ECOSYSTEMS » ENERGY » CHEMICAL REACTIONS » ATOMS

AMAZING SCIENCE 9

SIMON TOROK
PAUL HOLPER

WHY ATOMS BECOME EXPLOSIVE

5 amazing predators

LIVING ON A MOVING PLANET

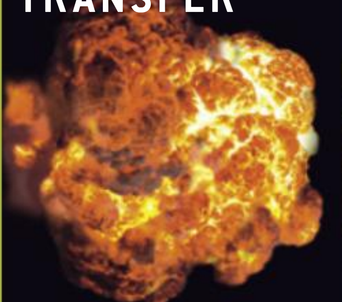
The impact of tectonic plates

THE BIG CATS

APEX PREDATORS IN DANGER

Who let the toads in?

ENERGY TRANSFER



Why are the reactions of acids important?

ENERGY FLOWS

How can we sustain ecosystems?

MULTICELLULAR ORGANISMS

X-rays: What are we being exposed to?

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AMAZING

SCIENCE 9

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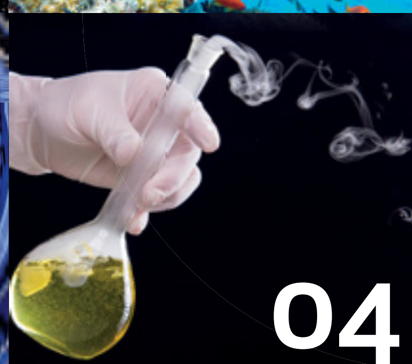
CONTENTS



CONTENTS

AMAZING EXPERIMENTS

Lots more experiments on the Teacher obook!

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MULTICELLULAR ORGANISMS

01

THE AUSTRALIAN SCIENTIST who developed penicillin

FIGHT OR FLIGHT

5 AMAZING SENSES

8

WHAT IS ESSENTIAL FOR LIFE?

10

THE HUMAN BRAIN

22

RADIATION HELPS AND HURTS

Scientists estimate that the Earth contains 8.7 million different species of organisms (excluding bacteria and viruses).

MULTICELLULAR ORGANISMS

Multicellular simply means more than one cell. All species of animals, including the human species, are multicellular organisms. Plants, and many fungi and algae, are also multicellular organisms. To survive, these living things need internal systems that are dependent on each other, coordinated, and responsive to change.

Organisms

Organisms are living things. Earth contains countless organisms. Just 1 millilitre of saliva contains as many as 100 million organisms.

These living things are grouped into **species** with similar characteristics. Many millions of the Earth's species are single-celled organisms that are invisible to us. Only a small fraction are the familiar multicellular organisms that you can see.

To survive, organisms need to reproduce, grow, respond to stimuli, and maintain their internal function in a changing environment. Multicellular organisms can have an amazing combination of cells, tissues, organs and systems working together to maintain a stable living being.

Humans are multicellular organisms made up of around 37 trillion cells (a trillion is a million million). The cells are grouped into various tissues and organs that have specialised functions.

Internal systems

Your body needs to balance its internal conditions to survive. It manages this through coordinated internal systems that work together and respond to changes inside and outside your body.

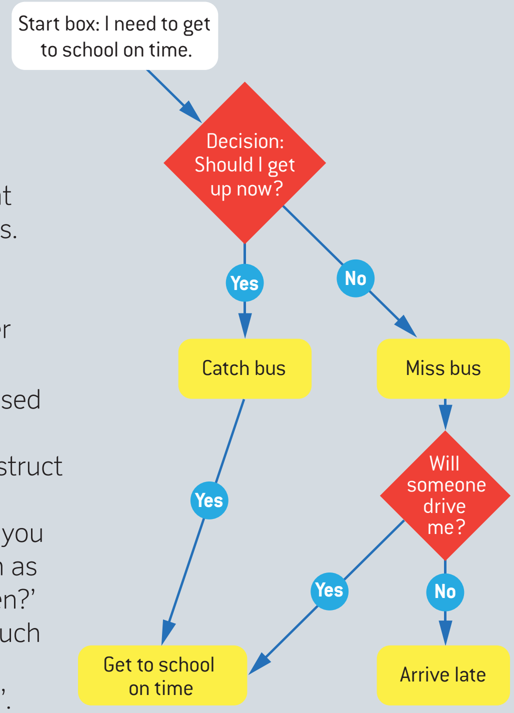
The different systems inside your body communicate largely through the brain, spinal cord and nerves. This nervous system works with the endocrine system, which produces hormones. Together, these two systems constantly monitor how your body's other systems are functioning.

The body's systems work together, similar to the many musical instruments of an orchestra: the different parts come together in a complicated way to create a symphony.

Flow diagrams

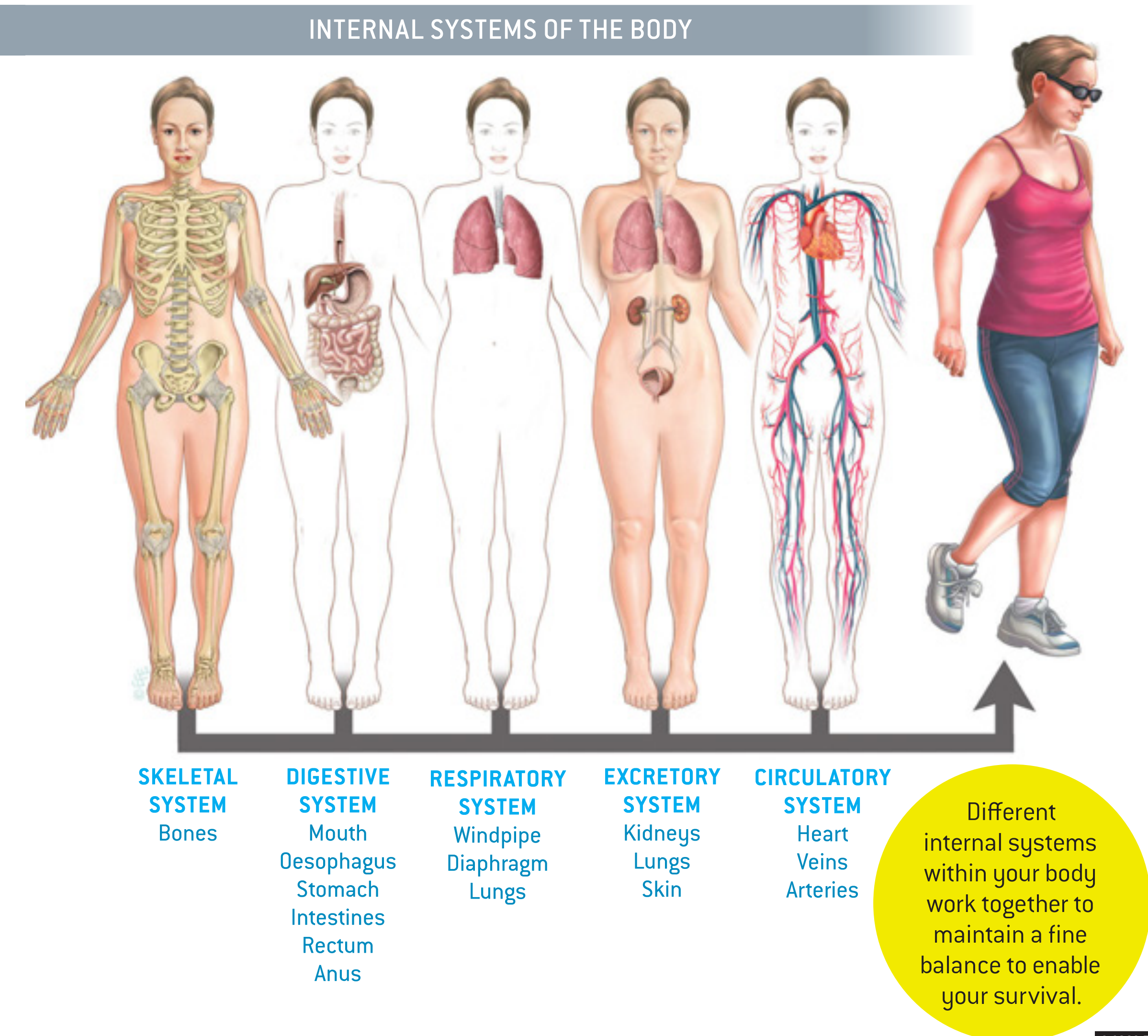
A **flow diagram** is a series of arrows and text in boxes. These represent different pathways that are influenced by decision points. In the flow diagram shown, decisions influence whether you catch or miss a bus, and whether you make it to school on time.

A flow diagram can also be used to demonstrate how your body systems interact. You could construct your own flow diagram to show changes that might occur when you exercise. Include questions such as ‘Do the cells have enough oxygen?’ and ‘Does the blood have too much carbon dioxide?’, and responses such as ‘Increase breathing rate’.



The nervous system coordinates other body systems through electrical signals.

A flow diagram describing decisions and pathways about how to get to school on time.



LOOK IT UP

flow diagram a series of arrows and text in boxes representing different pathways that are influenced by decision points

multicellular consisting of many cells, e.g. animals, plants

organism a living thing

species a group of similar organisms capable of breeding, such as *Homo sapiens*

CHECK IT OUT

1. What is the definition of a multicellular organism?
2. Why is the number of species on Earth an estimate rather than an exact number?
3. Are single-celled organisms visible to the naked eye?
4. a Name the two main internal body systems that monitor the body’s other systems.

   b List three other systems of the human body.

THINGS OUR BODIES NEED

You obtain nutrients from the food you eat.

You need food, water and oxygen to survive. You digest food to enable **nutrients** to be carried by blood to your cells. You breathe in air so oxygen can be transported by blood to your cells to enable energy production. You drink water to maintain blood pressure and volume, and because your cells need it for chemical reactions. Wastes, such as carbon dioxide and food that can't be digested, are expelled from the body.

You drink water or obtain it from other beverages and food.

Nutrients

Cells need nutrients to work, grow, and repair damage. Your body breaks down food into nutrients, which are in a form that the body can use. Nutrients include glucose and fat for energy, vitamins for cell function, amino acids and minerals.

Oxygen

Your body needs oxygen so your body can turn the nutrients from food into energy. Oxygen makes up about 21 per cent of the air, which you breathe in through your lungs. Without oxygen, the process to turn food into energy cannot occur.

Water

Water moves through your stomach to the small and large intestines. Your body needs water to maintain blood pressure, to regulate body heat, and for other uses. Water also makes up a large proportion of blood plasma (fluid) and so contributes to the volume of blood in your body. If your body is dehydrated, your large intestines absorb more water, which makes faeces hard and dry. When dehydrated, the kidneys also filter more water back into the blood, wasting less water in the urine. You feel thirsty when you are dehydrated, which is your body's way of telling us it needs more water.

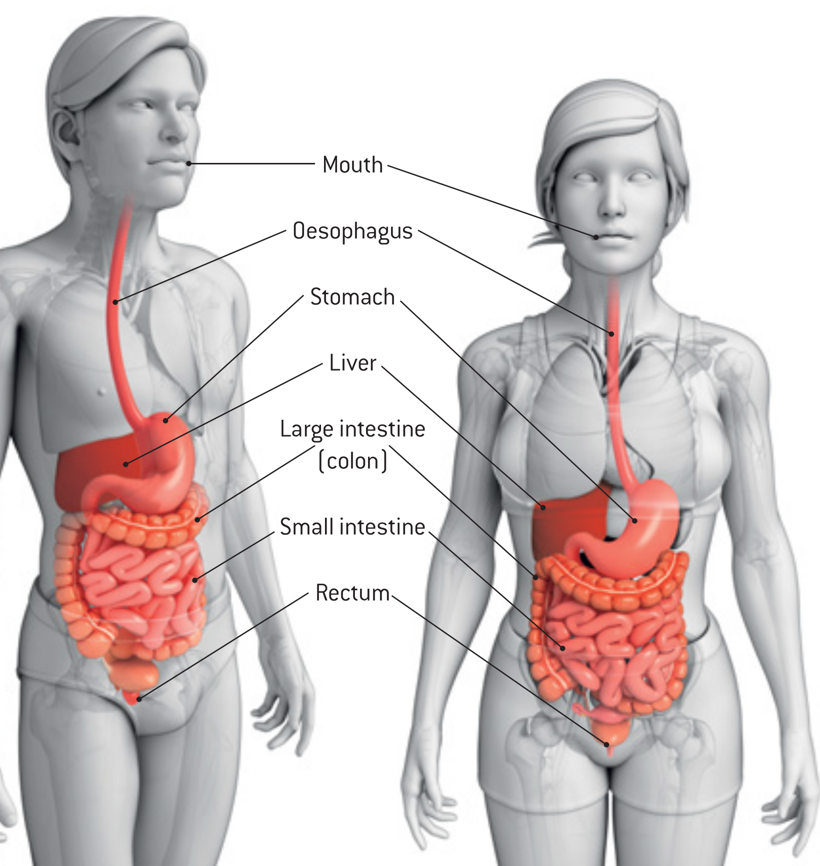
Things our bodies don't need

You digest without needing to think about it. Other actions that are involuntary (happen without your conscious control) include your heartbeat, breathing, salivation and sweating. You need to think about some parts of **digestion**, such as chewing and swallowing your food.

Food is broken down by the digestive system so nutrients can be absorbed into the blood, mainly from the small intestine. You don't immediately use all the nutrients you absorb after each meal, so your body processes store some of them. The liver is an important organ for storing and releasing stored nutrients when you need them. Some nutrients, such as certain vitamins, cannot be stored, so you need to regularly eat foods that contain them.

You do not absorb everything you eat, so your digestive system needs to remove the wastes. For example, your body is unable to digest the cellulose from the cell walls of plants such as fruit and vegetables. The cellulose passes through your body unused, acting as 'roughage' and assisting the movement of digestive waste through the body. Water is removed from the digestive waste in the large intestine so faeces are the right consistency for removal (egestion). Excretion is the removal of waste products. Excess water can be removed from the body via sweating, urinating and breathing. Some water is also used up in chemical reactions within cells. Breathing out also removes carbon dioxide from the body.

THE HUMAN DIGESTIVE SYSTEM



Breathing and blood circulation

When you breathe out, you expel carbon dioxide and water vapour.

When you breathe, the respiratory system ensures oxygen is absorbed into the blood. Oxygen molecules pass from the air in your lungs into the blood via air sacs called **alveoli** in the lungs. These sacs have very thin walls that gases can pass through. Carbon dioxide passes from the blood into these air sacs to be breathed out.

The blood then carries oxygen around the body. A protein in blood called **haemoglobin**, found within red blood cells, carries the oxygen. Iron is an essential part of haemoglobin, so obtaining iron from food is vital for oxygen transport. The haemoglobin in the blood delivers oxygen to all your cells. Blood also carries nutrients from food to cells throughout your body.

Our cells need oxygen to perform a chemical reaction called **cellular respiration**. This is the process of converting glucose (a sugar you obtain from foods you eat) into energy. Your cells need this energy to survive.

Together, the circulatory, respiratory, digestive and excretory systems in your body work to provide a stable internal environment for cells.

LOOK IT UP

alveoli tiny air sacs in the lungs where exchange of oxygen and carbon dioxide takes place

cellular respiration the process of converting the energy stored in molecules (such as glucose) into energy in cells

digestion when foods are broken down and absorbed into the blood to be transported to the cells

haemoglobin a protein in the blood's red blood cells that carries oxygen

nutrient a substance that provides nourishment essential for maintenance of life and for growth

CHECK IT OUT

1. Why do cells in your body need nutrients?
2. Why do you need water?
3. Why do you need oxygen?
4. Which body system enables food to be broken down into nutrients?
5. Which two body systems work together to absorb oxygen into the blood and transport it around the body?

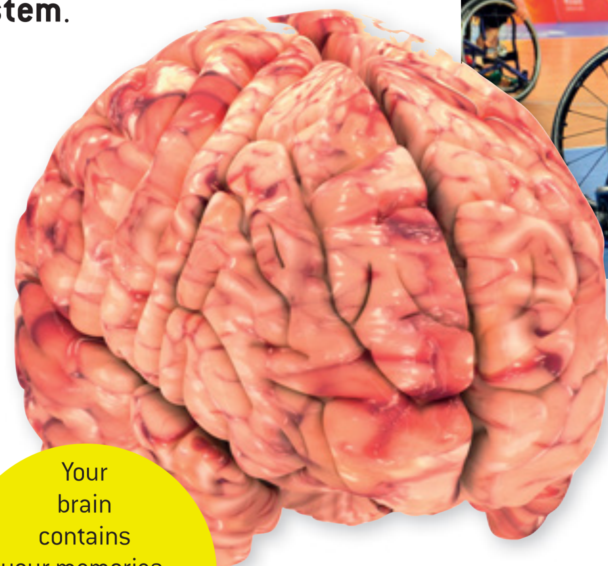
THE NERVOUS SYSTEM

How much of the body is able to move after a spinal injury depends on where the injury is in the spine. Paraplegia is spinal damage that affects the lower part of the body.

The nervous system coordinates other body systems through electrical signals. The nervous system is made up of the **central nervous system**, including the brain and spinal cord, and the **peripheral nervous system**.

Central nervous system

The central nervous system includes the brain and spinal cord. It receives and interprets messages from nerves around the body that make up the peripheral nervous system, and also sends out messages from the brain to the peripheral nervous system.



Your brain contains your memories, personality and thought processes.

Brain

Your skull contains and protects the brain, a soft organ that controls the rest of your body. The brain receives information from inside your body and from the surrounding environment. It makes decisions based on this information and sends instructions for other parts of your body to respond.

The brain is split into two parts. The left part of the brain is dominant in nearly all right-handed and most left-handed people. The dominant part of the brain usually controls language, while the other half is involved in non-verbal functions such as facial recognition. Both sides of the brain are needed for most things that you do.

An adult human brain weighs about 1.5 kilograms. Elephants, whales and bottle-nosed dolphins have larger brains than us. Despite your smaller brain size, humans have the most developed cerebral cortex. This is the ‘grey matter’ that makes up the outside of the brain, where neuronal cell bodies are located. It is vital for ‘higher order’ functions such as language, attention, creativity and emotion.

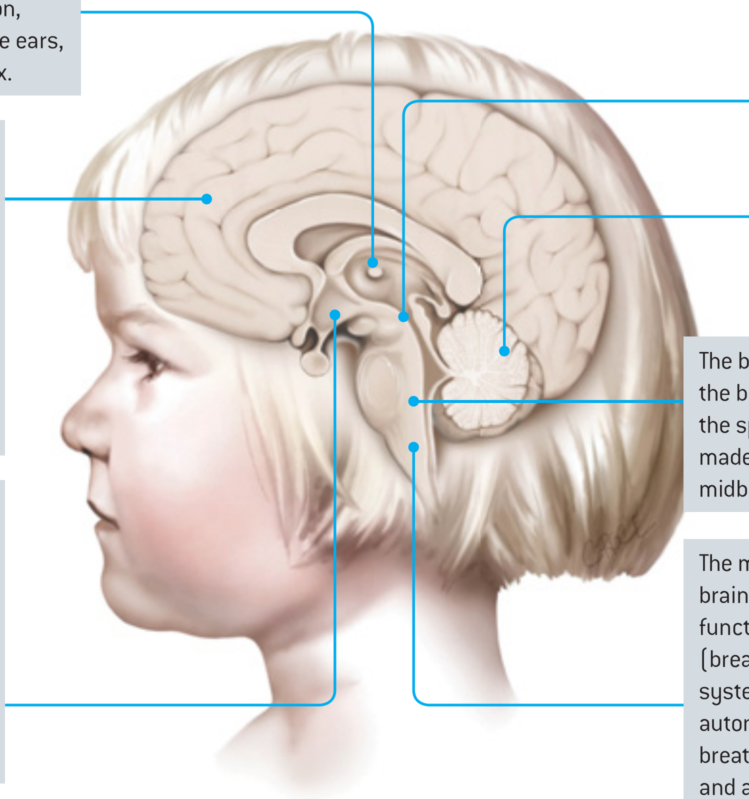
Spinal cord

The spinal cord is the pathway connecting the brain to the rest of the nervous system. Every action you take is planned by the brain before it is sent out to the body via the spinal cord.

The exceptions to this rule are reflex actions. For example, if you touch a hot stove, pain receptors in the skin send this message to your spinal cord. Without wasting time to send a message up to the brain, a signal is quickly sent straight back from the spinal cord to your arm muscles to take away your hand. This enables you to pull your hand away from a hot stove quickly to prevent serious injury. Once the message reaches your brain, information is processed and you feel the pain.

The bones of your spinal column, called vertebrae, protect the spinal cord. When the spine is damaged, messages to and from the brain may be cut off from the rest of the body at the level of the injury. People with damage to the upper part of the spinal cord have quadriplegia – they are unable to use their arms and legs. People with damage at lower spinal levels have paraplegia – they are still able to use their arms but not their legs.

THE STRUCTURE AND COMPONENTS OF THE HUMAN BRAIN



The thalamus processes and carries messages for sensory information, such as information sent from the ears, nose, eyes and skin, to the cortex.

The largest part of the brain is the cerebrum. It is divided into two paired cerebral hemispheres, joined by the corpus callosum. All of our conscious activities are controlled by the cerebrum. The outer layer of the cerebrum is called the cerebral cortex (also known as grey matter).

The hypothalamus is a tiny part of the brain primarily responsible for maintaining a constant heart rate, body temperature and sleep pattern. The hypothalamus is also involved in hormone production by control of the nearby pituitary gland.

The midbrain contains areas that receive and process sensory information, such as movement and vision.

The cerebellum (from Latin meaning 'little brain') is responsible for movement, balance and coordination.

The brain stem is the lower part of the brain. At its base it becomes the spinal cord. The brain stem is made up of three major parts – the midbrain, the pons and the medulla.

The medulla is at the bottom of the brain stem and controls automatic functions, such as respiration (breathing) and the digestive system. The pons assists in some automatic functions, such as breathing, and also controls sleep and arousal.

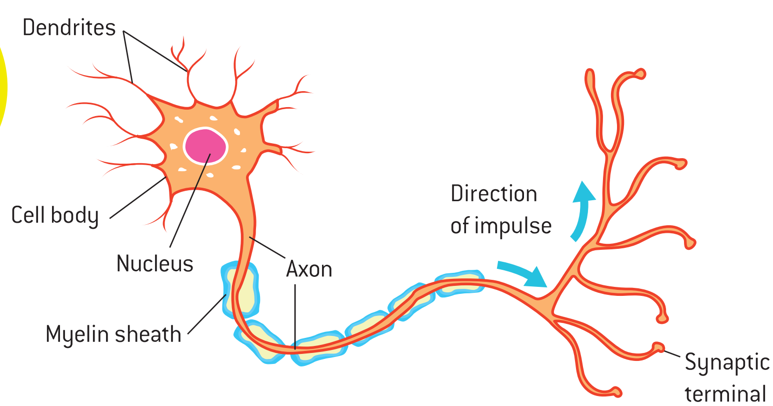
Peripheral nervous system

The peripheral nervous system detects stimuli and carries out instructions from the central nervous system. It controls voluntary joint and muscle movements, such as waving, and involuntary movements, such as breathing.

Our bodies contain up to 100 billion specialised cells called **neurons** (nerve cells), bundled together as nerves. Messages that travel along neurons are called **impulses**, which involve electrochemical changes and movement of charged atoms (ions) across membranes.

Electrical impulses pass along the neuron's axon towards its axon terminals. The impulse crosses a tiny gap (synapse) in chemical form before reaching another neuron's dendrites. The signal is converted back into electrical form and continues along this next neuron. Information travels along neurons very quickly – up to 120 metres per second.

Parts of the specialised nerve cell called a neuron.



LOOK IT UP

central nervous system the brain, spinal cord and nerves that connect these organs with the rest of the body

impulse an electrical signal that travels along an axon

neuron (nerve cell) a specialised cell that receives and sends electrical signals in the body

peripheral nervous system sense organs and nerves that connect these organs with the rest of the body

CHECK IT OUT

1 About how many nerve cells does your body contain?
2 Which of the following are parts of the central nervous system? Cerebral cortex, nerves in your arm, pain receptors in your fingertip, spinal cord, brain stem
3 Which animals have the most developed cerebral cortex?
4 'A reflex is a message sent by your brain to a limb.' True or false?
5 List two components of a nerve cell.

EXPERIMENT #1

SHEEP BRAIN DISSECTION

AIM: TO EXPLORE THE STRUCTURE OF A SHEEP'S BRAIN

MATERIALS

- Sheep's brain
- Dissecting board
- Scalpel
- Dissecting scissors
- Coloured pins
- Newspaper
- Microscope, slide and cover slip (optional)

SAFETY

- Wear your lab coat, safety goggles and gloves.
- Scalpels are extremely sharp – be very careful.
- Ensure you ask your teacher how to dispose of the specimen safely.

METHOD

1. Examine the outside of the brain as shown. Set the brain down so that the flatter side, with the white spinal cord at one end, rests on the board. Using the different coloured pins, identify the two cerebral hemispheres, the four brain lobes, the spinal cord and the cerebellum. Check this with your teacher before continuing.
2. Turn the brain over. Identify the brain stem, medulla and pons.
3. Place the brain with the curved top side of the cerebrum facing up. Use a scalpel to slice through the brain along the centre line, starting at the cerebrum and going down through the cerebellum, spinal cord, medulla and pons. Separate the two hemispheres of the brain. Record what you see.
4. Cut one of the hemispheres in half lengthwise. Record what you see.
5. (Optional) Use the microscope to examine thin slices of the brain placed on a slide and covered with a cover slip. Record what you see.

Use pins to identify the different parts of the upper brain.

Identify the medulla and pons.

Separate the two hemispheres.

Examine the internal structure.

DISCUSSION

1. What did the brain feel like? Was it easy to dissect?
2. Discuss the similarities between a human brain and that of a sheep.
3. Discuss the differences between a human brain and that of a sheep. Why would they be different?

CONCLUSION

Write a sentence to address the aim.

EXPERIMENT #2

HOW FAST IS THE NERVOUS SYSTEM?

AIM: TO MEASURE REACTION SPEED

MATERIALS

- 1-metre ruler
- Blindfold

METHOD

1 Working in pairs, one student holds a metre ruler between their thumb and index finger so the ruler hangs with the zero mark at the bottom. The other student needs to wait with their thumb and forefinger at the bottom of the ruler, level with the zero mark (see photo).

2 To test sight reflexes, the first student drops the ruler, without warning, while the other student catches the ruler as fast as they can between their thumb and forefinger.

3 Record the number of centimetres the ruler has dropped by looking at the location of the second student's thumb and forefinger on the ruler.

4 Repeat until you have 10 results for each student.

5 Work out the average reaction distance for each student.

6 Measure the approximate distance the messages must have travelled if they travelled from your eye to your brain, then to the muscles in your forearm that control your fingers.

7 To test touch reflexes, blindfold one student. Tap the blindfolded student on the head at exactly the same time as you drop the ruler. Does this make a difference to the reaction distance?

8 To test hearing reflexes, blindfold one student. Say 'now' when you drop the ruler. Does this make a difference to the reaction distance?

9 Which test had the fastest results? Why might this be?

In pairs, you can use a metre ruler and blindfold to test reflexes of sight, touch and hearing.

5 AMAZING SENSES

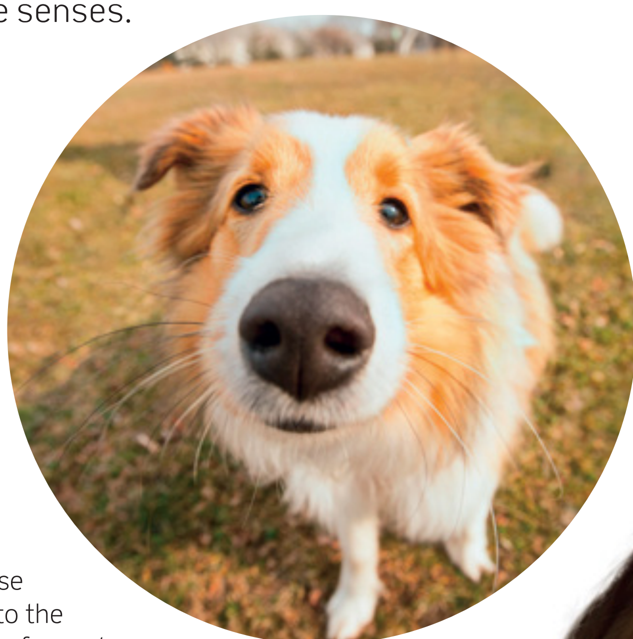
Multicellular organisms need to respond to their environment to avoid changes within the body that could cause illness or death. The easiest way to sense changes is to detect them with eyes, ears, tongue, nose and skin – the major organs that enable the five senses.

1 Smell

Smell is a chemical sense detected by sensory cells called **chemoreceptors**. Airborne odour molecules stick to some of the 300–400 chemoreceptors in the lining of your nose. Different smells trigger different receptors. These send electrical signals to the brain. The combination of receptors that are stimulated enables the brain to make sense of the smell.

Olfaction (smell) is linked to the parts of the brain that influence behaviour and process emotions and memory more closely than other senses. The link to this part of the brain means smells can evoke strong emotional responses and memories.

In evolutionary terms, smell is the oldest sense. Even single-celled organisms have a sense of smell. Detecting the chemical composition of the environment through smell is a basic ability needed for survival.



Nostrils draw air into the nose to enable animals to smell the external environment.

Each one of your thousands of tastebuds contain as many as 100 receptor cells that enable us to taste.

2 Taste

Your tongue, mouth and throat are covered in up to 10 000 tastebuds, which contain chemoreceptors. These react with chemicals in food and drink. Information from the taste receptor cells is sent to the brain, telling you the flavours you can taste.

Gustation (taste) is also a chemical sense and is closely related to smell. If you block your nose, it is more difficult to taste things. Tastebuds can recognise five kinds of taste: sweet, salty, sour, bitter and umami, an often-overlooked 'savoury' taste associated with foods such as meat.

3 Sight

Light enters your eyes through the clear, protective outer cornea, and through the pupil. The lens focuses an upside-down image at the back of the eye on a layer of tissue called the retina. The retina has rod cells that enable sight in low light, and cone cells that enable us to see colour and detail. Sensory cells on the retina called **photoreceptors** change when they are hit by light. They transform the light into electrical signals that travel to the brain via the optic nerves. The brain then interprets the information, telling you what you are seeing.

Sight provides more information about the world around us than any other of your five senses.

The iris (a coloured ring of muscle) changes the size of the pupil to control the amount of light that enters the eye.

4 Hearing

Vibrations enable audioception (hearing). Sounds travel as soundwaves to your ear. The soundwaves vibrate particles, so in the absence of particles (such as in the vacuum of space) you cannot hear. The satellite dish-like outer ear collects soundwaves and funnels them through the ear canal. These waves vibrate your eardrum. The vibrating eardrum moves a chain of three tiny bones in your middle ear, amplifying the vibrations before they reach the cochlear in your inner ear. Sensory cells called **mechanoreceptors** convert the vibrations into electrical impulses, which are then interpreted by your brain as sounds.

The smallest bone in the human body is the middle ear's 'stirrup bone' (stapes), which is approximately 2.6–3.4 millimetres long. The human body's shortest muscle, the stapedius, is approximately 1 millimetre long and controls the stapes.

5 Touch

Skin enables us to touch, as well as to feel temperature and pain. The deepest layer of skin, called the dermis, contains sensory cells that can detect pressure (mechanoreceptors), temperature (thermoreceptors) and pain (nociceptors). The cells send electrical impulses to your brain. Some parts of your body that are important for touch, such as your lips and fingertips, have more of these cells than less important parts, such as your forearm.

How you interpret the sense of touch is also important. A touch from another person may be caring, such as a hug; it may be healing, such as a massage; it may be exploratory, such as feeling in a dark bag to find something; or it may be aggressive, such as a push.

LOOK IT UP

chemoreceptor sensory cells in the lining of your nose

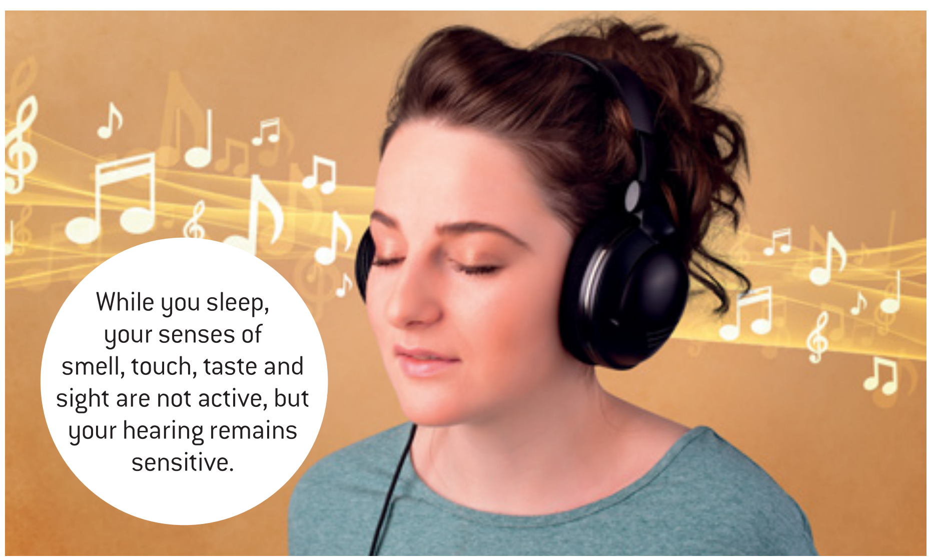
mechanoreceptor sensory cells in your ear that convert sound vibrations into electrical impulses

photoreceptor sensory cells on your eye's retina that transform light into electrical signals

When you touch something painful, a message is sent to the spine that activates a quick withdrawal reflex. The brain is not involved in this process.

CHECK IT OUT

1. List the five senses.
2. List the five tastes that your tastebuds can sense.
3. How many chemoreceptors are there in the lining of your nose?
4. Which sense is enabled by the smallest bone and smallest muscle in the human body?
5. Why do you think reflex actions bypass the brain?

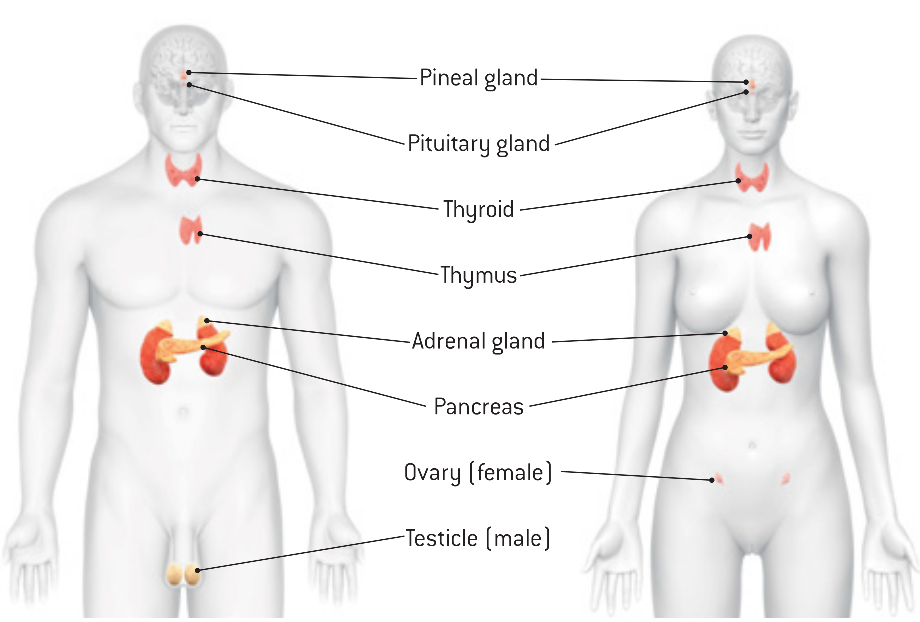


While you sleep, your senses of smell, touch, taste and sight are not active, but your hearing remains sensitive.

BODY RESPONSES

When you experience change in your external or internal environment, your body must respond to ensure cells function properly. Multicellular organisms have dedicated systems with specific roles that maintain a stable internal environment. Different systems respond to different changes, but all are coordinated by a combination of the nervous and endocrine systems.

HUMAN ENDOCRINE SYSTEM



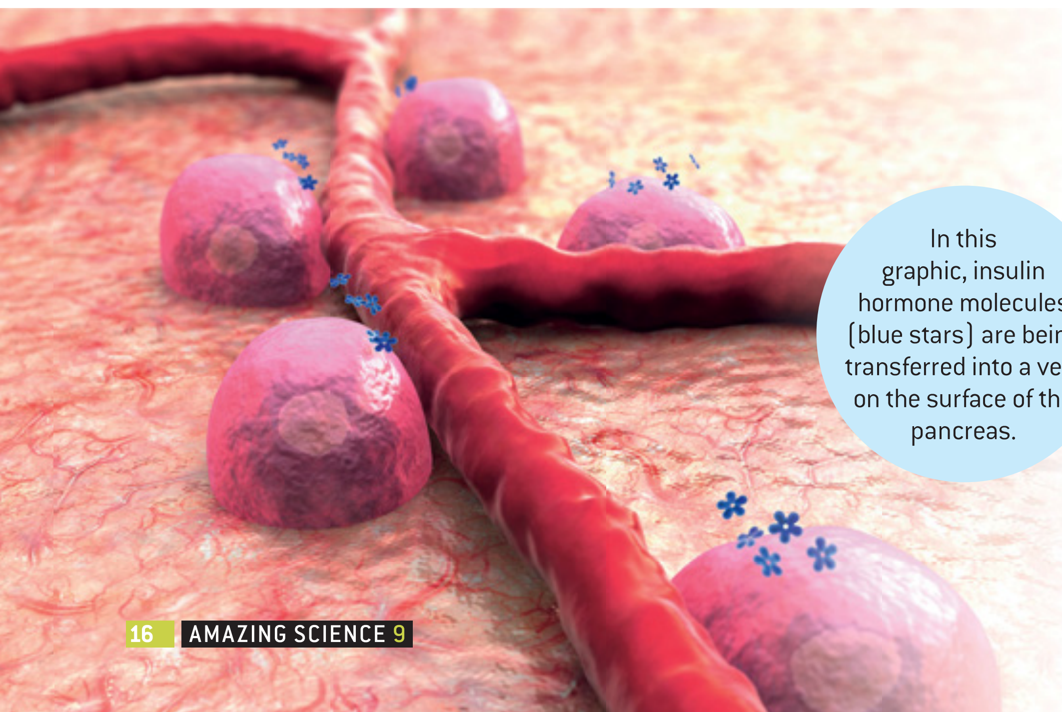
The nervous system works with the endocrine system, which controls the production of hormones, to ensure that the body functions properly.

Endocrine system

The endocrine system is made up of glands and organs. It is responsible for your body's growth and repair, digestion, sexual reproduction, and homeostasis (maintaining the stability and balance of internal systems).

Endocrine glands include the pituitary gland (inside the brain), thyroid and parathyroid glands (in the neck), and adrenal glands (above each kidney). These glands produce chemicals called **hormones**. Organs of the endocrine system include the pancreas, kidneys, and ovaries in females and testicles in males.

Problems with the endocrine system are fairly common. They occur when too many or too few hormones are produced. For example, type 1 diabetes results in too much glucose (sugar) in the blood due to the body not producing enough of the hormone called **insulin**. Insulin is an important hormone that carries glucose from your blood into your cells, where it can be used for energy.



In this graphic, insulin hormone molecules (blue stars) are being transferred into a vein on the surface of the pancreas.

People with type 1 diabetes need to inject themselves with insulin because their pancreas does not produce this important hormone.

Hormones

The glands of the endocrine system secrete hormones directly into the blood. The circulatory system then carries hormones around the body.

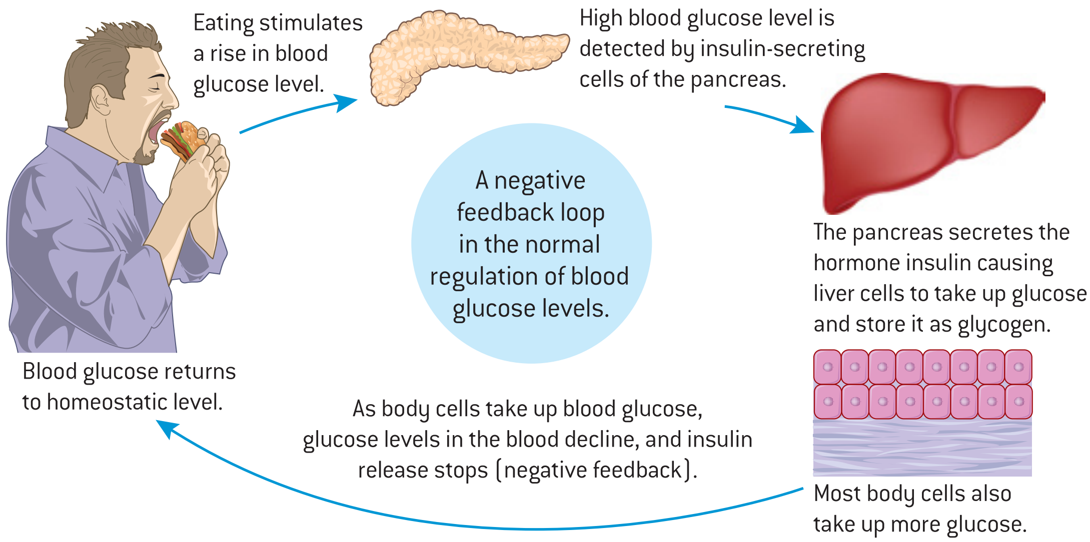
Hormones are chemical signals. They can increase the rate of breathing and heartbeat to prepare for sudden fright, pain and injury, or strong emotions.

There are two main types of hormones:

1 **Proteins** are made from amino acids by the pituitary, parathyroid and thyroid glands, the placenta and pancreas; most hormones are proteins.

2 **Steroids** are made from cholesterol by the adrenal glands and the ovaries or testicles.

The level of hormone release is controlled by the endocrine system's feedback mechanisms. After a hormone has been released, it travels all around the body in the blood. Only its target organs have receptors for it. This part of the body responds by sending (feeding) back information to the gland to say enough of the hormone has been received. This information slows or stops the hormone production to reduce the hormone's effects. Likewise, the target organs can provide feedback that not enough hormone is being received, causing the gland to increase its hormone secretion.

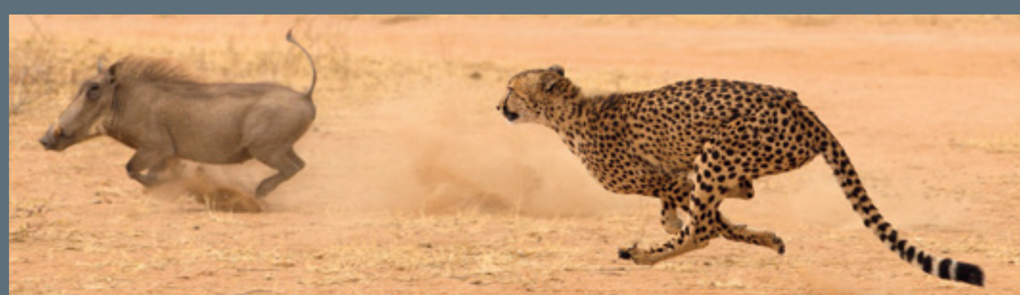


Fight or flight?

If you have ever been really scared, you may have noticed your body's response. Your heart beats faster, your breathing increases and you may break out in a cold sweat. Your senses bombard you with information on which to make a decision: defend yourself (fight) or run away (flight).

The adrenal glands produce a large amount of the steroid hormone called **adrenaline** in times of danger. A flood of adrenaline travels around your body and causes many responses, including increased heart rate and blood pressure, and the release of stored glucose into the bloodstream.

Adrenaline is not just produced at times of danger. It is constantly secreted in small doses for regulating your heart rate and the width of your blood vessels. If a fight or flight response is triggered at a time of perceived danger when there is no real danger, a panic attack can result.



The release of the hormone adrenaline at times of danger provides energy to the muscles for the extra effort required for fighting or running.

LOOK IT UP

adrenaline a steroid hormone produced by your adrenal glands that causes responses including increased heart rate and blood pressure

hormone a chemical signal in your body

insulin a hormone that carries sugar from your blood into your cells

protein a large, complex molecule; plays many critical roles in the body; made of amino acids

steroid a hormone made from cholesterol by the adrenal glands and the ovaries or testicles

CHECK IT OUT

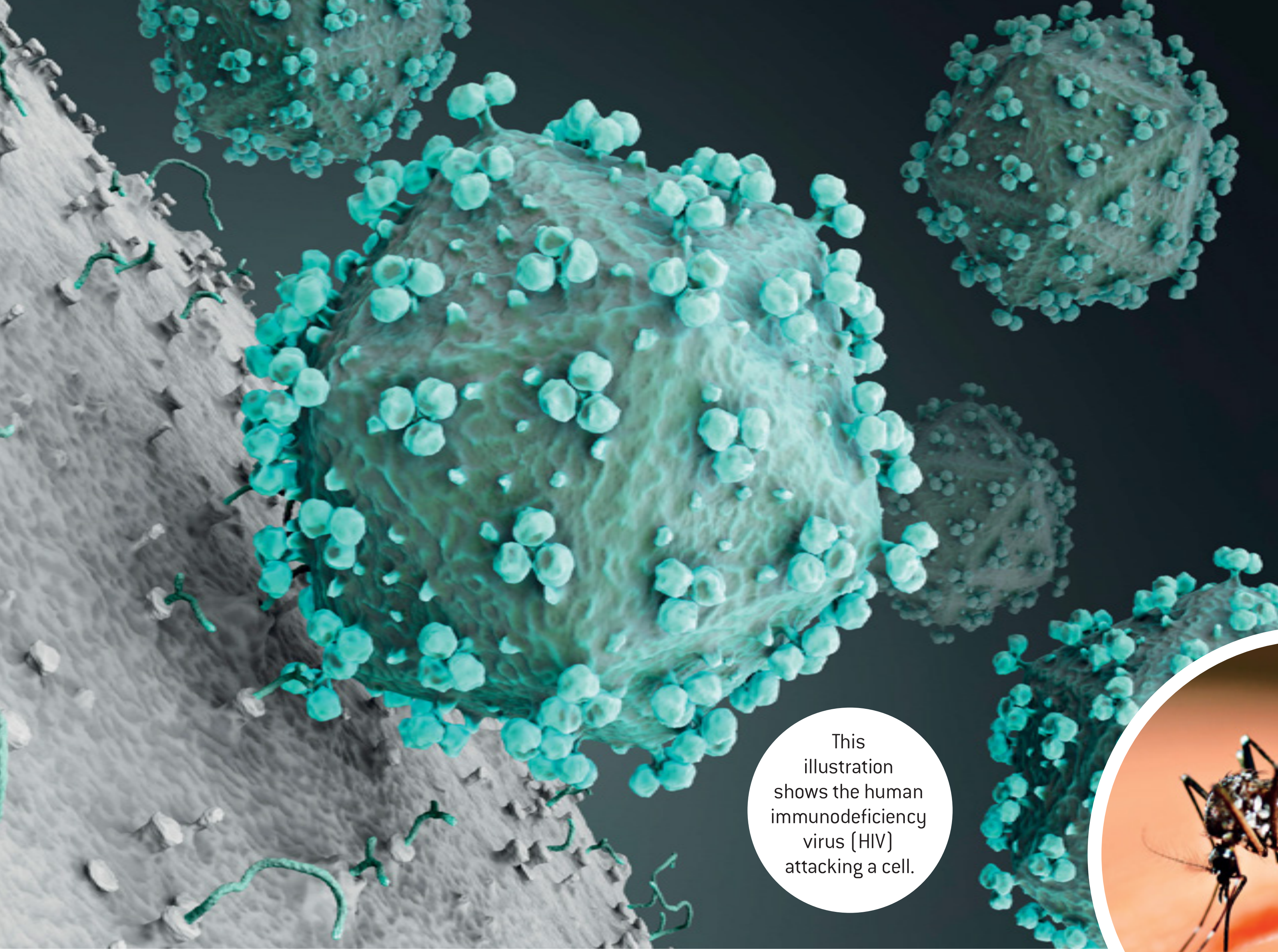
1 List three processes that the endocrine system is responsible for.

2 List three glands or organs that are part of the endocrine system.

3 List the two main types of hormones.

4 Why do some people with type 1 diabetes need to inject their body with insulin?

5 What two roles does the pancreas play in the regulation of blood glucose?



This illustration shows the human immunodeficiency virus (HIV) attacking a cell.

BODY ENEMIES

Diseases stop the body from functioning properly. Infectious diseases are caused by bacteria, viruses or other pathogens. Non-infectious diseases are caused by poor diet, lack of exercise, smoking, genetic mutations, poor mental health, ageing, cellular malfunction or environmental factors.

Infectious disease

Infectious diseases are caused by **pathogens**, such as bacteria in food or a virus from another person. They can be spread between people. Virulence is a measure of how easily an infectious disease is passed on to others and the speed at which it spreads.

An influenza ward at a US Army hospital in 1918 during the Spanish flu epidemic.

Pathogens

There are a number of different types of pathogens.

Bacteria are single-celled microorganisms. They have a cell wall, but no nucleus. Only a few cause disease in humans, such as those that give you food poisoning, or the sexually transmitted infection chlamydia. You need some types of bacteria for your body to function properly.

Viruses are smaller than bacteria. They are not an actual cell, but comprise genetic material surrounded by a protein coat. Viruses can only reproduce by hijacking the living cells of other organisms to replicate its genetic material. A virus can readily change into different forms, which is why it is difficult to treat viral infections. Viruses cause diseases such as the common cold, viral hepatitis and HIV/AIDS.

Prions are not organisms. They are faulty protein molecules that can convert normal proteins into infectious ones. Prions cause rare, untreatable brain diseases that are fatal, such as bovine spongiform encephalopathy ('mad cow disease').

Other types of pathogens include macroparasites such as ticks, fungi such as tinea, and protozoa such as plasmodia that cause malaria.

Malaria is an infectious disease caused by tiny, single-celled organisms called protozoa in the blood. It is spread by mosquitoes. Hundreds of millions of people contract malaria each year, with more than 1 million people dying from the disease annually.

Spanish flu epidemic

Influenza, often referred to as 'the flu', is a highly virulent infectious disease caused by a virus. Some viruses can move from animals to humans.

