a chart or a graph. Identify any patterns or trends in your data and include this in your discussion.

Hint #1: *There are many ways to visualise your data, such as bar charts, line graphs and pie charts. Make sure you choose the best one for your data set.*

AIM

To investigate the effect of exercise on heart rate, breathing rate, perspiration and body temperature

MATERIALS

- skipping rope or other equipment to use to exercise
- heart rate monitor (if available)
- body temperature thermometer (if available)
- stopwatch

METHOD

1 Copy the results table into your workbook, adding a title.
2 Find an area that is suitable to exercise in.
3 Observe and record any redness in your partner's skin tone (face and arms). Use a scale of 1–4, where 1 is normal, 2 is slight redness, 3 is red and 4 is very red.

4 Observe and record your partner's level of perspiration. Use a scale of 1–4, where 1 is no sweating, 2 is slight perspiration, 3 is sweat building up under the armpits and 4 is extremely sweaty.
5 Measure and record your partner's body temperature.
6 Measure and record your partner's heart rate (if using a pulse, measure for 15 seconds, then multiply by 4 to get beats per minute).
7 Measure and record your partner's breathing rate for 15 seconds. Multiply by 4 to get breaths per minute.
8 Your partner will then undertake vigorous exercise (e.g. skipping or jumping jacks) for 5 minutes. Measure and record their skin redness, level of perspiration, heart rate and breathing rate every minute. Measure and record their temperature if you have a thermometer that allows you to do this (e.g. an infrared one).
9 Take these measurements again every minute for 5 minutes after they have stopped exercising.

20 min Level 1

RESULTS TABLE I1.3B

Time (minutes)	Skin redness (1–4)	Perspiration level (1–4)	Body temperature (°C)	Heart rate (beats in 15 s)	Heart rate (beats per min)	Breathing rate (breaths in 15 s)	Breathing rate (breaths per min)
0 (rest)							
1							
2							
3							
4							
5 STOP exercise							
6							
7							
8							
9							
10							

QUESTIONS

1. Construct line graphs of your data, showing how the variables change over time.
2. How do the heart rate and breathing rate change? Why do they change?
3. Explain how the respiratory and circulatory systems work to maintain homeostasis during and after exercise.
4. What changes were observed in skin colour, perspiration and body temperature?
5. Explain how changes in skin colour, perspiration and body temperature during and after exercise are linked to homeostasis.
6. If you repeat an exercise routine regularly, you will become fitter and notice that your heart and breathing rate do not rise as high as they did before. Explain why.

CONCLUSION

Copy and complete.
'The results show that: (*respond to the aim*).'

Investigation **1.6**

The contagion game

60 min Level 1

KEY SKILL
EXPLAINING RESULTS USING SCIENTIFIC KNOWLEDGE

When you write a formal investigation report, there is always a discussion section that includes your analysis and explanation of the data you collected. This is where you get to explain your results by linking them to what you already knew about the science of what you are studying.

Hint #1: *You can use the following sentence stem to write about your results: 'My data shows ... and this makes sense because ...'.*

AIM

To investigate how diseases can spread through populations

MATERIALS

- small scraps of paper
- box to store scraps
- notecards or index cards
- pencils or pens
- masking tape

METHOD

1 Write your name on a scrap of paper and put it in the box. While you do this, your teacher will use the masking tape to divide the class into three areas, labelled 'susceptible', 'infected' and 'recovered'.

2 Write the numbers 1 to 5 down the side of your index card.

3 Walk up to another student, say hello and shake their hand. Both of you then write the name of the student you shook hands with on your index card, in the 1 position.

4 Repeat step 3 with four more students, writing their names in the 2–5 positions on your card. When your card is full, stand and wait in the 'susceptible' area.

5 When everyone is in the 'susceptible' area, your teacher will draw a name from the box. That student was infected with 'handshake disease'! Handshake disease is temporary but contagious, and always affects the next three people you shake hands with.

6 The infected student moves to the 'infected' area and reads out the first name on their card. That student also moves into the 'infected' area.

7 Each student in the 'infected' area reads the next name on their card. Those students move into the 'infected' area.

8 Continue reading names out as students move into the 'infected' area. When a student has read out the first three names on their card, they are cured and move into the 'recovered' area.

9 Continue playing until there is no one in the 'susceptible' area or until everyone in the 'infected' area has read out the first three names on their card.

QUESTIONS

1 Did anyone in the 'infected' area read out the name of a student who was already in that area? If so, what does this represent?

2 Did any students stay in the 'susceptible' area and never move into the 'infected' area? If so, what does this represent?

3 How does this game model the way diseases move through populations?

CONCLUSION

Copy and complete:
'The results show that: (*respond to the aim*)'.

Investigation **2.1**

Identifying community members in a terrestrial ecosystem

30 min

Level 1

KEY SKILL

IDENTIFYING AND MANAGING RELEVANT RISKS

Brainstorm with a partner to identify three possible hazards or risks that may be involved in this investigation. Suggest one way that each hazard or risk could be reduced.

AIM

To investigate different species in a terrestrial ecosystem

MATERIALS

- magnifying glass
- gardening gloves
- species identification resources for your area
- camera

METHOD

1. Copy the results table into your notebook, adding a title and rows as required.
2. Select a small ecosystem in or around your school, no larger than 20 metres by 20 metres. Mark out an area if necessary, using witches hats or other physical markers.
3. Record all the different plants in your ecosystem. Photograph or draw the leaves of each plant.
4. Put on the gloves.
5. Look for small organisms living on the plants. Look on the underside of leaves, and in the branches and grasses.
6. Carefully turn over fallen leaves, and look under rocks and soil.
7. Sit quietly to record the different organisms you can see and hear in this ecosystem. Some may move in and out of the ecosystem or be nocturnal.
8. Record the organisms you find, including a photograph or drawing, and make note of any interesting behaviour or relationships with other organisms you observe.

QUESTIONS

1. Identify the organisms in your table as producers, consumers or decomposers.
2. Create a food web of the organisms you observed in your ecosystem. You may need to conduct some extra research to do this.
3. What types of relationships between organisms did you observe?

CONCLUSION

Copy and complete:

'The results show that: (*respond to the aim*)'.

Location: ______________________ **Date:** ______________ **Time:** ______________

RESULTS **TABLE I2.1**

Organism	Photo/drawing	Number (approximate)	Observations of behaviour, including any relationships observed

Investigation **2.3**

Measuring abiotic factors

45 min

Level 1

KEY SKILL
WRITING A RESEARCH QUESTION

Turn the aim of this investigation into a question that asks what you are trying to discover. This is called a research question.
Hint #1: *Make sure that your research question has a question mark at the end.* ***Hint #2:*** *Your research question can also be used as a title for an experiment report.*

AIM

To investigate the abiotic factors in a terrestrial ecosystem

MATERIALS

- soil multiprobe (pH, light, moisture)
- trowel
- thermometer

METHOD

1 Copy the results table into your notebook, adding a title and rows as required.
2 Select a small terrestrial ecosystem in or around your school.
3 Measure the air temperature 1 metre above the ground in sunlight by holding the thermometer in the air for several minutes until the reading stabilises.
4 Measure the air temperature 1 metre above the ground in shade.
5 Carefully place the end of the thermometer in the leaf litter/on top of the soil. Leave for a few minutes to stabilise and record the value.
6 Use the trowel to carefully bury the thermometer bulb about 5 cm deep. Leave for a few minutes to stabilise and record the value.
7 Switch the soil multiprobe to the 'moisture' setting. Carefully push the ends of the probe about 5 cm into the soil. Leave for a few minutes to stabilise and record the value.
8 Leave the multiprobe in the soil and carefully switch the setting to 'pH'. Leave for a minute to stabilise and record the value.
9 Leave the multiprobe in the soil and carefully switch the setting to 'light/LUX'. Leave for a minute to stabilise and record the value.
10 Collect a soil sample from about 5 cm deep. Describe the soil colour and texture. Is it coarse, gritty, fine? Does it contain organic matter? You may wish to view the sample under a microscope.

RESULTS TABLE I2.3

Air temperature in sun (°C)	
Air temperature in shade (°C)	
Soil temperature, surface (°C)	
Soil temperature, 5 cm deep (°C)	
Soil moisture, 5 cm deep	
Soil pH, 5 cm deep	
Light intensity (lux)	
Soil colour	
Soil texture	

QUESTIONS

1 Compare your results with those of your classmates. Were the groups in the same or different locations? How might this have affected the results each group obtained?
2 Propose how these results might differ if you were to repeat this experiment at night, six hours earlier or later, or in six months' time.
3 Research to find out about the temperature, light, water and soil requirements of at least two major plant species in your ecosystem. How do these correlate with your results?

CONCLUSION

Copy and complete:
'The results show that: (*respond to the aim*)'.

Investigation **2.5**

Algal balls

30 min
Level 1

KEY SKILL

IDENTIFYING THE VARIABLES AND FORMULATING A HYPOTHESIS

Before you formulate a hypothesis, identify your independent, dependent and controlled variables.
The independent variable is the one thing that you purposefully want to change in an investigation.
The dependent variable is what you will be measuring.
The controlled variables are all the things you need to keep the same throughout the investigation.
To formulate your hypothesis, use the following sentence stem: It can be hypothesised that if (something to do with your independent variable), then (something to do with your dependent variable).
Hint #1: *If you get stuck, use the prompts on page 129 to help you.*
Hint #2: *In your conclusion, state whether your hypothesis was supported (correct) or rejected (incorrect).*

AIM

To investigate how different light levels affect the rate of photosynthesis, using algal balls

MATERIALS

- algal balls
- hydrogencarbonate indicator solution
- indicator colour chart
- 4 small sample jars with lids
- 10 mL measuring cylinder

METHOD

1 Copy the results table into your notebook, adding a title and rows as required.
2 Carefully place an equal number of algal balls in each sample jar.
3 Use the measuring cylinder to measure an equal amount of hydrogencarbonate indicator solution into each sample jar, ensuring the algal balls are covered.
4 Place the lids on the jars.
5 Place the jars in different places around your classroom that experience different levels of sunlight; for example, on the windowsill, on a shelf away from the window, in a cupboard.
6 Leave the jars until the next day.
7 Compare the colour of each solution to the indicator colour chart and record your results.

QUESTIONS

1 Consider the photosynthesis reaction. What:
  a are the reactants?
  b are the products?
  c else is required?
2 In which sample did the most photosynthesis take place? Which sample had the least? How do you know?
3 Design a procedure for an investigation using algal balls to test the effect of one of these variables on photosynthesis.
  a Wavelength of light (colour of light)
  b Temperature
  c Size of algal balls

CONCLUSION

Copy and complete:
'The results show that: (*respond to the aim*)'.

RESULTS TABLE I2.5

Sample jar location	Colour	pH	Rank (most photosynthesis = 1, least photosynthesis = 4)

Investigation **3.2A**

Making an atom

KEY SKILL

USING MODELLING AND SIMULATIONS

Scientists can use modelling and simulations to simplify and explain ideas. Models make things easier to understand and visualise, which helps us make predictions. However, there are some limitations to the use of models – how many can you think of?

PART 1

THE BOHR MODEL

AIM

To produce a Bohr model of an atom and to better understand subatomic particles

MATERIALS

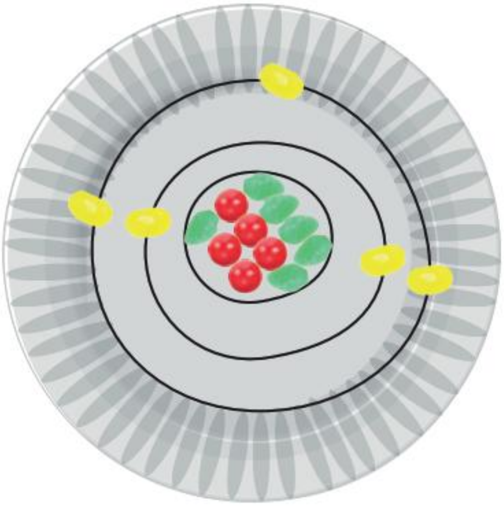
- paper plate
- three different types of lollies

METHOD

1 Copy and complete the results table into your notebook, adding a title.
2 Select an element, up to atomic number 6.
3 Work out the atomic number and atomic mass of the element by consulting a periodic table.
4 Calculate the number of protons, neutrons and electrons the atom has.
5 Select three different types of lollies.
6 On the paper plate, draw three circles. The inner circle represents the nucleus. The second and third circles represent electron orbitals. The second circle can only hold two 'electrons' and the third circle can hold the remaining 'electrons'.

