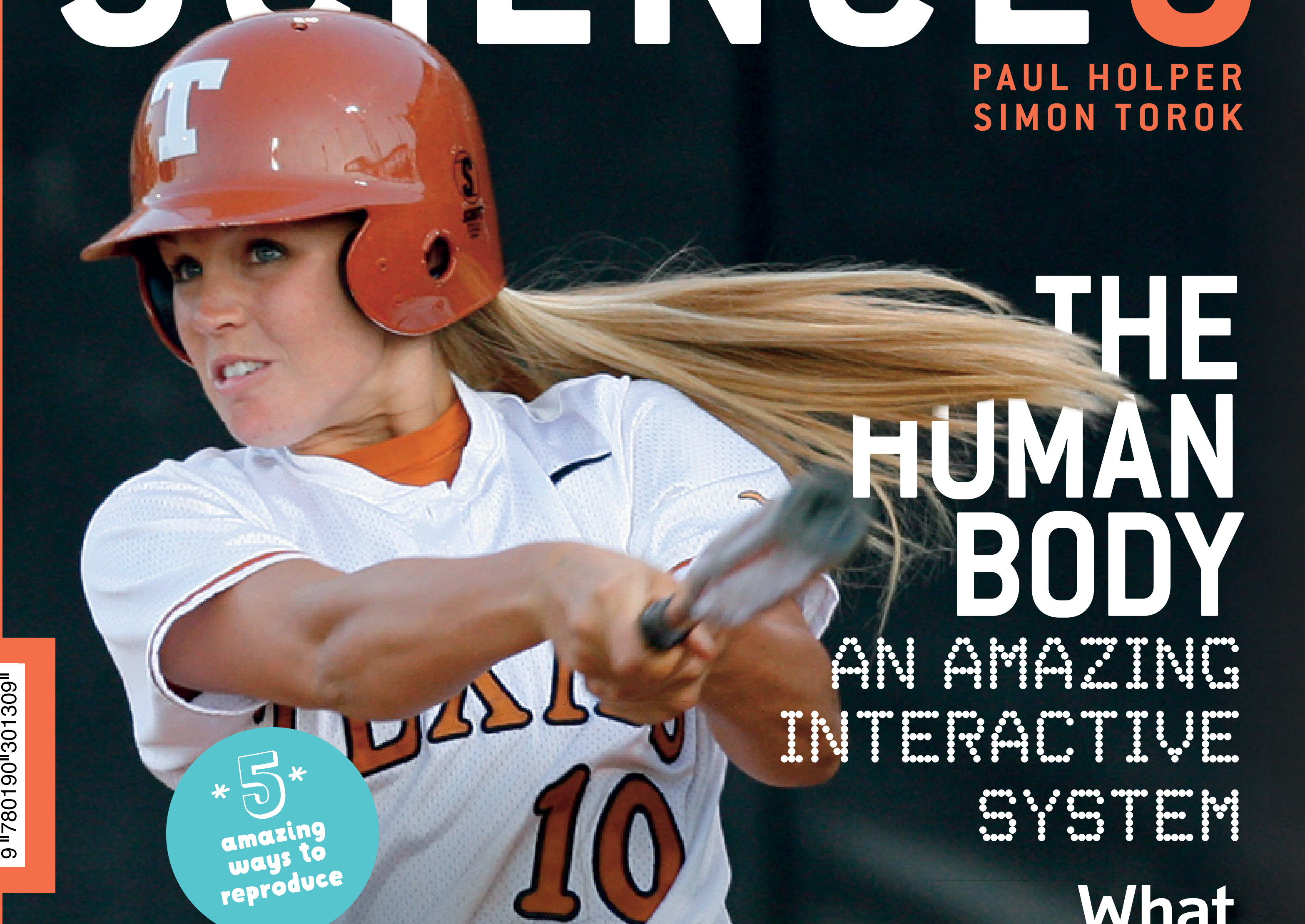
CHEMICAL CHANGE » BODY SYSTEMS » MATTER » ENERGY

AMAZING SCIENCE 8

PAUL HOLPER
SIMON TOROK

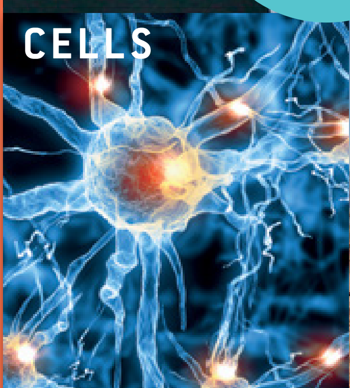


THE HUMAN BODY

AN AMAZING INTERACTIVE SYSTEM

What stories do stones tell us?

5 amazing ways to reproduce

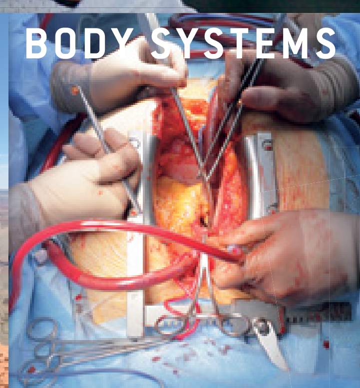


CELLS

How do our cells communicate?

ROCKS AND MINERALS

Why your laptop ROCKS!



BODY SYSTEMS

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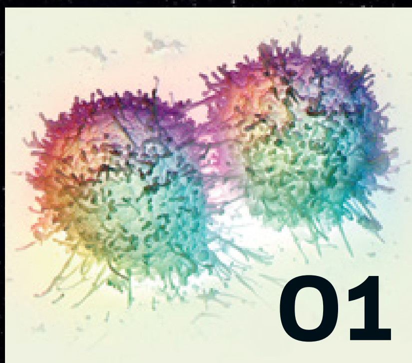

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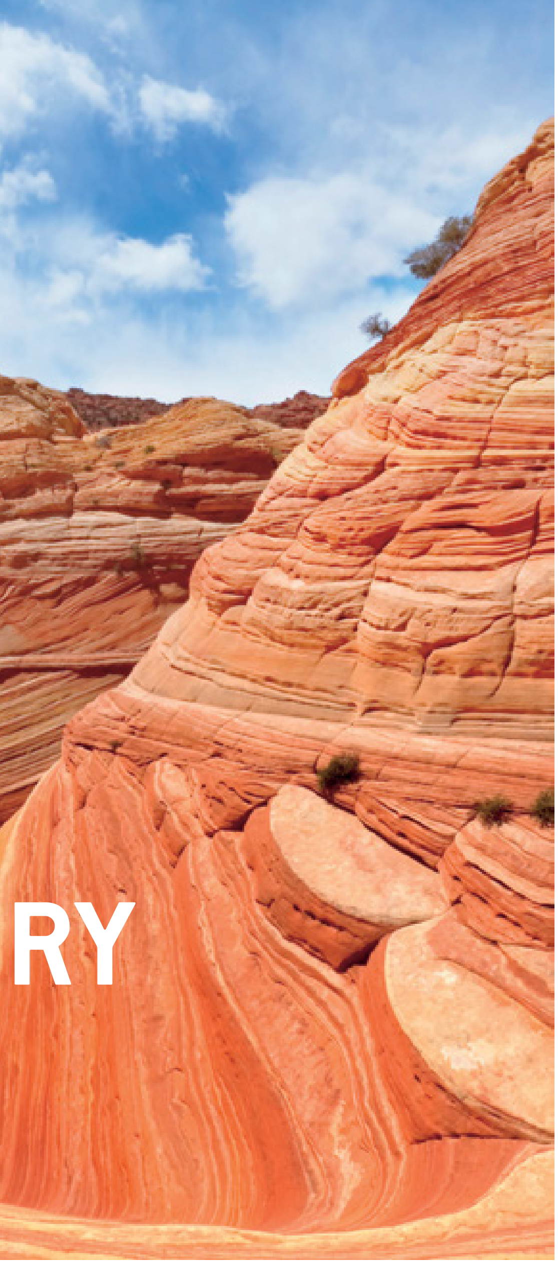

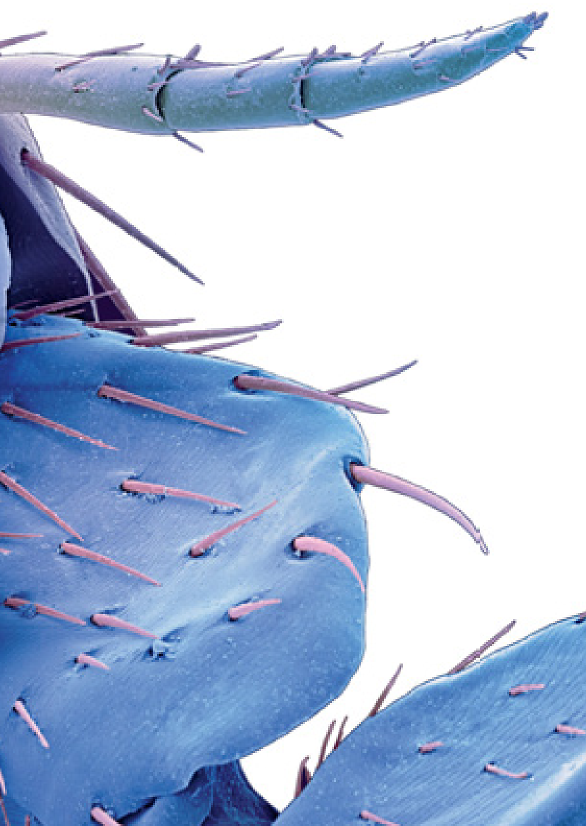

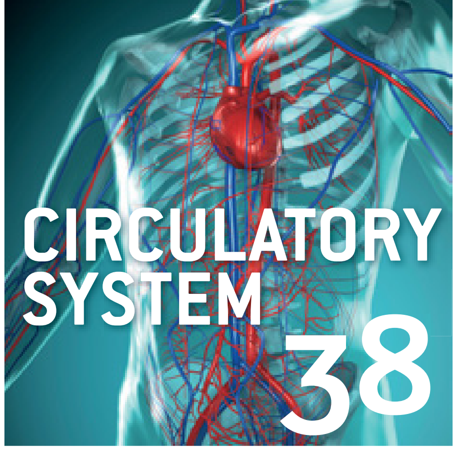

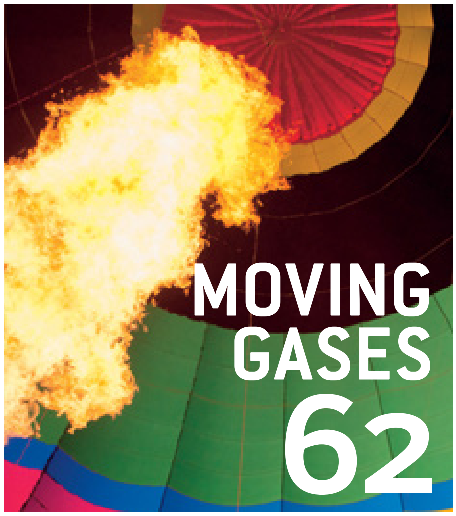

Lots more experiments on the Teacher obook

AMAZING EXPERIMENTS

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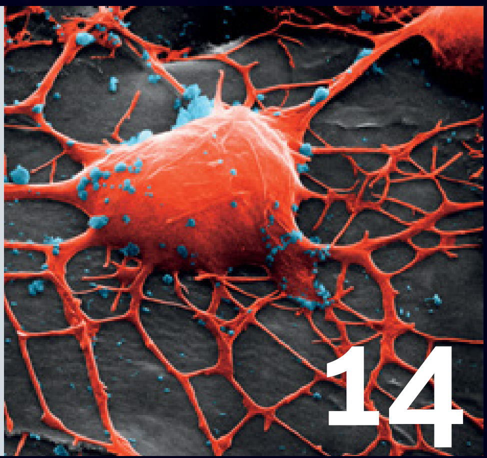

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HOW DO CELLS WORK TOGETHER?

ZOOMING IN

What are all living things made up of? How can we observe them more closely? These questions led to the invention of the microscope in the mid-1600s. The microscope helped scientists see that all living things are made up of **cells**. The microscope opened our eyes to a new world.

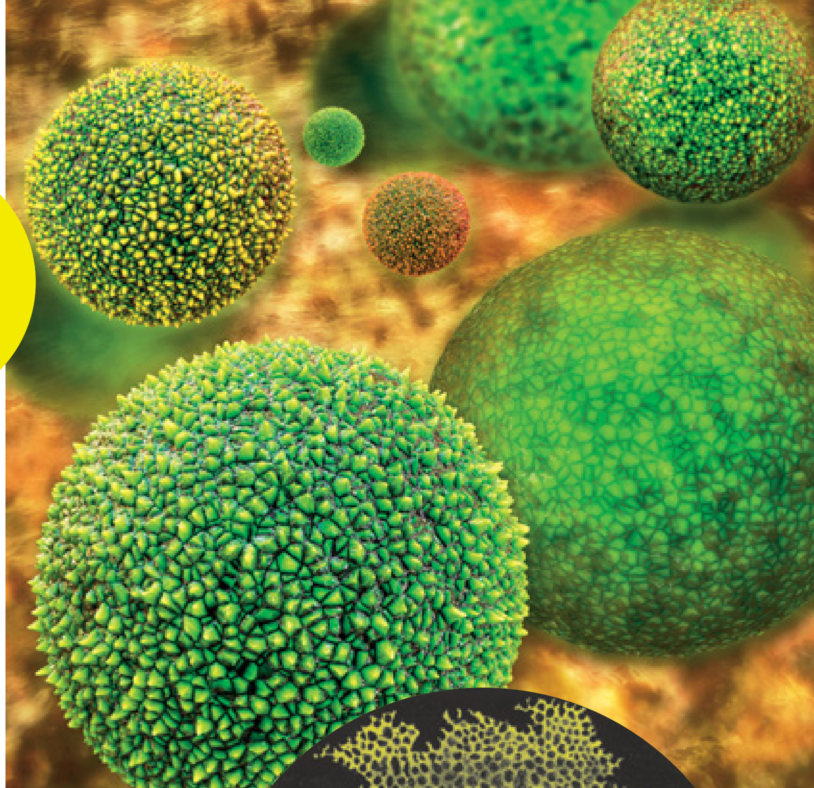
Human red blood cells, magnified by a scanning electron microscope

This amazing 3D image of the head of a flea was taken using a scanning electron microscope.

Microscopes

Microscopes **magnify** the size of objects. The first microscopes were very basic but over time their magnifying ability improved. Scientists can now look at images that have been magnified millions of times using different lenses.

Modern **scanning electron microscopes (SEM)** can magnify up to 1 million times. They produce amazing 3D images of tiny objects such as plant pollen. Scientists can use the information to increase their understanding of hay fever caused by pollen, or how plants **pollinate**. Other types of electron microscopes can magnify objects more than 50 million times. These new microscopes make it possible to study small features such as the structure of red blood cells. We can also look inside cells and learn more about their structures.



Scanning electron microscope view of pollen from a variety of plants.

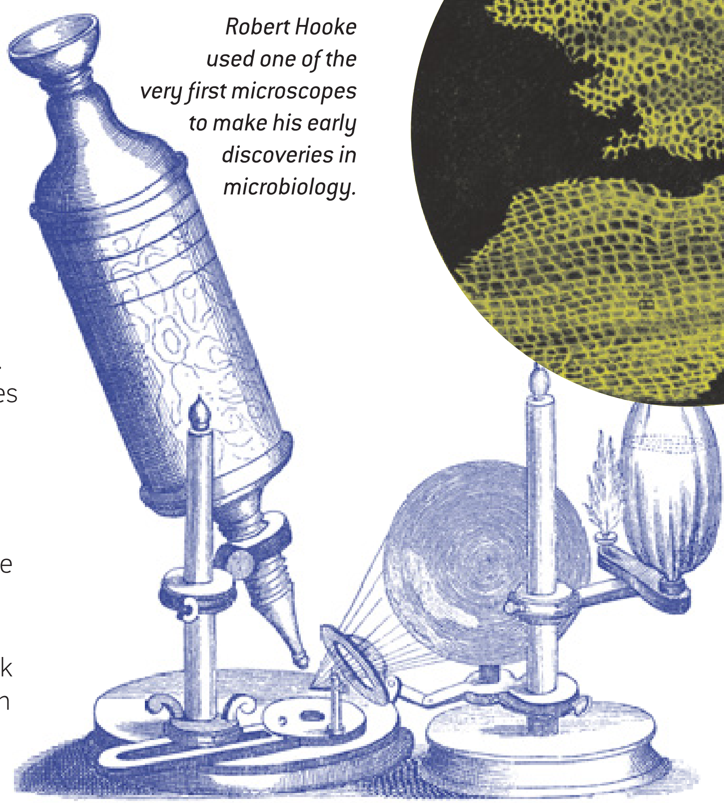
Discovering cells

Robert Hooke made one of the first microscopes. With it, he observed many types of living things and drew what he saw.

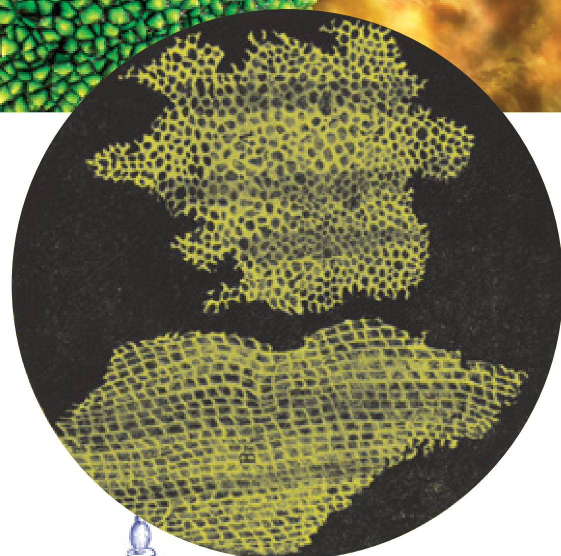
Robert Hooke's most famous success was his drawing of very thin slices of cork. He was surprised to see that through the microscope the cork looked like honeycomb. He described the 'holes' and their boundaries in the 'honeycomb' as cells because they reminded him of the rooms in a monastery (monks' home). Robert Hooke had discovered plant cells.

Hooke's work was important for the whole science of **microbiology**, which developed from this discovery of cells.

It was because of Hooke's important work in microbiology that other scientists went on to develop a further understanding of cells.



Robert Hooke used one of the very first microscopes to make his early discoveries in microbiology.



Robert Hooke's drawing of cork led to the discovery of cells.

LOOK IT UP

cells the building blocks of living things

magnify to increase the size of an image

microbiology the study of microscopic organisms

pollination the process that occurs in flowering plants when pollen lands on the stigma

scanning electron microscope (SEM) a type of electron microscope that bounces a beam of electrons off the surface of a specimen to create a 3D image

CHECK IT OUT

1. What does a microscope do?
2. What can scanning electron microscopes do?
3. Why was Robert Hooke's drawing of cork so important to the future study of microbiology?
4. Make a sketch of the early microscope and add labels to show how a microscope works. Take a look at page 8 to help you.

MICROSCOPES

The microscope allows us to see cells, whether they come from the smallest microscopic **bacteria** or the tallest eucalyptus tree.

COMPOUND LIGHT MICROSCOPE

STEREO MICROSCOPE

Light microscopes

As a science student you will probably use two types of light microscopes: the compound light microscope and the stereo microscope. Both of these microscopes use light to make viewing **specimens** possible.

The stereo microscope has two eyepieces to look through, whereas the compound light microscope can have one or two eyepieces. The word 'monocular' is used to describe a microscope with one eyepiece (*mono* meaning one). Microscopes with two **lenses** are called binocular (*bi* meaning two).

Compound light microscope

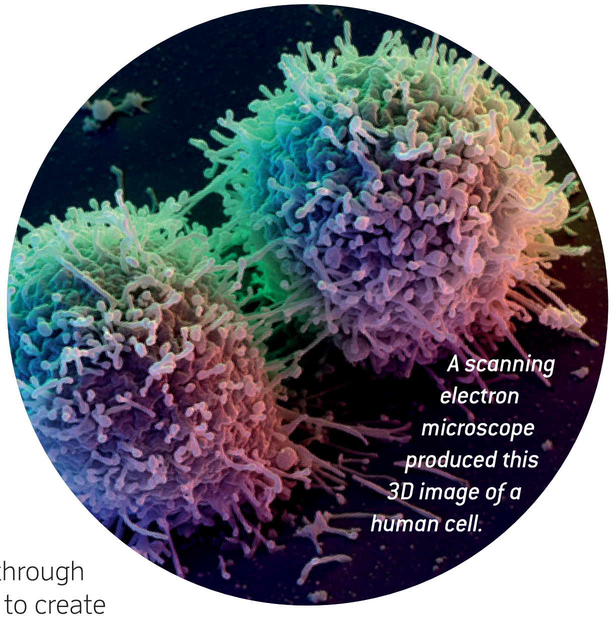
The compound light microscope is used to observe thin slices of specimens, such as blood cells. It can magnify specimens up to 1500 times. Its view is flat – that is, two-dimensional (2D). The specimen must be thin enough to allow light to pass through it. Major structures of individual cells (such as cell walls) can be seen with a compound light microscope.

Stereo microscope

The stereo microscope is used to observe larger objects, such as insects. It can magnify specimens up to 200 times and shows the surface of the object viewed, giving the object a three-dimensional view (3D). It cannot be used to see inside or through an object, making it difficult to see individual cells.

Electron microscopes

Electron microscopes are much more powerful than light microscopes. They use small particles called **electrons**. As we can't see electrons, computers are used to detect and create the image. The transmission electron microscope (TEM) fires a stream of electrons through thin slices of the specimen to create a detailed 2D image. The scanning electron microscope (SEM) bounces the electron stream off the surface of the specimen and creates 3D images. A computer program can add colour to the image to show detail.



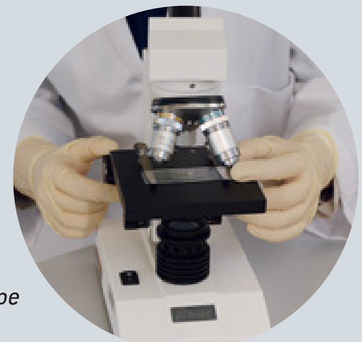
A scanning electron microscope produced this 3D image of a human cell.

Preparing cells for microscopy

Specimens are prepared by taking a very thin slice of the object using a very sharp blade or even a laser. Most cells are clear, which makes them difficult to see, so a stain such as iodine or methylene blue helps make them more visible. Different stains highlight different parts of the cells. Placing a cover slip over the top of a stained specimen protects it and keeps it in place.

1 *Add a drop of stain to the specimen*

2 *Gently lower the cover slip*



3 *Focus the microscope*

A stained image of a hair root under a compound microscope.

A stereo microscope shows that an insect's eye is a complex system of lenses that gives the insect amazing vision.

LOOK IT UP

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

electron a negatively charged particle found in atoms

lens (biology) a curved, transparent structure that focuses light on the retina

specimen a small sample to be studied or displayed

CHECK IT OUT

1. What is the difference between a compound light microscope and a stereo microscope?
2. How are specimens prepared for viewing under a classroom microscope?
3. There are two knobs to be turned for focusing. What is the difference between them?
4. How was the three-dimensional view of the insect on page 6 produced?

EXPERIMENT #1

GETTING TO KNOW YOUR MICROSCOPE

AIM: TO PREPARE MICROSCOPE SLIDES AND OBSERVE THEM WITH A COMPOUND LIGHT MICROSCOPE

MATERIALS

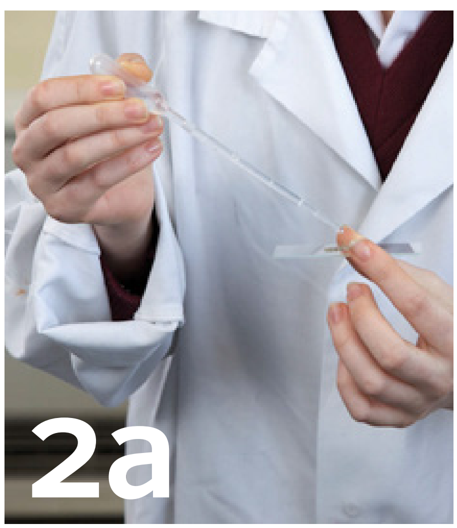
- Small piece of newspaper
- Small piece of tissue paper
- Scissors
- Compound light microscope
- Slides
- Cover slips
- Eyedropper
- Small beaker of water
- Hair (use your own)
- 1 cm of sticky tape (transparent)

METHOD

1 Cut out a word containing the letter 'e' from the newspaper.

Cut out a word.

2 Place the 'specimen' on the microscope slide and add two drops of water to help it 'stick' to the slide. Place a cover slip on top. This is called a wet mount.



Add two drops of water to the specimen.

Place a coverslip on top of the specimen.

3 On the lowest magnification (×10), focus on the letter ‘e’.

4 Move the slide slightly towards your body and observe what happens.

5 Move the slide slightly to the left and observe what happens.

6 Increase the magnification and observe what happens.

7 Draw a diagram of what you see.

8 Take the ‘specimen’ out and prepare another slide using the tissue paper. Make sure a drop of water is added and a cover slip is placed over the top carefully.

9 Draw what you see.

10 Repeat steps 2–7 with sticky tape and then a hair from your head.

Focus the microscope.

RESULTS

Present your diagrams.

DISCUSSION

1 Describe what the letter ‘e’ looked like through the microscope.

2 What did you observe when you moved the slide in various directions? Was it what you expected?

3 Is the newspaper smooth when you look at it with the naked eye? Compare this to what the newspaper looked like through the microscope.

4 What features could you see on the tissue paper and sticky tape that you could not see with the naked eye?

CONCLUSION

What is the purpose of a light microscope and how does it work? Write a sentence that answers the aim under the heading of Conclusion.

SCIENTIFIC EQUIPMENT

- Compound light microscope

- Small beaker

- Microscope slide and cover slip

- Eyedropper

BUILDING BLOCKS OF LIFE

Cells are the building blocks of life. They are the tiny units that form every living thing. An adult human body is made up of about 37 trillion cells.

A red blood cell, also called an erythrocyte. This cell carries oxygen from the lungs to the tissues.

How big are cells?

Cells and their parts are microscopic and are measured in **micrometres** (sometimes called microns). Look at 1 millimetre on your ruler. Now imagine this distance is divided into 1000 parts. One of those tiny parts is equal to 1 micrometre (μm). Cells have different sizes, depending on their function. A bacterial cell usually measures approximately 1 μm, whereas a plant cell may be up to 100 μm in size (one-tenth of a millimetre). Some nerve cell projections are over 1 metre long.

Magnified human cells show just how much detail there is in the smallest unit of life.

Cell components

Any living thing that has more than one cell is referred to as **multicellular**. There are many living things, such as amoeba, that consist of only one cell. These are called single-celled or **unicellular** organisms.

Bacteria do not contain a **nucleus**. Most other cells have a nucleus and share the same basic structure:

- cell **membrane** – the 'skin' of a cell; controls the entry and exit of things into and out of the cell
- cytoplasm – the 'jelly-like' fluid between the membrane and the nucleus; contains all the cell organelles (mini organs), dissolved nutrients and wastes
- nucleus – acts as the control centre of the cell; contains DNA, which provides instructions for every job that cells need to do.

A multicellular organism, such as a human, has many different cells that are more specialised than the single cell of a unicellular organism. All cells in our body are very similar to each other. However, each different type has a special role and is different from the others. Skin cells are not the same as muscle cells, but each has a cell membrane, a nucleus and other **organelles** that enable the cell to survive.

The cells in a multicellular organism cannot survive well on their own outside the organism. The entire organism depends upon the health of all its cells to survive.

LOOK IT UP

membrane a sheet-like structure acting as a lining or boundary in an organism

micrometre (µm) one millionth of a metre

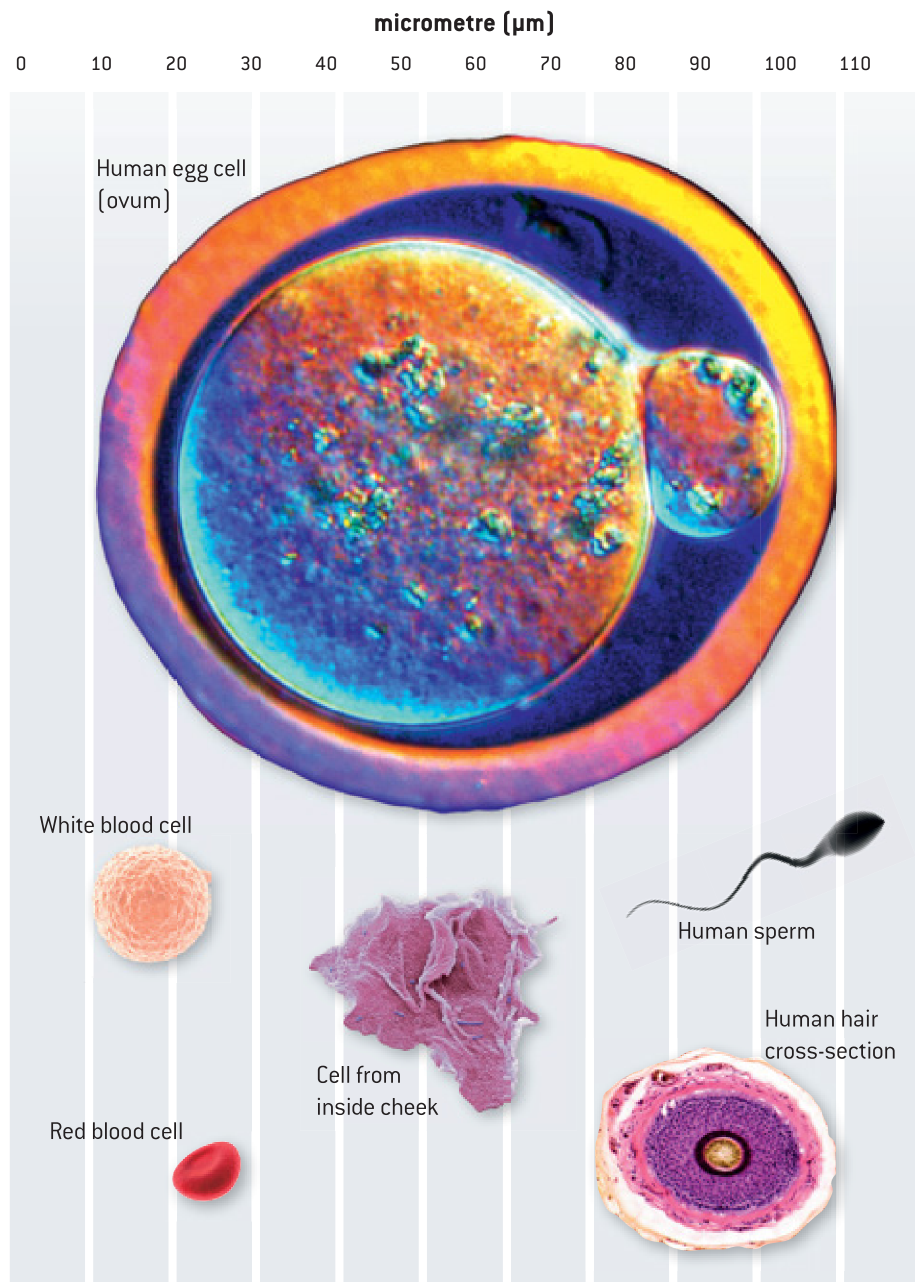
multicellular consisting of many cells, e.g. animals, plants

nucleus the control centre of the cell, providing instructions for every job that the cell needs to do

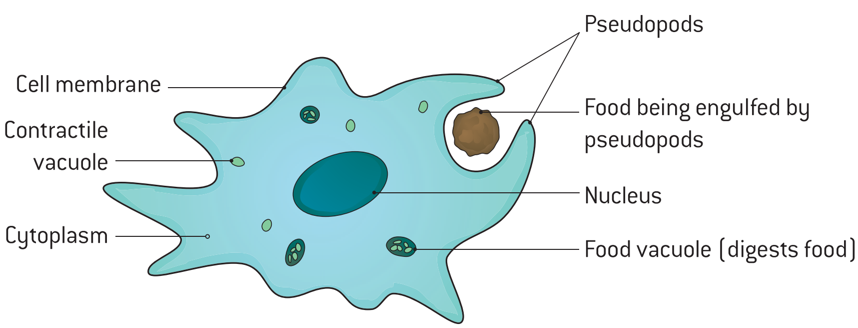
organelle a part of a cell with a special function

unicellular consisting of just one cell, e.g. bacteria

COMPARISON OF THE SIZE OF DIFFERENT HUMAN CELLS

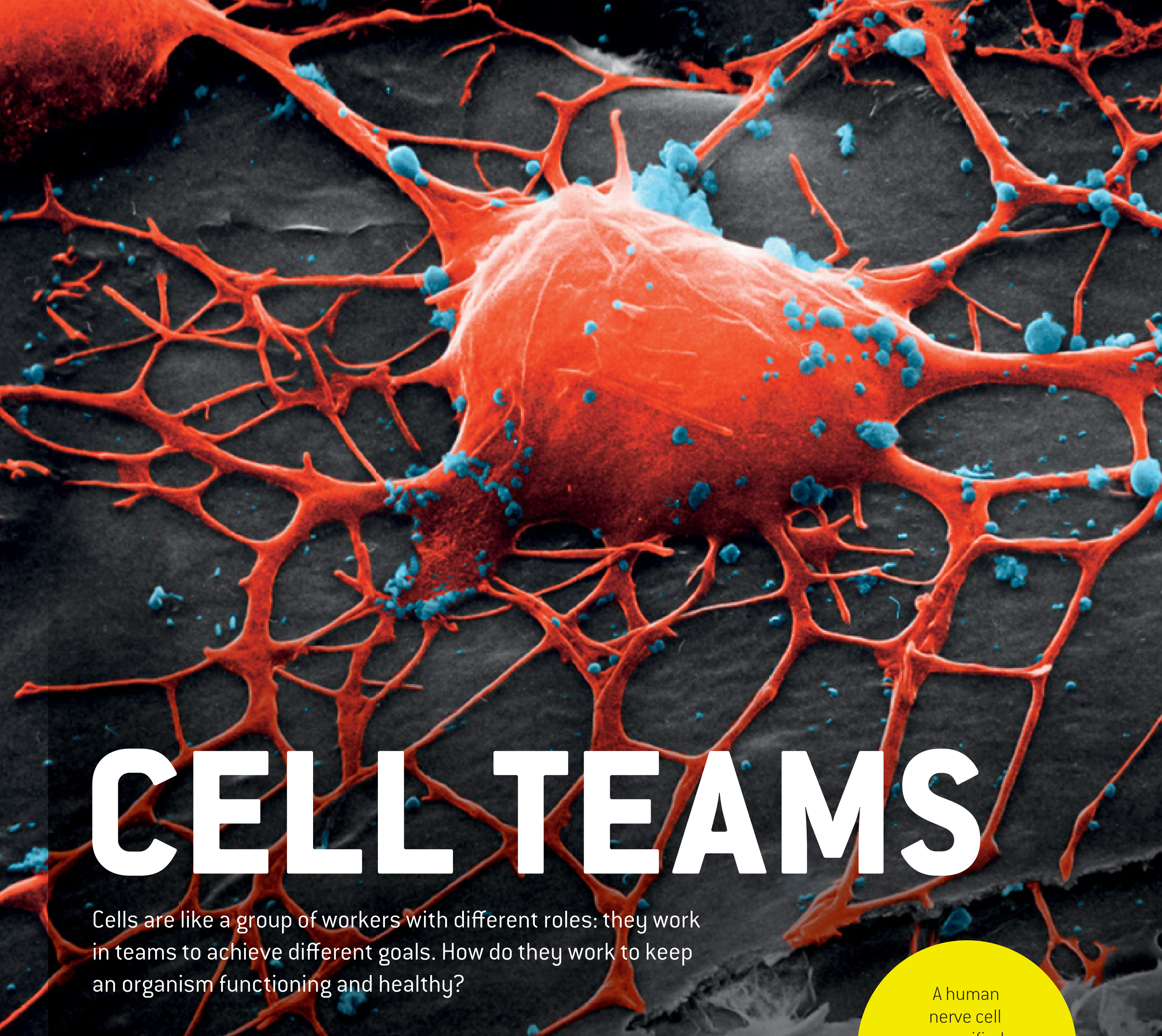


AMOEBA – A UNICELLULAR ORGANISM



CHECK IT OUT

1 What are unicellular and multicellular organisms? Give one example for each.
2 Why are cells called the building blocks of life?
3 What do cells in the human body have in common?
4 How do the cells in the body differ from each other?