A strain of the bird virus called H1N1 adapted to humans after the First World War. It was called the Spanish flu and could move from person to person, killing more than 20 million people worldwide between 1918 and 1920.

Non-infectious disease

Non-infectious diseases are not contagious, which means you cannot catch them from another person.

Genetic diseases are non-infectious diseases that can be passed down from parent to child through genes. Genetic disorders are a result of a mutation in DNA. If a mutation occurs in the DNA of sperm or eggs, the genetic disease can be passed on to children. Common genetic disorders include haemophilia, cystic fibrosis and Down syndrome.

Poor diet or lifestyle can cause non-infectious diseases. Smoking or excessive drinking of alcohol can cause cancers and liver failure. Too much or too little of the nutrients your body needs can cause diseases such as scurvy, heart disease and obesity.

Other causes of non-infectious diseases include abnormal functioning of cells, ageing, or problems in the surrounding environment such as air pollution or radiation.

Obesity is a non-infectious disease caused by poor lifestyle or diet.

LOOK IT UP

bacteria unicellular microorganisms that have cell walls but no nuclei (singular: bacterium)

pathogens bacteria, viruses, prions, macroparasites, fungi and protozoa that cause infectious diseases

prions faulty protein molecules that cause rare, untreatable brain diseases that are fatal

virus genetic material coated by a protein that causes diseases such as the common cold

CHECK IT OUT

1. List three types of pathogens.
2. List three causes of non-infectious diseases.
3. Can viruses be passed from animals to people?
4. Name a disease caused by bacteria, and a disease caused by viruses.
5. The Spanish flu killed more people at the end of the First World War than had been killed during the war. Discuss some of the reasons why you think the spread of this virus was particularly efficient at this time.

HOW THE BODY DEFENDS ITSELF

This illustration shows white blood cells flowing through red blood to seek out and destroy pathogens.

Humans and other multicellular organisms have an immune system to prevent pathogens from entering the body and to identify and destroy any invaders that make it inside. If the immune system fails to do its job, medicine may help the body fight disease.

The body's lines of defence

1 Barriers

Preventing pathogens from entering the body is your first line of defence against disease. The skin, a waterproof physical barrier to invasion, carries out this defence. It is supported by mucous, sweat and other secretions like earwax and tears where there are openings in the skin, such as the ears, nose and eyes. Secretions may trap pathogens, or contain chemicals that can deactivate them.

Our skin is home to many 'good' bacteria, which make it more difficult for foreign bacteria to colonise and survive. However, when the barrier of your skin is broken, such as when cut, pathogens can make it through this line of defence.

2 Body responses

Skin is an effective barrier to pathogens, unless it is broken.

The body's second line of defence includes the clotting of blood to help form a barrier when a blood vessel is broken, and a fever to increase the body's temperature to make conditions more difficult for heat-sensitive pathogens. The site of infection attracts increased blood flow, causing redness, heat and inflammation. More blood carries more white blood cells, which recognise that the pathogens do not belong to your body. White blood cells destroy the pathogens by enveloping and digesting them. Finally, the pain and swelling associated with injury prevents you from using the affected area, giving it the best change of healing.

Vaccination prevents many diseases that were once common. It has even resulted in some diseases, such as smallpox, completely disappearing.

3 Immunity

The body's third line of defence involves targeting any remaining foreign bodies using an immune response that is specific to the pathogen. When infected, the body takes about a week to produce enough **antibodies** to fight the infection. Antibodies are protein molecules that target specific protein molecules on the surface of the pathogen cell, called **antigens**.

Antibodies remain in the body long after the disease has been defeated. This means that the next time your body is infected by the same disease, you already have antibodies ready to recognise and fight it. This process of getting a disease and making antibodies that protect you from the same infection in the future is called having natural immunity to the disease.

Immunity to certain diseases can be passed from a mother to a baby in the womb and via breast milk. However, this immunity does not last more than a few months. This type of immunity is called passive immunity, because your body does not make the antibodies itself.

Another way to obtain immunity to disease is through **vaccination**. Vaccination involves being injected with or swallowing weakened or inactive antigens that prompt antibody production without the person becoming sick. The vaccine may be a dead pathogen, a live but non-infectious pathogen, the antigens with the pathogen removed, or weak toxins from bacteria. Getting a vaccination is like having a 'dress rehearsal' for your immune system so that it knows how to respond quickly if you ever get infected with the real pathogen.

LOOK IT UP

antibiotics medicines that fight bacteria

antibodies protein molecules that target specific parts of a pathogen cell

antigens protein molecules on the surface of pathogen cells

vaccination being injected with or swallowing weakened or inactive antigens that prompt antibody production without the person becoming sick

CHECK IT OUT

1. What are the body's three lines of defence?
2. Why does the skin around infections appear red and warm?
3. Which of the following are foreign bodies? Antigens, pathogens, antibodies, viruses
4. List three ways your body could acquire immunity to a disease.
5. Explain how vaccination can help your body fight disease.

Medicine

Medicines are drugs that can be taken to help the body's immune system fight disease and its symptoms. Medicines can work in a number of ways, such as replacing substances missing from your body, destroying microorganisms and foreign cells, changing how cells function, or reducing the symptoms of illness.

Antibiotics are medicines that fight bacteria. They do not work against viruses. Some antiviral medicines exist, but often the best way to fight viruses is to rest and allow your body's immune system to control the infection.

Penicillin: a life saver!

Penicillin is an antibiotic that is produced by some species of *Penicillium* fungus. In 1928, Scottish scientist Alexander Fleming discovered that *Penicillium* mould kills bacteria. During the Second World War, Australian scientist Howard Florey and his team developed *Penicillium* into a wonder drug that has saved many lives. Penicillin works by breaking down the cell walls of bacteria without harming human cell walls. If you've ever had a sore throat, your doctor may have given you penicillin to kill the bacteria making you sick.

As the developer of penicillin, Adelaide-born Howard Florey is credited with saving at least 50 million lives since 1941.

RADIATION AND THE HUMAN BODY

Exposure to radiation from nuclear weapon explosions (left) or nuclear power accidents such as occurred at Chernobyl in the Ukraine (right) can damage the DNA in the cells of people nearby and their future children.

Exposure to the harmful effects of the environment around us can cause non-infectious diseases. Some forms of electromagnetic radiation can damage the cells of an organism. Humans are affected by radiation, such as being sunburnt by ultraviolet radiation.

Health effects of electromagnetic radiation

The spectrum of electromagnetic radiation includes visible wavelengths (light energy) as well as wavelengths of **radiation** that are invisible to us. Exposure to some wavelengths of radiation is harmless in very small amounts, but with long or extreme exposure it can cause non-infectious diseases such as cancer. Radiation can also be used in a helpful way, such as to diagnose and treat cancer.

Gamma rays are the most harmful electromagnetic waves because they have a high frequency and therefore high energy. They have very short wavelengths, typically about the size of an atomic nucleus. X-rays are waves of radiation that have shorter wavelengths than visible light, about the size of an atom. Microwaves have wavelengths from as short as 1 millimetre to as long as 30 centimetres. Exposure to these wavelengths of radiation can be dangerous.

Radiation at some wavelengths can make and break chemical bonds. It can interfere with the molecules such as DNA in your body's cells. People exposed to dangerous levels of radiation can have the DNA in their sperm or egg cells damaged, and then pass faulty DNA to their children. This can cause stillbirths, physical deformities or increased child mortality.

DNA can copy itself, so the effect of one damaged DNA molecule can be multiplied millions of times. Tumours are formed from faulty cells that continue to multiply, replicating the fault and accumulating more faults with each cell division. This uncontrolled growth is called **cancer**. Treatment of cancer can involve focusing high doses of radiation on a tumour to try to destroy its cells.

Radiation therapy can be used to treat various forms of cancer.

Solar radiation and sunburn

Ultraviolet (UV) light has a shorter wavelength than visible light. You can't see UV light, but some insects can. Your body needs some exposure to sunlight to make vitamin D for healthy bones and muscles. However, exposure to the Sun's UV radiation causes sunburn, and repeated sunburn can cause skin cancer.

On an average summer weekend in Australia, almost 400 000 young people and 2 million adults are sunburnt. Sunburn is the skin's reaction to excessive UV radiation.

Wearing sunscreen and protective clothing, and staying out of the sun, help to shield us from UV light. Having a tan does not provide much protection against sunburn – it is only the equivalent of applying weak, SPF3 sunscreen.

Melanoma

UV radiation can affect your upper layer of skin, which releases chemicals that dilate your blood vessels. This causes inflammation, which appears as sunburn.

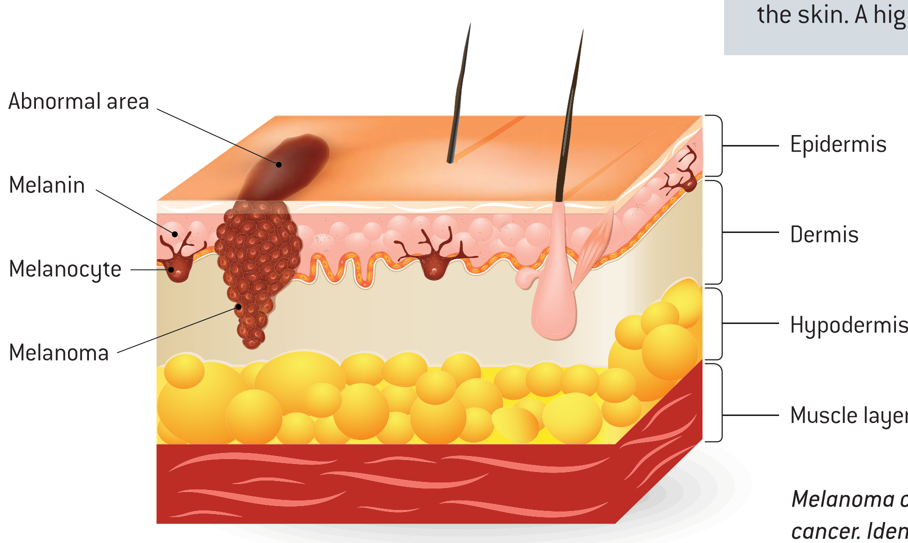
Some UV radiation penetrates deep into your skin and affects the generation of new skin cells. This can cause rough, dry, blotchy and wrinkled skin. Too much sunburn over many years can cause damage to genes in skin cells, leading to skin cancer.

Melanoma is the most dangerous type of skin cancer. Australia has the highest incidence of skin cancer and melanoma in the world. More than 2000 Australians die from skin cancer each year.

Sunburn or having a tan is not healthy; it is a sign that UV radiation has damaged your skin.

SPF (Sun Protection Factor) is a global standard for measuring the effectiveness of sunscreen.

SPF is a measure of a sunscreen's ability to prevent UV radiation from damaging the skin. A higher SPF factor provides greater prevention of skin damage. For example, SPF50+ filters out 98 per cent of dangerous UV radiation, compared with 96.7 per cent blocked by SPF30+, and 93 per cent blocked by SPF15.



Melanoma can be a fatal form of skin cancer. Identifying damaged skin early can prevent the cancer developing.

LOOK IT UP

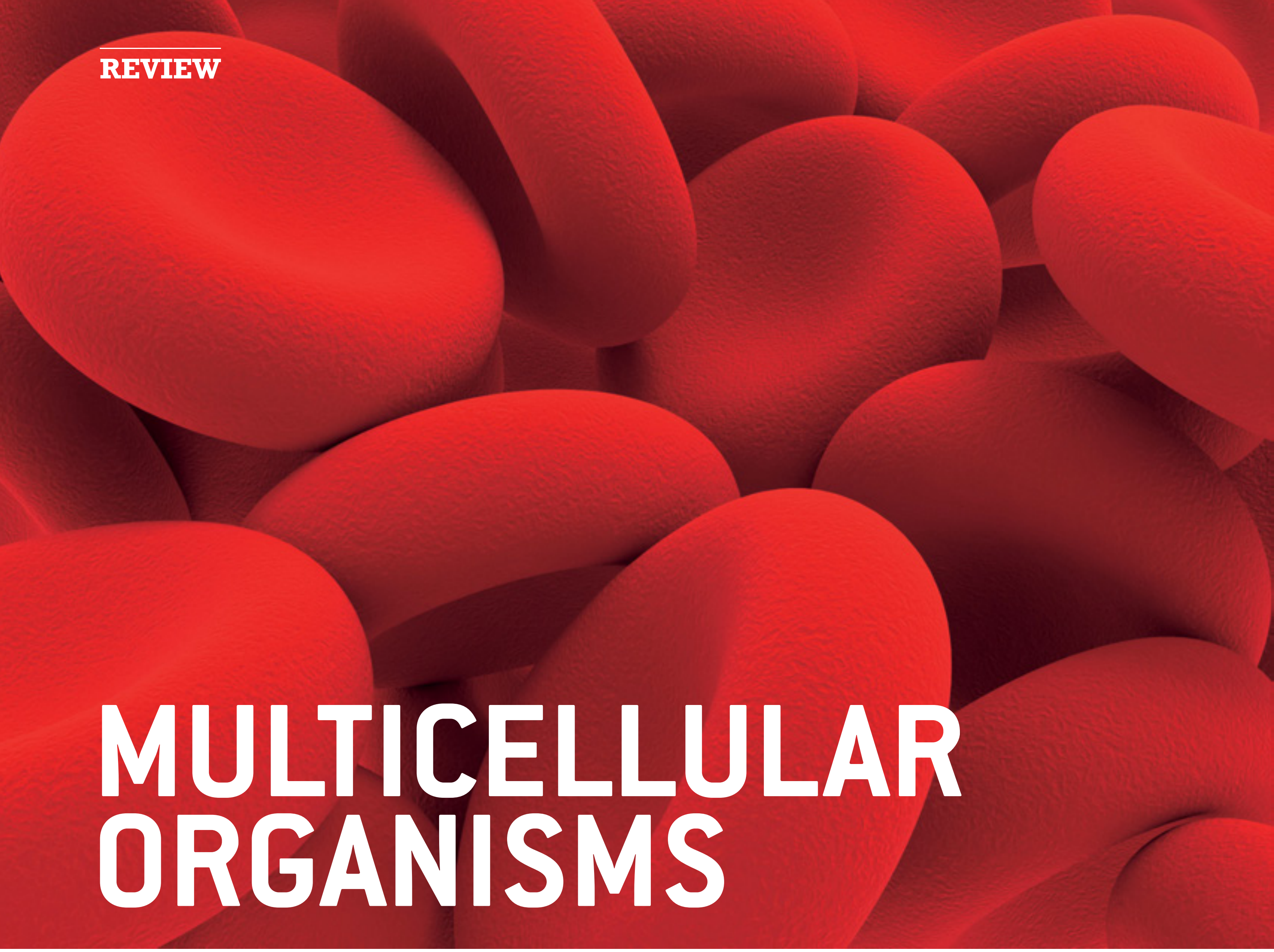
cancer a non-infectious disease caused by damage to genes and cells

melanoma the most dangerous type of skin cancer, caused by UV radiation

radiation the emission or transmission of energy in the form of waves through space or through a material

CHECK IT OUT

1. List three types of radiation that can damage cells.
2. Approximately how many Australians die from skin cancer each year?
3. List five actions you can take to protect your skin from the Sun's harmful UV radiation.
4. What is the difference between sunburn and skin cancer?
5. You need some exposure to UV light to make vitamin D, but too much can cause sunburn. Radiation can cause cancer, but can also be used to cure it. Discuss the benefits and harmfulness of radiation.



MULTICELLULAR ORGANISMS

MULTICELLULAR ORGANISMS (PAGES 6–7)

1 List three multicellular organisms.
2 List three components of the nervous system.
3 Provide an example of two body systems working together to maintain the health of an organism.

THINGS OUR BODIES NEED (PAGES 8–9)

4 Provide an example of plant matter that cannot be digested.
5 What component of blood carries oxygen?
6 Explain three involuntary actions in the body.

THE NERVOUS SYSTEM (PAGES 10–11)

7 What problems might a person have if they damaged their cerebellum (as in the x-rays below)? What things could you ask a person to do to see if their cerebellum was working?

8 Does the peripheral nervous system use electrical or chemical signals for communication?

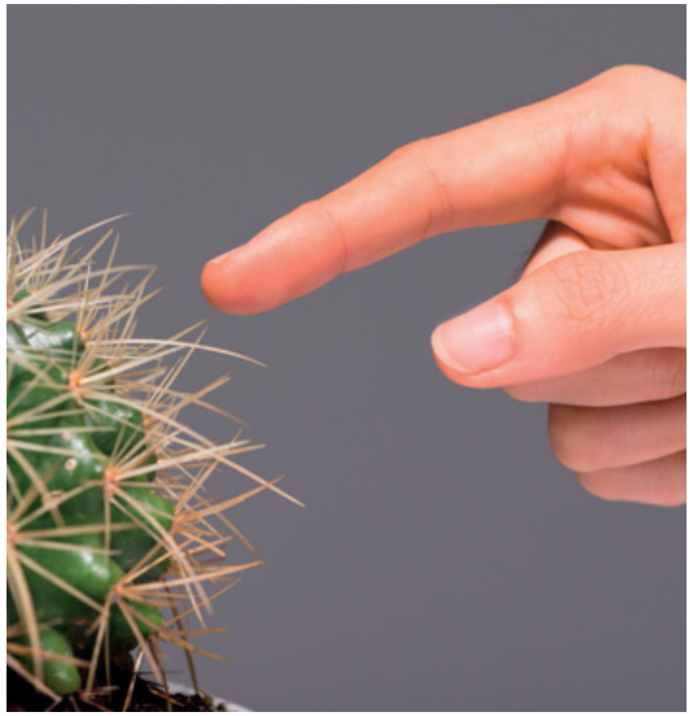
9 Which would be faster: the response to a nerve signal or the response to a hormonal signal? Why?

5 AMAZING SENSES (PAGES 14–15)

10 Which of your senses is still active during sleep?

11 Which sense can evoke strong memories? Why do you think this is?

12 Consider the different ways of interpreting touch: physically (for example, feeling pain, right) and emotionally (for example, interpreting the meaning of physical contact). Would different parts of the brain be used for these different responses?



BODY RESPONSES (PAGES 16–17)

13 What is the role of the hormone insulin?

14 Do hormones communicate using electrical or chemical signals?

15 Describe what is meant by a 'fight or flight' response.

BODY ENEMIES (PAGES 18–19)

16 Recall two causes of infectious diseases.

17 'All bacteria are harmful.' True or false?

18 List three non-infectious diseases.

HOW THE BODY DEFENDS ITSELF (PAGES 20–21)

19 Describe two components of the body's first line of defence.

20 Describe two components of the body's second line of defence.

21 What was Howard Florey's contribution to science involving mould and bacteria (right)?

RADIATION AND THE HUMAN BODY (PAGES 22–23)

22 What can happen if you are exposed to too much ultraviolet radiation?

23 Explain two positive uses or benefits of radiation.

24 'A suntan is healthy and protects you from sunburn.' True or false?

KEY IDEAS

1 Multicellular organisms (including humans) need internal systems that are dependent on each other, coordinated and responsive to change to survive.

2 Multicellular organisms also need to reproduce, grow, respond to stimuli, and maintain their internal function in a changing environment to survive.

3 Our body's digestive system breaks down food into nutrients – a form that it can use. Any nutrients that are not immediately needed are stored or excreted.

4 Haemoglobin in the blood carries oxygen, which is needed to turn food into energy within cells.

5 The nervous system, including the brain, spinal cord and peripheral nerves, coordinates other body systems through electrical signals.

6 The spinal cord connects the brain to the rest of the nervous system and is responsible for reflex actions.

7 Electrical impulses pass between nerve cells via the neuron's synapse.

8 Multicellular organisms need to respond to the environment to avoid changes within the body that could cause illness or death.

9 Our eyes, ears, tongue, nose and skin provide us with your five senses to detect change.

10 The endocrine system is responsible for growth and repair, digestion, sexual reproduction and homeostasis.

11 The glands of the endocrine system secrete hormones, including proteins and steroids, into the blood to control body functions, such as adrenaline at times of danger to prepare us for fighting or running.

12 Infectious diseases are caused by bacteria, viruses, prions, macroparasites, fungi and protozoa. Non-infectious diseases are not contagious and are caused by cell mutation, poor diet or lifestyle, ageing or problems in the surrounding environment.

13 The body's first line of defence includes skin and mucous membranes to prevent foreign bodies entering the body. Its second line of defence includes blood clots and white blood cells to stop and destroy pathogens. Its third line of defence involves immune responses that target specific pathogens.

14 Vaccinations and medicines can help the body fight disease.

15 Exposure to the Sun's ultraviolet radiation causes sunburn, and repeated sunburn can cause skin cancer. Radiation also provides benefits, such as allowing your skin to form vitamin D and as a method to treat some cancers.

DYNAMIC ECOSYSTEMS 02

EXPERIMENT
with competing seeds

Impacts of
CLIMATE CHANGE

* 5 *
AMAZING PREDATORS

WHAT ARE
ECOSYSTEMS?

A healthy coral reef is an example of an ecosystem where living and non-living things are in balance.

WHAT ARE ECOSYSTEMS?

A forest ecosystem provides people with products, such as food, and services, such as fresh water.

An **ecosystem** is a collection of interacting living and non-living things. It is a community of animals, plants and microbes whose survival depends on each other and their surrounding physical **habitat**, including air, water and soil. The concept was developed by English botanist Sir Arthur George Tansley in 1935 to show the importance of interactions between organisms and the environment.

Dynamic ecosystems

Ecosystems consist of **biotic** components that are living things, and **abiotic** components that are parts of the surrounding physical environment.

Ecosystems are dynamic, which means they are constantly changing. Organisms live and die. Habitats change naturally or as a result of human influences. Ecosystems are disturbed and then recover their **equilibrium** (balance).

Plants and animals depend on a balanced ecosystem to survive. Healthy ecosystems also provide people with products, such as food, and services, such as fresh water.

THE EARTH'S ECOSYSTEMS

AQUATIC

Marine

For example:
- Coral reefs
- Mangrove swamps
- Oceans
- Salt marshes

Freshwater

For example:
- Rivers
- Lakes
- Wetlands
- Creeks
- Springs

Terrestrial

For example:
- Rainforests
- Grasslands
- Deserts
- Tundras

ACTIVITY

ECOSYSTEM INPUTS AND OUTPUTS

This activity could be completed outside under a tree.

1 Working in groups, identify some of the resources (e.g. food) that living organisms need in an ecosystem.
2 Categorise each of these resources as biotic (living) or abiotic (non-living).
3 Consider the processes (ways that matter and energy are transferred) that naturally occur in ecosystems. Make a list of inputs these processes require. Are these items the same as the resources you listed in step 1? Why or why not?
4 Consider the inputs (components that flow into an ecosystem) and processes you have listed. Determine what outputs (components that flow out of an ecosystem) would be produced by the processes in your ecosystem.

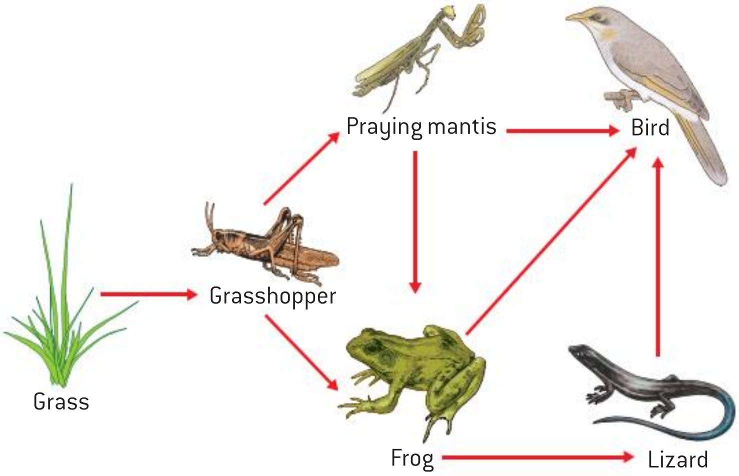
The Earth contains many different ecosystems. Some people consider the Earth to be a huge ecosystem.

Food webs

A **food web** is a simplified representation of an ecosystem's cycle of connected food chains. The food is at the tail of an arrow, and the head of an arrow points to the animal that eats the food.

Any change in one part of a food web affects all the other parts. If the population of one type of animal decreases (for example, due to disease), there will be an increase in the food it eats. This is because not as much of the food is being eaten. Meanwhile, there is a decrease in the number of larger animals that eat the diseased animal. This is because there is less food to go around.

Following the disruption to a food web, an ecosystem is likely to return to equilibrium but it may also be changed permanently. For example, the number of components of the ecosystem may be less than before.



A food web – the grasshopper eats the grass, and is then eaten by a frog or praying mantis, which in turn may be eaten by a lizard or bird.

LOOK IT UP

abiotic refers to the non-living things in an ecosystem, such as water

biotic refers to the living things in an ecosystem, such as plants and animals

ecosystem a community of living and non-living things that depend on one another for survival

equilibrium balance

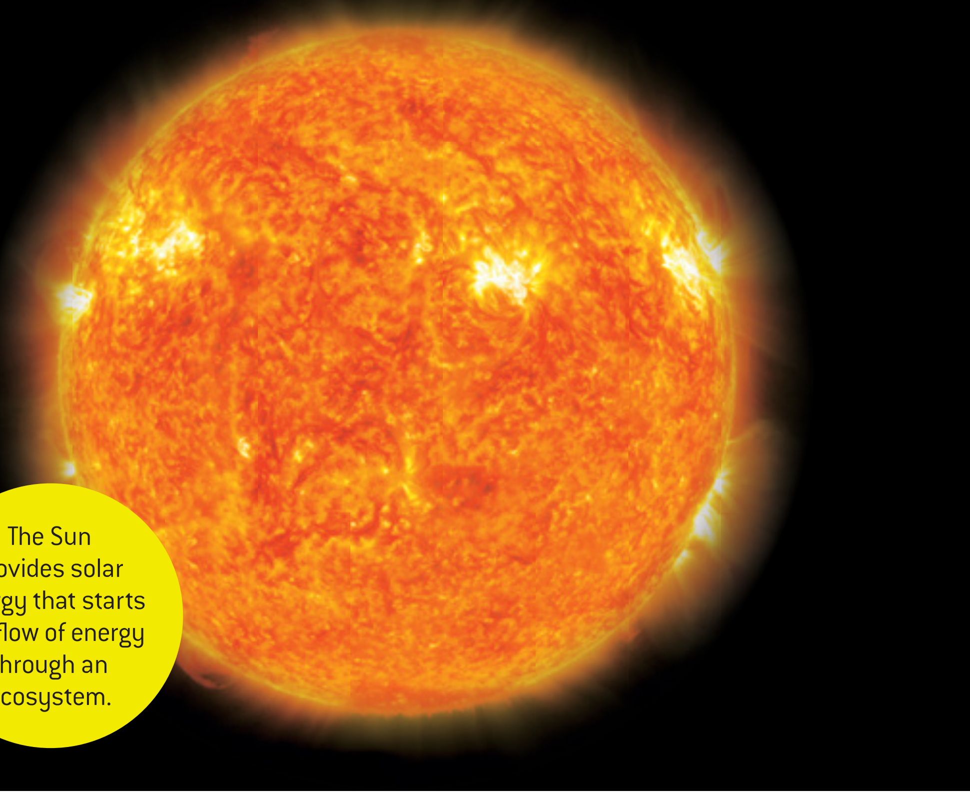
food web a diagram showing several food chains intertwined

habitat a place where a population of organisms lives

CHECK IT OUT

1 List three types of ecosystems.
2 What are the names for the following components of an ecosystem?
   a living
   b non-living
3 What ecosystems are the most common?
4 Explain the difference between a habitat and an ecosystem.
5 Study the food web image on this page. What will happen to the number of grasshoppers if the population of frogs decreases? What may happen to the bird population? Explain why.

GO WITH THE FLOW



The Sun provides solar energy that starts the flow of energy through an ecosystem.

Energy flows through an ecosystem. It begins as **solar energy**, which can be used by plants and other organisms called **producers**. Energy is used by the organisms in the food web but it is eventually lost as heat. Matter flows within an ecosystem. It is recycled, rather than being created or destroyed.

Energy flows

Energy enters most ecosystems as solar energy; that is, directly from the Sun. Plants capture solar energy through the process of **photosynthesis**, and use some of the energy to produce new cells and to grow. Plants store energy in the form of glucose, a chemical that can store large amounts of energy.

Animals cannot use solar energy directly. Instead, animals must eat plants, which contain stored energy, or eat other animals that have eaten plants. Digestion is the process of breaking down glucose into energy. The energy can be transformed into different types inside the body to enable work such as muscle movement, communication between cells (such as thinking), and growth. The amount of energy used is measured in joules or calories.

Predators at the top of the food chain obtain energy from animals lower in the food chain, which have obtained their energy from plants.

Not all of the produced energy is used. Some is lost from the ecosystem – it turns into heat energy and radiates into the air. Energy is not recycled within an ecosystem. The Sun must provide an ongoing source of energy to keep the flow going.

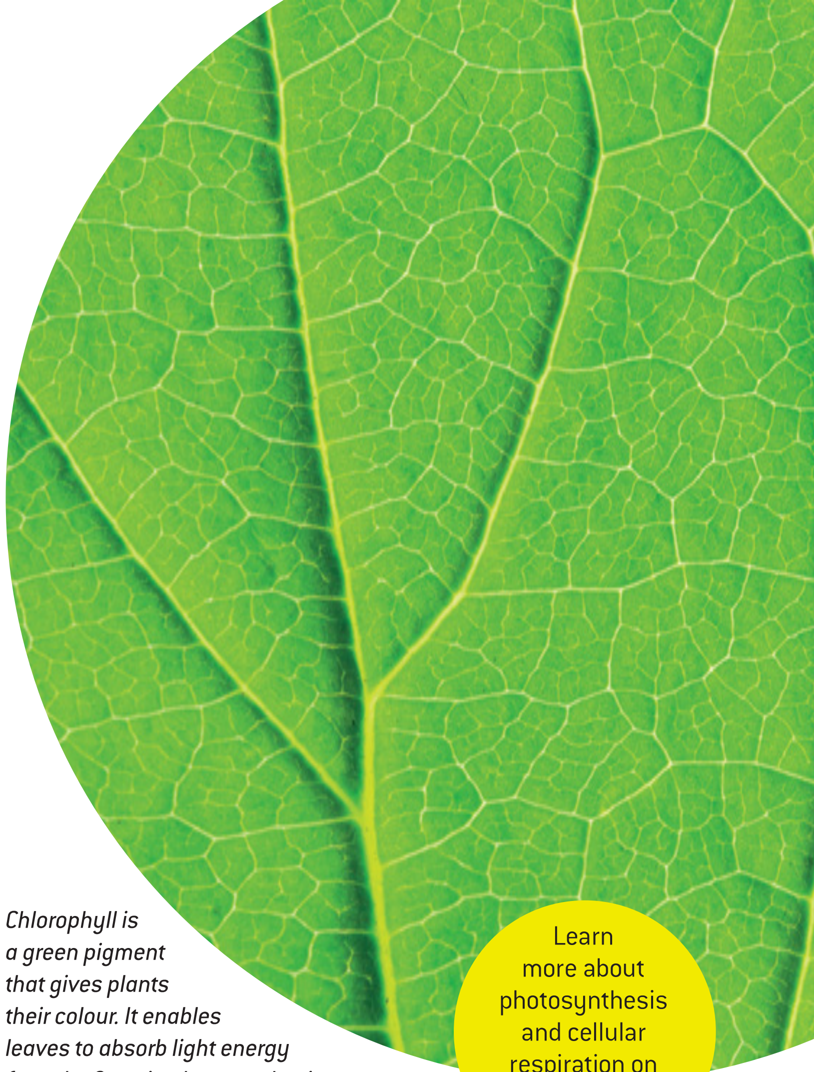
Some ecosystems can obtain energy from sources other than the Sun. Deep beneath the ocean surface, where there is no sunlight, bacteria trap energy from chemicals on the ocean floor. Bacteria inside volcanic craters obtain energy from chemical reactions that occur beneath the Earth's crust.

Matter flows

Matter, the basic building material of everything, flows around an ecosystem. Matter is different to energy in that it has mass – it can be weighed.

Plants absorb matter such as water, carbon dioxide (CO_2) from the air, and nutrients and minerals from the soil. This matter is converted into sugars and other compounds. When plant-eating animals die, they are decomposed by other components of the ecosystem. The decomposition of dead plants and animals turns matter back into simple nutrients and minerals in the soil. Plants then use these again. This recycling of matter within the Earth's soil, water and air creates cycles of matter within an ecosystem.

Decomposers break down matter in an ecosystem to obtain energy, and in doing so enable the recycling of matter.



Chlorophyll is a green pigment that gives plants their colour. It enables leaves to absorb light energy from the Sun via photosynthesis.

Learn more about photosynthesis and cellular respiration on pages 94 and 95.

Photosynthesis and respiration

Plants make glucose and oxygen from water and carbon dioxide using a process called photosynthesis. The term comes from the words *photo* (meaning light) and *synthesis* (meaning making).

Photosynthesis requires **chlorophyll**, the pigment that makes plants look green. Chlorophyll enables leaves to absorb light energy from the Sun. Some algae and bacteria have chlorophyll and can also photosynthesise. The process of photosynthesis occurs inside the plant cells, producing energy that is stored in the chemical bonds of glucose. Plants use the energy stored in the glucose to grow, make leaves and flowers, and to form starch. The process also releases oxygen.

Cellular respiration breaks down the carbon bonds in glucose to form a chemical called adenosine triphosphate (ATP), which then releases energy. The broken-down carbon combines with oxygen to produce carbon dioxide. Organisms use the energy and expel the carbon dioxide gas into the air.

The balance between organisms that photosynthesise and those that respire keeps the levels of carbon dioxide and oxygen at concentrations that enable life on Earth.

LOOK IT UP

cellular respiration the process of converting the energy stored in molecules (such as glucose) into energy in cells

chlorophyll a green pigment present in most plants; responsible for the absorption of light energy during photosynthesis

energy (biology) a resource that allows organisms to survive

matter a substance with mass and volume

photosynthesis the process in which the energy of the Sun is used to convert carbon dioxide and water into oxygen and sugars

producers plants and other photosynthetic organisms that can use solar energy directly

solar energy energy obtained from the Sun's radiation

CHECK IT OUT

1. What is the source of energy for most ecosystems?
2. Which of the following are recycled within an ecosystem?
   - A energy
   - B matter
   - C both
   - D neither
3. What is the green pigment that gives plants colour and enables photosynthesis?
4. How do consumers (organisms that cannot use solar energy directly) obtain their energy?

EXPERIMENT #3

PHOTOSYNTHESIS

AIM: TO FIND OUT IF LIGHT IS NECESSARY FOR THE PRODUCTION OF STARCH IN LEAVES

HYPOTHESIS

Construct an 'If … then …' statement that predicts the effect of light on the production of starch in leaves.

MATERIALS

- 2 soft-leaved plants (such as geraniums) of the same size, shape and colour, in seedling pots that have been kept in the dark for two days
- Hotplate and water bath
- Beakers (250 mL)
- Tongs or forceps
- 4 Petri dishes
- Methylated spirits
- Iodine solution
- Aluminium foil
- Paper towel
- Felt-tip pen

SAFETY

Methylated spirits is highly flammable and must not be heated using a naked flame.

METHOD

1 Label one plant 'A' and one plant 'B'. Cover the leaves of plant A with aluminium foil and place both plants in sunlight or under a bright desk lamp for several days.

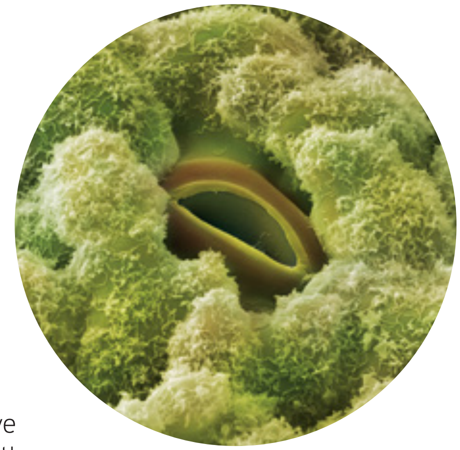
2 Break off two leaves from each plant. Remove the foil from the leaves of plant A and place them in a beaker. Place the leaves from plant B in another beaker. Add water and boil the leaves for several minutes. The leaves should become soft.

3 Place the plant A leaves in a small, labelled beaker of hot methylated spirits in a water bath. Repeat with the plant B leaves. Leave them for 5 minutes or until the chlorophyll has been removed from the leaves.

4 Remove the leaves with tongs, then rinse and dry them, ensuring you keep track of which leaves are from plant A and which are from plant B.

5 Place the leaves in separate Petri dishes and add iodine solution. If starch is present you will see a blue-black colour.

6 Observe any colour change and record your observations.



The carbon dioxide needed for photosynthesis, and the oxygen and water vapour produced during photosynthesis, move in and out of leaf cells through microscopic pores called stomata.

RESULTS

Include your observations in a table.

DISCUSSION

1 Explain why a positive test for starch is considered an indication that photosynthesis has occurred.

2 Is this experiment quantitative (measures quantity) or qualitative (identifies a quality)? Explain your answer.

3 Suggest a change to improve the method if you were to repeat this experiment.

CONCLUSION

Is light needed for photosynthesis? Justify your conclusion with the evidence of your results. Write a statement that answers the aim.

EXPERIMENT #4

PLANT COMPETITION

AIM: TO IDENTIFY HOW COMPETITION AFFECTS THE GROWTH OF GERMINATING SEEDS

HYPOTHESIS

Use your knowledge of the resources required by plants to write an 'If … then …' statement to predict the outcome of this experiment.

MATERIALS

- Packets of seeds (including a variety of vegetables or flowers)
- Small (20 × 20 cm) plot in a garden, divided into thirds (alternatively, three medium-sized pots containing good-quality potting mix)
- Measuring cylinder or graduated jug for watering

METHOD

1 Prepare the three plots so the soil is moderately deep and smooth. Label them 'A', 'B' and 'C'.

2 In plot A, densely scatter the seeds of one type (for example, only radish seeds).

3 In plot B, plant six seeds of the same type as for step 2, but spread them evenly apart.

4 In plot C, densely scatter a variety of seeds.

5 Water the soil each day as evenly as possible with the same amount of water.

6 Record the growth of the seeds. If possible, take photographs each week or every few days when the seeds begin to germinate. If the seeds become seedlings (small plants), you can measure their heights and recorded them in a table.

RESULTS

Record all your results. You could take photos showing the progress of growth and/or record the average heights of plants of different species in a table.

DISCUSSION

1 What assumptions did you make when making a conclusion?

2 How could you have improved the validity and reliability of this experiment?

3 What would be your advice to another student who wants to perform the experiment?

4 Was there evidence of competition between the seeds as they germinated? Explain using your results.

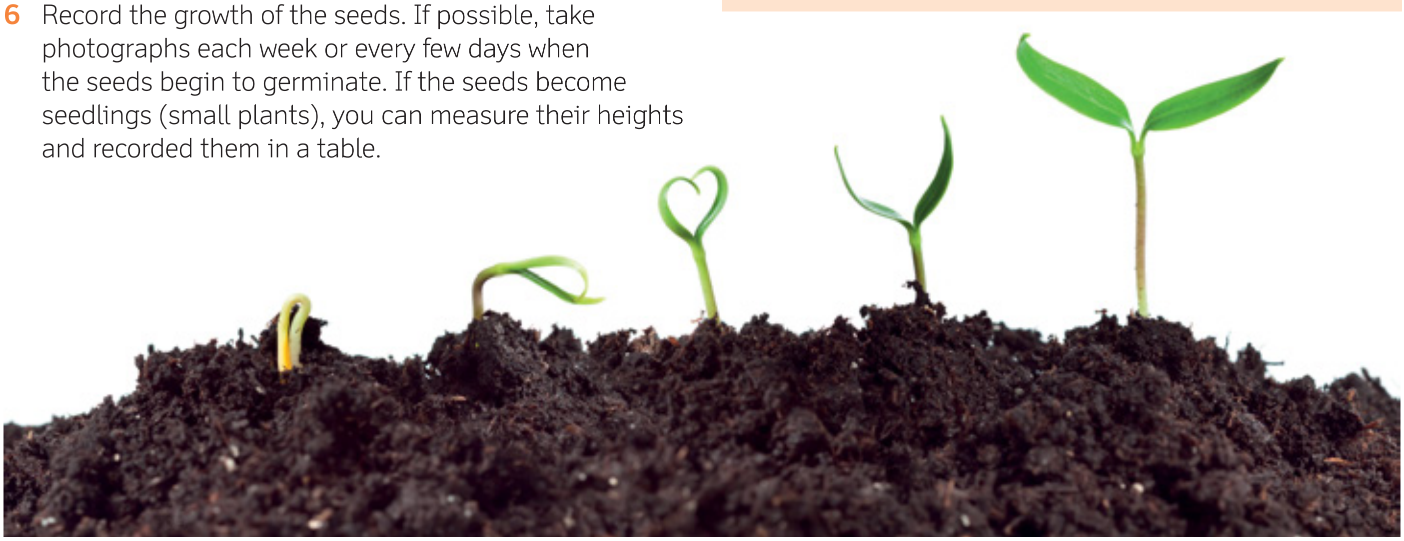
5 Are there other factors that might affect the growth of seeds?

6 If you were to complete this experiment again, how would you improve or extend it?

7 Have you previously observed competition between organisms in the natural environment? If so, describe it.

CONCLUSION

Write a conclusion about the factors that affect competition between germinating seeds.



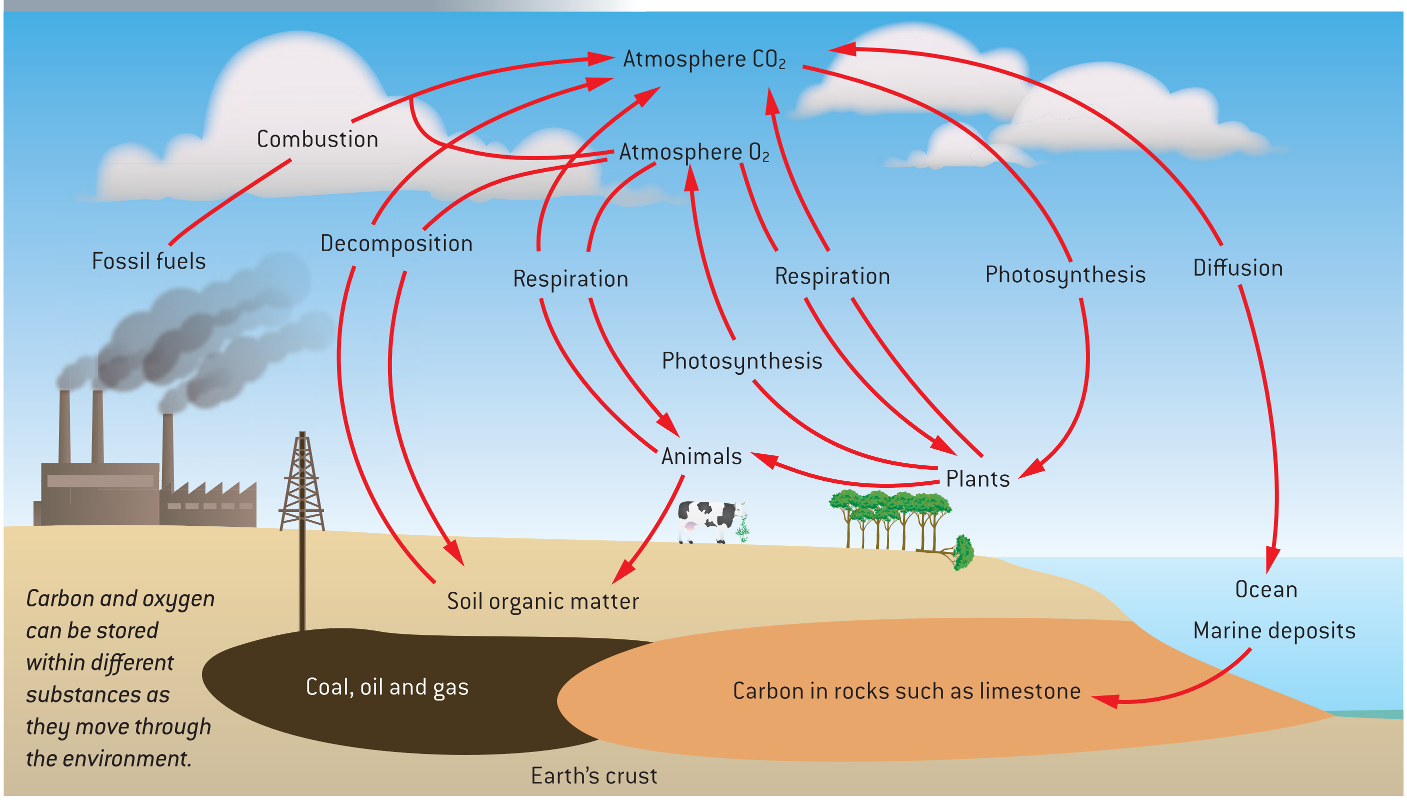
CYCLES MATTER

Matter is neither created nor destroyed in an ecosystem. Matter moves through natural cycles that are essential for life. Large amounts of carbon, oxygen, nitrogen and water are stored in the atmosphere during their cycles. Phosphorus, potassium and calcium are also cycled through the environment, and are largely stored in rocks within the Earth's crust.

Close-up view of a termite.

Termites play an important role in the carbon cycle, decomposing wood in regions that are too dry for other decomposers such as fungi. This giant termite mound is in the dry grasslands of Kakadu National Park in the Northern Territory.

THE CARBON CYCLE



Carbon cycle

Carbon and oxygen flow in and out of the land, air, ocean and living things. They are balanced by photosynthesis and respiration as part of the **carbon cycle**.

On land, green plants take in carbon dioxide (CO_2) and create oxygen (O_2) during photosynthesis. Animals reverse the processes by taking in oxygen and returning carbon dioxide to the air. When plants and animals die, bacteria and fungi break down the stored carbon and release carbon dioxide into the air.

At sea, phytoplankton (tiny plant-like organisms) photosynthesise at the ocean surface. This removes carbon dioxide, allowing more carbon to dissolve into the water from the atmosphere. When phytoplankton die, they sink to the ocean floor, taking the carbon with them.

Each year, natural processes such as respiration, decay, forest fires and volcanic eruptions add 190.2 billion tonnes of carbon to the air. The oceans, land and plants balance that by absorbing 190.2 billion tonnes of carbon from the air, mainly through photosynthesis.

But humans have changed the carbon cycle over the past 200 years. Now, an additional 9.1 billion tonnes of carbon enters the air annually, mainly from burning fossil fuels such as coal and oil. The oceans absorb 2.2 billion tonnes of this extra carbon. Plants and the land take up 2.8 billion tonnes. The imbalance, 4.1 billion tonnes, stays in the air, which leads to an increase in carbon dioxide concentration of the air, and global warming.

Nitrogen cycle

About 78 per cent of the atmosphere is nitrogen gas (N_2). Nitrogen-fixing bacteria in the soil convert the nitrogen from the air into a form that plants can absorb. Animals absorb the nitrogen when they eat plants. When plants and animals die and decompose, the nitrogen returns to the soil and is used again as part of the **nitrogen cycle**.

People add nitrogen-based fertilisers to the soil to help plants grow. If they use too much, it can run into lakes and rivers. The excess nitrogen causes tiny organisms called blue–green algae to grow to large proportions. This is called an **algal bloom**, and can damage ecosystems.

A bloom of blue–green algae (cyanobacteria) in a lake can rob it of nutrients and oxygen, harming the ecosystem.

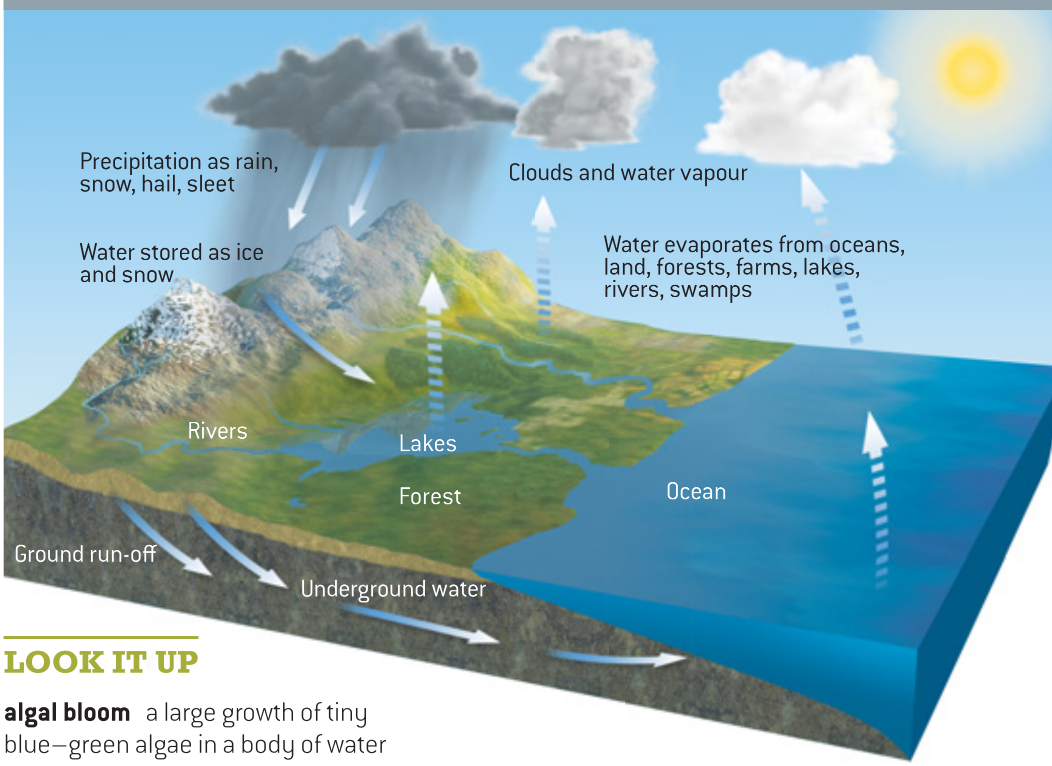
Water cycle

Water moves through the Earth's land, oceans and air in solid, liquid and gaseous forms. While the total mass of water on Earth is fairly constant, the relative amounts of fresh water, salt water, ice and water vapour can change depending on the climate.