RESULTS TABLE I3.2A

Element	
Atomic number	
Atomic mass	
Symbol	
Number of protons	
Number of neutrons	
Number of electrons	



30 min

Level 1

PART 2

THE THOMSON MODEL

AIM

To produce Thomson's plum pudding model of an atom and to better understand subatomic particles

MATERIALS

- paper plate
- whipped cream
- one type of lolly

METHOD

1 Select an element, up to atomic number 10.
2 Work out the atomic number and atomic mass of the element by consulting a periodic table.
3 Calculate the number of electrons the atom has.
4 Select one type of lolly to represent electrons.
5 Use the whipped cream to represent a positively charged sphere on the paper plate.
6 Add the exact number of 'electrons' and spread them around on the whipped cream.

QUESTIONS

1 Describe the Bohr model that you constructed.
2 Describe the Thomson model that you constructed.
3 How are the two models similar and how are they different?
4 Describe the usefulness and limitations of using models in science.

CONCLUSION

Copy and complete:
'The results show that: (*respond to the aim*)'.

Investigation **3.2B**

Flame test

KEY SKILL

IDENTIFYING THE INDEPENDENT, DEPENDENT AND CONTROLLED VARIABLES

The independent variable is the one thing that you purposefully want to change in an investigation. The dependent variable is what you will be measuring. The controlled variables are all the things you need to keep the same throughout the investigation.

Hint #1: *Brainstorm with a partner three things that will be or were kept the same in your investigation. These will be the controlled variables.*

AIM

To use the distinctive colours produced by metallic ions in a flame test and use the results to identify an unknown metallic ion

MATERIALS

- set of 0.1 mol/L metal chloride solutions ($NaCl$, $CuCl_2$, KCl, $CaCl_2$, $SrCl_2$, $LiCl$, $CoCl_2$, $BaCl_2$)
- 2 unknown solutions
- 8 popsticks
- matches
- Bunsen burner
- cobalt glass plate

METHOD

1 Copy the results table into your notebook, adding a title.
2 Light the Bunsen burner and adjust it to the blue flame.
3 Using a clean popstick, dip it into one of the solutions until it is saturated and then hold the soaked end in the hottest part of the flame, ensuring you do not set it on fire.
4 Observe the colour of the flame. Try not to let the popstick catch fire. Otherwise you won't be able to reuse it to double check the colour later.
5 Carefully record your observations in the results table. Be as accurate as possible – your description of the colour must be specific enough to distinguish this metal ion from the other ions tested.
6 Repeat steps 3–5 for each solution using a new, clean popstick to test each solution.
7 When you examine the sodium and potassium ions, first look at their colour unaided, then look through a cobalt glass plate. Record both observations separately in your results table.
8 When you have tested all the known solutions and can accurately describe the colour of each metal ion, obtain two different unknown solutions from your teacher and determine which metal ions are present by performing a flame test and comparing this data to your previous data.

RESULTS **TABLE I3.2B**

Metal ion	Colour of flame
Lithium	
Strontium	
Calcium	
Barium	
Copper	
Cobalt	
Sodium	
Sodium (with cobalt glass)	
Potassium	
Potassium (with cobalt glass)	
Unknown 1	
Unknown 2	

Based on your observations, identify the two unknown ions.

Unknown ion 1 is ____________________

Unknown ion 2 is ____________________

45 min

Level 2

QUESTIONS

1 Which ions produce similar colours in the flame tests?
2 What was the purpose of the cobalt glass?
3 Explain how the colours observed in the flame tests are produced.
4 Did you correctly identify the two unknown solutions?
5 What factors contributed to your correct or incorrect identifications?
6 State at least three problems that may arise when using flame tests for identification purposes in a laboratory.

CONCLUSION

Copy and complete:
'The results show that: (*respond to the aim*)'.

AN OPEN FLAME IS A HAZARD. BE CAREFUL. IF YOU BURN YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND PLACE YOUR SKIN UNDER COLD RUNNING WATER FOR 20 MINUTES.

DISPOSE OF WASTES APPROPRIATELY.

Investigation **3.3**

Half-life coin experiment

KEY SKILL

REPRESENTING DATA TO IDENTIFY PATTERNS AND TRENDS

When you write a formal investigation report, there is always a results section that includes your data, often as a table, chart or image. Choosing how to represent your data so that it can be clearly communicated to someone reading your investigation report is an important skill. In this investigation, after you have collected and recorded your data in the results table, turn your data into a chart or a graph. Identify any patterns or trends in your data and include this in your discussion.

Hint #1: *There are many ways to visualise your data, such as bar charts, line graphs and pie charts. Make sure you choose the best one for your data set.*

AIM

To model radioactive decay, using coins

MATERIALS

- 100 coins and a large container with a lid

METHOD

1. Copy the results table into your notebook, adding a title.
2. Place 100 coins in the container and fasten the lid.
3. Shake the container several times and remove the lid. Carefully empty the coins onto a flat surface, making sure the coins don't roll away.
4. Remove all the coins that show heads.
5. Record the number of coins removed and the number of coins remaining in the results table.
6. Return the remaining coins to the container and repeat steps 3–5 until no coins are left in the container.
7. Draw a graph of your data. Label the *x*-axis 'Shake number' and the *y*-axis 'Number of coins remaining'.

RESULTS **TABLE I3.3**

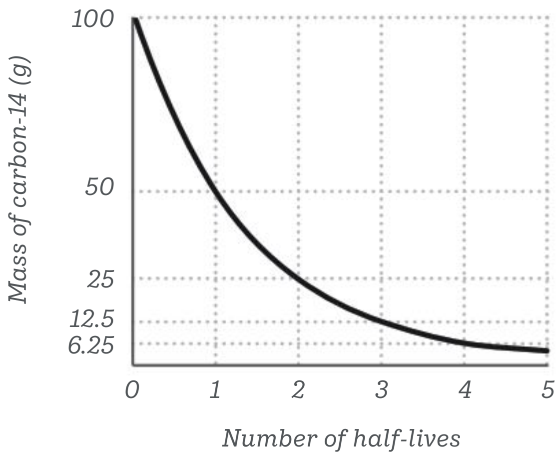
Shake number	Number of coins removed	Number of coins remaining
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

30 min

Level 1

QUESTIONS

1 Compare the decay curve of carbon-14 with your graph for the coins. Explain any similarities that you see.



2 Recall that the probability of landing heads in a coin toss is $\frac{1}{2}$. Use this information to explain why the remaining number of coins is reduced by about half each time they are shaken and tossed.

CONCLUSION

Copy and complete:

'The results show that: (*respond to the aim*)'.

Investigation **3.4**

Nuclear energy debate

KEY SKILL

REFERENCING SOURCES OF INFORMATION

As your science skills become more advanced, you may wish to do some research prior to completing an investigation. This allows you to understand the investigation better; in particular, the science of what is happening. Whenever you do research it is important to get information from trusted sources and to reference where the information came from. When you reference a source, you include details such as who the author of the information is, when it was published and the title of the website or article.

Hint #1: *Two widely used referencing conventions are Harvard and APA. You can look these up to learn more about them, or there are even websites that will format your references for you.*

AIM

As a class, select one of the three critical and creative thinking strategies and use it to debate one of these issues about nuclear energy.

- The consequences of continuing to rely on fossil fuels are greater than those posed by a potential nuclear disaster.
- It is unethical to cure a patient of an illness using nuclear technology because it may cause long-term side effects for the patient.
- Australia must move to nuclear energy as our main source of electricity.

Use the information in lesson 3.4 and other sources to help you form your arguments.

45 min | Level 1

STRATEGY 1: LINE DEBATE

1. Divide the class evenly into two groups and form two lines, facing each other.
2. One line is 'for' the issue (the affirmative team), the other line is 'against' the issue (the negative team).
3. Any student from the affirmative team can put forward an argument to begin the debate.
4. If it is judged as a fair point (by your teacher, or a student in the adjudicator role), the affirmative team can 'steal' someone from the negative team to join their line.
5. The 'stolen' student now becomes a member of the affirmative team and must put forward an argument for the issue. If it is judged as a fair point, they can again steal someone from the negative team to join their line. If it is not a fair point, any student from the negative line is allowed to put forward an argument and then has the chance to steal an affirmative team member.
6. The debate continues in this fashion until the teacher calls 'time'. At this point, the line with the most students 'wins' the debate.

STRATEGY 2: FISH BOWL DEBATE

1. Two students sit facing each other in the centre of the room. One student is on the affirmative side and the other is on the negative side of the debate.
2. The rest of the class sits in a circle around them.
3. The two central students begin debating one of the issues, taking it in turns to put forward arguments one by one.
4. Students in the outside circle must listen carefully because they may be called upon to swap with one of the central people at any time in the debate. You could be called upon to join either the affirmative team or the negative team so you need to have arguments prepared for both sides of the issue.
5. Your teacher will nominate students to move from the outer circle into the centre periodically throughout the discussion. The goal is to keep the debate flowing.

STRATEGY 3: THINK-PAIR-SHARE DEBATE

1. Form a pair and select a topic to 'debate'. Allocate one person as 'affirmative' and one as 'negative'.
2. First, work independently. On your own, think about your response to the issue. Consider it in depth. Write notes if that helps you to organise your thoughts.
3. Now turn to your partner. Listen respectfully while your partner talks through their arguments for or against the issue, then offer your response. Consider the similarities and differences in your responses.
4. Share your opposing points of view on the issue with another pair or the whole class.

QUESTIONS

1. Reflect on the critical and creative thinking strategy that you used. How did the strategy help you to evaluate the use of nuclear energy?
2. Think about the way you prefer to learn. Develop a new critical and creative thinking strategy that your class could use next time you are called upon to evaluate an issue.

CONCLUSION

Copy and complete:
'The results show that: (*respond to the aim*)'.

Investigation **4.2**

Exothermic and endothermic reactions

KEY SKILL

EXPLAINING RESULTS USING SCIENTIFIC KNOWLEDGE

When you write a formal investigation report, there is always a discussion section that includes your analysis and explanation of the data you collected. This is where you get to explain your results by linking them to what you already knew about the science of what you are studying.

Hint #1: *You can use the following sentence stem to write about your results: 'My data shows ... and this makes sense because ...'.*

AIM

To investigate whether a chemical reaction is exothermic or endothermic

MATERIALS

- 15 mL vinegar
- sodium bicarbonate
- 2 × 3 cm pieces of magnesium ribbon
- 5 mL of 1 mol/L hydrochloric acid (HCl)
- 5 mL of 1 mol/L copper sulfate solution
- 5 mL of 1 mol/L sodium hydroxide
- 5 mL of 1 mol/L sulfuric acid
- 10 mL measuring cylinder
- 5 test tubes
- stirring rods
- spatula
- steel wool
- thermometer

METHOD

Copy the results table into your notebook, adding a title.

PART A

1. Add 5 mL of vinegar to a test tube.
2. Use a thermometer to record the temperature of the vinegar.
3. Add a spatula of sodium bicarbonate to the test tube.
4. Mix gently with a stirring rod, being careful not to break the base of the test tube. After a minute, record the temperature of the mixture.
5. Record your results in the results table.

PART B

1. Add 5 mL of hydrochloric acid to a test tube.
2. Record the temperature of the hydrochloric acid.
3. Add 5 mL of 1 mol/L sodium hydroxide.
4. Mix gently with a stirring rod, being careful not to break the base of the test tube. After a minute, record the temperature of the mixture.
5. Record your results in the results table.

PART C

1. Add 5 mL of copper sulfate to a test tube.
2. Record the temperature of the solution.
3. Add a 3 cm piece of magnesium that has been cut into small pieces.
4. Record the temperature of the solution after 1 minute.
5. Record your results in the results table.

PART D

1. Add 5 mL of sulfuric acid to a test tube.
2. Record the temperature of the solution.
3. Add a 3cm piece of magnesium ribbon that has been cut into small pieces.
4. Record the temperature of the solution after 1 minute.
5. Record your results in the result table.

45 min | Level 2

RESULTS TABLE I4.2

Part	Reactants	Initial temp. (°C)	Final temp. (°C)	Observations	Exothermic or endothermic
A	Vinegar + sodium bicarbonate				
B	Hydrochloric acid + sodium hydroxide				
C	Copper sulfate + magnesium				
D	Sulfuric acid + magnesium				
E	Vinegar + steel wool (iron)				

PART E

1 Add 10 mL of vinegar to a test tube.
2 Record the temperature of the vinegar.
3 Add a piece of steel wool so that it is completely submerged.
4 Record the temperature of the vinegar after 1 minute.
5 Record your results in the results table.