CELL TEAMS

Cells are like a group of workers with different roles: they work in teams to achieve different goals. How do they work to keep an organism functioning and healthy?

A human nerve cell magnified 3000 times by a scanning electron microscope.

How cells work together

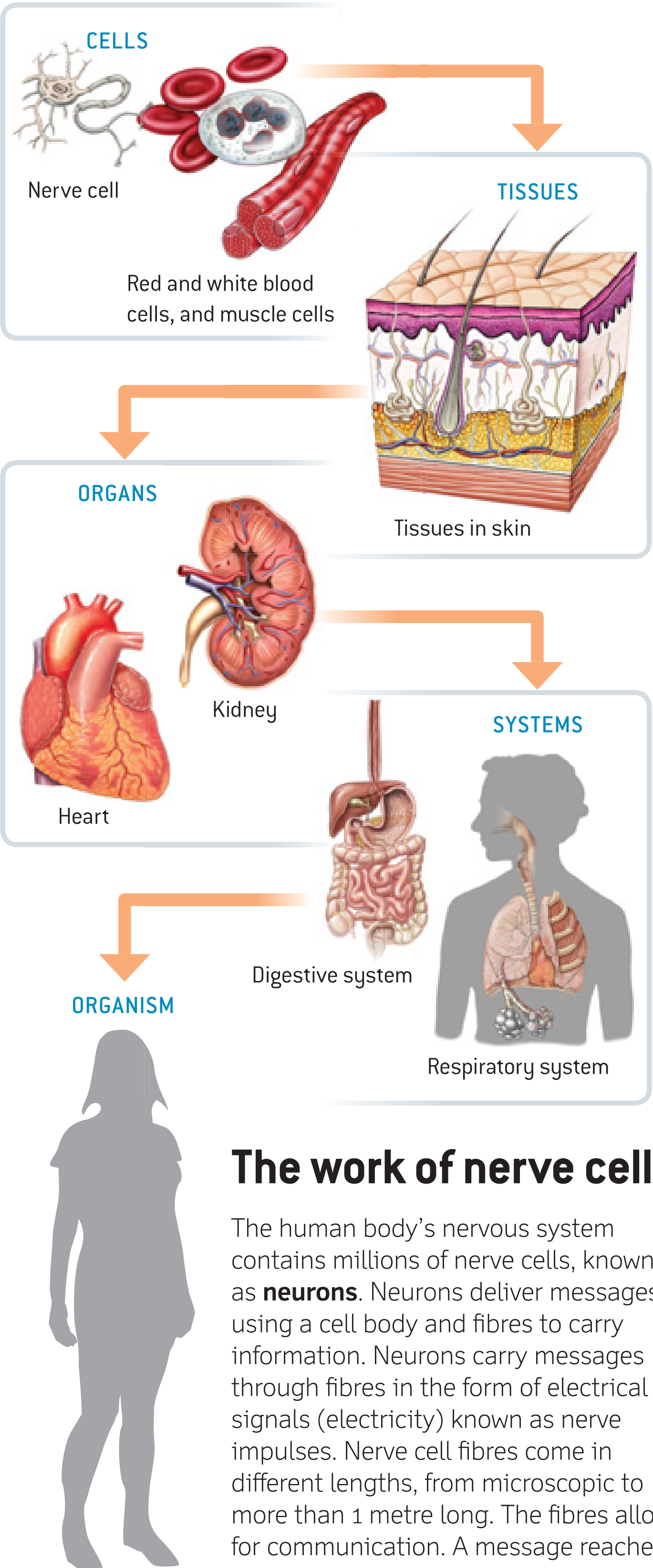
Like all living things, humans are made of different types of cells. Each cell type is necessary to do a specific job to keep you alive. For example, muscle cells have many more mitochondria than skin cells because they need more energy to do their job.

Cells come in lots of different shapes and sizes to help them perform tasks. Some cells have branches like trees to help them to connect to other cells. Others look more like saucers to help them move easily. Much like a football team where each individual player has a role and works together, these cells work together in teams. Groups of cells that do a similar task are called **tissue**.

For example, we have muscle tissue, nerve tissue and bone tissue. Groups of tissues that work together are called **organs**. The liver, heart, eyes, brain, skin and intestines are all examples of organs.

When groups of different organs work together, they are called a body system. Our mouth, oesophagus, stomach and intestines make up the digestive system. All the systems work together to increase the survival of the whole organism.

HOW CELLS WORK TOGETHER



LOOK IT UP

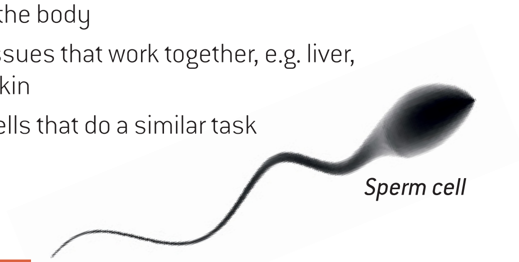
axon the part of a nerve cell (neuron) that carries a nerve impulse away from the cell body

dendrites short branched projections of a neuron's cell body; receive impulses from other neurons and transmit these to the cell body

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

organ a group of tissues that work together, e.g. liver, heart, eyes, brain, skin

tissue a group of cells that do a similar task



CHECK IT OUT

1 Why do cells come in different shapes and sizes?

2 Describe the different parts of the nerve cell. How does it work?

3 The job of the male sperm cell is to swim to the fallopian tubes and fertilise the female egg by piercing the outer layer of the ovum.

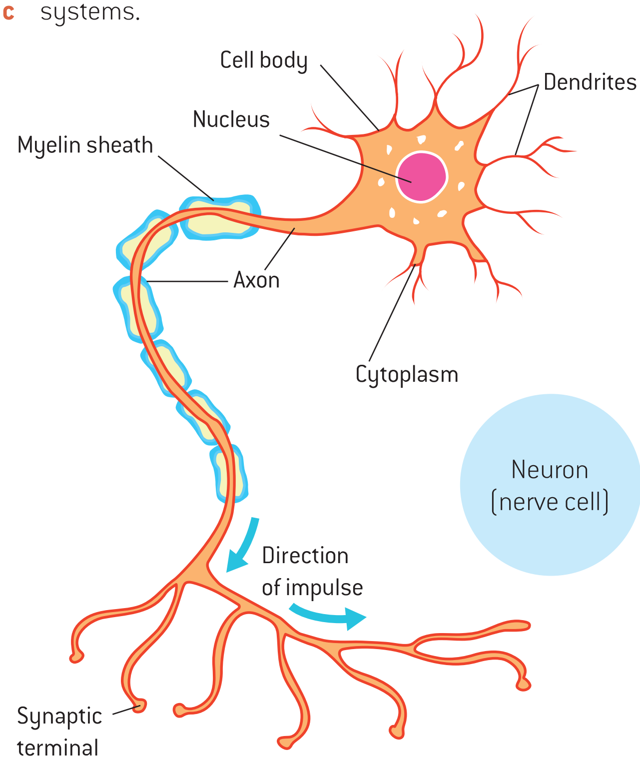
Sketch the sperm cell above and provide labels to show how the shape of the cell is an advantage for the task.

4 Explain the role of cells in:

- a tissues
- b organs
- c systems.

The work of nerve cells

The human body's nervous system contains millions of nerve cells, known as **neurons**. Neurons deliver messages, using a cell body and fibres to carry information. Neurons carry messages through fibres in the form of electrical signals (electricity) known as nerve impulses. Nerve cell fibres come in different lengths, from microscopic to more than 1 metre long. The fibres allow for communication. A message reaches the **dendrites** and is carried along the **axon** to the axon terminal. From here, the message continues to another neuron's dendrites.



INSIDE CELLS

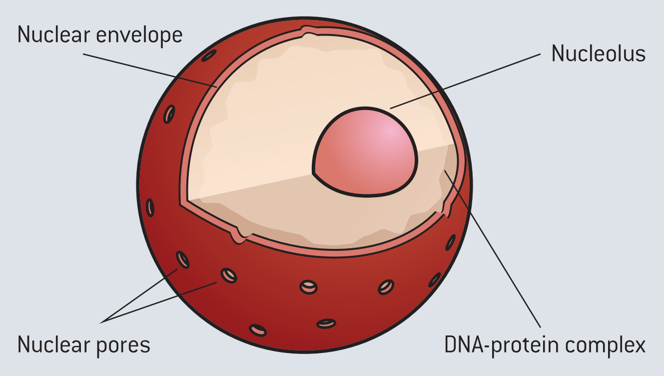
Cells are complex. They are made up of a lot of smaller parts to help them do their job.

The nucleus

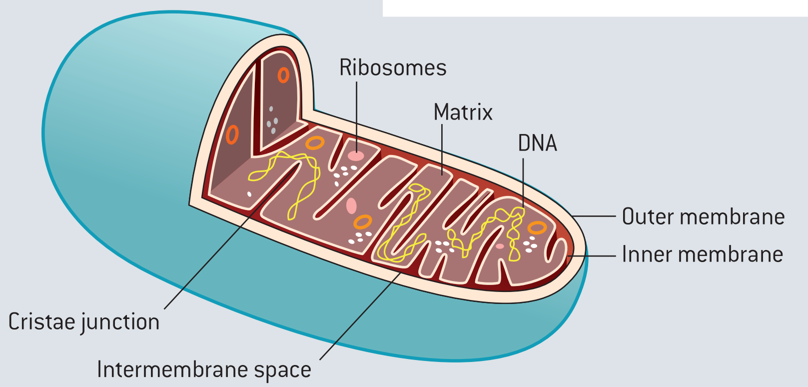
The nucleus is like the brain of the cell. It is separated from the rest of the cell by a double **membrane** (protective cover) called the nuclear envelope. Within the nucleus, **ribosomes** are assembled and then sent outside the nucleus to make **proteins**. The nuclear envelope has pores (small holes) that allow the substances to move into and out of the nucleus.

There are long strands of **DNA** in the nucleus. When a cell divides, the DNA strands coil up to form chromosomes. Chromosomes are like packets of genetic material that carry two sets of instructions for our cells. Human cells usually have 46 chromosomes – 23 from the mother and 23 from the father.

Structure of the cell nucleus



Structure of a mitochondrion



Mitochondria

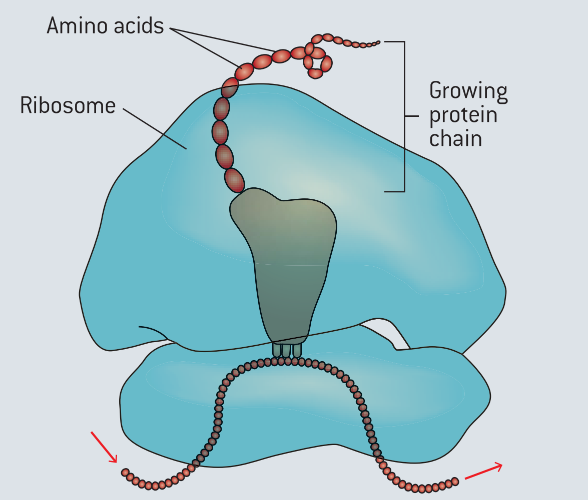
Mitochondria are like the powerhouses of the cell. They produce energy within the cell. There may be several thousand mitochondria in a cell depending on what the cell does. For example, the muscle cells in our legs contain a lot of mitochondria to make sure we have enough energy to run around.

Mitochondria have their own DNA, make some of their own proteins, and are able to grow and divide when a cell needs more of them. Mitochondria are rod-shaped organelles with an inner and outer membrane. The folds of the inner membrane are called cristae. The folding increases the area on the surface to allow more work to be done. Cellular respiration occurs inside the mitochondria. During cellular respiration, glucose (a type of sugar) and oxygen react to form water, carbon dioxide and energy. This energy is used by our bodies to help us function.

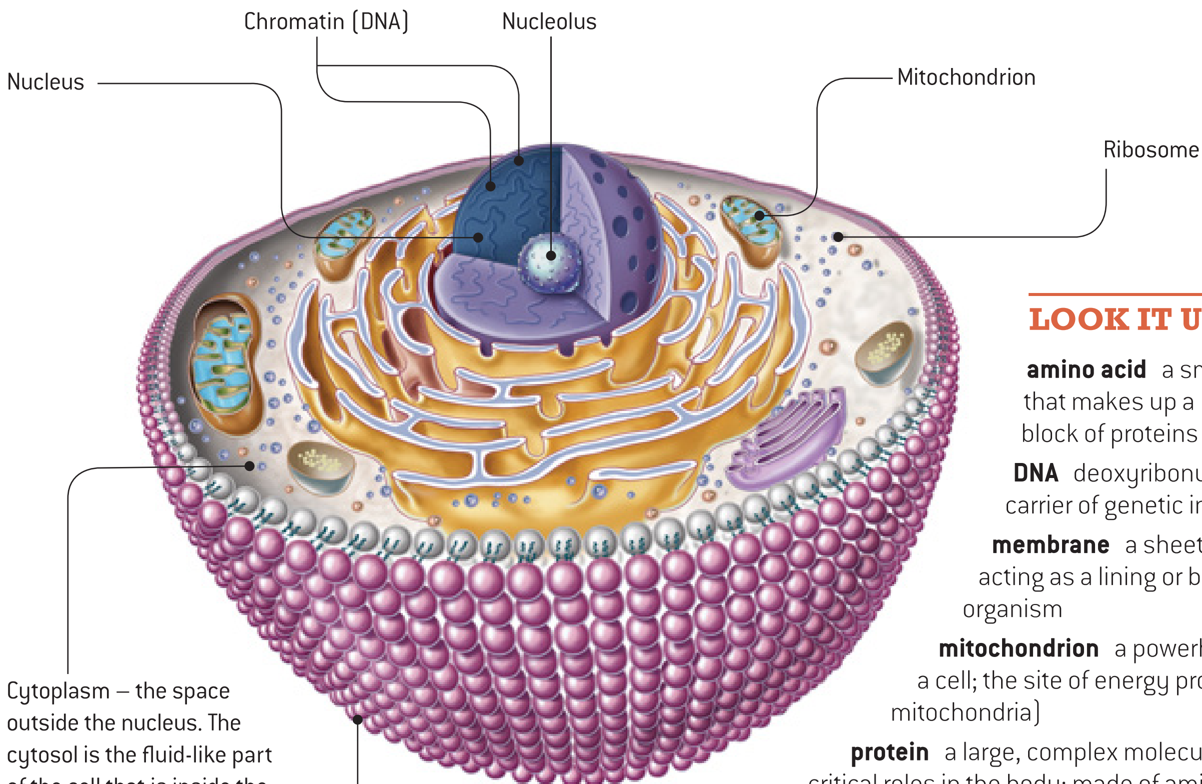
Ribosomes

Ribosomes are where proteins are produced within the cell. Ribosomes use code from the DNA to assemble **amino acids** into proteins with different roles. Some proteins are structural, such as hair and nails. Others proteins are globular (like 'globs'), such as haemoglobin, which is found in red blood cells and helps transport oxygen through the bloodstream. Some proteins take part in chemical reactions and the structure of the cell, such as in the cell membrane.

Structure of a ribosome



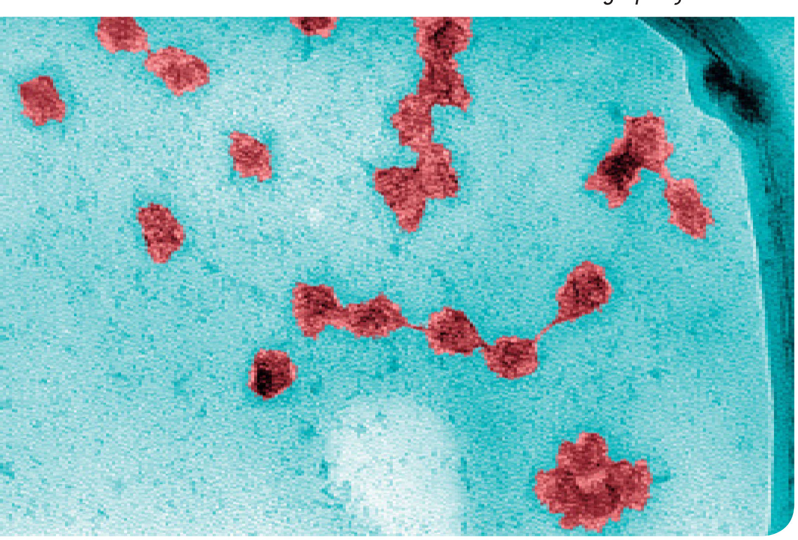
CROSS-SECTION OF AN ANIMAL CELL



Cytoplasm – the space outside the nucleus. The cytosol is the fluid-like part of the cell that is inside the cell membrane but outside the nucleus. It houses the cell's mini organs, or organelles, and many dissolved substances. These substances may take part in chemical reactions or as food storage for the cell.

Cell membrane – the protective covering that controls the entry and exit of things into and out of the cell. It is covered in material that helps cells identify each other.

Electron micrograph of ribosomes



LOOK IT UP

amino acid a small compound that makes up a protein; building block of proteins

DNA deoxyribonucleic acid; the carrier of genetic information

membrane a sheet-like structure acting as a lining or boundary in an organism

mitochondrion a powerhouse organelle of a cell; the site of energy production (plural: mitochondria)

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

ribosome a cell organelle where protein production takes place

CHECK IT OUT

1 Match the cell feature with its purpose:

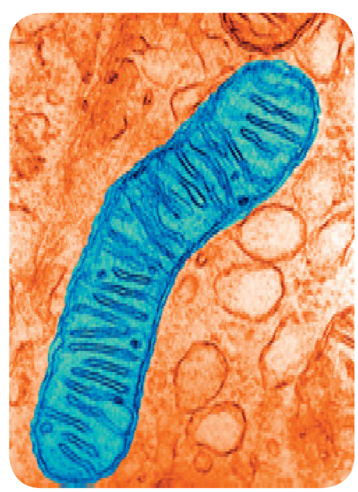
Feature	Purpose
nucleus	powerhouse
membrane	protein builder
mitochondrion	fluid
cytoplasm	brain
ribosome	wall

2 What role does DNA play in the cell?

3 Which part of the cell is shown in the microscope image to the right? How do you know?

4 How do mitochondria create energy?

5 How and why do ribosomes create proteins?



DIFFERENT CELLS

What are the differences between plant and animal cells? How do these differences help explain the different characteristics of plants and animals?

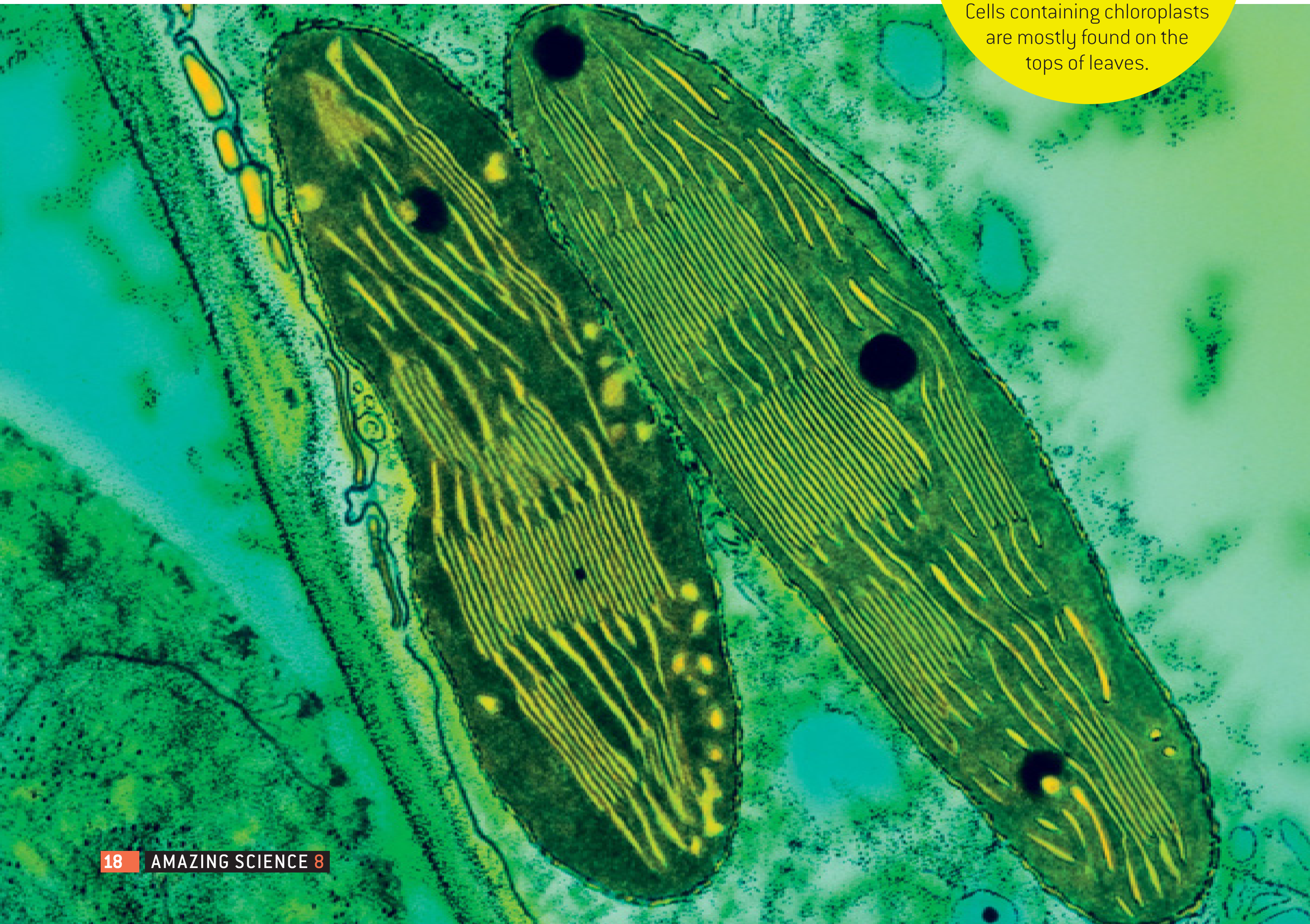
The differences between cells

We can classify cells based on whether they have organelles or not, as well as the types of organelles they have. Plant cells and animal cells all contain organelles. Plant cells tend to have one large **vacuole** (storage area) while animal cells often have many smaller vacuoles. Plant cells contain **chloroplasts** (which have chlorophyll) whereas animal cells do not.

The green pigment in chloroplasts is called **chlorophyll** and absorbs solar energy for photosynthesis. Photosynthesis means 'making with light'.

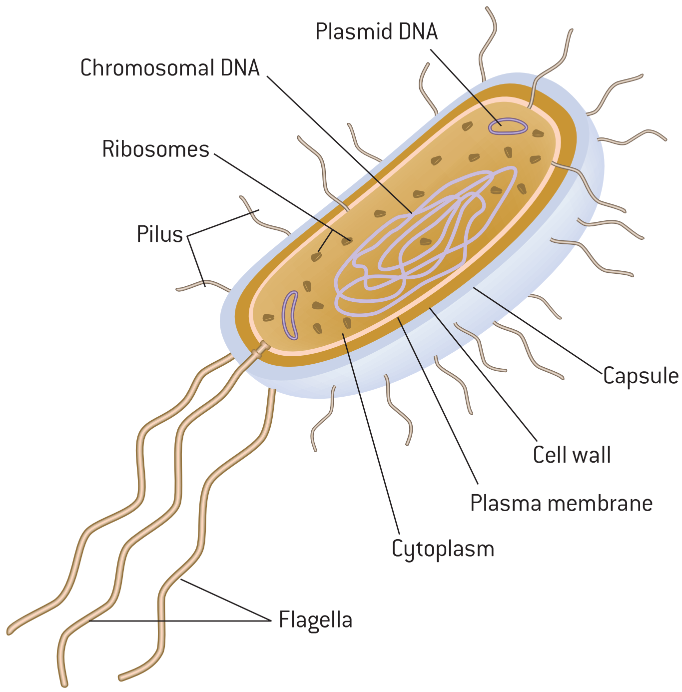
Solar energy allows carbon dioxide and water molecules to form glucose and oxygen. Glucose (a type of sugar) can then be used as energy for the plant and for any animal that eats that plant.

Bacteria do not have any true organelles but still contain DNA. Their DNA floats inside the **cytoplasm** rather than being held within a nucleus. Many of these bacterial cells also have a cell wall. The cell wall in bacteria is made of a different chemical to the cell walls found in plant cells.

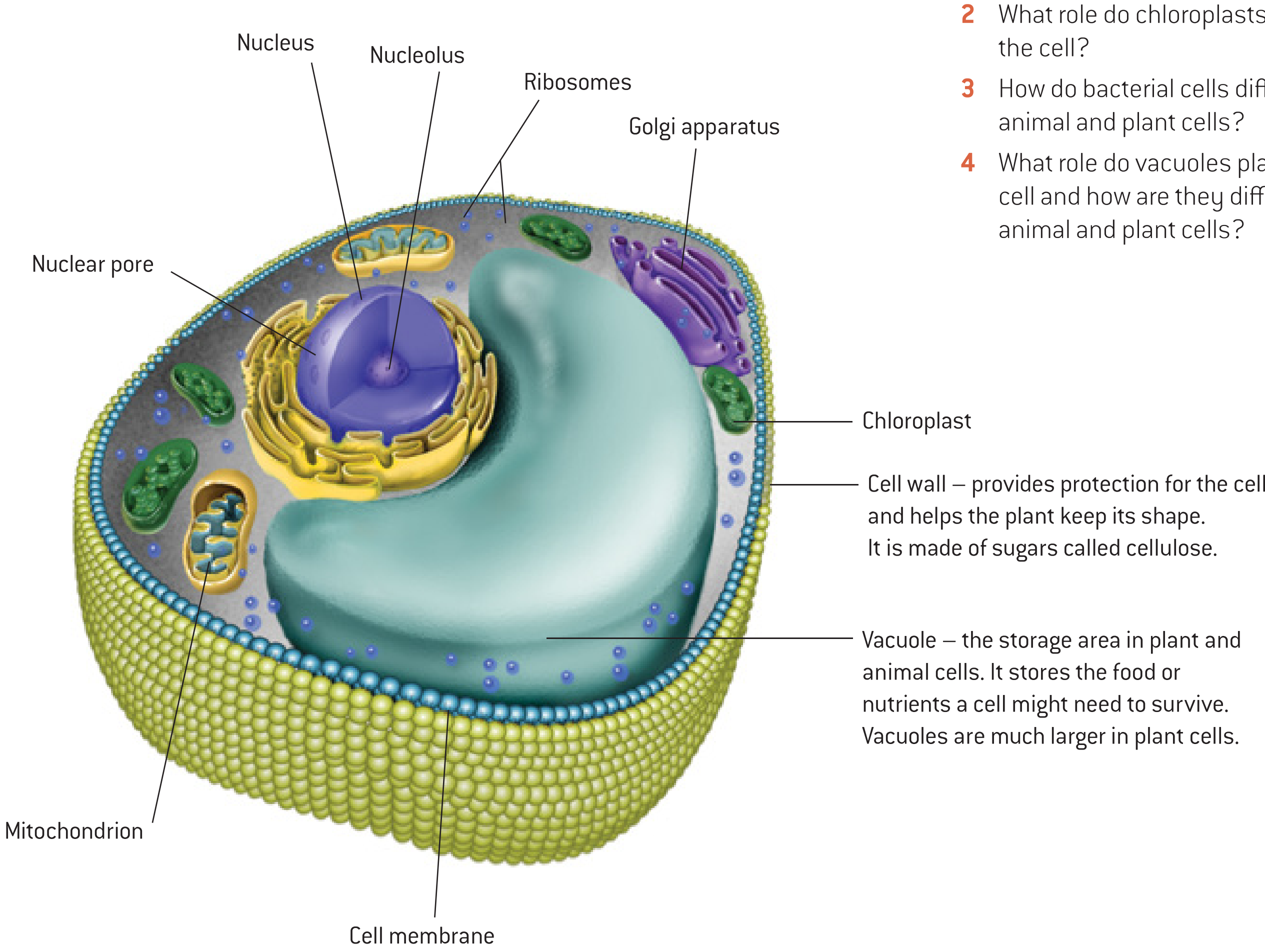


Electron micrograph of a chloroplast. Chloroplasts are food producers. These organelles are like microscopic solar panels that convert solar energy into chemical energy. Cells containing chloroplasts are mostly found on the tops of leaves.

BACTERIUM CELL



CROSS-SECTION OF A PLANT CELL



LOOK IT UP

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

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

chloroplast a structure (organelle) mainly found in large numbers in the leaf cells of plants; contains chlorophyll

cytoplasm the material found inside the cell; includes fluid (cytosol) and mini organs (organelles)

vacuole the space within the cytoplasm of a cell, enclosed by a membrane

CHECK IT OUT

1. What are the similarities and differences between plant and animal cells?
2. What role do chloroplasts play in the cell?
3. How do bacterial cells differ to animal and plant cells?
4. What role do vacuoles play in a cell and how are they different in animal and plant cells?

EXPERIMENT #2

PLANT AND ANIMAL CELLS

AIM: TO COMPARE PLANT AND ANIMAL CELLS

By looking at different characteristics of plants and animals, it's fairly easy to see that they are different types of organisms.

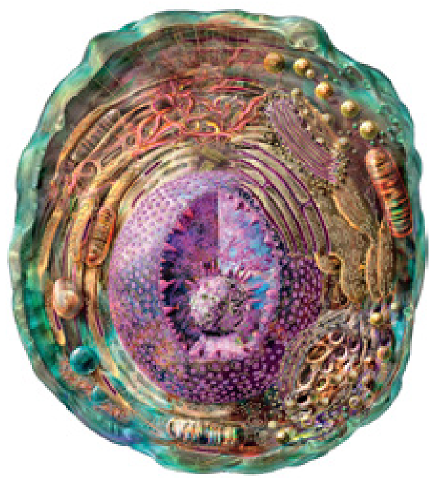
a *Typical plant cell*

MATERIALS

- Brown onion
- Compound light microscope
- Slide
- Cover slip
- Iodine in dropper bottle
- Prepared slide of animal cells

METHOD

1. Peel off a very thin piece of brown onion skin so that it looks a bit like cling film.
2. Place the skin on the microscope slide and add a tiny drop of iodine. This stains parts of the cells to make them easier to see.
3. Place one edge of the cover slip onto the slide and carefully lower it so that no air bubbles get trapped underneath.



b *Typical animal cell*

1

2

3

4 Place the slide on the stage.

5 Focus the microscope.

6 Draw the cells you observe. Don't forget to label your diagram and write down the total magnification.

7 Remove the slide and place the prepared slide of animal cells under the microscope. Focus the microscope.

8 Draw the cells you observe.

9 Write down the total magnification and label the diagram.

RESULTS

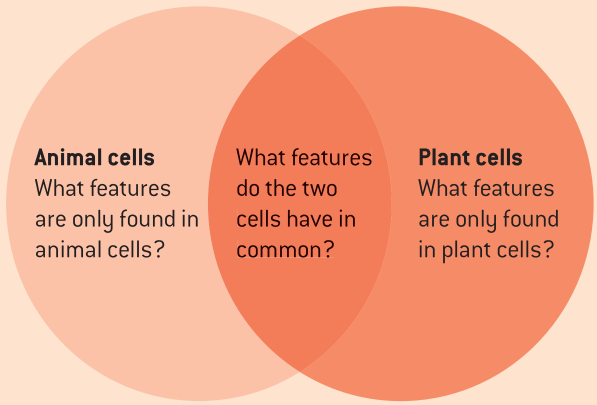
Include your cell diagrams here.

DISCUSSION

1 What is the purpose of staining the onion skin cells?

2 Compare the two sketches you have prepared with the images of plant and animal cells on page 20. List any differences and similarities.

3 Use the following Venn diagram to show how plant and animal cells are similar and how they are different.



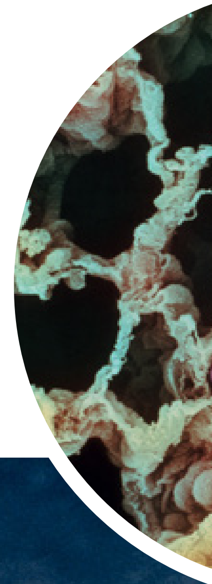
CONCLUSION

What do you know about plant and animal cells?