Heat from the Sun drives the **water cycle**. Liquid water evaporates into invisible vapour when heated. When the vapour cools, it condenses into drops of water or crystals of snow and sleet. It may then fall as **precipitation** (rain or snow). Over land, precipitation is greater than evaporation so water flows into rivers, lakes and the sea. Here it evaporates, continuing the cycle. Water also moves from plants and soils into the atmosphere through a process called **transpiration**.

Water does not cycle around just one ecosystem. For example, water can evaporate from a desert and fall as rain in a forest. In Australia, some areas can be in drought while others are flooded.

THE WATER CYCLE



LOOK IT UP

algal bloom a large growth of tiny blue–green algae in a body of water

carbon cycle the flow of carbon in and out of the land, ocean and living things

nitrogen cycle the flow of nitrogen through soil, air, plants and animals

precipitation liquid (rain) or solid (hail, sleet and snow) forms of water that fall to Earth

transpiration the process by which plants take up water from the soil through their roots and up into their leaves and then release it into the air

water cycle the continuous movement of water on the land and in the atmosphere

CHECK IT OUT

1 Draw a diagram to show how the nitrogen cycle works.
2 What drives the water cycle?
3 List two organisms that decompose wood as part of the carbon cycle.
4 List three types of matter that are stored in the atmosphere during their cycles.
5 How have humans changed the carbon cycle and what problem is this causing?

ECOSYSTEM RELATIONSHIPS

Species of plants and animals exist in balance in an ecosystem. Being part of the same ecosystem means organisms interact with each other in a range of ways. These interactions are called **relationships**. The relationships may involve different species helping each other or competing against each other. Individuals within the same species may also compete or cooperate.

Lantana is one of Australia's worst invasive weeds and is a threat to biodiversity.

Competition and cooperation

Different species can compete for survival when there is limited food, water or territory in an ecosystem. For example, weeds compete with crops – the weeds use water and nutrients that then reduce the crop yield. Some organisms can slow the growth of another by releasing a chemical. For example, lantana (*Lantana camara*) is an introduced species of plant in Australia that releases a chemical into the soil that inhibits the growth of native plants.

Competition can also occur within the same species. Competition can occur between individuals within a species for a mate or for resources – for example, seedlings from the same plants compete for light, nutrients and water to grow.

Cooperation within a species helps it survive. For example, ants cooperate by leaving a scented trail to food so that other ants can find it. Cooperation between different species is called symbiosis.

Fish cooperate within a species, swimming together in a school. This makes it more difficult for predators to single out an individual creature as prey.

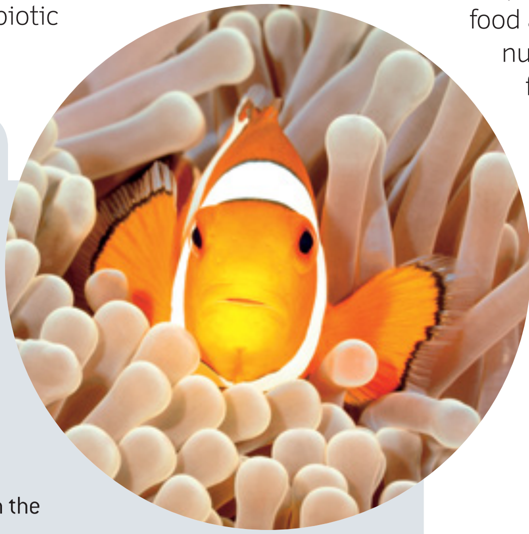
Symbiotic relationships

Symbiosis is where two different species help each other over a long time to survive. The relationships are sometimes beneficial and sometimes harmful. **Mutualism**, **parasitism** and **commensalism** are different types of symbiotic relationships.

Mutualism

Both species may benefit

Clown fish escape predators by hiding within the stinging tentacles of sea anemones. The clown fish is immune to the stinging cells. It feeds on organisms that can harm the anemone, and its faeces provide nutrients that help the anemone grow.



The anemone is providing this fish with a home safe from predators, and the fish eats organisms that can harm the anemone.

Parasitism

One species benefits at the expense of another

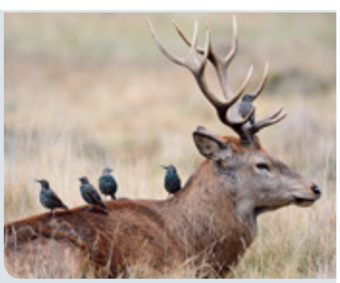
Parasites live on or in the body of a host species. The host can be harmed or even killed. For example, ticks live on the bodies of animals, feeding on blood while infecting the host with their bacteria.

A parasitic tick uses a dog as a host. The tick is of no benefit to the dog.

Commensalism

One species may benefit while the other is neither helped nor harmed

A species may use another species for housing, such as when a spider builds a web on a plant. Or a species may obtain food from another. Species can also use other species for transportation. For example, some plants have seeds that hook onto passing animals so they are dispersed.



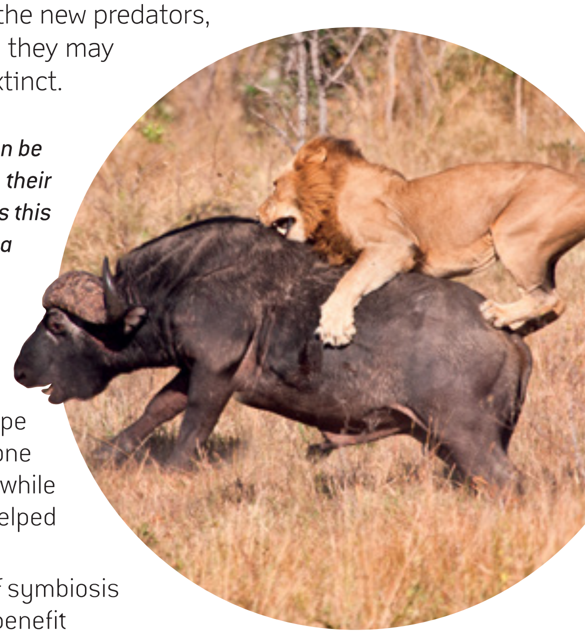
The starlings are feeding on a red deer's parasites, which benefits both the birds and the deer.

Predators and prey

Predators are animals that eat other animals. The animals that are killed are called **prey**.

Predators and prey live in a balanced relationship. If the predator eats too many of its prey, there is not enough food and predator numbers decrease. This enables the number of prey to increase, which provides more food for the predators. In turn, this enables predator numbers to increase again.

Introduced predators can have devastating effects on species, changing the predator–prey balance. Organisms that have evolved to cope with predators in their ecosystem need to adapt to the new predators, otherwise they may become extinct.



Predators can be smaller than their prey, such as this lion hunting a buffalo.

LOOK IT UP

commensalism a type of symbiosis where one species may benefit while the other is neither helped nor harmed

mutualism a type of symbiosis where both species benefit

parasitism a type of symbiosis where one species benefits at the expense of another

predator an animal that kills other animals to eat

prey animals killed by predators as food

relationship the ways in which species relate or interact with each other

symbiosis a relationship where two different species help each other to survive

CHECK IT OUT

1. Name two species that compete in an ecosystem.
2. Name a species that cooperates with other individuals in its own species.
3. Parasitic symbiosis is one type of symbiotic relationship. List two other types of symbiotic relationships between species.
4. Consider a parasitic symbiotic relationship and a predator–prey relationship. How are they different? How are they similar?

5 AMAZING PREDATORS

Bears attack for a number of reasons: if surprised, to protect their cubs, to defend their space, or if they are just after something to eat and have learnt that humans have food with them.

1 Shark tale

There are around 350 species of sharks. The largest and most feared is the great white. Females can be particularly large – up to 6 metres long and weighing more than 2 tonnes. Their sharp, saw-like teeth are excellent for attacking prey. They are fast, intelligent and have highly refined senses.

Only 30 species of shark are known to have attacked humans. Around a quarter of shark attacks are fatal. Australia has more recorded shark fatalities than any other country, with an average of one person killed per year.

However, you are much more likely to drown than be eaten by a shark. On average, more than 300 people a year drown in Australia. With around 2000 people killed on Australian roads each year, the real danger is the drive home from the beach.

2 King of the jungle

A full-grown male lion can weigh 230 kilograms. Lions can run at up to 60 kilometres per hour. You can hear a lion's roar from as far away as 9 kilometres.

Lions can see well in bright sunlight or low light. They can hear their prey from more than a kilometre away, and can use their refined sense of smell to tell how close they are. Lions hunt together and can attack prey that is more than twice their size.

Lions living in the wild are found mainly in parts of Africa south of the Sahara. About 400 lions live under protection in the Gir Forest National Park in India. In total, there are fewer than 30 000 wild lions remaining in the world.

3 Bear facts

Bears can weigh more than 600 kilograms, which is more than half a tonne. There are eight species of bears, including brown bears, black bears, polar bears and giant pandas. Most types of bear live for 20 to 30 years. Polar bears and brown bears are the largest land-based meat-eaters in the world.

Polar bears live in the Arctic; there are no polar bears in Antarctica. Although seals are their main source of food, polar bears also actively hunt humans – the only type of bear that does so. If hungry, polar bears will kill people to eat, as anything they come across is potential prey.

Although sharks are top predators, we kill sharks much more often than sharks kill us. Each year, we kill tens of millions of sharks for food (we call it flake), and for their fins, skin and liver oil, as well as by accident while fishing for other food.

Big cats do attack people, but not often.

4 Never smile at a crocodile

The saltwater or estuarine crocodile is the world's largest living reptile. They grow to more than 6 metres long and weigh more than 1.5 tonnes.

Crocodiles use surprise and speed to catch their prey. In northern Australia, a still crocodile can accelerate out of the water and grab a cow, kangaroo or even a tourist before the prey knows what's happened. For short periods of time, a crocodile can achieve speeds of around 12 to 14 kilometres per hour, and for a fraction of a second can reach more than 40 kilometres per hour.

Crocodiles and alligators have the strongest bite of any animal. Humans can bite with a force of 77 kilograms. The biting force of a crocodile is more than 1000 kilograms. This force is the equivalent of being crushed by a medium-sized car.

On average, saltwater crocodiles attack two people each year in Australia.

5 Don't go near a dingo

Dingoes, which are native to Australia, prey on foxes and rabbits, helping to control these introduced species. Dingoes are the largest mammalian predators in Australia.

European Australians have only recorded three cases where a dingo has killed a person. However, they have attacked many people and rightly have a reputation as fierce, unpredictable predators. You should never feed a dingo.

The first European killed by a dingo is believed to have been a 12-year-old girl in 1845, who was hiding from her parents in the bush overnight to avoid punishment. Her bones were found the next day, gnawed by dingoes. In 1980, 10-week-old Azaria Chamberlain was taken from a tent near Uluru.

Dingoes have attacked many people on Fraser Island off the Queensland coast. In May 2001, a pair of dingoes followed two boys walking near their campsite on the island. When one of the boys fell, he was fatally mauled. His older brother was also attacked, but survived.

Dingoes are considered a pest. One control method is the 8000-kilometre dingo fence from Queensland to South Australia. It is the world's longest fence.

CHECK IT OUT

1. Give two examples of prey that dingoes feed on.
2. 'Dingoes have been known to kill people.' True or false?
3. What is the largest meat-eater in the world that lives on land?
4. Compare a human's biting force to a crocodile's biting force.
5. Should we be afraid of sharks, or should sharks be afraid of us?

POPULATION SIZE

The number of individual members of a species is described as the **population**. The size of a population of organisms in an ecosystem increases if the total number of births and individuals joining the population (immigration) is greater than the total number of deaths and individuals leaving (emigration). The population decreases if births plus immigrants is less than deaths plus emigrants. The population is in a dynamic balance or equilibrium if these inputs and outputs are equal over time, even if the population rises and falls over short periods.

Balancing act

The number of individuals in an ecosystem that are living or dying, and joining or leaving, is influenced by many natural factors.

Individuals within an ecosystem need food and shelter. An environment's **carrying capacity** is the maximum number of individuals that can be supported by the area's resources. If the population increases beyond the carrying capacity, individuals may starve to death or leave the ecosystem to look for other food. This keeps the population in balance.

Some animals migrate with a change of seasons, moving to a more suitable climate; for example, where it is warmer or where there is plentiful water. This decreases the population in some areas and increases it in others. Population also can increase in spring when many animals are born.

Extreme weather events can influence populations of animals and plants. Australia experiences droughts and bushfires in some years, and floods in others.

A flood may increase populations of plant life due to increased water availability. However, it may also reduce the population of animals due to drowning, loss of food or migration. Similarly, bushfires reduce animal populations; however, bushfires are essential for increasing the population of many native Australian plant species that need fire to release their seeds.

Animals may migrate as seasons change, changing the population size in an area.

Each year, Lake Nakuru in Kenya becomes packed with one of the largest populations of flamingo in the world. Millions of flamingoes fly in to breed in the lake's shallow waters.

Disease

The population of a species can decline when exposed to a **disease**. If plants and animals have been exposed to the disease previously, they may have developed immunity and can fight the disease. If a new disease is introduced to an ecosystem (for example, by an introduced species), it is likely to have a greater impact on the population.

Small, isolated species lack genetic diversity and are therefore more exposed to new diseases. For example, a disease that causes facial tumours is infecting many Tasmanian devils. Scientists are breeding Tasmanian devils in other areas to try to increase their diversity and hence increase their immunity to the disease.

Counting critters

Scientists count or sample individuals to understand populations. This is important for monitoring the health, or biodiversity, of an ecosystem. If a population is decreasing, actions can be taken to help the species survive.

Almost every individual in a human population can be counted using a survey called a **census**. However, counting every animal or plant in an ecosystem is not practical. Scientists estimate a population of stationary organisms by sampling a small, randomly selected **quadrat** (representative area) or **transect** (line), and then multiplying the results up to the size of the habitat.

Sampling of mobile animals is done by capturing a sample (N_1), tagging and releasing them, and then capturing animals in the same area sometime later (N_2). A proportion of the animals will be re-captured (M_2), as identified by the tag. The estimated total number of animals in the area is then calculated using the formula

$$\frac{N_1 \times N_2}{M_2}$$

For example, zoologists tagged and released 20 koalas (N_1) in a forest. A year later they caught 50 koalas (N_2) in the same forest. Of the koalas caught in the second capture, 5 koalas (M_2) had tags from the first survey. The zoologists estimate that the forest holds a total of

$$\frac{20 \times 50}{5} = 200 \text{ koalas.}$$

Small, isolated populations can be susceptible to disease, such as the Tasmanian devil, whose population has been reduced by almost half by a facial tumour disease.

A quadrat is a sampling technique used to count the number of individuals in a small area and then relating this number to the size of the whole ecosystem.

LOOK IT UP

carrying capacity the maximum number of individuals that can be supported by an area's resources

census a survey to count the population of an area

disease a sickness or disorder in the body or part of the body of a person, animal or plant that may produce symptoms

population a group of the same kind of organisms that live in the same place at the same time

quadrat a representative area used to count the number of individuals in a small area to represent the size of the population in the whole ecosystem

transect a straight line across the Earth's surface, along which measurements are taken

CHECK IT OUT

1. What happens to a population of a species if births plus immigrants is greater than deaths plus emigrants?
2. In a census, who is counted?
3. List three reasons why a population of animals may increase in an area.
4. Why would small, isolated species that lack genetic diversity be more exposed to diseases than large, diverse populations?
5. Consider a sample of 25 marsupial mice captured in one night. All are tagged and then released. The next night, 30 marsupial mice are captured and 11 of them have tags. What is the estimated total number of small marsupials in the area?

HUMAN IMPACTS ON ECOSYSTEMS

People and ecosystems don't always mix well, such as this discarded plastic bag that can harm small marine animals and coral.

People have a huge impact on ecosystems, and have caused the extinction of many species. The world's population was more than 7.3 billion in 2015, and is growing at a rate of an extra 80 million people each year. Our need for food, water and other resources puts pressure on the populations of other species. For example, in Australia, our use of water from rivers for irrigation of farmland to grow food reduces the flow of water needed by fish and plants such as river red gum trees.

Some wild animals are able to survive in cities.

Much of the giant panda's bamboo forest habitat has been cleared in China to make way for agriculture and logging.

Cities and pollution

Although cities occupy only about 2 per cent of the Earth's surface, they have a big impact on ecosystems. Cities are important for human activities. In Australia, 9 out of 10 people live in a city.

Urbanisation causes loss of habitat as cities expand. New species are introduced to the area, such as pets that prey on native animals. Concrete and other hard surfaces raise the temperature. Water carrying waste and chemicals drains into waterways, affecting aquatic life. Extensive energy use and transportation causes air pollution.

In rural areas, clearing of land for agriculture reduces the variety of plants and causes animals to migrate or die. Pollution in rural areas also affects ecosystems. For example, fertiliser and topsoil from east-Queensland farms run off into rivers that flow to the ocean. These settle on the sea floor, killing parts of fragile coral reefs.

Biodiversity loss

Biodiversity is the variety of species living on Earth. The term comes from the words *bio* (meaning life) and *diversity* (meaning different). Biodiversity is a measure of the variety of plants and animals in an ecosystem, as well as bacteria and other organisms that we can't see. It is an indicator of the health of ecosystems. Healthy ecosystems contain a range of different species.

Biodiversity is reduced by human activities such as clearing land for human settlement, reducing species to a single crop through farming, or removing species for food, such as fish from the sea.

In 1859, 24 rabbits were released in Victoria for hunting purposes. Rabbits have now grown to plague proportions around Australia.

Around 100 species of organisms are known to have become **extinct** in Australia since European settlement in the late 1700s. More than a quarter of these have been mammals, such as the Tasmanian tiger. Other species are likely to have become extinct in Australia without us knowing, because so far only about a quarter of Australia's animals and plants have been identified by scientists.

Nonetheless, Australia still has a high level of biodiversity. More than 80 per cent of our mammals, flowering plants and temperature-zone fish are found nowhere else in the world.

Introduced species

Humans can deliberately or accidentally introduce new species of organisms into an ecosystem. The **introduced species** may be new diseases, ornamental plants for urban gardens, or domestic animals for pets. These foreign organisms change the make-up of life and threaten native species.

In Australia, we have introduced foxes and rabbits for hunting, cats and dogs as domestic pets, and cows and sheep for farming. Scientists introduced cane toads into Queensland in 1935 to catch sugar-cane beetles that threatened the sugar industry. The toads have become a pest themselves and have now spread well beyond Queensland. There are more than 20 species of introduced fish in Australia's rivers.

More than 170 non-native marine species now live in Australian waters. New species arrive in the ballast water of ships, on oil rigs, attached to boats or caught in fishing nets.

LOOK IT UP

biodiversity the variety of species living on Earth or a part of it

extinct a family, class or species that has died out

introduced species any species of plant or animal that has been moved by humans to an environment where it did not occur naturally

urbanisation building up of the environment into a town or city

CHECK IT OUT

1. How many Australian species have become extinct since European settlement?
2. What percentage of the Australian population lives in cities?
3. List three ways that cities affect an ecosystem.
4. With the world's population growing by 80 million people each year, how many extra people does the world hold each day?
5. Define 'biodiversity'. Discuss what the word means to you.

Ocean acidification has serious effects on corals, plankton and other marine organisms and affects the entire marine food chain.

ECOSYSTEM IMPACTS OF CLIMATE CHANGE

Climate change is the most serious environmental issue of our time. Climate change and other pressures have put 25 per cent of the world's mammals and 12 per cent of birds close to extinction. A study of more than 1700 wild animals and plants around the world found that climate change is forcing the locations of species towards the cooler poles by an average of 6 kilometres per decade.

Climate change

The **climate** has always changed. The amount of energy emitted by the Sun varies. The Earth's orbit wobbles. Volcanoes spew particles high into the atmosphere. These and other natural influences mean the Earth has seen a series of changes, from ice ages to warm periods, approximately every 100 000 years.

In addition to these natural fluctuations, climate also changes due to human activities that increase the concentration of carbon dioxide in the atmosphere. If you burn anything containing carbon (for example, wood, gas, petrol, oil or coal), the carbon atoms will react with oxygen atoms and form carbon dioxide. Scientists have known for decades that carbon dioxide and other waste gases we emit into the air are changing our climate.

Global surface temperature has risen by about 0.85°C since reliable global measurements began in 1880. There is no record of global temperature ever having increased as rapidly as it has over the past 100 years. Of the 15 warmest years ever measured, 14 of them have occurred in the 21st century. Australia's average temperature has risen by about 0.9°C since 1910, mostly since 1950.

Carbon dioxide is a colourless, odourless gas. It is a heat-trapping greenhouse gas that is adding to global warming.

Ecosystem impacts

Global warming affects the ecosystem. Flying foxes have moved hundreds of kilometres south. Feral brumbies and wallabies have moved up mountains, while snow gums are growing at higher elevations.

Migrating birds arrive in Australia sooner and leave later. Spring events are happening earlier at a rate of a couple of days per decade, on average. Such changes throw ecosystems out of balance.

By 2050, global warming may eventually lead to the extinction of 18 to 35 per cent of species. Eventually, 1 million species could become extinct.

To escape higher temperatures, some Australian butterfly species have shifted hundreds of kilometres south.

Ocean impacts

The oceans have absorbed approximately 90 per cent of the excess heat trapped by increased greenhouse gases in the atmosphere over the past 50 years. On the Great Barrier Reef there have been eight **coral bleaching** events since 1979, but there were none known before this. Bleaching happens when warmer-than-normal water makes coral turn white. If bleaching occurs too often and too severely, the coral ecosystem may be replaced by an ecosystem dominated by seaweed.

The world's oceans also absorb about a quarter of the carbon dioxide from human activity – that's more than 2 gigatonnes of carbon a year. The oceans have absorbed about half of the carbon emitted by humans over the past 200 years. When carbon dioxide is absorbed into water, it makes the water acidic. This has increased the acidity of the ocean, lowering its pH.

LOOK IT UP

climate the long-term weather conditions of an area

climate change long-term variations in the climate due to natural fluctuations and/or human activities changing the environment

coral bleaching the whitening of coral due to warmer-than-normal water that can cause the coral to die

global warming the large-scale, long-term warming of the planet, usually in reference to changes due to human activities

CHECK IT OUT

1 Approximately how many degrees Celsius has the Earth warmed since 1880?

2 Climate change is forcing animals and plants in Australia to move by an average of 6 kilometres per decade in which direction?

3 Natural influences change the Earth from ice ages to warm periods every how many years?

4 Most of the excess heat trapped by increased greenhouse gases over the past 50 years has been absorbed by:

A the land
B the atmosphere
C the oceans
D none of these.

5 Explain how the oceans are becoming more acidic, referring to the source of the acidity, the pH of the water and the impacts of the change.

Ask a scientist

Dr Dewi Kirono

Dr Dewi Kirono's Year 7 physics teacher told her that science is knowledge, and that knowledge is power. Back then she didn't understand what this really meant, but now she thinks he was right.

A climatologist is a scientist who studies the climate. They may have training in meteorology, physics, mathematics, computing, geography or another area of environmental science.

Dr Dewi Kirono is a climate scientist at CSIRO in Melbourne. She developed an interest in science during secondary school in Indonesia, and then studied geography at university. She completed a PhD in Australia to develop a computer model that predicts rainfall three months in advance, which enables better preparation and action to occur.

Her career choice was influenced by a childhood experience in East Java. 'I was close with nature from an early age – playing in paddy fields, swimming in the clean rivers and climbing the mountains,' says Dewi. 'Through this I learnt that our lives are shaped by nature. One day, due to very heavy rainfall, there was a huge flash flood and a landslide occurred in my village. There were fatalities and some of my friends lost their houses. I was sad, and I started to wonder why these disasters could happen and whether there is way to prevent them.'

She says studying nature is important. 'The Earth is like our home. All aspects of the Earth – the air, climate, water and topography – are shaping our lives. By having a better understanding about them, hopefully we will have a better quality of life.'

A video interview with Dr Dewi Kirono is available on your obook / assess.

SUSTAINABLE ECOSYSTEMS

Indigenous Australians use fire to manage ecosystems.

Indigenous Australians have lived in Australia for 60 000 years. European people have lived here for 250 years. Human settlement over both timescales has had an impact on Australian ecosystems. This has occurred through burning, farming, introduced pests and other pressures. Knowledge of Indigenous Australian **land management** and a scientific understanding of how to manage ecosystems are required to balance the competing pressures on the environment.

Sustainability

Australians expect food, clothing, housing, transport, power and other products for a comfortable life. Our modern lifestyle affects the Australian ecosystems and, through the global atmosphere and oceans, the global environment.

Environmental sustainability is the concept of balancing how we live with its impact on ecosystems. **Sustainable development** is the growth of economies, and political and cultural systems, in harmony with the environment. This ensures ecosystems remain diverse and productive.

Sustainability requires a scientific understanding of how ecosystems work and the impact that development (such as cities) has on the environment. It takes research and planning, cooperation and compromises, and action by individuals and groups.

Sustainability involves managing the way we live with our impact on the environment.

Indigenous Australians

Indigenous Australians, across a diverse range of languages and cultures, have the same concept of shared custodianship of the environment and the idea of living in harmony with nature. This contrasts with the traditional approach of European settlers, who favour individual ownership of land and control of the environment.

The dry landscape around Uluru and Kata Tjuta in central Australia receives very little rainfall, yet Indigenous Australians managed to survive in this harsh environment for thousands of years. They understood the changing seasons and where to find food and shelter. They hunted wildlife and gathered food in a sustainable way. However, over the past 200 years, new introduced species of grasses and animals such as camels, mice, rabbits, foxes, cats and dogs have harmed the environment. As a result, the communities living in these regions have suffered.

Indigenous Australians have used skills to survive in harsh environments for thousands of years.

Controlled burning is a way to manage biodiversity and fuel loads.

Burning off

Government land management departments have re-introduced the traditional fire practices of Indigenous Australians to manage the dominance of individual grass species in northern Australia. This method of controlled burning, known as **fire-stick farming**, has improved biodiversity.

Australian soil is low in nitrogen and phosphorus, which are essential for plant growth. Around Australia, burning vegetation in a controlled way produces ash containing these and other nutrients. Some seedlings require fire for germination, so there is an increase in the diversity of plants after a fire.

Controlled burning in the Australian bush also reduces the abundance of fuel for bushfires. Furthermore, some species of vegetation have evolved to rely on fire for their survival. Eucalyptus trees have thick bark that protects the inner tissue from the heat of bushfires. Buds beneath the bark sprout after the fire has passed.

LOOK IT UP

environmental sustainability balancing how we live with its impact on ecosystems to conserve an ecological balance by avoiding depletion of natural resources

fire-stick farming management of grass species using controlled burning, traditionally practised by Indigenous Australians

land management care of the land through controlling or dealing with things that affect it

sustainable development growth of economies, and political and cultural systems, in harmony with the environment

CHECK IT OUT

1 List three human activities that have affected the Australian environment.

2 How can fire help manage the landscape?

3 Explain the difference between Indigenous Australian and European approaches to ownership and land management.

4 Explain the meanings of environmental sustainability and sustainable development.

REVIEW

DYNAMIC ECOSYSTEMS

WHAT ARE ECOSYSTEMS? (PAGES 28–29)

1 In what decade was the concept of ecosystems developed?

2 In a food web, explain why the population decrease of one animal can affect the population of another animal that preys on it.

3 Discuss why the Earth is considered by some people to be an ecosystem.

GO WITH THE FLOW (PAGES 30–31)

4 Name two forms of energy transferred within an ecosystem.

5 Plants store energy in what form?

6 Name an organism that obtains energy from an ecosystem where there is no sunlight.

CYCLES MATTER (PAGES 34–35)

7 List three forms of matter that are cycled through an ecosystem.

8 Bacteria and fungi break down dead plants and animals.

- **a** What do they release into the air?
- **b** Which cycle is this a part of?

9 Name two gases that form part of the carbon cycle.

ECOSYSTEM RELATIONSHIPS (PAGES 36–37)

10 The photo below demonstrates mutualism, a type of symbiosis where both species benefit. List two other types of symbiotic relationships between species.

11 Name a top predator for each of the following habitats: land, ocean, ice, rivers.

12 Polar bears (opposite) kill humans for food. List two other predators that kill humans as prey.

5 AMAZING PREDATORS (PAGES 38–39)

13 What dingo-control method is used in eastern Australia?

14 What is the world's largest living reptile?

POPULATION SIZE (PAGES 40–41)

15 What happens to a population of a species if the total number of births and immigrants is less than the total number of deaths and emigrants?

16 Fishing removes species from the sea (above). List three factors that may cause an ecosystem's population to decline.

17 Suggest a scientific way to estimate the population of possums in your neighbourhood.

HUMAN IMPACTS ON ECOSYSTEMS (PAGES 42–43)

18 The animals in the ecosystem (opposite page) would leave if the climate became dry and the availability of food and water declined. List three other ways human activities may have a negative effect on ecosystems.

19 Explain why biodiversity can be an indicator of the health of ecosystems.

20 Name five foreign species that have been introduced to Australia in the past 200 years.

ECOSYSTEM IMPACTS OF CLIMATE CHANGE (PAGES 44–45)

21 How much has global surface temperature risen since 1880?

22 What has been the main cause of global surface temperature rise?

23 Describe three ways that climate change has had an impact on species.

SUSTAINABLE ECOSYSTEMS (PAGES 46–47)

24 List three ways that fire helps the natural landscape.

25 Describe ways that Indigenous Australians survive in harsh, dry regions of Australia.

26 What does the word 'sustainability' mean to you?

KEY IDEAS

1. An ecosystem is a collection of interacting living things whose survival depends on each other and their surrounding physical habitat.

2. Ecosystems may be terrestrial (e.g. rainforests, grasslands and deserts), freshwater (e.g. rivers and lakes) or marine (e.g. coral reefs and mangrove swamps).

3. Ecosystems are constantly changing, both naturally and due to human influences.

4. Energy enters most ecosystems from the Sun and flows through in different forms.

5. Matter, such as water, carbon dioxide and nutrients, flows around an ecosystem without being created or destroyed.

6. Human activities have added extra carbon to the air in the form of carbon dioxide, mainly from fossil fuels, which has unbalanced the carbon cycle.

7. Plants and animals exist in balance in an ecosystem due to relationships that may involve competition or cooperation.

8. The size of a population of organisms in an ecosystem depends on the balance between the total number of births and the number of individuals joining the population (immigration), and the total number of deaths and the number of individuals leaving (emigration).

9. Population declines can be caused by factors such as disease and extreme weather events.

10. The world's human population has a huge impact on ecosystems, and has caused the extinction of many species.

11. Biodiversity is the variety of species living on Earth and can be reduced by human activities such as land clearing, farming a single crop and over-fishing.

12. The climate has always changed, but climate also changes due to human activities that are increasing the concentration of carbon dioxide gas in the atmosphere. Carbon dioxide is a greenhouse gas. It traps heat.

13. Climate change and other pressures have pushed some animals and birds close to extinction, and is forcing the locations of species towards cooler regions.

14. Indigenous Australian and European settlement have both had an impact on Australian ecosystems.

15. Environmental sustainability is the balancing of how we live with the impact on ecosystems. Sustainable development is the economic and other growth in harmony with a diverse and productive environment.

16. Knowledge of Indigenous Australian land management and a scientific understanding of how to manage ecosystems are required to balance the competing demands on the Australian environment.

ATOMS 03

RADIOACTIVITY

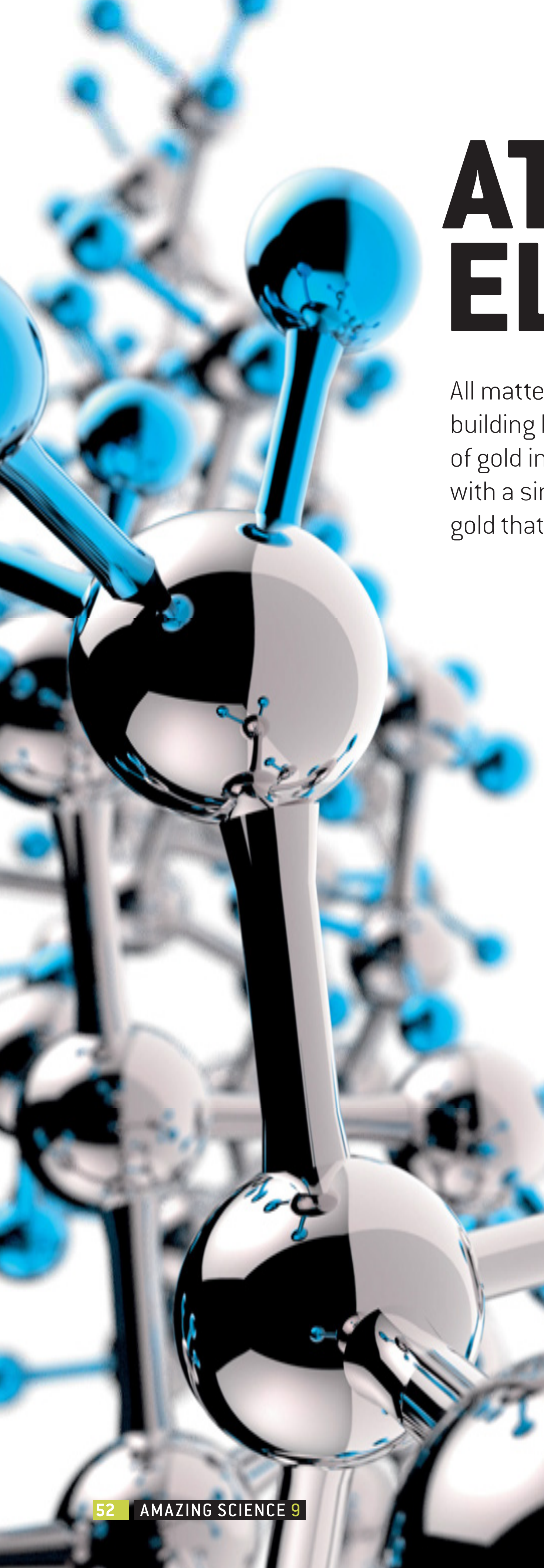
THE WORLD'S LARGEST MACHINE

AMAZING LOOK INSIDE the ATOM!

THE HEART OF AN ATOM

WHAT ARE QUARKS, MUONS AND TAUS?

X-RAYS



ATOMS AND ELEMENTS

All matter is made of tiny particles called **atoms**. Atoms are the building blocks of all materials. If you were able to divide a piece of gold into even smaller pieces, eventually you would end up with a single gold atom. That would be the smallest sample of gold that you could ever have.

What is an atom?

Atoms are the building blocks of ordinary matter. An atom is the smallest unit of a chemical **element**. An element is a pure substance made up of only one type of atom. Helium is an example of an element that exists as a gas. The gas consists of individual atoms of helium.

Your body is made up of billions and billions of atoms. The most common atoms in your body are hydrogen, oxygen and carbon.

Atoms can join together to form **molecules** (groups of two or more atoms bonded together), and molecules form most of the objects around us. A single water molecule, for example, consists of two atoms of hydrogen (which has the chemical symbol H) bound to an oxygen atom (O). Water has the formula H_2O.

A single salt crystal can contain a billion billion atoms.

A helium balloon contains billions of helium atoms. A typical party balloon holds more than 100 000 000 000 000 000 000 000 helium atoms.

The atomic theory states that atoms of an element, such as copper (top), are identical, and are different from atoms of another element, such as sodium (bottom).

The atomic theory of matter

In the 1800s, English scientist John Dalton decided that atoms were the smallest form of matter. He thought of atoms as tiny billiard balls and said that they could not be split. He developed an atomic theory that still guides science today. Important parts of the atomic theory are:

- All matter is made of atoms.
- All the atoms of a particular element are identical to each other and different from the atoms of other elements. Gold, for example, has different properties from the element hydrogen because of the differences in the atoms it contains.
- Atoms are rearranged in a chemical reaction.
- **Compounds** are formed when two or more different kinds of atoms join together.

Dalton even invented a method for measuring the masses of elements, such as hydrogen, oxygen, carbon and nitrogen. He did this based on the masses of elements that would react with each other to form compounds.

LOOK IT UP

atom the smallest particle of a substance that can exist

compound a substance made up of two or more different types of atoms bonded together, e.g. water

element a pure substance made up of only one type of atom, e.g. oxygen, carbon

molecule a group of two or more atoms bonded together, e.g. a water molecule

CHECK IT OUT

1 What is an atom?

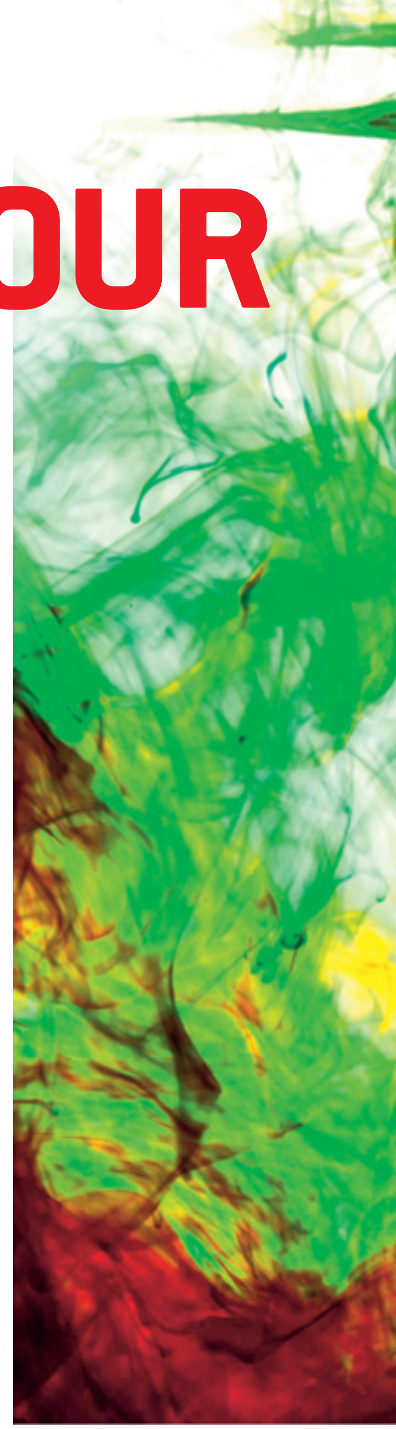
2 Which of the following are elements? Water, hydrogen, oxygen, carbon dioxide, gold, air

3 What is the difference between an atom and an element?

4 What is the difference between an element, a molecule and a compound?

5 Why do you think that John Dalton's ideas about atoms took so long to be accepted by many other scientists?

ATOMIC BEHAVIOUR



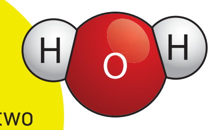
The atomic theory of matter explains the behaviour of atoms. When atoms combine to make compounds, they always do so in set numbers. For example, a water molecule always contains two hydrogen atoms bound to one oxygen atom.

Atoms and compounds

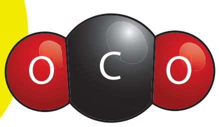
John Dalton used the word 'atom' to describe what he believed to be the smallest particle of an element. He came up with an atomic theory of matter. As well as saying that elements are made of atoms, Dalton's theory states that atoms form compounds by always reacting in set proportions. A carbon dioxide molecule, CO_2, will always contain two oxygen atoms for every carbon atom.

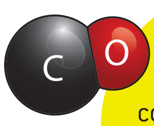
The atomic theory of matter also states that atoms can never be made or destroyed during a chemical reaction.

A water molecule is made up of one oxygen atom and two hydrogen atoms, always in the ratio 1:2.



A carbon dioxide molecule contains one carbon atom and two oxygen atoms, always in the ratio 1:2.





Carbon monoxide is a compound with one carbon atom and one oxygen atom, always in the ratio 1:1.

Scientific theory

A **scientific theory** is not a guess. Scientific theories are thoughtful explanations of some aspect of the natural world. The explanations come from careful experiments, controlled tests and observations. Scientific theories are repeatedly tested and based on the best available evidence. They are supported by observations and experiments.

Scientific theories can be updated as new and more accurate information is discovered. For example, with more research and better scientific equipment, scientists eventually realised that atoms are not the smallest possible particles. Atoms themselves are made of even smaller particles. Also, while atoms of an element are very similar, they are not always completely identical.

John Dalton's atomic theory of matter

John Dalton's atomic theory of matter has stood the test of time. Since Dalton first proposed his theory, it has been used to make accurate predictions about the behaviour of atoms, elements and compounds. Evidence that was not available in the 1800s during Dalton's time still supports the theory today.

Water molecules move constantly in a process known as Brownian motion. Brownian motion helps spread the dyes through the water.

Physicist Albert Einstein determined that small particles constantly move in water because they keep bumping into water molecules.

Particle movement

In 1827, the Scottish botanist Robert Brown was looking through a microscope at very fine pollen grains suspended in water. To his surprise, the grains seemed to be constantly moving. He repeated the experiment and checked different grains. The grains always jiggled around.

Something invisible was making the grains move. The random movement of the grains is now called **Brownian motion**.

Almost 100 years later, the famous physicist Albert Einstein suggested that Brownian motion was the result of the particles colliding with water molecules. This was more evidence for the existence of atoms.

LOOK IT UP

Brownian motion the random motion of particles suspended in a liquid or a gas

scientific theory a well-tested explanation of a scientific observation

CHECK IT OUT

1 The formula for methane is CH_4. Describe what the '4' in the formula means.

2 What is a scientific theory?

3 How does a scientific theory differ from an observation?

4 What is Brownian motion?

5 State one piece of evidence for the existence of atoms.

EXPERIMENT #5

PARTICLE MOVEMENT

These experiments examine the movement of particles in water and the spaces between molecules of water.

AIM: TO OBSERVE THE RANDOM, CONTINUOUS MOVEMENT OF PARTICLES IN WATER

MATERIALS

- Microscope (with objective of at least 20× and eyepiece 10×)
- Microscope slides and cover slips
- Full-cream milk
- Needle or fine wire
- Distilled water
- Petroleum jelly (such as Vaseline)

Milk is an emulsion of oil droplets in water.

METHOD

1. Place a small drop of distilled water in the middle of a microscope slide. (This drop must be very small so that no water escapes when the cover slip is placed on the slide.)
2. Dip the needle in the milk, and then quickly dip the tip of the needle into the drop of water.
3. Using the needle, carefully stir the milk into the water drop.
4. Using the needle again, carefully line the edges of the cover slip with petroleum jelly.
5. Gently lower the cover slip onto the drop of water with the milk.
6. Place the microscope slide under the microscope and bring it into focus. You should be able to see the tiny oil droplets in the milk.
7. Wait for the sideways movement of the oil droplets to stop and look for the 'jiggling' motion of the droplets.

RESULTS

If you observe a jiggling motion, you are seeing the direct action of water molecules on these oil droplets. The motion of the oil droplets is due to them colliding with water molecules.

DISCUSSION

1. What did you observe?
2. Suggest how this experiment could be improved.
3. What term describes the random movement of particles in water?
4. Explain why molecules of water are impossible to see, even with powerful microscopes.

EXPERIMENT #6

FILL THE GAPS

AIM: TO INVESTIGATE SPACES BETWEEN MOLECULES

MATERIALS

- Isopropyl alcohol
- Water
- Stirring rod
- Two 100 mL measuring cylinders

Isopropyl alcohol is found in many common household cleaning products and antiseptics.

METHOD

1. Measure 50 mL of water in a measuring cylinder.
2. Measure 50 mL of isopropyl alcohol in the second cylinder.
3. Add all the isopropyl alcohol to the water and gently stir.
4. Observe the total volume of the water–isopropyl alcohol mixture.

DISCUSSION

1. What is the total volume of the water–isopropyl alcohol mixture?
2. What total volume did you expect?
3. Explain what happened when the two solutions were mixed.
4. How could this experiment be improved?
5. A student says that the total volume is not 100 mL only because some of the isopropyl alcohol was left in its cylinder. Design an experiment to prevent this possibility.

There are spaces between the molecules of liquid water. The alcohol molecules fill some of the spaces between the molecules in the water. This causes the final volume of the water–alcohol solution to be less than the sum of the initial volumes.

SCIENTIFIC EQUIPMENT

- Measuring cylinder

- Stirring rod

JOURNEY TO THE CENTRE OF THE ATOM

Atoms are not the smallest particles. They contain a dense, central, positively charged **nucleus**. Tiny negatively charged particles called **electrons** surround the nucleus. The rest of the atom is empty space.

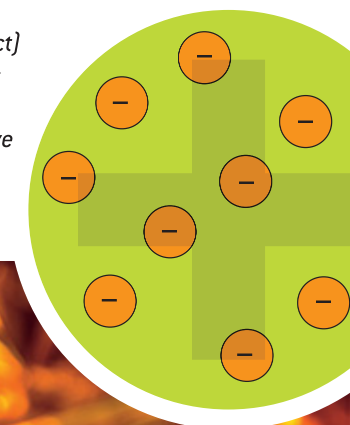
Discovery of the electron

For years after John Dalton developed an atomic theory of matter, people believed that atoms were the smallest form of matter that existed.

In 1897, English physicist Joseph John Thomson was studying charged particles in gases at low pressure. He discovered particles that weighed much less than an atom. Each of these particles was negatively charged. They were so small that approximately 1840 of them were needed to equal the mass of the smallest known atom, hydrogen. These tiny negatively charged particles are called electrons.

The (incorrect) plum pudding model

Thomson described the atom as a pudding (cake) of positive charge with negatively charged electrons scattered through it like raisins. These negative charges cancelled out the positive charge, making the overall charge of an atom zero (neutral). This 'plum pudding' model of the atom was soon shown to be wrong.



An early (but incorrect) model of the atom as positively charged material with negative charges throughout.

By firing particles at gold foil, scientists learnt about the structure of atoms.

Discovery of the atom's nucleus

In 1911, Ernest Rutherford, a former student of Thomson's, performed an experiment to test the pudding model of the atom.

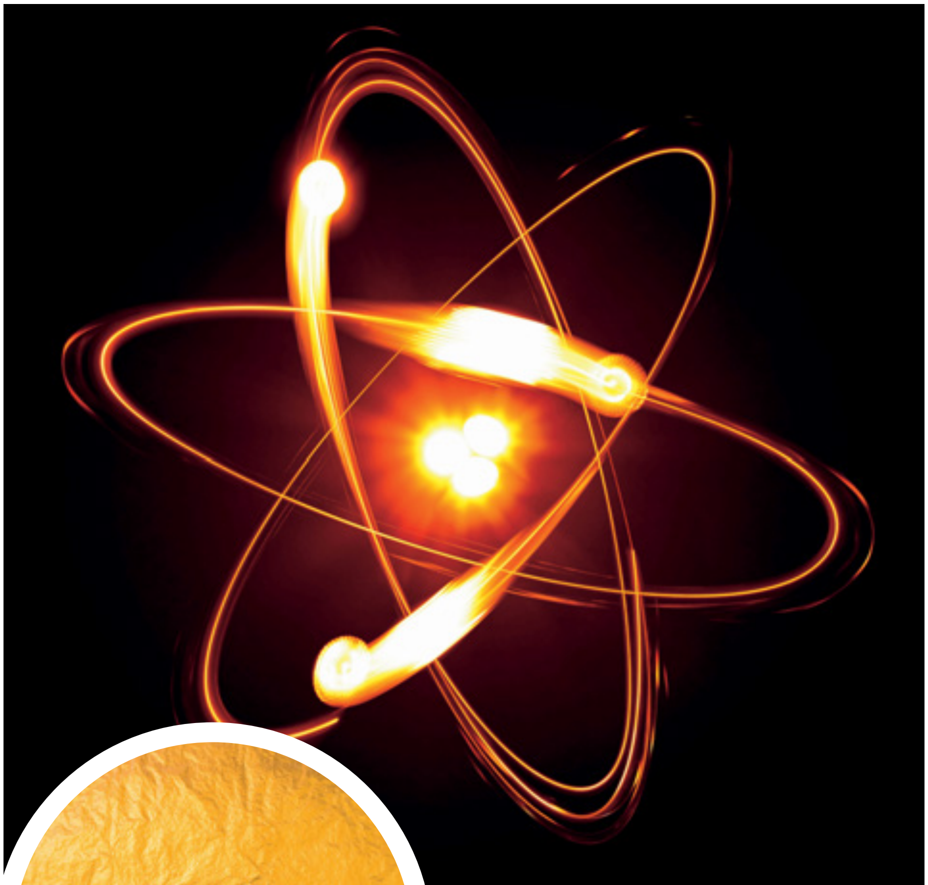
Between 1908 and 1913, Rutherford and two of his students, Hans Geiger and Ernest Marsden, performed their famous gold foil experiment. To learn more about the atom, the team tried to rip it apart.

The gold foil experiment

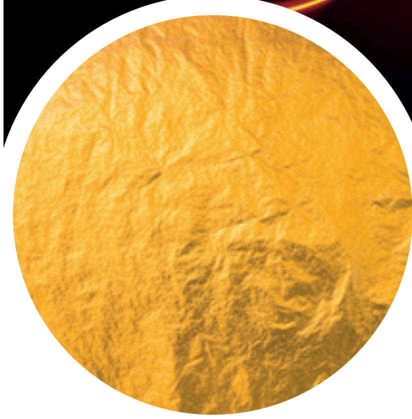
'Like' charges repel each other, as with magnets. Rutherford used this property to see how the charges in the gold atoms would affect any positive particles he fired at it. He fired positively charged particles from radioactive radium at a sheet of very thin gold foil. If Thomson's plum pudding model of an atom (a positively charged sphere) was correct, the researchers expected the positively charged particles to pass through the foil. They thought the gold atoms would push the fired particles off course a little. This is not what happened.

Most of the particles fired at the foil passed straight through with hardly any change in direction. It was as if there was nothing blocking their paths. More surprising, a very small number of particles bounced straight back. This could only happen if the particles had hit a solid mass of positive charge. Clearly, the Thomson model of spread-out positive 'cake' dotted with negative electron 'raisins' was wrong!

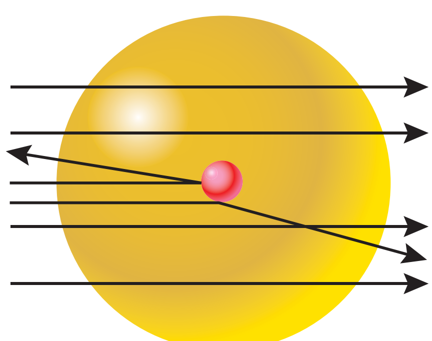
The gold foil experiment was a breakthrough in the understanding of the atom. We now know that atoms are mostly empty space with a tiny, central, positively charged nucleus surrounded by negatively charged electrons. It was the positive charge of the gold atom's tiny nucleus that had occasionally repelled the positively charged particles being fired at it.