QUESTIONS

1 Which reactions were exothermic and which were endothermic? Give evidence to support your choices.
2 Copy and complete equations for all the reactions in the table. The first one has been done for you.

a acetic acid + sodium bicarbonate → sodium acetate + carbon dioxide + water
b ________ + ________ → sodium chloride + water
c ________ + ________ → magnesium sulfate + copper
d ________ + ________ → magnesium sulfate + hydrogen
e ________ + ________ → iron acetate + hydrogen

CONCLUSION

Copy and complete:
'The results show that: (*respond to the aim*)'.

WEAR SAFETY GLASSES AND GLOVES WHILE DOING THIS EXPERIMENT TO PREVENT ACID FROM BURNING YOUR SKIN OR SPLASHING IN YOUR EYES, AND TO PREVENT METAL GETTING IN YOUR EYES.

DISPOSE OF WASTES APPROPRIATELY.

Investigation **4.3A**

Action of acids and bases – cleaning coins

30 min | Level 2

KEY SKILL

IDENTIFYING THE INDEPENDENT, DEPENDENT AND CONTROLLED VARIABLES

The independent variable is the one thing that you purposefully want to change in an investigation. The dependent variable is what you will be measuring. The controlled variables are all the things you need to keep the same throughout the investigation.
Hint #1: *Brainstorm with a partner three things that will be or were kept the same in your investigation. These will be the controlled variables.*

AIM

To investigate the actions of acids and bases

MATERIALS

- 3 coins of the same size and type
- 20 mL of 1 mol/L hydrochloric acid
- 20 mL ammonia
- 20 mL water
- cling film
- 3 × 50 mL beakers
- 3 × 25 mL measuring cylinders

METHOD

1. Copy the results table into your notebook, adding a title.
2. Label the three beakers as hydrochloric acid, ammonia and water.
3. Add a coin to each 50 mL beaker.
4. Measure 20 mL of hydrochloric acid and add it to the first beaker.
5. Measure 20 mL of ammonia and add it to the second beaker.
6. Measure 20 mL of water and add it to the third beaker.
7. Cover all the beakers with cling film and leave them overnight. Record your observations in the results table.
8. Compare your results with those of other groups.

RESULTS TABLE I4.3A

Substance	Observations
Hydrochloric acid	
Ammonia	
Water	

QUESTIONS

1. Is the action of acids and bases with metal a chemical reaction?
2. What does this experiment tell you about cleaning metals?
3. Suggest what would happen to the coins if you left them in the solutions for a month.

DISCUSSION

1. List the controlled variables, independent variable and dependent variable.
2. What benefit is there to repeating the experiment?

CONCLUSION

Copy and complete.
'The results show that: (*respond to the aim*).'

ACIDS ARE CORROSIVE; WEAR SAFETY GLASSES.

AMMONIA GIVES OFF FUMES; DO NOT INHALE. USE IN A VENTILATED ROOM.

DISPOSE OF WASTES APPROPRIATELY.

Investigation **4.3B**

Acid or base?

45 min | Level 2 | ⚠

KEY SKILL
EVALUATING RESULTS FOR RELIABILITY AND VALIDITY

In order for our investigations to be considered scientific, we need to check that our results were reliable and valid. It sounds like a difficult thing to check but it's actually simple. If your results are reliable, it means that if you repeated your test or investigation you would get the same results. If your results are valid, it means that you were able to measure what was intended to be measured.

Hint #1: *If someone makes a human error (for example, dropping something, adding too much or too little of a substance, spilling something or using different equipment each time) then the results are probably not valid or reliable.*

AIM

To prepare a natural indicator and use it to find out if some household substances are acids or bases

MATERIALS

- 1 leaf red cabbage
- solutions of household products: ammonia, baking soda, conditioner, detergent, lemon juice, oven cleaner, shampoo, lemonade, vinegar
- 5 mL of 0.1 mol/L hydrochloric acid
- 5 mL of 0.1 mol/L sodium hydroxide
- plastic pipette
- water
- 12 test tubes
- test-tube rack
- 3 × 10 mL measuring cylinders
- cutting board
- knife
- large beaker
- hot plate
- strainer

METHOD

1. Copy the results table into your notebook, adding a title and rows as required.
2. Chop the cabbage, put it in the large beaker and add enough water to cover it.
3. Put the beaker on the hot plate and bring it to a boil and then simmer for 5 minutes.
4. Once cooled, strain the cabbage. The resulting solution is a natural indicator.
5. Prepare three test tubes by adding 5 mL of hydrochloric acid to the first one, 5 mL of sodium hydroxide to the second one and 5 mL of water to the third one.
6. Add 5 drops of the red cabbage indicator to each test tube and record your results. Identify the colour changes in acid, base and neutral solutions.
7. To each of the remaining 9 test tubes, add 5 mL of one of the provided household solutions.
8. Add 5 drops of the red cabbage extract to each test tube. Shake the test tube and observe the colour.
9. Identify whether each household substance is an acid or a base and record your results in the table.

RESULTS

TABLE I4.3B

Substance	Colour with red cabbage indicator	Acid or base
Hydrochloric acid		
Sodium hydroxide		
Water		

QUESTIONS

1. Is red cabbage an effective indicator? Explain.
2. Do you think the acidic and basic household substances are safe to use in the home? Explain.

CONCLUSION

Copy and complete:
'The results show that: (*respond to the aim*)'.

⚠

THE HOUSEHOLD SUBSTANCES MAY IRRITATE YOUR SKIN AND EYES AND BE TOXIC. WEAR GLOVES AND SAFETY GLASSES. USE THE KITCHEN KNIFE WITH CARE. IF BURNT BY HOT LIQUIDS, RUN COLD WATER ON THE AFFECTED AREA.

DISPOSE OF WASTES APPROPRIATELY.

Investigation **4.3C**

The effect of indicators on acids and bases

45 min | Level 2

KEY SKILL

IDENTIFYING AND MANAGING RELEVANT RISKS

Brainstorm with a partner to identify three possible hazards or risks that may be involved in this investigation. Suggest one way that each hazard or risk could be reduced.

AIM

To observe the effect of indicators on acids and bases

MATERIALS

- 25 mL vinegar
- 25 mL of 0.1 mol/L hydrochloric acid
- 25 mL of 1 mol/L ammonia
- 25 mL of 0.1 mol/L sodium hydroxide
- universal indicator solution
- universal indicator chart
- bromothymol blue
- phenolphthalein
- methyl orange
- litmus paper
- 20 test tubes
- test-tube rack
- 4 × 10 mL measuring cylinders
- plastic pipette

METHOD

1. Copy the results table into your notebook, adding a title.
2. Add 5 mL of vinegar, hydrochloric acid, ammonia and sodium hydroxide to four test tubes.
3. Add 3 drops of universal indicator to each of the solutions. Use the universal indicator chart to identify each solution as acid or base.
4. Repeat the experiment with the rest of the indicator solutions – bromothymol blue, methyl orange, phenolphthalein, litmus paper (add a small piece of litmus paper to each test tube) – and observe their colours in acidic and in basic solutions.
5. Compare your results with those of other groups.

QUESTIONS

1. Identify the substances that are acidic and those that are basic.
2. If lemonade is acidic, what colour would it change bromothymol blue to?
3. What characteristics are useful in an indicator?
4. Would we be able to use bromothymol blue to identify if two unknown substances were acids or bases? Explain.
5. What limitations does the use of litmus paper as an indicator present?

CONCLUSION

Copy and complete:

'The results show that: (*respond to the aim*)'.

RESULTS TABLE I4.3C

Substance	Acid or base according to indicator				
	Universal indicator	Bromothymol blue	Methyl orange	Phenolphthalein	Litmus paper
Vinegar					
Hydrochloric acid					
Ammonia					
Sodium hydroxide					

WEAR SAFETY GLASSES TO PROTECT YOUR EYES FROM CHEMICALS.

Investigation **4.4A**

Reactions of acids with metals

45 min | Level 2 | ⚠

KEY SKILL

EXPLAINING RESULTS USING SCIENTIFIC KNOWLEDGE

When you write a formal investigation report, there is always a discussion section that includes your analysis and explanation of the data you collected. This is where you get to explain your results by linking them to what you already knew about the science of what you are studying.

Hint #1: *You can use the following sentence stem to write about your results: 'My data shows ... and this makes sense because ...'.*

AIM

To investigate the rate of reaction of hydrochloric acid with a range of metals

MATERIALS

- similar sized pieces of metals: aluminium, copper, iron, magnesium and zinc
- 25 mL of 2 mol/L hydrochloric acid
- 10 mL measuring cylinder
- 5 test tubes
- test-tube rack
- matches
- thermometer
- 5 rubber stoppers
- sandpaper

METHOD

1. Copy the results table into your notebook, adding a title.
2. Clean all the metals with sandpaper.
3. Add 5 mL of hydrochloric acid to each of the five test tubes.
4. Record the initial temperature of the acid in each test tube.
5. Add aluminium to one test tube and stopper it with a rubber stopper until the reaction stops.
6. Light a match, remove the rubber stopper and hold the match inside the test tube. If a pop sound occurs, it means that the gas produced was hydrogen.
7. Measure the final temperature of the contents of the test tube.
8. Repeat steps 5–7 with the rest of the metals.

QUESTIONS

1. What can you conclude about the bubbles produced?
2. Comment on the final temperature readings obtained.
3. Were these reactions exothermic or endothermic?
4. **a** Rank the metals from the most reactive to the least reactive.
   b Explain why you ranked the metals in that way.
5. Did all the reactions give a positive pop test? Explain.

CONCLUSION

Copy and complete:

'The results show that: (*respond to the aim*)'.

⚠

ACIDS ARE CORROSIVE. IF YOU BURN YOUR SKIN, RINSE THE AFFECTED AREA UNDER COLD RUNNING WATER. WEAR SAFETY GLASSES TO PROTECT YOUR EYES FROM ACID OR METALS.

DISPOSE OF WASTES APPROPRIATELY.

RESULTS TABLE I4.4A

Metals	Initial temp. (°C)	Final temp. (°C)	Change in temp. (°C)	Observations
Aluminium				
Copper				
Iron				
Magnesium				
Zinc				

Investigation **4.4B**

Reactions of acids with carbonate

KEY SKILL

IDENTIFYING AND MANAGING RELEVANT RISKS

Brainstorm with a partner to identify three possible hazards or risks that may be involved in this investigation. Suggest one way that each hazard or risk could be reduced.

AIM

To observe the reaction between hydrochloric acid and sodium carbonate

MATERIALS

- sodium carbonate
- 5 mL of 2 mol/L hydrochloric acid
- 10 mL limewater
- 2 × 10 mL measuring cylinders
- spatula
- 2 test tubes connected by a delivery tube with rubber stoppers
- retort stand
- bosshead and clamp

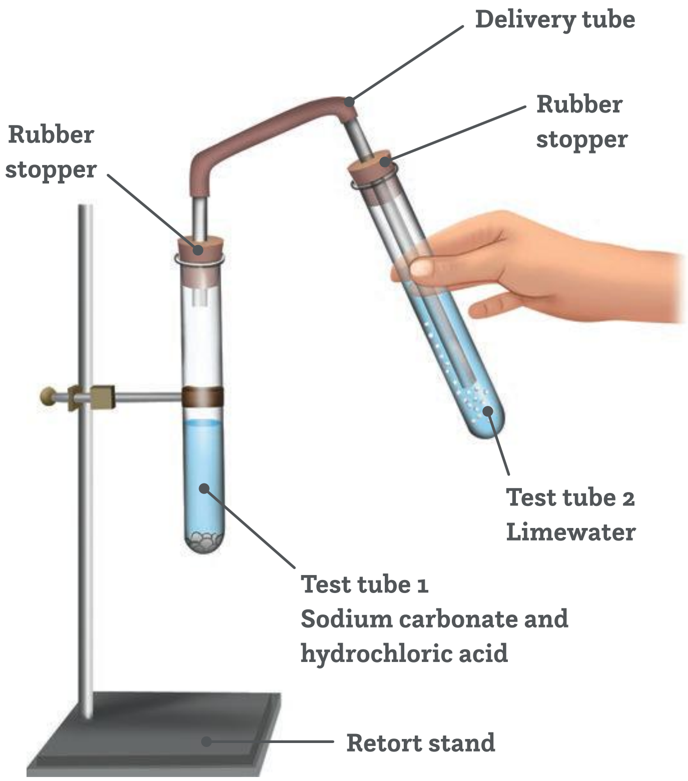
METHOD

1 Copy the results table into your notebook, adding a title.
2 Set up the equipment as shown in the diagram. Note that the delivery tube must go into the limewater.
3 Add 2 spatulas full of sodium carbonate to the clamped test tube (test tube 1) and have someone hold the test tube containing 10 mL of limewater (test tube 2).
4 Add 5 mL of hydrochloric acid to the test tube containing sodium carbonate and stopper both test tubes. Make sure they are connected by the delivery tube as shown in the diagram.
5 Observe what happens in both the test tubes and record your results.