SCIENTIFIC EQUIPMENT

- Compound light microscope
- Microscope slide and cover slip
- Iodine in dropper bottle

FIGHTING CANCER



Most of us know someone who has been diagnosed with cancer. There are around 200 different known cancers that affect humans. Medical research has increased the survival rate (how long people can live) for many common cancers by 30 per cent in the past 20 years.

What is cancer?

Cells, like organisms, need to carry out many functions to survive. They need to process many substances, create and use energy, and reproduce (produce more cells). When cells are ready to reproduce, they split in half in a process known as **mitosis**. New cells need to be made to replace old or damaged cells, help an organism grow, or carry out a specific job. Each new cell has its own copy of the full set of DNA.

Cancer describes a group of diseases that result from uncontrolled cell division (when cell division can no longer be controlled by the cell). A cancer can form in any part of the body and affects humans and other animals. As an organism grows, cells reproduce to replace cells that are old or have died. The process of a cell dying is a normal and important part of the life cycle of an organism. Programmed cell death is known as **apoptosis**.

If a cell experiences some kind of damage, the genetic material may also be damaged or altered. DNA may be damaged by radiation, viruses or chemicals, which are called **mutagens**. Cancer-causing substances are called **carcinogens**. The change to the DNA results in a change in the instructions for the cell. If the instructions for the cell are changed (a mutation), the cell may no longer function as required.

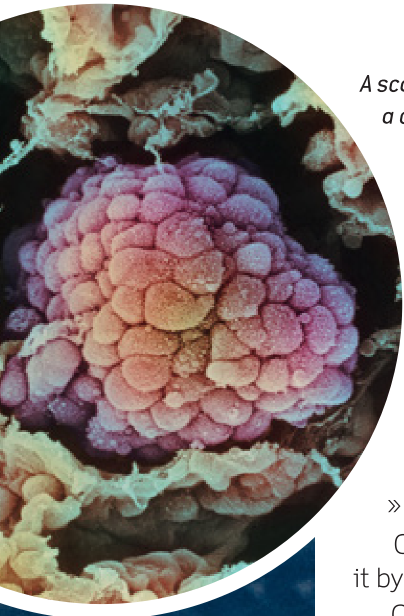
A scanning electron micrograph of a lung cancer cell dividing. The two daughter cells remain temporarily joined at the cytoplasmic bridge.

Tumours

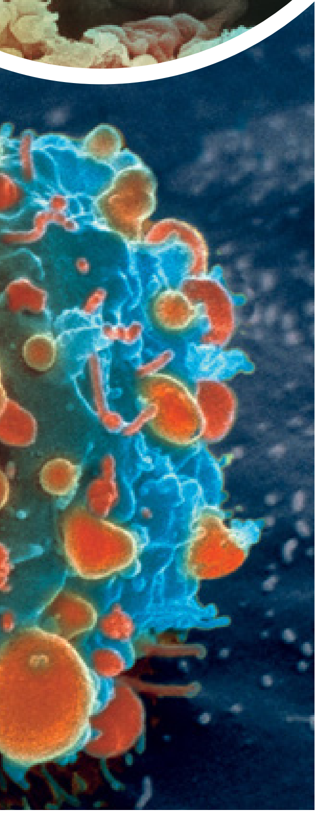
Damage to the genetic material may prevent a cell from self-destructing. It may also activate signals that were switched off, causing the cells to divide where they shouldn't. When cell division gets out of control, a lot of cells grow. This is called a **tumour**.

The tumour is the cancer. The tumour may split off (metastasise) and spread throughout the body, causing secondary cancers. The secondary cancers can damage or destroy other organs.

There are two types of tumours: benign and malignant. Benign tumours tend to grow slowly and do not spread. However, they can cause other problems such as ugly ulcers or symptoms due to pressing on nearby structures. Malignant tumours can spread to different parts of the body and can be fatal if their growth is not stopped.



A scanning electron micrograph of a cancerous tumour in the lung.



Detecting and treating cancer

The most common types of cancer in Australia are skin, prostate, bowel, breast and lung cancer. Cancer can be detected through:

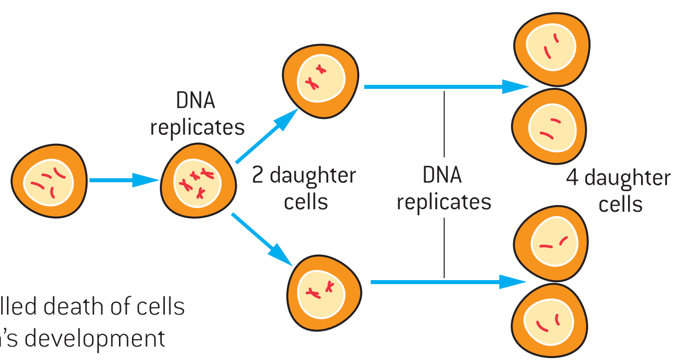
» signs and symptoms diagnosed by a doctor
» screening tests, such as blood and urine samples
» medical imaging, such as X-rays or MRI scans.

Once a possible cancer is detected, doctors diagnose it by looking at a tissue sample under a microscope.

Cancer is usually treated with combinations of **chemotherapy**, radiation therapy and surgery. Chemotherapy uses drugs to kill or slow the growth of cancer cells. The drugs travel through the bloodstream to reach cancer cells in organs and tissues. Chemotherapy kills cancer cells, but can also affect and sometimes kill normal cells that rapidly divide and grow. These include cells that make hair, which is why patients often lose their hair during chemotherapy.

Cancer cells recover more slowly than normal cells. When the next treatment starts, some of the body's normal cells have recovered but the cancerous cells have not. With every chemotherapy treatment, more cancer cells are destroyed.

THE PROCESS OF MITOSIS



LOOK IT UP

apoptosis the controlled death of cells as part of an organism's development

carcinogen a cancer-causing substance

chemotherapy the treatment of disease, such as cancer, by the use of chemical substances

mitosis the process of cell division to provide growth or repair; results in two daughter cells identical to the parent cell

mutagen an agent promoting mutation, e.g. radiation

tumour a growth caused by faulty cells growing out of control

CHECK IT OUT

1. Why do new cells need to be made?
2. What is cancer?
3. How do tumours form?
4. What is the difference between a benign and malignant tumour?
5. Describe how chemotherapy works.
6. Why do chemotherapy patients often lose their hair?

Ask a scientist

Dr Misty Jenkins

Dr Misty Jenkins studies the white blood cells that fight infected and cancerous cells.

Dr Misty Jenkins went to school in Ballarat, Victoria. Her lifelong interest in biology led her to undertake a Bachelor of Science degree, majoring in microbiology and immunology at the University of Melbourne. After her four-year course, she continued her studies, working with Professor Stephen Turner and Professor Peter Doherty. Professor Doherty is an Australian Nobel Prize winner. Misty investigated T-cells, the body's white blood cells that fight infection. T-cells can also attack cancer cells.

After obtaining a PhD, Misty travelled to Cambridge University in England. She became the first Indigenous student to undertake post-doctoral studies at the prestigious university.

Today, Misty is a researcher in the Cancer Cell Death laboratory at the Peter MacCallum Cancer Centre in Melbourne.

'I'm trying to work out how killer T-cells do their job. I hope to then apply this knowledge to help patients,' says Misty. The T-cells can destroy a cancer cell in minutes before moving on to hunt down others.

A video interview with Dr Misty Jenkins is available on your obook / assess.

REVIEW

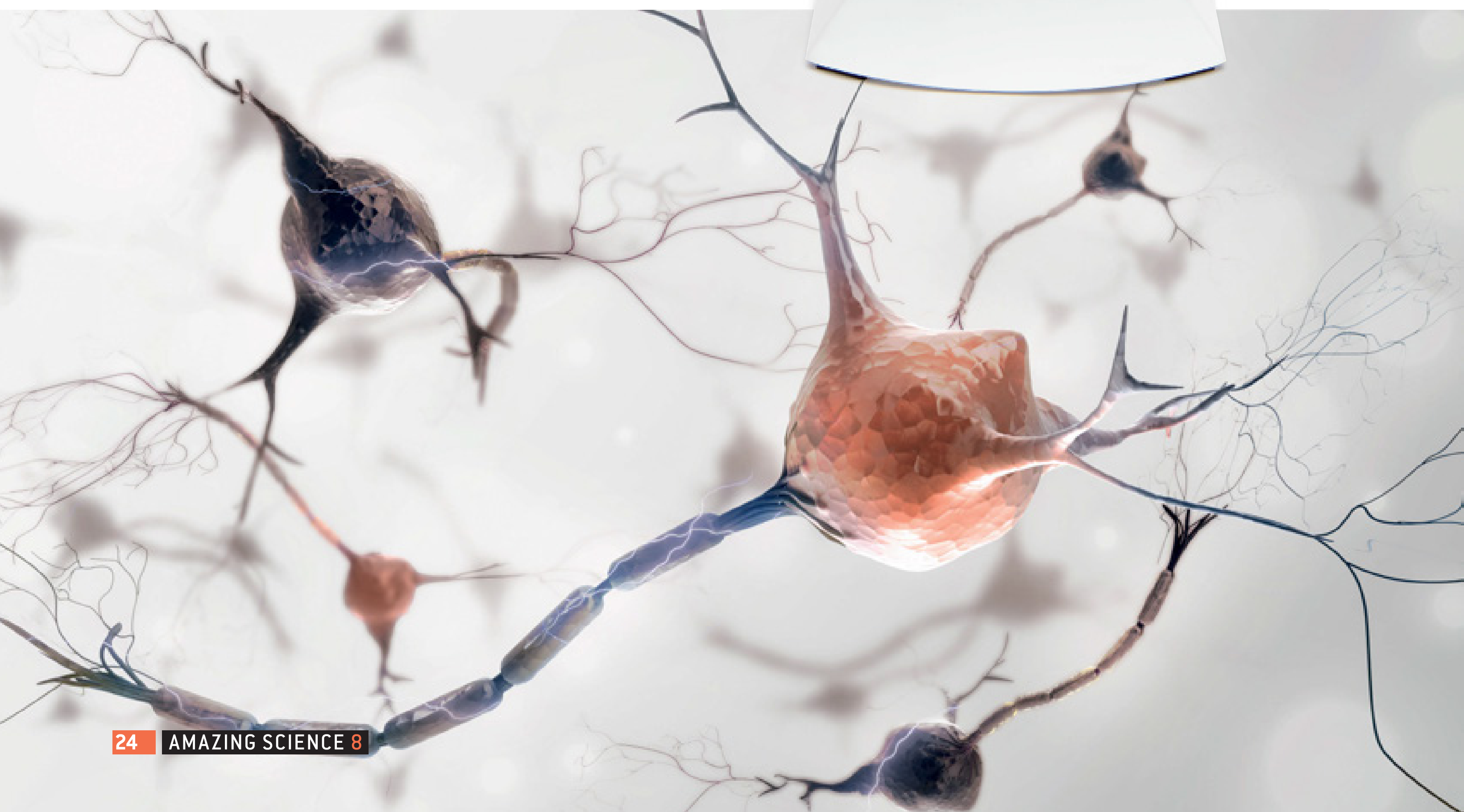
CELLS

ZOOMING IN (PAGES 6–7)

1 What did the invention of microscopes show?
2 What part of the microscope helps magnify the size of an object?
3 Name three things that would be useful to study under microscopes.
4 In what ways do you think Hooke's discoveries have helped science?

MICROSCOPES (PAGES 8–9)

5 Identify the type of microscope shown to the right.
6 Is a compound light microscope or a stereo microscope more suitable to view smaller objects like red blood cells?
7 What are the objective lenses and how could you use them to see things in a different way?
8 Why should you watch from the side when lowering the lens close to the cover slip?
9 What has been done to the hair follicle (opposite) to help it be clearly seen under the microscope?
10 Describe how computers may be used to improve microscopes.



BUILDING BLOCKS OF LIFE (PAGES 12–13)

11 Approximately how many cells are there in the human body?

12 Why are cells different sizes?

13 What do all cells have in common?

14 How are the cells in unicellular and multicellular organisms different?

CELL TEAMS (PAGES 14–15)

15 Why are skin cells and muscle cells different?

16 How do cells combine to form an organ?

17 Explain how cells work as a team to form a body system.

18 Look carefully at the cells shown in the photograph at the bottom of page 24.

- **a** What type of cells are these?
- **b** Sketch one of the cells and label it.

INSIDE CELLS (PAGES 16–17)

19 Name three of the components of cells.

20 What is the function of the pores in the nuclear envelope of a cell?

21 What happens to the DNA in the nucleus when a cell divides?

22 Why do different cells contain a different amount of mitochondria? Which do you think would have more mitochondria, the cells in your arm muscles or in your hair follicles?

23 What are some of the roles of mitochondria?

DIFFERENT CELLS (PAGES 18–19)

24 What are some of the features of animal cells?

25 Describe how energy is created in plant cells.

26 What might you find inside a bacterial cell?

27 If a plant doesn't have enough water, it can affect the cell walls. How do you think this might happen?

FIGHTING CANCER (PAGES 22–23)

28 Why do you think the process of mitosis is important?

29 Describe why it is important that old cells are replaced.

30 How are secondary cancers formed?

31 What are the major types of cancer in Australia?

32 Why do you think it is important that unusual moles on the skin are checked?

The root of a hair follicle, highly magnified.

KEY IDEAS

1 The microscope was invented in the mid-1600s and helped scientists understand that all living things are made up of cells.

2 The microscope allows us to see cells under lenses, which can magnify by different amounts. As a science student you will probably use two types of light microscopes: the compound light microscope and the stereo microscope.

3 Cells are the building blocks of life. Organisms can be multicellular or unicellular. All cells contain a cell membrane (the 'skin' of a cell) and cytoplasm (the 'jelly-like' fluid). All cells (except bacteria) have a nucleus (the control centre of the cell).

4 Cells work together like a team to achieve a specific goal. Groups of cells that do a similar task are called tissue. Groups of tissues that work together are called organs. When groups of different organs work together, they are called a body system.

5 Cells are made up of organelles (mini organs), cytoplasm, DNA, nutrients, wastes and other substances. Some of the organelles include the nucleus, mitochondria and ribosomes. Cells also have a cell membrane, which holds the contents of the cell together.

6 Plant cells and animal cells contain organelles. Plant cells tend to have one large vacuole (storage area) while animal cells often have many smaller vacuoles. Plant cells contain chloroplasts (which have chlorophyll) whereas animal cells do not.

7 Cells reproduce by splitting or dividing, which is called mitosis. Cancer is when uncontrolled cell division occurs.

8 The most common cancers in Australia are skin, prostate, bowel, breast and lung cancer. Cancer can be detected through signs and symptoms diagnosed by a doctor, screening tests such as blood and urine samples, and medical imaging such as X-rays or MRI scans.

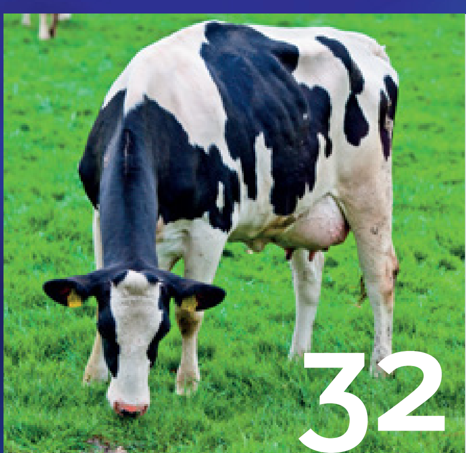
BODY SYSTEMS 02

HOW DO OUR BODIES WORK?

5 AMAZING WAYS TO REPRODUCE

What happens to the food we eat?

WHAT DOES BLOOD DO?

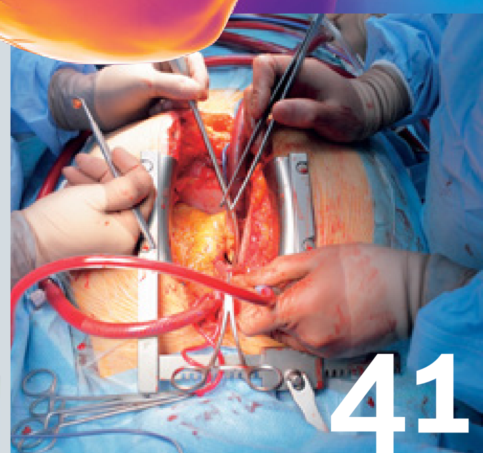


32

THE AMAZING STOMACH OF A COW

34

HOW DO WE BREATHE?



41

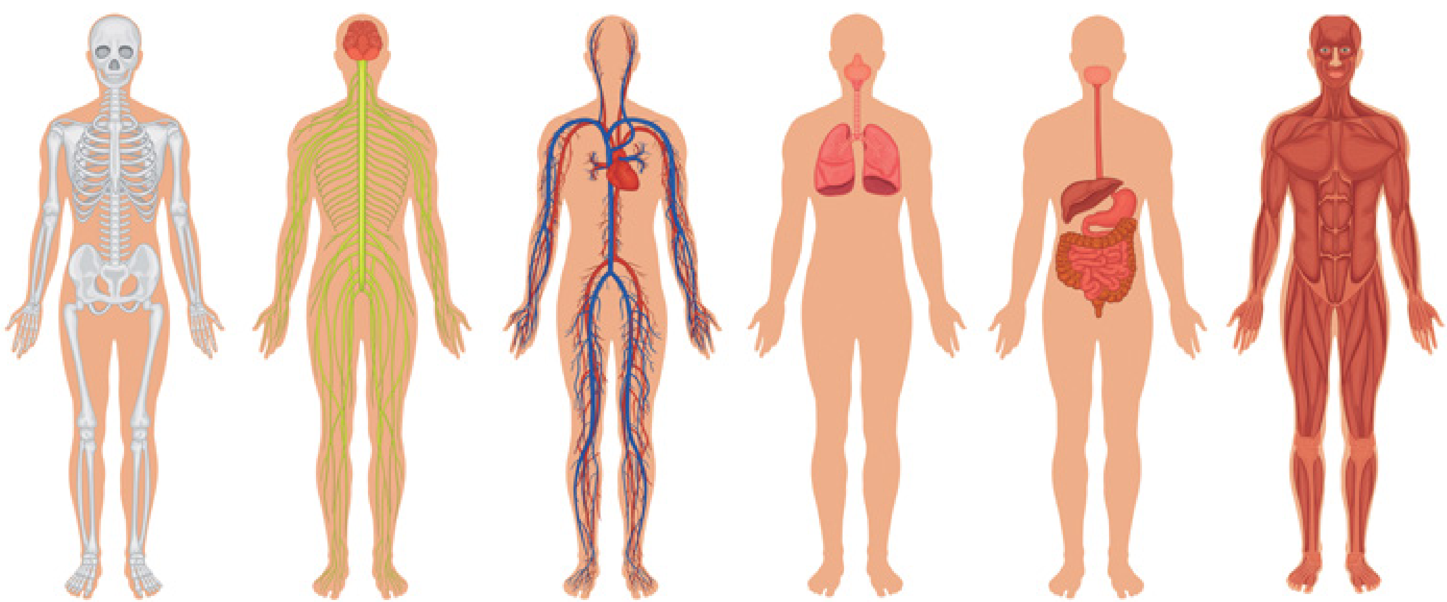
HOW CAN YOU MEND A BROKEN HEART?

HUMAN BODY SY

The human body is an amazing machine made up of many systems. Each system consists of two or more **organs** that work together to perform a function. For example, the nervous system is a combination of the brain, spinal cord and nerves. Connected by more nerves, these work together to carry electrical signals around our body to help us see, hear, think and react.

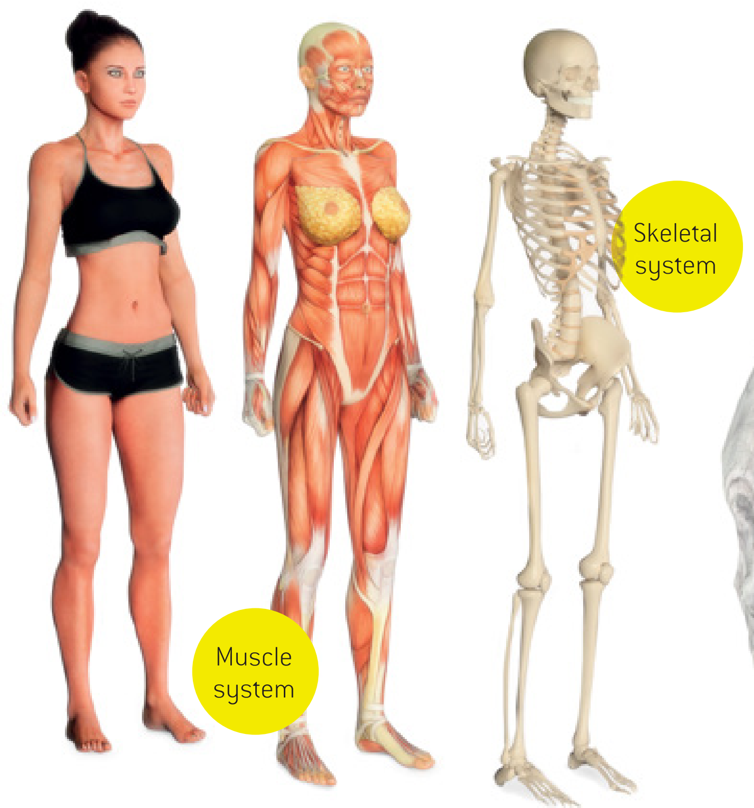
Major body systems

HOW BODY SYSTEMS WORK TOGETHER



SKELETAL SYSTEM	NERVOUS SYSTEM	CIRCULATORY SYSTEM	RESPIRATORY SYSTEM	DIGESTIVE SYSTEM	MUSCLE SYSTEM
The skeletal system supports and gives the body shape. It is made up of **tissues** including bone, cartilage, tendons and ligaments.	The brain, spinal cord and **nerves** are the organs of the nervous system that carry electrical signals around our body.	The heart, blood and blood vessels work together to deliver oxygen and nutrients throughout the body and remove wastes.	Our lungs, windpipe, nose and diaphragm work together to allow us to breathe.	The mouth, oesophagus, stomach, liver, small intestine and large intestine assist in the digestion of food to provide energy.	Each muscle in our body is an organ. Our muscles work together along with our bones to help us move.

STEMS



The human body is made up of a range of systems that work together to help us stay alive, move and remain healthy.

LOOK IT UP

nerves the fibres in the body that carry messages to and from the brain, so that parts of the body can feel and move

organ a group of tissues that work together, e.g. liver, heart, eyes, brain, skin

tissue a group of cells that do a similar task

CHECK IT OUT

1. What is meant by the term 'body system'?
2. What is the function of the circulatory system?
3. Name three organs that are part of the digestive system.
4. Which body systems work together to help us move?

DIGESTIVE SYSTEM

Digestion occurs when foods are broken down and absorbed into your blood to be transported to your cells. The food we eat gives us the energy to stay alive and the building blocks for growth and repair. We also need to eat food with fibre in it, such as fruits and vegetables. These foods help move everything through the digestive system.

What happens to the food we eat?

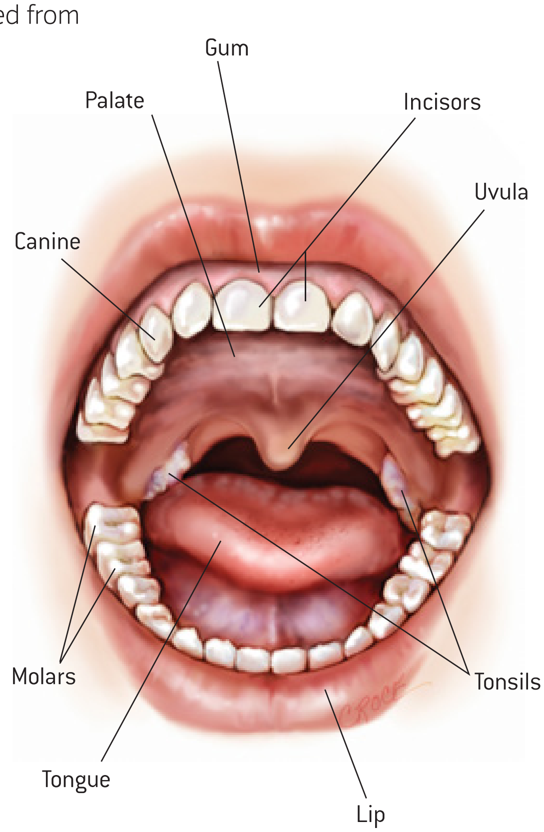
Food enters your mouth and passes through the digestive tract. The digestive tract forms a tube stretching from your mouth to your anus. Along the way, food is broken down and absorbed across the walls of the intestines and into the blood. The blood pushes **nutrients** from the food around the body to where they are needed. Food that cannot be digested by the body becomes waste and stays in the digestive tract until the end, where it is discharged from the body.

Mechanical digestion

Mechanical digestion is where the mouth works like a machine, biting and breaking food to divide it into smaller pieces.

Chemical digestion

Chemical digestion happens when chemicals called **enzymes** break down the food. Chemical digestion begins in the mouth.



Your mouth is home to three main types of teeth: the front ones are called incisors (for cutting); the pointy teeth next to the incisors are called canines (for piercing and holding food); and the rest of your teeth, which are flatter, are called molars (used for grinding food). Your tongue, a large muscular organ, pushes food around, helping your teeth crush it.

Teeth and mouth

The teeth are responsible for the physical breakdown of food and the tongue is important in pushing the food towards the teeth. Salivary glands make saliva, which contains enzymes to start chemical digestion.

Oesophagus

The oesophagus is a tubular muscle that forces food down to your stomach in a process called peristalsis.

Liver and gall bladder

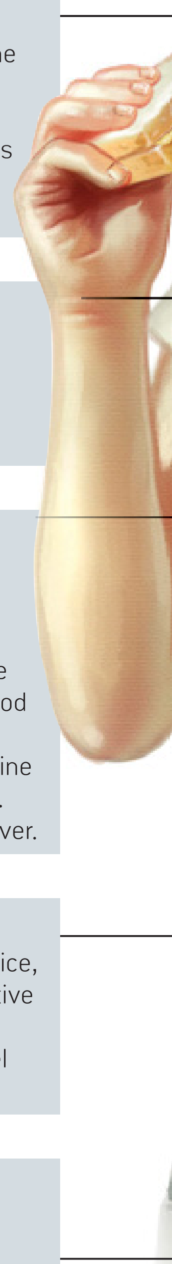
The liver makes a mixture of chemicals called bile, which is used to digest fat and neutralise (deactivate) stomach acid. The bile is stored in the gall bladder until food reaches the small intestine. Bile is then released into the small intestine through a tube called the bile duct. Food does not travel through the liver.

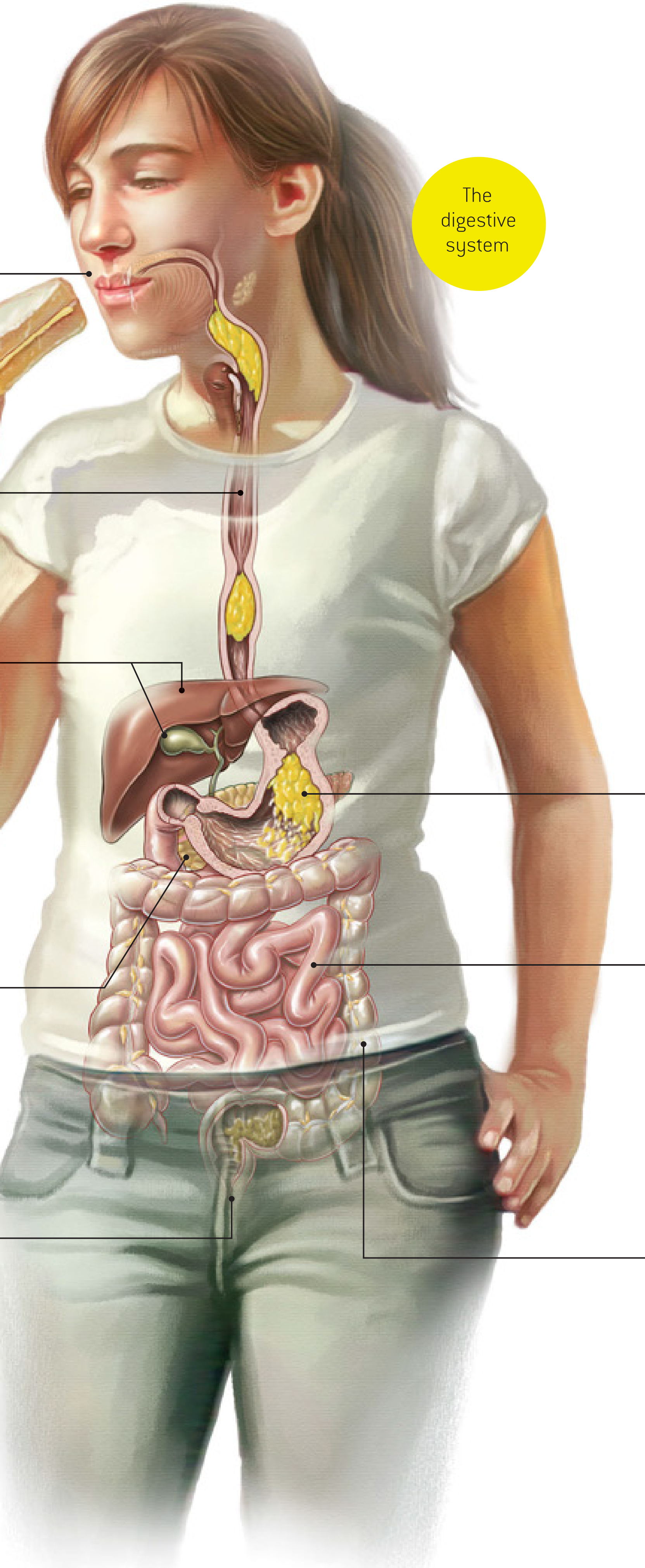
Pancreas

The pancreas makes pancreatic juice, which contains a mixture of digestive enzymes and also neutralises stomach acid. Food does not travel through the pancreas.

Rectum and anus

The rectum is the final part of the journey for what is now solid, undigested food, or faeces (poo). The rectum stores faeces until it starts to become full. As the rectum starts to stretch, messages are sent to the brain to make you realise that you need to go to the toilet. Rectal muscles push the faeces out of the ring of muscle at the end of the rectum called the anus.





LOOK IT UP

chemical digestion the breakdown of food by enzymes and acids

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

enzyme a substance produced by living organisms that helps make chemical reactions happen

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

CHECK IT OUT

1 Starting from the mouth, list the organs of the digestive tract, in order.
2 Food doesn't pass through the pancreas or liver, but these organs still play a role in the digestion of food. What do these organs do?
3 What is the difference between mechanical and chemical digestion?
4 What important role does the small intestine play?
5 What is faeces and how is it expelled from the body?

Stomach

The stomach stores food for about 3 hours while it uses gastric juice to help digest the food. The food in your stomach looks nothing like what you ate for dinner. It is very runny, warm and smelly and has a totally different taste. This mixture is called chyme.

Small intestine

The small intestine is called small because it is quite narrow. If you laid a small intestine out in a straight line, it would be approximately 5 metres long. The intestines are very important because they absorb the nutrients that feed all the cells of the body. The ability to absorb nutrients is increased by wrinkles, called villi, along the inner wall of the intestine that increase the surface area for absorption. Surface area is important in many systems of the body. Bacteria in the small intestine also help with digestion. Sometimes bacteria can produce foul-smelling gases, which escape from the rectum. Chyme takes about 5 or 6 hours to pass through the small intestine.

Large intestine

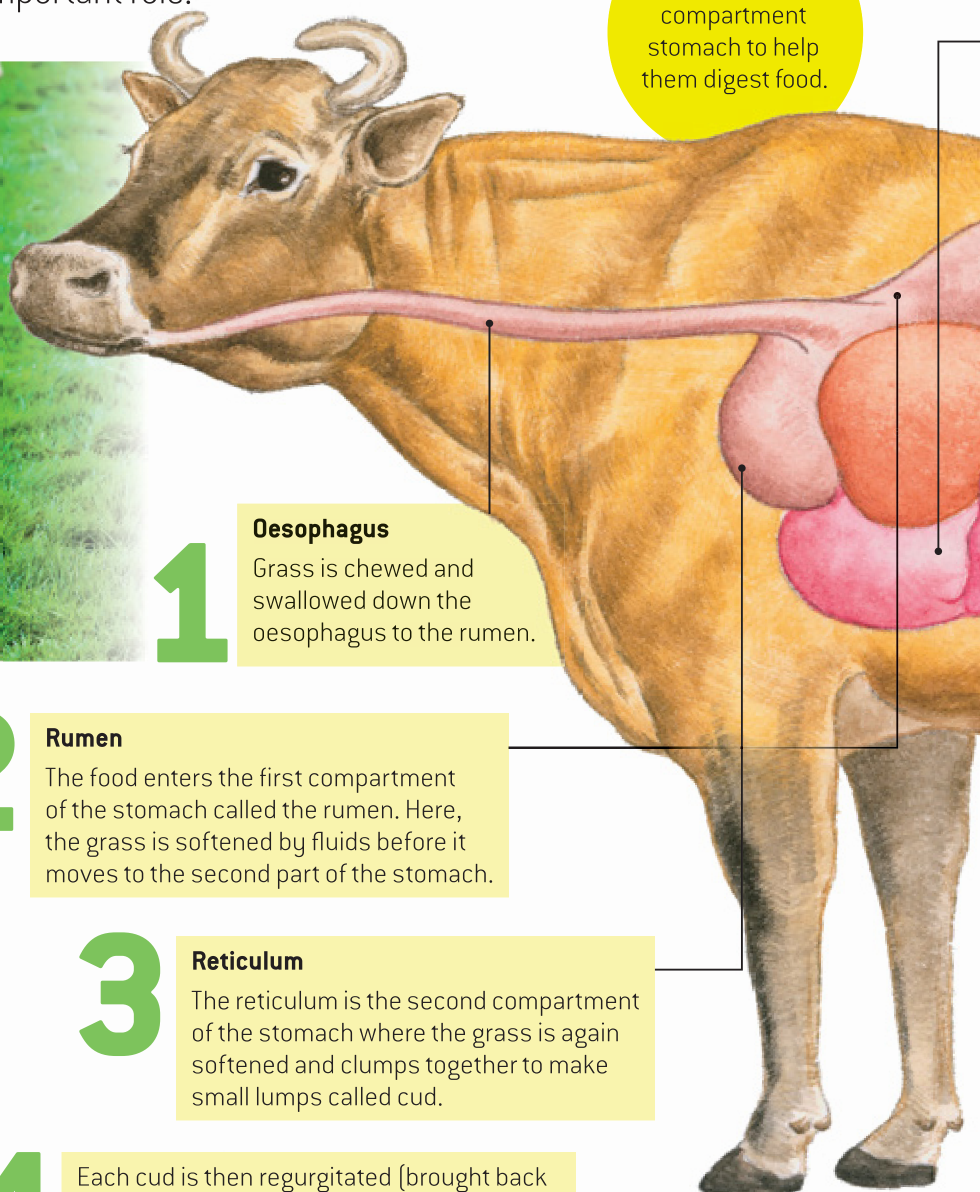
The large intestine is also called the colon and is wider but shorter than the small intestine. The large intestine is approximately 1.5 metres long. By the time the chyme reaches the large intestine, most nutrients have been absorbed into the bloodstream. However, some vitamins are absorbed from the large intestine. Water is also absorbed into the bloodstream from the large intestine. Chyme stays in the large intestine for up to 14 hours, or sometimes longer.