J.J. Thomson discovered tiny negatively charged particles in atoms. These particles (electrons) showed that it was possible to split the atom into even smaller parts. Electrons orbit an atom's nucleus.



By firing positively charged particles at gold foil, Ernest Rutherford discovered that atoms have a central core or nucleus.



The gold foil experiment. Most of the positively charged particles fired at the gold foil passed straight through. However, some bounced back as they were repelled by the solid nucleus of the gold atom.

LOOK IT UP

electron a negatively charged particle found in atoms

nucleus (chemistry) the positively charged central part of an atom; contains protons and neutrons (plural: nuclei)

CHECK IT OUT

1 What was J.J. Thomson's major contribution to the understanding of the atom?
2 What was the function of the gold foil in Rutherford's experiment?
3 What were the two main findings from Rutherford's experiment?
4 What is the charge on an atom's nucleus?
5 What is the charge on an electron?

INSIDE THE ATOM

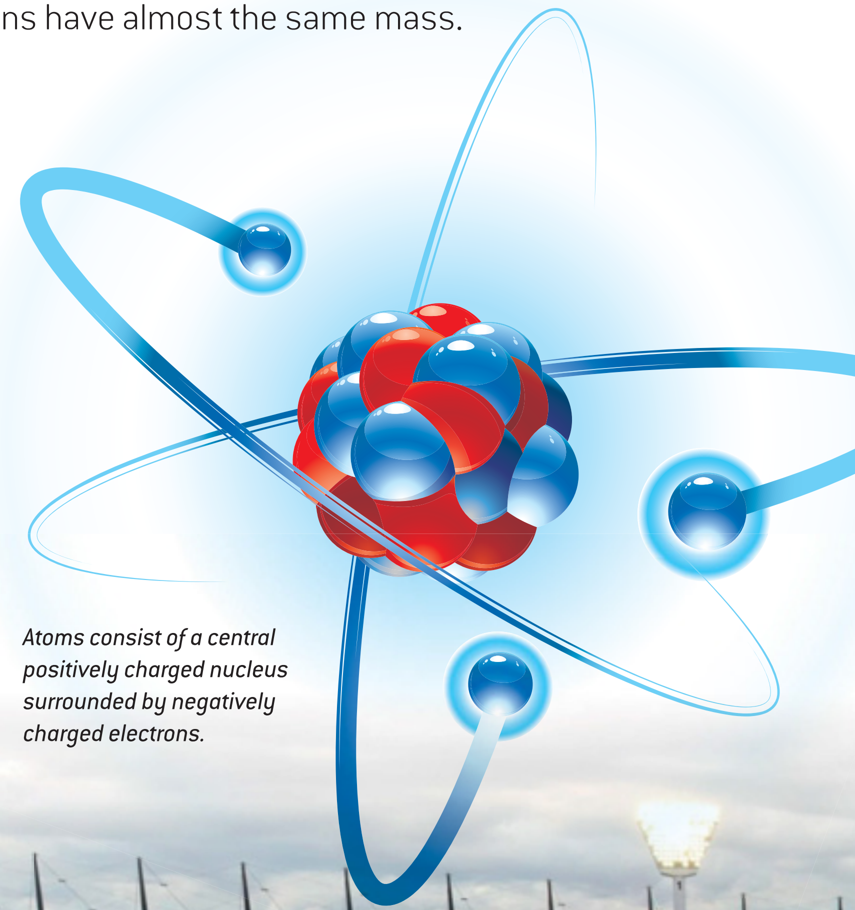
The nucleus of an atom holds its **protons** and **neutrons**. Protons have a positive charge, neutrons have no charge. Protons and neutrons have almost the same mass.

Protons and electrons

Ernest Rutherford was the first to realise that atoms have a central positively charged nucleus and lots of empty space. Electrons surround the nucleus.

The nucleus holds most of the mass of an atom. It contains particles called protons, which have a positive electric charge. Electrons have a negative electric charge, but very little mass.

Because atoms contain both positively charged particles (protons) and negatively charged particles (electrons), the charges cancel each other. Atoms are neutral, as they have no overall electrical charge. In an atom, the number of positive protons equals the number of negative electrons.



Atoms consist of a central positively charged nucleus surrounded by negatively charged electrons.

Atoms are mostly empty space. If an atom were expanded to the size of the Melbourne Cricket Ground, the nucleus would be about the size of a garden pea.

Neutrons

James Chadwick showed that uncharged particles (neutrons) form part of an atom's nucleus. He did this by firing nuclei at beryllium, an element present in emerald gemstones.

Rutherford discovered the protons within the atom's nucleus. However, further experiments showed that the nucleus contained more than just protons. The nucleus had a greater mass than the mass of its protons.

For example, helium atoms each contain 2 protons, but measurements show that helium atoms have a mass of 4 units. Electrons have almost no mass, so some other particles must have been adding the extra mass.

Rutherford suggested that there could be a particle with mass but no charge. He called it a neutron, but scientists still needed evidence that neutrons really existed.

In 1932, English physicist James Chadwick fired atomic nuclei at atoms of the element beryllium. The experiment proved that neutrons exist. Neutrons have no charge and a mass almost the same as that of protons.

Protons, neutrons and electrons are the three main sub-atomic particles.

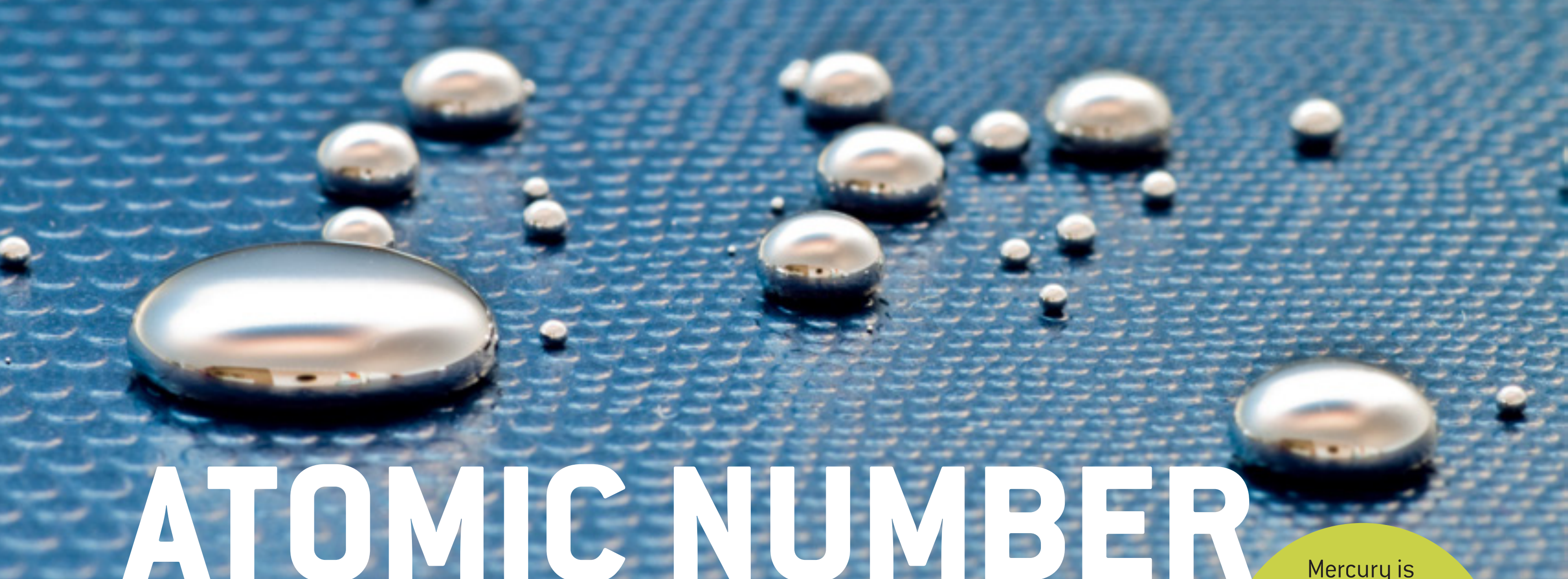
LOOK IT UP

neutron a neutral particle found in the nucleus of atoms

proton a positively charged particle found in the nucleus of atoms

CHECK IT OUT

1. Helium atoms have a mass of 4 units. The 2 protons in the nucleus have a mass of 1 unit each. Where do the other 2 units of mass come from?
2. Name the three sub-atomic particles, state their charges and describe where in the atom they are located.
3. Compare the masses of the three sub-atomic particles.
4. What was the contribution of James Chadwick to the understanding of the atom?



ATOMIC NUMBER

Mercury is an element with an atomic number of 80. This means that all mercury atoms contain 80 protons.

The number of protons in an atom is called the **atomic number**. All atoms of an element have the same atomic number. As atoms are neutral, the number of electrons equals the atomic number. An atom's **mass number** is the number of protons *and* neutrons.

Inside the nucleus

The mass of an atom is made up mainly of the protons and neutrons in the nucleus of the atom. Electrons have very little mass — it takes almost 2000 electrons to equal the mass of one proton.

Relative mass and charge of sub-atomic particles

PARTICLE	RELATIVE MASS	RELATIVE CHARGE
Proton	1	+1
Neutron	1	0
Electron	0.005	−1

Elements have a specific number of protons in their nuclei. Hydrogen is the element with the smallest atoms. Every hydrogen atom contains just one proton in its nucleus.

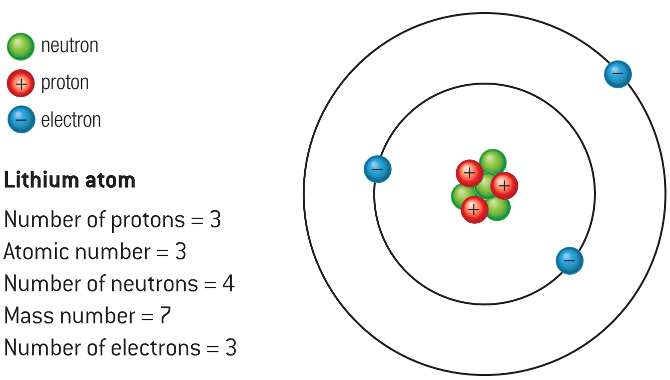
The number of protons in an atom is called the atomic number. Atoms of the same element have the same atomic number. The periodic table lists elements in order of their atomic numbers. Hydrogen appears first as it has an atomic number of 1. Atoms are always neutral – they have no charge. Hydrogen atoms have 1 electron to balance the charge of the 1 proton.

Helium is an element with 2 protons. Hence, helium atoms have 2 electrons. Most helium atoms also have 2 neutrons in their nucleus. The relative mass of this atom with 2 protons and 2 neutrons is 4.

The total number of protons and neutrons in an atom is called the mass number. The mass number of an atom with 2 protons and 2 neutrons is 4.

Lithium has an atomic number of 3. Its nuclei always hold 3 protons. Most lithium atoms have 4 neutrons. These atoms have a mass number of 7.

LITHIUM ATOM

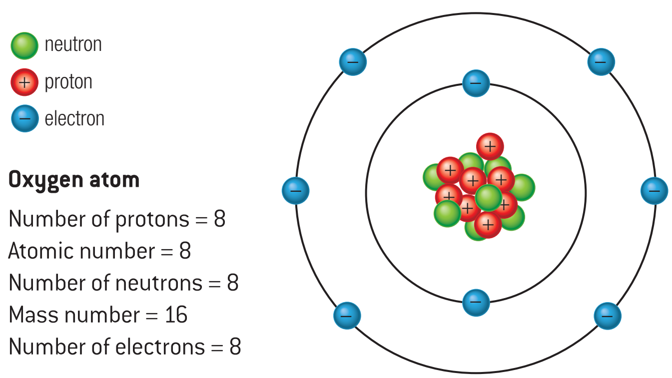


Lithium atom

Number of protons = 3
Atomic number = 3
Number of neutrons = 4
Mass number = 7
Number of electrons = 3

A lithium atom with mass number 7 and atomic number 3.

OXYGEN ATOM



Oxygen atom

Number of protons = 8
Atomic number = 8
Number of neutrons = 8
Mass number = 16
Number of electrons = 8

An oxygen atom with mass number 16 and atomic number 8.

The number of neutrons in an atom can be calculated by subtracting the atomic number from the mass number:

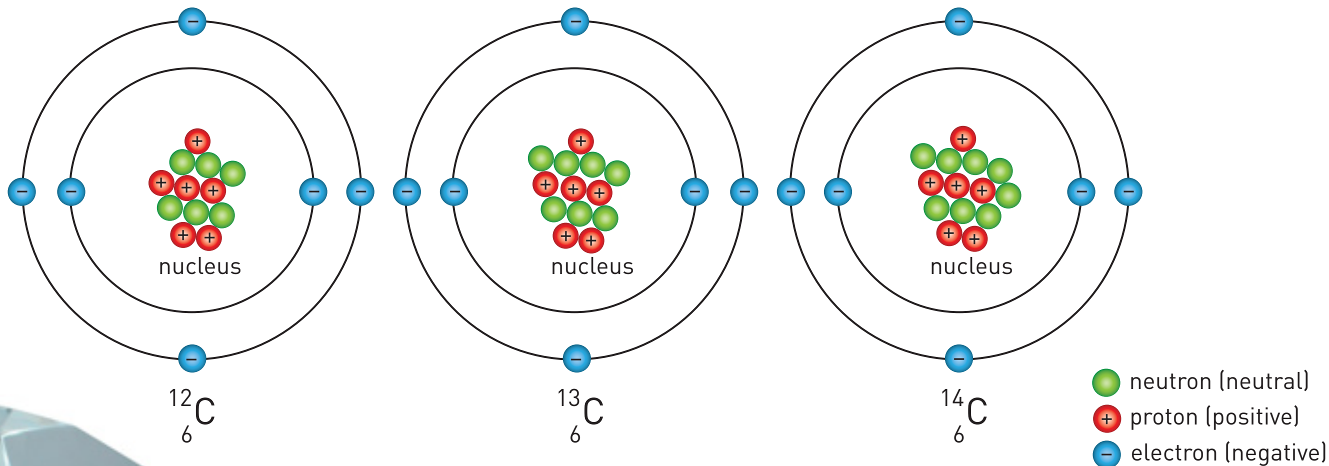
Number of neutrons = mass number – atomic number

Isotopes

Carbon atoms always contain 6 protons. A carbon atom with 6 neutrons has a mass number of 12. Some carbon atoms have 7 neutrons. These atoms have a mass number of 13. They are heavier than carbon atoms with a mass number of 12. These two different atoms of carbon are known as **isotopes**. Isotopes have the same number of protons (that is, the same atomic number) and the same number of electrons, but different numbers of neutrons.

Scientists represent isotopes with a dash (-) after the element name or with the mass number as a superscript before the element's symbol. For example, the two carbon isotopes referred to above are carbon-12 (^{12}C) and carbon-13 (^{13}C).

ISOTOPES OF CARBON



Three naturally occurring isotopes of carbon: carbon-12, carbon-13 and carbon-14. They differ only in their number of neutrons.

Diamond is a pure form of carbon. Most of the carbon atoms are carbon-12, containing 6 protons and 6 neutrons.

LOOK IT UP

atomic number the number of protons in an atom

isotopes atoms of an element with different numbers of neutrons

mass number the total number of protons and neutrons in an atom

CHECK IT OUT

1 The following table shows the numbers of sub-atomic particles in various atoms. Copy and complete all cells in the table.

ATOM NAME AND SYMBOL	ATOMIC NUMBER	MASS NUMBER	NUMBER OF PROTONS	NUMBER OF NEUTRONS	NUMBER OF ELECTRONS
Hydrogen (H)	1	1			
Carbon (C)	6	13	6	7	6
Fluorine (F)	9	19	9		
Neon (Ne)	10			11	
Chlorine (Cl)	17			18	
Chlorine (Cl)				20	17
Potassium (K)			19	20	
Calcium (Ca)		40	20		

2 Which sub-atomic particles are found in the nucleus?

3 Which sub-atomic particles are not found in the nucleus?

4 What term describes the two different atomic forms of chlorine described in the table?

5 'An element's mass number will always be bigger than its atomic number.' True or false? Explain your answer.

AMAZING LOOK INSIDE THE ATOM

Protons, neutrons and electrons are not the only sub-atomic particles in nature. Research using high-energy particle accelerators has revealed hundreds of even smaller sub-atomic particles. They have names such as neutrinos, leptons, quarks, mesons, hadrons, bosons and antiprotons.

Quarks

Quarks are the building blocks of protons and neutrons. They are extremely small particles that contribute to the strong forces that hold together an atom's nucleus. Quarks combine with each other so quickly that one has never been found on its own.

Quarks are so fundamental (elementary) that no one has discovered anything smaller. Scientists believe that quarks cannot be broken apart into smaller particles.

There are various types of quarks. They have curious names such as 'up', 'down', 'charm', 'strange', 'top' and 'bottom'. Each carries either a positive or negative charge less than that of the electron or proton.

The particle detector of the Large Hadron Collider in Europe.

Leptons

Like quarks, **leptons** are fundamental sub-atomic particles. They do not appear to be made up of smaller units. Leptons can either carry a charge (+1 or –1), or be neutral. Electrons are the lightest leptons. There are also heavier leptons called muons and taus.

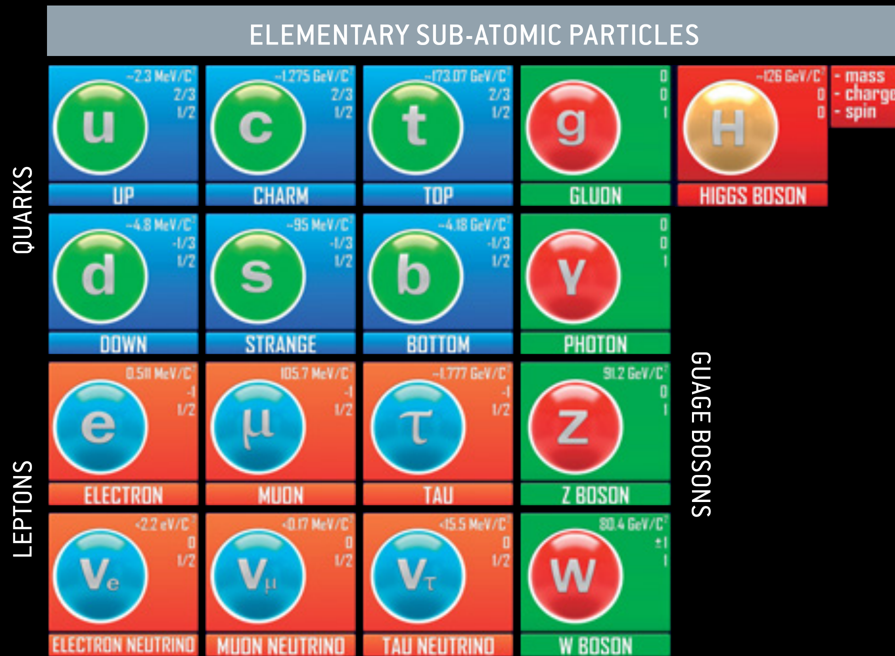
Large Hadron Collider

More than 100 metres underground, beneath the border between France and Switzerland, is a 27-kilometre-long circular tunnel. This is part of the Large Hadron Collider, the world's largest and most powerful particle accelerator. The Large Hadron Collider is designed to increase our knowledge about the universe.

Hadrons are particles made up of quarks, such as protons and neutrons. The objective is to smash these particles into each other and study the results. Superconducting magnets steer particles accelerated to almost the speed of light. One beam of particles travels in the tunnel in one direction; the other beam travels the other way.

The magnets must steer the tiny particles with amazing precision. Making them collide is like firing two needles 10 kilometres apart with such precision that they meet halfway.

In 2012, researchers observed for the first time a particle known as the Higgs boson. Scientists needed to prove the existence of the Higgs boson to explain some unusual properties of some elementary particles.



The vacuum tube inside the Large Hadron Collider. Particles travel inside the tube at almost the speed of light before colliding with particles travelling in the opposite direction.

Scientists study the results of high-speed collisions between particles in the Large Hadron Collider.

LOOK IT UP

hadrons sub-atomic particles made up of quarks, such as protons and neutrons

leptons a class of sub-atomic particles including electrons

quarks sub-atomic particles with a fractional electric charge; a component of protons and neutrons

CHECK IT OUT

1 What are quarks?
2 What are leptons?
3 Why do scientists refer to quarks and leptons as fundamental sub-atomic particles?
4 How does the Large Hadron Collider get its name?
5 Construction of the Large Hadron Collider cost approximately $7 billion. In your opinion, is this investment justified?

RADIOACTIVITY

A nuclear power station in Belgium. The electricity comes from the heat released during nuclear fission reactions, in which uranium decays and releases radiation.

A sample of mineral containing uranium.

Radioactivity involves the decay (breakdown) of the nuclei of unstable atoms to form different, more stable atoms. As unstable atoms decay, they release energy and particles. This is called **radiation**. Not all atoms are radioactive. Alpha, beta and gamma are different forms of radiation.

Uranium – a radioactive element

Uranium (U) is a metallic, silver-grey, heavy element. Australia is one of the world's largest producers of uranium, with mines in the Northern Territory and South Australia. The world's largest uranium deposit is at Olympic Dam in South Australia.

Uranium is **radioactive**. Its atoms are unstable and decay. The atomic number of uranium is 92. All uranium atoms contain 92 protons. The most common atom is uranium-238 (^{238}U), which contains 146 neutrons (238 – 92 = 146). More than 99 per cent of the world's natural uranium exists as this isotope. The rest is mostly uranium-235 (^{235}U).

Forming new elements

As uranium-238 decays, it forms a new element: thorium-234. Thorium has an atomic number of 90. Thorium has 2 fewer protons in its nucleus than uranium. To form a thorium atom, uranium releases an **alpha particle**. An alpha particle is the equivalent of the nucleus of a helium atom. It contains 2 protons and 2 neutrons bound together. Alpha particles have a charge of +2.

As well as producing thorium-234 and an alpha particle, the decay of uranium-238 produces energy. This happens because the combined mass of the alpha particle and thorium nucleus is slightly less than that of the original uranium nucleus. The mass turns into energy.

The equation for the decay of uranium-238 is:

$^{238}U \rightarrow {}^{234}Th + {}^{4}He$

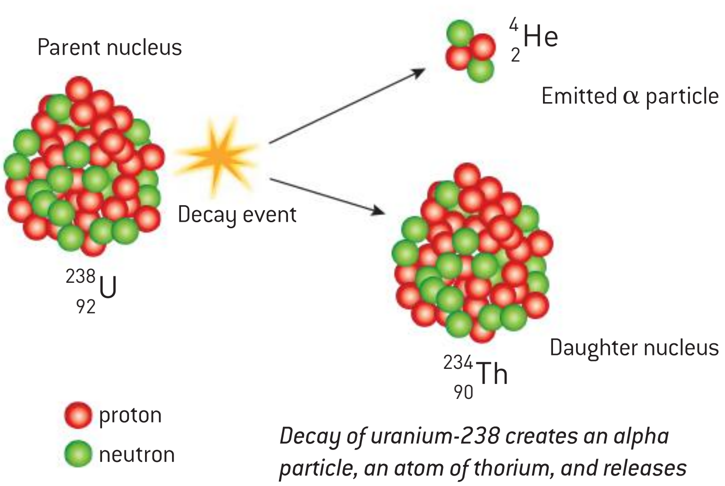
The thorium produced by decay of uranium is also radioactive. When it decays, it releases radiation. Through a series of steps, the final product of this decay chain is a stable isotope of lead.

Half-life

The time that it takes for half of a radioactive material to decay to another substance is called its **half-life**. It would take almost 4.5 billion years for 1 kilogram of uranium-238 to decay to half a kilogram of uranium, so uranium-238's half-life is 4.5 billion years.

The Ranger open-cut uranium mine in the Northern Territory.

DECAY OF URANIUM-238 NUCLEUS



Decay of uranium-238 creates an alpha particle, an atom of thorium, and releases energy. The number at the lower left of the element symbol is the atomic number, or number of protons.

Uranium usage

Uranium is the main fuel used in nuclear power stations, where uranium atoms are split into two smaller atoms with the release of a lot of energy. This process is called **nuclear fission**. Uranium is also used in radioisotopes for medical use and in nuclear science research.

LOOK IT UP

alpha particle a sub-atomic fragment consisting of 2 protons and 2 neutrons; a form of radiation

half-life the time taken for a substance's radioactivity to fall to half its original value

nuclear fission a nuclear reaction in which a heavy nucleus splits, releasing energy

radiation the emission or transmission of energy in the form of waves through space or through a material

radioactive emitting radiation

CHECK IT OUT

1 What is radioactivity?
2 Uranium-238 and uranium-235 are different isotopes of uranium. What are isotopes?
3 Define the term 'half life'.
4 The half-life of carbon-14 is 5730 years. What mass of 1 kilogram of carbon-14 will remain after
   a 5730 years?
   b 11 460 years?
5 What is an alpha particle and how is it produced from uranium?
6 State one advantage and one disadvantage of generating electricity from nuclear fission.

NUCLEAR RADIATION

There are three forms of nuclear radiation. From weakest to strongest they are alpha radiation, beta radiation and gamma radiation. X-rays are similar to gamma rays and are commonly used to take images of people's bodies.

Alpha, beta and gamma

Radioactive substances, such as uranium, release radiation all of the time. There are three forms of nuclear radiation, which are named after the first three letters of the Greek alphabet: alpha (α), beta (β) and gamma (γ).

An alpha particle has the same make-up as the nucleus of a helium atom. It contains 2 protons and 2 neutrons. The 2 protons give it a +2 charge. Alpha particles have a low penetrating power – a sheet of paper will stop them.

Beta particles are fast-moving electrons. Beta particles are produced when a neutron decays into a proton. They have a lot of energy and a charge of –1. Beta particles can penetrate paper – a thin sheet of aluminium will stop them.

Radioactive strontium-90 emits beta particles. The particles are used to destroy the cancerous cells of tumours in bones and to treat eye disease.

X-rays mostly pass through skin and body tissue, but they do not easily pass through bone.

Radioactive americium-241 in smoke detectors constantly emits alpha particles. If smoke affects the flow of the particles between two electrodes, the alarm sounds. It takes 1 gram of americium-241 to make 5000 smoke detectors.

Gamma radiation is the most penetrating form of radiation. It has no charge and extremely high energy – it takes thick lead or metres of concrete to stop it. **Gamma rays** and **X-rays** are similar forms of radiation. Gamma rays occur naturally from decay of radioactive substances. X-rays are artificially produced.

Gamma radiation is used to sterilise surgical instruments, to kill harmful bacteria in food and to kill cancer cells.

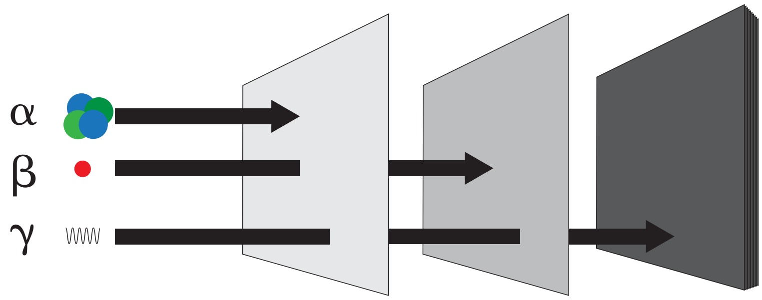
X-rays

In 1895, physicist Wilhelm Röntgen was working one evening in his laboratory at the University of Würzburg in Germany. He was passing an electric current through a glass tube containing gas at low pressure.

Röntgen had sealed the tube inside thick black cardboard to keep out light. In the dark laboratory, he noticed that a fluorescent screen faintly glowed whenever the electron beam was turned on. The screen was in line with the tube. Röntgen discovered that radiation was passing from inside the tube through the glass, air and cardboard to the screen, making it glow.

As Röntgen didn't know what the radiation was, he named them X-rays. The 'X' means something unknown. He asked his wife to hold her hand between the glass tube and a light-sensitive photographic plate. The plate was the first ever 'X-ray'. It showed a picture of the bones in Anna Bertha Ludwig's hand.

RADIOACTIVITY PENETRATION RANGE



There are three forms of nuclear radiation: alpha, beta and gamma. Alpha radiation is the least penetrating form; gamma the most.

The world's first X-ray image, produced in 1895. You can see the bones in Anna Bertha Ludwig's fingers, and her wedding ring.

A radiologist preparing to X-ray a patient. The X-ray machine works by passing electrons through a glass vacuum tube. When a speeding electron collides with the target electrode, it releases energy as X-rays.

LOOK IT UP

beta particles fast-moving electrons; the source of beta radiation

gamma rays high-energy radiation formed from the decay of radioactive substances

X-rays a form of radiation emitted by electrons

CHECK IT OUT

1. Name the three forms of nuclear radiation. Which is the strongest?
2. Name a practical application of each of these three forms of radiation.
3. A radiation meter detects a signal from a radioactive substance. Wrapping the substance in paper has little impact on the reading. Wrapping it in aluminium foil reduces the reading to almost zero. Wrapping it in lead reduces it to zero. What type of radiation is the substance emitting?
4. What does the 'X' in X-ray mean?

REVIEW

ATOMS

Air: is it an element?

ATOMS AND ELEMENTS (PAGES 52–53)

1 What contribution did John Dalton make to our understanding of atoms?

2 Giving two examples of each, explain the difference between elements, molecules and compounds.

3 Which of the following substances are elements?

a oxygen
b hydrogen
c carbon
d water
e gold
f air
g sodium chloride

ATOMIC BEHAVIOUR (PAGES 54–55)

4 What information is given by the formula for ammonia, NH_3?

5 Write the formula for a compound made of molecules containing two atoms of hydrogen bound to one atom of sulfur.

6 What is the difference between a scientific theory and a guess?

7 Describe Brownian motion and explain how it was first seen.

JOURNEY TO THE CENTRE OF THE ATOM (PAGES 58–59)

8 What is the charge of the nucleus?

9 How did Ernest Rutherford learn about the structure of the atom?

10 What were Rutherford's two main discoveries about the structure of the atom?

INSIDE THE ATOM (PAGES 60–61)

11 Match the following terms with the correct statements.

Nucleus	Negatively charged sub-atomic particle
Proton	Sub-atomic particle with no charge
Neutron	Atom's central core
Electron	Positively charged sub-atomic particle

ATOMIC NUMBER (PAGES 62–63)

12 A boron atom (top right) contains 5 protons and 6 neutrons. What is this atom's atomic number? What is this atom's mass number?

13 What is an isotope?

14 How does boron-10 differ from boron-11?

15 How many electrons do boron atoms contain?

AMAZING LOOK INSIDE THE ATOM (PAGES 64–65)

16 What are sub-atomic particles?

17 Name five sub-atomic particles.

18 How does the Large Hadron Collider (bottom right) make particles collide?

RADIOACTIVITY (PAGES 66–67)

19 How does radioactivity result in the formation of new elements?

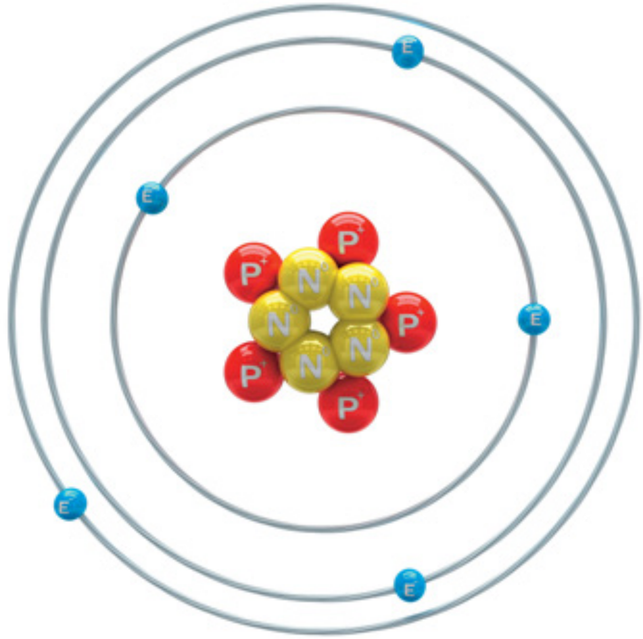
20 The half-life of technetium-99 is 6 hours. Calculate what fraction of technetium-99 will be left after 18 hours.

21 List some uses of uranium.

NUCLEAR RADIATION (PAGES 68–69)

22 Name the three forms of nuclear radiation. Which form is the most penetrating?

23 What was Wilhelm Röntgen's main contribution to science?



Mining for borax, a naturally occurring mineral containing boron.

KEY IDEAS

1 An atom is the smallest complete unit of a chemical element.

2 Elements combine in set ratios to form compounds. For example, a water molecule always contains two hydrogen atoms bound to one oxygen atom.

3 The dense, central core of an atom is called the nucleus. The nucleus holds sub-atomic particles called protons and neutrons.

4 Protons have a positive charge and neutrons have no charge. They have almost the same mass as each other.

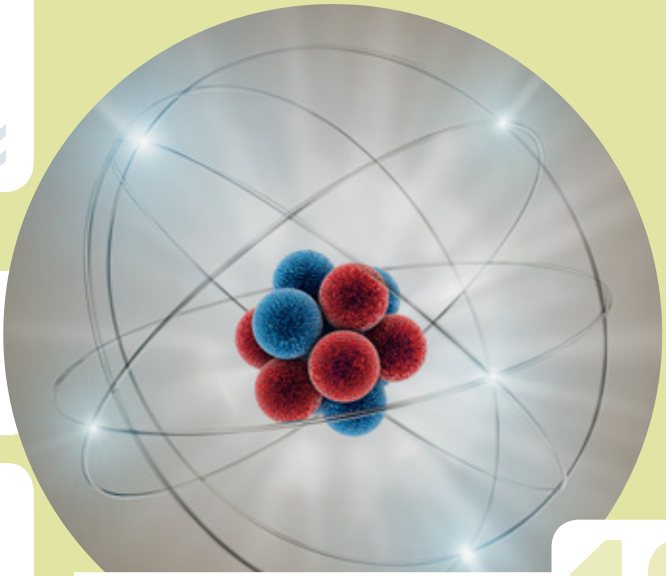
5 Negatively charged electrons surround the nucleus. Electrons have a much lower mass than protons and neutrons.

6 Protons, neutrons and electrons are the three main sub-atomic particles.

7 An atom's atomic number is equal to its number of protons.

8 An atom's mass number is equal to its combined number of protons and neutrons.

9 Protons, neutrons and electrons are not the only particles that exist. There are many other sub-atomic particles, including quarks and neutrinos.



10 Some atoms are unstable and decay to form more stable atoms. As they decay, they release energy and particles. This release is called radiation.

11 There are three forms of nuclear radiation: alpha, beta and gamma radiation.

12 Alpha particles contain 2 protons and 2 neutrons. Beta particles are fast-moving electrons.

13 Gamma rays are high-energy radiation formed from the decay of radioactive substances. X-rays are similar to gamma rays and are commonly used to take images of people's bodies.

CHEMICAL REACTIONS

04

3 AMAZING REACTIONS involving acids

Why is our **CLIMATE CHANGING?**

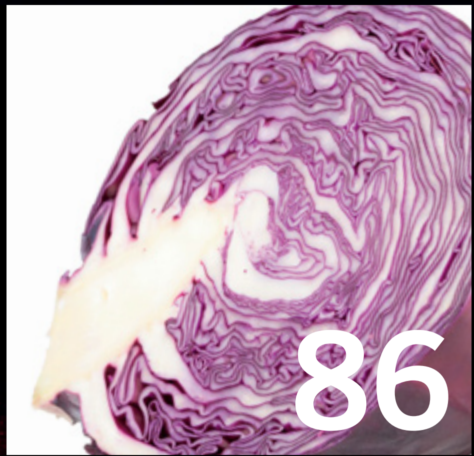
THE IMPORTANCE OF OXYGEN

74

WHAT HAPPENS WHEN ATOMS COMBINE?

78

CHEMICAL REACTIONS THAT CREATE HEAT



86

UNUSUAL USE FOR RED CABBAGE

MAKING NEW SUBSTANCES

During chemical reactions, substances react to form new materials. The starting chemicals are called **reactants**. The new materials are called **products**. Matter is never created or destroyed during a chemical reaction.

Chemical reactions involving metallic compounds produce the bright colours of burning sparklers.

Writing equations

There are more than 100 chemical elements. Elements can combine to form compounds. For example, the elements carbon and oxygen react to form carbon dioxide gas. This is an example of a chemical reaction, which involves rearrangements of atoms to form new substances.

In this example, carbon and oxygen are the reactants. They react to form a new substance, carbon dioxide, which is the product of this chemical reaction.

Chemical equations show what happens during a reaction. The reactants are on the left of the equation. The products are on the right. The chemical change is shown by an arrow.

The reaction between carbon and oxygen can be written like this:

carbon + oxygen → carbon dioxide

The element carbon occurs naturally in a pure form, for example, in graphite. Carbon also occurs naturally in hundreds of compounds. Examples include methane, octane, sugar and testosterone. The element oxygen occurs in nature as **molecules**, each containing two oxygen atoms joined together. The chemical formula is O_2. Molecules consist of two or more atoms held together by chemical bonds.

Chemical reactions can also be written using the formulae or symbols of the reactants and products. Symbol equations give more information about what is happening in the reaction. The symbol equation for producing carbon dioxide is:

$C + O_2 \rightarrow CO_2$

Keeping track of atoms

Atoms don't appear or disappear during chemical reactions. All the atoms that you start with are still there at the end of the reaction, but might be arranged differently or combined with other atoms. Scientists call this the Law of Conservation of Mass. In other words, matter is never created or destroyed during a chemical reaction.

When you count up the numbers of atoms of each element on the left side of a chemical equation, it must equal the number of atoms on the right side.

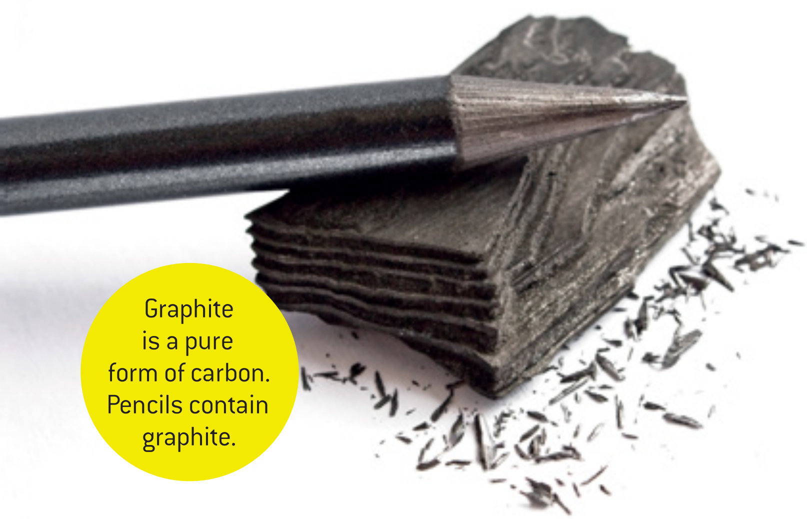
During the reaction between carbon and oxygen to form carbon dioxide, there is one atom of carbon at the start. You can see it written on the left side of the equation. That one atom combines with two atoms of oxygen in the oxygen molecule (O_2) to form one molecule of carbon dioxide (CO_2). The carbon dioxide molecule has that one atom of carbon chemically bound to two oxygen atoms. There are three atoms at the start of the reaction. There are still three at the end.

	C	+	O_2	→	CO_2
	one atom of carbon	*combines with*	two atoms of oxygen in the oxygen molecule	*to form*	a molecule of carbon dioxide, containing one atom of carbon and two atoms of oxygen
Atom count:	1	+	2		
		= 3 atoms			3 atoms

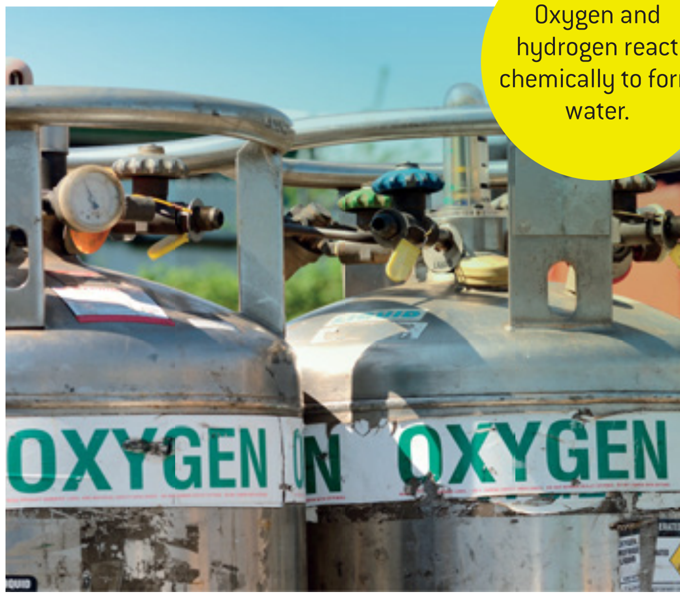
Another example is the reaction between hydrogen and oxygen to form water. Hydrogen gas contains molecules each with two hydrogen atoms bound together. The formula is H_2. Water molecules have two atoms of hydrogen and one of oxygen. The formula is H_2O.

hydrogen + oxygen → water

$2H_2 + O_2 \rightarrow 2H_2O$



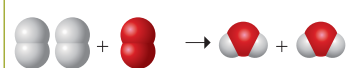
Graphite is a pure form of carbon. Pencils contain graphite.



Oxygen and hydrogen react chemically to form water.

Since we know that the number of atoms stays the same during a chemical reaction, we have to use numbers to balance the sides of the equation. That's why we need two molecules of hydrogen on the left and two molecules of water on the right of the equation. Otherwise, the equation won't 'balance'.

The table shows the number of atoms taking part in this reaction.

	$2H_2 + O_2$	$\rightarrow 2H_2O$
		
NUMBER OF HYDROGEN ATOMS	2 × 2 = 4	2 × 2 = 4
NUMBER OF OXYGEN ATOMS	2	2 × 1 = 2
TOTAL NUMBER OF ATOMS	**6**	**6**

LOOK IT UP

molecule a group of two or more atoms bonded together, e.g. a water molecule

product a substance formed at the end of a chemical reaction; written on the right side of a chemical equation

reactant a substance used at the beginning of a chemical reaction; written on the left side of a chemical equation

CHECK IT OUT

1 What happens during a chemical reaction?
2 Name the reactants and products when carbon combines chemically with oxygen.
3 What is a molecule? Give four examples.
4 What do scientists mean by 'conservation of mass'?
5 Identify the error in the following equation:
$Na + 2H_2O \rightarrow 2NaOH + H_2$

EXPERIMENT #7

MEASURING MASS

BEFORE AND AFTER A REACTION

During this experiment you will track how the total mass of reactants at the start of the reaction compares with the total mass of products at the end.

AIM: TO INVESTIGATE WHAT HAPPENS TO MASS DURING A CHEMICAL REACTION

MATERIALS

- Balance
- Measuring cylinder
- Watch glass
- Spatula
- Balloon
- 2 conical flasks
- Sodium bicarbonate
- Dilute hydrochloric acid (1 M)

PART A

METHOD

1 Copy the results table for part A to record your results.

2 Weigh 2 g of sodium bicarbonate onto the watch glass.

3 Measure 20 mL of hydrochloric acid into a conical flask.

4 Ensure the balance is reading zero. Weigh the flask containing the hydrochloric acid. Record this mass as the initial mass (M_1).

5 Predict whether the mass of the flask after the reaction of hydrochloric acid with sodium bicarbonate will be more, the same or less than the initial mass.

6 Add 2 g of sodium bicarbonate (M_2) to the flask containing the hydrochloric acid and swirl until the bubbling stops.

7 Weigh the flask after the reaction has stopped. Record the final mass (M_3).

RESULTS

MASS OF FLASK AND HYDROCHLORIC ACID (M_1)	MASS OF SODIUM BICARBONATE (M_2)	TOTAL MASS BEFORE REACTION ($M_1 + M_2$)	MASS AFTER REACTION (M_3)

PART B

METHOD

1 Copy the results table for part B to record your results.
2 Weigh 2 g of sodium bicarbonate onto the watch glass.
3 Add 20 mL of hydrochloric acid to a conical flask.
4 Ensure the balance is reading zero. Weigh the flask containing the hydrochloric acid, plus a balloon. Record this mass as the initial mass (M_1).
5 Predict whether the mass of the flask (including the balloon) after the reaction of hydrochloric acid with sodium bicarbonate will be more, the same or less than the initial mass.
6 Add 2 g of sodium bicarbonate (M_2) to the flask and quickly stretch the opening of the balloon over the neck of the flask to collect gas.
7 Weigh the flask, with the balloon still attached, after the reaction has stopped. Record the final mass (M_3).

RESULTS

MASS OF FLASK, HYDROCHLORIC ACID AND BALLOON (M_1)	MASS OF SODIUM BICARBONATE (M_2)	TOTAL MASS BEFORE REACTION ($M_1 + M_2$)	MASS AFTER REACTION (M_3)

DISCUSSION

1 Compare the initial and final masses for each part of the experiment.
2 Is this what you expected? Explain why or why not.
3 What is the evidence that a gas was produced?
4 What was the purpose of the balloon?
5 How could the design of this experiment be improved?

CONCLUSION

Do you think that any matter was created or destroyed during this chemical reaction?

State symbols

It is often helpful to know whether the reactants and products in a chemical reaction are solids, gases, liquids or dissolved in water. The state symbols in an equation show this.

SYMBOL	MEANING
(s)	solid
(l)	liquid
(g)	gas
(aq)	aqueous (dissolved in water)

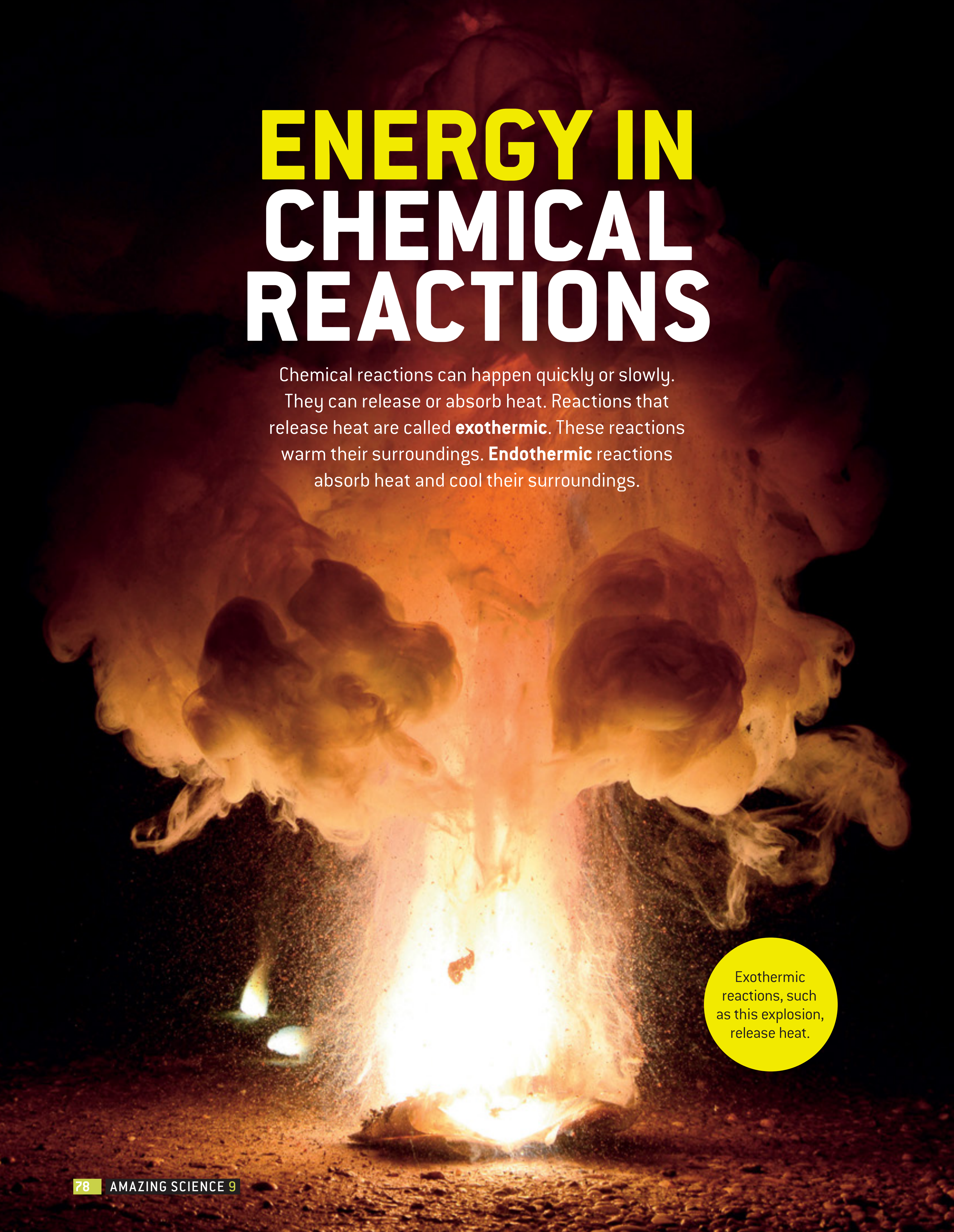
In this experiment, solid sodium bicarbonate ($NaHCO_3$) reacts with a solution of hydrochloric acid (HCl) to form a solution of sodium chloride (NaCl), carbon dioxide gas (CO_2) and liquid water (H_2O).

Here is the symbol equation with the states added:

$$NaHCO_3(s) + HCl(aq) \rightarrow NaCl(aq) + CO_2(g) + H_2O(l)$$

ENERGY IN CHEMICAL REACTIONS

Chemical reactions can happen quickly or slowly. They can release or absorb heat. Reactions that release heat are called **exothermic**. These reactions warm their surroundings. **Endothermic** reactions absorb heat and cool their surroundings.



Exothermic reactions, such as this explosion, release heat.