RESULTS **I4.4B**

	Observations	Colour of limewater	Equation
Test tube 1			Sodium carbonate + hydrochloric acid → ________________
Test tube 2			

30 min | Level 2



QUESTIONS

1 Did the test tube with the sodium carbonate and hydrochloric acid get hot?
2 What happened to the test tube containing limewater?
3 What colour did the limewater change to?
4 An endothermic reaction absorbs heat from the surroundings and the reaction container becomes cold to touch. An exothermic reaction releases heat to the surroundings and the reaction container becomes hot. Do you think this reaction was endothermic or exothermic?
5 Which gas do you think was released during this reaction?
6 Complete the sentence and equation:

When __________ gas is bubbled through limewater, the limewater goes __________ in colour.

Acid + carbonate → salt + __________ + water

CONCLUSION

Copy and complete.
'The results show that: (*respond to the aim*).'

HYDROCHLORIC ACID IS CORROSIVE. WEAR SAFETY GLASSES TO PREVENT IT FROM SPLASHING INTO YOUR EYES.

DISPOSE OF WASTES APPROPRIATELY.

Investigation **4.5A**

Combustion of fuels

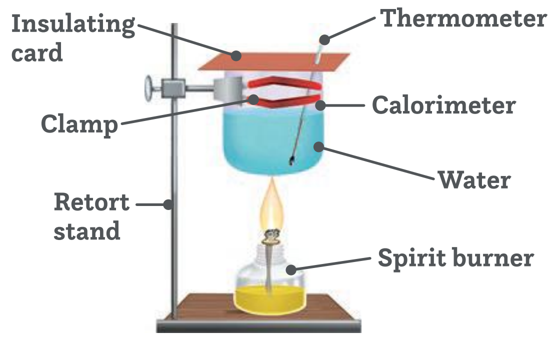
45 min | Level 2

KEY SKILL
EVALUATING RESULTS FOR RELIABILITY AND VALIDITY

In order for our investigations to be considered scientific, we need to check that our results were reliable and valid. It sounds like a difficult thing to check but it's actually simple. If your results are reliable, it means that if you repeated your test or investigation you would get the same results. If your results are valid, it means that you were able to measure what was intended to be measured. ***Hint #1:*** *If someone makes a human error (for example, dropping something, adding too much or too little of a substance, spilling something or using different equipment each time) then the results are probably not valid or reliable.*

AIM

To find out which fuel – methanol, ethanol or propanol – will burn the fastest



FUELS ARE FLAMMABLE. BE CAREFUL NOT TO SET THEM ALIGHT.

MATERIALS

- 3 spirit burners – methanol, ethanol and propanol (50 mL each)
- water
- measuring cylinder
- thermometer
- stopwatch
- retort stand
- calorimeter
- insulating card or lid
- heatproof mat
- bosshead and clamp

METHOD

1. Copy the results table into your notebook, adding a title.
2. Set up the equipment as shown in the diagram.
3. Fill the calorimeter with 100 mL of water. Fill the spirit burner with 50 mL of methanol.
4. Record the initial temperature of water.
5. Light the spirit burner and record the time taken for the temperature of water to increase by 10°C.
6. Extinguish the flame with the cap of the spirit burner.
7. Check and record if the bottom of the metal can or calorimeter has soot on it (black substance).
8. Repeat steps 3–7 with ethanol and propanol.
9. Record all your observations.

QUESTIONS

1. What are the products of combustion of these fuels?
2. Which was the best fuel? Explain.
3. List some assumptions (things you took for granted) that could have interfered with your results.
4. Can combustion occur without oxygen?

CONCLUSION

Copy and complete.

'The results show that: (*respond to the aim*).'

RESULTS

TABLE I4.5A

Fuel	Initial temp. (°C)	Final temp. (°C)	Change in temp. (°C)	Time (s) for water temperature to increase by 10°C	Soot/no soot
Methanol					
Ethanol					
Propanol					

Investigation **4.5B**

Complete and incomplete combustion reactions

30 min

Level 2

KEY SKILL

IDENTIFYING THE CONTROLLED VARIABLES

The controlled variables are all the things you need to keep the same throughout the investigation.

Hint #1: *Brainstorm with a partner three things that will be or were kept the same in your investigation. These will be the controlled variables.*

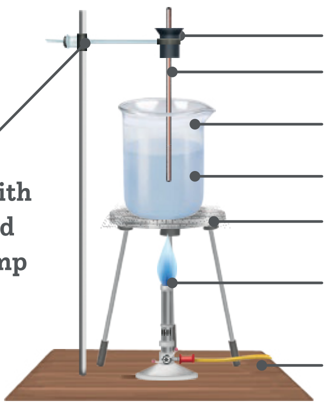
Hint #2: *Some examples of controlled variables are listed on page 129.*

AIM

To determine whether complete or incomplete combustion of gas will heat water to a higher temperature

MATERIALS

- water
- Bunsen burner
- matches
- thermometer
- tripod
- gauze mat
- retort stand
- rubber stopper
- 2 × 250 mL beaker
- stopwatch
- heatproof mat
- bosshead and clamp



METHOD

1. Copy the results table into your notebook, adding a title.
2. Set up the equipment as shown in the diagram.
3. Record the initial temperature of water.
4. Light the Bunsen burner and, with the air hole almost closed, heat the water for 5 minutes.
5. Record the final temperature and find the change in temperature.
6. Observe the bottom of the beaker to see if any soot was formed.
7. Replace the beaker of water and repeat steps 3–5 with the air hole open.

QUESTIONS

1. Identify the black particles you observed under one of the beakers.
2. Describe the difference in the colour of the flame in complete and incomplete combustion and explain why this was so.
3. What is the difference between complete and incomplete combustion?
4. Write a word and a formula equation for the complete combustion of methane.
5. Write a word and a formula equation for the incomplete combustion of methane.

CONCLUSION

Copy and complete.
'The results show that: (*respond to the aim*).'

RESULTS

TABLE I4.5B

	Flame colour	Soot/ no soot	Initial temp. (°C)	Final temp. (°C)	Temperature change after 5 minutes (°C)
Incomplete combustion					
Complete combustion					

Investigation **4.7A**

Corrosion of iron

40 min | Level 2

KEY SKILL

DRAWING CONCLUSIONS CONSISTENT WITH EVIDENCE

When you write a formal investigation report, there is always a conclusion section that summarises the investigation by responding to (or answering) the aim. To do this you need to draw a conclusion that is consistent with the data or evidence you collected.

Hint #1: *You can use the following sentence stem in your conclusion: 'The results of this investigation show ...'.*

Hint #2: *Make sure your conclusion answers or responds to your aim.*

AIM

To investigate the conditions required for the rusting of iron

MATERIALS

- 5 ungalvanised iron nails
- 2 × 10 mL measuring cylinders
- tap water
- boiled water
- salt water
- oil
- drying agent such as calcium hydroxide
- 5 test tubes
- test-tube rack
- 5 rubber stoppers
- spatula
- paper towel
- electronic balance

METHOD

1 Copy the results table into your notebook, adding a title.
2 Set 5 test tubes on a test-tube rack.
3 Label the first test tube 'Air only'.
4 Label the second test tube 'Drying agent'. Add one spatula of calcium hydroxide.
5 Label the third test tube 'Water and air'. Add 5 mL of tap water.
6 Label the fourth test tube 'Salt water'. Add 5 mL of salt water.
7 Label the fifth test tube 'Oil and boiled water'. Add 5 mL of boiled water.
8 Weigh the five nails separately. Note each mass and add a nail to each test tube.
9 Add oil to cover the boiled water in test tube 5.
10 Stopper all test tubes with the rubber stoppers.
11 Observe the test tubes every second day for a week.
12 Remove the nails, clean and dry them and weigh them.

QUESTIONS

1 Should there have been a gain or a loss in mass of the nails? Explain.
2 Which environment causes the most rust? Research why this environment causes the most rusting of iron.
3 Why was it important to measure the mass of the iron nail before and after the experiment?

CONCLUSION

Copy and complete.

'The results show that: (*respond to the aim*).'

WEAR SAFETY GLASSES AND GLOVES WHILE DOING THIS EXPERIMENT TO PREVENT RUSTED METAL FROM ENTERING YOUR EYES OR TOUCHING YOUR SKIN.

RESULTS TABLE I4.7A

	Test tube				
	1 Air only	2 Drying agent	3 Water and air	4 Salt water	5 Oil and boiled water
Initial mass of nail (g)					
Final mass of nail (g)					
Change in mass (g)					
Observations					

Investigation **4.7B**

Preventing corrosion

45 min | Level 2

KEY SKILL
IDENTIFYING LIMITATIONS TO THE METHOD AND SUGGESTING IMPROVEMENTS

When you write a formal investigation report, there is always a discussion section that includes a discussion of potential errors. These errors are limitations (or problems) with the method. For each error, you list a way to control it (your suggested improvement).
Hint #1: *Brainstorm three potential errors that might have occurred in this investigation that could have affected or changed the results you collected (for example, if through human error something was not measured accurately). Now work with a partner to suggest ways each error could be controlled.*

AIM
To investigate some methods of preventing corrosion

MATERIALS
- 4 ungalvanised iron nails
- 1 galvanised iron nail
- salt water
- magnesium ribbon
- paint
- oil
- 5 test tubes
- test-tube rack
- 5 stoppers to fit test tubes

METHOD
1. Copy the results table into your notebook, adding a title.
2. Prepare the nails.
   - Nail 1: leave as is for the control.
   - Nail 2: Paint it and let it dry.
   - Nail 3: Dip it in oil and let the oil drip off.
   - Nail 4: Wrap magnesium ribbon tightly around it.
   - Nail 5: The galvanised nail that is coated with zinc.
3. Label five test tubes 'Untreated', 'Painted', 'Oil coated', 'Magnesium twirled' and 'Galvanised'.
4. Half-fill all test tubes with salt water.
5. Add the nails to their appropriate test tubes.
6. Stopper the test tubes and leave them to stand for a week.
7. Record your observations and determine if the method used to prevent the corrosion of iron was effective.

QUESTIONS
1. What happened with the nail that had magnesium wrapped around it? Explain why this happened.
2. What is a galvanised nail?
3. How does galvanising prevent corrosion?

CONCLUSION
Copy and complete.
'The results show that: (*respond to the aim*).'

METAL PARTS OR SOLUTIONS MAY ENTER YOUR EYES. WEAR SAFETY GLASSES TO PREVENT THIS. WEAR GLOVES TO PREVENT THE PAINT OR OIL FROM TOUCHING YOUR SKIN.