THE AMAZING STOMACH OF A COW

Unlike humans, cows have a four-compartment (part) stomach to help them digest and process food. Each of the four compartments plays an important role.

Cows have a four-compartment stomach to help them digest food.

Dairy cows eat grass for 9 to 12 hours every day and take an amazing 60 bites per minute.



1 Oesophagus

Grass is chewed and swallowed down the oesophagus to the rumen.

2 Rumen

The food enters the first compartment of the stomach called the rumen. Here, the grass is softened by fluids before it moves to the second part of the stomach.

3 Reticulum

The reticulum is the second compartment of the stomach where the grass is again softened and clumps together to make small lumps called cud.

4

Each cud is then regurgitated (brought back to the mouth) so the cow can now chew it quickly and easily. This is why cows always appear to be chewing.

Cow's digestive system

Cows are **ruminants** (so too are sheep and goats). Ruminants convert grass and other foods into protein and energy through their amazing four-compartment stomach. It takes one to three days for food to pass through a cow's digestive tract, depending on the type of food.

5

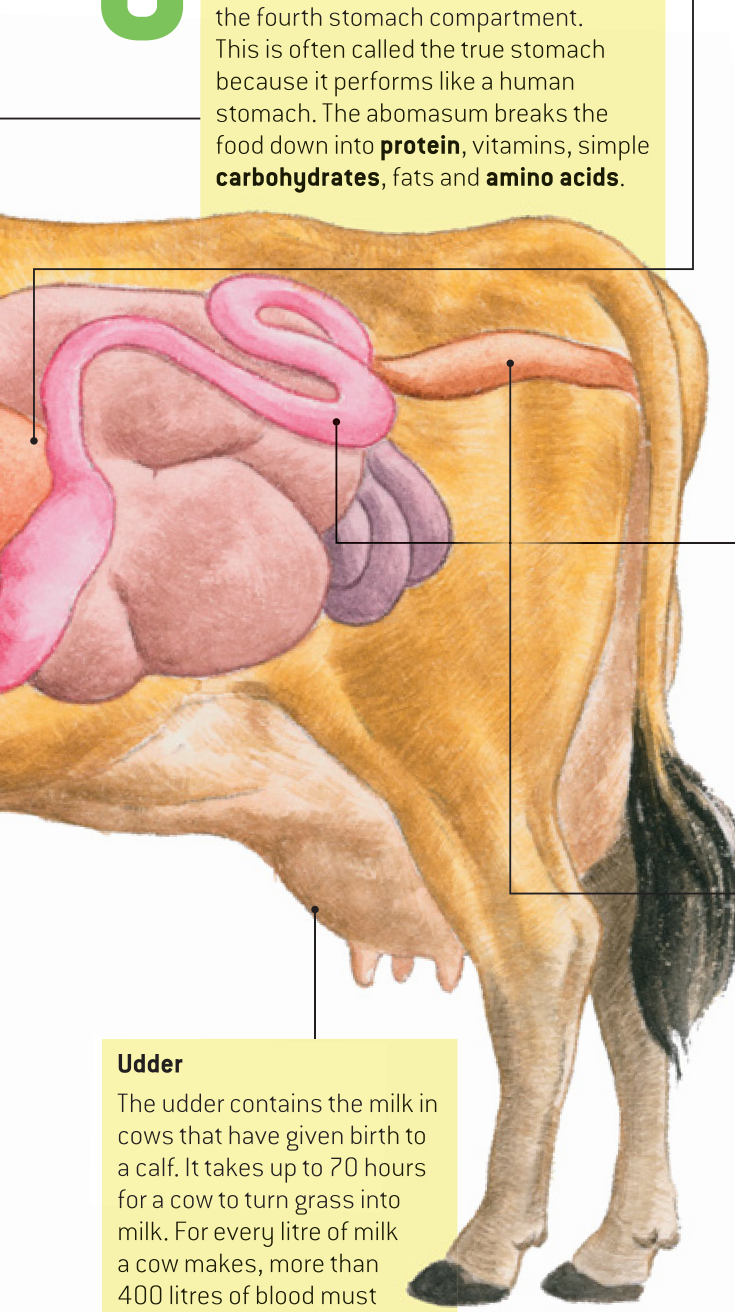
Omasum

The chewed cud travels into the omasum, the third stomach compartment. The omasum has many folds of tissue that look like a partly open book. Here, the cud is pressed and further reduced in size.

6

Abomasum

The cud then travels to the abomasum, the fourth stomach compartment. This is often called the true stomach because it performs like a human stomach. The abomasum breaks the food down into **protein**, vitamins, simple **carbohydrates**, fats and **amino acids**.



7

Small intestine

The small intestine is the main site for absorption of important chemicals.

8

Large intestine

The large intestine absorbs, re-circulates and conserves water. It also absorbs minerals.

Udder

The udder contains the milk in cows that have given birth to a calf. It takes up to 70 hours for a cow to turn grass into milk. For every litre of milk a cow makes, more than 400 litres of blood must travel around her udder to deliver the nutrients from the grass. Australian dairy cows produce about 15 litres of milk a day.

A cow's mouth

Cows have fewer teeth than other animals. In the front of the mouth, incisor teeth (cutting teeth) occur only on the bottom jaw. Instead of the top incisors that humans have, a cow has a hard leathery dental pad. A cow uses its tongue to grab a clump of grass and then bites it with its incisor teeth.

Molar teeth in the back of the mouth grind the plant material into small pieces as the cow chews in a side-to-side motion. As the cow chews, enzymes in its saliva mix with the food before it passes down the **oesophagus** into the four-compartment stomach.

Cows have a dental pad instead of top incisor teeth, and a long tongue to grab clumps of grass.

LOOK IT UP

amino acid a small compound that makes up a protein; building block of proteins

carbohydrate a class of compound containing carbon, hydrogen and oxygen atoms

oesophagus part of the digestive system; a tube that carries food from the mouth to the stomach

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

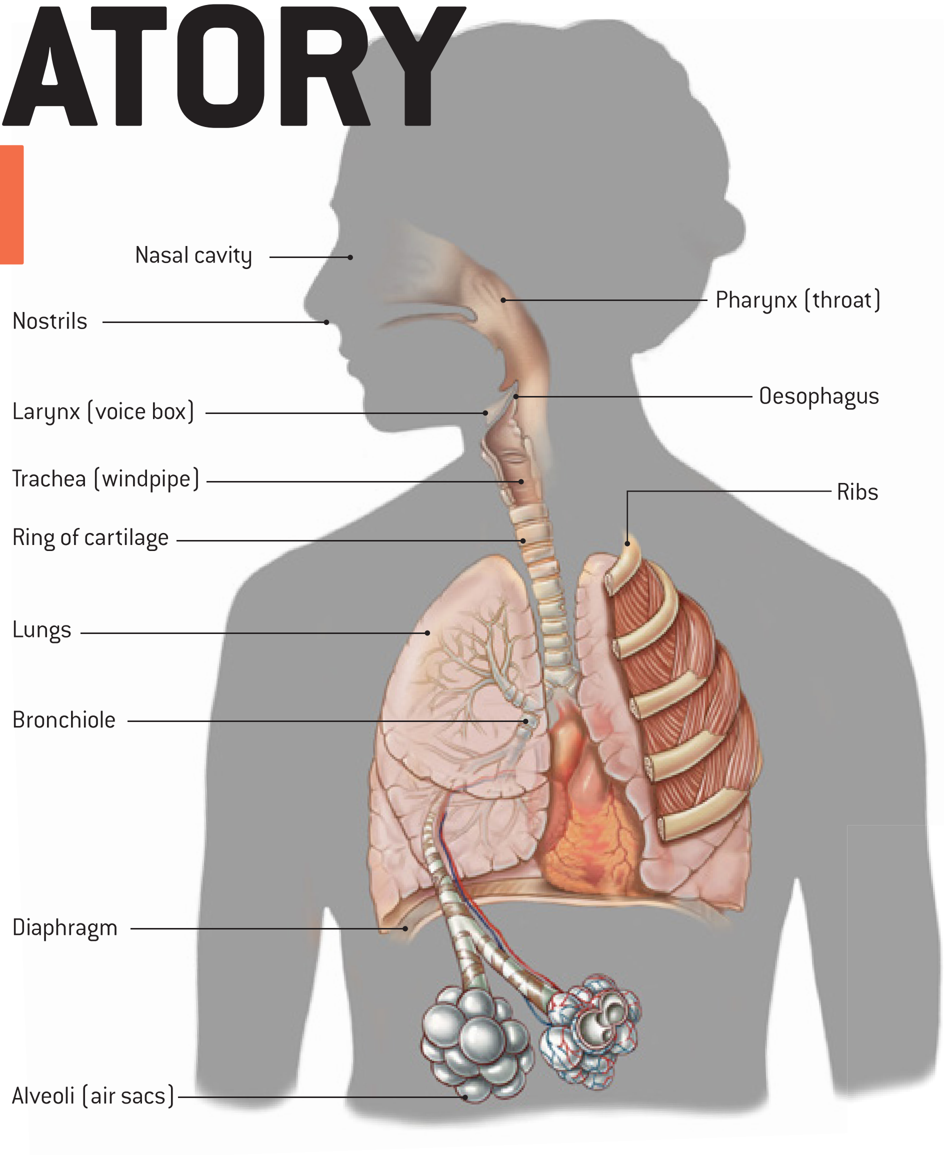
ruminant a mammal that chews cud regurgitated (brought up again) from its four-compartment stomach to further break down the cellulose, which is difficult to digest

CHECK IT OUT

1 How is the stomach of a cow different to yours?
2 Which other animals have a similar digestive system to a cow? What is this group of animals called?
3 Describe the purpose of a cow's incisor and molar teeth.
4 Why does a cow always appear to be chewing, even when it isn't eating grass?
5 Which of the four compartments in a cow's stomach is known as the true stomach? What job does it do?

RESPIRATORY SYSTEM

The respiratory system gives the cells in your body the oxygen they need, and removes carbon dioxide. We breathe oxygen into our lungs and transfer it into our blood so it can be transported around the body. Cells need oxygen to create energy from the food we eat.



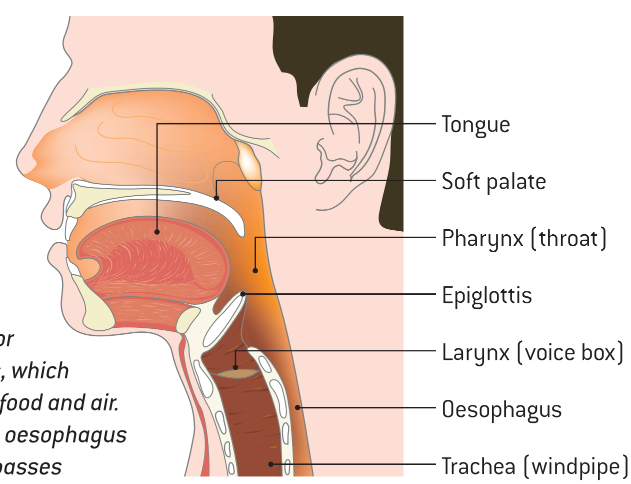
The lungs

There are two **lungs** in our chest. Every time we take a breath, each lung fills with air and increases in size. The trachea branches into two tubes to carry air into each lung. These branches are called bronchi. The lungs feel spongy because they are home to millions of tiny air sacs called **alveoli**. If these air sacs were untangled and flattened, they would be the size (surface area) of almost half of a tennis court!

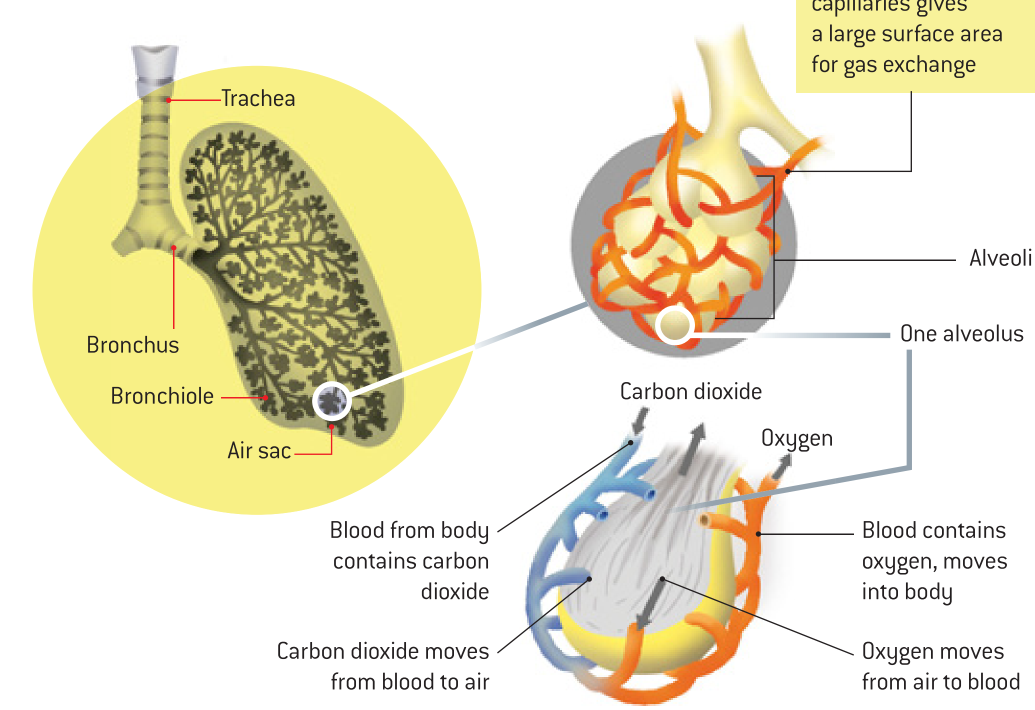
Each tiny alveolus (air sac) is covered by a mesh of even smaller blood vessels called **capillaries**. The lungs are organised to have as many air sacs as close to as many blood vessels as possible. For oxygen and carbon dioxide to pass between the air sacs and the blood, the blood vessels need to be able to get really close to the air. Oxygen passes into the blood, whereas carbon dioxide passes out of the blood into the air. We then exhale (breathe out), releasing the carbon dioxide from our bodies as each lung decreases in size.

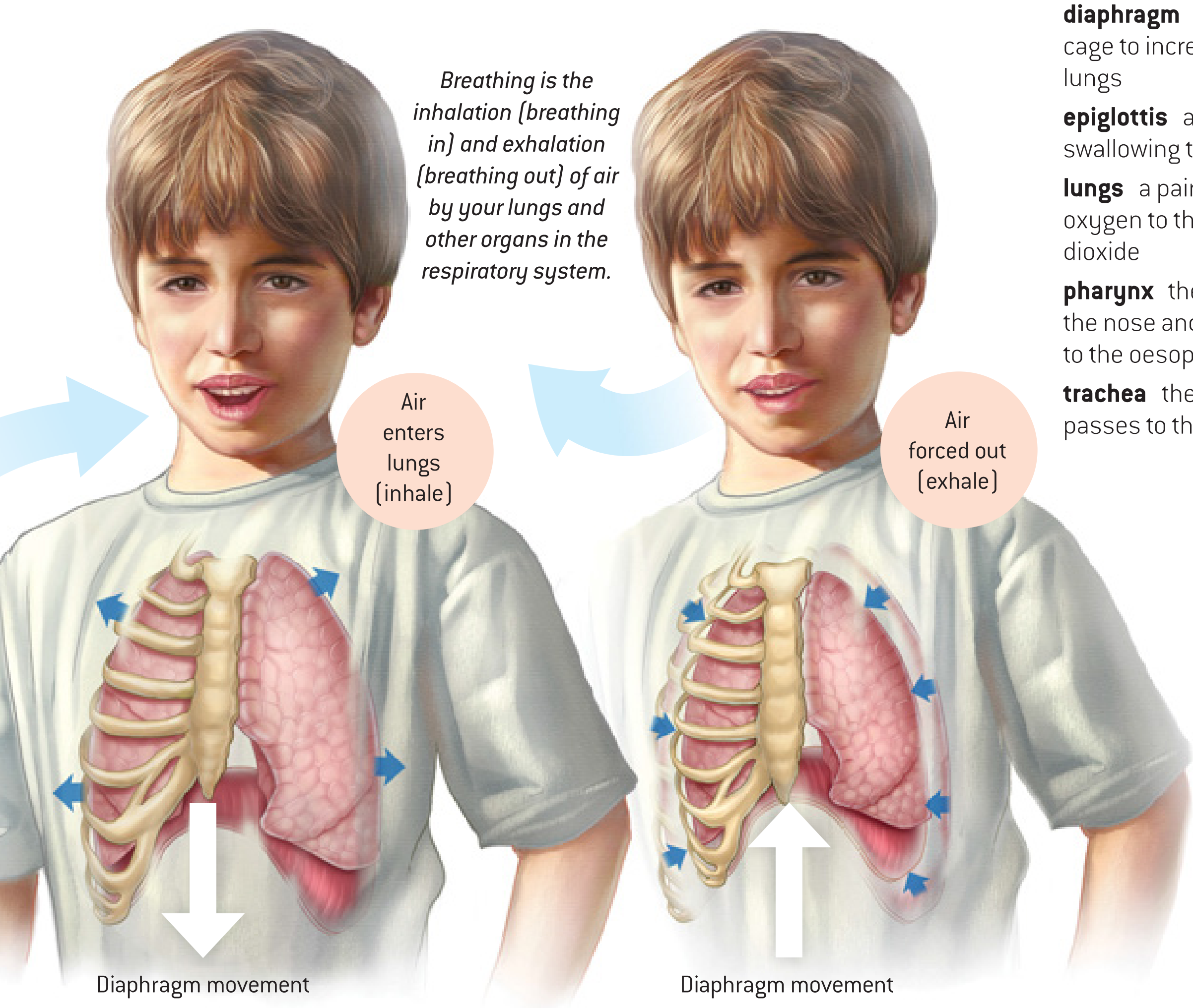
THE RESPIRATORY SYSTEM

*We breathe air in through our nose and mouth. As we breathe, the air is cleaned with hairs and wet surfaces as it travels to our **pharynx** (throat). At the bottom of the pharynx is a trapdoor called the **epiglottis**, which controls the path of food and air. Food goes down the oesophagus to the stomach. Air passes through the **trachea** (windpipe) to the lungs.*



GAS EXCHANGE IN THE ALVEOLI





Breathing is the inhalation (breathing in) and exhalation (breathing out) of air by your lungs and other organs in the respiratory system.

The diaphragm

The **diaphragm** is a dome-shaped muscle that is connected to your ribs and moves up and down beneath your lungs. The muscle contracts down and relaxes up. When the muscle doesn't move properly, you feel winded. The dome shape of the diaphragm protects the heart and lungs from the other organs. The lungs have no muscle tissue, so they can't move on their own. Muscles between the ribs lift the rib cage up and out to increase the 'suction' of air into the lungs, pulling the air in and filling them up.

LOOK IT UP

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

capillaries small blood vessels connecting arteries and veins

diaphragm the muscle that lifts the rib cage to increase suction of air into the lungs

epiglottis a flap that closes during swallowing to cover the windpipe

lungs a pair of breathing organs that bring oxygen to the blood and remove carbon dioxide

pharynx the cavity with muscles behind the nose and mouth, connecting them to the oesophagus

trachea the windpipe through which air passes to the lungs

CHECK IT OUT

1. What is the function of the respiratory system?
2. What role does the epiglottis play?
3. Describe what happens to your diaphragm when you inhale and exhale.
4. How do the lungs change in size and why?
5. What two key jobs do alveoli perform?

HOW DOES A FISH BREATHE?

Human lungs would not work for a fish because they would fill with fluid instead of air. Fish can breathe underwater by taking in oxygen from the water using their amazing **gills**.

Sharks are fish. They take in water through their mouth and expel it through their gills. As the water passes over the gills, oxygen is taken out and absorbed into the blood.

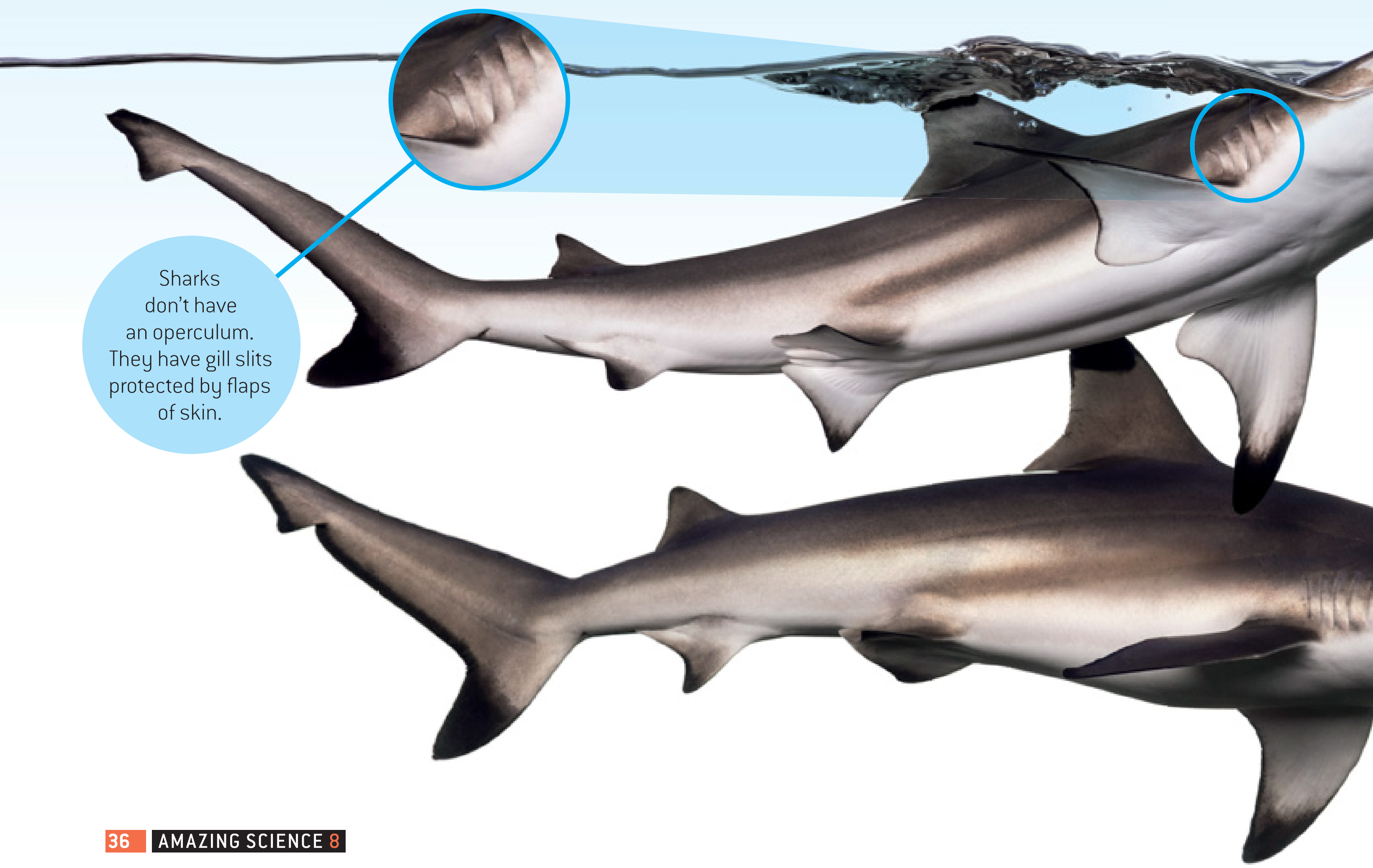
The respiratory system of fish

When we breathe, tiny air sacs in our lungs take **oxygen** out of the air. A mammal's lungs wouldn't work for a fish. One breath under the water would fill the lungs with water, making the lungs useless.

Fish breathe under water by taking in oxygen from the water through their gills. The gills are found on either side of the head of the fish.

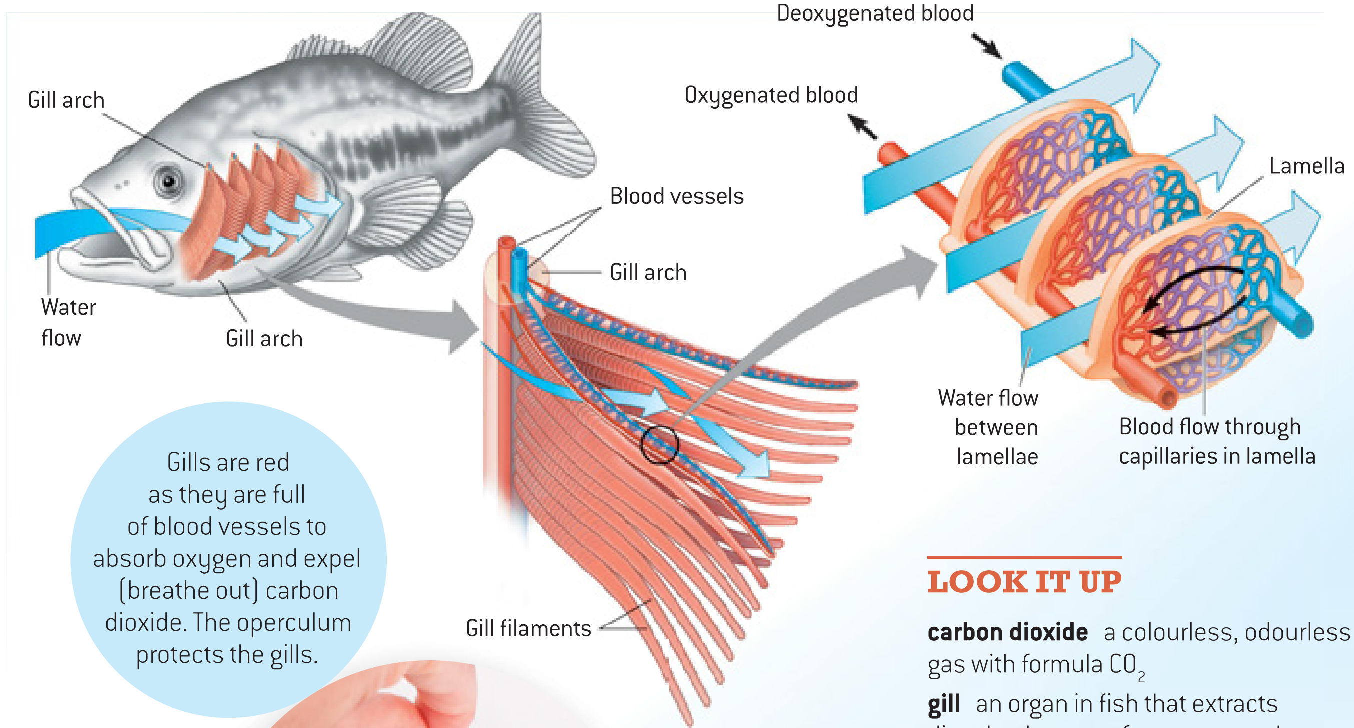
Fish open their mouths to take in water and force it out through the gills. Gills are organs that are full of blood vessels, which give them a bright red colour. As water passes over the gill filaments (small threads of tissue), dissolved oxygen is absorbed into the blood. Any **carbon dioxide** is then breathed out into the water.

Gills have bony loops called gill arches underneath them, and are protected by a hard bony flap called the **operculum**. Fish such as sharks and stingrays don't have an operculum and simply have flaps of skin to protect the gills.



Sharks don't have an operculum. They have gill slits protected by flaps of skin.

HOW FISH GILLS WORK



Gills are red as they are full of blood vessels to absorb oxygen and expel (breathe out) carbon dioxide. The operculum protects the gills.

LOOK IT UP

carbon dioxide a colourless, odourless gas with formula CO_2

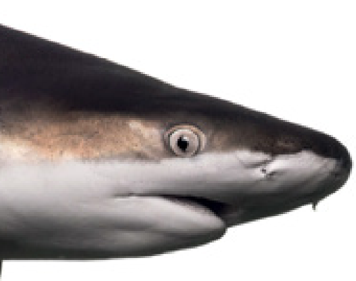
gill an organ in fish that extracts dissolved oxygen from water and releases carbon dioxide

operculum a hard bony flap that protects the gills

oxygen a colourless, odourless reactive gas; the life-supporting component of air

How do dolphins and whales breathe?

Dolphins and whales are mammals and, like humans, they have lungs. They must swim to the surface to breathe in air through the blowhole on top of their heads.



CHECK IT OUT

1 Why don't fish have lungs like mammals?

2 Complete this sentence: Fish take in water through their ________ and absorb ________ into their ________.

3 How do fish absorb the oxygen they need from water?

4 Why are gills red?

5 How do dolphins and whales breathe?

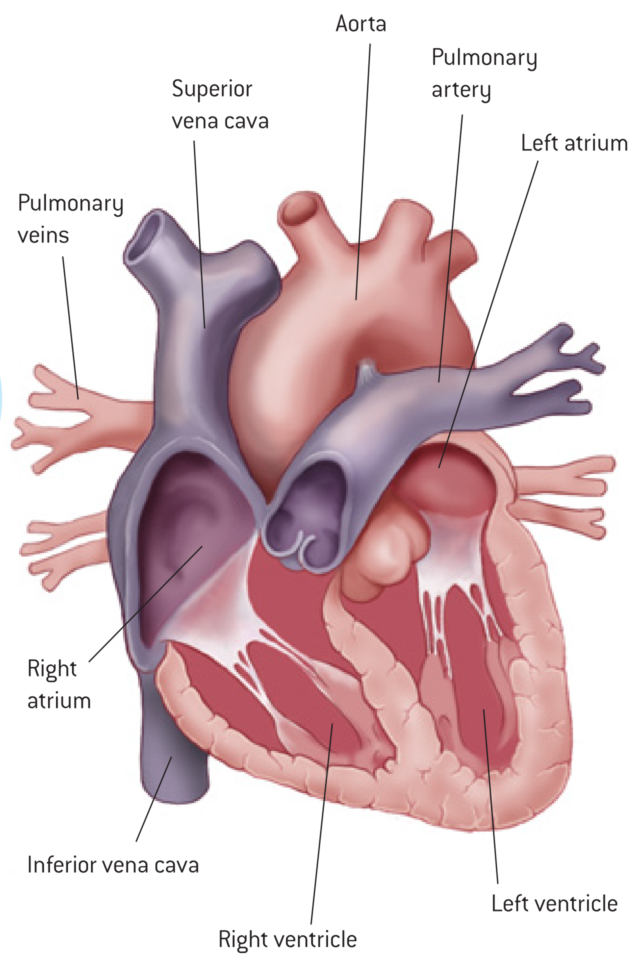
CIRCULATORY SYSTEM

The circulatory system is the body system that moves blood around your body. The blood transports substances such as nutrients and wastes.

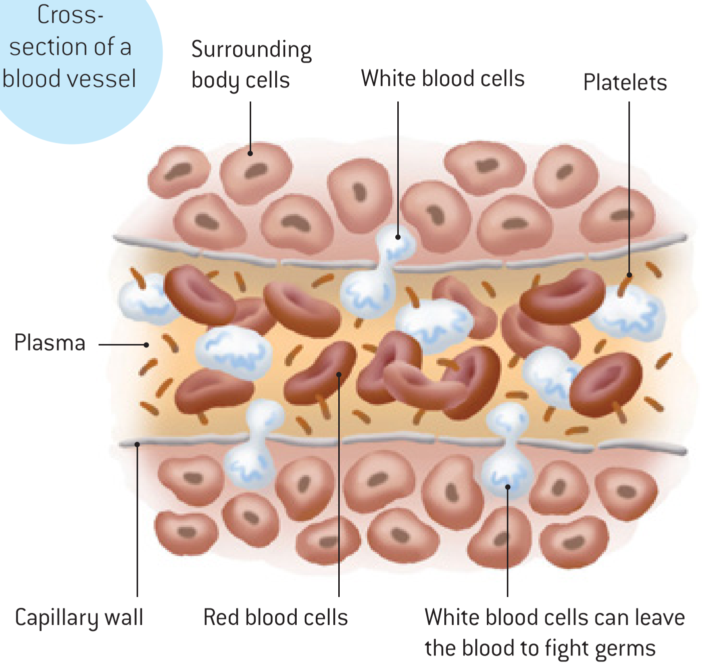
Heart

The **heart** is a large two-part pump about the size of your fist. It is made of four chambers: two **atria** (compartments) at the top and two **ventricles** (compartments) at the bottom. The right side pumps blood to the lungs to release carbon dioxide and absorb oxygen. The left side pumps blood around the body. Flaps of tissue called valves keep the blood moving in the correct direction. The largest blood vessel in the body, the **aorta**, starts at the top of the heart and extends downwards.

The heart and some of the major blood vessels travelling to and from the heart



Cross-section of a blood vessel



Blood

Blood delivers nutrients and oxygen to cells and transports waste away from them. The main components of blood are:

- red blood cells – carry oxygen to the body's tissues and carbon dioxide away from them
- haemoglobin – carries oxygen in red blood cells
- plasma – component of the blood in which nutrients and wastes are dissolved for transport to and from cells
- white blood cells – germ fighters that travel in the blood to places where an immune response is needed
- platelets – cell fragments that travel in the blood to cuts to block the cuts and stop bleeding.