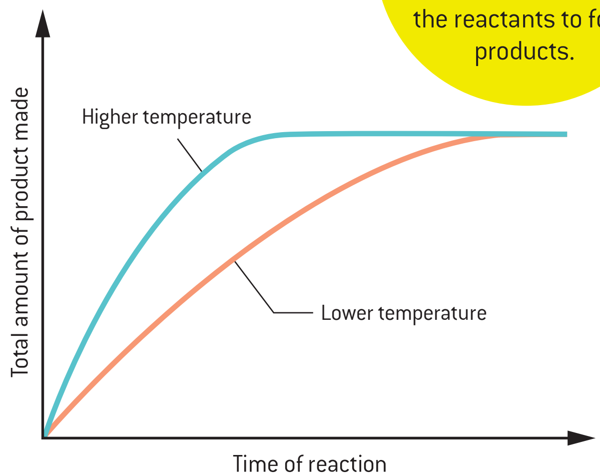
Fast and slow reactions

Chemical compounds contain atoms held together by chemical bonds. Chemical reactions involve breaking and making chemical bonds.

Chemical reactions can happen at different rates. An explosion is a reaction that happens very quickly. It may take just a fraction of a second. Rusting is a reaction that happens slowly. It can take decades for iron to turn into hydrated iron oxide – the chemical name for rust.

Many chemical reactions happen more quickly at high temperatures as the particles have more energy. The particles move more rapidly and collide more often and with greater force.

Many reactions happen more quickly at high temperatures. It takes less time for the reactants to form products.



Methane gas burning and releasing heat is an example of an exothermic reaction.

Hot and cold reactions

When natural gas burns, it releases heat. This is an example of a combustion reaction. Methane is the main component of natural gas. It reacts with oxygen gas when it burns.

All chemicals contain stored energy. Reactions that release energy are called exothermic reactions (*exo* means 'to give out'; *thermic* means 'heat'). Burning methane is an exothermic reaction that releases heat.

An exothermic reaction can be as fast as a match burning or as slow as the rusting of iron. In an exothermic reaction, the products have less stored energy than the reactants at the start of the reaction. This energy is released from the chemicals and goes into the surroundings, making the temperature rise.

When salt dissolves in water, the temperature of the salt solution falls. If this is done in a beaker or glass, you may see water condensing on the outside of the glass. Reactions that absorb energy like this are called endothermic reactions.

Some types of cold packs used to treat injuries work due to an endothermic reaction. They usually contain a salt called ammonium nitrate. When you break the inner bag, the ammonium nitrate dissolves in the water, absorbing heat as it does so. This makes the bag feel cold.

Endothermic reactions take energy from their surroundings. The products have more energy than the reactants. As a result, the chemicals will get colder.

This cold pack works because of an endothermic reaction that absorbs heat.

LOOK IT UP

endothermic a reaction that absorbs heat

exothermic a reaction that releases heat

CHECK IT OUT

1 What happens to the bonds between chemicals during reactions?

2 Explain why many chemical reactions happen more quickly at high temperatures.

3 What is the main compound in natural gas?

4 What is the name for reactions that:

a release heat to their surroundings?

b absorb heat?

5 Give an example of a reaction in which products have more energy than the reactants.

EXPERIMENT #8

GLOW STICK CHEMISTRY

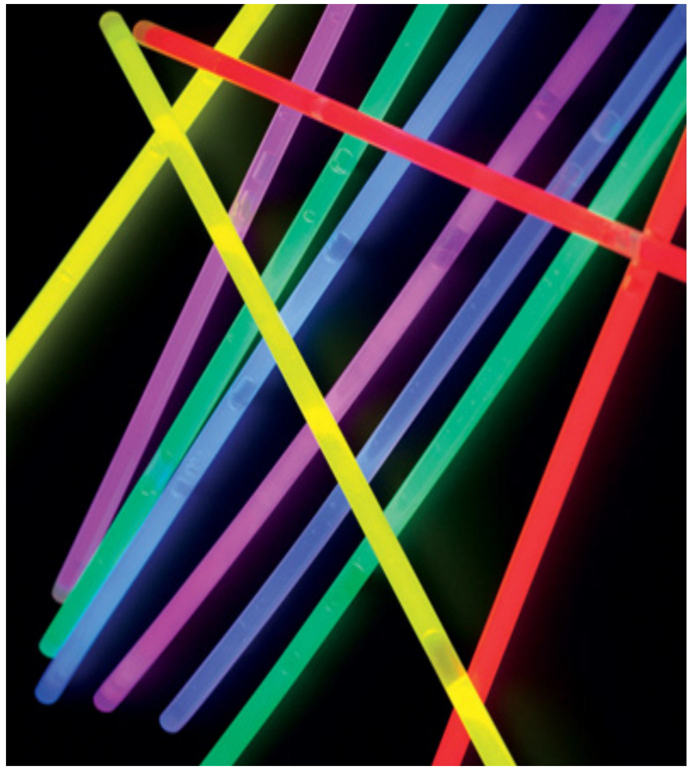
AIM: TO INVESTIGATE HOW WARMING AND COOLING AFFECT THE REACTION IN A GLOW STICK

MATERIALS

- Hot water in an insulated container
- Ice water in an insulated container
- 2 glow sticks

METHOD

1. Place one un-activated glow stick in hot water for 5 minutes, and a similar un-activated glow stick in ice water for 5 minutes.
2. Remove the two sticks at the same time and bend them to start them glowing.
3. Observe any differences between the two sticks.



Glow sticks shine when the dye mixture inside them reacts with another chemical, hydrogen peroxide, in the tube.

DISCUSSION

To make a glow stick work, you bend it. This breaks a small container filled with a chemical inside the stick. The break allows the chemical in the container to mix with another chemical in the stick, which sets off the chemical reaction that releases light.

1. How can you tell whether the chemical reaction is happening faster or slower in each glow stick?
2. How could you make the glow stick last for the longest possible time?

RESULTS

Describe what you observed during the experiment.

EVALUATION

Explain, using the movement of particles, why warming reactants can change the rate of a chemical reaction.

EXPERIMENT #9

ENERGY CHANGES

AIM: TO INVESTIGATE AN EXOTHERMIC AND AN ENDOTHERMIC REACTION

MATERIALS

- Measuring cylinder
- Stirring rod
- 2 polystyrene cups
- 2 spatulas
- Thermometer or temperature sensor
- Stopwatch
- Wash bottle
- Residue bottle
- Sealed bottle containing potassium nitrate (KNO_3)
- Sealed bottle containing calcium chloride ($CaCl_2$)
- Water

SAFETY

- Check the safety data sheets, available on your obook / assess, to see how to safely handle the chemicals in this experiment.
- Wear your lab coat, safety goggles and plastic gloves.

METHOD

1. Copy the table from the Results section to record the times and temperatures.
2. Measure 50 mL of water into a polystyrene cup.
3. Measure the temperature of the water and record it.
4. Place three heaped spatulas of calcium chloride into the water and immediately begin gentle stirring and timing.
5. Record the temperature every 15 seconds for 3 minutes.
6. After the final measurement, dispose of the solution into the residue bottle. Carefully rinse the thermometer with the wash bottle, ensuring the rinse water is also added to the residue bottle. Dispose of the cup as directed by your teacher.
7. Repeat steps 2–6 using potassium nitrate.

RESULTS

TIME (MIN:SEC)	CALCIUM CHLORIDE	POTASSIUM NITRATE
0:00		
0:15		
0:30		
0:45		
1:00		
1:15		
1:30		
1:45		
2:00		
2:15		
2:30		
2:45		
3:00		

Draw a graph of temperature (vertical axis) against time (horizontal axis) and plot your results from the two chemicals on the same graph. Make sure you label both axes and use the correct units.

DISCUSSION

1. Which reaction was endothermic and which was exothermic?
2. In which reaction did the products have less energy than the reactants?
3. In which reaction did the products have more energy than the reactants?
4. Use the graphs to describe how quickly the temperature rose or fell.
5. Did the temperature reach a steady value after some time? Discuss why you think this is.
6. What happened to the heat released from the exothermic reaction?
7. Where did the endothermic reaction draw its heat from?
8. Describe how you would make a hot pack from one of the chemicals in this experiment.

EVALUATION

Suggest how the method used in this experiment could be changed to improve the accuracy of the results.

SCIENTIFIC EQUIPMENT

This experiment may be carried out using a temperature probe and data-logging equipment instead of a thermometer.

ACIDS AND BASES

Acids and **bases** play an important role in many chemical reactions. Acids are common substances. They contain hydrogen. Some bases can dissolve in water to form solutions called alkalis. An indicator, such as litmus or universal indicator, shows whether a solution is acidic, neutral or alkaline.

Oranges, lemons, grapes and apples contain weak acids.

Introducing acids and bases

You have probably heard about lots of different acids. You have acid in your stomach, called hydrochloric acid, which helps digest food. Car batteries contain sulfuric acid. The acid found in vinegar is acetic acid. Fizzy drinks contain carbonic acid.

Unripe fruits taste sour because they contain acid. Weak acids in fruit include citric acid in oranges and lemons, tartaric acid in tea and grapes, malic acid in green apples and oxalic acid in rhubarb. Vitamin C is ascorbic acid. Sour milk and yoghurt contain lactic acid.

Acids are a group of chemical compounds, all with similar properties. All acids contain at least one hydrogen atom. For example, the formula of hydrochloric acid is HCl and the formula of sulfuric acid is H_2SO_4.

The opposite of an acid in chemistry is a base. Sodium hydroxide, magnesium hydroxide and ammonia are examples of bases. When bases like these dissolve in water, they form **alkalis** and the solutions are said to be alkaline. Alkalis taste bitter and feel slippery or soapy (but you should never touch or taste laboratory chemicals).

Sulfuric acid is an example of a strong acid.

Many cleaning products are alkaline solutions – bases dissolved in water.

	RED LITMUS PAPER	BLUE LITMUS PAPER
ACIDIC SOLUTION	Stays red	Turns red
NEUTRAL SOLUTION	Stays red	Stays blue
ALKALINE SOLUTION	Turns blue	Stays blue

There is red litmus paper and blue litmus paper. The name refers to the colour of the paper before it is used to test a solution. The table shows the colour changes it can make.

Testing acids and bases

It is easy to test whether a liquid is an acid or an alkali. In the 1600s, Irish-born chemist Robert Boyle discovered that juice from various plants changed colour when acid was added to them. He soaked small strips of paper in juice from lichens, combined fungi and algae. The strips turned red in acids and blue in alkalis. Today, we call these strips **litmus paper**.

An **indicator** is a substance, such as litmus, that changes colour in an acid or a base. The coloured chemicals in many flowers, fruits and vegetables can be extracted with hot water and then used as indicators for acids and bases.

Red cabbage contains a pigment called flavin, which also occurs in plums, poppies, grapes and apple skin. Very acidic solutions turn flavin red; neutral solutions turn it purple; and alkaline solutions turn it greenish-yellow.

Universal indicator is a mixture of different indicators. It is useful because it uses different colours to show the strength of the acidic or the alkaline solution that it is testing.

LOOK IT UP

acid a chemical compound containing hydrogen; turns litmus red

alkali a base dissolved in water; turns litmus blue

base a substance that reacts with and neutralises acids

indicator a substance that shows whether a substance is acidic or alkaline by changing colour

litmus paper an acid–base indicator that turns red in presence of acids and blue with alkalis

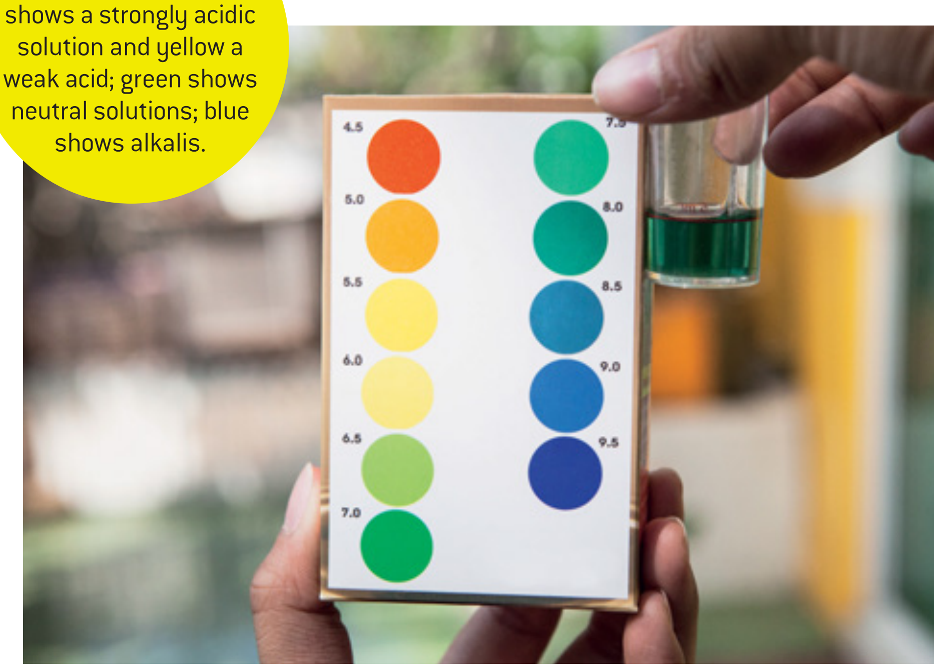
CHECK IT OUT

1 List three examples of acids and three examples of bases.

2 What is the difference between a base and an alkali?

3 What is an indicator and how is it used?

4 What advantage does universal indicator have over litmus?



Universal indicator – red shows a strongly acidic solution and yellow a weak acid; green shows neutral solutions; blue shows alkalis.

3 REACTIONS INVOLVING ACIDS

There are reactions that all acids have in common. Acids react with bases in neutralisation reactions, forming a salt (a compound made from charged atoms called ions) and water. Acids react with carbonates, forming a salt and carbon dioxide gas. Acids react with some metals to form a salt and hydrogen gas. Acids have pH values of less than 7. Neutral solutions, such as pure water, have a pH of 7. Alkalis have a pH greater than 7.

Bee stings are acidic, whereas wasp stings are alkaline.

1 Acids and bases (neutralisation)

acid + base → a salt + water

When acids and bases react, they **neutralise** each other. A strong acid, such as hydrochloric acid, and a strong alkali, such as sodium hydroxide, will react with each other. If the quantities of acid and alkali match, amazingly, the products are water and common salt (sodium chloride).

Here are the word and symbol equations for the reaction between hydrochloric acid and sodium hydroxide:

hydrochloric acid	+	sodium hydroxide	→	sodium chloride	+	water
HCl	+	$NaOH$	→	$NaCl$	+	H_2O

The type of salt produced depends on which acid and base are used. For example, sulfuric acid will produce salts called sulfates. Nitric acid produces salts called nitrates.

Farmers use 'lime' (a powder containing bases such as calcium carbonate) to neutralise acid soils. Your stomach contains hydrochloric acid – heartburn can occur if this acid rises from the stomach up into the oesophagus.

Antacid tablets contain bases such as magnesium hydroxide and magnesium carbonate – the bases neutralise some of the acid, so that if it rises from the stomach it won't burn the oesophagus and cause pain.

2 Acids and carbonates

acid + metal carbonate → salt + carbon dioxide + water

Another type of base are metal **carbonates**. These compounds also react with acid to form a salt and water, plus an additional product – carbon dioxide. Carbonates contain carbon bound to oxygen, which turns into bubbles of carbon dioxide gas.

The equations for the reaction between sulfuric acid and calcium carbonate are:

sulfuric acid	+	calcium carbonate	→	calcium sulfate	+	carbon dioxide	+	water
H_2SO_4	+	$CaCO_3$	→	$CaSO_4$	+	CO_2	+	H_2O

This equation describes how limestone buildings and statues can be corroded by acid rain. Limestone is made of calcium carbonate. Acid rain may contain sulfuric acid from air pollution. The acid dissolves the calcium carbonate and can damage the buildings and statues.

Acid rain reacts with limestone, causing damage to statues and buildings.

3 Acids and metals

metal + acid → salt + hydrogen

All acids contain hydrogen. Metals such as magnesium can free the hydrogen from acids, releasing it as hydrogen gas.

Here are the equations for the reaction between magnesium and hydrochloric acid:

magnesium + hydrochloric acid → magnesium chloride + hydrogen

$$Mg + 2HCl \rightarrow MgCl_2 + H_2$$

The metals aluminium, zinc, iron and tin will also react with acids.

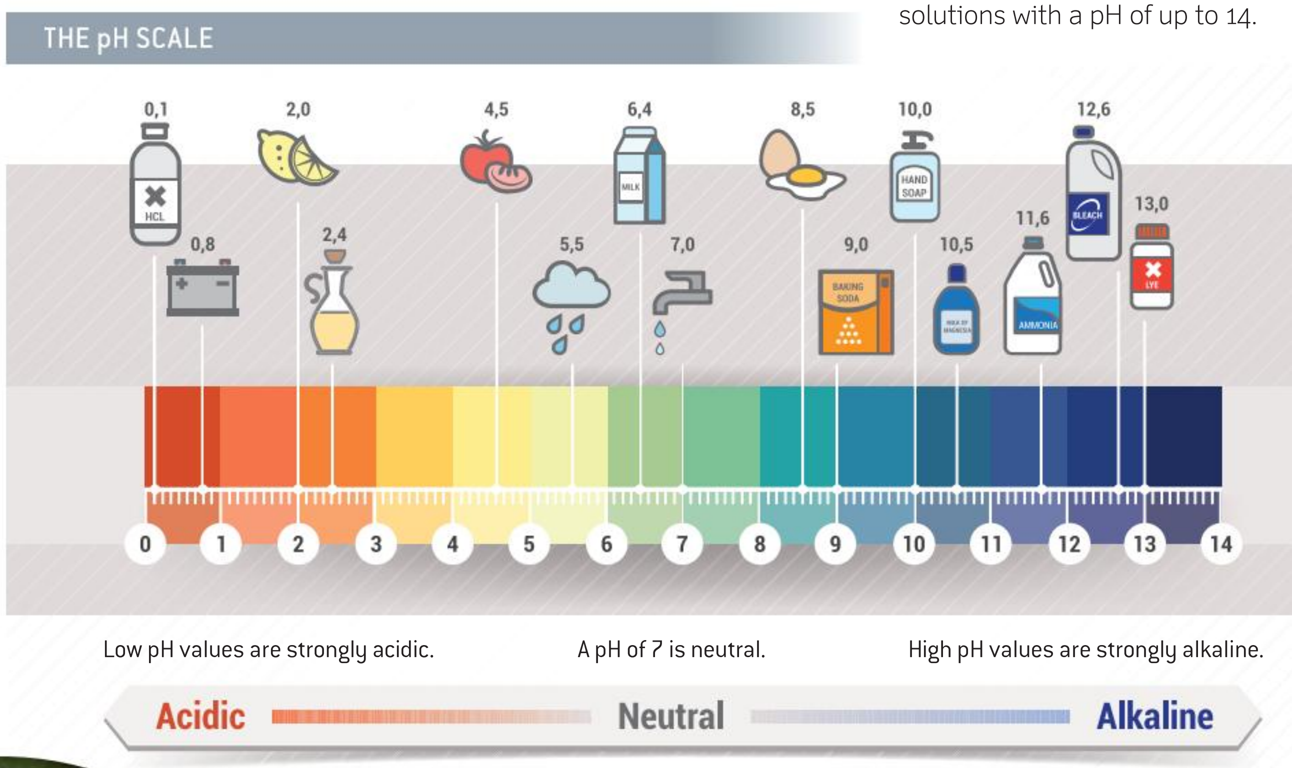
The pH scale

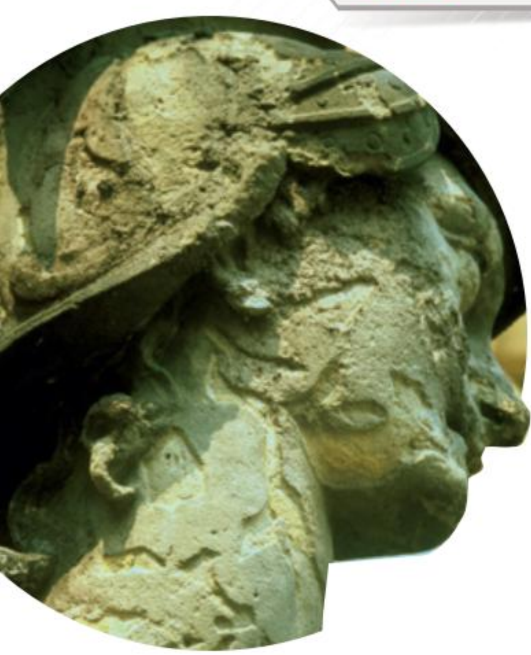
Scientists use the **pH scale** to measure the acidity and alkalinity of a solution.

» Acidic solutions have pH values of less than 7. Low pH values show higher acidity. A pH of 1 or less indicates a very acidic solution.

» Neutral solutions (neither an acid nor a base) have a pH of 7. Pure (distilled) water has a pH of 7.

» Alkalis have pH values greater than 7. Strong bases, such as caustic soda (sodium hydroxide), can form solutions with a pH of up to 14.





LOOK IT UP

carbonate a salt containing a carbonate (CO_3) group

neutralise the reaction in which an acid and a base combine to form water

pH scale the measure of how acidic or alkaline a substance is

CHECK IT OUT

1. Name the reactants and products in a neutralisation reaction.
2. What is a practical example of a neutralisation reaction?
3. What occurs when you add acid to a metal carbonate?
4. Name the gas produced when a metal such as magnesium is dropped into acid.
5. Which of the following is most acidic: oven cleaner with a pH of 13, pure water, orange juice with a pH of 4 or stomach acid with a pH of 2.5?

EXPERIMENT #10

MAKE YOUR OWN INDICATOR

AIM: TO MAKE AN INDICATOR FROM RED CABBAGE AND SHOW HOW IT CAN BE USED TO IDENTIFY ACIDS AND BASES

MATERIALS

- 250 mL beaker
- Stirring rod
- Strainer
- Hotplate or Bunsen burner, tripod and gauze mat
- Test tubes and test tube rack
- 2 leaves from a fresh red cabbage (shredded)
- Distilled water
- 0.1 M hydrochloric acid solution
- 0.1 M sodium hydroxide solution
- Other products for testing, such as shampoo, vinegar, baking soda and tap water

SAFETY

This experiment involves using a Bunsen burner:

- Be careful of naked flames.
- Ensure that long hair is tied back and loose clothing such as a tie is tucked away.
- Do not leave flames unattended.
- Handle hot sample with tongs.
- Ensure you follow laboratory safety procedures and wear safety glasses and a lab coat.
- The apparatus will be very hot at the end of this experiment. Leave it to cool before packing it away.

METHOD

PART A: MAKE THE INDICATOR

1 Place the shredded red cabbage leaves into the beaker.

2 Cover the cabbage leaves with water and boil the mixture until the water is purple.

3 Cool the liquid and then strain it, discarding the cabbage leaves.

The coloured liquid formed from boiling red cabbage makes an acid–base indicator.

PART B: TEST THE INDICATOR

1 Add a small amount of hydrochloric acid to a test tube and add a few drops of red cabbage indicator. Record any colour change in a table.

2 Add a small volume of water (neutral solution) to a test tube and add a few drops of red cabbage indicator. Record any colour change in your table.

3 Add a small volume of sodium hydroxide (alkali) to a test tube and add a few drops of red cabbage indicator. Record any colour change in your table.

4 Test a variety of products by adding a few drops of red cabbage indicator solution to them. Record the colour changes and determine which products are acids and which are bases.

RESULTS

Construct and complete a table of observations.

DISCUSSION

1 What colour is the extract from red cabbage?

2 What colour does the extract become in:

a an acid?

b a base?

c distilled water?

CONCLUSION

How well does the red cabbage solution work as an acid–base indicator?

EXTENSION

Plan an investigation to discover what other plants, flowers, vegetables or fruits could be used to create an acid–base indicator.

EXPERIMENT #11

TESTING WITH pH PAPER

AIM: TO IDENTIFY COMMON PRODUCTS AS ACIDS OR BASES USING pH PAPER

MATERIALS

- pH paper and colour chart
- White tile
- Variety of laboratory acids and bases
- Variety of common acids and bases, such as vinegar, milk, toothpaste and lemon juice

METHOD

1 Tear off about 1 cm of pH paper and place it on a white tile.

2 Place a drop of acid on the paper.

3 Compare the colour of the wet spot on the pH paper with the pH colour chart.

4 Repeat using a drop of base and the other substances.

5 For each substance, record the pH colour and number. Note whether the substance is an acid, a base or neutral.

6 Dilute some of the substances in water and measure the pH of the diluted solutions with more indicator paper.

RESULTS

Construct and complete a table of observations.

DISCUSSION

1 Which was the most acidic solution that you tested (lowest pH)?

2 Which was the most alkaline solution that you tested (highest pH)?

3 What happens to the pH of an acid when the acid is diluted in water? Is it more or less acidic?

4 Using your answer to the previous question, suggest a way of treating a burn caused by acid.

EXPERIMENT #12

NEUTRALISATION

AIM: TO INVESTIGATE A NEUTRALISATION REACTION

MATERIALS

- Test tubes and test tube rack
- Dropping pipettes
- 10 mL measuring cylinder
- Universal indicator solution
- 100 mL beaker
- Evaporating dish
- Magnifying glass
- 1 M hydrochloric acid solution
- 1 M sodium hydroxide solution

SAFETY

Wear safety goggles during this experiment and avoid skin contact with the chemicals.

METHOD

1. Using the measuring cylinder, pour 5.0 mL of hydrochloric acid solution into the beaker and then rinse out the measuring cylinder with water.
2. Add 2 drops of universal indicator solution to the acid in the beaker.
3. Pour 10 mL of sodium hydroxide solution into the measuring cylinder.
4. Using the dropping pipette, add the sodium hydroxide from the measuring cylinder to the acid in the beaker one drop at a time.
5. Stop adding the sodium hydroxide when the acid has been neutralised (the indicator will turn green at this point).
6. Record how much sodium hydroxide you added.
7. Carefully empty and rinse out your glassware and repeat the whole experiment. This time do not add any universal indicator but use the same amount of sodium hydroxide as you did before.
8. Pour the solution into the evaporating dish and leave open in a safe place in the laboratory for a few hours. As the solution evaporates, record your observations.

RESULTS

Record all your observations.

DISCUSSION

1. Why was it important to rinse the measuring cylinder with water after it was used?
2. Why was the experiment repeated without the indicator?
3. How could you produce the solid salt more quickly in the last step of the method?
4. Describe the appearance of the salt remaining in the evaporating dish after the liquid had evaporated.
5. Suggest names for the two products from this neutralisation reaction.
6. Write a word equation for the neutralisation reaction between hydrochloric acid and sodium hydroxide.

CONCLUSION

What have you observed about neutralisation reactions?

EXPERIMENT #13

ACID REACTIONS WITH METALS

Magnesium ribbon

AIM: TO INVESTIGATE THE REACTIONS BETWEEN ACIDS AND METALS

MATERIALS

- Test tubes and test tube rack
- 1 M hydrochloric acid solution
- Small samples of metals such as magnesium, zinc, aluminium, copper, iron and tin

SAFETY

Wear safety goggles during this experiment and avoid skin contact with the chemicals.

Dispose of all chemicals as instructed by your teacher.

METHOD

1 Add a small piece of one metal to a test tube and pour in enough hydrochloric acid to cover it.

2 Observe what happens (e.g. bubbling, metal dissolving, colour change, test tube warming) and record your observations.

3 Repeat steps 1 and 2 for each metal, using a clean test tube.

RESULTS

Record all your observations.

DISCUSSION

1 Which metal was the most reactive with the hydrochloric acid?

2 Which metal was the least reactive with the hydrochloric acid?

CONCLUSION

Summarise what you observe when acid is added to reactive metals.

TESTING FOR GASES

Hydrogen gas

When acid is added to reactive metals, hydrogen gas is produced. Hydrogen is a colourless, odourless gas with a lower density than air. A test tube containing hydrogen gas ignites with a distinctive 'pop' if a flame is brought near it.

A 'pop' can be heard if hydrogen gas is present.

Carbon dioxide

Metal carbonates react with acid to produce carbon dioxide. Carbon dioxide is colourless and odourless and has a higher density than air. When carbon dioxide gas is bubbled into limewater (calcium hydroxide), the solution turns a cloudy milky white colour. Another test for carbon dioxide gas is that it will extinguish a flame.

Carbon dioxide gas turns limewater milky.

REACTIONS INVOLVING OXYGEN

Oxygen is very reactive. It reacts with elements and compounds in **combustion** and **oxidation** reactions. The reactions can happen quickly, such as natural gas burning. They can happen slowly, such as iron rusting. Metals and non-metals react with oxygen to form **oxides**.

Rusting is an oxidation reaction in which iron slowly reacts with oxygen.

Oxygen

Air is 21 per cent oxygen gas.

Oxygen is the most common chemical element by mass found on Earth. About half of the mass of the Earth's crust is oxygen. Almost 90 per cent of the mass of the oceans is due to oxygen. Oxygen makes up about two-thirds of the mass of your body. In all of these examples, the oxygen atoms are combined with other elements. In the case of the oceans, the oxygen is present as water, H_2O.

Oxygen gas (O_2) makes up about one-fifth of the air. It is a colourless, odourless, reactive gas that readily forms compounds.

Carl Scheele, a German–Swedish chemist, discovered oxygen in 1773. Substances burnt so well in pure oxygen that Scheele named the gas 'fire air'.

Oxygen reacts with materials at different rates. A fire is an example of a combustion reaction. This reaction happens quickly. Methane in natural gas burns in air rapidly to supply heat for cooking. Petrol burns readily in a car engine.

Oxygen can also react with substances slowly. Rusting of iron, for example, involves a slow chemical reaction between oxygen and the metal. There are no flames, just gradual corrosion of the metal. So rusting is not called a combustion reaction – it is an oxidation reaction.

Reactions with metals

Many metals and non-metals react and combine with oxygen in the air to produce compounds called oxides. These are called oxidation reactions. Heating the metal will often increase the speed of the reaction.

Metals can react with oxygen, to form a metal oxide:

metal + oxygen → metal oxide

Magnesium is a reactive metal that will react rapidly with oxygen if heated or lit. The magnesium will burn with a brilliant white flame forming magnesium oxide, a white solid. This is an exothermic reaction, producing lots of heat. The flame is so bright that you should never look at it directly as it can damage your eyes.

The equations for this reaction are:

magnesium + oxygen → magnesium oxide

$$2Mg + O_2 \rightarrow 2MgO$$

For moderately reactive metals such as iron, the oxidation reaction still produces heat, but it is slow.

Magnesium metal reacts rapidly with oxygen in air to form magnesium oxide.

Gold and silver are very unreactive metals. They will not react with oxygen even if heated.

Reactions with non-metals

Most (about 80 per cent) of the elements are metals, which conduct heat and electricity. Non-metals are poor conductors of heat and electricity. They can be solids under normal conditions, such as carbon, sulfur and phosphorus. Lots of non-metals are gases. These include hydrogen, helium, nitrogen, chlorine and argon.

Non-metals, like metals, can react with oxygen in the air to produce oxides.

Carbon burns in air to form carbon dioxide:

carbon + oxygen → carbon dioxide

$C + O_2 \rightarrow CO_2$

Sulfur burns in air to form sulfur dioxide:

sulfur + oxygen → sulfur dioxide

$S + O_2 \rightarrow SO_2$

These are all exothermic reactions, releasing heat.

LOOK IT UP

combustion the process of burning something

oxidation the formation of an oxide

oxide a compound containing oxygen and one other element

CHECK IT OUT

1. List five properties of oxygen.
2. What is the approximate mass of oxygen in a person weighing 60 kg?
3. What is a combustion reaction? Give an example.
4. Name an example of a fast and slow reaction involving oxygen.
5. What are oxides and how do they form?

WHAT HAPPENS WHEN FUELS BURN?

Combustion involves a substance burning. It is an example of a rapid chemical reaction involving a **fuel** and oxygen. **Hydrocarbons** (compounds containing hydrogen and carbon) burn and form carbon dioxide and water.

Combustion reactions

A bushfire, a candle, a gas burner flame and petrol burning in a car engine are all examples of combustion reactions. Combustion involves a substance, such as wood, a wick, gas or petrol, reacting rapidly with oxygen in a chemical reaction. Usually, there is a flame, which creates heat and light.

Wood, coal, oil, petrol and natural gas are examples of fuels. They undergo a chemical reaction with oxygen, releasing lots of heat. The reactions are exothermic. The heat released can be turned into different forms of energy, such as electricity or the motion of cars.

Many fuels consist of compounds of carbon and hydrogen, which are known as hydrocarbons. The simplest example is methane (CH_4), which is the main component of natural gas.

When hydrocarbons such as methane burn in unlimited air, carbon dioxide and water are produced. These are oxidation reactions too. When the air supply is limited, such as in a confined space, the poisonous gas carbon monoxide can be formed.

The word equation for oxidation of a hydrocarbon when there is plentiful air available is:

hydrocarbon + oxygen → carbon dioxide + water

A combustion reaction needs oxygen.

When methane burns, the main reaction is:

methane	+	oxygen	→	carbon dioxide	+	water
CH_4	+	$2O_2$	→	CO_2	+	$2H_2O$

Two molecules of oxygen gas react with a single molecule of methane, forming two molecules of water vapour. The equation is balanced. There is one atom of carbon on the left and right sides. There are four atoms of oxygen and four atoms of hydrogen on both sides of the equation.

Petrol contains a lot of octane. Octane is a hydrocarbon with the formula C_8H_{18}.

The equations for combustion of octane, such as in a car engine, are:

octane	+	oxygen	→	carbon dioxide	+	water
$2C_8H_{18}$	+	$25O_2$	→	$16CO_2$	+	$18H_2O$

Combustion of petrol provides energy for transport.

LOOK IT UP

fuel a material such as coal, gas or oil that is burned to produce heat or power

hydrocarbon a compound containing hydrogen and carbon

CHECK IT OUT

1 What is combustion?

2 Give three examples of combustion reactions.

3 Name the two products formed when a hydrocarbon is burnt in a plentiful supply of air.

4 How many carbon atoms are there on the left and right sides of the equation when octane burns in air?

When coal burns, the carbon in it forms carbon dioxide.

HOW PLANTS MAKE AND USE OXYGEN

Plants produce glucose via a process called **photosynthesis**. Photosynthesis requires light and turns carbon dioxide and water into **glucose** and oxygen. Plants use this glucose to produce the energy they need. This process is called **cellular respiration**.

Photosynthesis

In 1707, English scientist Joseph Priestley performed a series of experiments. He first placed a burning candle into a sealed container. The candle flame used up the oxygen in the air and went out. He added mint plant to the container and discovered that after 27 days he was able to relight the candle. He also found that there was now enough oxygen in the container to keep a mouse alive.

Priestley's experiment showed that plants produce oxygen. We call this process photosynthesis.

As well as producing oxygen, plants make their own food by photosynthesis. Photosynthesis is a chemical reaction in which carbon dioxide and water react together to make glucose and oxygen.

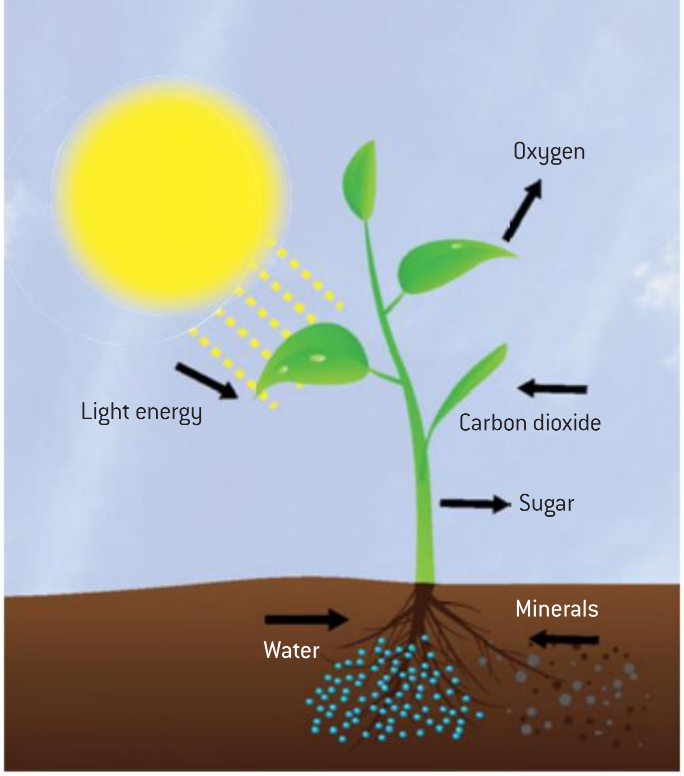
Glucose is a sugar containing a lot of stored chemical energy. The reaction needs the green pigment **chlorophyll** and sunlight. So photosynthesis happens in nature only during the day.

The word and chemical equations for photosynthesis are:

carbon dioxide + water → glucose + oxygen (light energy and chlorophyll needed)

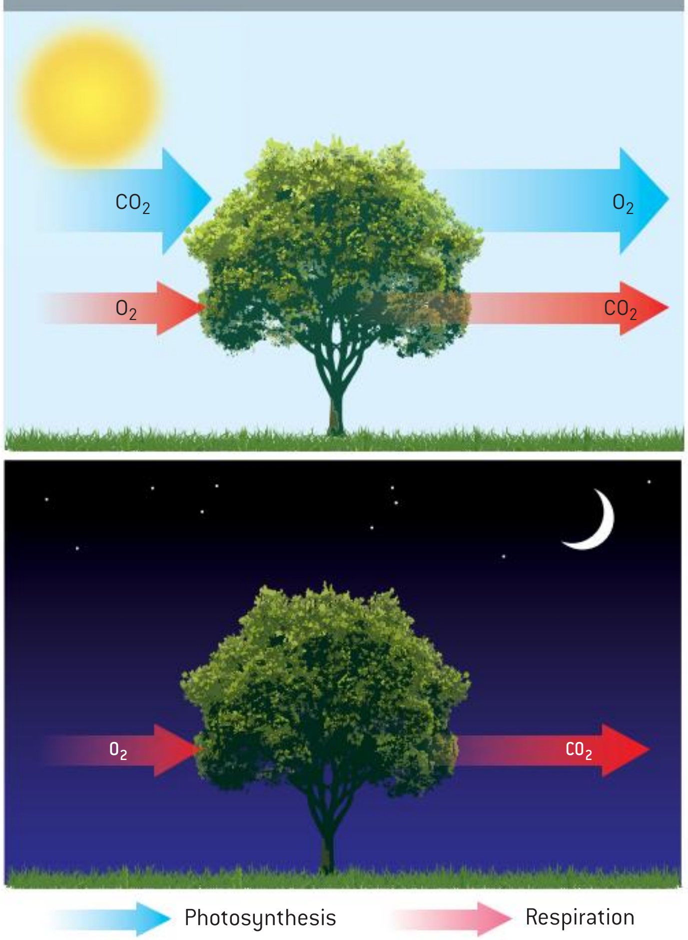
$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

Plants convert glucose into starch, fats and oils. They make cellulose for cell walls, and proteins for growth and repair. Plants also use the glucose as an energy source during the process called cellular respiration.



A green pigment called chlorophyll in the chloroplasts of green leaves absorbs light energy. The reaction called photosynthesis produces glucose and oxygen.

HOW PLANTS AFFECT THE ATMOSPHERE



Plants respire all the time. Photosynthesis needs sunlight, so plants only undergo photosynthesis during the day.

Cellular respiration

Plants get their energy from a process called cellular respiration. The energy comes from glucose, made during photosynthesis.

Respiration occurs continuously in the cells of animals and plants. There are two types of respiration: **aerobic respiration** (requires oxygen) and **anaerobic respiration** (does not require oxygen).

Aerobic respiration converts glucose and oxygen into carbon dioxide and water, releasing energy from the glucose. The reaction is exothermic and is effectively the reverse of the reaction occurring during photosynthesis. It can be represented by these equations:

glucose + oxygen → carbon dioxide + water (+ energy)

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

Respiration gives us the energy we need for every aspect of our lives. It allows us to make molecules such as proteins, to move our muscles and to keep warm. During exercise, muscles may run short of oxygen. When this occurs, anaerobic respiration is used to obtain energy from glucose. The waste product is lactic acid rather than carbon dioxide and water. A build-up of lactic acid can make your muscles feel sore. Anaerobic respiration releases far less energy than aerobic respiration.

LOOK IT UP

aerobic respiration respiration in presence of oxygen

anaerobic respiration respiration that does not use oxygen

cellular respiration the process of converting the energy stored in molecules (such as glucose) into energy in cells

chlorophyll a green pigment present in most plants; responsible for the absorption of light energy during photosynthesis

glucose a simple sugar containing six carbon atoms

photosynthesis the process in which the energy of the Sun is used to convert carbon dioxide and water into oxygen and sugars

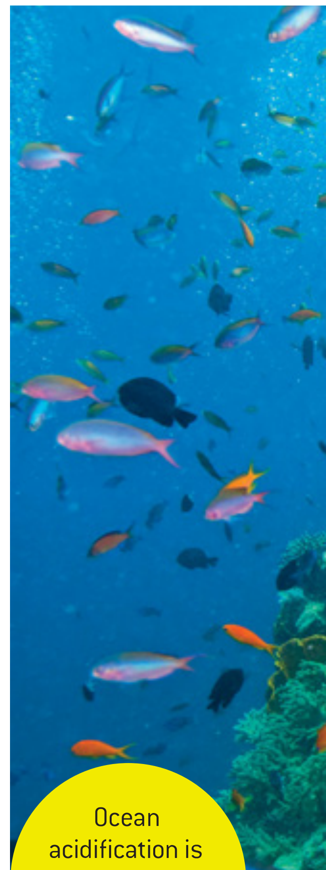
CHECK IT OUT

1. How did Joseph Priestley show that plants produce oxygen gas?
2. What is photosynthesis?
3. Name the reactants and products involved in photosynthesis.
4. What is cellular respiration?
5. Write the word equation for aerobic respiration.
6. What is anaerobic respiration and what is the waste product of the reaction?

AIR POLLUTION AND CLIMATE CHANGE

Burning coal, oil and gas adds sulfur dioxide, carbon dioxide and other **pollutants** into the air. Sulfur dioxide can form sulfuric acid, creating an environmental problem called **acid rain**. Carbon dioxide makes the air trap more heat. The extra warmth is changing our climate. The carbon dioxide in the air is also making the oceans more acidic.

Industry adds pollutants into the air that cause air pollution, acid rain and climate change.



Ocean acidification is a major threat to the Great Barrier Reef.

Acid rain

Rainwater is not neutral – it is slightly acidic. This is because air contains many natural acidic substances. The pH of unpolluted rainwater is usually between 5 and 6.

Extra acid in rainwater and cloud droplets causes 'acid rain'. Acid rain is corrosive to building materials, marble and limestone. Acid rain can kill fish and plants.

Human activities can cause acid rain. This happens when we release acidic sulfur and nitrogen compounds into the air. Coal is a fossil fuel that contains sulfur. When power stations burn coal, they can release sulfur dioxide gas into the air. Smelting, a process in which metals are extracted from metal ores, also produces sulfur dioxide. Burning fossil fuels, forests and vegetation can release oxides of nitrogen gases.

Wind can blow sulfur dioxide and oxides of nitrogen long distances. These chemicals may come into direct contact with soil, lakes, plants, buildings and people. Rainwater and cloud droplets can dissolve sulfur dioxide and oxides of nitrogen, forming sulfuric acid and nitric acid respectively.

Reducing acid rain involves reducing the usage of fuels containing sulfur. Companies can use methods such as water sprays in chimneys to reduce the amount of sulfur dioxide that goes into the air.

Climate change

During the last 200 years, the amount of carbon dioxide in the air has increased by more than 40 per cent. Most of this increase is from the burning of fossil fuels, including coal, oil and natural gas, for energy.

The extra carbon dioxide and other heat-trapping **greenhouse gases** in the air are changing our climate. This process is known as **climate change**. The extra carbon dioxide is also making the oceans acidic. Sea water dissolves carbon dioxide, forming carbonic acid (H_2CO_3).

Ocean acidity is harming marine ecosystems. Coral reefs are made of calcium carbonate ($CaCO_3$). Acid dissolves calcium carbonate. Shellfish are also affected because their shells are made of calcium carbonate.

Like the atmosphere, the oceans are warming. Water expands as it warms. This raises the sea level. Warmer conditions are causing snow and glaciers to melt. This is adding to the volume of the oceans, resulting in a rising sea level.

Over the past 100 years, sea level globally has risen by about 20 centimetres.

Global warming is causing ice melt worldwide.

LOOK IT UP

acid rain rainfall made acidic by air pollution

climate change long-term variations in the climate due to natural fluctuations and/or human activities changing the environment

greenhouse gas a gas such as carbon dioxide that traps heat and contributes to climate change

pollutant a substance introduced into the environment with undesired effects

CHECK IT OUT

1 Why is rainwater naturally acidic?

2 What is acid rain and how is it caused?

3 Name two acids that contribute to acid rain.

4 Why are the amounts of greenhouse gases in the air increasing?

5 Name three greenhouse gases.

6 List three impacts of climate change.

Ask a scientist

Ms Jenny Powell

Jenny Powell measures air quality, checking for levels of pollutants including compounds that cause acid rain.

Jenny Powell is an experimental scientist at CSIRO. Her specialty is air pollution. She regularly analyses air samples in her laboratory to determine levels of pollutants. She also measures amounts of particles in the air called aerosols.

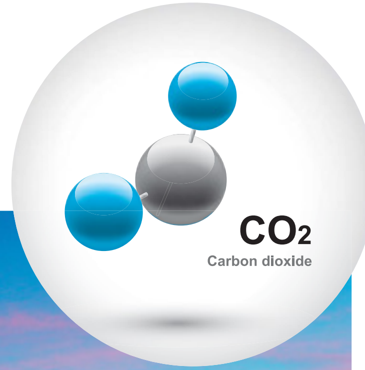
As part of a team of CSIRO scientists, Jenny analysed air samples collected from Western Australia's Burrup Peninsula. The Burrup Peninsula in the north-west of the state is home to one of the world's largest collections of Indigenous rock art. Environmentalists were concerned that pollution from nearby industry, including iron-ore loading, liquefied natural-gas production and salt production, was harming the art.

The scientists sampled air and rainwater at eight different locations, including some close to the industrial areas and some well away. Jenny and her colleagues measured concentrations of pollutants such as sulfur dioxide, nitrogen dioxide, ammonia and aerosols. These pollutants can react with sunlight and water to form acid rain, gases or aerosols. The team also measured acidity of the rainwater, aerosols and gases to understand whether the levels were affecting the rock art.

CSIRO reported that Burrup Peninsula air pollution concentrations were generally very low in industrial areas, and similar to those found well away from the industry.

oo A video interview with Ms Jenny Powell is available on your obook / assess.

CHEMICAL REACTIONS



MAKING NEW SUBSTANCES (PAGES 74–75)

1 On which side of a chemical equation do reactants occur?

2 What is the difference between a symbol equation and a word equation for a reaction?

3 In four molecules of carbon dioxide, how many of the following atoms are there?

a carbon

b oxygen

4 Two molecules of water take part in a reaction. What is the total number of hydrogen atoms that will appear in the products of the reaction?

5 What term describes the fact that matter is never created or destroyed during a chemical reaction?

ENERGY IN CHEMICAL REACTIONS (PAGES 78–79)

6 What is a common way of speeding up a chemical reaction?

7 What is an exothermic reaction? Give an example.

8 What is an endothermic reaction? Give an example.

9 Is the reaction occurring in the glass bottle, causing condensation on the outside, an endothermic or exothermic reaction?

Coal-fired power stations are a major source of carbon dioxide.

ACIDS AND BASES (PAGES 82–83)

10 Name the element present in all acids.

11 What word describes a substance that changes colour in an acid or alkali?

12 How was litmus paper discovered?

3 REACTIONS INVOLVING ACIDS (PAGES 84–85)

13 Complete this equation: acid + base → ________ + ________

14 Write the word equation for the neutralisation reaction between hydrochloric acid and magnesium hydroxide.

15 A reaction between an acid and a carbonate produces magnesium chloride. Name the acid and the carbonate.

16 Zinc reacts with hydrochloric acid in the same ratios as magnesium. Write the word and symbol equations for the reaction.

17 Magnesium reacts with sulfuric acid to form magnesium sulfate and hydrogen gas. Write a word equation and a balanced symbol equation for this reaction.

18 What is measured by the pH scale?

REACTIONS INVOLVING OXYGEN (PAGES 90–91)

19 What is the most common chemical element by mass found on Earth?

20 In what form do atoms of oxygen occur in oxygen gas?

21 What is an oxidation reaction?

22 Why is the reaction of magnesium with oxygen termed exothermic?

WHAT HAPPENS WHEN FUELS BURN? (PAGES 92–93)

23 Name the two products of combustion of a hydrocarbon, such as methane in the Bunsen burner shown, in a plentiful supply of air.

24 Name the hydrocarbon that contains just one carbon atom in its molecules.

25 Explain why using coal and petrol as fuels adds lots of carbon dioxide gas into the air.

26 Is combustion an endothermic or exothermic reaction?

HOW PLANTS MAKE AND USE OXYGEN (PAGES 94–95)

27 Why was Joseph Priestley able to relight a candle in his sealed container experiment?

28 What are the products of photosynthesis?

29 How do plants use glucose?

30 What are the two types of respiration and how do they differ?

AIR POLLUTION AND CLIMATE CHANGE (PAGES 96–97)

31 What is the normal pH of rainwater?

32 How is acid rain formed?

33 What are three impacts of acid rain?

34 What is climate change?

35 How does the coal (left) contribute to climate change?

36 What is ocean acidification and why is it occurring?

Climate change is leading to rising sea levels.

KEY IDEAS

1

During chemical reactions, substances react together to form new materials. The starting chemicals are called reactants. The new materials are called products.

2

Atoms are never created or destroyed during a chemical reaction. The mass of the products is equal to the mass of the reactants.

3

Chemical reactions can occur at different speeds. An explosion is an example of a rapid reaction. Rusting is a slow reaction.

4

Reactions can release or absorb heat. Exothermic reactions release heat – they warm their surroundings. Endothermic reactions absorb heat.

5

Acids have pH values of less than 7. Neutral solutions (such as pure water) have a pH of 7. Bases dissolve in water to form alkalis, which have a pH greater than 7. Universal indicator and litmus are both indicators that show whether a solution is acidic, neutral or an alkali.