RESULTS TABLE I4.7B

	Nail				
	1 Untreated (control)	2 Painted	3 Oil coated	4 Magnesium twirled	5 Galvanised
Observations					

Investigation **4.8**

Precipitation reactions

KEY SKILL

IDENTIFYING THE INDEPENDENT, DEPENDENT AND CONTROLLED VARIABLES

The independent variable is the one thing that you purposefully want to change in an investigation. The dependent variable is what you will be measuring. The controlled variables are all the things you need to keep the same throughout the investigation.
Hint #1: *Brainstorm with a partner three things that will be or were kept the same in your investigation. These will be the controlled variables.*

AIM

To find out which reactions form a precipitate

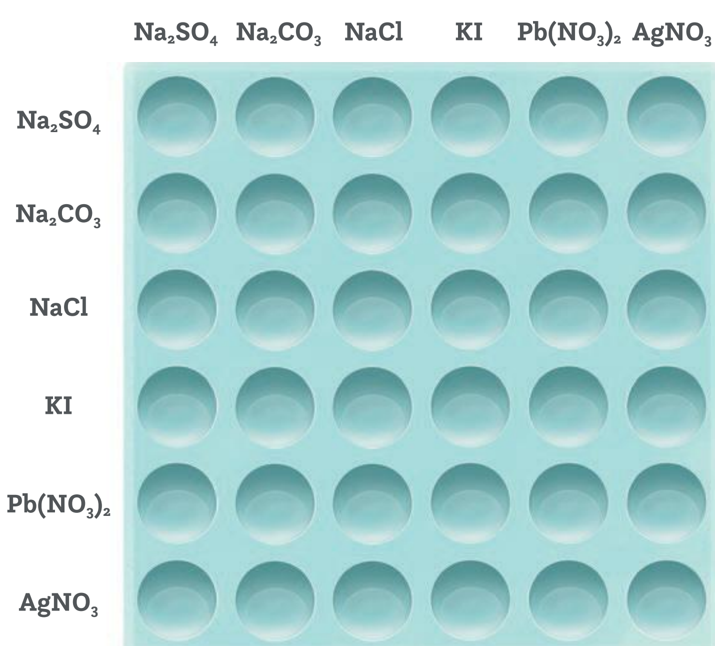
MATERIALS

- 0.1 mol/L solutions in dropper bottles of: sodium sulfate, sodium carbonate, sodium chloride, potassium iodide, lead nitrate, silver nitrate, barium chloride, copper sulfate, sodium hydroxide
- spotting tile
- paper towel
- a piece of blank paper

METHOD

1. Copy the results table into your notebook, adding a title.
2. Put the spotting tile on the piece of blank paper. Write the names of the solutions being used down the left-hand side and across the top of the spotting tile, in the same order as your results table. Depending on the size of your spotting tile, you may have to wash it and re-use it to get through all the solutions.
3. Into each cavity on the spotting tile, add one drop of the solution written at the top of the column and one drop of the solution written to the left of the row. Observe whether a precipitate has formed. Record your results in the table, by using 's' for soluble and 'p' for precipitate. Be careful not to contaminate the solutions.

Spotting tile



45 min | Level 2

RESULTS

TABLE 14.8

	Na_2SO_4	Na_2CO_3	NaCl	KI	$Pb(NO_3)_2$	$AgNO_3$	$BaCl_2$	$CuSO_4$	NaOH
Na_2SO_4									
Na_2CO_3									
NaCl									
KI									
$Pb(NO_3)_2$									
$AgNO_3$									
$BaCl_2$									
$CuSO_4$									
NaOH									

QUESTIONS

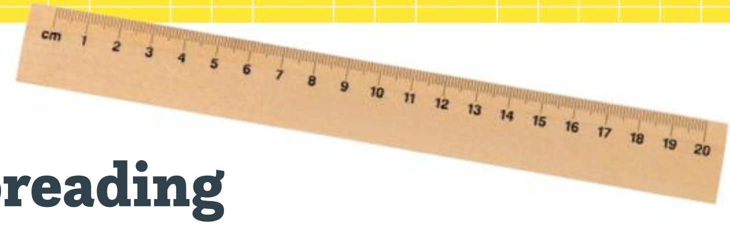
1 Why did you use dropper bottles of solution instead of using solutions from a beaker?
2 Why did you use spotting tiles and not test tubes to carry out these reactions?
3 Write the net ionic equation for the formation silver chloride precipitate.
4 Use your results to predict whether the following salts will be soluble: barium sulfate, silver hydroxide, copper carbonate, silver chloride, lead iodide.
5 Explain how precipitation reactions occur.

CHEMICALS MAY ENTER YOUR EYES. WEAR SAFETY GLASSES TO PREVENT THIS. SILVER SALTS ARE TOXIC AND MAY STAIN YOUR SKIN AND CLOTHES. WEAR GLOVES TO PROTECT YOUR SKIN.

CONCLUSION

Copy and complete.
'The results show that: (*respond to the aim*).'

Investigation **5.1**



Modelling seafloor spreading

KEY SKILL

REFERENCING SOURCES OF INFORMATION

As your science skills become more advanced, you may wish to do some research prior to completing an investigation. This allows you to understand the investigation better; in particular, the science of what is happening. Whenever you do research it is important to get information from trusted sources and to reference where the information came from. When you reference a source, you include details such as who the author of the information is, when it was published and the title of the website or article.

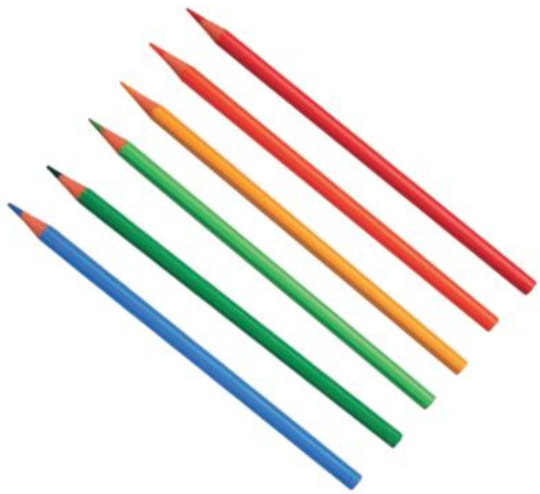
Hint #1: *Two widely used referencing conventions are Harvard and APA. You can look these up to learn more about them, or there are even websites that will format your references for you.*

AIM

To model the process of seafloor spreading

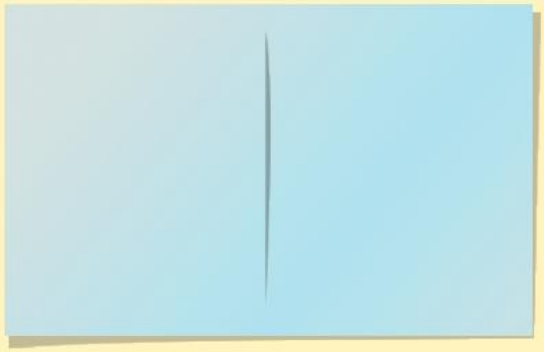
MATERIALS

- 2 sheets of A4 paper
- pencil
- ruler
- coloured pencils or crayons
- sticky tape
- scissors



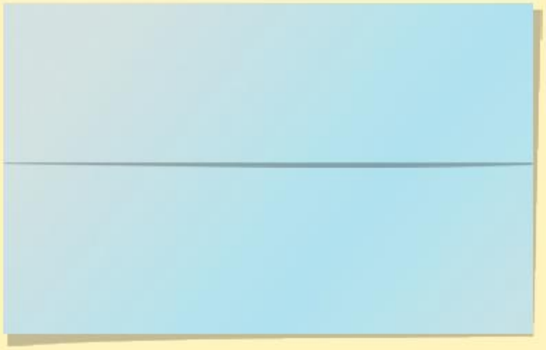
METHOD

1. Place a piece of A4 paper in landscape orientation. Use the ruler and pencil to draw a straight line down the centre of the paper as shown. Label the line 'Mid-ocean ridge'.
2. Carefully use the scissors to cut along the line so that there is a slit in the paper. Be careful not to cut to the ends of the paper. Leave about 3 cm either side of the slit.

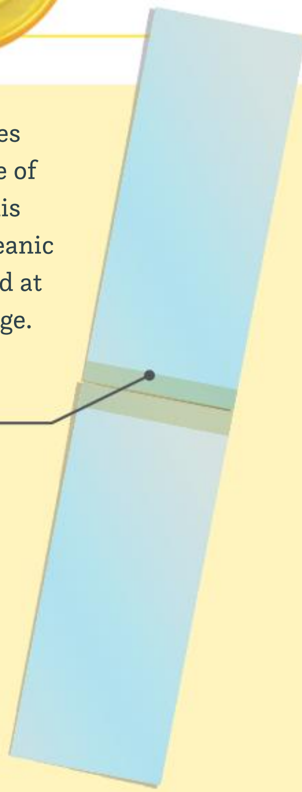


Mid-ocean ridge

3. Cut the second piece of A4 paper in half lengthwise as shown.



20 min Level 1

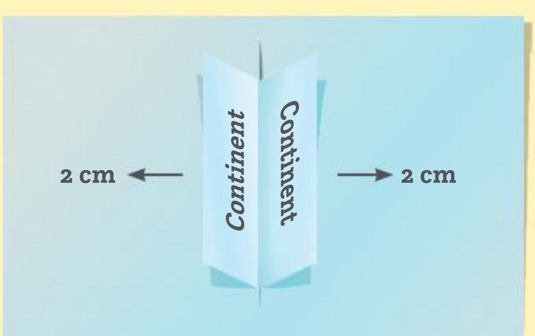


4 Tape the two pieces together along one of the short ends. This represents the oceanic crust being formed at the mid-ocean ridge.

5 Carefully insert the two ends of this paper into the mid-ocean ridge slot from underneath. Separate the pieces so that one will move towards the left and the other towards the right. Leave about 2 cm exposed.

6 Write 'Continent' on both sides of the exposed paper and draw a line where the paper comes out of the mid-ocean ridge, as shown.

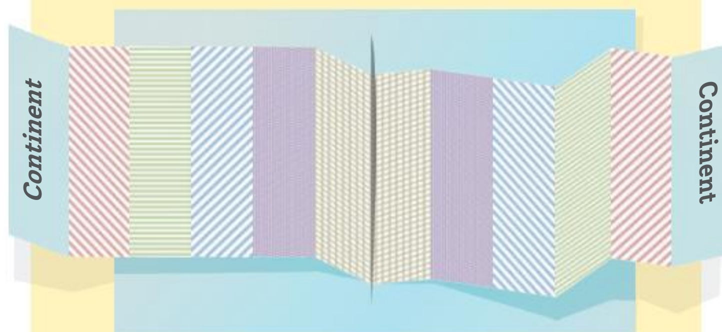
Mid-ocean ridge



7 Evenly pull the paper outwards 1–3 cm and colour the white paper with the first colour.

8 Repeat step 7, using different colours until all of the paper has been pulled through the mid-ocean ridge.

Mid-ocean ridge



9 Remove the coloured strip of paper for analysis.

QUESTIONS

1 What do the different coloured stripes on your model represent?
2 Describe any patterns that you observe in the stripes.
3 Your stripes may not all be of the same width. What does this represent?
4 Critique how well this model demonstrates seafloor spreading. How could it be improved?

CONCLUSION

Copy and complete:
'The results show that: (*respond to the aim*)'.

Investigation **5.2**

Modelling plate boundaries

30 min

Level 1

KEY SKILL

IDENTIFYING AND MANAGING RELEVANT RISKS

Brainstorm with a partner to identify three possible hazards or risks that may be involved in this investigation. Suggest one way that each hazard or risk could be reduced.

AIM

To model the interactions happening at tectonic plate boundaries, using a Mars bar

MATERIALS

- paper towel or napkin
- Mars bar

METHOD

1. Wash your hands before you begin.
2. Unwrap the Mars bar. Hold it over the paper towel and use your fingernails to break the chocolate all around the middle of the bar.
3. Very slowly start to pull the Mars bar apart. Record your observations by drawing a diagram or taking a photograph.
4. Carefully place the two pieces of Mars bar back together again. While keeping them together, push each side in opposite directions. Record your observations by drawing a diagram or taking a photograph.
5. Squeeze the two pieces of Mars bar together from either end. Record your observations by drawing a diagram or taking a photograph.

QUESTIONS

1. Identify the types of plate boundary that you modelled in steps 2–4.
2. What does the top layer of chocolate represent?
3. What do the inside layers of the Mars bar represent?
4. Were you able to model subduction? Explain why or why not.

CONCLUSION

Copy and complete:
'The results show that: (*respond to the aim*)'.

Investigation **5.3A**

Modelling slab pull

60 min

Level 2

KEY SKILL

WRITING A RESEARCH QUESTION

Turn the aim of this investigation into a question that asks what you are trying to discover. This is called a research question.

Hint #1: *Make sure that your research question has a question mark at the end.*

Hint #2: *Your research question can also be used as a title for an experiment report.*

AIM

To create a model that represents the force of slab pull on a tectonic plate

MATERIALS

- a variety of materials provided by your teacher

METHOD

1. Review the information on page 84 about how the force of slab pull moves a tectonic plate. You could also use the internet to undertake some further research.
2. Brainstorm how you could use the materials provided to create a model that represents slab pull moving a tectonic plate.
3. Construct your model.
4. Share your model with the class.