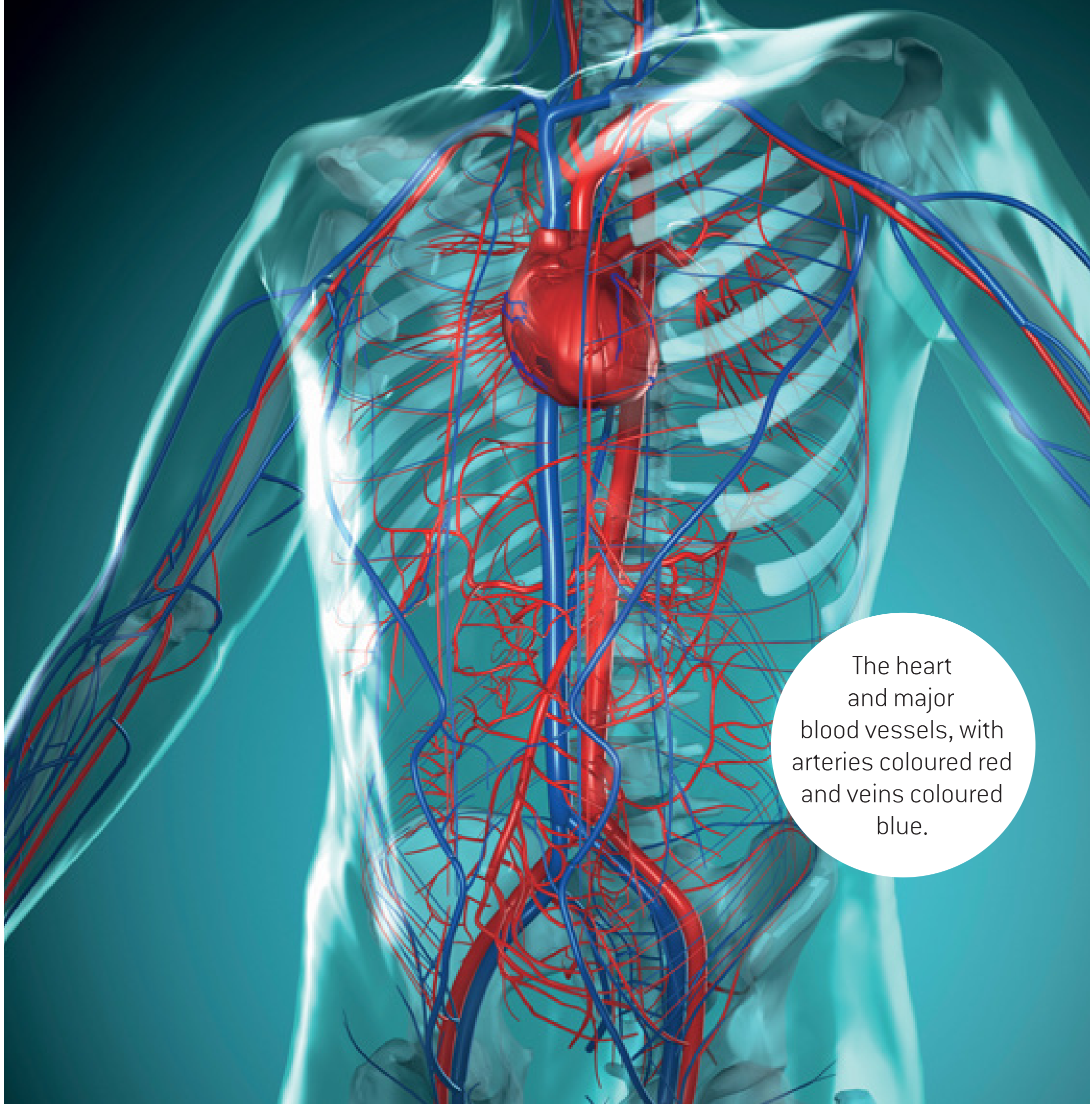
Blood vessels

Blood travels through tubes called **blood vessels**. Blood vessels have different sizes and structures. Their size and shape depends on the amount of blood they need to carry, as well as the speed of the blood and whether it is picking up or dropping off substances.

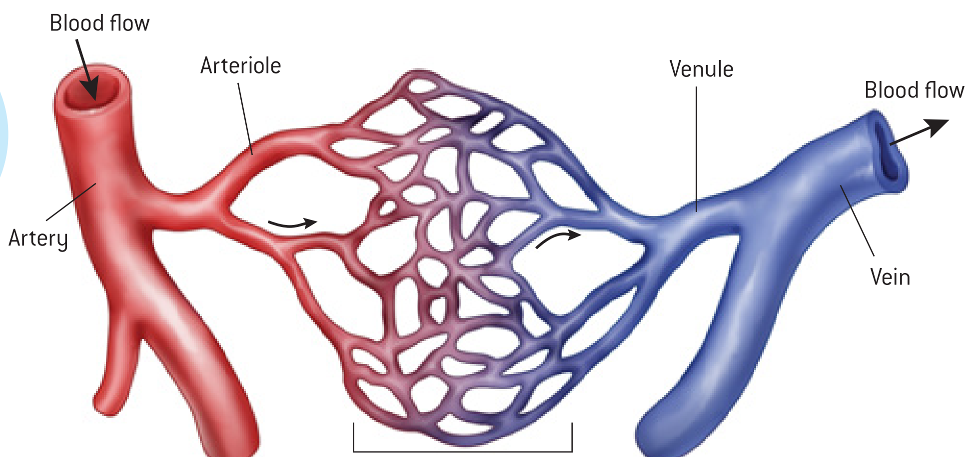
Arteries are the largest blood vessels. Arteries have thick, muscular walls to cope with high pressure and to squeeze the blood along. Arteries travel away from the heart, and the blood is at a higher pressure here because it has just been pumped. Arteries branch into arterioles (smaller arteries).

Veins carry blood back to the heart. These vessels are similar in size to the arteries, but only have a small amount of muscle in their walls. Veins have one-way valves in them to avoid any blood going backwards due to a lack of pressure. Venules (smaller veins) are joined together to make larger veins.

Capillaries have walls that are only one cell thick to allow substances to easily pass in and out of the blood. Capillaries are the vessels connecting the arteries and veins – the arterial and venous systems.



The heart and major blood vessels, with arteries coloured red and veins coloured blue.



Relationship between arteries, veins and capillaries

LOOK IT UP

aorta the largest blood vessel in the body, which starts at the top of the heart and extends downwards

atrium each of the two upper cavities of the heart from which blood is passed to the ventricles (plural: atria)

blood vessels arteries, veins and capillaries that transport blood around the body

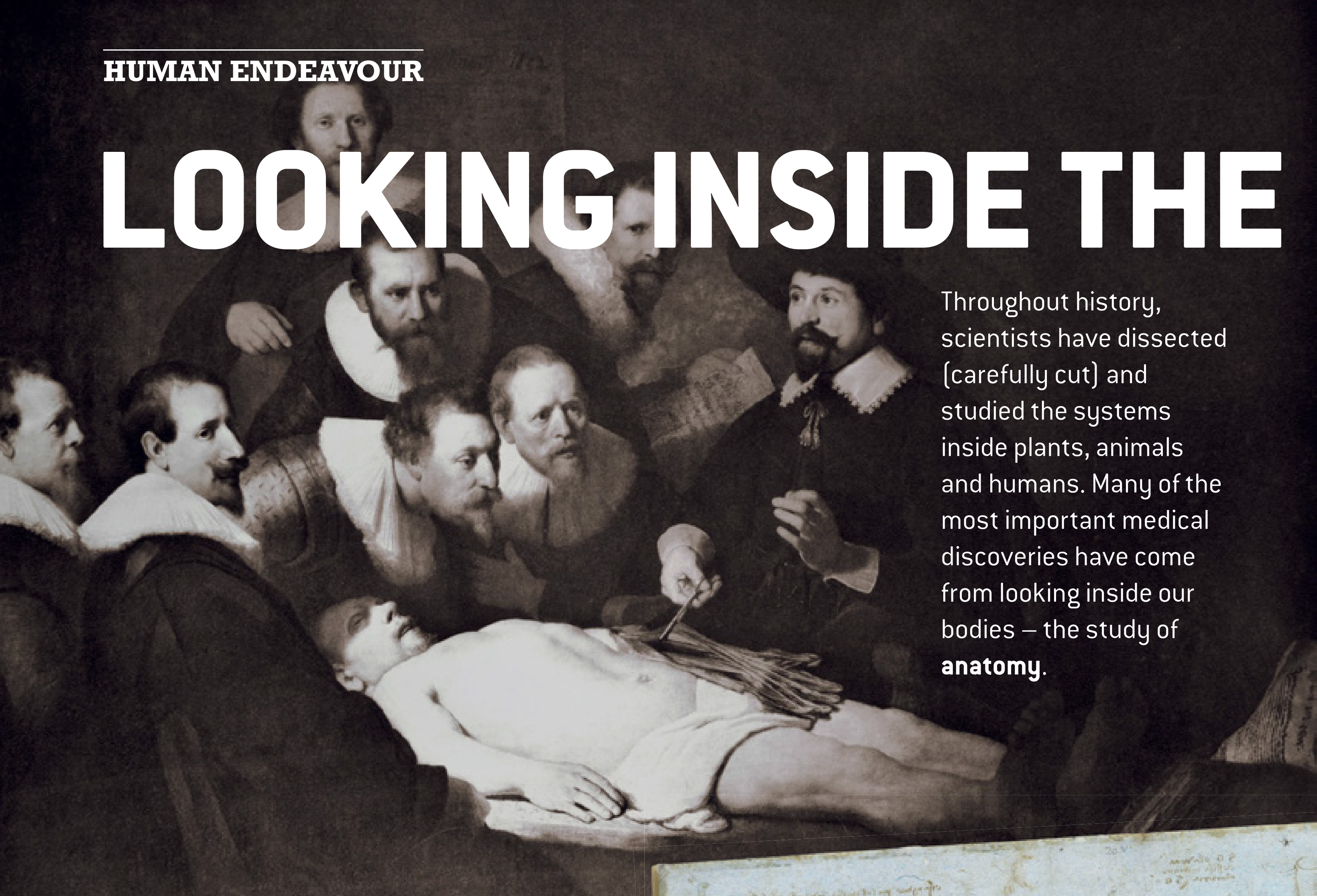
heart a muscular organ that pumps blood through blood vessels

ventricle a lower chamber of the heart

CHECK IT OUT

1 What are two main jobs of blood?
2 What role do white blood cells play?
3 Explain the roles of the three different types of blood vessels.
4 What is the difference between the functions of the right and left sides of the heart?
5 Why do some blood vessels have valves?

LOOKING INSIDE THE



Throughout history, scientists have dissected (carefully cut) and studied the systems inside plants, animals and humans. Many of the most important medical discoveries have come from looking inside our bodies – the study of **anatomy**.

The history of dissections

The very first scientists to study anatomy lived in the Egyptian city of Alexandria in 300 BC. These scientists performed dissections on the human body to discover how it worked. Many observations were made while preparing **corpses** for burial (mummification). As part of this process, the Egyptians removed key organs from the body. As a result, much of the early knowledge about human body systems and organs came from these dissections.

Leonardo da Vinci

Leonardo da Vinci studied the human body in the late 1400s and early 1500s. Da Vinci began studying the human body through life drawing and by going to the public dissections run by medical schools. He started by drawing skeletons, and then moved onto other body systems when he was able to dissect corpses from a local hospital.

Da Vinci also studied the human heart and even created a model of the **aortic valve**, the one-way valve (flap of tissue) in the main **artery** of the body, using glass. Da Vinci almost discovered how blood moves through the body, but he never finished his work.

Leonardo da Vinci's drawings of the heart and blood vessels

HUMAN BODY

The body snatchers

In the 1700s, there was a need for more doctors that performed surgery and operations in Britain. Due to a lack of doctors, schools opened to teach surgical skills – but human bodies were needed to practise on. People who studied anatomy paid 'body snatchers' to steal bodies from graveyards. The pay was so good that people were murdered so that they could be dissected!

Many advances in medicine happened at this time, such as the development of the smallpox vaccine, safer childbirth and improved dental surgery techniques. Some of these advances were due to the dissections, which led to a greater understanding of how the human body's systems worked.

The medical profession has come a long way since the first dissections. Medical knowledge is now so vast that doctors may specialise in one specific system of the human body, or even in a single organ.

LOOK IT UP

anatomy the study of the bodily structure of animals and plants

aortic valve a one-way valve (flap of tissue) in the main artery of the body

artery a thick, muscular-walled blood vessel that carries oxygenated blood away from the heart

corpse a dead body

CHECK IT OUT

1. How have scientists throughout history learnt about the human body?
2. How did Leonardo da Vinci make accurate drawings of the heart?
3. Why were body snatchers hired in the 1700s?
4. How does a heart attack occur?

How to perform open heart surgery

Skilled cardiac (heart) surgeons work to repair damaged hearts. The heart, just like all organs, needs a blood supply to give it the oxygen it needs to function. Cardiac arteries wrap around the outer surface of the heart to give it blood. A person may suffer a heart attack when substances build up and block these important blood vessels. Without enough oxygen, heart muscle cells may die. If too many cells die, the heart cannot pump and the person may not survive.

A surgeon sawing through the sternum.

STEP 1: Sawing through the sternum

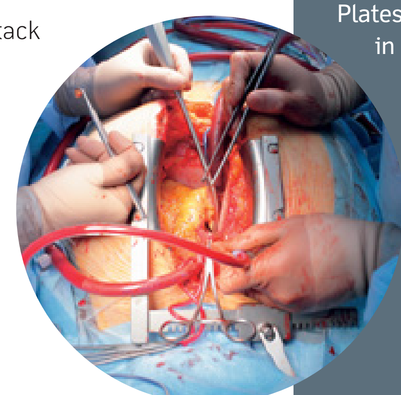
The heart sits beneath the sternum (breastbone), which is where the ribs are attached. The surgeon uses a small saw to cut the bone open.

STEP 2: Operating on the heart

The surgeon can trim, reshape or replace damaged heart **valves**. Blocked **arteries** (tubes that allow blood flow) may be replaced by a healthy vein or artery from another part of the body. The surgeon makes a detour or 'bypass' around the blocked area in the artery.

STEP 3: Putting the sternum back together again

Plates and screws hold the sternum in place until it heals.



In open heart surgery, cardiac surgeons use a retractor to hold open the sternum. They repair and replace damaged valves and arteries. In the case of a heart transplant operation, the heart itself is replaced.

EXPERIMENT #3

HEART DISSECTION

AIM: TO EXPLORE THE STRUCTURE AND FUNCTION OF A HEART

MATERIALS

- Sheep, cow, ox or pig heart
- Scalpel
- Newspaper
- Dissecting probe and forceps

SAFETY

Refer to the dissection skills and safety guidelines on page 43.

METHOD

1 Examine the outside of the heart and identify the left and right sides using your fingers.

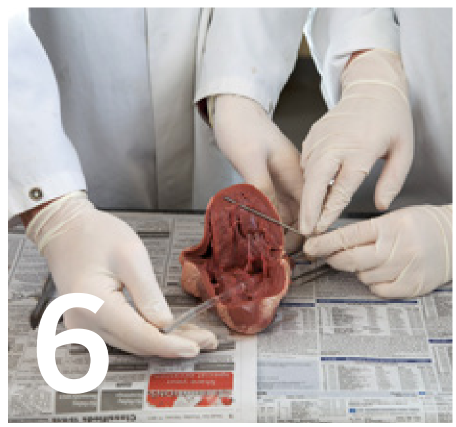
2 Feel the right side of the heart. Compare the thickness of the right and left sides. Feel the muscle in the centre of the heart.

3 Using a scalpel, cut open the right atrium and right ventricle. Pull back the wall and look inside to see the atrium and the ventricle. The ventricle is the chamber closest to the pointed end of the heart. The white tendons hold the valves in place.

4 Push a dissecting probe or your finger out through the artery leading from the right ventricle.

5 Cut open the left side of the heart. Find the atrium, ventricle and tendons holding the valves.

6 Push a dissecting probe or your finger out through the artery leading from the left ventricle.



RESULTS

Include labelled diagrams and observations.

DISCUSSION

1 What is the name of the artery leading from the right ventricle?

2 What is the name of the artery leading from the left ventricle? How does the thickness of this artery wall compare with the thickness of a vein wall?

3 How does the thickness of ventricle walls compare with that of atrial walls?

4 How can you explain the difference between the left and right ventricle walls?

CONCLUSION

What do you know about the structure and function of the heart?

DISSECTION SKILLS AND SAFETY GUIDELINES

A few simple guidelines are required to keep you safe and germ free while performing a dissection.

Step 1 Make sure you're wearing appropriate safety gear: gloves, lab coat and safety glasses.

Step 2 Set up your workspace, covering surfaces with newspaper that can be disposed of easily and collecting any dissection tools you may need.

Step 3 Collect your specimen for dissection. Identify all external structures.

Step 4 Pin the specimen to the dissection board to keep it from moving.

Step 5 Use probes to look inside any folds.

Step 6 Use forceps to hold and pull tissue.

Step 7 Use scalpels to cut carefully. Run the scalpel gently over the tissue several times to cut through.

Do not dig the scalpel into the specimen or expect to cut through in one movement.

Step 8 Use scissors to cut when you can see what's under the structure you're cutting. Scissors with rounded ends are less likely to cause unnecessary damage than those with pointed ends.

Step 9 Fingers are always the safest way to 'look around' your specimen.

Step 10 When finished, your specimen should be wrapped in newspaper for disposal. Your instruments should be rinsed, cleaned and disinfected, and your hands should be washed thoroughly.

Dissection instruments and workspaces should be cleaned while you are still wearing your safety gear. Your lab coat and gloves should be on before you start your dissection and they shouldn't come off until the dissection is completely finished – this includes disposal and cleaning. The last things you should do are: remove your gloves and throw them in the bin; wash your hands thoroughly; and take off your lab coat and hang it up.

EXCRETORY SYSTEM

Our bodies create waste products. These wastes need to be removed through **excretion**. To remain healthy, the human body gets rid of waste products from the digestive and respiratory systems.

Waste products

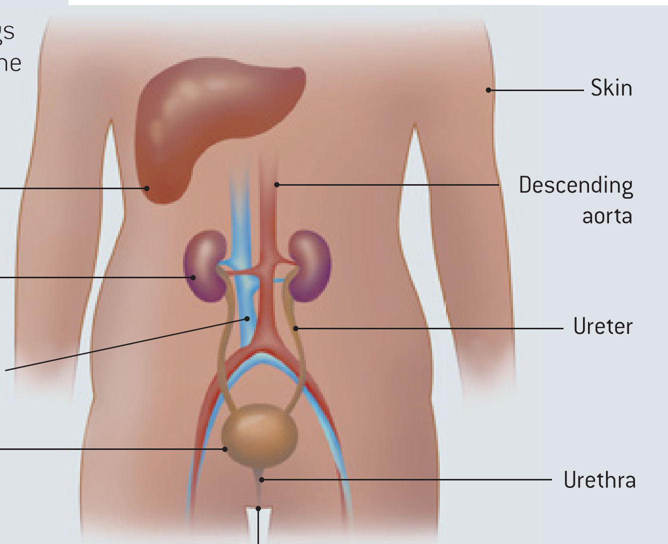
» Heat – removed by evaporation of sweat through the skin's sweat glands
» Carbon dioxide – removed through the lungs during exhalation
» Urine – created by the kidneys, stored in the bladder, and then expelled through the urethra during urination
» Faeces (poo) – the material that remains after absorption is expelled through the anus during defecation
» Gas from the intestines – expelled through the anus during flatulence (farting)
» Gas from the stomach – expelled through the mouth during eructation (burping)

Flatulence

Flatulence, or farting, is a natural human process to get rid of gases created in the intestine. When a person eats more than usual, or eats different foods, the **bacteria** work harder to break down the food and therefore produce more gas. These gases escape through the **anus**.

Excretory system

The kidneys, liver, lungs and skin are some of the organs that make up the excretory system.

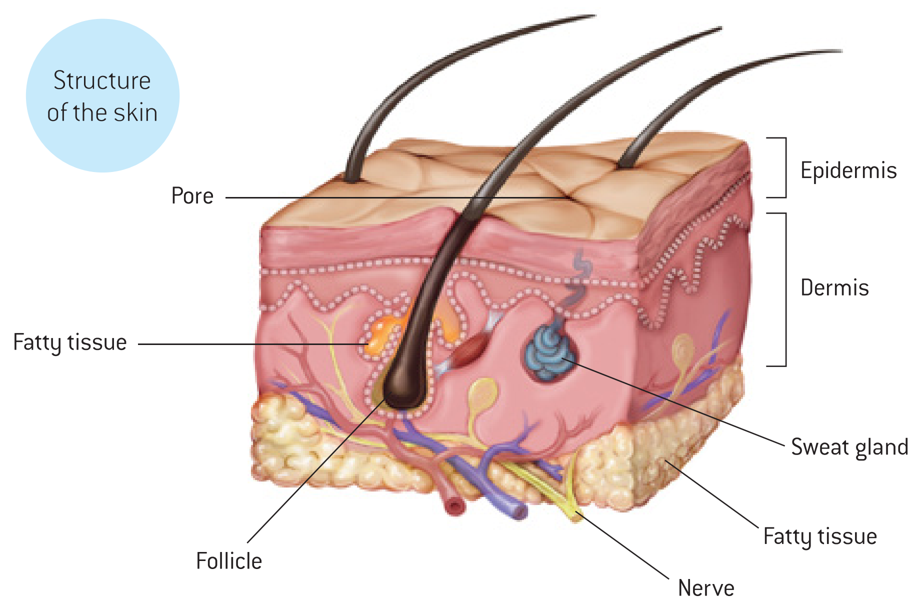


Skin

Sweat or perspiration flows out through the skin to cool us down. Sweat also contains waste products such as salts and urea (also found in urine). There are two types of sweat glands:

» eccrine sweat glands – more than two million found all over the body. Each gland has its own small opening or exit to the skin's surface, which is called a pore. Sweat from eccrine glands is made from water, salt and other chemicals.
» apocrine sweat glands – found in armpits and in the genital and anal area. These glands start working when you reach puberty.

Structure of the skin

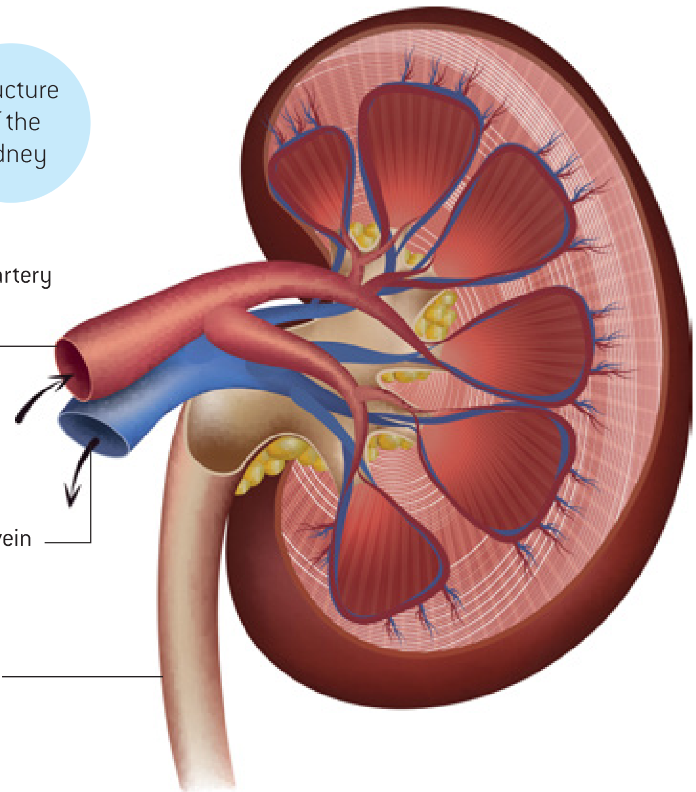


Kidneys

Humans have two kidneys, one on each side of the back, and each is approximately 10 centimetres long. Blood carrying waste products enters each kidney through the renal artery. The waste is then filtered by the millions of tiny filtering units, called nephrons.

The waste from the filtering process combines with water to make urine. The urine travels down the **ureters** and collects in the **bladder**. When the bladder is about half full, your body tells you to go to the toilet. When you urinate, the urine passes from the bladder through the **urethra** (a small tube) and out of your body.

Structure of the kidney

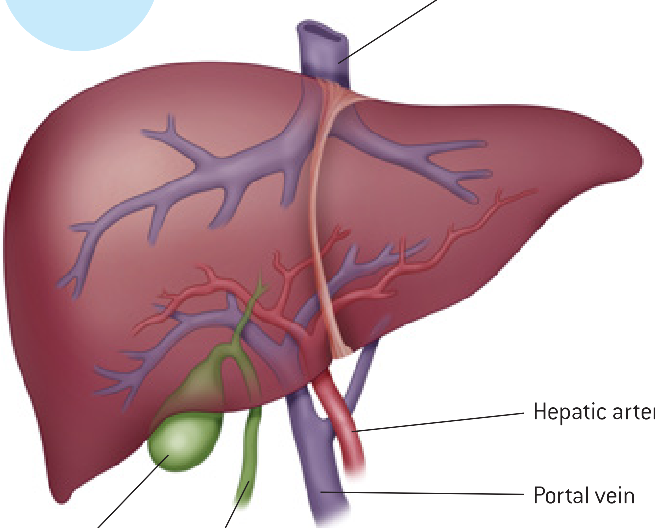


Liver

The liver is our body's biggest internal organ. It performs many roles, including removing toxins (chemicals that could harm the body) and making proteins that allow the blood to clot during injuries.

The liver also makes bile, a substance needed to break down fats and absorb some vitamins from food. Bile is stored in the gall bladder. Dangerous chemicals such as ammonia (a toxic chemical produced when making protein) are changed by the liver into a safer form (urea), which the body releases in urine.

Structure of the liver



LOOK IT UP

anus the opening at the end of the digestive system through which solid waste matter leaves the body

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

bladder a hollow organ in the pelvis that stores urine

excretion the removal of waste products from the body

ureters a pair of tubes through which urine passes from the kidney to the bladder

urethra the tube that leads from the bladder; transports and discharges urine outside the body

CHECK IT OUT

1 Match the waste product to the method by which it is released from the body:

Waste product	Method released
gas from stomach	defecation
gas from the intestine	flatulence
urine	eructation
faeces	urination

2 What waste do the lungs remove?

3 What are the two different ways in which sweat glands remove waste?

4 How do kidneys filter the blood and remove the waste products?

5 What role does the liver play in treating and removing waste from our body?

SEXUAL REPRODUCTION

Animals and plants need to mate and reproduce for the species to survive.
Most animals reproduce sexually. Sexual reproduction begins with the fertilisation of an egg by a **sperm**.
This occurs during sexual intercourse, where **semen** containing sperm cells is released from the male's **penis** into the female's **vagina**.

Ladybirds reproduce sexually. The female ladybird uses chemicals called pheromones to attract a mate.

Reproduction in animals

Most animals reproduce sexually. In sexual reproduction, a male and a female produce a baby that has genetic features from both of the parents. For a baby to be born, a female egg needs to be fertilised by a male sperm. The fertilised egg, or **zygote**, must then be nourished and protected until it has grown into a baby. The period of time it takes for the zygote to be nourished is called gestation, which most people know as pregnancy. How all this occurs, and what happens next, depends on the type of animal involved.

Mammals such as humans use internal fertilisation. The unborn baby is called a **foetus**, and develops in the mother's **uterus**. The mother supports the needs of the growing foetus with the **placenta**, the tissue that provides blood carrying oxygen and nutrients. Placental mammals such as humans keep the foetus in the uterus until it is fully developed. Marsupial foetuses, such as kangaroos, crawl into the pouch for the final stages of development.

Sexual intercourse between the male and female lion. The male lion delivers sperm from his penis into the female lion's vagina.

MALE REPRODUCTIVE SYSTEM

The job of the male reproductive system is to make sperm cells and release them inside a female. The key parts of the male reproductive system are:

- testes – produce sperm cells and the male sex hormones. the two testes are inside a sack of skin called the scrotum.
- glands – the prostate gland and seminal vesicles make fluid that helps to protect and feed sperm.
- vas deferens – a sperm duct (tube) that transports sperm from the testis to the seminal vesicle where it mixes with fluid. there are two ducts, one for each testis. the mixture of sperm and fluid is called semen.
- urethra – a tube that carries semen or urine out of the body.

FEMALE REPRODUCTIVE SYSTEM

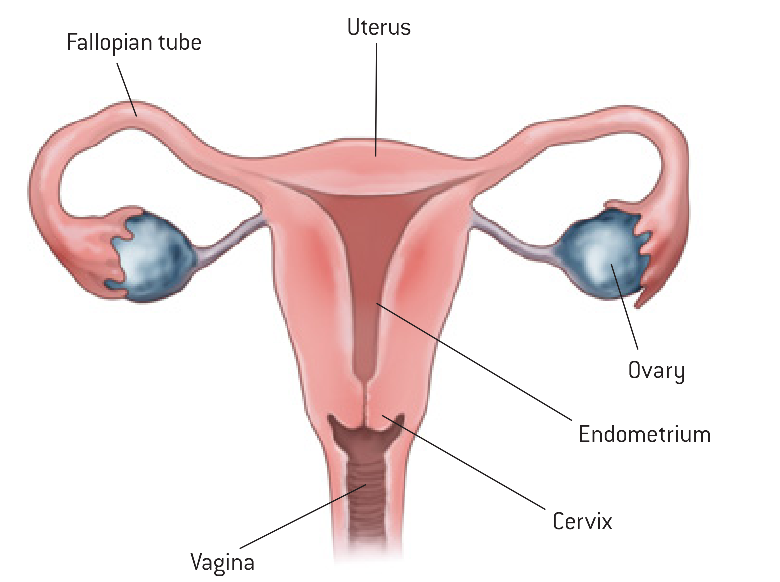
The female reproductive system can produce egg cells and then grow a baby until it can be born and survive. The key parts of the female reproductive system are:

- ovaries – the two ovaries contain egg cells. After puberty, one egg is released (via ovulation) each month until menopause.
- fallopian tubes – carry the egg to the uterus. Hair-like structures lining the tube sweep the egg through the narrow tube towards the uterus.
- uterus – where a foetus develops until it is born. It is also known as the womb.
- cervix – tissue at the entrance to the uterus that keeps the foetus in place while a woman is pregnant.
- vagina – the canal between the cervix and vulva. It is where the man's penis enters the female's body and delivers sperm during sexual intercourse.

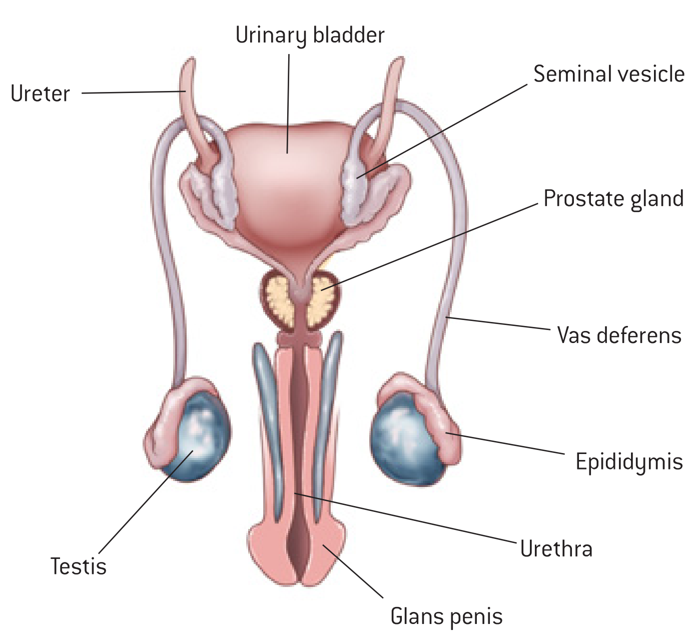
Menstruation (having a period) is the process in which a woman's body releases blood and other material from the lining of the uterus. It starts at puberty and happens approximately monthly, except during pregnancy.

Menstrual blood flows from the uterus through the small opening in the cervix and passes out of the body through the vagina. Most menstrual periods last from 3 to 5 days, but anywhere between 2 to 7 days is considered normal.

Menopause is when a woman's menstrual period stops permanently. This commonly occurs between the ages of 45 and 55.



- penis – an organ that swells with blood and stiffens as an erection. An erect penis allows the male to release semen (via ejaculation) into a female during sexual intercourse. The bladder cannot empty when the penis is erect, so semen and urine are not released at the same time.



LOOK IT UP

foetus a stage in the development of a mammal, particularly an unborn human more than 8 weeks after conception

penis the male organ for mating and urinating

placenta an organ in the uterus of pregnant mammals for nourishing the foetus

semen the male reproductive fluid, consisting of sperm in suspension

sperm male reproductive cells

uterus a hollow muscular organ in the pelvic cavity of female mammals; the site where a fertilised egg implants and develops into a foetus

vagina the canal between the cervix and vulva of a female mammal

zygote a fertilised egg cell; develops into an embryo

CHECK IT OUT

1 Match each organ to its function in sexual reproduction:

Organ	Function
penis	contains eggs
vagina	produces sperm
vas deferens	carries egg to uterus
fallopian tube	receives sperm during sexual intercourse
testes	carries sperm towards penis
ovaries	releases sperm during sexual intercourse

2 What is the difference between sperm and semen?

5 AMAZING WAYS TO REPRODUCE

1 Frogspawn

Frogs reproduce through sexual intercourse. In the male frog, the two testes (where the sperm cells are produced) are connected to the kidneys. There is no penis, and sperm is forced out from an opening called the cloaca directly onto the eggs as the female lays them.

When frogs mate, the male climbs on the female's back. He wraps his front legs around her body and they hold this position for several days. The grip of the male frog causes the female to release her eggs. The eggs are wrapped in jelly and are called **spawn**. Tadpoles hatch from the eggs and develop into frogs.

2 Eggs

Birds, reptiles and monotremes (echidnas and platypuses) lay eggs. Reptile eggs are leathery, whereas bird eggs have a hard shell. The eggs contain all the nutrients the foetus (the unborn baby) needs to develop fully. When they hatch, monotremes feed their babies milk in a pouch. Birds bring food to their chicks, but most reptiles leave their babies alone to survive by themselves.