6

Three important reactions involving acids:

- Acids and bases neutralise each other, producing a salt and water.
- Acids react with carbonates, producing a salt, water and carbon dioxide.
- Acids react with some metals, producing a salt and hydrogen gas.

7

Oxygen is very reactive. It reacts with elements and compounds in combustion and oxidation reactions. Oxygen reacts with some metals and non-metals to form oxides.

8

Combustion is an example of a rapid chemical reaction involving a fuel and oxygen. Combustion of a hydrocarbon when a lot of air is present produces carbon dioxide and water. Combustion is an example of an oxidation reaction.

9

Photosynthesis is the process that plants use to make glucose. Plants use glucose as an energy source. Photosynthesis needs sunlight and chlorophyll to occur. It is a chemical reaction in which carbon dioxide and water react together to produce glucose and oxygen.

10

Cellular respiration is effectively the opposite of photosynthesis, converting glucose and oxygen into energy, carbon dioxide and water.

11

Acid rain is an environmental problem caused by release of gases such as sulfur dioxide. Sulfur dioxide can form sulfuric acid in rainwater and clouds. Acid rain damages buildings and materials and can kill fish and plants.

12

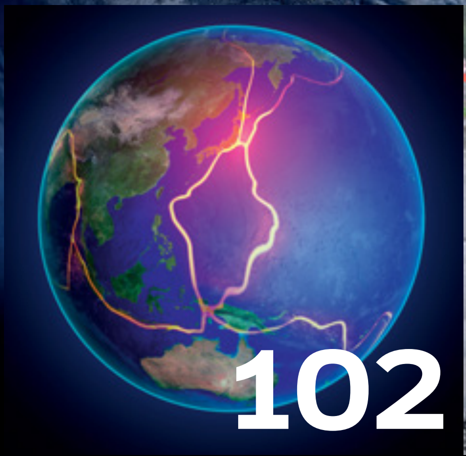
Burning fossil fuels such as coal, oil and gas adds carbon dioxide and other heat-trapping gases into the air. The extra warmth is changing our climate. The carbon dioxide is also making the oceans more acidic.

PLANET EARTH 05

AMAZING EXPERIMENT using CHOCOLATE BARS!

The MARIANA TRENCH

SLEEPING GIANTS



THE RESTLESS EARTH

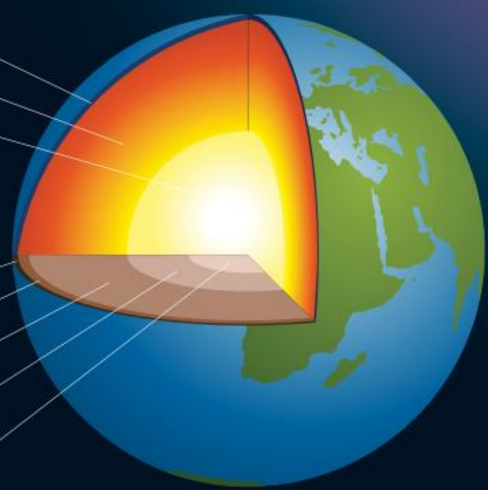
The slow, long-term, large-scale movement of the Earth's upper layers across the surface is called plate tectonics. The word 'tectonic' comes from the Greek language meaning building, as tectonic plates are the building blocks of the planet's surface.

Plate tectonics

The **lithosphere** is the surface layer of the Earth. This layer consists of the crust and the brittle upper part of the mantle, and is approximately 100 kilometres thick. The lithosphere is made up of 15 main segments called **tectonic plates**, which fit together like a jigsaw puzzle on the surface of the Earth. Tectonic plates are rigid and less dense than the liquid magma below, so they basically float on the surface.

The lithosphere is slowly but constantly moving as it floats on top of the mantle. The tectonic plates slide slowly at slightly different speeds. Some move at about the speed that your fingernail grows (3 centimetres per year), while others move slightly faster at the speed that your hair grows (about 16 centimetres per year).

LAYERS OF THE EARTH

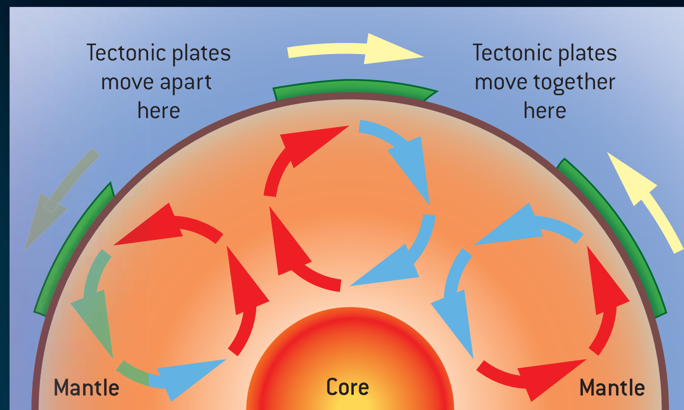


The Earth is composed of the crust, mantle and core. The crust and some of the mantle make up the lithosphere, which floats on the inner section of mantle.

The Earth's upper layers consist of tectonic plates, separated by boundaries.

Convection currents

As rock in the mantle heats up, it expands and becomes less dense. This causes it to rise, like hot air, while cooler regions sink. As hot mantle approaches the surface it spreads out below a tectonic plate, pushing and moving the plate. The heating and cooling of the mantle causes the convection currents that move plates towards or away from each other.



Convection currents in the Earth's mantle cause tectonic plates in the crust above to move.

Earthquakes occur when two jammed tectonic plates jolt free, causing massive vibrations and often devastating destruction, such as this damage in Christchurch, New Zealand, in 2011.

LOOK IT UP

lithosphere the 100-kilometre thick surface layer of the Earth containing the crust and the brittle upper part of the mantle

tectonic plate a rigid segment of the Earth's surface that floats on the liquid magma below

CHECK IT OUT

1. Name the process that describes the movement of the Earth's upper layers.
2. Describe the movement of tectonic plates, including what they move on.
3. What type of currents drive the movement of tectonic plates?
4. 'A continent can drift at the speed your hair grows.' True or false?
5. Tectonic plates move at a speed of between 1 and 16 centimetres a year. Calculate this speed in kilometres per hour. Now convert it to kilometres per century, and kilometres per million years. Estimate the time it would take at this speed for Australia to move to Indonesia and to the United States.

EXPERIMENT #14

MAKING CONVECTION CURRENTS

In this experiment you will see how Pangaea broke into the seven continents of today.

AIM: TO INVESTIGATE HOW A SUPERCONTINENT MAY HAVE BROKEN UP INTO SMALLER CONTINENTS.

MATERIALS

- Bunsen burner
- Tripod
- Heatproof mat
- Gauze mat
- 250 mL beaker
- Measuring cylinder
- Large spoon
- Rice
- Cooking oil
- Water

SAFETY

This experiment involves using a Bunsen burner:

- Be careful of naked flames.
- Ensure that long hair is tied back and loose clothing such as a tie is tucked away.
- Do not leave flames unattended.
- Handle hot sample with tongs.
- Ensure you follow laboratory safety procedures and wear safety glasses and a lab coat.
- The apparatus will be very hot at the end of this experiment. Leave it to cool before packing it away.

METHOD

1. Read steps 2 to 5 and predict what will happen when the beaker contents are cooled, based on your scientific knowledge. Give reasons for your prediction.
2. Place a spoonful of rice into the beaker and add 100 mL of water.
3. Pour a thin layer of cooking oil over the surface of the water.
4. Set up the Bunsen burner beneath the tripod, with the heatproof mat and gauze mat above it. Place the beaker on the mat and heat the water, rice and oil in the beaker.
5. The rice will show how the water moves as it is heated.

Carefully heat the water, rice and oil.

RESULTS

Describe what happens to the rice and the oil when the water begins to boil.

DISCUSSION

1. Why did the rice move when the water was heated?
2. How does this experiment relate to the breaking up of Pangaea?

CONCLUSION

Write a conclusion for this experiment and relate it to your aim and the breaking up of Pangaea. How accurate was your prediction in step 1?

EXPERIMENT #15

CHOCOLATE PLATES

MATERIALS

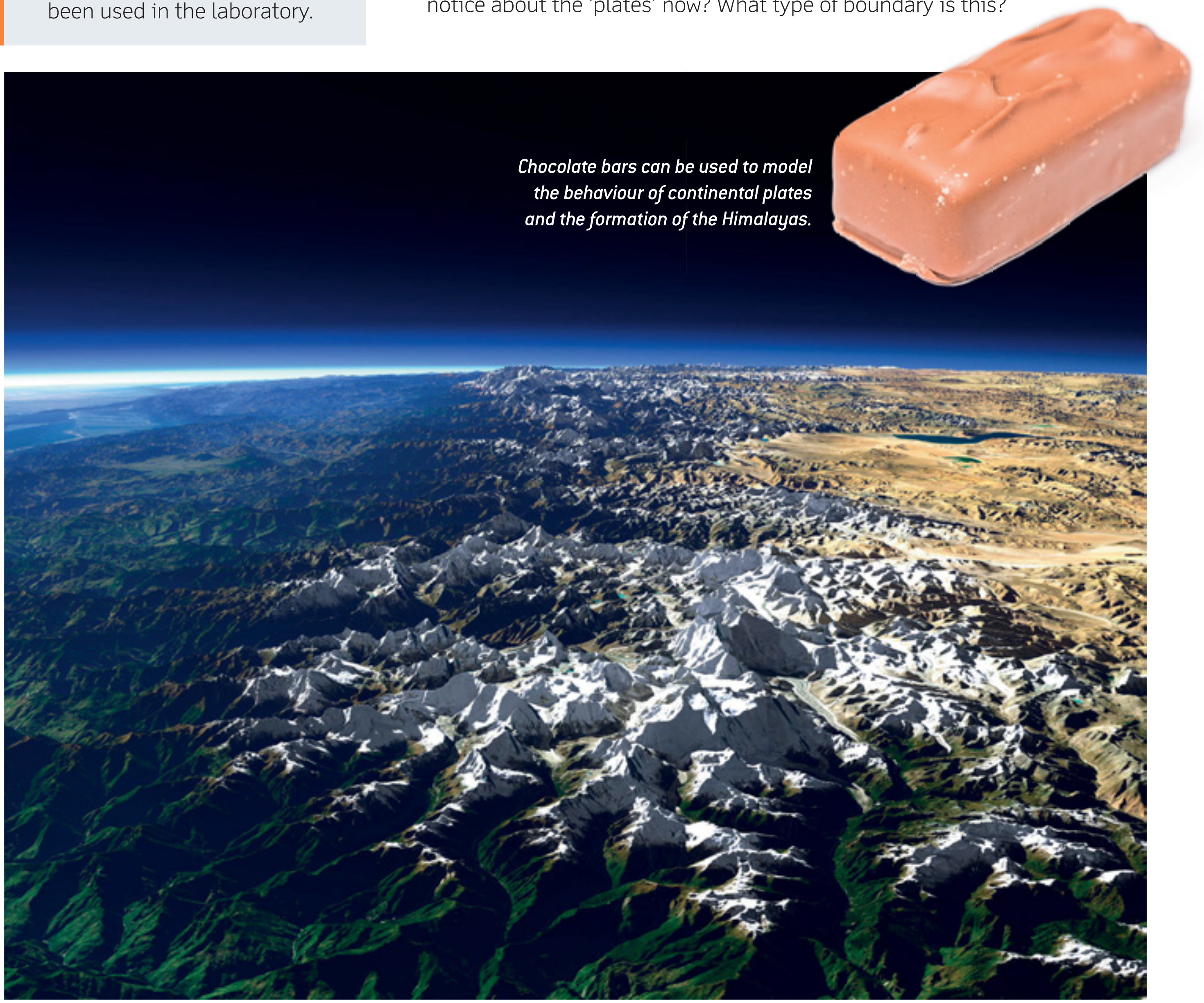
- Soft chocolate bar (such as a Mars Bar or Milky Way)
- Spatula
- Baking paper

SAFETY

- Wash your hands before starting this activity.
- Do not eat any food that has been used in the laboratory.

METHOD

1. Lay a sheet of baking paper on the desk to provide a clean surface.
2. Use a clean spatula to cut the chocolate bar in half.
3. To illustrate a transform boundary, gently push the chocolate bar back together, then slide one half of the chocolate bar (one 'plate') forward and the other backwards. Describe what happens.
4. Next, to illustrate the force of compression associated with mountains forming when continental plates collide, push on both ends of the chocolate bar to squeeze it together. What do you notice about the 'plates' now? What type of boundary is this?



Chocolate bars can be used to model the behaviour of continental plates and the formation of the Himalayas.

THE EARTH ON A PLATE

There are eight major tectonic plates. Around Australia are the Indian and Australian plates (sometimes referred to as one Indo–Australian plate). The other major plates are the African, Antarctic, Eurasian, North American, Pacific and South American plates. There are also seven smaller plates and dozens of even smaller plates.

Where have we been?

The development of today's continents began with **Pangaea**, a single supercontinent that formed about 300 million years ago. At that time it was the only continent on the planet, and was located mainly in the southern hemisphere. Pangaea was not the first continent though – other supercontinents had previously formed and broken apart before eventually forming Pangaea.

The separation of the original supercontinent is still continuing today, with parts of Pangaea continuing to break apart in East Africa and the Middle East.

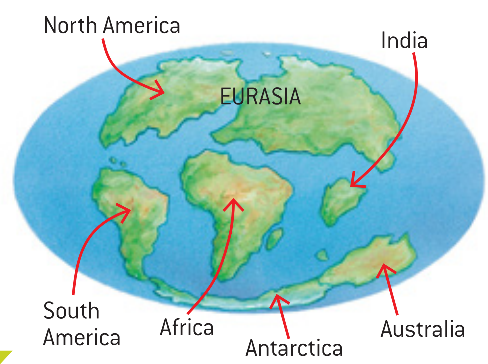
Before Pangaea there were other supercontinents. Supercontinents have formed and broken up many times in the past as part of an ongoing cycle.

With the ongoing movement of tectonic plates, this cycle of formation and breaking apart of supercontinents will continue.

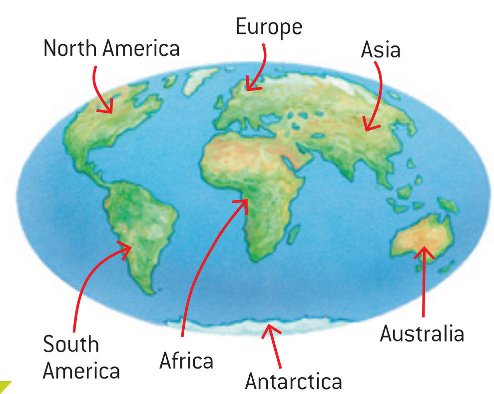
Thingvellir National Park in Iceland is located over the Mid-Atlantic Ridge, which is a boundary between two tectonic plates.

220 MILLION YEARS AGO A map of Pangaea, as it would have been 220 million years ago, showing the outline of today's continents.

200 MILLION YEARS AGO Pangaea began to break apart due to the movement of the tectonic plates. The separation first formed two land masses: **Laurasia**, which drifted to the north, and **Gondwana**, which drifted to the south.

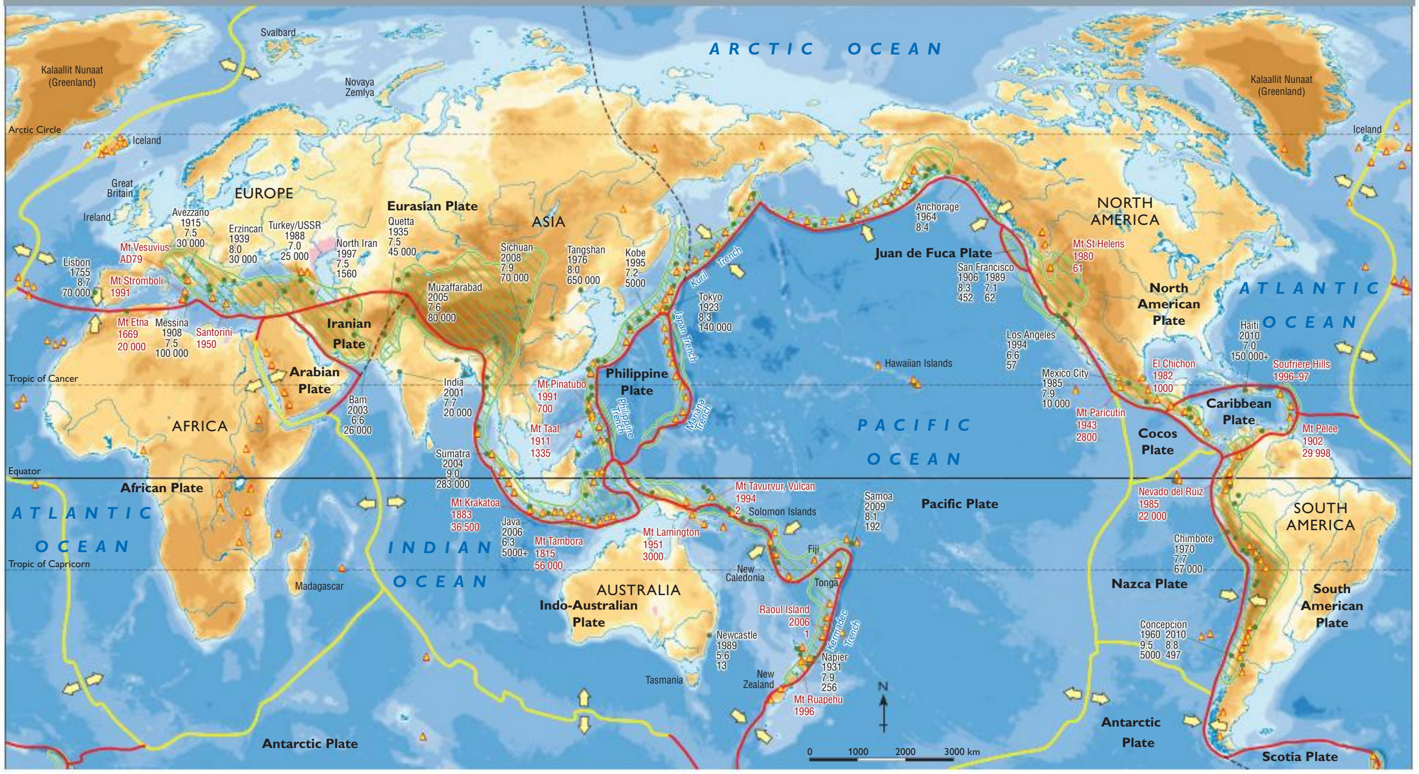


150 MILLION YEARS AGO Gondwana began to separate into the continents of Africa, Antarctica, Australia, India and South America. Then, about 60 million years ago, Laurasia broke apart from North America and Greenland, separating from Europe and Asia.



NOW The continents as they are today.

THE WORLD'S MAJOR TECTONIC PLATES



Where are we going?

Geologists can accurately measure the movement of continents using data obtained from **Global Positioning System (GPS)** satellites. Currently, Australia is moving to the north-east at about 5–6 centimetres per year. Therefore, each year we get about 3.5 centimetres closer to Japan, 5 centimetres closer to New Guinea and 10 millimetres closer to the east coast of the United States.

In the future it may be that all of the world's continents will re-form into a new supercontinent, which scientists have already named Amasia. This is just one prediction of how the plates will move over the next 250 million years.

LOOK IT UP

Global Positioning System (GPS) a way of obtaining accurate locations based on the reception of signals from satellites in orbit around Earth

Gondwana a land mass that broke away from Pangaea about 200 million years ago and drifted to the south before separating into Africa, Antarctica, Australia, India and South America

Laurasia a land mass that broke away from Pangaea about 200 million years ago and drifted to the north before separating into North America, Greenland, Europe and Asia

Pangaea a single supercontinent that formed about 300 million years ago

CHECK IT OUT

1. What is the name of the supercontinent from which all today's continents formed?
2. What is the name of the minor supercontinent from which Australia formed?
3. How long ago did Australia and other continents begin to separate?
4. At what speed and in which direction is Australia currently moving due to tectonic movements?
5. Scientists propose that all of the world's continents may re-form into a new supercontinent called Amasia. Consider ways that the continents may move, collide and separate in the future, and draw the outlines of possible new continents.

A new supercontinent called Amasia is one possible outcome of the current movement of the Earth's tectonic plates.

EVIDENCE THAT THE EARTH MOVED

The movement of tectonic plates occurs over a very long time. A supercontinent takes millions of years to separate. We can't see continents moving because the movement is so slow, but evidence including fossils, continental plate shape, earthquakes and volcanoes shows us that tectonic plates are constantly on the move.

We feel the Earth move during sudden earthquakes, but geologists rely on other evidence to show how the continents moved over millions of years.

Fossils

Palaeontologists have found similar **fossils** on different continents, which are now separated by vast distances. For example, trees that grow in Australia can be found fossilised in Antarctica. Ancient plants that couldn't move, and animals that couldn't swim, can only have existed in areas separated by an ocean if the continents were joined together at the time these plants and animals lived.

There are also links between plants and animals living today whose evolution dates back to the time of the supercontinent Pangaea. For example, a species of spider in Tasmania is related to a species in France and two species in North America. All four of these spider species belong to the same genus.

Fossils of a type of fern, called Glossopteris*, occur in South America, Africa, India, Australia and Antarctica. These continents must once have been joined.*

Shape of continents

More than 400 years ago, Dutch map-maker Abraham Ortelius noticed that the boundaries of America, Europe and Africa fitted neatly together, giving a strong indication that these continents were once joined. The outlines fit together even better if you use the shape of the undersea continental shelves beyond a country's coastline. This giant jigsaw puzzle, when combined with other evidence, suggests how the continents used to be connected.

Geological change and magnetism

Volcanoes and earthquakes often occur along the boundaries between tectonic plates. Other geological activity also occurs at these boundaries, including the submersion of some areas of the seafloor, the appearance of mountains on the seafloor, or the growth of the seafloor. Movement of the tectonic plates causes these changes.

Palaeomagnetism is the study of magnetism of ancient rocks. In the past, there has been periodical switching of the magnetism between the Earth's north and south poles. Some sections of rock on the seafloor have normal magnetic polarity and some have reversed magnetic polarity. This suggests that new seafloor has been continually created throughout time as some plates have spread apart.

New technologies

In addition to evidence of past continental drift, new technologies, such as GPS and laser measurements, enable scientists to measure the speed that tectonic plates are moving today.

New ideas take time to be accepted

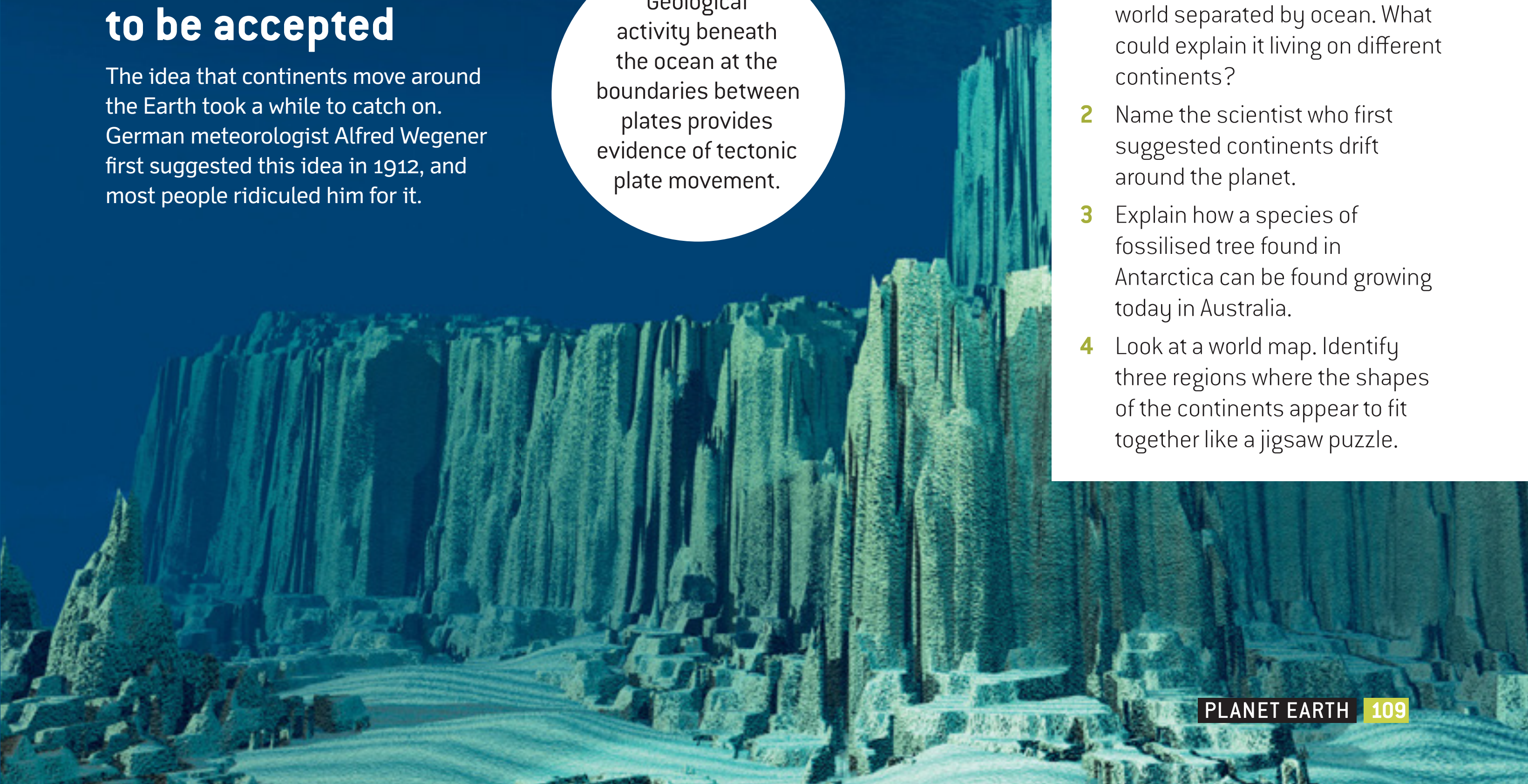
The idea that continents move around the Earth took a while to catch on. German meteorologist Alfred Wegener first suggested this idea in 1912, and most people ridiculed him for it.

Although Wegener's background was physics, meteorology and astronomy, he is known for noticing that the continents seemed to fit together like a jigsaw puzzle. He also saw similarities in rocks and fossils between the west coast of Africa and the east coast of South America on the other side of the Atlantic Ocean.

To explain his observations, Wegener developed the theory of **continental drift**. He proposed that today's continents had once been joined together as a giant land mass. Most geologists at the time refused to believe his revolutionary ideas.

It wasn't until after Wegener died that his ideas became accepted. Measurements of magnetism and the discovery of seafloor spreading led to the development of the continental drift theory into an understanding of plate tectonics.

Alfred Wegener started one of the greatest scientific revolutions of the 1900s, proposing that continents drift across the Earth. Wegener died in 1930 during a meteorological expedition in Greenland.



Geological activity beneath the ocean at the boundaries between plates provides evidence of tectonic plate movement.

LOOK IT UP

continental drift the theory that today's continents were once joined together as a giant land mass before drifting apart

fossil the remains or imprints of an animal, plant, bacteria or other living organism preserved in rock

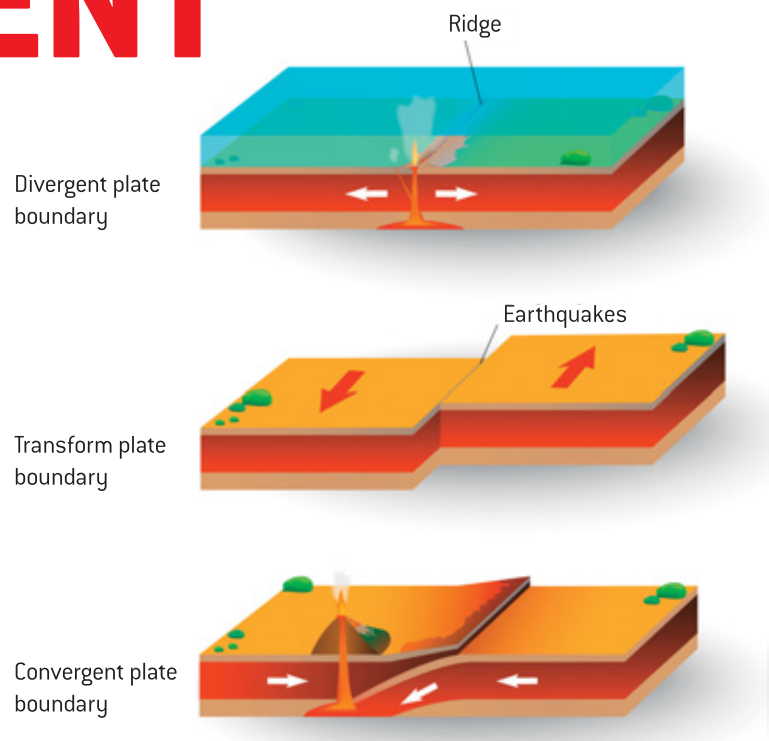
palaeomagnetism the study of magnetism of ancient rocks

CHECK IT OUT

1. Consider a similar type of insect found in countries around the world separated by ocean. What could explain it living on different continents?
2. Name the scientist who first suggested continents drift around the planet.
3. Explain how a species of fossilised tree found in Antarctica can be found growing today in Australia.
4. Look at a world map. Identify three regions where the shapes of the continents appear to fit together like a jigsaw puzzle.

OUR VIOLENT PLANET

The movement of tectonic plates causes the Earth to change: mountains form, new seafloor appears, earthquakes occur and volcanoes erupt. The way plates interact with each other explains geological features. Two plates can move towards each other and collide (converge), move apart (diverge) or slip past each other (transform).



The main types of boundaries between tectonic plates: convergent, divergent and transform.

Converging boundaries

A **convergent boundary** between two plates is like a collision that takes millions of years.

When two continental plates converge, the land is pushed up at the boundary to slowly form a mountain range. The highest mountain range in the world, the Himalayas, was formed this way. These mountains are rising by 2 centimetres each year as the convergence continues.

When two oceanic plates converge, the older crust is pushed below the newer crust to form a deep ocean trench, as well as undersea volcanoes that can rise to form islands. The deepest point on the Earth's surface, called the Mariana Trench, formed this way.

When an oceanic plate converges with a continental plate, the oceanic crust is pushed below the continental crust. This forms a deep trench on the ocean floor, and a range of mountains on the crumpled continental edge. Magma can also be pushed up at this boundary to form volcanoes.

Mount Everest (the world's highest peak) and the Himalayan mountains surrounding it were pushed up by the collision of the Indian and Eurasian plates 20 million years ago.

The plates are still converging, so the mountains are increasing in height by about 2 centimetres each year.

The long and narrow Red Sea formed as the African plate moved away from the Arabian plate.

Diverging boundaries

A **divergent boundary** (or spreading boundary) is two plates moving apart. New crust forms when magma rises from the mantle beneath the Earth and then cools.

When the plates first separate, a block of land drops down between the plates. As the gap widens, a long, wide valley forms. The East African Rift is an example of this formation. As the gap widens further, a long, narrow sea can form. The Red Sea formed in this way due to the divergence of the African and Arabian plates.

Millions of years of divergence can create an ocean. Along the boundary where the two plates are moving apart, magma emerges from below to fill the gap. This cools, forming a chain of underwater mountains. This is called a **mid-ocean ridge**.

Transform boundaries

A **transform boundary** is two plates slipping past one another. The two plates can become stuck, and the pressure builds up so much that the plates suddenly jolt past each other as much as several metres. This rapid movement of earth causes earthquakes.

Two plates slipping past each other caused the San Andreas Fault in the United States.

LOOK IT UP

converging boundary the region where two plates come together

diverging boundary the region where two plates move apart

mid-ocean ridge a chain of underwater mountains formed at the boundary where two plates are moving apart beneath the ocean

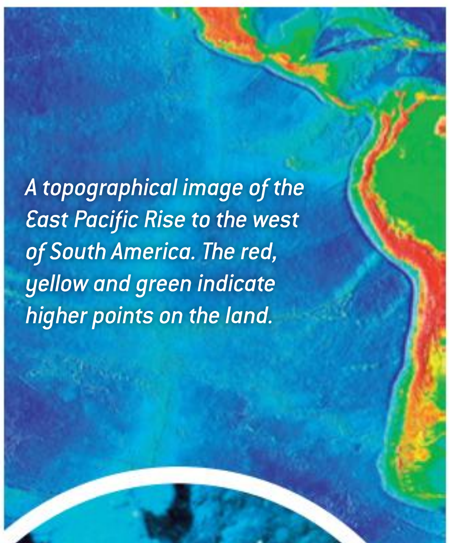
transform boundary the region where two plates slide past each other

CHECK IT OUT

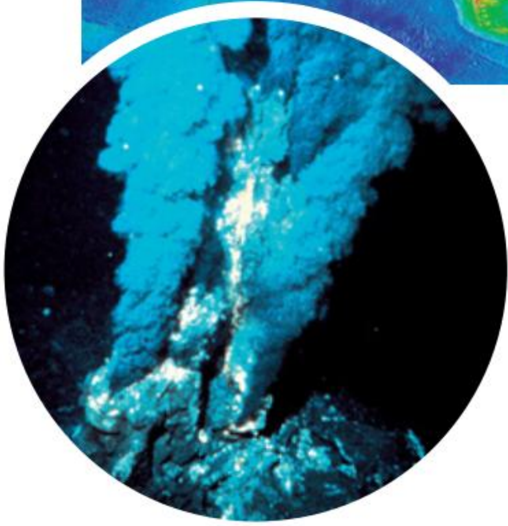
1. 'The world's highest mountain range will be 2 metres higher in 100 years' time.' True or false?
2. What is the name of the boundary between two plates slipping past each other?
3. Name a geological formation that you would expect at the boundary between:
   - a an oceanic and continental plate
   - b two continental plates
   - c two oceanic plates.
4. Were the Himalayas formed by converging, diverging or transform plate boundaries?
5. Place the following geological features resulting from diverging plates in the order that they would form: *ocean, sea, rift valley, mid-ocean ridge*.

CHANGES BENEATH THE SEA

The geology of the seafloor is constantly changing due to tectonic plate movements. Hot magma pushes into the oceanic crust where plates are diverging to form new ground at the bottom of the sea. The seafloor moves apart to slowly enlarge some oceans.



A topographical image of the East Pacific Rise to the west of South America. The red, yellow and green indicate higher points on the land.



A black smoker at the Atlantic Ocean mid-ocean ridge.

Seafloor spreading

All of the world's oceans contain a crease down the middle, called a mid-ocean ridge. Here, under hundreds or thousands of metres of water, are the longest chains of mountains in the world. At up to 70 000 kilometres long and 4000 kilometres wide, mid-ocean ridges are the largest geological features in the world.

Mid-ocean ridges are formed by **seafloor spreading**. Magma rising up from the Earth's mantle forms a ridge. Eventually, the ridge splits and the mantle pushes newly formed seafloor in opposite directions away from the opening. The spreading occurs very slowly, at about 5 centimetres a year.

Although the Earth is billions of years old, seafloor spreading is constantly creating new seafloor. There are no areas of ocean floor more than 180 million years old. Volcanic activity often occurs in the areas near mid-ocean ridges. This is because seafloor spreading forms new crust that is thin and unstable.

Although most mid-ocean ridges are underwater, some rise above sea level such as this valley in Thingvellir National Park, Iceland, which is located over the Mid-Atlantic Ridge.

Black smokers

Black smokers are volcanic, chimney-like formations that release mineral-rich water up into the ocean. Immense heat from volcanic activity superheats water in rocks deep within the Earth's crust. The water, which can be rich in dissolved gold, silver and other minerals, escapes through a volcanic hole in the seafloor called a hydrothermal vent. This makes the holes appear to smoke. The cool ocean causes the dissolved minerals to precipitate or fall from the water. The minerals settle on the seafloor, building into chimney-shaped towers up to 60 metres high.

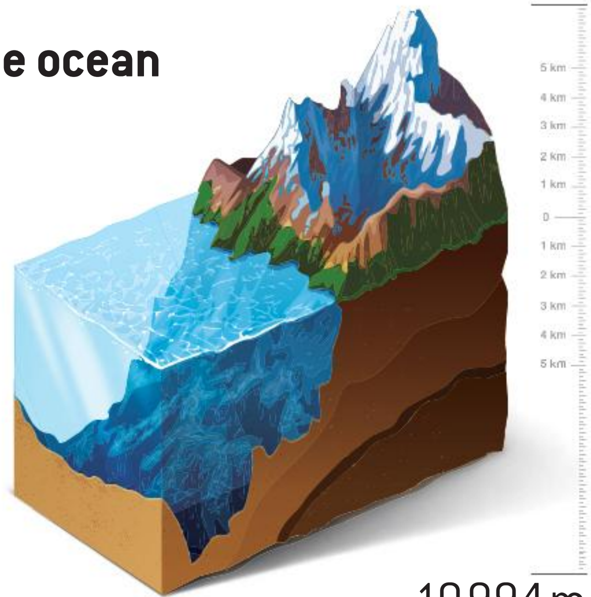
Scientists first found black smokers in 1977 near the East Pacific Rise – a mid-ocean ridge in the Pacific Ocean that is home to one of the fastest spreading areas of seafloor on Earth. In 1991, CSIRO scientists discovered rich undersea deposits of gold, silver, copper and zinc sulfide located 1.7 kilometres below the ocean surface, near Papua New Guinea. The deposits have about 10 times as much gold as typical land-based gold fields in Western Australia, and 5 times as much copper as huge mines in South America.

Deepest point in the ocean

The Mariana Trench is the world's deepest point, and the lowest part of the surface of the Earth's crust. It is 2500 kilometres long, an average of 69 kilometres wide, and an amazing 11 kilometres deep.

The Mariana Trench is the deepest part of the boundary between two tectonic plates in the Pacific Ocean, and the plates are colliding. The western part of the Pacific Plate is being pushed beneath the younger and lighter Mariana Plate in a process called **subduction**.

8 848 m
Mount Everest



10 994 m
Mariana Trench

The Mariana Trench is so deep you could fit the world's highest mountain inside it.

Exploring the Mariana Trench

In 2012, filmmaker James Cameron, director of *Titanic*, dived to the bottom of Challenger Deep – the deepest point of the Mariana Trench. He descended in the *Deepsea Challenger* manned submersible, which was built in Sydney. He stayed down there on his own for three hours using the specially designed equipment to investigate the seafloor before returning to the surface.

LOOK IT UP

black smoker a volcanic, chimney-like formation that releases mineral-rich water up into the ocean

seafloor spreading a region on the ocean floor where magma rises up and pushes newly formed seafloor in opposite directions

subduction the process where one plate is pushed beneath a younger and lighter plate

CHECK IT OUT

1. Name the chimney-like formations on the seafloor that are rich in gold, silver and other minerals.
2. What is the name of the world's deepest point? How deep is it?
3. Explain why there are no areas of ocean floor more than 180 million years old.
4. 'The ocean floor is older than continental land.' True or false?
5. What problems would you encounter attempting to dive to the world's deepest point?

Ask a scientist

Dr Jo Whittaker

Dr Jo Whittaker in front of the Marine National Facility's research ship, which is used to explore the oceans.

Dr Jo Whittaker's research at the University of Tasmania helps us to understand how continents form and move in the Earth's upper mantle and crust. Her research about the ocean floor helps us understand how tectonic plates move.

She says that the seas surrounding Australia contain unique ecosystems and support valuable industries, such as oil and gas production, fisheries and tourism. However, large parts of the ocean floor surrounding Australia remain unknown and unexplored.

Jo says it is really exciting to go where no one has been, and see things no one has ever seen before.

Her work at the university involves reconstructing how the Indian, Australian and Antarctic tectonic plates separated over the past 160 million years, forming the Indian Ocean.

She has investigated how past supercontinents and superoceans have affected the seafloor. She discovered, with a team of other geologists, a new link between the break-up of the ancient supercontinent Pangaea and the topography of the deep ocean floor, improving understanding of the seafloor's roughness.

A video interview with Dr Jo Whittaker is available on your obook / assess.

EARTHQUAKES

Sudden movements of the Earth's crust cause earthquakes and associated vibrations in the ground. The sudden shocks can occur following a build-up of pressure from the gradual movement of tectonic plates. Major earthquakes can cause extensive damage to buildings, create landslides and avalanches, set off fires and floods, and generate giant coastal waves.

Earthquakes can cause large cracks in the ground, such as this one following the major earthquake in Christchurch, New Zealand, in early 2011.

Damage to a highway following an earthquake in Los Angeles, California, in January 1994.

What causes an earthquake?

A **fault line** is a fracture line in rock that has occurred due to large-scale ground movement. An earthquake occurs when tectonic plates suddenly slip horizontally or vertically past each other.

Around half a million earthquakes occur worldwide each year, with people able to feel about 100 000 of these. There are on average 18 major earthquakes (with a magnitude between 7.0 and 7.9) and one great earthquake (magnitude more than 8.0) each year. Following a major earthquake, aftershocks or smaller earthquakes usually occur.

More than 75 per cent of the world's earthquakes occur around the Pacific 'Ring of Fire'.

The Pacific Ring of Fire extends from New Zealand, past Indonesia and Japan, along the west coast of North America, and down to the tip of South America.

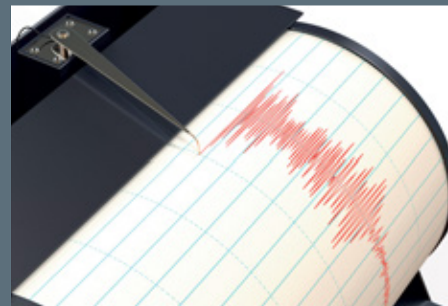
Measuring earthquakes

The sudden release of energy by an earthquake causes ripples called **seismic waves** to travel through the Earth. These can be measured using a **seismometer**.

The size and frequency of seismic waves can help locate an earthquake's **epicentre**. This is a point on the ground directly above where a fault has fractured, and is often the area of greatest damage.

The Richter scale

The Richter scale was developed in the 1930s and previously used to describe the amount of energy in seismic waves, and therefore the severity of earthquakes. The **moment magnitude scale** developed in the 1970s is used today. It is a logarithmic, not linear, scale. This means a magnitude 6 earthquake is 10 times more powerful than one measuring 5, which is 10 times more powerful than one measuring 4 on the scale, and so on.



Part of a seismometer moves as the ground shakes during an earthquake, enabling a stable needle to record the amount of movement.

Tsunamis

When an earthquake occurs beneath the ocean, the movement of the seafloor displaces the water above and can start a giant wave. This wave is called a **tsunami** (from the Japanese language meaning 'harbour wave'). Volcanic eruptions, undersea landslides or other disturbances beneath the ocean can also cause tsunamis.

A tsunami starts as a long, shallow wave but when it reaches the shore it grows into a wave that can be tens of metres high. Tsunamis can demolish buildings, lift cars to the top of trees, and carry large boats and debris far inland.

Japan has many tsunamis as it is located near three tectonic plate boundaries. In 2011, a magnitude 9.0 earthquake off the coast of Japan caused a 40-metre-high tsunami that killed more than 15 000 people and destroyed entire towns. The waves travelled to other parts of the Pacific, with 2-metre waves causing damage on the west coast of the United States, and higher-than-normal waves reaching northern Australia.

This tsunami wave, caused by an earthquake off the Japanese coast in 2011, is shown breaching a sea wall. It washed over a seaside village and caused devastating damage.

LOOK IT UP

epicentre the point on the ground directly above where a fault has fractured during an earthquake

fault line the broken rock along the line of the transform boundary

moment magnitude scale a logarithmic scale used to describe the amount of energy in seismic waves and the severity of earthquakes

seismic waves waves in the Earth produced by an earthquake

seismometer an instrument that records land movement and seismic waves

tsunami a giant wave caused by the movement of the seafloor during an earthquake beneath the ocean

CHECK IT OUT

1. What are the giant waves caused by earthquakes called?
2. What instrument is used to measure the severity of an earthquake?
3. Explain why most of the world's earthquakes occur around the Pacific 'Ring of Fire'.
4. What is the magnitude of an earthquake 10 times more severe than an earthquake of magnitude 7.0?
5. Consider the movement of tectonic plates that cause an earthquake. Devise a simple demonstration using your hands to recreate the slippage, jamming and jolting release of the plates that cause an earthquake.

VOLCANOES

Lava erupting from Tungurahua, an active volcano in Ecuador, South America.

Volcanic eruptions occur frequently at plate boundaries due to tectonic movement. Volcanoes can cause destruction due to emissions of poisonous gas, boiling lava and clouds of ash. Major eruptions even lower global temperatures. In 1815, Mount Tambora erupted in Indonesia, sending dust high into the atmosphere, cooling the planet for years and causing crops to fail in many countries.

Volcano formation

Bubbles of volcanic gas formed holes in this piece of pumice stone (left).

A volcano is an opening in the Earth's crust that allows melted rock, gas, steam and ash to escape or explode to the surface. Beneath the volcano is a **magma** chamber, which is an underground pool of liquid rock hotter than 1000°C. Magma reaching the surface is called **lava**, which slowly cools and solidifies on the ground.

As magma rises to the surface, dissolved gas forms bubbles due to a decrease in pressure. This is similar to the carbon dioxide dissolved in a soft drink forming bubbles when the pressure is released on opening. The huge pressure from the gas bubbles forces magma to the surface and, if it ruptures the ground, into the air.

Volcanoes are different shapes depending on the eruption and behaviour of the lava. Volcanoes can also form on the ocean floor.

One of the thousands of eruptions each year of Mount Sakurajima in Japan, just a few kilometres from a city of more than half a million people.

Sleeping giants

There are currently about 1500 volcanoes on Earth that are active, which means they have recently erupted and may erupt again in the near future.

Volcanoes that are inactive but may erupt again one day are called **dormant**, which means sleeping. Those that are unlikely to erupt ever again are called **extinct**.

There are no active volcanoes on the Australian mainland, but the Australian territories of Heard Island and the McDonald Islands, south-west of Western Australia, have active volcanoes. Most volcanoes on the Australian continent are extinct, except for a region of south-west Victoria that has dormant volcanoes.

Tower Hill in western Victoria is a dormant volcano that last erupted about 25 000 years ago.

EXPERIMENT #16

VOLCANIC ACTIVITY

Fizzy soft drinks contain dissolved carbon dioxide gas. These are supersaturated solutions, and contain more carbon dioxide than they normally would because they are under high pressure. When you open the lid, the pressure is released and the excess carbon dioxide comes out of the solution in the form of bubbles.

AIM: TO EXPLAIN THE FORMATION OF VOLCANIC ROCKS USING A FIZZY SOFT DRINK

MATERIALS

- Bottle of fizzy soft drink
- Powdered chalk
- Vinegar
- Red food dye
- Beaker

SAFETY

Do not consume food or drink in the laboratory.

METHOD

PART A

1. Observe an unopened soft drink bottle (lemonade is best because it is clear). Make a note of the number, position and relative size of any bubbles you can see.
2. Carefully twist the lid of the bottle until you hear the seal break and you hear the 'pfshh' sound. Take note of the amount, size and movement of the bubbles that form.

PART B

1. Add a few drops of food dye to a small amount of powdered chalk in a beaker.
2. Add a teaspoon of vinegar to the chalk mixture. The reaction produces carbon dioxide bubbles and the food dye makes the froth look like lava.

RESULTS

Draw a flow chart showing step-by-step the changes you saw in the bubbles as you opened the soft drink bottle.

DISCUSSION

1. Describe what happens to the soft drink bubbles (size, number and movements) as the pressure is released, and suggest an explanation for these changes.
2. Explain how the volcanic eruption process is similar to the bubble formation in an opened bottle of soft drink.
3. Explain the similarities and differences between the carbon dioxide emitted from the chalk mixture and that released during a volcanic eruption.

LOOK IT UP

dormant the state of a volcano that is inactive but may erupt again

extinct (geology) the state of a volcano that is unlikely to erupt ever again

lava melted rock (magma) that has reached the surface when a volcano erupts

magma molten rock beneath the Earth's surface

CHECK IT OUT

1. What is magma?
2. Bubbles form from gas dissolved in a liquid when there is a decrease in what?
3. Describe three ways a volcano can cause damage or death.
4. Does Australia have any active volcanoes?
5. Name the three possible states of a volcano.

THE AUSTRALIAN PLATE

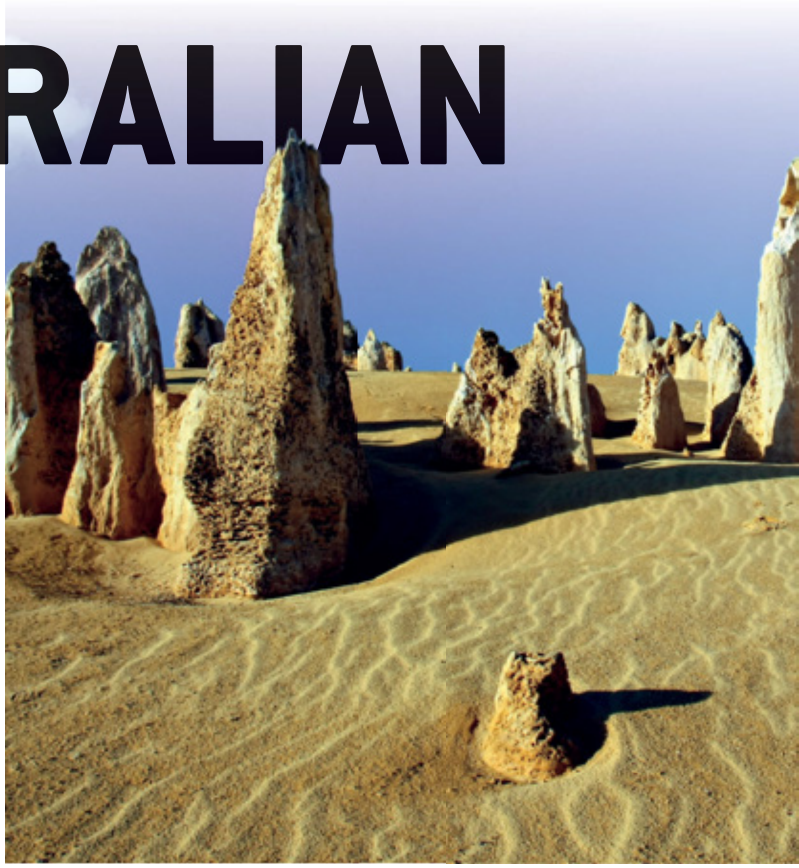
Australia is a very old continent. It is far from plate boundaries and fault lines, so it is more stable than some other parts of the world. But volcanoes happened here in the past, and earthquakes still happen in Australia.