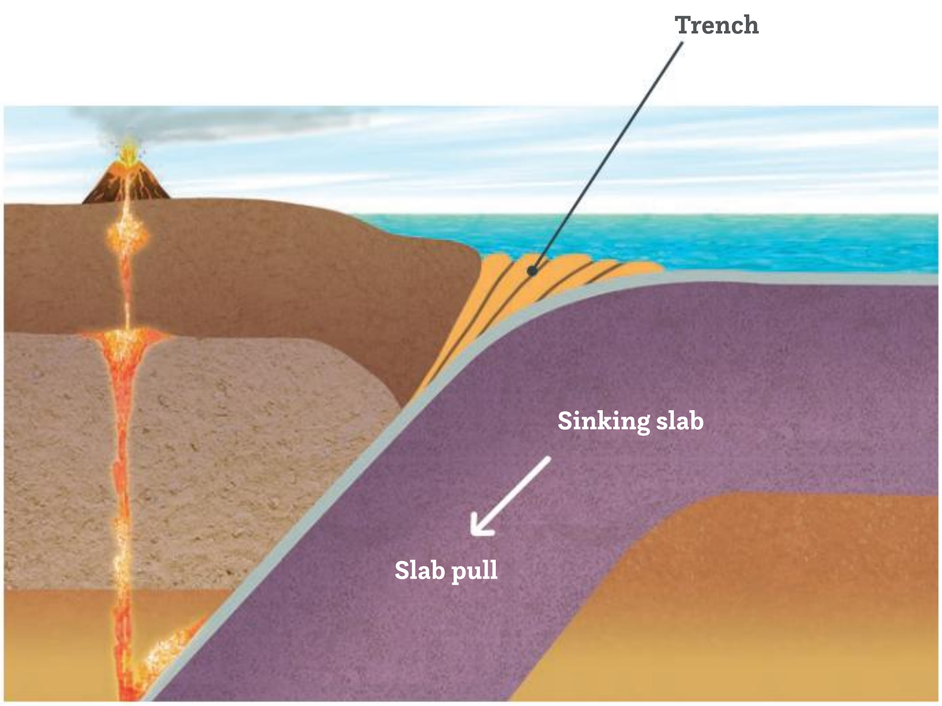
QUESTIONS

1. Explain how your model represents the force of slab pull moving a tectonic plate.
2. Critique your model. Is there anything that is inaccurate? Could it be improved?

CONCLUSION

Copy and complete:

'The results show that: (*respond to the aim*)'.



Investigation **5.3B**

Observing convection currents

30 min | Level 2

KEY SKILL
EXPLAINING RESULTS USING SCIENTIFIC KNOWLEDGE

When you write a formal investigation report, there is always a discussion section that includes your analysis and explanation of the data you collected. This is where you get to explain your results by linking them to what you already knew about the science of what you are studying.

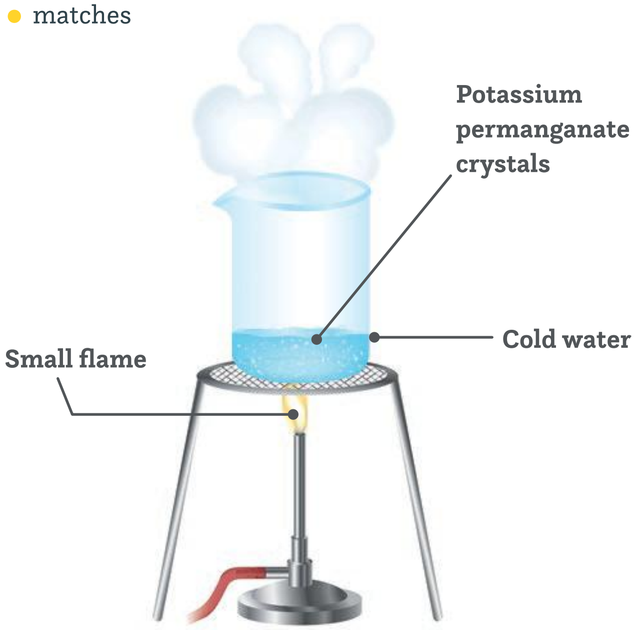
Hint #1: *You can use the following sentence stem to write about your results: 'My data shows ... and this makes sense because ...'.*

AIM

To investigate the movement of convection currents

MATERIALS

- potassium permanganate crystals
- glass tube
- 500 mL beaker
- Bunsen burner
- tripod
- heatproof mat
- wire gauze
- matches



METHOD

1 Set up the Bunsen burner and heatproof mat.
2 Fill the beaker with cold water and place it on the tripod as shown in the diagram.
3 Use the glass tube to carefully place a couple of crystals of potassium permanganate on the bottom of one side of the beaker.
4 Light the Bunsen burner and place the flame under the crystals.
5 Observe how the coloured water moves.

QUESTIONS

1 Draw a diagram that illustrates the movement of the coloured water that you observed.
2 Explain what happened to the cause the pattern of movement. Use the terms *heat* and *density* in your explanation.
3 Relate the movement of the coloured water in the beaker to the movement of rock in the mantle.

CONCLUSION

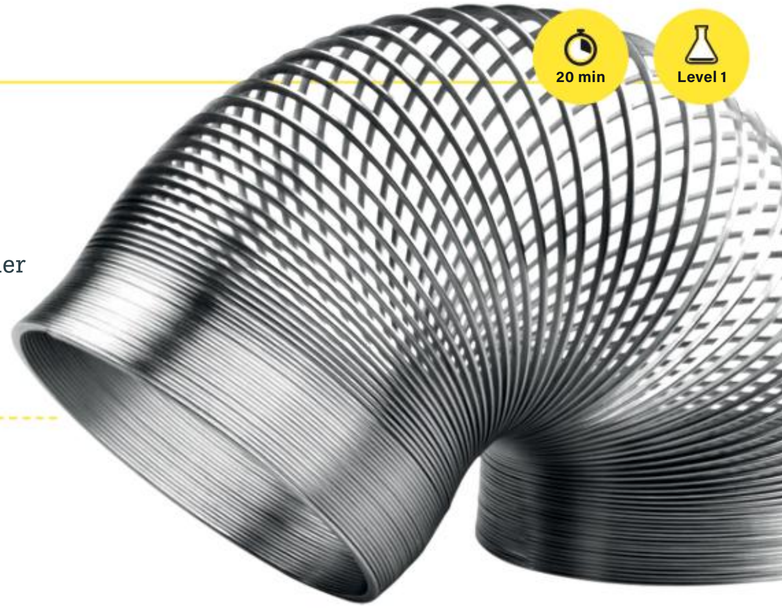
Copy and complete.
'The results show that: (*respond to the aim*).'

AN OPEN FLAME IS A HAZARD. TAKE CAUTION. IF YOU BURN YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND PLACE YOUR SKIN UNDER COLD RUNNING WATER FOR 20 MINUTES.

DISPOSE OF WASTES APPROPRIATELY.

Investigation **5.4**

Slinky waves



KEY SKILL

USING MODELLING AND SIMULATIONS

Scientists can use modelling and simulations to simplify and explain ideas. Models make things easier to understand and visualise, which helps us make predictions. However, there are some limitations to the use of models – how many can you think of?

AIM

To use slinkies to model different seismic waves

MATERIALS

- 2 slinkies
- paperclip
- 5 cm piece of wool or string

METHOD

1 Copy the results table into your notebook, adding a title.
2 Have one person hold one end of the slinky on the ground. A second person holds the other end in the air above the first.
3 Tie the piece of wool or string in a bow around one of the coils near the middle of the slinky.
4 The first person should pull some of the coils directly down and release them.
5 Observe how the wool moves and record your observations.
6 When the slinky is still again, the first person should move the bottom of the slinky from side to side.
7 Observe how the wool moves and record your observations.
8 Use the paperclip to create a hook to connect the end of one slinky to the middle of the other slinky. Have people hold each of the three ends. One slinky should be held vertically and the other horizontally.
9 Tie the piece of wool in a bow along the second slinky that is being held horizontally.
10 The person holding the bottom of the vertical slinky should pull some of the coils down and to the side before releasing them.
11 Observe how the wool moves and record your observations.

QUESTIONS

1 Identify which movements relate to primary waves and secondary waves.
2 What were you modelling in steps 9–11?

CONCLUSION

Copy and complete:
'The results show that: (*respond to the aim*)'.

RESULTS TABLE I5.4

Movement	Observations – description of how the string on the slinky moves
Compression	
Side to side	
Both	

Investigation **5.5A**

Viscosity of lava

30 min

Level 1

KEY SKILL
EVALUATING RESULTS FOR RELIABILITY AND VALIDITY

In order for our investigations to be considered scientific, we need to check that our results were reliable and valid. It sounds like a difficult thing to check but it's actually simple. If your results are reliable, it means that if you repeated your test or investigation you would get the same results. If your results are valid, it means that you were able to measure what was intended to be measured.

***Hint #1:** If someone makes a human error (for example, dropping something, adding too much or too little of a substance, spilling something or using different equipment each time) then the results are probably not valid or reliable.*

AIM

To investigate how the viscosity of a substance affects how well it flows over a distance

MATERIALS

- whipped cream
- thickened cream
- tray
- protractor
- 2 stopwatches
- 2 spatulas

METHOD

1 Copy the results table into your notebook, adding a title.

1 Use the spatula to place dollops about the size of a 20-cent coin of each type of cream at one end of the tray.

2 Start both stopwatches and immediately lift up the end of the tray with the cream on it so that the tray is at a 45° angle.

3 Time how long it takes for each dollop of cream to reach the opposite end of the tray.

4 Record any other observations.

5 Clean and dry the tray and repeat steps 2–4 two more times.

QUESTIONS

1 Compare the flow rates of the two types of cream.

2 Explain how viscosity affected the time it took for the cream to travel down the length of the tray.

3 Relate the types of cream used in this investigation to lava from hot spot and strato volcanoes and the shape of volcano they form.

CONCLUSION

Copy and complete:

'The results show that: (*respond to the aim*)'.

RESULTS TABLE I5.5A

	Time taken to travel the length of the tray (s)				Distance (cm)	Flow rate (distance/time) (cm/s)
	Trial 1	Trial 2	Trial 3	Average		
Whipped cream						
Thickened cream						

Investigation **5.5B**

Wax volcano

50 min | Level 2

KEY SKILL

IDENTIFYING AND MANAGING RELEVANT RISKS

Brainstorm with a partner to identify three possible hazards or risks that may be involved in this investigation. Suggest one way that each hazard or risk could be reduced.

AIM

To model a volcanic eruption using wax

MATERIALS

- coloured candle wax
- washed sand
- 500 mL beaker
- hot plate or Bunsen burner

METHOD

1 Melt the candle wax to form a 1 cm layer in the bottom of the beaker and allow it to set.
2 Cover the wax with a 1–2 cm layer of sand.
3 Carefully fill the beaker with water.
4 Place the beaker on the hot plate and turn on the heat.
5 Observe from a safe distance with written notes or by taking a short video.
6 Record the results of the eruption by drawing a diagram or taking a photograph.

QUESTIONS

1 Describe the eruption.
2 What structures of Earth do these layers represent in this model?
 a wax
 b sand
 c water
3 Critique this model. How does it reflect real volcanic eruptions? How is it different?

CONCLUSION

Copy and complete:
'The results show that: (*respond to the aim*)'.

HOT WAX CAN BURN.

AN OPEN FLAME IS A HAZARD. TAKE CAUTION. IF YOU BURN YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND PLACE YOUR SKIN UNDER COLD RUNNING WATER FOR 20 MINUTES.

Investigation **6.2**

Modelling a simple circuit

15min

Level 1

KEY SKILL

USING MODELLING AND SIMULATIONS

Scientists can use modelling and simulations to simplify and explain ideas. Models make things easier to understand and visualise, which helps us make predictions. However, there are some limitations to the use of models – how many can you think of?

AIM

To model a simple circuit and the concepts of current and resistance

MATERIALS

- a piece of rope at least 4 metres long, tied in a loop
- two pairs of thick fabric gloves

METHOD

1 As a class, stand in a circle, holding the rope very loosely.
2 One student acts as the 'battery' and adds voltage to the circuit by pulling one end of the rope. Observe what happens to the rope (it should move in a circle).
3 The student increases the energy with which they pull the rope, just like a 'battery' adding more voltage. Observe what happens to the speed of the rope.
4 One or two students act as 'resistors'. They put on gloves and then hold the rope a little more tightly than the others. Observe what happens to the speed of the rope as resistance is added.