3 Marsupials

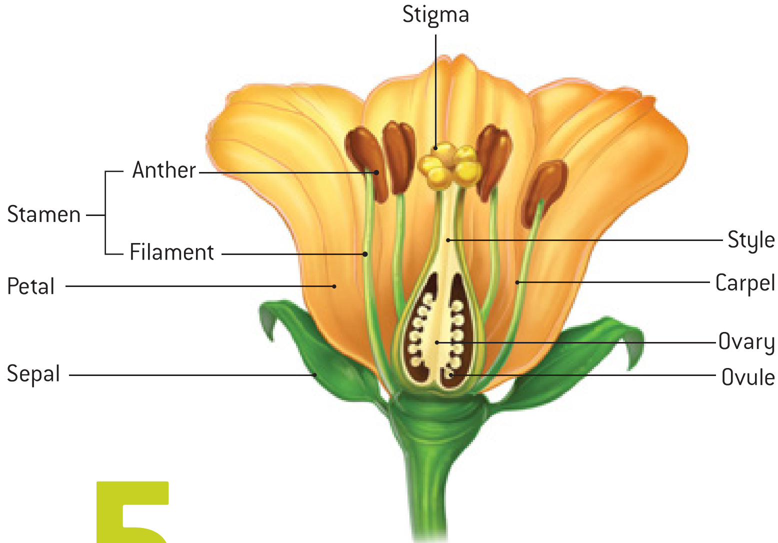
Marsupials, such as kangaroos, koalas, possums and wombats, reproduce sexually like other mammals. Their young are born at a very early stage of development. Marsupial foetuses finish developing in the pouch.

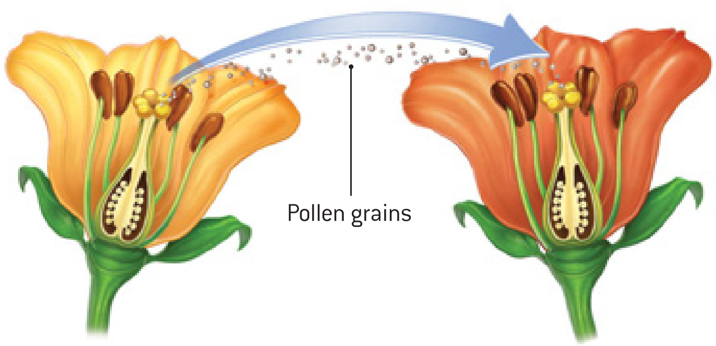
4 Reproduction in plants

A flower contains the sexual reproductive organs of the plant, and has features that help fertilisation to occur and new flowers to be created. The female gamete (sex cell) is located at the base of the **stigma** inside the ovary. All these female parts together are called the carpel. The anther produces the male gamete or pollen. For fertilisation to occur, the male gamete needs to find its way to the ovum. This requires **pollination**, where the pollen attaches to the stigma. The pollen creates a tube down to the ovary.

Flowers need help from insects, birds or mammals, or from wind or rain for pollination to occur. Plants try to attract animals or pollinators with colourful, sweet-smelling or tasty flowers. Just like animals, the pollen from one flower can only fertilise flowers from the same species (type of flower).

BASIC STRUCTURE OF A FLOWER

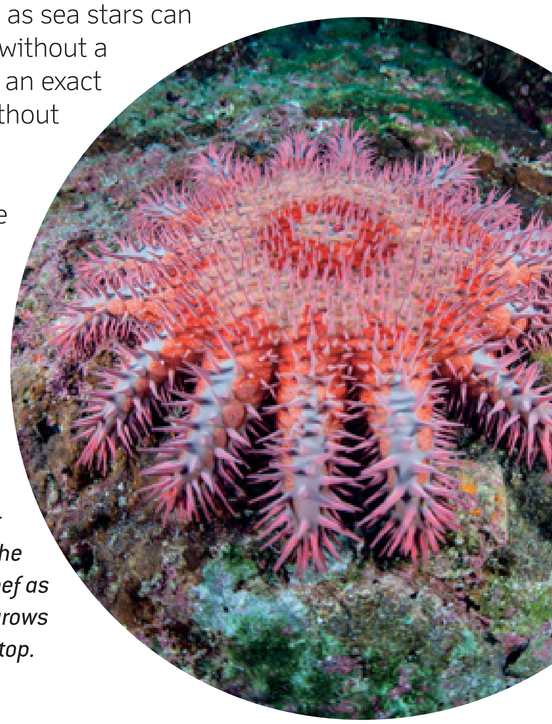




Cross-pollination occurs when pollen from a flower lands on the stigma of a flower on a different plant, producing greater variation. The pollen from one flower usually only fertilises flowers from the same species. When species cross-pollinate, the new flower is called a hybrid (a combination of two different plants).

5 Asexual reproduction

Some organisms such as sea stars can reproduce **asexually** (without a mate). They can make an exact copy of themselves without producing eggs and sperm. Sea stars can regrow arms if they are cut off. The arm that is cut off also grows into a new individual sea star.



The crown-of-thorns starfish can destroy coral. It is threatening the Great Barrier Reef as its population grows too quickly to stop.

LOOK IT UP

asexual reproduction to reproduce without a mate

pollination the process that occurs in flowering plants when pollen lands on the stigma

spawn the eggs of fish, frogs and other aquatic organisms

stigma a component of the female reproductive part of a flower

CHECK IT OUT

1. What is frogspawn?
2. What is pollen?
3. How is pollen similar to sperm?
4. How is marsupial reproduction similar and different from human reproduction?
5. How are the external eggs laid by reptiles and birds similar and different to human reproduction?
6. How do plants produce greater variations within species?
7. One organism on these pages uses asexual reproduction. Describe how this amazing creature reproduces.

EXPERIMENT #4

FLOWER DISSECTION

AIM: TO EXAMINE THE MAIN PARTS OF A FLOWER

MATERIALS

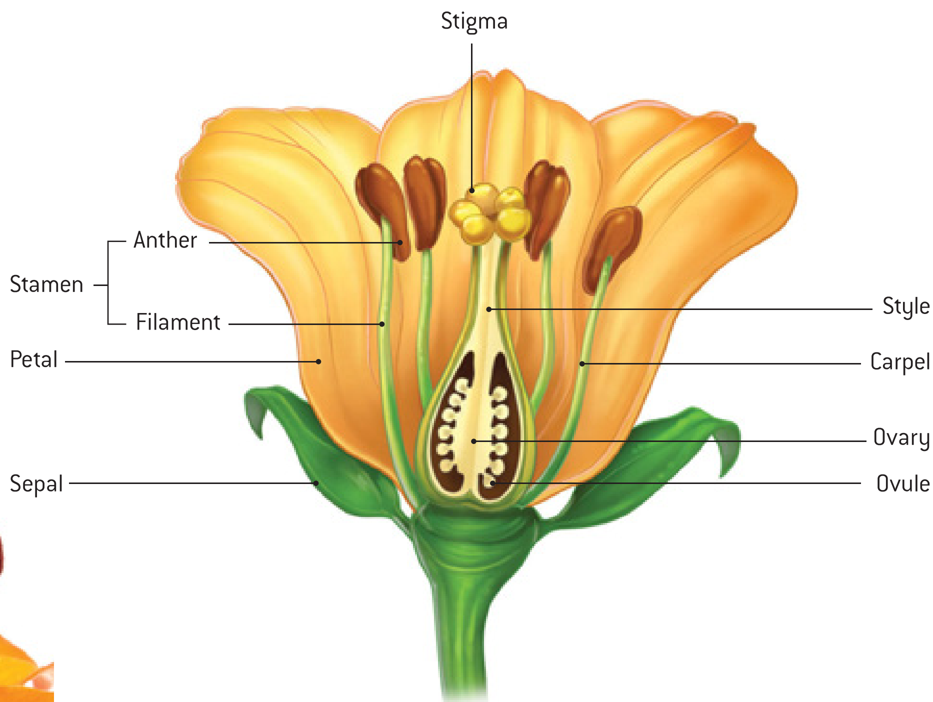
- A flower (any type available – lilies or fuchsias are a good choice)
- Scalpel blade or sharp knife
- Newspaper
- Hand lens

METHOD

1 Place the newspaper on the bench.

2 Cut the flower off the stalk.

3 Observe the flower. Identify the main parts of the flower (see diagram).



4 Gently remove the sepals and petals.

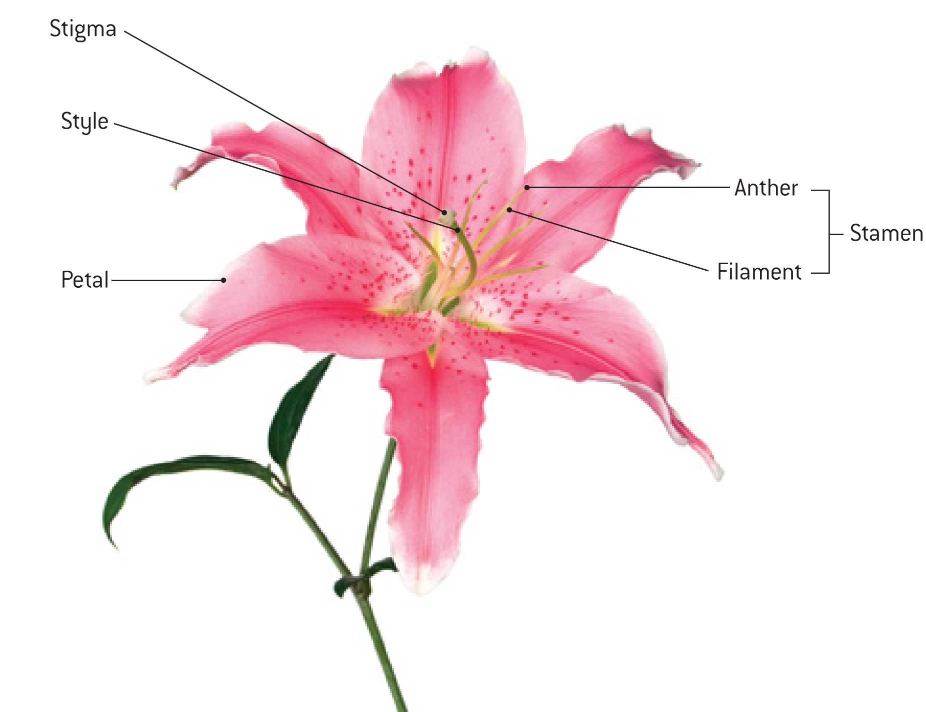
5 Look for the stamen with anthers at the top. This is the male part of the flower. The anthers hold the pollen. You should be able to dust some pollen onto your finger.

6 Cut off the male parts at the bottom of the petal.

7 Observe the female part of the flower. It has the stigma at the top and the ovary at the bottom.

8 Cut the ovary lengthwise. In it you will see tiny white scales, which are the ovules. When the ova inside the ovules are fertilised by the pollen, they will grow to become seeds and the ovary will grow to become the fruit.

9 Clean up your bench by wrapping the flower in the newspaper. Wash your hands.



RESULTS

Draw diagrams of the male and female parts of the flower.

DISCUSSION

1 What colour is the filament (the stem of the stamen)? Why do you think this is?

2 How easy was it to clean the pollen from your fingers? Is this good for the flower?

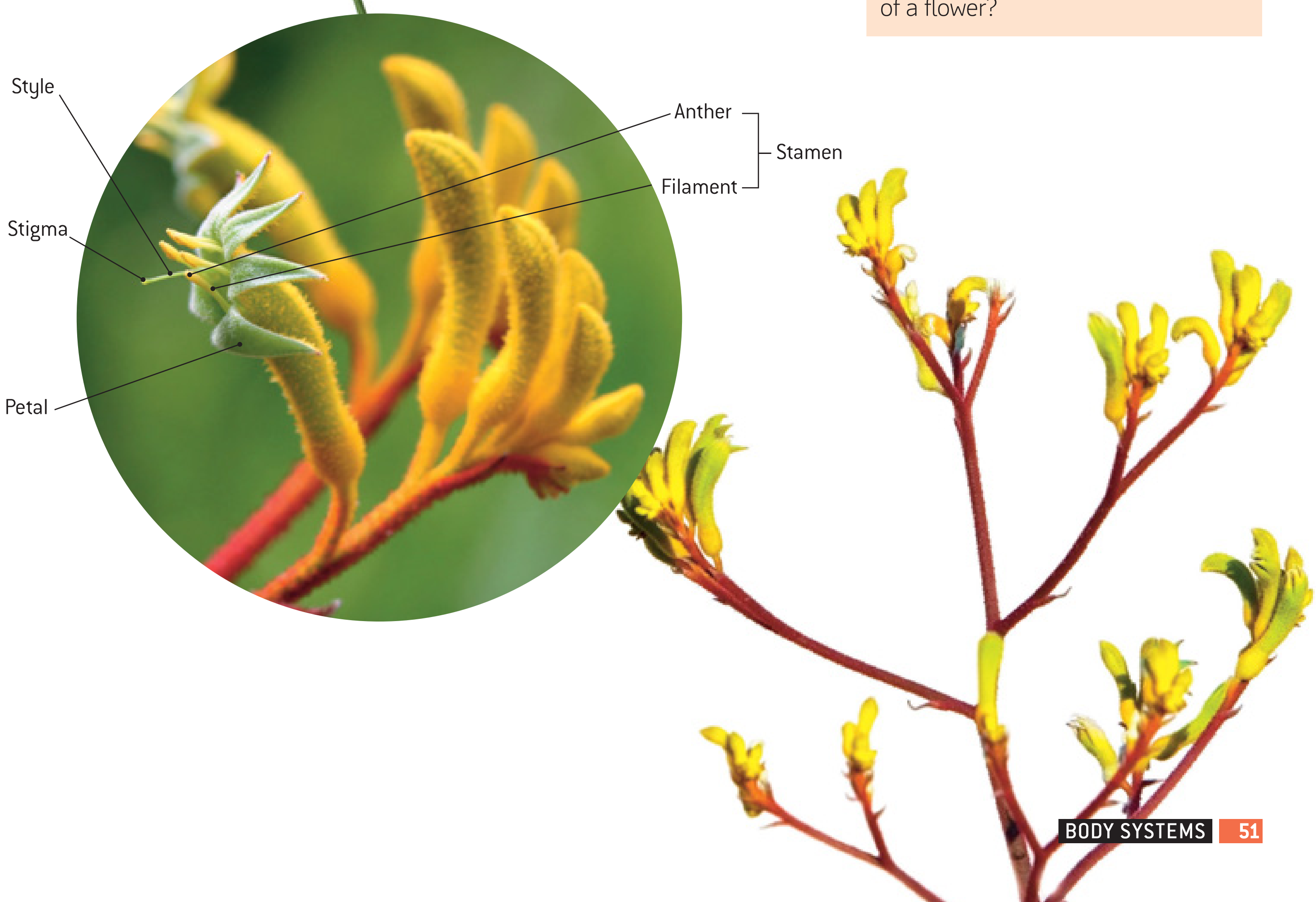
3 How were the male and female parts arranged to encourage pollination? Explain.

4 Do you think the flower is more likely to be self-pollinated or cross-pollinated? Explain.

5 Do you think pollination is more likely to be by wind, water or animals? Explain.

CONCLUSION

What do you know about the parts of a flower?



BODY SYSTEMS

HUMAN BODY SYSTEMS (PAGES 28–29)

1 What are the main components of the nervous system?
2 What is the skeletal system made up of?
3 Why do you think the circulatory system is important?
4 What are some of the things that might happen if the digestive system wasn't working properly?

DIGESTIVE SYSTEM (PAGES 30–31)

5 Why is the digestive system so important?
6 Briefly describe how food is digested in your body.
7 Describe the role that enzymes play in chemical digestion and give two examples.
8 What are the functions of the small and large intestines?

THE AMAZING STOMACH OF A COW (PAGES 32–33)

9 Why do cows have fewer teeth than other animals?
10 Draw a flow diagram of a cow's stomach to describe how the food moves through each of the stomach compartments.
11 What other animals have a four-compartment stomach? What is the name for this group of animals?
12 What is cud and how does it get into the cow's mouth?

RESPIRATORY SYSTEM (PAGES 34–35)

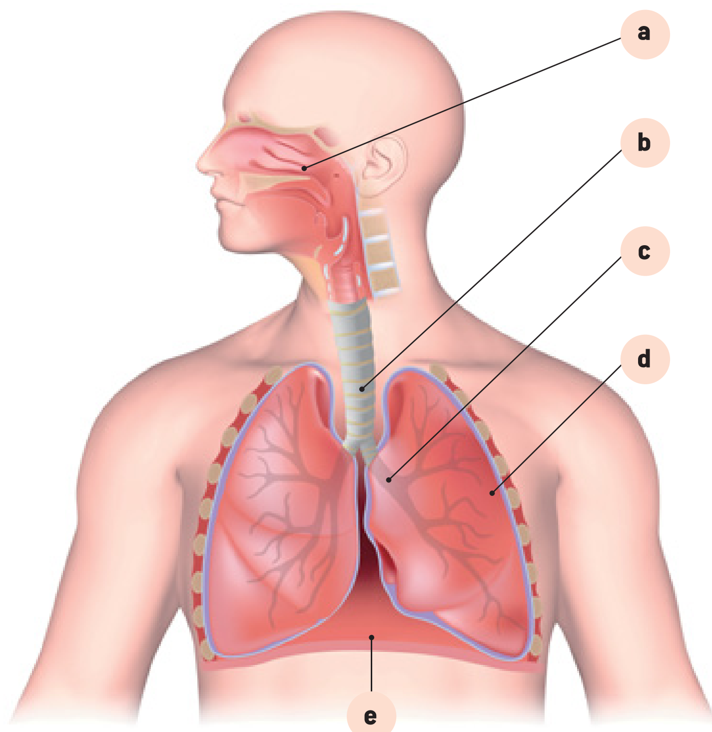
13 Match the letters on the diagram (right) with the following labels: lung, pharynx, diaphragm, trachea, bronchial tube.
14 What clever way does the body have to separate the paths of food and air?
15 Describe how oxygen and carbon dioxide pass between the alveoli and the blood.
16 What is the role of the diaphragm?

HOW DOES A FISH BREATHE? (PAGES 36–37)

17 How do fish take in oxygen and expel carbon dioxide?
18 What is the role of the operculum?

CIRCULATORY SYSTEM (PAGES 38–39)

19 Briefly describe the role of the heart.
20 List what can be found inside a blood vessel.
21 Briefly explain how and why blood is carried to and from the heart.
22 Using the information you know about the circulatory system, what substances do you think capillaries would allow to travel into and out of the blood?



LOOKING INSIDE THE HUMAN BODY (PAGES 40–41)

23 How did the Egyptians help our early knowledge of the human body?

24 What were some of the advantages of dissections? What do you think about body snatching for the purpose of dissection?

25 Why do you think the amount of time it takes to fix a damaged heart valve is less than for a heart transplant?

26 Research organ donation. Would you donate your heart to science? Why or why not?

27 Research some risk factors for having a heart attack. Divide these into those that can be prevented and those that can't.

28 Consider a heart donation. What is likely to have happened to the donor of the heart? Who should receive the heart: the person in most need or the person who is strong and healthy in which the heart is more likely to survive?

EXCRETORY SYSTEM (PAGES 44–45)

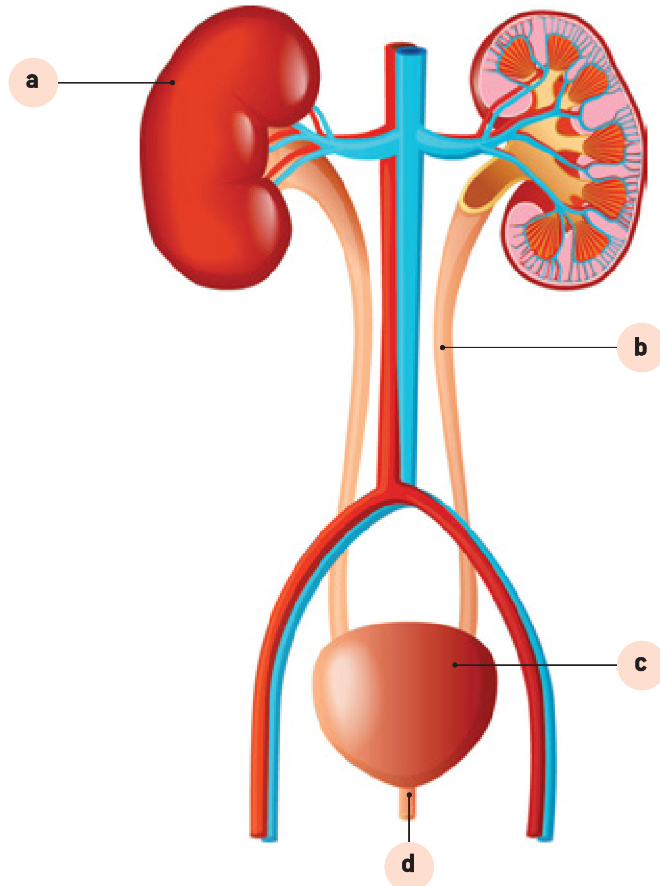
29 Match the features to the letters on the diagram opposite: kidney, bladder, ureter, urethra.

30 What is the function of flatulence?

31 Explain why teenagers may need to start wearing deodorant when they reach puberty.

32 Sometimes people need to have a kidney removed but can still function with one kidney. Why is this, and what might be some of the dangers?

33 Why is the liver such an important organ?



SEXUAL REPRODUCTION (PAGES 46–47)

34 Why do you think a zygote must be nourished and protected?

35 Where is the vas deferens located and why is it important to reproduction?

36 Placental mammals (such as humans) keep the foetus in the uterus during development, whereas marsupials (such as kangaroos) keep the foetus in a pouch. What do you think are the advantages and disadvantages of each method?

37 The female reproductive system contains the fallopian tubes. What do they do and what do you think would happen if they were blocked?

5 AMAZING WAYS TO REPRODUCE (PAGES 48–49)

38 What strategies do frogs use to make sure that tadpoles are produced?

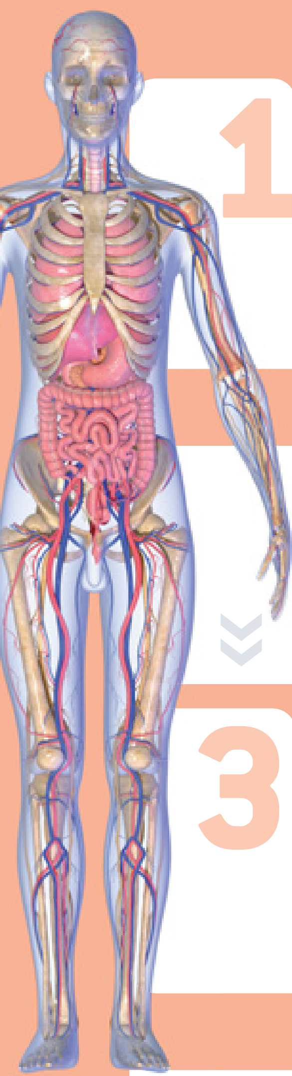
39 In your opinion, do birds, monotremes or reptiles look after their babies the best? Explain your answer.

40 Look at the photograph opposite. How is the bee helping the flower to reproduce?

41 Describe how cross-pollination works.

42 Snails, worms, clownfish and other creatures are hermaphrodites. Find out how hermaphrodites reproduce.

KEY IDEAS



1 The human body is made up of many systems that work together for the body to function at its best. These include the skeletal, circulatory, digestive, excretory, respiratory, nervous and muscle systems.

2 The digestive system is important for providing the body with energy. During digestion, foods are broken down and absorbed into the blood for transport to the cells.

3 Digestion occurs through a chemical and mechanical process. It includes the teeth and mouth, the oesophagus, stomach, liver and gall bladder, pancreas, small intestine, large intestine, rectum and anus.

4 Cows have a four-part stomach to help digest and process food:

- rumen – where the grass is softened
- reticulum – where the grass is further softened and then regurgitated
- omasum – where the cud is compressed and becomes smaller
- abomasum – where the food is digested (much like in a human stomach).

5 The respiratory system gives cells the oxygen they need and removes carbon dioxide.

6 The respiratory system consists of the lungs, alveoli, bronchi, capillaries and diaphragm.

7 Fish breathe under water by taking in oxygen from the water through their gills and expelling carbon dioxide back into the water.

8 The heart is part of the circulatory system and pumps blood containing nutrients, gases and other important substances around the body.

9 In the circulatory system, the blood travels through tubes called blood vessels. Arteries are the thickest blood vessels and travel away from the heart. Veins are smaller and carry blood back to the heart. Capillaries have walls that are only one cell thick to allow substances to easily pass in and out of the blood.

10 Throughout history, scientists have dissected the human body to find out how it works.

11 Our bodies create waste products that need to be removed through the process of excretion from the digestive and respiratory systems. Wastes can be removed through sweat, exhalation (of carbon dioxide), urine, faeces, flatulence or eructation (burping).

12 Animals and plants need to mate and reproduce for the species to survive. Most animals reproduce sexually through internal fertilisation. Placental mammals (such as humans) keep the foetus in the uterus until it is fully developed. Marsupial foetuses (such as kangaroos) crawl into the pouch for the final stages of development.

THE NATURE OF MATTER 03

WHAT LIES at the HEART of MATTER?

5 AMAZING PROPERTIES OF MATTER *

What's the difference between elements and compounds?

56 STATES OF MATTER


64 CHANGING STATES


69 FLAMMABILITY

STATES OF MATTER

To help make sense of our world, we classify the things around us. They might be heavy or light, red or blue, shiny or dull. They may be alive, such as plants, animals, and you and me. They might be non-living, such as sand, rocks, concrete, water and air. A useful way of learning about the behaviour and structure of objects is to **classify** them as solid, liquid or gas. These are called states of **matter**.

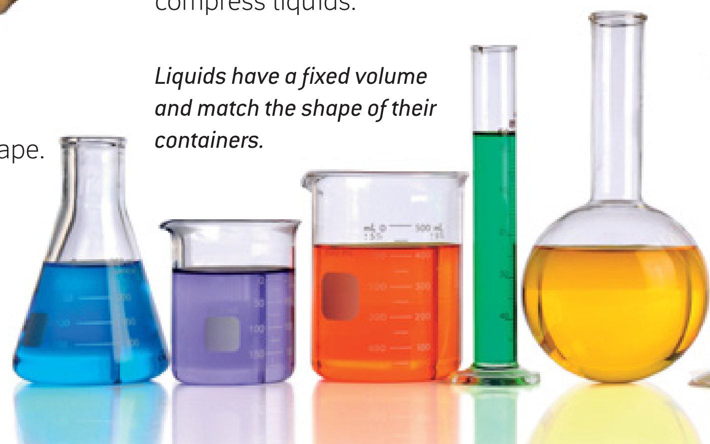
A gold nugget is a solid. It has a fixed shape.

Solids

Solids usually have a set shape. They take up a set space, or volume, and are difficult to compress.

Liquids

A liquid's **volume** is fixed but its shape will change to match its container. If you pour a litre of milk from a jug into a bucket, it will take a different shape. The volume of the milk in the bucket will still be one litre. Just like solids, it is difficult to compress liquids.



Liquids have a fixed volume and match the shape of their containers.

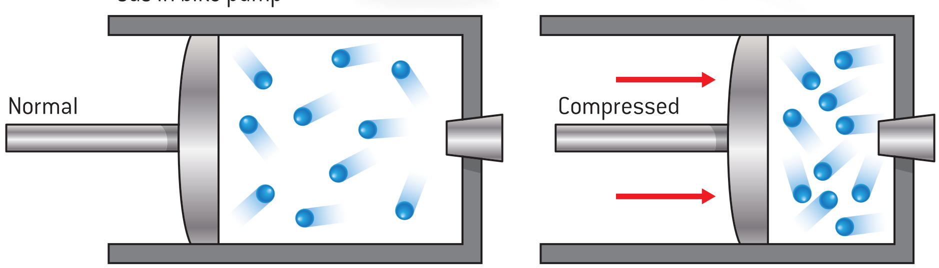
Water is here in different forms. There is liquid water in the lake, solid water as ice on the ground, and invisible water vapour (a gas) in the air.

Gases expand to completely fill their containers.

Gases

Gases take the shape of their containers. If you pump air into a bike tyre, the air will take the shape of the tube in the tyre. Unlike solids and liquids, it is easy to compress gases into a smaller volume. A bike tyre holds a lot of air, under pressure.

When you pump up a bike tyre, you are compressing air into a smaller space. The more the air is compressed, the higher the pressure in the tyre.



Plasma

The material inside a fluorescent light or neon sign is not solid, liquid or gas. Electricity charges the gas in the tube, turning it into glowing **plasma**. Plasma is often called the fourth state of matter (after solids, liquids and gases). It is present in the Sun, where gases are extremely hot. Plasma makes up over 99 per cent of known matter in the universe.

Lightning creates massively high temperatures – over five times hotter than the surface of the Sun. This high temperature creates charged particles in the air, known as plasma.

LOOK IT UP

classify to arrange things into categories depending on the properties they share

matter a substance with mass and volume

plasma (physics) an electrically charged gas, occurring at very high temperatures or low pressures

volume the space occupied by a solid, liquid or gas

CHECK IT OUT

1 Name four states of matter.
2 Why do you think that it is helpful to classify objects into their states?
3 What properties do liquids share with gases?
4 Name the three states of water.
5 Under what conditions does plasma form?

EXPERIMENT #5

STATES OF MATTER

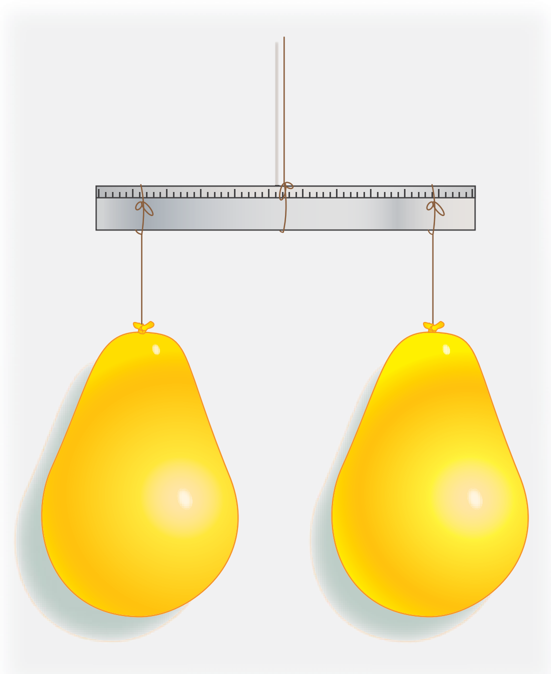
AIM: TO DETERMINE IF AIR HAS MASS

MATERIALS

- 2 balloons
- String
- Scissors
- Sticky tape
- Ruler (or stick or clothes hanger)
- Needle or sharp pin

METHOD

1. Cut three pieces of string approximately 30 centimetres long.
2. Blow up the two balloons so they are the same size. Tie a string to the neck of each balloon.
3. Tie a balloon to each end of the ruler, securing the strings with sticky tape.
4. Tie the last string loosely around the centre of the ruler so that you can slip the knot back and forth to evenly balance the balloons.
5. Prick one of the balloons with the needle.



Is sand a solid or a liquid? Individual grains of sand are solid, but the behaviour of a group of grains can be quite different from the behaviour of a single grain. In this image, sand flows like a liquid. Can you think of other solids that behave like this?

CONCLUSION

1. Which weighs more: a balloon full of air or an empty balloon?
2. What is the evidence for your answer to question 1?

EXPERIMENT #6

SLIME STATE

AIM: TO MAKE 'SLIME', A MATERIAL WITH SURPRISING PROPERTIES

MATERIALS

- Cornflour
- Food dye (optional)
- Small mixing bowl
- Plastic spoon
- Water

METHOD

1. Pour two cups of cornflour into the mixing bowl.
2. Add a few drops of food dye to the water.
3. Stir in small amounts of the coloured water until the cornflour becomes a thick paste.
4. Stir the slime very slowly and note what happens.
5. Stir the slime very fast and note what occurs.
6. Punch the slime hard and fast. What happens?

7. Scoop some of the slime into your hand and roll it into a ball between your palms. Now stop rolling the slime and observe what happens.

DISCUSSION

1. What happened when you stirred the slime very slowly?
2. What happened when you stirred the slime quickly?
3. What happened when you punched the slime?
4. Compare the behaviour of the slime when a force is applied to it slowly and rapidly.

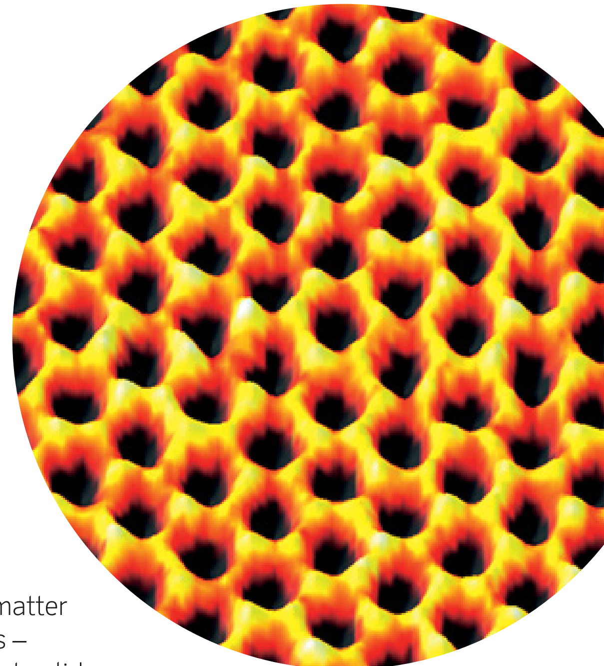
Anything that flows is called a fluid. This means that both gases and liquids are fluids.

Water flows easily – it has a low viscosity. On a cold day, honey does not flow easily. Cold honey has a high viscosity. Cornflour slime is a special type of fluid. When force is applied to the slime, it becomes thicker and its viscosity increases. Custard made from cornflour has similar properties. If you had a large enough volume of custard, you could walk on it!

Quicksand has similar properties to cornflour slime. If you struggle when trying to escape quicksand, you are applying force to it and it becomes hard, making it difficult to escape.

LOOKING INSIDE MATTER

To find out why the three states of matter – solids, liquids and gases – behave as they do, we need to explore the nature and behaviour of the tiny **particles** that make up everything in our world. Those tiny particles are called **atoms**. We can use the particle model of matter to explain how matter behaves and the differences between solids, liquids and gases.



Graphene, a thin sheet of pure carbon one atom thick, as seen under an electron microscope. Each hexagon consists of six individual carbon atoms (coloured yellow).

Birth of the atomic age

More than 2400 years ago, Democritus, a Greek philosopher (thinker), decided that everything was made up of particles. He believed that if you kept cutting a substance into smaller and smaller pieces, you would end up with tiny particles that could not be cut up any more. Democritus called these particles *atomos*, which is Greek for 'cannot be divided.' Our word 'atom' comes from this Greek term.