Old Australia

The oldest minerals in the world are located in Western Australia. Scientists have discovered rare grains of sand called zircon that formed more than 4 billion years ago. Some of the oldest soils in the world are found across large parts of Western Australia, which has not been covered by sea for more than 2.5 billion years.

Some areas at the surface of Victoria and Queensland are geologically much younger because they were formed by more recent volcanic eruptions.

Australia formed as a separate continent when it broke away from Gondwana almost 100 million years ago. It has been isolated from other continents for a very long time, so unique animals and plants have developed here. Many plants and animals in Australia are found nowhere else in the world.



The oldest rocks and soils on Earth are found in the west of Australia. The Pinnacles are limestone formations, located north of Perth in Western Australia.

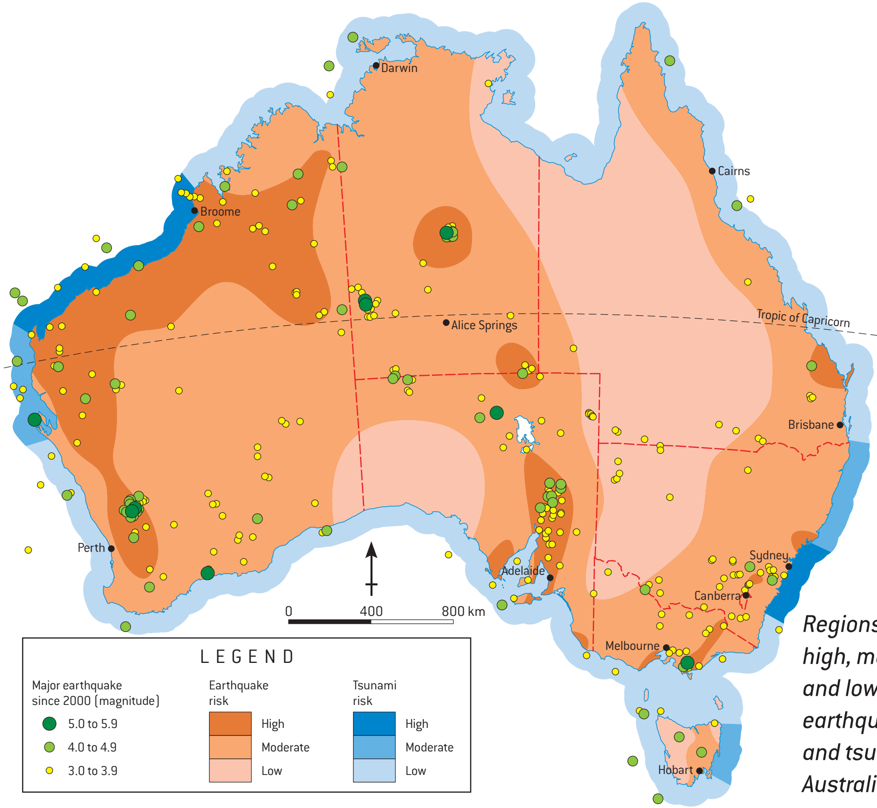
Australian earthquakes

The Australian continent sits near the centre of a plate, where tectonic activity occurs less than at plate boundaries. Nonetheless, in Australia there are on average 80 earthquakes of magnitude 3.0 or greater each year. One earthquake of magnitude 6.0 or more occurs about every five years on average.

Blue Lake in Mount Gambier, South Australia, is a volcanic crater formed by Australia's most recent volcanic eruption.

Australian earthquakes occur due to the Australian plate moving towards the Eurasian, Philippine and Pacific plates. Forces at the tectonic plate boundaries create stresses across the Australian plate that, when released, causes earthquakes.

The largest earthquake ever measured in Australia was of magnitude 7.2. It occurred in 1941 at Meeberrie, Western Australia. Thankfully this is a remote and sparsely populated area so no lives were lost, but the walls of a local homestead were damaged, rainwater tanks burst and the ground cracked.



Regions of high, moderate and low risk for earthquakes and tsunamis in Australia.

Our volcanic past

Volcanoes erupted along Australia's east coast around 45 million years ago as Australia moved north after separating from Antarctica. The plate moved over a **volcanic hotspot** in the mantle. This means southern areas of the northward-moving continent experienced volcanic activity more recently.

There are several hundred volcanoes in south-western Victoria and south-eastern South Australia that were active until relatively recently. Today, many are considered dormant rather than extinct.

Tower Hill, near Warrnambool in western Victoria, erupted 23 000–33 000 years ago. Red Rock, near Colac in western Victoria, erupted 7800–15 200 years ago. The youngest volcano on the Australian continent is Mount Gambier in South Australia. It last erupted 4000–6000 years ago.

Active volcanoes in the regions surrounding Australia can cause disruption. In June 2011, many airports in Australia had to be closed due to the Chilean volcano, Puyehue. The millions of tonnes of ash, sand and **pumice** stones it erupted into the sky caused an ash cloud stretching from Argentina to Australia. Volcanic ash can cause jet engines to stop, so aircraft in Australia were grounded.

*The Glasshouse Mountains near Brisbane, Queensland, have spectacular rock formations. They are the remains of **lava plugs** from a volcano that erupted 25–34 million years ago.*

LOOK IT UP

lava plug a landform created by magma solidifying in a volcanic crater

pumice a light, porous volcanic rock used in cleaning or polishing

volcanic hotspot an area of increased volcanic activity

CHECK IT OUT

1. Are either of the following statements true?
   a. Australia experiences many earthquakes every year.
   b. Australia experiences many volcanic eruptions every year.
2. Where are the world's oldest minerals located?
3. Where did a volcano erupt most recently in Australia?
4. Explain why many plants and animals are found only in Australia?
5. Considering the northward movement of the Australian plate, explain why volcanoes in the south of the country are younger than volcanoes in the north.

OUR PLACE IN THE SOLAR SYSTEM

The planets of our Solar System.

After the Sun began to form about 5 billion years ago, dust and gas gathered in rocky clumps. As the clumps grew, their gravity increased and attracted more rock, eventually forming four rocky inner planets, four gaseous or icy giants and icy outer planetoids. The solar system also contains more than 100 moons, several thousand asteroids and billions of comets. The planets' landscapes are very different but they each have rocks as old as the Earth and minerals similar to ours.

1 Mercury

- closest planet to the Sun
- has no atmosphere
- crater-covered surface reaches temperatures of 400°C
- surface is rough and rocky with a layer of dust and sand
- probably has a solid iron core surrounded by a molten iron layer, similar to Earth, although we can't be sure because no spacecraft has landed on Mercury

2 Venus

- surface temperature is around 460°C
- surface is mainly bare rock, with some soil-covered rolling plains
- high mountains and volcanoes
- surface is covered by lava flows, and there are fault lines carved by earthquakes – one lava-filled basin is larger than Australia and there is a volcano taller than Mount Everest
- crust is composed of silicates (sand and other minerals similar to Earth)
- core is likely to be iron and nickel

3 Earth

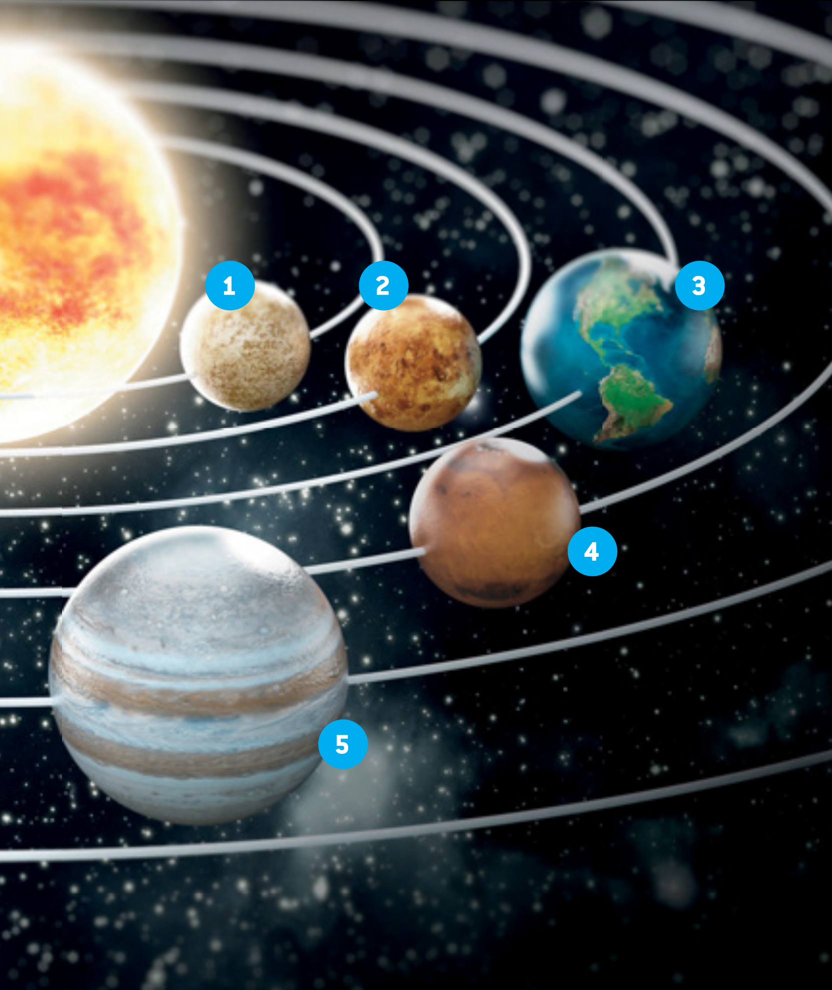
- global average surface temperature is 15°C
- highest recorded temperature in shade is 58°C in Libya; lowest is –89.2°C in Antarctica
- thin crust with diverse landscapes at surface, vegetation on land, huge oceans, frozen water at the poles
- mantle made of silicate salts (like sand); iron and nickel core

4 Mars

- surface temperature is around –33°C
- rich in iron – iron on Earth rusts when exposed to air, turning a reddish-brown colour; the iron in Martian soil reacted with ancient water, forming red rust, which makes Mars stand out as a red dot in our sky among the many blue and white dots
- surface is a wind-blown desert with many sand dunes – strong winds blow dust particles from the rust-red surface into the Martian atmosphere, adding to the red appearance

5 Jupiter

- gas giant – is more like a sun than an Earth-type planet
- beneath its thick atmosphere of hydrogen and helium gas is a layer of liquid metallic hydrogen; beneath this there may be solid rock at its core
- Io, the third largest moon of Jupiter, is the most volcanically active object in our solar system – Io is orange because of the sulfur erupting from hundreds of volcanoes across its surface



6 Saturn

- gas giant
- has rings made of lumps of ice-coated rock, frozen gases and ice – the rocks probably came from comets or asteroids that broke up before they reached Saturn
- probably has a core of iron and rock, surrounded by metallic hydrogen, and a thick gaseous atmosphere (similar to Jupiter)

7 Uranus

- ice giant
- probably has a small rocky core made of iron, nickel and silicates, surrounded by an icy mantle of frozen gas – methane gas above the clouds gives the planet its blue–green colour
- may contain liquid diamond oceans, with solid diamond icebergs

8 Neptune

- ice giant
- small rocky core made of iron, nickel and silicates, surrounded by an icy mantle of frozen gas, and an atmosphere of hydrogen and helium
- may contain liquid diamond oceans, with solid diamond icebergs (similar to Uranus)

And beyond ...

There are several dwarf planets beyond Neptune, including Pluto, Ceres, Eris, Haumea and Makemake, plus several others thought to be dwarf planets, and hundreds of minor planets. These are probably made up of ice and rock.

Asteroids, meteors and meteorites

Asteroids are rocky bodies less than 1000 kilometres across. There are many thousands of these in a region called the asteroid belt.

Meteors are particles that enter the Earth's atmosphere. Every day, hundreds of tonnes of meteor dust enters our atmosphere. When material from space reaches the ground, we call it a meteorite.

Most meteorites are rocks, made up of silicates. A small number are metallic iron and nickel, or a combination of rocky and metallic material.

Most meteorites are about 4.6 billion years old. This is the age of the oldest rocks found on the Earth.

CHECK IT OUT

1 'Other planets experience earthquakes and volcanic eruptions.' True or false?

2 Name two minerals found on Earth that you would also find on other planets.

3 Explain the similarities between the internal structure of rocky planets (Mercury, Venus and Mars) and the internal structure of Earth.

4 Imagine in the future that it is possible to extract mineral resources from other planets. Explain which planet you would choose to mine, taking into account the cost of getting there and the value of the minerals.

5 DEADLY DISASTERS

Some of the damage following the April 2015 Nepal earthquake.

1 Krakatoa volcano

The 1883 volcanic eruption of Krakatoa in Indonesia was one of the deadliest and most destructive eruptions ever recorded. More than 36 000 people were killed by the eruption and ensuing tsunamis. Explosions collapsed most of the island and only a third of it remains today.

The eruption was probably the loudest sound ever heard in recorded history. People heard the main eruption 5000 kilometres away, including in Perth and Alice Springs. Barometers around the world measured the shock wave of the final explosion for days.

The ash distributed around the upper atmosphere reflected away sunlight, lowering the global temperature by more than a degree for the following year.

An artist's impression of the eruption of Krakatoa in Indonesia.

2 The Nepal earthquakes

Nepal experienced a series of deadly and damaging earthquakes in 2015. They were caused by a release of built-up stress where the Indian plate converges with the Eurasian plate, pushing up the Himalayas.

A magnitude 7.8 earthquake occurred 80 kilometres north-west of the Nepalese capital of Kathmandu on 25 April 2015. It was Nepal's strongest earthquake in more than 80 years. More than 8000 people were killed and 19 000 injured. The earthquake caused an avalanche that killed 19 people on the world's highest mountain, Mount Everest. About 100 people were also killed in neighbouring China, India and Bangladesh.

Two weeks later, on 12 May, a magnitude 7.3 earthquake (one of many aftershocks) occurred between Kathmandu and Mount Everest. This killed more than 125 people and injured more than 2500.

The earthquakes caused $5 billion worth of damage, and the death toll of the combined disaster was the highest in the country's history.

The remains of the Indonesian volcano Krakatoa are still active today. This smaller volcano is called Anak Krakatoa, which means 'child of Krakatoa'.

Damage in Thailand following the 2004 Indian Ocean tsunami.

3 Boxing Day tsunami

On the morning of Boxing Day 2004, an earthquake of magnitude 9.0 struck the ocean floor off Sumatra, Indonesia. The seafloor rose several metres, causing a tsunami to speed towards countries around the Indian Ocean.

Waves up to 15 metres high struck coastlines in many countries, killing about 300 000 people. It is the deadliest tsunami in recorded history and one of the world's worst disasters ever.

4 Pompeii

Mount Vesuvius near Naples, Italy, erupted in 79 CE. The Ancient Roman city of Pompeii was buried beneath metres of hot ash and pumice. The city was discovered 1500 years later, preserved beneath the ground.

It is estimated that 16 000 people were killed by the heat of the eruption, suffocated by the hot ash or crushed by rocks or collapsing buildings. It is the third-highest death toll due to a volcanic eruption, surpassed only by Krakatoa and Mount Tambora.

Mount Vesuvius is still active today. The last eruption was in 1944, destroying several nearby towns.

5 Newcastle earthquake

Australia has dozens of small earthquakes each year, and about every two years an earthquake above magnitude 5.5 shakes the country.

The magnitude 5.6 earthquake in Newcastle, New South Wales, in December 1989, was one of Australia's worst natural disasters. More than 160 people were injured and 13 people were killed. The earthquake damaged more than 35 000 homes, 147 schools and 3000 other buildings. The estimated damage bill was $4 billion.

The earthquake occurred about 11 kilometres below the surface, with the epicentre about 15 kilometres south of the Newcastle city centre. It was felt hundreds of kilometres away.

CHECK IT OUT

1. In what year did the volcano Krakatoa erupt?
2. Are the volcanoes Krakatoa and Vesuvius active, dormant or extinct?
3. What was the magnitude of the earthquake that damaged Newcastle, NSW, in 1989?
4. If Mount Vesuvius experienced a major eruption today, would the death toll likely be greater or less than the death toll in 79 CE? Consider changes in population and warning systems.
5. Explain the factors that you think contributed to the 2004 Boxing Day tsunami being the world's deadliest tsunami.

The eruption of Mount Vesuvius in 79 CE covered residents of Pompeii in hot ash and volcanic rock. Their remains were found centuries later, showing the positions they were buried in.

PLANET EARTH

THE RESTLESS EARTH (PAGES 102–103)

1 What is the Earth's crust and upper layer of the mantle called?

2 What causes convection currents in the Earth's mantle?

3 At what speed do tectonic plates move?

THE EARTH ON A PLATE (PAGES 106–107)

4 Name the two large continents that the supercontinent Pangaea broke into.

5 How many major tectonic plates are there on Earth?

6 Is it possible that the continents will re-form into a single supercontinent in future? Briefly explain your answer.

EVIDENCE THAT THE EARTH MOVED (PAGES 108–109)

7 List three sources of evidence that tectonic plates move.

8 What was Alfred Wegener's theory?

9 Fossils of a type of fern are found in South America, Africa, India, Australia and Antarctica. How long ago must the fern have lived to explain its appearance on all these continents?

OUR VIOLENT PLANET (PAGES 110–111)

10 What type of boundary is caused by:

- **a** two plates slipping past one another?
- **b** two plates moving apart?
- **c** two continental plates moving towards each other?

CHANGES BENEATH THE SEA (PAGES 112–113)

11 When and where are mid-ocean ridges formed?

12 Name three minerals that you would find around a black smoker beneath the ocean surface.

13 What is the Mariana Trench?

EARTHQUAKES (PAGES 114–115)

14 The February 2011 earthquake in Christchurch, New Zealand (below), was magnitude 6.3. How much more powerful is an earthquake of magnitude 7.0 than an earthquake of magnitude 6.0?

15 What types of waves does a seismometer measure?

16 'More than 100 000 earthquakes occur worldwide each year.' True or false?

VOLCANOES (PAGES 116–117)

17 What is magma called when it reaches the Earth's surface (right)?

18 Does the Australian mainland have any dormant volcanoes?

19 How many volcanoes on Earth are active?

THE AUSTRALIAN PLATE (PAGES 118–119)

20 Where is Australia's youngest volcano located?

21 On average, Australia experiences how many earthquakes of magnitude 3.0 or greater each year?

22 Explain how Australia can experience earthquakes even though it is far from a tectonic plate boundary.

OUR PLACE IN THE SOLAR SYSTEM (PAGES 120–121)

23 Name the four rocky inner planets and the four gaseous or icy giant planets.

24 What is the most volcanically active object in our solar system?

25 What are Saturn's rings (right) made of?

26 What is material from space that reaches the Earth's surface called?

5 DEADLY DISASTERS (PAGES 122–123)

27 What was the date of the world's deadliest tsunami?

28 How many centuries passed between the eruption of Mount Vesuvius and the discovery of the buried city of Pompeii?

29 Considering the available technology at the time of the 1883 volcanic eruption of Krakatoa, list some of the scientific and anecdotal recordings that have documented the size of the eruption.

KEY IDEAS

1 The Earth's crust and the brittle upper part of the mantle are made up of 15 main segments called tectonic plates that constantly move at a speed of 1–16 centimetres a year.

2 Tectonic plates move towards or away from each other due to convection currents caused by the heating and cooling of the Earth's mantle.

3 The supercontinent Pangaea began to break apart about 200 million years ago into two land masses: Laurasia to the north, and to the south Gondwana, from which Australia separated about 100 million years ago.

4 The idea that continents move was first suggested by Alfred Wegener in 1912. Evidence that tectonic plates move includes continental plate shape, fossils and the location of earthquakes and volcanoes.

5 Two plates can move towards each other and collide to form a converging boundary; move apart to form a diverging boundary; or slip past each other to form a transform boundary.

6 All of the world's oceans contain a mid-ocean ridge formed by seafloor spreading, which is constantly creating new seafloor.

7 The 11-kilometre deep Mariana Trench is the world's deepest point, and is part of the boundary between two tectonic plates in the Pacific Ocean.

8 An earthquake occurs when two plates suddenly slip horizontally or vertically past each other, causing the ground to move by up to several metres. The magnitude of an earthquake is described using a logarithmic scale, which means every increase of one on the scale is an increase of ten in the earthquake's power.

9 Each year there are around half a million earthquakes. On average, about 100 000 can be felt, about 18 are major earthquakes (with a scale magnitude of between 7.0 and 7.9) and one is a great earthquake (more than magnitude 8.0).

10 When an earthquake occurs beneath the ocean, the movement of the seafloor can push the water above to start a giant wave called a tsunami.

11 A volcanic eruption can cause destruction due to emissions of poisonous gas, boiling lava and clouds of ash, or by lowering global temperatures. There are about 1500 volcanoes on Earth that are active, 80 known undersea volcanoes, many volcanoes that are dormant, and others that are extinct.

12 Australia is an old continent with some of the oldest minerals and soils in the world.

13 There are many dormant volcanoes in south-eastern Australia that were active until relatively recently.

14 Australia has an average of 80 earthquakes of magnitude 3.0 or greater each year, and one of magnitude 6.0 or more about every five years.

15 The solar system comprises other rocky planets as well as gaseous or icy giants, icy outer planetoids, moons, asteroids and comets. Meteorites consist of material from space that reaches the Earth's surface.

ENERGY TRANSFER 06

Hear the **WAVES**

MAKE AN **ELECTRICAL CIRCUIT**

5 AMAZING USES OF electromagnetic radiation



SURFING THE WAVES

Waves are vibrations that transfer energy from place to place. An ocean wave can travel many hundreds of kilometres, transferring lots of energy. Water at the surface just moves up and down as the wave passes. The water doesn't move long distances, but the energy can.

Ocean waves

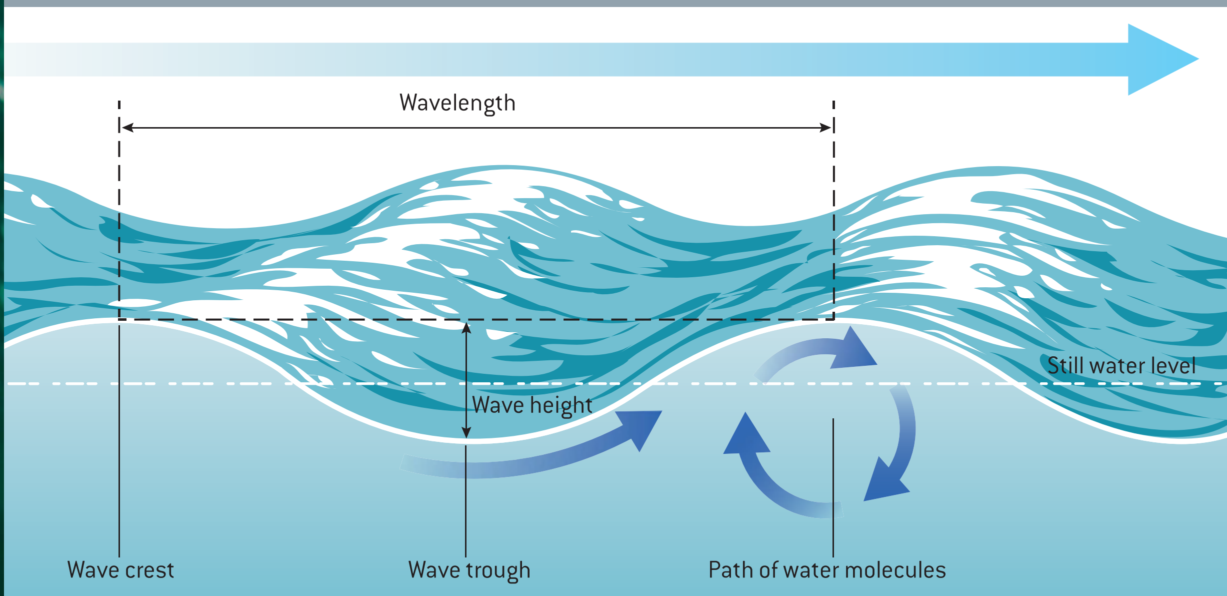
Surfers swim out through breaking waves and wait to catch a wave. The waves pass under the board, raising it up and down. There is a lot of energy passing through the water towards the shore, but the water itself is not moving to the shore.

Waves are energy passing through the water, causing it to move in a circular motion. When a wave passes under a surfer floating on a board, the wave makes the surfer move forwards and upwards and then down and back. The surfer ends up in approximately the same position as before the wave came. While the surfer and the water underneath them haven't moved towards the beach, energy has passed by.

The energy for waves usually comes from strong winds. Surf conditions are often good after a storm further out at sea.

One of the largest waves ever surfed was 24 metres high, off Nazare, Portugal. That's as high as an eight-storey building!

THE PARTS OF AN OCEAN WAVE



An ocean wave can travel many kilometres, transferring lots of energy. The ocean water itself is not moving kilometres. Waves transfer energy, not mass.

Waves break when they reach shallow water. This can happen at the beach or at a sandbar or reef. The waves slow and get closer together, and the wave crests climb higher. Finally, the fast-moving back of the wave spills over the front of the wave. This process is called breaking or cresting.

Waves can reach enormous heights. The Banzai Pipeline in Oahu, Hawaii, features waves up to 9 metres tall. Mavericks, in California, has waves up to 15 metres high.

In 2004, a huge earthquake beneath the Indian Ocean off the coast of Sumatra, Indonesia, caused a tsunami that affected the coasts of many countries. The wave speed reached 800 kilometres per hour. When the wave hit land, in some places it was as high as 15 metres. Approximately 300 000 people were killed.

Ripples in a pond are an example of the movement of waves.

LOOK IT UP

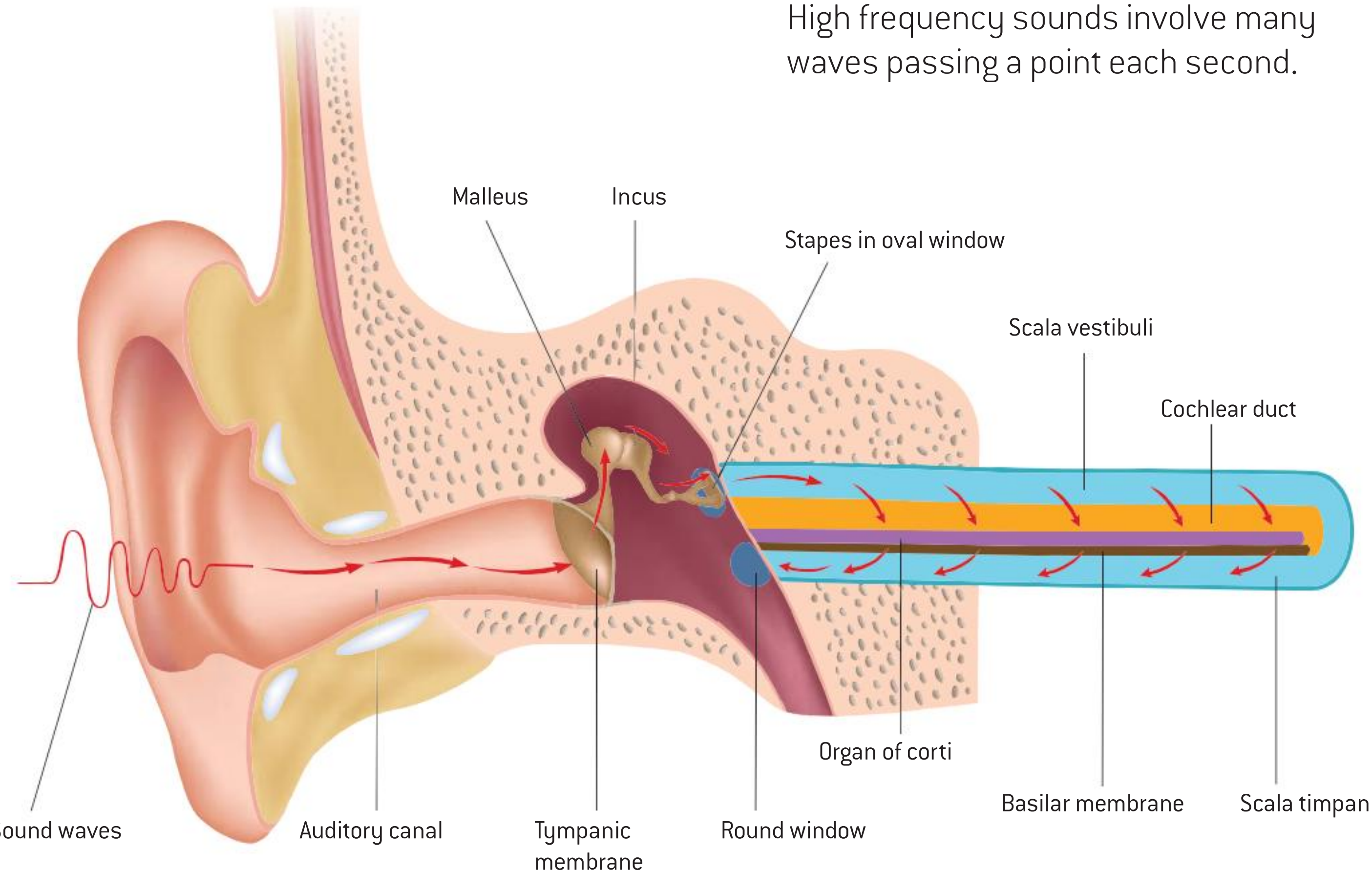
waves vibrations that transfer energy from place to place

CHECK IT OUT

1 What happens to a floating surfer as a wave passes?
2 Define the terms wavelength and wave crest.
3 Complete this sentence:
Ocean waves transfer ________;
they do not transfer ________.
4 Describe the process that can occur when a wave moves into shallow water.

LISTEN TO THE WAVES

Sound travels as waves carried by **vibrating** particles. Sound moves far more slowly than light. Sound travels faster through solids than liquids and gases. It cannot travel through a **vacuum** such as in space. High frequency sounds involve many waves passing a point each second.



Seeing before hearing

Imagine you're watching a cricket match. The bowler runs in. The batter strikes the ball, sending it sailing up into the sky. You see the bat hit the ball before you hear the sound. That is because light travels much faster than sound.

Light travels at least 1 million times faster than sound. Light travels at about 300 million metres per second, whereas sound in air travels at about 300 metres per second.

If you are 300 metres away from the batter, it will take 1 second for the sound from the bat hitting the ball to reach your ears.

The crack of the bat hitting the ball sets up vibrations in the air around it. The vibrations push the air particles further apart in one place – called **rarefaction**, and closer together in another – called **compression**. This is the start of a sound wave that travels in all directions from the bat. Air particles move back and forth as the vibration passes through the air. The sound passes through the air as a wave. The air particles themselves don't race from the bat to your ear, but the energy does.

Finally, the air close to your ears vibrates and causes your eardrum to vibrate too. That's when you hear the sound.

You can work out how far away a lightning strike is by measuring the number of seconds between the flash of light and the sound of thunder. Every 3 seconds between the light and sound is about 1 kilometre.

Speed of sound

Vibrating particles transmit sound. There is no sound in the vacuum of space because there are too few particles there.

Sound travels faster through solids than through liquids, and faster through liquids than through gases. For example, sound moves through steel about 15 times faster than through air. Sound passes through sea water about 5 times faster than through air.

Sound travels quickly through solids because their particles are packed more closely together. The particles can readily collide with each other, transmitting the sound energy.

People doing The Wave at a sporting event. The crowd of people represents the wave medium. The people moving up and down represent the disturbance. Although each person just moves up and down, the wave can travel all the way around the stadium.

LOOK IT UP

compression a point in a wave with maximum density

rarefaction a point in a wave with minimum density

sound vibrations that travel through the air or another substance and can be heard

vacuum a space with nothing in it

vibrating moving rapidly to and fro

CHECK IT OUT

1. How far does sound travel through air in 1 second?
2. How do air particles transmit a sound wave?
3. Why is there a delay between seeing lightning and hearing the thunder?
4. Why does sound pass through solids more quickly than through gases?

SOUNDS

High frequency sounds have short **wavelengths**. Low frequency sounds have long wavelengths. Loudness depends on the amount of sound energy.

Sounds can be loud …

or soft.

High and low notes

The sounds of a piccolo or whistle, or a mosquito's buzz, are high notes. The sounds of a bass drum or bass guitar, or thunder, are low notes. The difference between high and low notes is due to their different frequencies.

Frequency is a measure of how many waves (rarefactions and compressions) pass every second and is measured in cycles per second, or **hertz (Hz)**. Our ears can detect sounds with frequencies as high as 20 000 Hz and as low as 15 Hz.

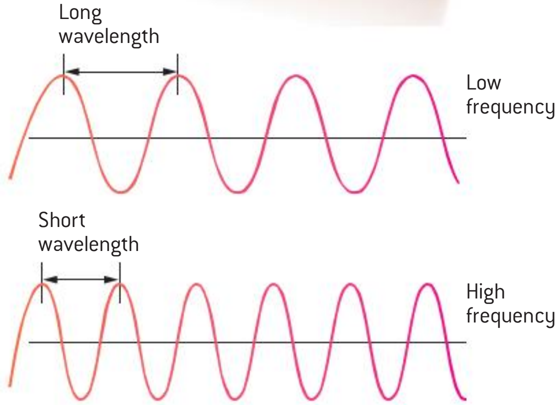
High-frequency sounds have short wavelengths. That is, the rarefactions and compressions are close together. A high-frequency note at 20 000 Hz has a wavelength of 17 millimetres in air at room temperature. Low-frequency sounds have long wavelengths. The low, rumbling 15 Hz sound has a wavelength of 23 metres.

Sounds can be pitched high, such as from a flute, or low, like the sound of a bass drum.

How loud?

Loudness depends on the amount of sound energy. The further away you are from the source of the sound, the lower the loudness or volume. As the waves move away from their source, the energy is spread across more and more air particles so there is less sound energy.

At a distance of 2 metres from the source of a sound, the volume is one-quarter of the volume at 1 metre. At 3 metres from the source, the volume is one-ninth of the volume at a distance of 1 metre.



Low-frequency sounds have long wavelengths; high-frequency sounds have short wavelengths.

EXPERIMENT #17

SLINKY SOUNDS

AIM: TO USE A SLINKY SPRING TO MODEL THE COMPRESSIONS AND RAREFACTIONS OF A SOUND WAVE

MATERIALS

- Slinky spring

METHOD

1. Two students hold the slinky spring, one person at each end.
2. On the floor, slowly stretch the spring out slightly beyond its normal length.
3. One person pushes their end of the spring firmly towards their partner. This will create areas where the coils are pushed together (compressions) and areas where the coils are stretched out (rarefactions). These areas will travel along the spring to the other end, as a wave. The person at the other end needs to hold the spring motionless.
4. Give the wave more or less energy by changing how hard you push the end. Try to keep the speed of the wave the same. This is the same as making a sound louder. Pushing gently models a softer sound.
5. Create a different type of wave with one person moving their hand quickly from left to right, while the other holds the spring still.

RESULTS

Record your observations, including a labelled diagram.

DISCUSSION

1. What happened when the wave reached the other end of the spring?
2. Do you know what this is called in real life? (Think of what happens to sounds as they hit a hard surface. What do you hear?)
3. Describe the shape and behaviour of the wave in step 5. How does it differ from the first wave?

CONCLUSION

Write a conclusion for this experiment that addresses the aim.

LOOK IT UP

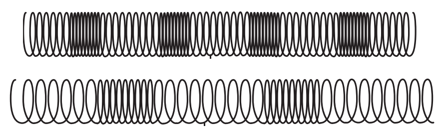
frequency the measure of how many waves pass a point every second; measured in cycles per second (hertz)

hertz (Hz) the unit of frequency, equal to one cycle per second

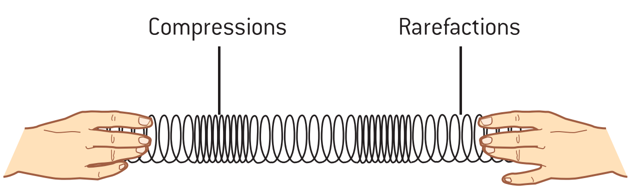
wavelength the distance between successive crests of a wave

CHECK IT OUT

1. What is sound frequency and how is it measured?
2. Which of the two springs in the diagram shown represents a lower frequency note?



3. Consider three tuning forks of frequencies 250 Hz, 500 Hz and 1000 Hz. Which fork would:
   a. sound the deepest?
   b. have the highest pitch?
4. Why does sound volume drop as you move further away from the source?



Waves passing along a slinky spring.

PARTICLES OR WAVES?

Scientists explain the features of light by saying that it behaves both as tiny particles, called **photons**, and as waves. There are **longitudinal waves**, such as sound waves, where particles move backwards and forwards along the direction of the energy flow. There are also **transverse waves**, in which the wave travels at right angles to the energy movement. Ocean waves are an example of transverse waves.

A transverse wave is passing along this rope.

Christiaan Huygens described light as waves, while Isaac Newton proposed that light is made of particles.

What is light?

What is light? You can't touch it or weigh it.

Scientists 1000 years ago described vision as a process involving light rays bouncing from an object to a person's eye.

In 1690, Dutch scientist Christiaan Huygens proposed that light passes through the air as a series of vibrations or waves.

Soon after, in 1704, English physicist Isaac Newton disagreed with Huygens. Newton proposed that light is made up of particles that move in straight lines and reflect off a mirror just like balls bouncing off a wall.

One of the reasons why many scientists thought that light was made of particles was that it travelled through space. Light from the Sun passes through the vacuum of space to reach us. The only waves that scientists knew about at the time were ocean waves and sound waves. Both of these needed something to travel through, such as sound needing to travel through air.

Today we know that light waves *can* pass through a vacuum.

However, there are some aspects of the behaviour of light that can't be fully explained by the idea of light waves. In 1905, Albert Einstein described light as travelling in little packets. He called these packets photons.

Photons are little packets of energy with no mass. They can travel through space, air, water and glass. Photons have different energies, representing different colours.

Physicists now describe light as a collection of one or more photons passing through space as waves. Thinking of light as particles explains some of its properties; thinking of light as waves explains other properties.

Different types of waves

There are two different ways that waves can travel: as longitudinal waves and as transverse waves.

Longitudinal waves move in the same direction as the energy flow. This happens with sound waves. Waves moving backwards and forwards are considered longitudinal waves. They can be set up in a spring by moving it backwards and forwards – the longitudinal wave moves along the spring. Seismic waves are also longitudinal waves. They are shock waves, usually caused by earthquakes, that travel through the ground.

Transverse waves travel at a right angle to the energy movement. Ocean waves are a good example of transverse waves. Wave energy passes horizontally through the water, sometimes towards a beach. The actual movement of the water is up and down as the waves pass by.

LOOK IT UP

longitudinal wave a wave that moves in the same direction as the energy flow

photon a particle representing light

transverse wave a wave that moves at right angles to the energy flow

CHECK IT OUT

1. How did Huygens and Newton differ in their models of the nature of light?
2. What are photons?
3. How do scientists today describe the nature of light?
4. What are longitudinal waves? Give an example.
5. What are transverse waves? Give an example.

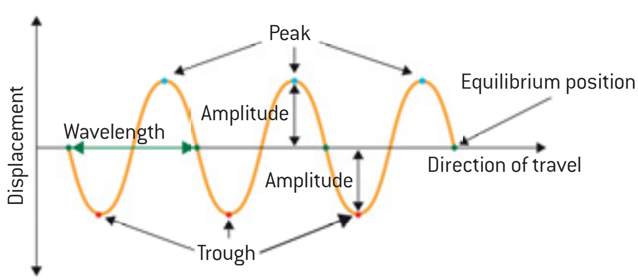
Light reflects off opaque objects and passes through transparent and transluscent objects.

MATTER CLASSIFIED BY BEHAVIOUR WHEN LIGHT STRIKES

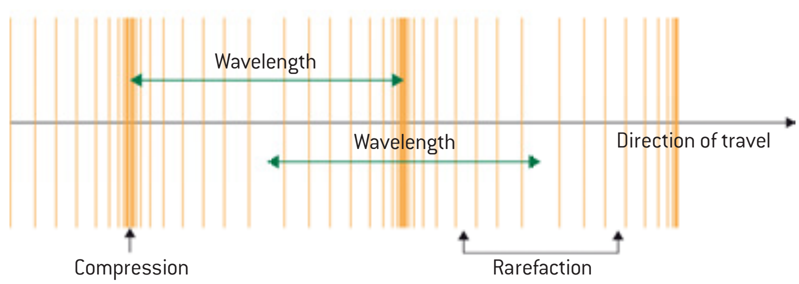
MATTER	TRANSPARENT	TRANSLUSCENT	OPAQUE
EFFECT ON INCIDENT LIGHT	Transmits	Transmits some	Absorbs or reflects
EFFECT ON VISIBILITY	See through	Not clear	Cannot see through
EXAMPLES			

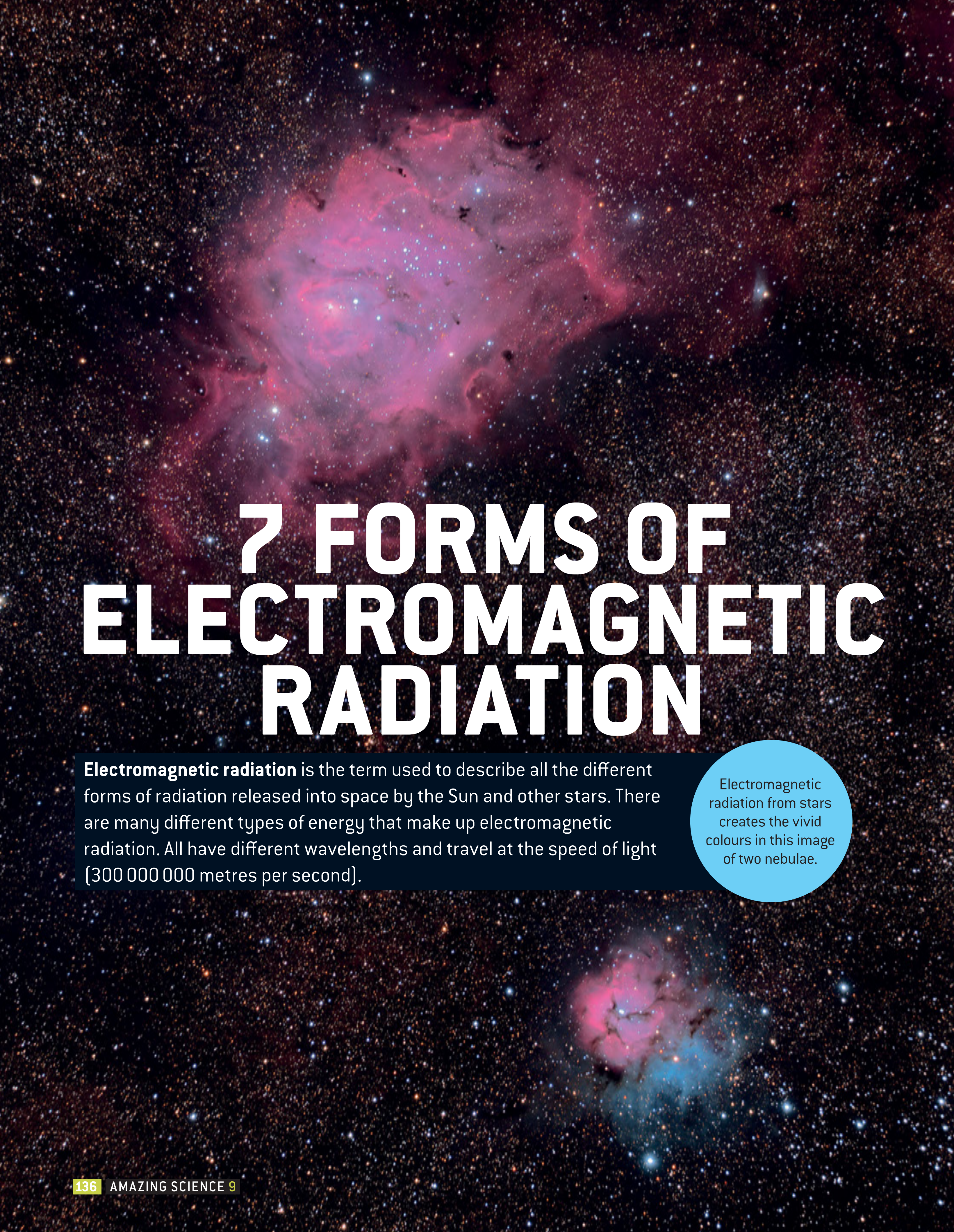
LONGITUDINAL AND TRANSVERSE WAVES

Transverse wave



Longitudinal wave





7 FORMS OF ELECTROMAGNETIC RADIATION

Electromagnetic radiation is the term used to describe all the different forms of radiation released into space by the Sun and other stars. There are many different types of energy that make up electromagnetic radiation. All have different wavelengths and travel at the speed of light (300 000 000 metres per second).

Electromagnetic radiation from stars creates the vivid colours in this image of two nebulae.

1 Gamma rays

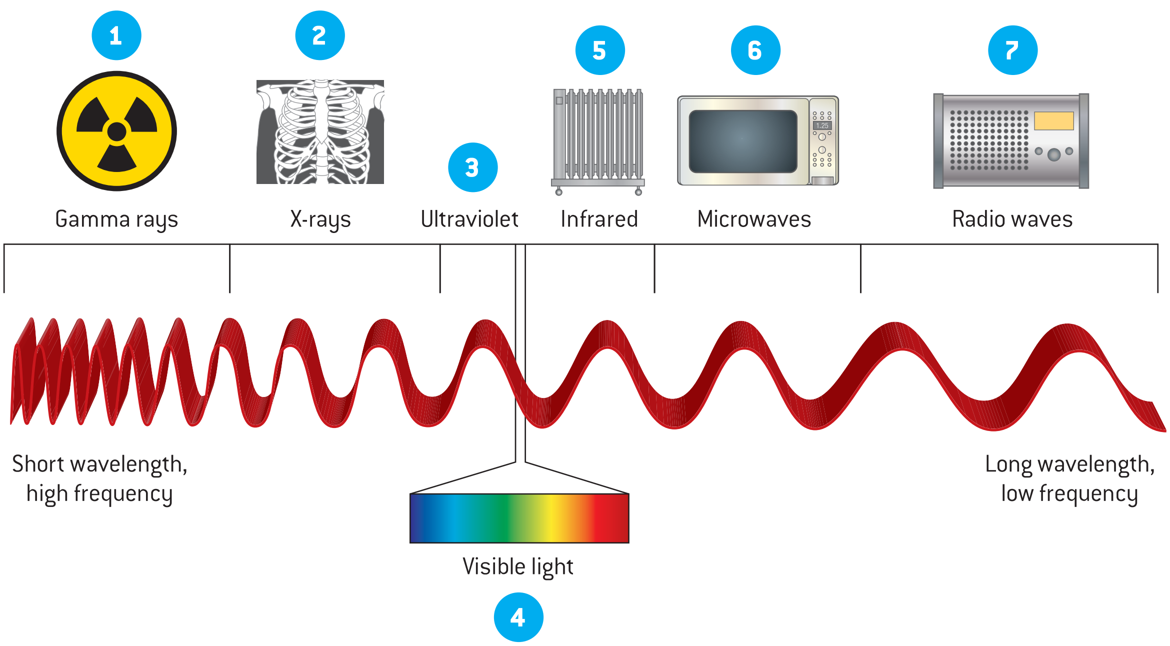
Gamma rays occur naturally from the decay of radioactive substances. Gamma rays have high energy and very short wavelengths, typically about the size of an atomic nucleus. Gamma rays have a range of medical applications.

2 X-rays

X-rays have slightly longer wavelengths than gamma rays – about the size of an atom. X-rays are used for images of people's bodies because they mostly pass through skin and soft tissue, but do not easily pass through bone.

3 Ultraviolet radiation

The Earth's protective ozone layer, 15–30 kilometres above the ground, protects us from most, but not all, of the ultraviolet radiation released by the Sun. Ultraviolet radiation can cause normal cells to become cancerous. Humans can't see ultraviolet waves, but some insects, such as bees, can.



4 Visible light

Visible light makes up about half of the electromagnetic radiation released by the Sun. Light ranges from shorter wavelength violet light to longer wavelength red light. The colours of a rainbow are arranged in order from longer to shorter wavelengths – red, orange, yellow, green, blue, indigo and violet. Passing light through a glass prism will also split light into its different colours, just like a rainbow.

5 Infrared radiation

Our skin absorbs infrared radiation. We feel it as heat. Infrared radiation has longer wavelengths than visible light. Heaters, toasters and ovens produce infrared radiation.

6 Microwaves

Water and fat absorb microwaves. Wavelengths range from as short as 1 millimetre to as long as 30 centimetres. Microwave cooking involves the radiation penetrating food and making the water and fat molecules inside it vibrate more quickly. This is different from conventional heating, where the oven's heat must penetrate the food from the outside of the food to the middle.

7 Radio waves

Radio waves are used to transmit television and radio programs. Television uses shorter wavelengths than radio. Radio waves can have wavelengths of up to many kilometres.

LOOK IT UP

electromagnetic radiation all the different kinds of energies released into space by the Sun and other stars

CHECK IT OUT

1 What is electromagnetic radiation?
2 How far will microwave radiation travel in space in one-hundredth of a second?
3 How are the forms of energy that make up electromagnetic radiation different?
4 Arrange the following in order of longest to shortest wavelengths: ultraviolet, gamma rays, infrared, X-rays, visible light and radio waves.
5 What is the difference between violet light and ultraviolet light?

5 AMAZING USES OF ELECTROMAGNETIC RADIATION

We use electromagnetic radiation in so many ways. Here are examples that rely on radio waves, light, infrared radiation and X-rays.

Wi-Fi networks link computers using radio waves.

1 Wi-Fi

Wi-Fi uses radio waves to create a zone where computers, including smart phones and tablets, can access broadband internet. This is a two-way process.

A computer's wireless adapter turns data into a radio signal and transmits it from an inbuilt antenna. A wireless router receives the signal and sends the information to the internet via its direct, wired connection.

The router also receives information from the internet, translates it into a radio signal, and then sends it to the computer's wireless adapter.

A mobile phone tower uses radio waves to send and receive signals from your mobile phone.