QUESTIONS

1 In what ways are models (like the one above) helpful in demonstrating scientific concepts?
2 What could you add or change in this model and role play in order to improve it?
3 Explain the role of the resistors in your own words.
4 How are resistors imporant in the conduction of electricity?

CONCLUSION

Copy and complete:
'The results show that: (*respond to the aim*)'.

Investigation **6.3**

Exploring Ohm's law

30min

Level 2

KEY SKILL
IDENTIFYING THE VARIABLES AND FORMULATING A HYPOTHESIS

Before you formulate a hypothesis, identify your independent, dependent and controlled variables. The independent variable is the one thing that you purposefully want to change in an investigation. The dependent variable is what you will be measuring. The controlled variables are all the things you need to keep the same throughout the investigation. To formulate your hypothesis, use the following sentence stem: It can be hypothesised that if (something to do with your independent variable), then (something to do with your dependent variable).

Hint #1: *If you get stuck, use the prompts on page 129 to help you.*

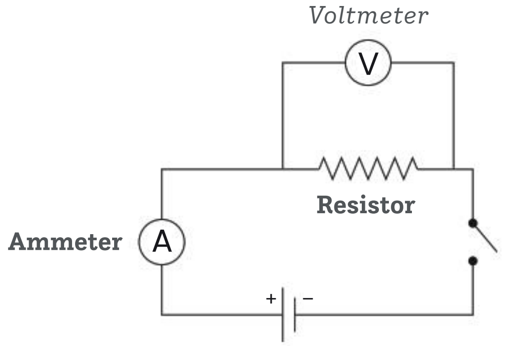
Hint #2: *In your conclusion, state whether your hypothesis was supported (correct) or rejected (incorrect).*

AIM

To investigate Ohm's law and determine the resistance of a resistor

MATERIALS

- fixed resistor (5–10 ohms)
- 0–12 V voltmeter
- 0–5 A ammeter
- variable DC power supply (2–12 V)
- 5 electrical leads



RESULTS

TABLE I6.3

Power (V)	Voltmeter reading (V)	Ammeter reading (A)
2		
4		
6		
8		
10		
12		

METHOD

1. Copy the results table into your notebook, adding a title.
2. Construct the circuit shown in the diagram but do not turn it on.
3. Set the power supply to 2 volts.
4. Close the switch. Note and record the readings on the ammeter and voltmeter in the results table.
5. Open the switch and increase the power supply by 2 volts. Note and record the readings on the ammeter and voltmeter.
6. Continue increasing the power supply by 2 volts, and recording the readings, until the results table is complete.

QUESTIONS

1. Draw a graph plotting current (y-axis) versus voltage (x-axis) using the data from your results table.
2. What does the slope of the line in the graph you drew equal?

CONCLUSION

Copy and complete.

'The results show that: (*respond to the aim*).'

Investigation **6.4**

Investigating conductors and insulators

KEY SKILL

IDENTIFYING THE VARIABLES AND FORMULATING A HYPOTHESIS

Before you formulate a hypothesis, identify your independent, dependent and controlled variables. The independent variable is the one thing that you purposefully want to change in an investigation. The dependent variable is what you will be measuring. The controlled variables are all the things you need to keep the same throughout the investigation. To formulate your hypothesis, use the following sentence stem: It can be hypothesised that if (something to do with your independent variable), then (something to do with your dependent variable).

Hint #1: *If you get stuck, use the prompts on page 129 to help you.*

Hint #2: *In your conclusion, state whether your hypothesis was supported (correct) or rejected (incorrect).*

AIM

To investigate which materials are electrical conductors and which are insulators in an electrical circuit

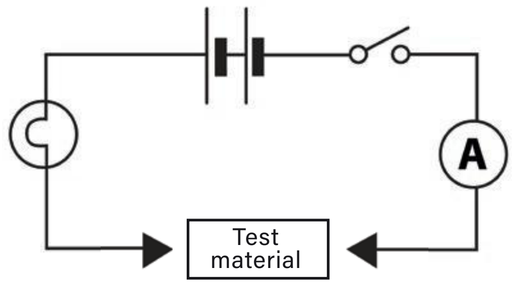
MATERIALS

- selection of materials (such as fabric, iron nail, strip of tin, icy pole stick, strip of copper, chalk)
- variable power supply
- ammeter
- switch
- 6 V, 10 W light bulb
- conducting wires with alligator clips
- conducting wires with suitable attachments for a power pack

30 min Level 2

METHOD

1 Copy the results table into your notebook, adding a title and rows as needed.
2 Copy the circuit diagram and label all the symbols used.
3 Set up the circuit as shown in the diagram.
4 Set the DC power supply to 6 V.
5 Attach both contacts to one of the materials.
6 Switch on power to the circuit and record your observations of the light bulb. Also record the ammeter reading.
7 Repeat steps 5 and 6 for each material.



QUESTIONS

1 What did you observe when the test material was a good conductor?
2 How did you know which of the materials was an insulator?
3 Based on your table, what do the materials that were good conductors have in common?
4 What do the good insulating materials have in common?

CONCLUSION

Copy and complete:
'The results show that: (*respond to the aim*)'.

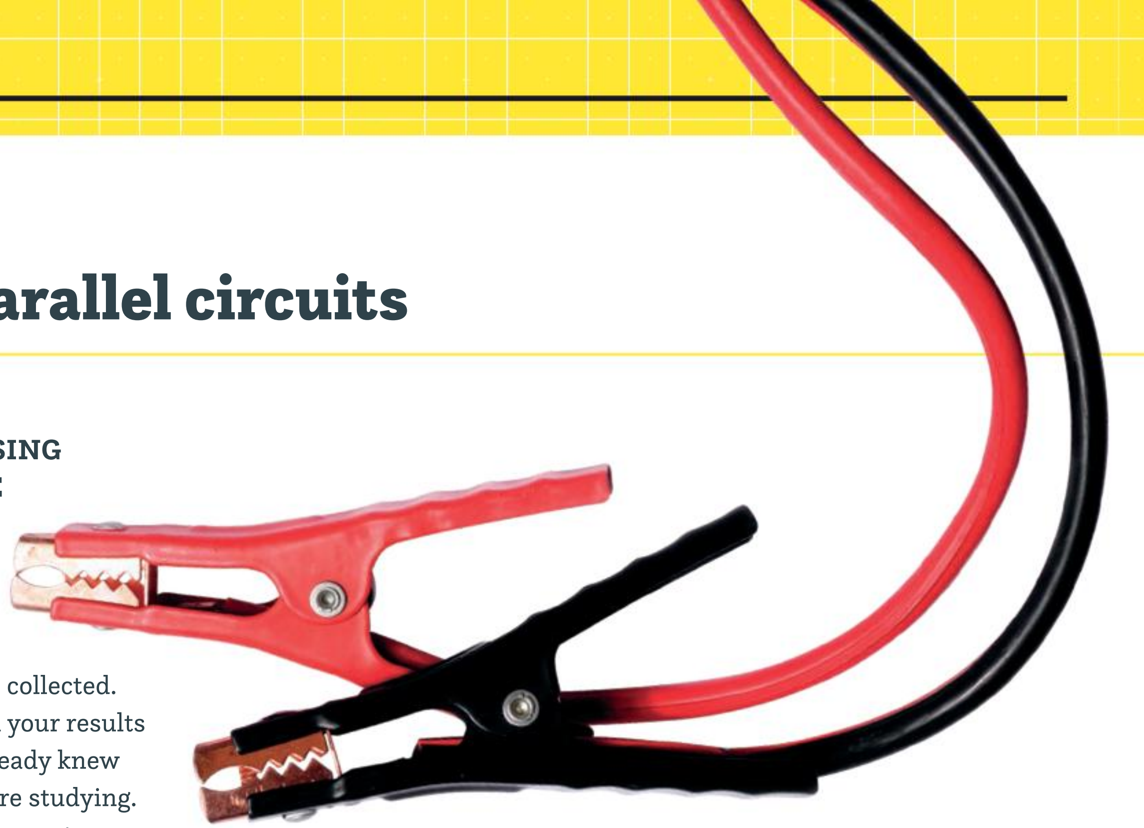
ELECTRICITY IS A HAZARD. TAKE CAUTION.

RESULTS TABLE 16.4

Material	Did the light turn on?	Ammeter reading (mA)	Conductor or insulator?

Investigation **6.5**

Series and parallel circuits



KEY SKILL

EXPLAINING RESULTS USING SCIENTIFIC KNOWLEDGE

When you write a formal investigation report, there is always a discussion section that includes your analysis and explanation of the data you collected. This is where you get to explain your results by linking them to what you already knew about the science of what you are studying.

Hint #1: *You can use the following sentence stem to write about your results: 'My data shows ... and this makes sense because ...'.*

AIM

To investigate series and parallel circuits

MATERIALS

- 2 ammeters
- voltmeter
- 9 × electrical leads
- 2 × 10 ohm resistors
- power-pack

METHOD

Copy the results table into your notebook, adding a title.

PART A

SERIES CIRCUIT

1 Set up the circuit as shown in diagram 1.
2 Set the power-pack to 2 V and turn it on. Record the current and voltage across each resistor in the results table.
3 Repeat step 2, increasing the power supply by 2 V each time, until your results table is complete.

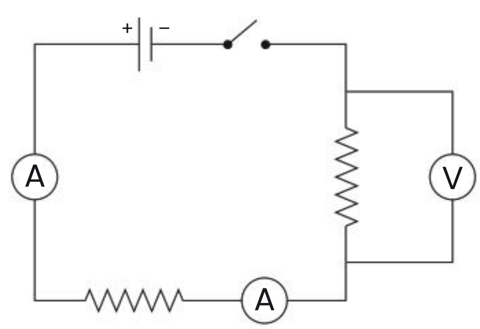


Diagram 1

30min Level 2

RESULTS TABLE I6.5

Power supply (V)	Part A		Part B	
	Voltmeter reading (V)	Ammeter reading (A)	Voltmeter reading (V)	Ammeter reading (A)
2				
4				
6				
8				
10				
12				

PART B

PARALLEL CIRCUIT

1 Set up the circuit as shown in diagram 2.
2 Set the power-pack to 2 V and turn it on. Record the current and voltage across each resistor in the results table.
3 Repeat step 2, increasing the power supply by 2 V each time, until your results table is complete.

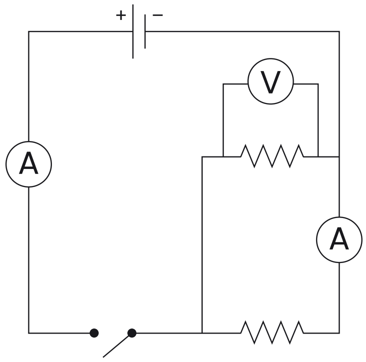


Diagram 2

QUESTIONS

1 Consider the series circuit. What relationship exists between the voltage of the power-pack and the voltage across both resistors?
2 What do you notice about the voltage across each resistor in the parallel circuit?
3 What do you notice about the current through the ammeter of the series circuit compared to the parallel circuit?

CONCLUSION

Copy and complete:
'The results show that: (*respond to the aim*)'.

Investigation **7.2**

Magnets and Matchbox cars

30 min
Level 1

KEY SKILL

WRITING A RESEARCH QUESTION

Turn the aim of this investigation into a question that asks what you are trying to discover. This is called a research question.

Hint #1: *Make sure that your research question has a question mark at the end.*

Hint #2: *Your research question can also be used as a title for an experiment report.*

AIM

To investigate the behaviour of magnets

MATERIALS

- 2 bar magnets
- 2 Matchbox cars
- tape

METHOD

1. Tape a bar magnet to the roof of each Matchbox car, with the north pole pointing to the front.
2. Position the cars so that they are close together and facing each other, then release them. Record your observations.
3. Remove the bar magnet from one of the cars and replace it so that the south pole is pointing to the front.
4. Repeat step 2.

QUESTIONS

1. What happened when both cars had north poles at the front?
2. What happened when the cars had different poles at the front?
3. Explain the behaviour of the cars in terms of fields.

CONCLUSION

Copy and complete:
'The results show that: (*respond to the aim*)'.