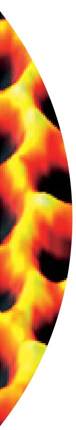
However, many people disagreed. Other philosophers thought that all matter was made from four basic ingredients – fire, air, water and earth. They said that solids such as wood and iron contained a lot of earth. Liquids all had water in them.

It took until the 1800s for Democritus's idea to be developed further. English chemist John Dalton studied the work of many earlier scientists. Dalton came to the conclusion that all matter really is made of tiny particles called atoms. He also concluded that atoms cannot be created, destroyed or divided. All atoms of the same **element** are identical, but different from atoms of other elements. For example, all atoms of the element gold are the same. All atoms of silver are identical, but different from gold atoms.

Dalton also said that when atoms combine to form **compounds**, each atom remains in its original form. The atoms combine to form compounds in simple, whole number ratios. For example, a water molecule is formed from two hydrogen atoms and one oxygen atom. The formula is H_2O.

The Greek philosopher Democritus proposed that all matter is made of atoms.

English chemist John Dalton (1766–1844) helped to develop modern atomic theory.



Particles in solids

The particles in a solid are held closely together in a regular structure. Strong attractive forces bind them together. The particles vibrate continuously. The way particles in solids are tightly held explains why solids have a constant shape and are difficult to compress. Solids do not flow unless they are made of tiny pieces, such as sand or salt.

Individual grains of salt contain billions of sodium and chlorine particles. The grains are cube shaped because the individual particles naturally fit into a cube shape.

Particles in liquids

In liquids, particles are close together but they are not held as strongly as they are in solids. The particles in a liquid do not have a regular pattern and can move past each other. This is why liquids can flow and take the shape of their containers. Liquids cannot be easily compressed. Although there are spaces between the particles of a liquid, the forces between the particles resist compression.

Particles in liquids can move past each other. This is why a liquid, such as engine oil, flows out of its container.

Particles in gases

The particles in gases are far apart and completely free to move. They move quickly. At room temperature, air particles move at an average speed of almost 2000 kilometres per hour. The forces of attraction between gas particles are very weak. Gases completely fill their containers. Gases are easily compressed because there is so much space between the particles.

LOOK IT UP

atom the smallest particle of a substance that can exist

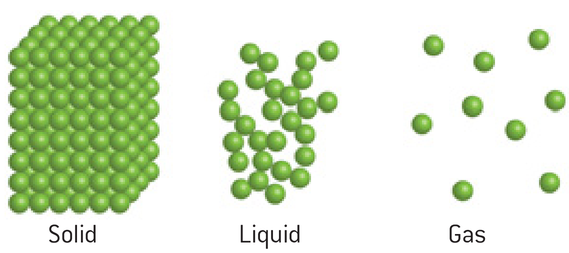
compound a substance made up of two or more different types of atoms bonded together, e.g. water

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

particle a building block of matter

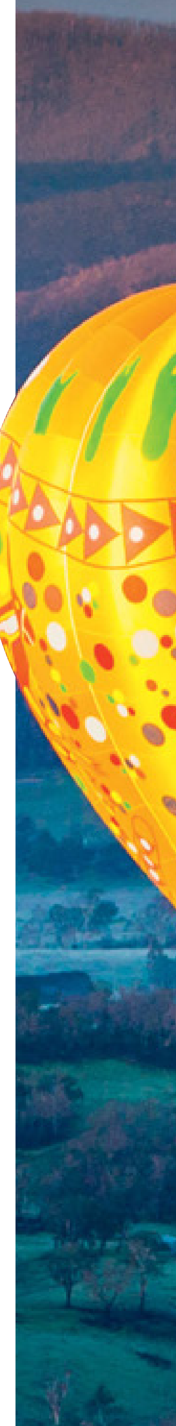
CHECK IT OUT

1. How did John Dalton help our understanding of matter?
2. Use the particle theory of matter to explain why:
   - **a** solids have a fixed shape
   - **b** liquids flow
   - **c** gases completely fill their containers.
3. List solids, liquids and gases in order from the weakest forces of attraction between their particles to the strongest.



Particles in solids are bound closely together. In a liquid, particles can move around each other more freely. In gases, the particles move quickly and separately to each other.

MOVING GASES



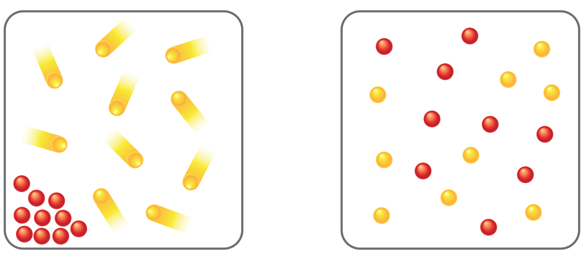
The **particle model** describes gases as being made of tiny, fast-moving particles. They are far apart and move independently of each other. In a container, particles collide with the walls, creating a force measured as gas pressure. When released into air, gases diffuse (spread out) as they mix.

Diffusion

When the lid is taken off a bottle of perfume, the smell of the perfume spreads throughout the room. This occurs without any breeze or wind, and is called **diffusion**. Perfume diffuses from the open bottle and spreads throughout the entire room. Diffusion also occurs in liquids; for example, tea spreading out from a tea bag in a cup of hot water.

Diffusion occurs fastest in gases. This is because the particles in gases are moving freely and quickly, and there is plenty of space between them.

GAS DIFFUSION



Before (left) and after (right) diffusion in a gas. The red gas particles spread out and mix with the yellow air particles.

What factors affect diffusion speed?

Three factors influence the speed of diffusion:

- temperature – at higher temperatures, particles move more quickly and therefore diffuse more quickly. Perfume particles leaving warm skin travel faster than perfume particles diffusing from a cold bottle.
- particle size – bigger, heavier particles diffuse more slowly than smaller, lighter ones.
- state – diffusion occurs quickly in a gas state because particles are far apart. In a liquid state, particles are closer together. In a solid state, the particles cannot move, so diffusion does not occur.

Pressure and temperature

When you blow up a balloon, you are filling the balloon with air. The air particles inside the inflated balloon apply a force pushing the balloon outwards. The particles constantly collide with the balloon skin. One single gas particle does not create much force, but billions of particles produce a force that can be measured. The force of the air pushing against an object is called **air pressure**.

The large spaces between gas particles allow gases to be **compressed** or squashed into a space. You compress air when you pump up a tyre. Adding more air to the tyre increases the number of particles that it contains. This increases the pressure, as more particles are striking the tyre walls. The tyre becomes firmer on the outside as the air pressure becomes greater on the inside.

Heat will also raise the pressure inside a container such as a tyre. Heat will make the particles move faster. They will have more energy and collide with the tyre walls with greater force. This is why the pressure of car tyres is higher after driving.

A hot-air balloon rises because the heated air particles in it are moving quickly and spread further apart than the cold air particles outside of the balloon. Hot air is less dense than cold air. The pilot makes the balloon drop by letting hot air escape from the top of the balloon.

A blast of gas ignites, filling a balloon with hot air, ready to rise.

LOOK IT UP

air pressure the force of air pushing against an object

compress to reduce in volume

diffusion a movement of gas or dissolved substance from a region of higher concentration to a region of lower concentration

particle model a model in which all matter is made up of tiny particles that behave in different ways depending on whether the substance is a solid, liquid or gas

CHECK IT OUT

1. Complete the following sentences.
   When food is cooking, you can smell it because some ________ leave the food and mix with the ________. This is called ________. The higher the temperature, the ________ the diffusion.
2. Why is diffusion in liquids slower than diffusion in gases?
3. Why is perfume on the skin easier to detect than smelling it from a bottle?
4. How is the girl pictured below increasing air pressure in the balloon?

5. Why are racing-car tyres pumped to a lower pressure at the start of a race?
6. Why does a hot-air balloon rise when filled with heated air?
7. What will happen to the volume of a sealed balloon if it is put into a refrigerator?

CHANGING STATES

Water exists naturally in three states. The liquid form of water falls as rain and gathers in rivers, lakes and oceans. In very cold conditions, such as in your freezer or on a mountain top, water occurs as ice. Water is all around us in the air in the form of an invisible gas called **water vapour**.

Melting point and boiling point

The **melting** point of a substance is the temperature at which it melts. Melting is a change in state of matter from solid to liquid. The boiling point is the temperature at which a substance boils. Boiling involves a change in state of matter from liquid to gas. Pure water, for example, **freezes** at 0°C and boils at 100°C at sea level.

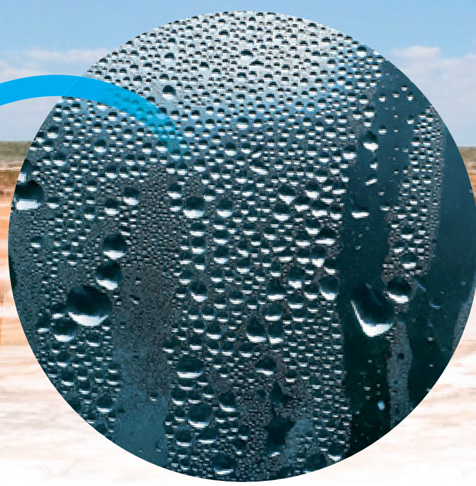
Nitrogen gas makes up about 78 per cent of air. When nitrogen is cooled down to its boiling point of –196°C, it goes through the process of **condensation** and becomes a liquid. Cooled further to –210°C, nitrogen freezes and becomes a solid.

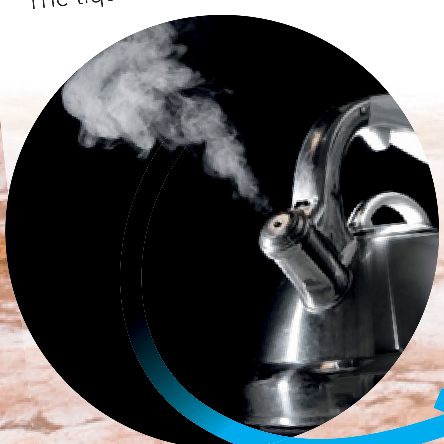
Liquid to solid = freezing

When a liquid freezes, its particles are forced to change state from a liquid to a solid. When the temperature of a liquid decreases, its particles lose energy and their movement slows. As the particles slow down, they are held in place by the particles around them and do not have enough energy to move on their own. Finally, they become particles locked into a set shape. The liquid has solidified or frozen to become a solid.

Liquid to gas = evaporation

The process of a liquid changing into a gas is called **evaporation**. When a liquid is heated, its particles move around and past each other. As the particles gain more energy, they move faster and take up more space. If there is enough heat energy, the particles will escape. They will break free of the forces that hold them together. The liquid boils to become a gas.





Gas to liquid = condensation

Gas changes to a liquid through the process of condensation. As a gas cools and the temperature decreases, the particles move more slowly. The particles begin to attract each other and move closer together. When the temperature is reduced to below the boiling point, the gas changes state to become a liquid. Condensation is often seen on windows when warm, humid air is cooled on a cold window.

Lake Eyre is Australia's largest lake. Located in the dry interior of the continent, most of the water evaporates from its liquid form leaving solid salt. This photo shows the solid salt surface of Lake Eyre.

Energy of particles

When substances are heated, their particles vibrate and jump around, moving faster and further apart. This particle vibration causes a solid to expand when it is heated.

Melting

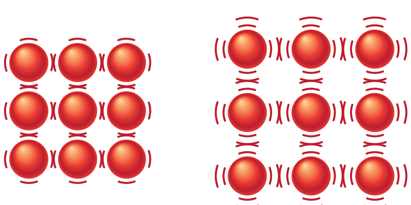
Melting a solid object turns it into liquid. When a solid is heated, its particles vibrate faster and take up more space. The particles are still held in place in the solid structure by the forces of attraction to all the particles around them. As the solid becomes hotter, the particles gain more energy and move and vibrate faster. Eventually, the particles have so much energy that they break free of the particles around them. The particles are still vibrating or moving but they are not held in place any more. The solid melts to become a liquid.

Solid to gas = sublimation

A solid can change directly to a gas through the process of **sublimation**. Snow and ice can sublime at very low temperatures. Dry ice (solid carbon dioxide) changes to a gaseous form at room temperature.

Gas to solid = deposition

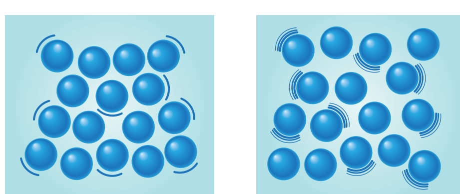
When a gas changes directly into a solid state, it is called **deposition**. Snow and frost are formed through this process. They are created when water vapour in the air freezes into ice crystals.



Cold

Hot

In a hot solid, the particles vibrate more than in a cold solid.



Cold water

Hot water

In a hot liquid, the particles move around faster and take up more space than in a cold liquid.

LOOK IT UP

condensation the change of state from a gas to a liquid

deposition the change of state from a gas to a solid

evaporation the change of state from liquid to a gas

freezing the change of state from liquid to a solid

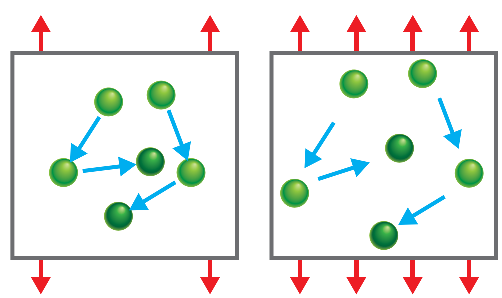
melting the change of state from solid to a liquid

sublimation the change of state straight from a solid to a gas

water vapour an invisible, gaseous form of water

CHECK IT OUT

1. Define the terms 'melting point' and 'boiling point'.
2. A small volume of water in a glass disappears overnight. Explain what has happened.
3. Explain the difference between melting and freezing.
4. Use the behaviour of particles to explain why a balloon expands when heated.
5. Use the behaviour of particles to explain what happens when liquid water is left in a freezer.



Cold gas

Hot gas

In a hot gas, the particles move faster and collide with each other harder than in a cold gas. Hot gases create more pressure than cold gases.

EXPERIMENT #7

CHANGE OF STATES

PART A: WET SWEAT

AIM: TO INVESTIGATE EVAPORATION

MATERIALS

- Water

METHOD

Wet the palm of one hand, keeping the other hand dry. Wait for 10 to 20 seconds. Now blow air over both palms.

DISCUSSION

1 Which feels cooler: the wet palm or the dry palm?

2 What effect did blowing air across your wet palm have on the temperature you felt?

Evaporation has a cooling effect. The faster, more energetic particles in the liquid change into a gas, leaving behind cooler, less energetic particles. Heat energy is consumed as the liquid turns into a vapour (vaporises).

PART B: BOILING WATER

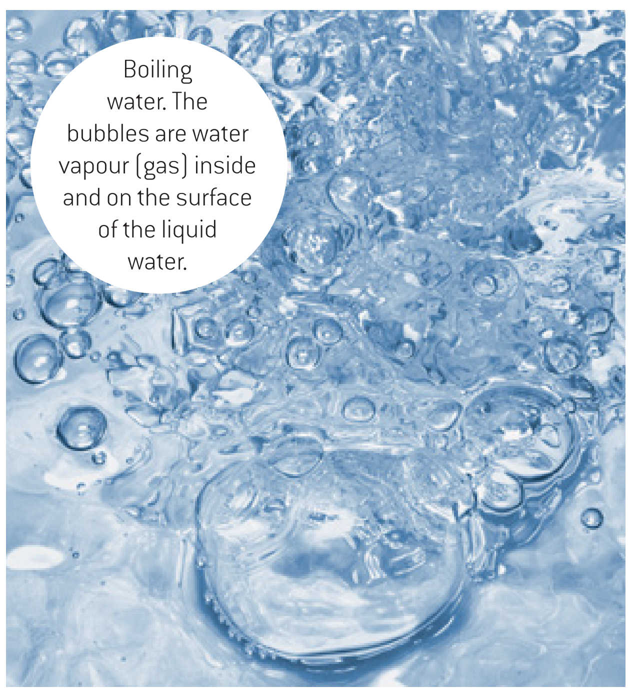
AIM: TO TRACK CHANGES TO THE TEMPERATURE OF WATER AS IT IS HEATED

MATERIALS

- Watch or clock
- Crushed ice
- Water
- Beaker (250 mL)
- Thermometer (0–110°C) or thermistor probe
- Bunsen burner
- Heatproof mat
- Tripod stand
- Gauze mat
- Retort stand, clamp and boss head
- Stirring rod

SAFETY

- Take great care when measuring the higher temperatures as steam and boiling water can both burn the skin and scald.
- If scalded, immediately place the area of skin under cold running water and tell your teacher.
- Wear safety glasses, enclosed footwear and a lab coat.
- Tie long hair back.

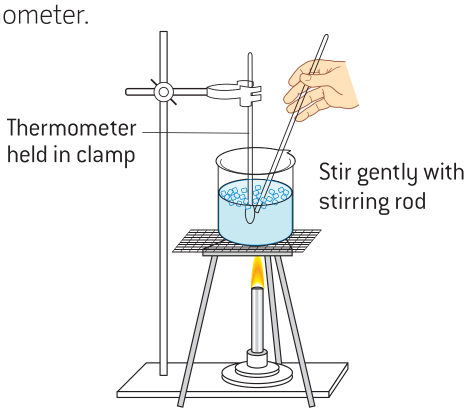


Boiling water. The bubbles are water vapour (gas) inside and on the surface of the liquid water.

METHOD

1 Place approximately 200 mL of ice and water into the beaker.

2 Set up the equipment as shown. Make sure the thermometer is secure in the clamp and does not touch the bottom of the beaker. Do not stir with the thermometer.



3 Copy the following table into your workbook.

TIME (MINUTES)	TEMPERATURE (°C)
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

4 Stir the ice and water with the stirring rod for approximately 1 minute. Take care that you don't break the thermometer with the stirring rod.

5 Measure and record the temperature of the water and ice mixture. This is the melting point of ice. Record the temperature in your table at time = 0 minutes.

6 Light the Bunsen burner and start heating the ice and water.

7 Measure and record the temperature of the mixture in the beaker every minute until the water boils.

8 Continue heating and record the temperature for another 4 minutes, unless most of the water has evaporated.

9 Using graph paper (or a suitable computer program or calculator), draw a graph with temperature on the vertical axis and time on the horizontal axis.

DISCUSSION

1 What temperature did you measure as the melting point of ice? What difference is there between the value you measured and the standard measurement of 0°C?

2 What is melting?

3 What temperature did you measure as the boiling point of water? What difference is there between the value you measured and the standard measurement of 100°C?

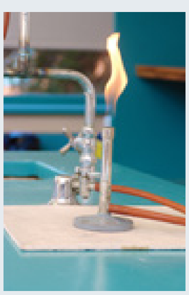
4 What is boiling?

5 Describe and explain the shape of the graph that you have plotted.

6 What do you think was happening to the water when the temperature was constant, even though it was being heated?

SCIENTIFIC EQUIPMENT

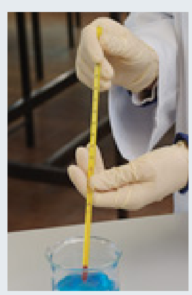

Beaker (250 mL)

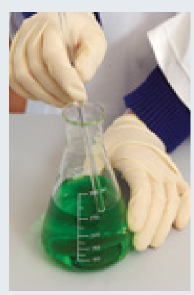

Bunsen burner and heatproof mat


Tripod stand


Gauze mat


Retort stand, clamp and boss head


Thermometer


Stirring rod

5 AMAZING PROPERTIES OF MATTER

Matter shares different characteristics or properties. The properties of a substance describe what it looks like and how it behaves. **Physical properties** include strength, **density** and boiling point. **Chemical properties** are only obvious when we observe a chemical reaction between substances; for example, how flammable a substance is.

Transparent, flexible sheets of graphene, a pure form of carbon, could serve as the building material for mobile phones in the future. Graphene is incredibly strong and an excellent conductor of electricity.

1 Hardness

Hardness is the ability of a substance to scratch another substance. An iron nail will scratch a plastic ruler because the iron is harder than plastic. The particles in hard substances, such as iron, are held together very strongly and it is difficult to separate them. Diamond is one of the hardest known natural materials. Diamonds are used in cutting and polishing tools.

2 Density

One kilogram of feathers has the same mass as one kilogram of gold. The difference is their volume. The gold would be the size of a small chocolate bar and the feathers would fill a large doona. We say that gold has a greater density, or that it is more dense, than a feather. **Density** is the mass of a certain volume of a substance.

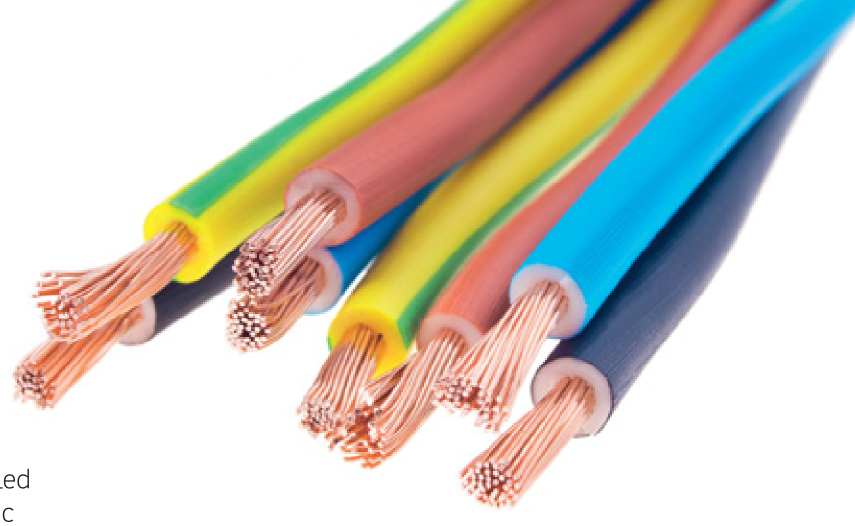
3 Strength

The strength of a material depends on how it reacts to stresses and strains. A rubber band is easily stretched, but what about a piece of wire? Different wires made of different metals will break if stretched. Tensile strength is a measure of the force needed to break a stretched piece of wire. The opposite of tensile strength is compressional strength – the ability to withstand large forces without being crushed.

In 2013, Chinese scientists created the world's least dense solid material. The graphene aerogel is seven times lighter than air. A cubic centimetre of the graphene aerogel weighs just 0.16 milligrams and can balance on a flower.

4 Conductivity

Conductivity is how easily something moves through a substance. Electrical conductivity refers to how easily an electric current flows through a substance. Metals have a high conductivity, which means that they conduct electricity readily, and so they are commonly called 'conductors'. Materials such as rubber and plastic have a low electrical conductivity and do not conduct electricity. Elements and compounds that do not conduct electricity are called insulators.



Electrical cables contain copper wiring with high electrical conductivity, surrounded by layers of insulating plastic with low electrical conductivity.

A firefighter's clothing is made from Nomex. This material is flame and melt resistant.

5 Flammability

Flammability is a chemical **property** of matter. It refers to how easily a substance will burn or catch fire (ignite). Substances that are easy to ignite have a high flammability. Substances that are hard to ignite have a low flammability. If a substance cannot burn or catch fire, it is called non-flammable.

LOOK IT UP

chemical property a property used to characterise materials in reactions that change their identity

conductivity how easily something moves through a substance

density the mass per unit volume

physical properties properties that can identify substances, e.g. appearance, texture, colour, odour, melting point, boiling point and density

property a characteristic, quality or feature that distinguishes something from other things, e.g. the properties (characteristics) of a mineral

CHECK IT OUT

1 Which of the five properties of matter shown here is a chemical property?

2 What is the difference between a kilogram of gold and a kilogram of feathers?

3 What is the difference between hardness and strength?

4 Find the information about graphene. Comment on its strength and density.

5 Why are electrical wires in the home covered in plastic or rubber?

6 Look at the saucepan (left). Thermal conductivity refers to how easily heat flows through a substance.

   a This saucepan is made from steel. What properties of steel make it suitable for heating food?

   b Why do you think the saucepan has a plastic handle?

PERIODIC TABLE

An element is a pure substance made of only one type of atom. **Elements** cannot be easily broken down into other substances. The **periodic table** is an ordered list of all the elements. It groups together elements with similar properties.

Periods, groups and symbols

The horizontal rows in the table are called periods. The vertical columns are called groups. The elements in a group often have similar properties, such as the way they look or behave.

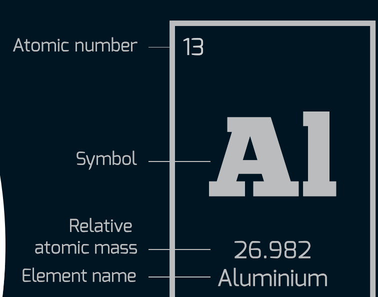
Each element has a symbol of one or two letters. Hydrogen has the symbol H; helium He. Many of the symbols are simply the first one or two letters of the element's name; for example: oxygen O, carbon C, nitrogen N, sulfur S and calcium Ca. Gold has the symbol Au, which comes from *aurum*, the Latin word for gold.

PERIODIC TABLE OF THE ELEMENTS

- Other nonmetals
- Alkali metals
- Transition metals
- Post-transition metals
- Metalloids

	1 I A	2 II A	3 III B	4 IV B	5 V B	6 VI B	7 VII B
1	1 H 1.0079 Hydrogen						
2	3 Li 6.941 Lithium	4 Be 9.0122 Beryllium					
3	11 Na 22.990 Sodium	12 Mg 24.305 Magnesium					
4	19 K 39.098 Potassium	20 Ca 40.078 Calcium	21 Sc 44.956 Scandium	22 Ti 47.867 Titanium	23 V 50.942 Vanadium	24 Cr 51.996 Chromium	25 Mn 54.938 Manganese
5	37 Rb 85.468 Rubidium	38 Sr 87.62 Strontium	39 Y 88.906 Yttrium	40 Zr 91.224 Zirconium	41 Nb 92.906 Niobium	42 Mo 95.94 Molybdenum	43 Tc (98) TECHNETIUM
6	55 Cs 132.91 Caesium	56 Ba 137.33 Barium	57-71 La-Lu Lanthanide	72 Hf 178.49 Hafnium	73 Ta 180.95 Tantalum	74 W 183.84 Tungsten	75 Re 186.21 Rhenium
7	87 Fr (223) Francium	88 Ra (226) Radium	89-103 Ac-Lr Actinide	104 Rf (261) Rutherfordium	105 Db (262) Dubnium	106 Sg (266) Seaborgium	107 Bh (264) Bohrium

57 La 138.91 Lanthanum	58 Ce 140.12 Cerium	59 Pr 140.91 Praseodymium	60 Nd 144.24 Neodymium
89 Ac (227) Actinium	90 Th 232.04 Thorium	91 Pa 231.04 Protactinium	92 U 238.03 Uranium



Copper, silver and gold are all shiny, dense, hard metals that are good conductors of electricity. They are listed in the same column of the periodic table.

LOOK IT UP

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

periodic table an ordered table of the elements

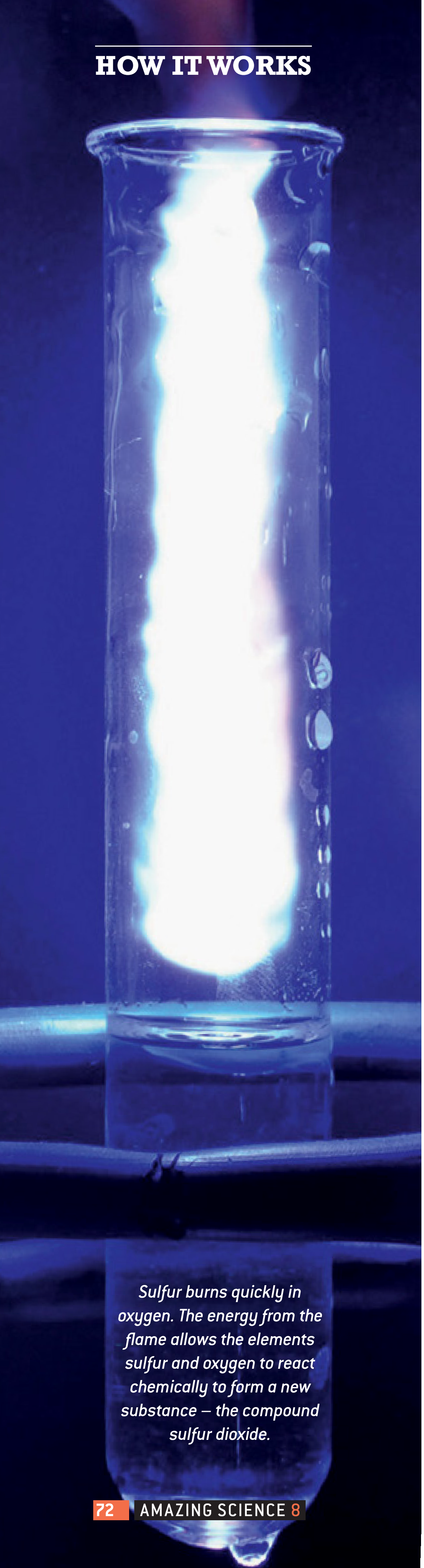
CHECK IT OUT

1 What is an element?
2 What name is given to the horizontal rows in the periodic table?
3 What name is given to the vertical columns?
4 Name three elements that are likely to have similar properties to fluorine.

- Alkaline earth metals
- Noble gases
- Halogens
- Lanthanoids
- Actnoids

VIII B 8	9	10	11 I B	12 II B	13 III A	14 IV A	15 V A	16 VI A	17 VII A	18 VIII A
										2 He 4.0026 Helium
					5 B 10.811 Boron	6 C 12.011 Carbon	7 N 14.007 Nitrogen	8 O 15.999 Oxygen	9 F 18.998 Fluorine	10 Ne 20.180 Neon
					13 Al 26.982 Aluminium	14 Si 28.086 Silicon	15 P 30.974 Phosphorus	16 S 32.065 Sulphur	17 Cl 35.453 Chlorine	18 Ar 39.948 Argon
26 Fe 55.845 Iron	27 Co 58.933 Cobalt	28 Ni 58.693 Nickel	29 Cu 63.546 Copper	30 Zn 65.39 Zinc	31 Ga 69.723 Gallium	32 Ge 72.64 Germanium	33 As 74.922 Arsenic	34 Se 78.96 Selenium	35 Br 79.904 Bromine	36 Kr 83.80 Krypton
44 Ru 101.07 Ruthenium	45 Rh 102.91 Rhodium	46 Pd 106.42 Palladium	47 Ag 107.87 Silver	48 Cd 112.41 Cadmium	49 In 114.82 Indium	50 Sn 118.71 Tin	51 Sb 121.76 Antimony	52 Te 127.60 Tellurium	53 I 126.90 Iodine	54 Xe 131.29 Xenon
76 Os 190.23 Osmium	77 Ir 192.22 IRIDIUM	78 Pt 195.08 Platinum	79 Au 196.97 Gold	80 Hg 200.59 Mercury	81 Tl 204.38 Thallium	82 Pb 207.2 Lead	83 Bi 208.98 Bismuth	84 Po (209) Polonium	85 At (210) Astatine	86 Rn (222) Radon
108 Hs (277) Hassium	109 Mt (268) Meitnerium	110 Uun (281) Ununnilium	111 Uuu (272) Unununium	112 Uub (285) Ununbium	113 Uut (286) Unutrium	114 Fl (289) Flerovium	115 Uup (289) Ununpentium	116 Lv (293) Livermorium	117 Uus (294) Ununseptium	118 Uuo (294) Ununoctium

61 Pm (145) Promethium	62 Sm 150.36 Samarium	63 Eu 151.96 Europium	64 Gd 157.25 Gadolinium	65 Tb 158.93 Terbium	66 Dy 162.50 Dysprosium	67 Ho 164.93 Holmium	68 Er 167.26 Erbium	69 Tm 168.93 Thulium	70 Yb 173.04 Ytterbium	71 Lu 174.97 Lutetium
93 Np (237) Neptunium	94 Pu (244) Plutonium	95 Am (243) Americium	96 Cm (247) Curium	97 Bk (247) Berkelium	98 Cf (251) Californium	99 Es (252) Einsteinium	100 Fm (257) FERMIUM	101 Md (258) Mendelevium	102 No (259) Nobelium	103 Lr (262) Lawrencium



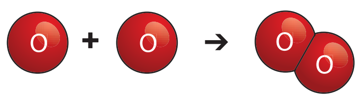
Sulfur burns quickly in oxygen. The energy from the flame allows the elements sulfur and oxygen to react chemically to form a new substance – the compound sulfur dioxide.

JOINING ELEMENTS

Elements can combine to form compounds. There are thousands of compounds around us. Compounds have properties different from those of the elements that form them.

Compounds

When atoms bond they can form **molecules**. The simplest molecules are made of two or more atoms of the one element. Hydrogen gas has molecules with two strongly linked hydrogen (H) atoms. The hydrogen molecule can be written as H_2. Oxygen gas is made of molecules with two bound oxygen atoms. It is written as O_2.

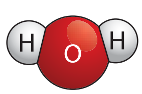


An oxygen molecule (O_2) is formed when two oxygen atoms are joined together.

Hydrogen and oxygen will combine chemically to form water. Water molecules have two hydrogen atoms and one oxygen atom. The formula is H_2O.

Water is an example of a compound. Compounds have two or more elements held together by forces called **chemical bonds**. Compounds always have the same ratio of elements. For example, a single molecule of water always contains two hydrogen atoms and one oxygen atom.

The reaction between hydrogen and oxygen to make water can be written as:
hydrogen + oxygen → water



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

A carbon dioxide molecule (CO_2) is made up of one carbon atom and two oxygen atoms.

Common salt is also a compound. Its chemical formula is NaCl. The formula shows that salt contains equal parts of sodium and chlorine.

Sodium is a soft, silvery-white, reactive metal. It can burst into flames if it contacts air. Chlorine is a greenish-yellow poisonous gas with a terrible smell. When these two elements react chemically, they form common salt, an ingredient of many foods.

Common salt is a compound of sodium and chlorine. It has properties very different from those of sodium and chlorine.

Most of the substances we use are compounds. Chemists can change the properties of compounds by combining different numbers and types of atoms. Pharmaceuticals (medications), fertilisers, polymers (plastics) and food products are examples of important compounds.