2 Mobile phones

A mobile phone is a combined radio transmitter and radio receiver. When you are speaking to a friend, your mobile converts your voice into an electrical signal, which it then transmits as radio waves.

Mobile phones have small antennas and little power. They can send signals over only a short distance. Nearby mobile phone towers pick up the signals and relay them via radio waves to a tower near your friend's mobile phone. Their phone picks up the radio signal and turns it back into sound.

Mobile phones are sometimes called cell phones as cities are divided up into a patchwork of hexagonal cells, each with its own phone tower.

3 Optic fibres

An **optic fibre** is a strand of high-quality glass as thin as a human hair. It can transmit computer data, such as the information from the internet, and telephone calls. The electrical signals that make up the data or telephone call are converted into either visible light signals or infrared signals, and then passed along the fibre.

The National Broadband Network aims to deliver fibre-optic cables to 93 per cent of Australian homes, schools and businesses by 2021. This will provide much faster internet speed than provided by the current copper telecommunications network.

A single optical fibre can carry the equivalent of thousands of landline telephone calls.

4 Infrared remote controls

Most home entertainment system remote controls use infrared radiation to carry their signals. The remote control transmits pulses of infrared that represent codes. These codes match commands, such as power on and volume up.

A **light-emitting diode (LED)** at the top of the remote transmits the infrared pulses. The TV or other device has an infrared receiver that reads the signal and activates the relevant controls.

Infrared remotes usually have a range of just 10 metres. Infrared won't pass through walls or go around corners – you need a straight line between the remote and the device that it controls for it to work.

The LED in the remote control transmits signals using infrared radiation.

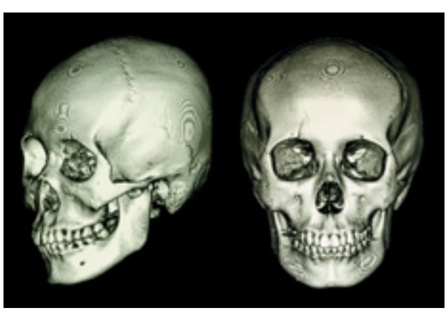
5 CT scans

CT scan stands for computerised tomography scan. Tomography involves generating a 2D image of a slice or section of an object. Many pictures of the same region are taken from different angles and then combined to produce a 3D image.

CT scanning is an important medical tool for producing detailed 3D images of parts of the body, such as blood vessels, the lungs, the brain, the abdomen and bones. Doctors use the technique for diagnosing cancers. Scans can reveal the size, location and impact of tumours.

A CT scanner moves in an arc around a person, emitting narrow X-ray beams. The final picture is far more detailed than a single X-ray image.

A doctor examines a patient with a CT scanner, which generates 3D images of the body using X-rays.



A CT scan provides detailed images, such as these of a skull.

LOOK IT UP

CT scan a detailed 2D or 3D body scan formed from many X-ray images

light-emitting diode (LED) a diode that glows when electricity passes through it

optic fibre a thin, flexible thread of glass or other transparent material that transmits light signals

CHECK IT OUT

1. Name the form of electromagnetic radiation used by both mobile phones and Wi-Fi.
2. What is the role of a mobile phone tower?
3. What advantage does optic fibre have over copper wire?
4. How does an infrared remote control work?
5. What advantage does a CT scanner have over an X-ray machine?

HEAT TRANSFER

Heat can be transferred by conduction, convection and radiation. Conduction and convection occur through materials. Radiation does not need any material to go through, not even air.

Ways of warming up

Heat is thermal energy. There are three ways that heat can be transferred from place to place: **conduction**, **convection** and **radiation**. You have experienced all three.

1 Conduction

On a cold day, you can warm your hands by touching a warm object. This is an example of heating by conduction.

2 Convection

A hot-water heater works mainly by convection. The hot metal pipes heat the air in contact with them. The hot air rises, creating what is known as a convection current. Eventually, this moving hot air will warm the whole room.

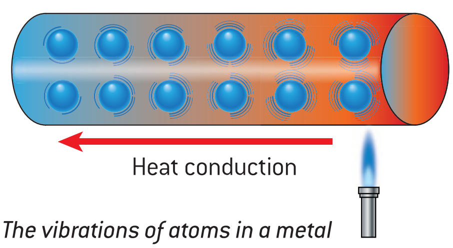
Hot-water heaters warm the air in a room by convection.

3 Radiation

You can warm yourself through radiation. You experience radiation from the Sun. Even in the middle of winter when the air around you is cold, you will feel warmth if you stand in sunshine.

Conduction – heating by direct contact

A crane lifts blocks of hot iron from a blast furnace, which converts iron ore into iron at temperatures of up to 2000°C.



The vibrations of atoms in a metal rod conduct heat away from the Bunsen burner.

Firefighters need to keep heat away from their bodies. They wear clothes that insulate and protect them from the fierce heat of fires.

Metals, such as copper, iron and brass, are excellent conductors of heat. The atoms in metals are aligned in a regular pattern, with each atom close to its neighbours. Heating a metal makes its atoms vibrate more quickly. The atoms pass on their vibrations to other atoms, passing the heat through the metal by conduction. Heat energy is conducted from the hot part of an object to the cold part.

Insulators

Non-metals and gases are usually poor conductors of heat. Plastic and wood are non-metals, and air is a gas. All of these are poor conductors of heat – they are **insulators**.

Clothes act as insulators, trapping warmth near our body in cold conditions and keeping heat out in hot environments. In cold weather, clothes trap air warmed by your body. They also act as a barrier, stopping wind and cold air currents replacing the warm air near your skin.

Wind chill is the way in which you feel colder when you have skin exposed to moving air. For example, if you are outside when the temperature is 10°C, a gentle wind may make you feel as if the temperature is actually 5°C, and a stronger wind may make you feel as if the temperature is 0°C.

Water conducts heat better than air does, so wet clothes do not insulate as well as dry clothes. The wet clothes conduct heat from your body. Additionally, there is the cooling effect of water evaporating.

EXPERIMENT #18

INVESTIGATING HEAT CONDUCTION

AIM: TO INVESTIGATE HOW HEAT SPREADS ALONG A METAL

MATERIALS

- Hot plate
- Wooden block
- Metal rod (about 30 cm long)
- Wax candle
- Matches
- Greaseproof paper
- Ruler
- Felt-tip pen
- Stopwatch

METHOD

1 Starting 5 or 6 cm from the end of the metal rod, make a pen mark every 1 cm for a length of 10 cm.

2 Place the rod on a piece of greaseproof paper. Light the candle and carefully pour a drop of wax on the rod at each mark. Leave the wax to set.

3 Place the unmarked end of the rod on the hotplate, with the marked end on the wooden block.

4 Place a sheet of paper on the bench underneath the rod to catch drips of wax and begin heating. Start the stopwatch immediately and record how long it takes for the wax to drip off each mark.

RESULTS

1 Record your data in a suitable table.

2 Construct a graph of time taken to melt the wax (vertical axis) against distance from the heated end (horizontal axis).

DISCUSSION

1 How do you think the heat was carried along the rod to each blob of wax?

2 Explain the shape of your graph.

CONCLUSION

Write a conclusion for this experiment that addresses the aim.

LOOK IT UP

conduction the direct transfer of heat through a substance

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

insulator a substance that does not readily allow the passage of heat

radiation the emission or transmission of energy in the form of waves through space or through a material

CHECK IT OUT

1 List the three ways that heat can be transferred.

2 How do you heat an object by conduction?

3 How do you heat an object by convection?

4 Describe the behaviour of atoms that allows objects to conduct heat.

5 Name two conductors and two insulators.

HOT AIR RISING

Rising convection currents of warm air, known as thermals, help hang-gliders fly.

Convection transfers heat through the movement of warm, low-density liquids and gases.

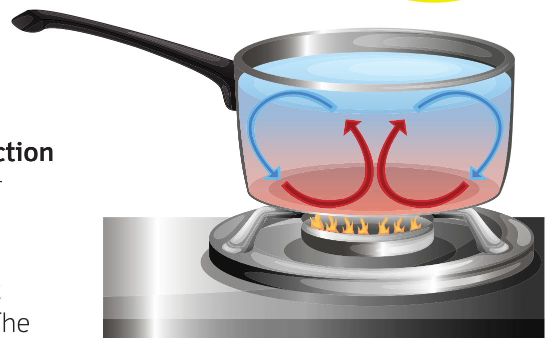
Convection – movements of gases and liquids

Hot air rising from a heater or a hot plate is an example of heating by convection.

Liquids and gases expand when they are heated. Their particles move faster when they are heated than they do when they are cold. As a result, the particles take up more volume. The spaces between the particles increase.

Air close to a heater warms and becomes less dense and rises. The denser cold air falls. This process sets up convection currents that transfer heat from place to place. **Convection currents** move hotter and colder particles within a gas or liquid.

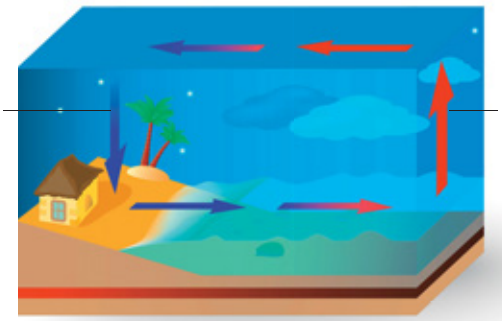
Convection also causes sea breezes. A sea breeze is one that blows from the sea to the land. The Sun heats the beach and nearby land, and the warmed ground heats the air above it by conduction. The warmed air is less dense than the cooler air above it, so it rises. This air is then replaced by cooler air, drawn in from over the sea.



Heating a saucepan full of water sets up convection currents. Conduction transfers heat from the hot saucepan to the water molecules touching the metal. The heated water (shown in red) is less dense – it rises. The cooler water (shown in blue) sinks.

THE CIRCULATION OF AIR IN A SEA BREEZE

Sea breeze



Land breeze

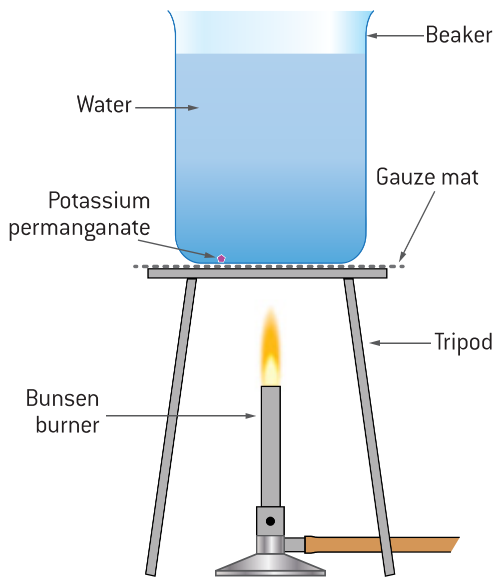
EXPERIMENT #19

INVESTIGATING HEAT CONVECTION

AIM: TO INVESTIGATE HEATING WATER BY CONVECTION

MATERIALS

- Bunsen burner
- Tripod
- Water
- Heatproof mat
- 600 mL beaker (Pyrex)
- Potassium permanganate crystals (or a few drops of food colouring)
- Dropper or pipette



METHOD

1 Set up the equipment as shown.

2 Fill the beaker with water. Place a few crystals of potassium permanganate on the bottom edge of the beaker. (Alternatively, add a drop of food colouring to the bottom of the full beaker using a dropper or pipette.)

3 Heat the water gently over the Bunsen burner and observe the movement of the coloured water. If possible, use a small flame and no heatproof mat between the burner and the beaker.

4 Observe the path that the coloured water takes.

RESULTS

Draw a labelled diagram showing the movement of the coloured water.

DISCUSSION

1 Describe the movement of the coloured water.

2 Why do you think the coloured water moved like this?

3 What was happening to the molecules of water when the water was being heated?

CONCLUSION

What have you observed about heating water by convection?

LOOK IT UP

convection current the transfer of heat by movement of heated fluid into an area of cooler fluid

CHECK IT OUT

1 What is convection and why does it occur?

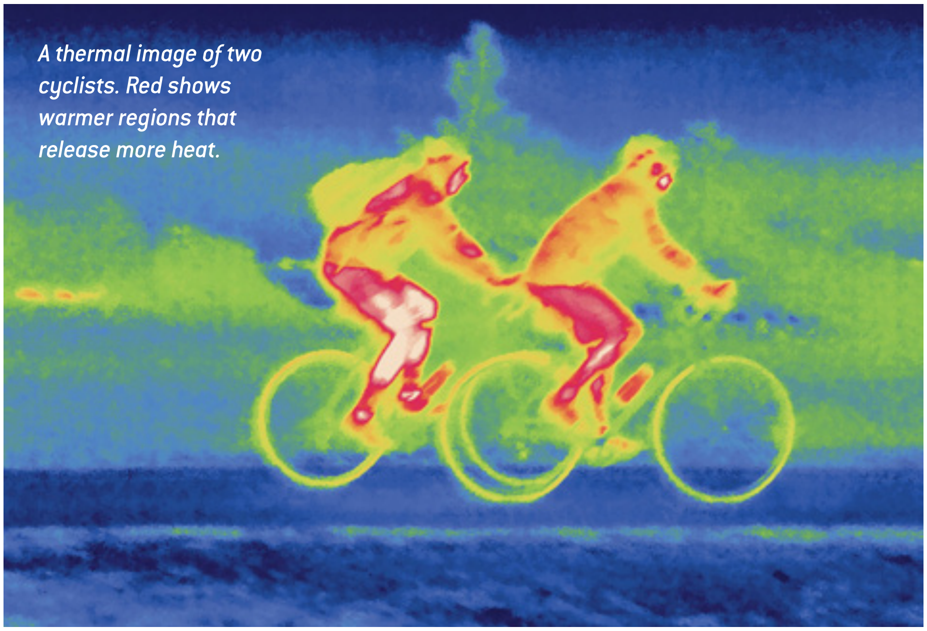
2 Explain why convection cannot occur within solids.

3 Why is heating a liquid or gas from below more effective than heating it from above?

4 How does convection cause sea breezes?

5 Modern saucepans have a copper bottom, steel sides, a plastic handle and a glass lid. Describe why each of these materials is used in these ways.

INFRARED RADIATION



A thermal image of two cyclists. Red shows warmer regions that release more heat.

All objects release and take in thermal (infrared) radiation. Infrared radiation can travel through space.

Heat

Hot objects emit more **infrared radiation** than cold objects. The vibrating atoms release infrared waves.

Infrared radiation is a form of electromagnetic radiation. It does not require particles in liquids or gases so it can pass through a vacuum. We can feel the heat of the Sun, which is 150 million kilometres away from the Earth, because the Sun's infrared radiation travels through space.

The hot wires in this heater contain rapidly vibrating atoms, which release infrared radiation that we feel as heat.

Ask a scientist

Dr Niraj Lal

Dr Niraj Lal, working to turn more energy from the solar spectrum into electricity.

Dr Niraj Lal studied physics at the Australian National University (ANU). He worked as a travelling science presenter to primary school children across regional Western Australia. He then obtained a PhD in physics from the University of Cambridge in the United Kingdom.

Niraj has returned to ANU to study and develop high-efficiency solar cells. Solar cells turn sunlight into electricity. Light with enough energy knocks electrons from the materials in the solar cells and creates an electric current.

Niraj has recently studied solar cells consisting of two layers – a high-efficiency silicon cell beneath a cheap, thin film of another semiconductor. This upper film is a material called perovskite – calcium titanium oxide.

The advantage of a two-layer solar cell is that it can turn more wavelengths of light into electricity. The lower layer converts wavelengths that don't activate the top layer. These dual cells can turn more than 30 per cent of the Sun's visible light energy into electricity.

A video interview with Dr Niraj Lal is available on your obook / assess.

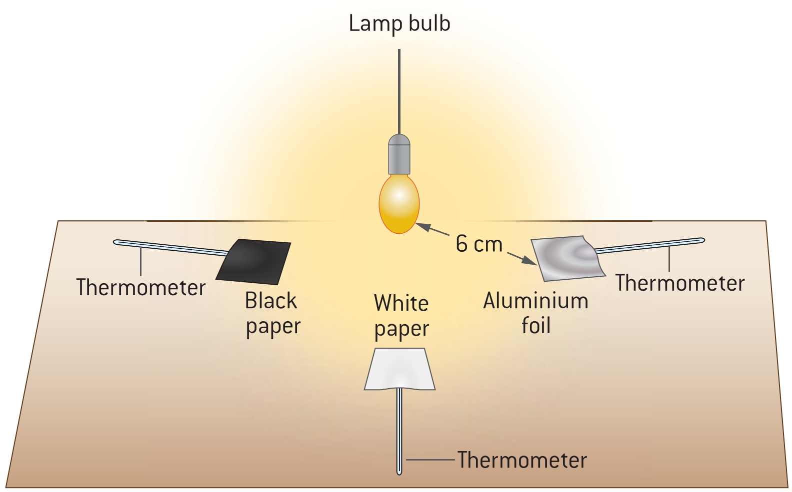
EXPERIMENT #20

INVESTIGATING HEAT RADIATION

AIM: TO INVESTIGATE HEATING BY RADIATION

MATERIALS

- 3 cm squares of black paper, white paper and aluminium foil
- 3 thermometers
- Lamp or sunlight
- 3 stopwatches



METHOD

1 Place the bulbs of the thermometers under the different materials and then place them in the Sun (or under a lamp, ensuring that they are all about 6 cm from the lamp).

2 Construct a table to record the temperature of each thermometer every minute for 10 minutes.

3 Construct graphs of the change in temperature (vertical axis) against time (horizontal axis) for the different materials.

RESULTS

List the materials from best to poorest absorbers of infrared radiation.

DISCUSSION

1 Why do you think the best absorber behaved as it did?

2 Why do you think the poorest absorber behaved as it did?

3 From your knowledge of the electromagnetic spectrum, which coloured paper is likely to absorb more heat: red or blue? Explain your answer.

CONCLUSION

What have you observed about absorption of infrared radiation by different materials?

LOOK IT UP

infrared radiation part of the electromagnetic spectrum; detected as warmth

CHECK IT OUT

1 What are two other names for infrared radiation?

2 What causes infrared radiation?

3 What is the main difference between the way in which infrared radiation and sound are transmitted?

ELECTRICAL CIRCUITS

There are millions of kilometres of copper wire in Australia carrying electricity, internet and telephone signals.

Movement of electrons through a wire creates an electrical **current**. Metals are good conductors because their electrons can move easily. The pathway travelled by electrical energy is called an **electrical circuit**.

Moving electrons

Copper is an excellent electrical conductor.

Metals such as copper are made of positively charged atoms (called ions) surrounded by electrons that are free to move. Metals are good **conductors** of electricity because these free electrons carry electrical current.

Electrical circuits

The pathway travelled by electrical energy is called an electrical circuit. A circuit always needs a power source, such as a battery, with wires connected to the positive (+) and negative (–) ends.

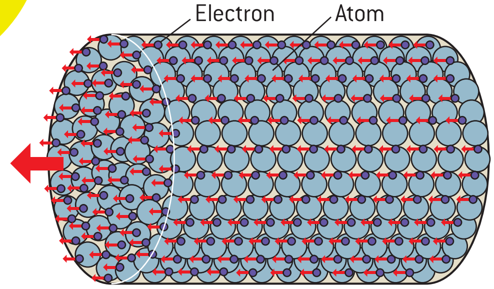
Electrical circuits usually contain devices that use energy, such as a globe or motor. Electricity will only travel around a circuit that is complete, which means it has no gaps. A switch can act as a gap, turning off the flow of electricity by creating a gap, and turning on the flow by completing the circuit.

Energy transformations occur in circuits, with electrical energy being turned into other forms of energy such as heat, light or sound.

Drawing circuit diagrams

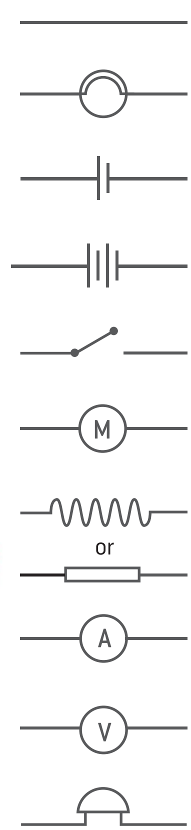
A **circuit diagram** shows the key parts of an electrical circuit. Each component is represented by a specific symbol. Connecting wires are usually shown as straight lines. Wires that join are shown as right angles.

The battery or other power source is represented as a pair of parallel lines of different lengths. The power source pushes electrical current through the circuit. The longer line represents the positive terminal (often indicated by a plus symbol) and the shorter line represents the negative terminal. Wires are connected to these terminals.



The movement of electrons through a metal forms an electrical current.

Some common symbols in circuit diagrams.



Different types of copper cable.

EXPERIMENT #21

MAKING A SIMPLE CIRCUIT

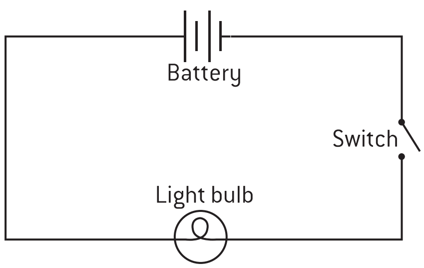
AIM: TO CONSTRUCT AND TEST A BASIC ELECTRICAL CIRCUIT

MATERIALS

- Lengths of wire
- 2 × 1.2 V light globes and holders
- Switch
- 1.5 V battery
- Alligator clips

METHOD

1 Connect the equipment as shown.



A simple electrical circuit.

2 Close the switch and observe what occurs.

3 Change the position of the switch and observe what occurs.

4 Add the second globe into the circuit and observe what occurs.

RESULTS

1 Briefly document what you observed during the activity.

2 What was the effect of changing the position of the switch?

3 What occurred when you added a second globe to the circuit?

DISCUSSION

1 Explain your observation regarding changing the position of the switch.

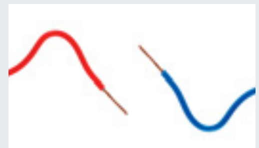
2 In terms of electrical energy, explain the impact of adding the second globe.

CONCLUSION

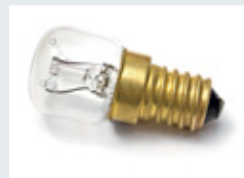
Summarise your findings.

SCIENTIFIC EQUIPMENT

- Wire



- Light globe



- Switch

- Battery

- Alligator clip

LOOK IT UP

circuit diagram a picture showing the key parts of an electrical circuit

conductor a material or device that conducts or transmits heat or electricity

current the flow of electricity

electrical circuit a path through which electrons from a power source flow

CHECK IT OUT

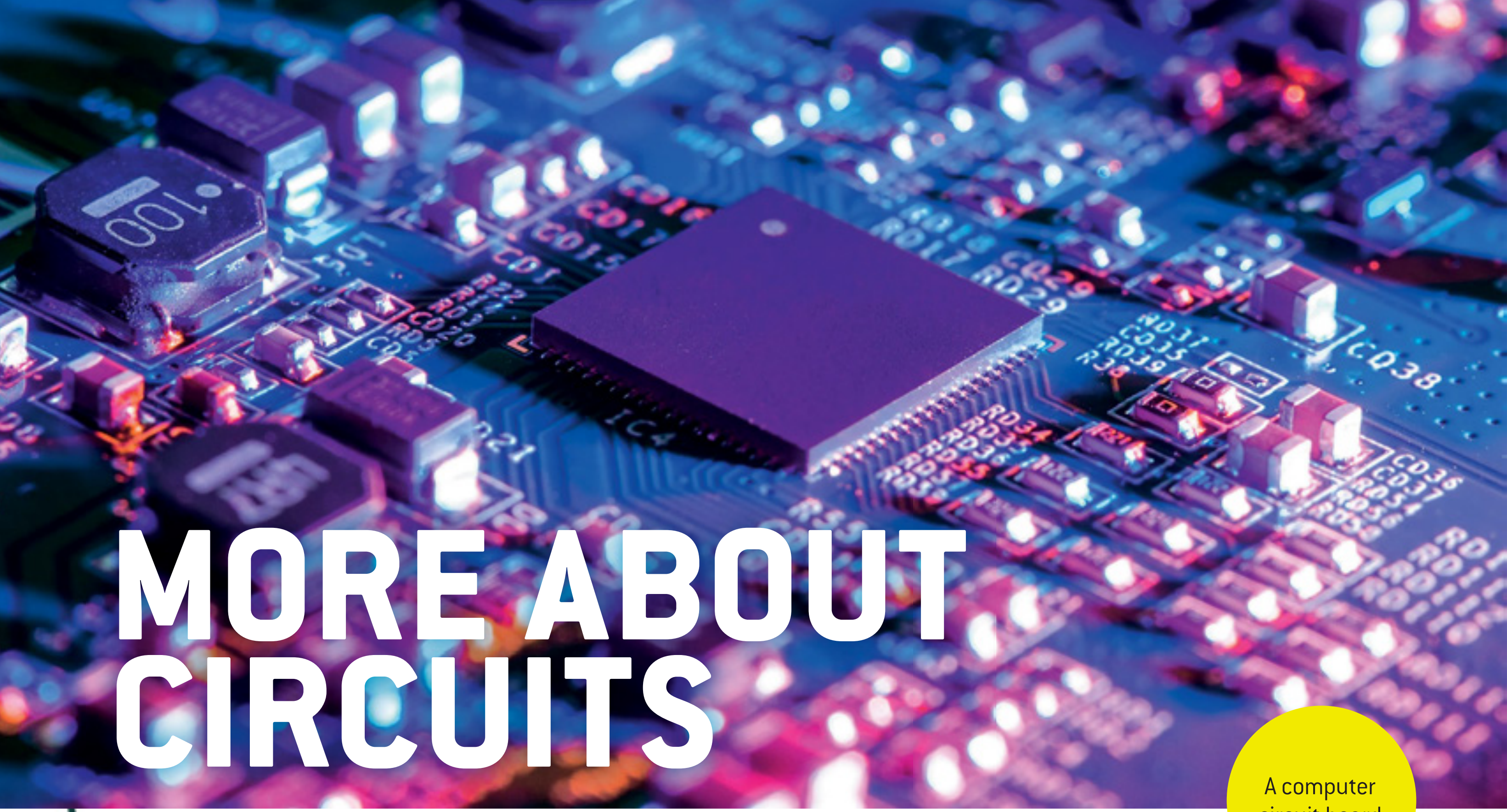
1 Why are metals good electrical conductors?

2 What is an electrical circuit?

3 Name an energy transformation that can occur in an electrical circuit and a device that will cause the transformation.

4 What is a circuit diagram?

5 What are the essential components of an electrical circuit?



MORE ABOUT CIRCUITS

A computer circuit board

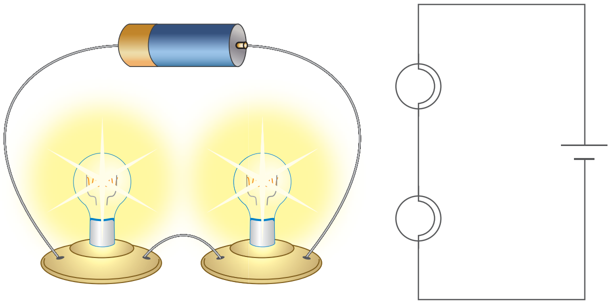
A series circuit has all components connected via a single wire. A parallel circuit has components on branches.

Sometimes Christmas lights are connected as a series circuit – if one globe stops working, they all stop working.

Series circuits

There are two different ways of connecting two light globes in a circuit. One way is to have the two globes directly connected to each other so the current goes through one globe and then the other. This is called a **series circuit**.

A SERIES CIRCUIT



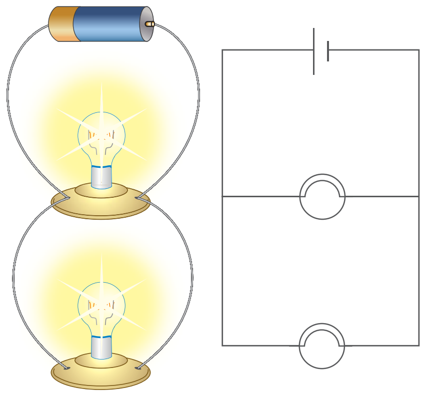
Parallel circuits

A second way of connecting a circuit is to have the globes on separate wires, with the current being split between them. This is called a **parallel circuit**.

A problem with a series circuit is that if one component fails, it acts like a switch and stops current flowing. In the series circuit with two globes, if one globe fails, the other globe will go off.

The parallel circuit avoids this problem as electricity has more than one path to follow. If one globe fails, current can still pass through the other wire, lighting the second globe. Household circuits are wired in parallel. A faulty fridge will not stop current flowing to your TV.

A PARALLEL CIRCUIT



EXPERIMENT #22

COMPARING SERIES AND PARALLEL CIRCUITS

AIM: TO DISCOVER HOW MANY DIFFERENT WAYS YOU CAN CONNECT TWO GLOBES IN A CIRCUIT

MATERIALS

- Lengths of wire
- 2 × 1.2 V light globes and holders
- Switch
- 1.5 V battery
- Alligator clips

METHOD

1 Construct circuits with two globes, placing the switch so that it controls:

   a both globes, with both either on or off at the same time

   b one globe only, with the other on all the time

   c the other globe only, with the first globe on all the time.

RESULTS

Draw the circuit diagram for each of your circuits.

DISCUSSION

1 Describe the effect of the switch in each circuit.

2 What impact did turning on the second globe have on the brightness of the other globe in circuit b and circuit c?

CONCLUSION

1 Summarise your findings.

2 Describe each of your circuits as either series or parallel.

LOOK IT UP

parallel circuit an electrical circuit in which current flows along two or more paths

series circuit an electrical circuit in which all current flows along one path

CHECK IT OUT

1 Sometimes a row of Christmas tree lights stops working.

   a Are the globes connected in series or parallel? Explain your answer.

   b Draw a circuit diagram showing how these Christmas lights are wired.

2 Describe one advantage and one disadvantage that a series circuit has over a parallel circuit.

3 A fuse is a safety device consisting of a strip of wire that melts if the current exceeds a safe level and breaks an electric circuit. Explain whether a fuse should be wired in series or in parallel with the components it is protecting.

ENERGY TRANSFER

SURFING THE WAVES (PAGES 128–129)

1 What is a wave?

2 What is the wavelength of an ocean wave if the distance from the crest to the trough is 10 metres?

3 What causes a wave to break (right)?

LISTEN TO THE WAVES (PAGES 130–131)

4 Lightning hits a tree on a hill 10 kilometres away. How long will it take for the sound of the thunder to reach you?

5 You loudly yell 500 metres from a rock face. How long will it take for you to hear the echo of that sound?

6 What will happen to the sound of a bell ringing in a glass jar as the air is evacuated? Explain your answer.

7 Describe an experiment to test the effect of air temperature on the speed of sound.

8 Matilda calculates that if a massive explosion happened 100 000 kilometres away in space, it would be almost four days before we would hear the bang. Comment on whether Matilda is correct.

SOUNDS (PAGES 132–133)

9 Explain the terms 'rarefaction' and 'compression' relating to sounds.

10 If 120 ocean waves pass a rock in 30 minutes, what is the wave frequency in hertz?

11 Which has a higher pitch: a sound with a wavelength of 2 metres or a sound with a wavelength of 20 metres?

PARTICLES OR WAVES? (PAGES 134–135)

12 How did Christiaan Huygens' and Isaac Newton's explanation of the behaviour of light differ?

13 Draw a diagram showing:

- a a transverse wave passing along a slinky spring
- b a longitudinal wave passing along a slinky spring.

7 FORMS OF ELECTROMAGNETIC RADIATION (PAGES 136–137)

14 What do all forms of electromagnetic radiation have in common?

15 Name one way in which we use:

- **a** X-rays
- **b** ultraviolet radiation
- **c** infrared radiation
- **d** microwaves.

16 Astronomers measure the vast distances of space in light years. Research 'light years' and write your own definition of a light year.

17 How are we naturally protected from most of the Sun's harmful ultraviolet radiation?

5 AMAZING USES OF ELECTROMAGNETIC RADIATION (PAGES 138–139)

18 List four applications of radio waves.

19 How do optic fibres work?

20 What is the role of an LED in a TV remote control?

21 Briefly explain whether you think the National Broadband Network represents a good investment for Australia.

HEAT TRANSFER (PAGES 140–141)

22 List the forms of heat transfer (conduction, convection and/or radiation) provided by each of the following:

- **a** hair dryer (below)
- **b** neck heat pack
- **c** hot-water bottle
- **d** open fire
- **e** sunshine.

23 Which of the following is likely to be the best conductor of heat: glass, gold or air?

HOT AIR RISING (PAGES 142–143)

24 Explain how convection transfers heat.

25 Explain how convection can warm you when you are sitting in a room on the opposite side of a small heater.

INFRARED RADIATION (PAGES 144–145)

26 Explain how heating by infrared radiation is different from heating by conduction or convection.

27 What is the Earth's main source of infrared radiation?

ELECTRICAL CIRCUITS (PAGES 146–147)

28 Which particles are responsible for the flow of electricity through a metal?

29 What is the function of a battery in an electrical circuit?

30 Name the energy transformation(s) that occur in an electrical circuit due to a:

- **a** light globe
- **b** motor
- **c** bell
- **d** heater.

31 Draw a diagram for an electrical circuit containing two cells, three light globes, a switch and a resistor.

MORE ABOUT CIRCUITS (PAGES 148–149)

32 Describe the difference between a circuit wired in series and one wired in parallel.

33 Draw a diagram for an electrical circuit containing:

- **a** three light globes in series
- **b** two light globes in series and one in parallel.

KEY IDEAS

1 Waves are vibrations that transfer energy from place to place. Ocean waves carry energy, not mass. Sea water moves up and down as waves pass; that same water does not move to the shore.

2 Sound travels as waves carried by vibrating particles. Sound cannot travel through space or a vacuum, as there are no particles present. Sound travels far more slowly than light.

3 High-frequency sounds have short wavelengths. Low-frequency sounds have long wavelengths. Frequency is a measure of how many waves pass every second.

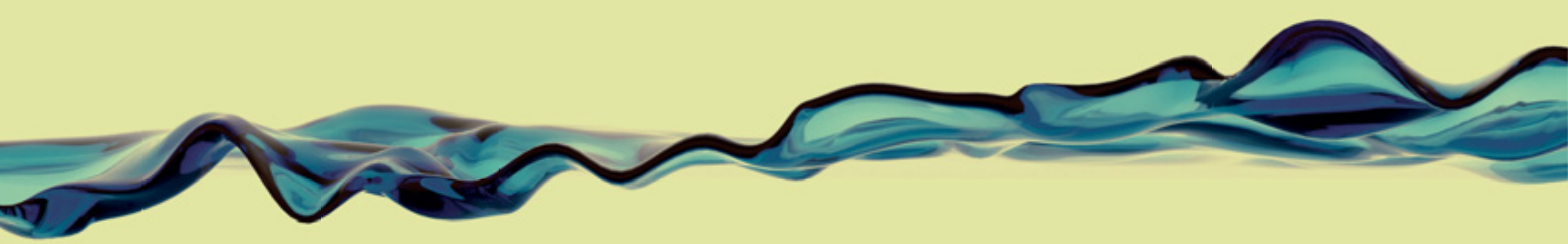
4 Scientists explain the features of light by saying that it behaves both as tiny particles, called photons, and as waves.

5 Waves can travel in two different ways. Longitudinal waves move in the same direction as the energy flow – sound is an example. Transverse waves travel at right angles to the energy movement – light is an example.

6 Forms of electromagnetic radiation, in order of increasing wavelength, are gamma rays, X-rays, ultraviolet radiation, visible light, infrared radiation, microwaves and radio waves.

7 There are three different ways that heat can transfer. Conduction involves heating by direct contact. Convection occurs through the movement of liquids and gases. Radiation is released by the action of vibrating atoms.

8 An electrical current involves movement of electrons. The pathway travelled by the electrons is called an electrical circuit. A series circuit has all components connected via a single wire. A parallel circuit has components connected on branches.



GLOSSARY

abiotic
refers to the non-living things in an ecosystem, such as water

acid
a chemical compound containing hydrogen; turns litmus red

acid rain
rainfall made acidic by air pollution

adrenaline
a steroid hormone produced by your adrenal glands that causes responses including increased heart rate and blood pressure

aerobic respiration
respiration in presence of oxygen

algal bloom
a large growth of tiny blue–green algae in a body of water

alkali
a base dissolved in water; turns litmus blue

alpha particle
a sub-atomic fragment consisting of 2 protons and 2 neutrons; a form of radiation

alveoli
tiny air sacs in the lungs where exchange of oxygen and carbon dioxide takes place

anaerobic respiration
respiration that does not use oxygen

antibiotics
medicines that fight bacteria

antibodies
protein molecules that target specific parts of a pathogen cell

antigens
protein molecules on the surface of pathogen cells

asteroid
a rocky body left over from the formation of the solar system

atom
the smallest particle of a substance that can exist

atomic number
the number of protons in an atom

bacteria
unicellular microorganisms that have cell walls but no nuclei (singular: bacterium)

base
a substance that reacts with and neutralises acids

beta particles
fast-moving electrons; the source of beta radiation

biodiversity
the variety of species living on Earth or a part of it

biotic
refers to the living things in an ecosystem, such as plants and animals

black smoker
a volcanic, chimney-like formation that releases mineral-rich water up into the ocean

Brownian motion
the random motion of particles suspended in a liquid or a gas

cancer
a non-infectious disease caused by damage to genes and cells

carbonate
a salt containing a carbonate (CO_3) group

carbon cycle
the flow of carbon in and out of the land, ocean and living things

carrying capacity
the maximum number of individuals that can be supported by an area's resources

cellular respiration
the process of converting the energy stored in molecules (such as glucose) into energy in cells

census
a survey to count the population of an area

central nervous system
the brain, spinal cord and nerves that connect these organs with the rest of the body

chlorophyll
a green pigment present in most plants; responsible for the absorption of light energy during photosynthesis

chemoreceptor
sensory cells in the lining of your nose

circuit diagram
a picture showing the key parts of an electrical circuit

climate
the long-term weather conditions of an area

climate change
long-term variations in the climate due to natural fluctuations and/or human activities changing the environment

combustion
the process of burning something

commensalism
a type of symbiosis where one species may benefit while the other is neither helped nor harmed

compound
a substance made up of two or more different types of atoms bonded together, e.g. water

compression
a point in a wave with maximum density

conduction
the direct transfer of heat through a substance

conductor
a material or device that conducts or transmits heat or electricity

continental drift
the theory that today's continents were once joined together as a giant land mass before drifting apart

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

convection current
the transfer of heat by movement of heated fluid into an area of cooler fluid

converging boundary
the region where two plates come together

coral bleaching
the whitening of coral due to warmer-than-normal water that can cause the coral to die

CT scan
a detailed 2D or 3D body scan formed from many X-ray images

current
the flow of electricity

digestion
when foods are broken down and absorbed into the blood to be transported to the cells

disease
a sickness or disorder in the body or part of the body ofa person, animal or plant that may produce symptoms

diverging boundary
the region where two plates move apart

dormant
the state of a volcano that is inactive but may erupt again

ecosystem
a community of living and non-living things that depend on one another for survival

electrical circuit
a path through which electrons from a power source flow

electromagnetic radiation
all the different kinds of energies released into space by the Sun and other stars

electron
a negatively charged particle found in atoms

element
a pure substance made up of only one type of atom, e.g. oxygen, carbon

endothermic
a reaction that absorbs heat

energy
(biology) a resource that allows organisms to survive

environmental sustainability
balancing how we live with its impact on ecosystems to conserve an ecological balance by avoiding depletion of natural resources

epicentre
the point on the ground directly above where a fault has fractured during an earthquake

equilibrium
balance

exothermic
a reaction that releases heat

extinct
(biology) a family, class or species that has died out

extinct
(geology) the state of a volcano that is unlikely to erupt ever again

fault line
the broken rock along the line of the transform boundary

fire-stick farming
management of grass species using controlled burning, traditionally practised by Indigenous Australians

flow diagram
a series of arrows and text in boxes representing different pathways that are influenced by decision points

food web
a diagram showing several food chains intertwined

fossil
the remains or imprints of an animal, plant, bacteria or other living organism preserved in rock

frequency
the measure of how many waves pass a point every second; measured in cycles per second (hertz)

fuel
a material such as coal, gas or oil that is burned to produce heat or power

gamma ray
high-energy radiation formed from the decay of radioactive substances

Global Positioning System (GPS)
a way of obtaining accurate locations based on the reception of signals from satellites in orbit around Earth

global warming
the large-scale, long-term warming of the planet, usually in reference to changes due to human activities

glucose
a simple sugar containing six carbon atoms

Gondwana
a land mass that broke away from Pangaea about 200 million years ago and drifted to the south before separating into Africa, Antarctica, Australia, India and South America

greenhouse gas
a gas such as carbon dioxide that traps heat and contributes to climate change

habitat
a place where a population of organisms lives

hadrons
sub-atomic particles made up of quarks, such as protons and neutrons

haemoglobin
a protein in the blood's red blood cells that carries oxygen

half-life
the time taken for a substance's radioactivity to fall to half its original value

hertz (Hz)
the unit of frequency, equal to one cycle per second

hormone
a chemical signal in your body

hydrocarbon
a compound containing hydrogen and carbon

impulse
an electrical signal that travels along an axon

indicator
a substance that shows whether a substance is acidic or alkaline by changing colour

infrared radiation
part of the electromagnetic spectrum; detected as warmth

insulator
a substance that does not readily allow the passage of heat

insulin
a hormone that carries sugar from your blood into your cells

introduced species
any species of plant or animal that has been moved by humans to an environment where it did not occur naturally

isotopes
atoms of an element with different numbers of neutrons

land management
care of the land through controlling or dealing with things that affect it

Laurasia
a land mass that broke away from Pangaea about 200 million years ago and drifted to the north before separating into North America, Greenland, Europe and Asia

lava
melted rock (magma) that has reached the surface when a volcano erupts

lava plug
landform created by magma solidifying in a volcanic crater

leptons
a class of sub-atomic particles including electrons

light-emitting diode (LED)
a diode that glows when electricity passes through it

lithosphere
the 100-kilometre thick surface layer of the Earth containing the crust and the brittle upper part of the mantle

litmus paper
an acid–base indicator that turns red in presence of acids and blue with alkalis

longitudinal wave
a wave that moves in the same direction as the energy flow

magma
molten rock beneath the Earth's surface

mass number
the total number of protons and neutrons in an atom

matter
a substance with mass and volume

mechanoreceptor
sensory cells in your ear that convert sound vibrations into electrical impulses

melanoma
the most dangerous type of skin cancer, caused by UV radiation

meteor
a particle that enters the Earth's atmosphere from space

meteorite
material from space that reaches the ground

mid-ocean ridge
a chain of underwater mountains formed at the boundary where two plates are moving apart beneath the ocean

molecule
a group of two or more atoms bonded together, e.g. a water molecule

moment magnitude scale
a logarithmic scale used to describe the amount of energy in seismic waves and the severity of earthquakes

multicellular
consisting of many cells, e.g. animals, plants

mutualism
a type of symbiosis where both species benefit

neuron (nerve cell)
a specialised cell that receives and sends electrical signals in the body

neutralise
the reaction in which an acid and a base combine to form water

neutron
a neutral particle found in the nucleus of atoms

nitrogen cycle
the flow of nitrogen through soil, air, plants and animals

nuclear fission
a nuclear reaction in which a heavy nucleus splits, releasing energy

nucleus
(chemistry) the positively charged central part of an atom; contains protons and neutrons; (plural: nuclei)

nutrient
a substance that provides nourishment essential for maintenance of life and for growth

optic fibre
a thin, flexible thread of glass or other transparent material that transmits light signals

organism
a living thing

oxidation
the formation of an oxide

oxide
a compound containing oxygen and one other element

palaeomagnetism
the study of magnetism of ancient rocks

Pangaea
a single supercontinent that formed about 300 million years ago

parallel circuit
an electrical circuit in which current flows along two or more paths

parasitism
a type of symbiosis where one species benefits at the expense of another

pathogens
bacteria, viruses, prions, macroparasites, fungi and protozoa that cause infectious diseases

peripheral nervous system
sense organs and nerves that connect these organs with the rest of the body

pH scale
the measure of how acidic or alkaline a substance is

photon
a particle representing light

photoreceptor
sensory cells on your eye's retina that transform light into electrical signals

photosynthesis
the process in which the energy of the Sun is used to convert carbon dioxide and water into oxygen and sugars

pollutant
a substance introduced into the environment with undesired effects

population
a group of the same kind of organisms that live in the same place at the same time

precipitation
liquid (rain) or solid (hail, sleet and snow) forms of water that fall to Earth

predator
an animal that kills other animals to eat

prey
animals killed by predators as food

prions
faulty protein molecules that cause rare, untreatable brain diseases that are fatal

producers
plants and other photosynthetic organisms that can use solar energy directly

product
a substance formed at the end of a chemical reaction; written on the right side of a chemical equation

protein
a large, complex molecule; plays many critical roles in the body; made of amino acids

proton
a positively charged particle found in the nucleus of atoms

pumice
a light, porous volcanic rock used in cleaning or polishing

quadrat
a representative area used to count the number of individuals in a small area to represent the size of the population in the whole ecosystem

quarks
sub-atomic particles with a fractional electric charge; a component of protons and neutrons

radiation
the emission or transmission of energy in the form of waves through space or through a material

radioactive
emitting radiation

rarefaction
a point in a wave with minimum density

reactant
a substance used at the beginning of a chemical reaction; written on the left side of a chemical equation

relationship
the ways in which species relate or interact with each other

scientific theory
a well-tested explanation of a scientific observation

seafloor spreading
a region on the ocean floor where magma rises up and pushes newly formed seafloor in opposite directions

seismic waves
waves in the Earth produced by an earthquake

seismometer
an instrument that records land movement and seismic waves

series circuit
an electrical circuit in which all current flows along one path

solar cell
a device that converts light into electricity

solar energy
energy obtained from the Sun's radiation

sound
vibrations that travel through the air or another substance and can be heard

species
a group of similar organisms capable of breeding, such as *Homo sapiens*

steroid
a hormone made from cholesterol by the adrenal glands and the ovaries or testicles

subduction
the process where one plate is pushed beneath a younger and lighter plate

sustainable development
growth of economies, and political and cultural systems, in harmony with the environment

symbiosis
a relationship where two different species help each other to survive

tectonic plate
a rigid segment of the Earth's surface that floats on the liquid magma below

transect
a straight line across the Earth's surface, along which measurements are taken

transform boundary
the region where two plates slide past each other

transpiration
the process by which plants take up water from the soil through their roots and up into their leaves and then release it into the air

transverse wave
a wave that moves at right angles to the energy flow

tsunami
a giant wave caused by the movement of the seafloor during an earthquake beneath the ocean

urbanisation
building up of the environment into a town or city

vaccination
being injected with or swallowing weakened or inactive antigens that prompt antibody production without the person becoming sick

vacuum
a space with nothing in it

vibrating
moving rapidly to and fro

virus
genetic material coated by a protein that causes diseases such as the common cold

volcanic hotspot
an area of increased volcanic activity

water cycle
the continuous movement of water on the land and in the atmosphere

waves
vibrations that transfer energy from place to place

wavelength
the distance between successive crests of a wave

X-rays
a form of radiation emitted by electrons

INDEX

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The featured scientists: Misty Jenkins, Dewi Kirono, Niraj Lal, Jenny Powell, Aaron Stewart and Jo Whittaker.

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(bottom) /Nolte Lourens, 30 (bottom) /onair, 135 (left) /outdoorsman, 39 (top left) /Pablo Hidalgo Fotos593, 101 (right), 116 (top) /Pal Teravagimov, 48 (top) /pedrosala, 96 (left) / Peter Hermes Furian, 102 (bottom) /Phichai, 135 (right) /Phil MacD Photography, 84 (top) /Photo Africa SA, 40 (bottom) /photoiconix, 69 (top), 135 (bottom) /photolinc, 31 (right) /Piotr Garlik, 34 (right) /Piotr Krzeslak, 131 (top) /pisaphotography, 119 /Pixeljpy, 6 / Poznyakov, 69 (right)) /Praisaeng, 79 (right) /Prill, 58 /Puwadol Jaturawutthichai, 139 (bottom left) /Pyty, 35 /R. Classen, 66 (left) / kra2studio, 15 (bottom) /Radu Berkan, 105 (top) /Raimundas, 148 (top) /Rawpixel, 127 (right), 138 (top) /remedios55, 75 (bottom) / Richard Whitcombe, 27 (middle), 42 (main) /Robert Crow, 125 (top) /Robert Kylio, 70 (bottom) /robin2, 104 (top) /Roman Sakhno, 134 (right) /Roman Sigaev, 51 (left), 59 (top) /Romanenko Alexey,24 (top) /S K Chavan, 9 (right), 9 (left) /saiko3p, 87 (lemon) /Scott Rothstein, 147 (switch) /Sergey Nivens, 5 (right), 7, 22 (left) /Sergey Uryadnikov, 38 (left) /sfam_photo, 24 (bottom) /Sirocco, 93 (bottom) /Sophie James, 132 (top) /SSSCCC, 71 (bottom) /Steve Collender, 148 (left) / Steven Collins, 123 (top) /stockphoto mania, 83 (left) /StockPhotosArt, 144 (bottom) / Stubblefield Photography, 36 (bottom) / sunabesyou, 19 /Surrya Tjahya, 2 (top), 132 (bottom) /Tagstock1, 81 (right) / TFoxFoto, 75 (top) /think4photop, 122 (top) /Tom Grundy, 71 (middle) /Triff, 30 (top) / tubuceo, 113 (bottom right) /UGreen3s, 16 (bottom) /Ventin, 62 /vichie81, 70 (top) /Viktar Malyshchyts, 73 (right), 86 /violetkaipa, 32 (bottom) /Viori Sima, 152 (top) /Vladislav S, 116 (left) /VojtechVik, 14 (bottom) /wawritto, 95 (top) /wdeon, 116 (middle) /WH Chow, 82 (left) /Wildnredpix, 48 (bottom) /Wouter Tolenaars, 5 (left), 9 (top) /XXL Photo, 93 (top) /Yu Lan, 23 (top) /Yurly Chertok, 36 (top) /Zerbor, 68-9/ zhangyang13576997233, 146 (top) /zyxx, 152 (bottom); Simon Torok, 39 (middle), 45 (right), 116 (bottom), 118 (bottom)

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