Investigation **7.3**

Building an electric motor

60 min

Level 2

KEY SKILL

IDENTIFYING AND MANAGING RELEVANT RISKS

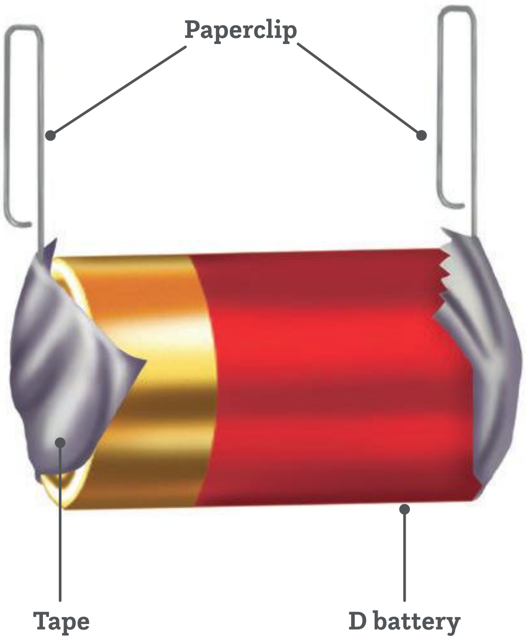
Brainstorm with a partner to identify three possible hazards or risks that may be involved in this investigation. Suggest one way that each hazard or risk could be reduced.

AIM

To build and investigate a simple electric motor

MATERIALS

- insulated copper wire
- cylinder
- utility knife
- D-cell battery
- 2 metal paperclips
- electrical tape
- bar or round magnet



METHOD

1 Wrap the insulated copper wire around the cylinder several times to make a coil, leaving the ends sticking out.
2 Carefully remove the wire from the cylinder and place it on a wooden board. With extreme care, scrape the plastic coating away from the wire.
3 Bend one end of each paperclip so that it sticks out. Tape the paperclips to the battery as shown.
4 Slide the coil of wire through the paperclips so that it is supported within the loops. Make sure the coil can spin freely.
5 Hold the magnet over the top of the coil and spin the coil.

QUESTIONS

1 What happened when you spun the coil?
2 Explain what happened to the coil in terms of magnetic fields.
3 Explain how a simple electric motor works, in your own words.

CONCLUSION

Copy and complete:
'The results show that: (*respond to the aim*)'.

TAKE CAUTION USING THE UTILITY KNIFE. IF YOU CUT YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND SEEK FIRST AID.

GLOSSARY

abiotic non-living

accuracy how close the results are to the true values

adaptation a feature that enables an organism to survive in its environment

alkali a base that is dissolved in water

alloy a mixture of two or more metals

alpha (α)particle a positively charged particle that is four times larger than a proton

amino acid a simple molecule that is the basic unit of a protein

ammeter a device that measures electric current

amplifier an electronic component that boosts electrical current

antibody a protein that responds to a specific antigen

asthenosphere the portion of Earth's mantle underneath the lithosphere that can flow

asymptomatic displaying no symptoms of a disease

atmospheric nitrogen nitrogen that is found in the atmosphere

atom the smallest particle of matter, made up of electrons orbiting a nucleus of protons and neutrons

atomic number the number of protons in an atom

attractive force a force that pulls objects towards each other

bacteria tiny, single-celled organisms that can live in a range of environments

biodiversity the variety of species in an ecosystem

biotic living

cathode ray a stream of electrons observed in a high-vacuum tube

carbonate a substance containing the elements carbon and oxygen

caustic able to burn or corrode organic tissue through chemical action

cellular respiration the process that all living things use to produce cellular energy from glucose and oxygen

chemical reaction a reaction that involves the creation of new substances

circuit a closed path containing a collection of components connected to a power source that allows current to flow

combustion a reaction that involves burning in the presence of oxygen to release heat

community a naturally occurring group of animals, plants and other organisms

component a part of an electric circuit in an electrical device

compound a substance made up of two or more types of atoms bonded together

conductor a material that allows the flow of current

concentration the amount of a substance in a volume of solution

conservation of mass the scientific law that mass cannot be created or destroyed

consumer an organism that gains energy by consuming other living organisms

contagious able to spread from one organism to another

continental drift the theory that the continents have moved position over time

controlled variables all the things that need to stay the same during an investigation

convection the transfer of heat by movement of a liquid or a gas

convergent boundary where two tectonic plates are moving towards each other, also referred to as a destructive boundary

corrosive highly reactive and damaging or destructive to another substance

current a measure of how fast electrons move in a circuit

Dalton's atomic theory the theory that states that all matter is made up of tiny particles

degrade to wear down a substance

dengue fever a mosquito-borne viral disease occurring in tropical and subtropical areas

dependent variable the thing that will be measured and is altered by the independent variable

diffuse to move from an area of high concentration to an area of low concentration

digestive enzyme a chemical that acts to break down large chemical structures in food into smaller forms

diode an electrical component that allows electric current to flow in only one direction

dissociate to split apart into ions

divergent boundary where two tectonic plates are moving away from each other, also referred to as a constructive boundary

dosimeter a device used to measure an absorbed dose of ionising radiation

ecosystem a community of living things and their environment

effector a muscle, gland or organ that responds to a message sent by the nervous or endocrine system

electrically neutral having an equal number of protons (positively charged) and electrons (negatively charged)

electrolysis a decomposition reaction using electricity

electromagnet a device that uses electricity to make a magnetic field

electron shell the space around the nucleus where electrons circulate

electrostatic force a non-contact force between any objects with an electric charge

element a pure substance made up of one type of atom

endothermic a reaction that absorbs energy in the form of heat

epicentre the point on Earth's surface directly above the focus of an earthquake

epidemic the widespread occurrence of an infectious disease in a community

error the difference between the measured value and the actual value

eutrophication the process in which nutrient levels increase in a waterway, resulting in increased algal growth and decreased dissolved oxygen levels

exothermic a reaction that releases energy in the form of heat

experiment an investigation carried out under controlled conditions, to test a hypothesis

fair test an investigation in which only one factor is changed and all other variables are kept the same

fault a break in Earth's surface where blocks of rock slide past each other

field an area of space where objects are affected by a non-contact force

field line a line used to show the direction of a force within a field

fieldwork an investigation conducted in the natural environment, not a laboratory

focus the origin of an earthquake

fold mountain a mountain formed by the folding of continental crust when tectonic plates collide

gas exchange the exchange of oxygen and carbon dioxide between an organism and the environment

generator a device that converts kinetic energy into electricity

germinate to grow and put out shoots

gland tissue that secretes hormones

GPS global positioning system

graft a piece of living tissue that is transplanted surgically

gravitational force a non-contact force that affects all matter

habitat the natural environment where a species or organism lives

half-life the time taken for half of a radioactive material to decay

hormone a chemical secreted by a gland that triggers a response in certain cells

homeostasis maintaining a stable, balanced state within the body

hot spot volcano a volcano formed by magma upwelling underneath a tectonic plate

hydrocarbon a compound made up of only hydrogen and carbon

hygiene ways of doing things that support health and prevent disease, often through cleanliness

hypothesis a scientific statement that can be tested

immune resistant to a particular illness or disease

independent variable the thing that is purposefully changed during an investigation

inference an educated guess or judgement based on observations

insoluble unable to be dissolved

insulator a material that resists the flow of current

intensity (earthquakes) a measure of the amount of destruction caused by an earthquake

intensity (fire) how much heat is released from a fire front

ionic compound a compound made up of metal and non-metal ions

ionise to remove electrons from an atom or molecule

ionising radiation radiation, made up of particles, X-rays or gamma rays, that has sufficient energy to cause cancer

isotopes atoms of the same element with the same number of protons but a different number of neutrons

keystone species a species that plays a crucial role in its ecosystem

lava molten rock above Earth's surface

like poles magnetic poles that are the same (both north or both south); they repel each other

lithosphere Earth's rigid outer zone (crust and uppermost part of the mantle), made up of tectonic plates

load any part in a circuit that receives power

Lorentz force a force created by a current flowing through a magnetic field

lymphocyte a type of white blood cell that produces antibodies in response to a pathogen

magma molten rock below Earth's surface

magnetic force a non-contact force that affects any object made of certain metals, such as iron

magnetic pole one of the two ends of a magnet

magnitude a measure of the energy released by an earthquake

mantle Earth's middle layer, made up of two layers

matter particles that make up all physical substances

mean the values of a data set added together and divided by the number of values

median the middle result in a set of data

mid-ocean ridge a long chain of mountains under the ocean formed by plate tectonics

mistake something that has been done incorrectly in an experiment

molecule two or more atoms chemically bonded to each other

moment magnitude scale a logarithmic scale used to compare the amount of energy released by earthquakes

motor a device that converts electricity into kinetic energy

mutualism a relationship in which both organisms benefit

neuron a specialised cell that makes up the nervous system

neutralise to make something chemically neutral

neutralisation reaction a reaction involving an acid and a base to produce water and a salt

negative feedback a response that counteracts the stimulus

nitrogenous containing nitrogen

nucleus the central part of an atom, containing protons and neutrons

observation something you see and know to be true

Ohm's law a law that states that the current through a conductor between two points is directly proportional to the voltage across the two points

oxidation a reaction taking place in the presence of oxygen

pandemic a disease occurring within a whole country or around the world

parallel circuit a circuit in which all components are connected between the same points, so the current has more than one path to take

parasite an organism that lives in or on another organism, causing it harm

pathogen an agent that causes disease

penetrating power how well radiation from radioactive materials can pass through matter

pH a figure expressing the acidity or alkalinity of a solution

phagocyte a type of cell capable of engulfing and destroying bacteria

photosynthesis the chemical reaction, powered by sunlight, that plants use to change carbon dioxide and water into glucose and oxygen

polarity the direction of a force, such as a magnetic force

pollinator an organism that transfers pollen from the male to the female part of a plant

precipitate an insoluble product

precision how close the results of repeated trials are to each other

predator an organism that kills and feeds on prey

prediction a statement about the future based on observation and evidence

prey an organism killed by a predator

primary data first-hand data, from your own investigation

producer an organism that makes its own food using energy from the Sun

product a substance formed in a chemical reaction

pustule a small blister

qualitative written descriptions and observations

quantitative numerical information and data

quarantine the isolation of people, plants, animals or objects that may have been exposed to biosecurity threats

radioisotope an isotope that emits radiation

radiotherapy a therapy that uses radiation to kill cancerous cells

range the largest value in a data set minus the smallest value

reactant a substance that starts a chemical reaction

receptors specialised cells and organs that detect changes

reciprocal the reciprocal of a number is 1 divided by that number

reliable provides consistent results when repeated

repulsive force a force that pushes objects away from each other

research to gather data and information in an organised way to inform a hypothesis or an investigation

resistance how much a substance opposes an electric current moving through it

respiration the chemical reaction that occurs in cells to release energy

rift valley a valley formed when a continent is being pulled apart

sample size the number of participants in a survey or samples tested in an experiment

sanitation facilities and services to ensure safe treatment of human waste (urine and faeces)

secondary data second-hand data, from someone else

seismic wave a wave of energy that passes through Earth's layers and is caused by an earthquake

seismometer a scientific instrument that detects seismic waves

sensationalised language that aims to shock or produce an emotional reaction in the reader

series circuit a circuit in which components are arranged in a chain, so the current has only one path to take

solenoid a tight coil of wire

soot a black form of carbon formed by incomplete combustion

spectral line a dark or bright line in an otherwise uniform spectrum

speculative relying on theories or opinions rather than facts

strato volcano a volcano formed at a subduction zone

strong acid an acid that ionises completely in water

subduction when one tectonic plate moves underneath another

synapse the gap between the axon and dendrite of two neighbouring neurons

tectonic plate a section of Earth's lithosphere

transform to change from one form to another

transform boundary where two tectonic plates are sliding past one another

transistor an electronic component that can act as a switch or an amplifier

transmissible able to be passed from one person to another

trend a consistent change in the values of a data set

trophic level the position of an organism in a food chain

tsunami a sea wave caused by the displacement of water as a result of an earthquake or other disturbance

uncertainty the margin of error of a measurement

unlike poles magnetic poles that are different (south-north or north-south); they attract each other

valid measures what is intended to be measured

virus a tiny infectious agent that multiplies in its host

volcano a point in Earth's crust where lava erupts

voltage the difference in potential energy between two points in a circuit

voltmeter a device that measures potential difference (voltage)

weak acid an acid that partially ionises (loses or gains electrons) in water

word equation a representation of a chemical reaction using words

zone of tolerance the range of an abiotic factor that an organism can survive in

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