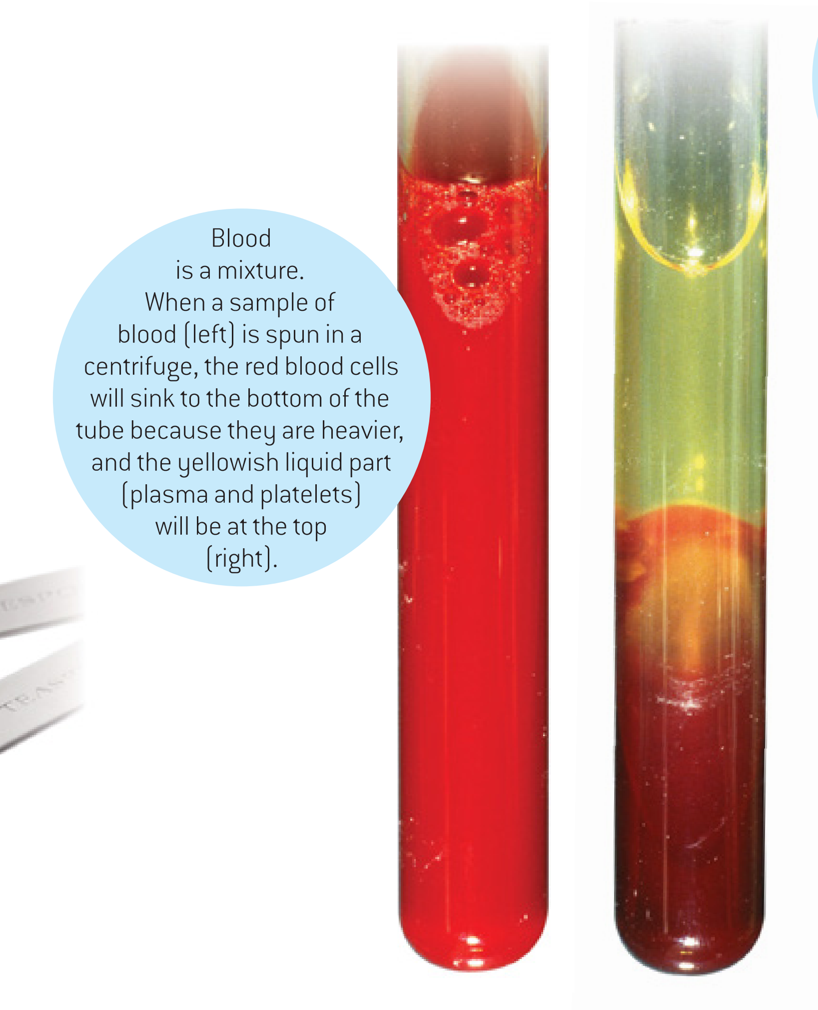
Mixtures

A mixture is a combination of two or more substances that are not chemically joined. A mixture can usually be separated back into its original parts. Each substance in the mixture keeps its own properties. The different substances in a mixture can be elements or compounds. Most natural substances are mixtures.

Examples of mixtures include sea water, most rocks, wood, air, milk, salad dressing, orange juice, smoke, shaving cream, blood, clay suspended in water, hair spray and ink.

You can separate sea water into its parts by heating it. This will cause the water to evaporate and the salt will be left behind. If the water vapour is cooled so that it condenses, pure water will form.

Salad dressings are mixtures. The oil and vinegar in the salad dressing on the right have separated, with the oil floating on top.



Blood is a mixture. When a sample of blood (left) is spun in a centrifuge, the red blood cells will sink to the bottom of the tube because they are heavier, and the yellowish liquid part (plasma and platelets) will be at the top (right).

LOOK IT UP

chemical bond the attraction between atoms that allows the formation of chemical substances that contain two or more atoms

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

CHECK IT OUT

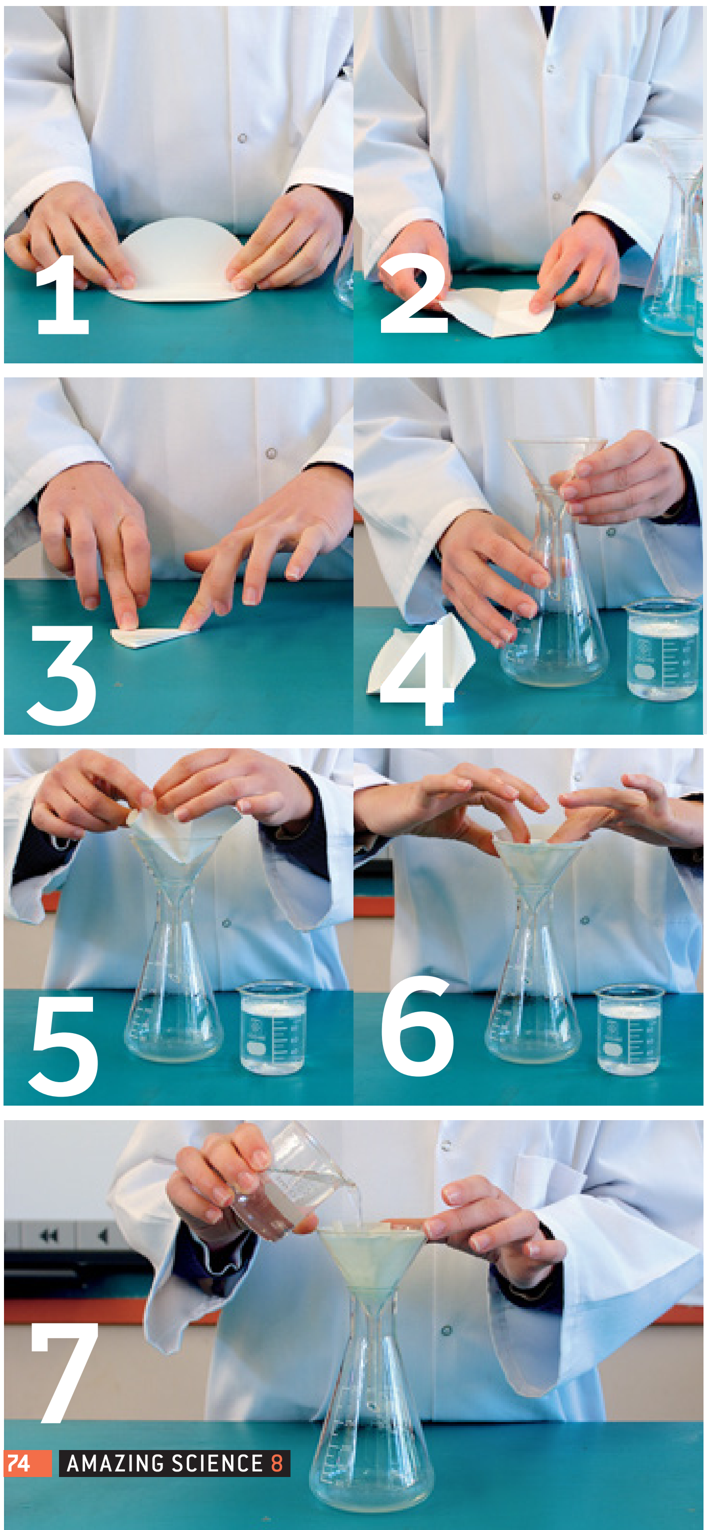
1. Define the terms 'molecule' and 'compound'.
2. Methane is a gas that has molecules with the formula CH_4. What elements are present in methane and what is the ratio of atoms in each methane molecule?
3. How many oxygen atoms are there in 1000 molecules of sulfuric acid, H_2SO_4? What is the total number of atoms in 1000 molecules of sulfuric acid?
4. Explain why blood is classified as a mixture.
5. What is the difference between a compound and a mixture?

EXPERIMENT #8

SEPARATING MIXTURES

A huge magnet collecting iron from a recycling depot

There are many ways that mixtures can be separated into their components. Some of these will be explored in this experiment.



HOW TO FILTER

1 Fold a round filter paper in half, then in half again to get quarters, then in half again to get eighths.

2 Unfold the filter paper and lay it flat.

3 Re-fold back and forth over the creases to obtain a fluted shape.

4 Set up the funnel and flask as shown.

5 Place the filter paper into the funnel.

6 Dampen the filter paper to help it stick to the sides of the funnel.

7 Slowly pour the mixture from the beaker into the funnel. Do not overfill the funnel.

8 Keep adding the mixture slowly until it is all used up.

9 Wait for the filtration to finish. Remove the filter paper carefully and let it dry.

PART A: SEPARATING A MIXTURE

AIM: TO SEPARATE A MIXTURE INTO ITS COMPONENTS

MATERIALS

- Mixture of iron filings, salt and sand
- Funnel
- Flask
- Filter paper
- Magnet
- Plastic lunch wrap
- Water
- Dish

METHOD

1 Copy and complete the following table, with ticks or crosses, listing the properties of the three materials in the mixture:

MATERIAL	WATER SOLUBLE	MAGNETIC
Iron		
Salt		
Sand		

2 Wrap the magnet in plastic lunch wrap and pass it through the mixture of the three solids.

3 Mix the remaining salt and sand in water and stir. Use the smallest volume of water that will just dissolve all of the salt.

4 Following the 'How to filter' guidelines, use the funnel, flask and filter paper to filter the sand from the saltwater solution.

5 Leave the salt solution in a warm place to evaporate the water.

DISCUSSION

1 Define the term 'mixture'.

2 Briefly explain how the different properties of the substances in the mixture allowed it to be separated.

PART B: COLOURFUL SECRETS

AIM: TO SEPARATE DYE INTO ITS COMPONENT COLOURS

MATERIALS

- Water-soluble felt-tip pens
- Filter paper, cut in strips about 1 cm wide and 10 cm long
- Glass beaker or container

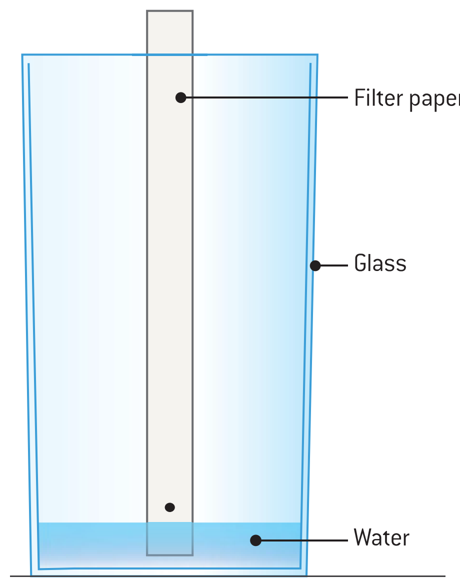
METHOD

1 Draw a small dot with the pen about 2 cm from the bottom of a filter paper strip.

2 Pour water into the beaker to a height of about 1 cm.

3 Rest the strip of filter paper upright in the glass so the bottom of the paper just touches the water. Keep the filter paper in place until the water moves up and is almost at the top of the paper.

4 Repeat the experiment with different coloured felt-tip pens.



DISCUSSION

1 What does this activity tell you about the dyes in felt-tip pens?

2 Explain whether the dye in a felt-tip pen is a compound or a mixture.

3 Suggest another common substance that could be separated into its components in a similar activity.

This experiment demonstrates chromatography. The first part of the word chromatography comes from *khroma*, the Greek word for colour. Scientists use different forms of chromatography to separate and identify the components of mixtures. Medical scientists can identify some diseases by studying blood and urine with chromatography. Forensic scientists use it to solve crimes.

REVIEW

THE NATURE OF MATTER

STATES OF MATTER (PAGES 56–57)

1 List the three common states of matter in order from most to least difficult to compress.

2 Name the fourth state of matter and describe how it forms.

3 **a** If 1 L of oil is poured into a 5-L container and sealed, what is the volume of oil in the container?

b If 1 L of helium gas is pumped into an empty 5-L container and sealed, what is the volume of helium gas in the container?

LOOKING INSIDE MATTER (PAGES 60–61)

4 What contribution did Democritus make to our understanding of matter?

5 Suggest some reasons why people at the time disagreed with Democritus's ideas.

6 Suggest some of the evidence that Dalton may have used to decide that all matter is made of atoms.

7 Use the particle model of matter to explain why liquids take the shape of their container whereas gases completely fill their containers.

8 Why do solids have a fixed shape?

9 Examine the photos (right) and use the particle model of matter to explain your observations of the different rates of diffusion in cold and warm water.

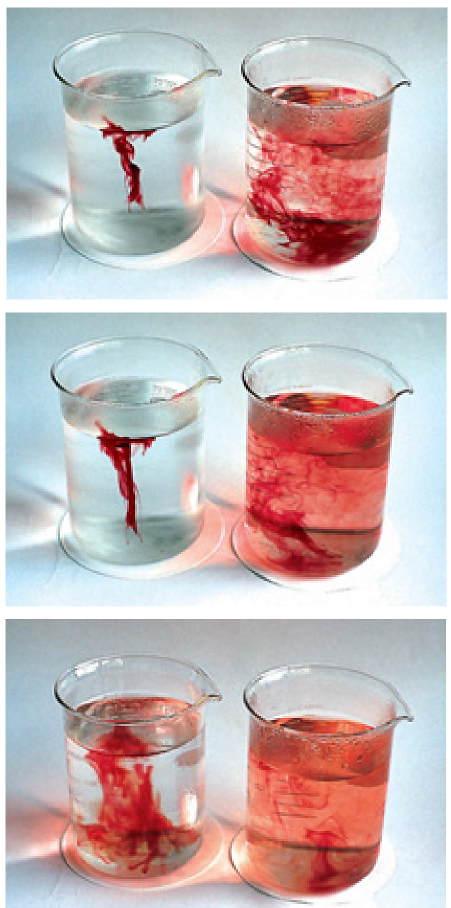
MOVING GASES (PAGES 62–63)

10 The terrible smell of a skunk can be detected up to a kilometre away. Explain how its scent can travel so far.

11 Is diffusion faster in a gas or a liquid? Explain your answer.

12 What force causes a balloon to expand when you blow air into it?

13 Your friend comments that a soft drink bottle is empty once the liquid has been drunk. How could you demonstrate that the bottle is not really empty because it contains air?



Dye added to cold water (left) and warm water (right) in photographs taken over time.

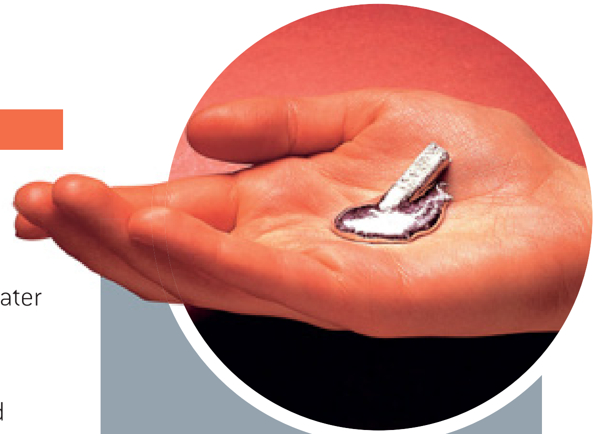
CHANGING STATES (PAGES 64–65)

14 Look at the photograph of the iceberg opposite.

- **a** Identify examples of the solid, liquid and gaseous states of water.
- **b** What would happen to the particles in the iceberg if it was heated?
- **c** The cloud in the photograph is ice and condensed water vapour. What is water vapour and what happens to its particles when condensation occurs?

15 Read the information about the metal gallium to the right.

- **a** Describe what would happen to a teaspoon made of gallium as you stirred a cup of tea.
- **b** What does heat do to the movement of particles in a solid?



Gallium is a blue-grey metal. In its pure form, it has a stunning silver colour. Solid gallium is soft enough to be cut with a knife. At room temperature, the metal is a solid. However, gallium becomes a liquid at just 30°C. If you hold gallium, your body heat will melt it, much like what happens with a piece of chocolate.

5 AMAZING PROPERTIES OF MATTER (PAGES 68–69)

16 What is the difference between a physical and a chemical property of a substance?

17 What physical property of copper makes it useful for electrical wiring in a house?

18 Iron is the most commonly used element in the world. Identify whether each of the following are chemical or physical properties of iron.

- **a** It is solid at room temperature.
- **b** It will melt at temperatures of 3000°C.
- **c** It can conduct electricity.

19 Look at the table of densities (right). Objects that are less dense than water will float. Objects that are more dense than water will sink.

- **a** List one solid and one liquid item from the table that will float.
- **b** Which has a greater volume – a kilogram of gold or a kilogram of polystyrene foam?
- **c** How can the huge iceberg pictured float on water?

TABLE OF DENSITIES (g/cm^3)		
polystyrene foam	0.1	FLOAT IN WATER
cork	0.2	
pine wood	0.4	
petrol	0.7	
polystyrene plastic	0.9	
ice	0.9	
water	1.0	
aluminium	2.7	SINK IN WATER
granite	2.7	
iron	7.8	
nickel	8.9	
lead	11.3	
gold	19.3	
osminium	22.5	

PERIODIC TABLE (PAGES 70–71)

20 What is the periodic table?

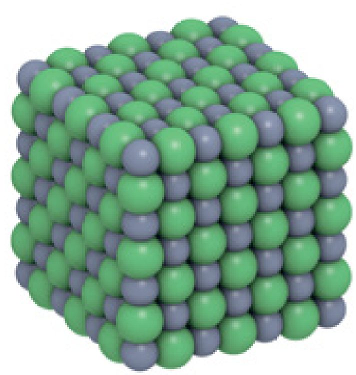
21 Refer to the periodic table on pages 70–71.

- **a** Name the elements with the following symbols: Ne, Al, W, K, C, Ca, Co, Pb, Fe.
- **b** Write the symbol for each of the following: silver, silicon, gallium, gold, hydrogen, helium.
- **c** Divide this list into metals and non-metals: Ag, Zn, H, Ti, Kr, Ne, W.

JOINING ELEMENTS (PAGES 72–73)

22 Look at the model of sodium chloride (common salt) below.

- **a** Is sodium chloride an element or a compound? Explain.
- **b** Sodium (Na) is represented by the green particles in the model. How many chlorine (Cl) particles are there for each sodium particle?
- **c** What is the chemical formula for sodium chloride?



KEY IDEAS

1

Scientists classify most matter as solids, liquids or gases. These are called states of matter. Plasma is referred to as the fourth state of matter. It occurs in the Sun, where gases are extremely hot.

2

Democritus, in ancient Greece, stated that everything was made up of particles. In the 1800s, John Dalton developed the understanding of atoms, and proposed that they cannot be created or destroyed, nor split.

3

Solids have a set shape and take up a set space. Liquids change their shape to match their container. It is difficult to compress solids and liquids. Gases take the shape of their containers. Gases are easy to compress.

4

Matter is made of tiny particles called atoms. The particle model of matter uses the behaviour of atoms to explain the properties of solids, liquids and gases.

» In solids, particles are tightly held together. This explains why solids have a constant shape and are difficult to compress.

» In liquids, particles can move past each other. This is why liquids flow and take the shape of their containers.

» In gases, the particles are far apart and completely free to move. The forces between gas particles are weak.

5

Gases exert pressure due to their tiny, fast-moving particles constantly striking the walls of their container. Gas pressure increases when more gas is added to a container or when the gas is heated. Gases can diffuse (spread out) and mix with the air when released from a container.

6

The melting point of a substance is the temperature at which it melts, changing from solid to liquid. The boiling point is the temperature at which a substance boils, changing state from liquid to gas. Gases cool and condense to become a liquid. Additional cooling will lead to solidification (freezing).

7

Matter shares different characteristics or properties. Physical properties include strength, density and conductivity. Chemical properties, such as flammability, are only obvious when we observe a chemical reaction.

8

Atoms have different sizes and weights. Elements are substances made up of just one type of atom. The periodic table arranges all the elements in order of the mass of their atoms. The table groups together elements with similar properties.

9

Each element has a symbol, which consists of one or two letters. Hydrogen, the lightest of all elements, has the symbol H.

10

Elements can combine in set ratios to form compounds. A mixture is a combination of two or more substances that are not chemically joined. A mixture can usually be separated back into its original parts.

CHEMICAL CHANGE 04

5 AMAZING COMPOUNDS

WHY DO substances change?

WHY DO THINGS EXPLODE?

CHEMICAL AND PHYSICAL CHANGES

Substances constantly change. They can change physically and chemically. Physical changes involve **changes of state** – between solid, liquid and gas forms. Chemical changes lead to new substances being formed, with different properties. For example, the digestion of food is a chemical change.

Fireworks are spectacular examples of chemical change.

Physical changes

When ice melts, it changes into liquid water. If the liquid water is cooled below zero degrees it freezes, changing back into ice. If the liquid water is boiled, it forms water vapour. If the water vapour is collected and cooled, it will condense back to liquid water. These are all **physical changes** of state, involving solids, liquids and gases. Each change can be reversed, simply by heating or cooling.

Water can change its form to become a solid, liquid or gas, but it remains as water. Water is always made of molecules of hydrogen and oxygen. The difference is how strongly the **molecules** are held together – very strongly in ice (solid) and weakly in vapour (gas).

Compressing a gas is also a physical change. The gas still contains the same **particles**, but they take up a smaller space.

Heating chocolate so that it melts is an example of a physical change. When cooled, the liquid chocolate will change back into a solid.

Chemical changes occur during cooking, with new substances being created.

Chemical changes

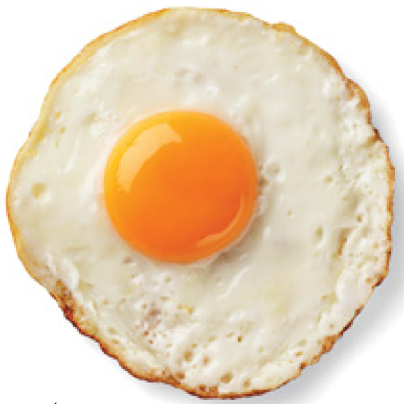
Without chemical changes, there would be no life on Earth. Chemical changes are happening everywhere, including in your body. **Chemical changes** turn sugar we eat into energy, which we then use to do things. Plants use chemical changes, also known as chemical reactions, to turn carbon dioxide from the air and sunlight into energy and oxygen.

Baking bread and cakes, making caramel and burning natural gas all involve chemical changes.

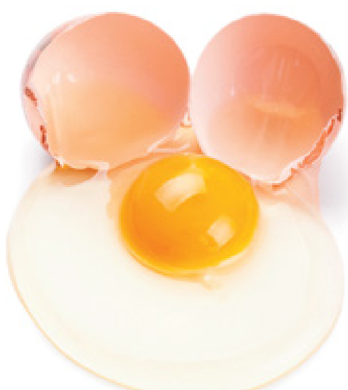
During chemical changes, new substances with different properties are formed. Usually, chemical changes are not easy to reverse.

Chemical changes can include:

- colour changes
- a gas being formed
- light or heat being produced or absorbed
- a **precipitate** being formed (precipitates are solids that cannot be dissolved).



A fried egg is an example of chemical change – it is very different from a raw egg.



Chemical changes in leaves cause the beautiful colours of autumn leaves.

LOOK IT UP

change of state the transformation of matter from one form to another, i.e. solid to liquid (melting), liquid to gas (evaporating), solid to gas (sublimation), liquid to solid (freezing), gas to liquid (condensation)

chemical change where a new substance is formed with different properties

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

particle a building block of matter

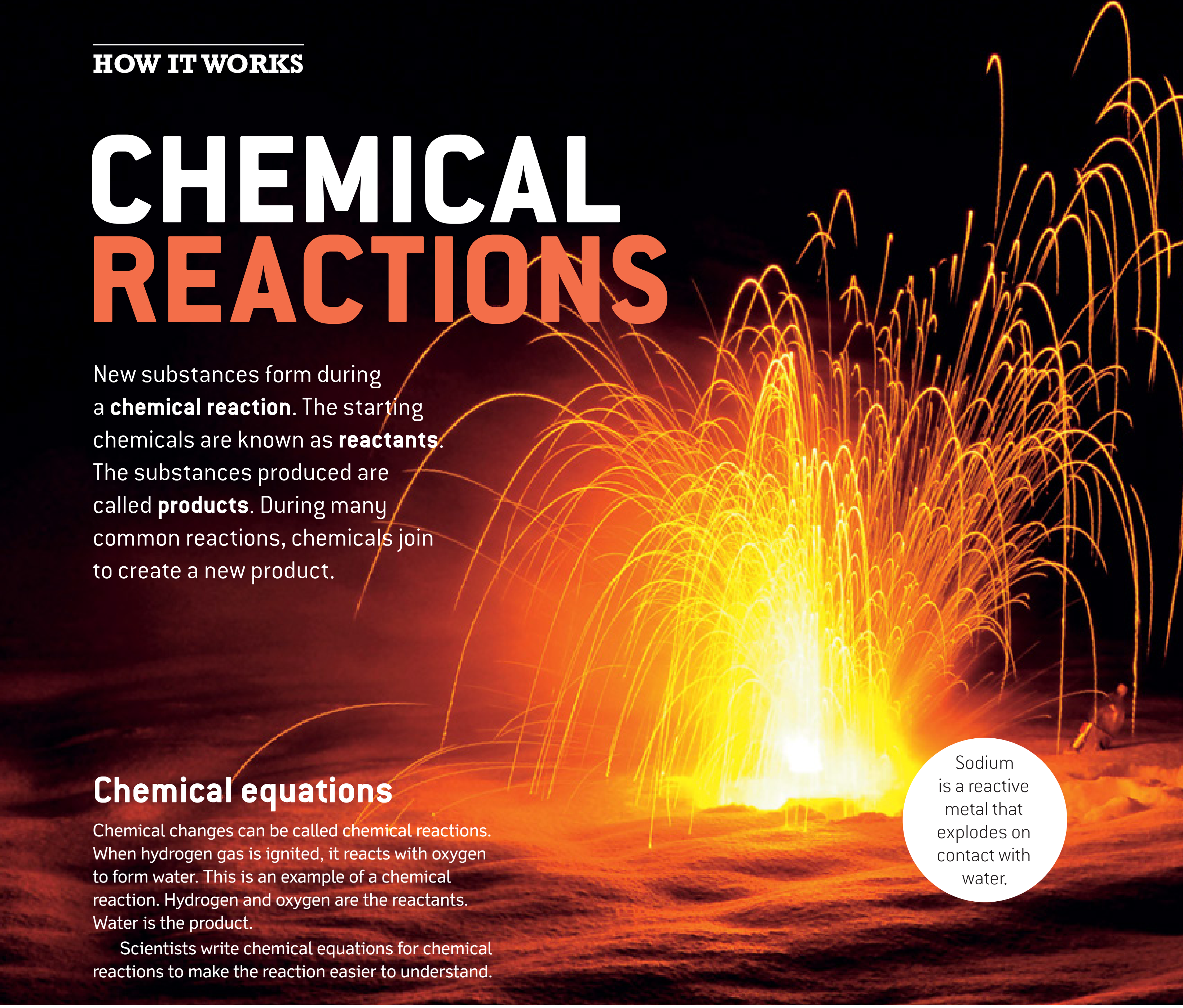
physical change a change in state between solid, liquid and gas forms

precipitate an insoluble solid substance

substance a matter that has a specific composition and specific properties

CHECK IT OUT

1. What are the main differences between a physical and a chemical change?
2. When a substance changes its temperature, what has taken place?
3. Name three different things that could happen during a chemical change.
4. Classify the type of change (physical or chemical) that occurs in each of the following:
   a making toast
   b water evaporating
   c a nail rusting
   d solid carbon dioxide becoming a gas
   e adding magnesium to hydrochloric acid, generating bubbles of hydrogen gas
   f melting a gold brick and pouring it into a mould
   g burning wood in a campfire
   h petrol being used in a car
   i pumping up a bike tyre.



CHEMICAL REACTIONS

New substances form during a **chemical reaction**. The starting chemicals are known as **reactants**. The substances produced are called **products**. During many common reactions, chemicals join to create a new product.

Sodium is a reactive metal that explodes on contact with water.

Chemical equations

Chemical changes can be called chemical reactions. When hydrogen gas is ignited, it reacts with oxygen to form water. This is an example of a chemical reaction. Hydrogen and oxygen are the reactants. Water is the product.

Scientists write chemical equations for chemical reactions to make the reaction easier to understand.

reactants → products

The reactants are written on the left of the equation.

The chemical change is shown by an arrow.

The products are written on the right.

The reaction between hydrogen and oxygen can be written as the following word equation:

hydrogen + oxygen → water

Combination reactions

Combination reactions involve two or more chemicals combining or joining to form a more complex product. An example is hydrogen and oxygen reacting to form water.

When magnesium (a metal) burns in oxygen (a gas), the product is a new compound called magnesium oxide. Magnesium oxide is a white powder. In this case, the reactants are very different to the product.

The word equation for this reaction is:

magnesium + oxygen → magnesium oxide

reactants

chemical change

product

Chemists react nitrogen gas with hydrogen gas to make ammonia. Ammonia is an ingredient of fertiliser. The equation for this reaction is:

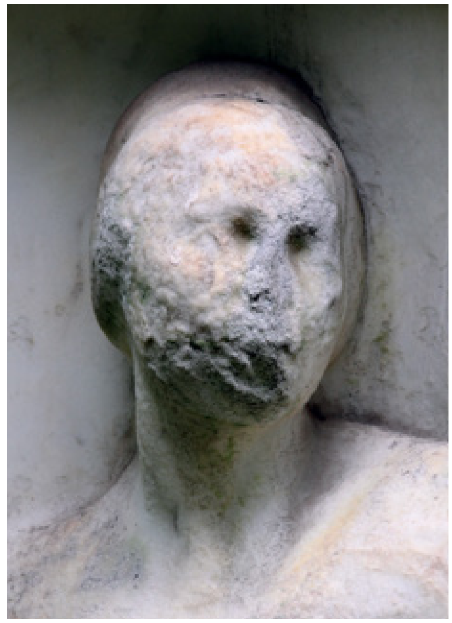
nitrogen + hydrogen → ammonia

Reaction rates

Chemical reactions can happen quickly, such as magnesium burning in air or an explosion. They can also happen slowly. It can take years for iron to rust or for the acid in rainwater to corrode and wear away limestone statues.

Many chemical reactions happen more quickly at high temperatures. The particles move more quickly at high temperatures, and collide more often and with greater force.

Iron will wear away, or corrode, when exposed to water and oxygen. The chemical name for rust is hydrated iron oxide.



This limestone statute has been corroded over time by acid rainwater.

LOOK IT UP

chemical reaction a process in which one or more substances are converted to different substances

combination reaction a reaction in which two reactants combine to form one product

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

Magnesium burns in the oxygen present in air with a bright flame.

CHECK IT OUT

1 Are the products written on the left or right side of a chemical equation?

2 What does the arrow represent in a chemical equation?

3 What is a combination reaction? Give an example of a combination reaction.

4 The reaction between carbon and oxygen forms carbon dioxide. Write a chemical equation to show this reaction.

5 What is the evidence that the reaction between magnesium and oxygen represents a chemical change?

HOT REACTION

The reaction between iron and sulfur is a spectacular one. It creates heat, and the product is very different from the **reactants**.

Combination of iron and sulfur

Iron is a metallic **element**. Sulfur is an element that is not metallic. These two very different elements can be made into powder.

When a substance is formed into a powder, it greatly increases the surface area. The large surface area provides more contact between the reactants, helping them react together.

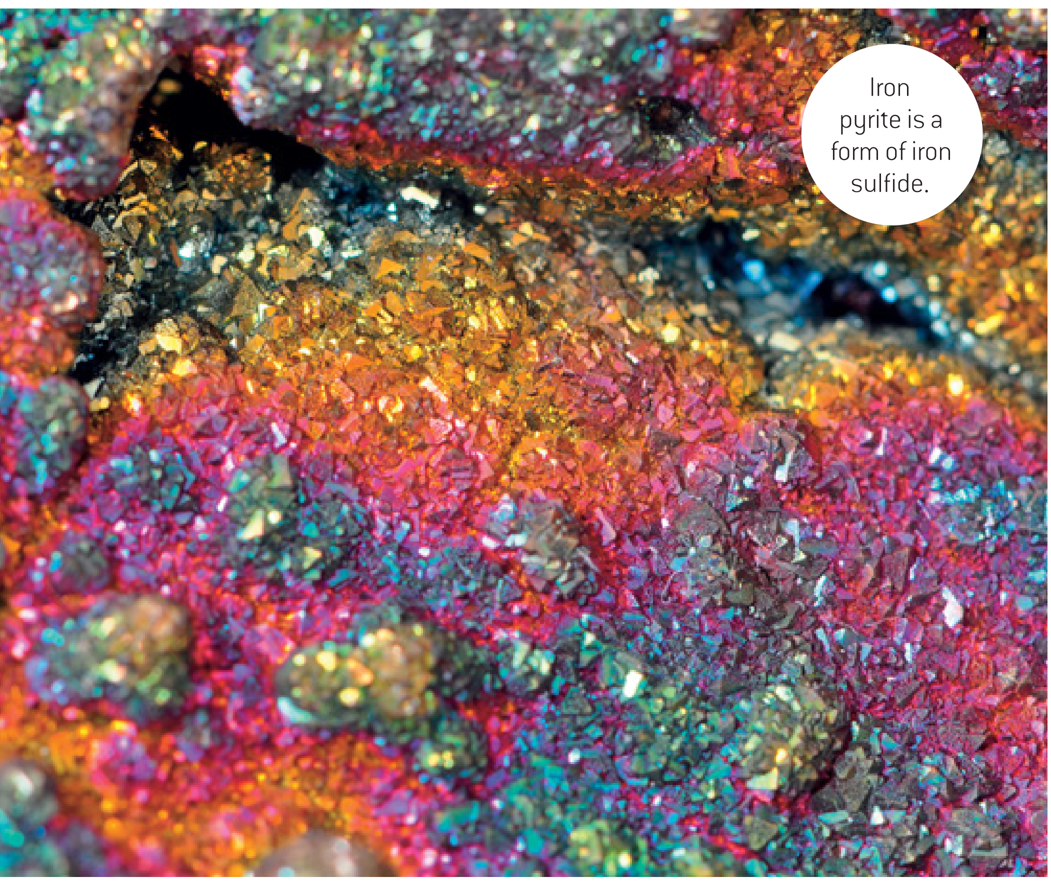
When powdered iron and sulfur are placed into a test tube and heated with a Bunsen burner, they glow with an orange colour. If the burner is turned off at this point, the glow will continue and move throughout the mixture.

The chemical reaction between the two reactants is started by applying heat. The heat gives the iron and sulfur particles the energy to start reacting with each other. Once the reaction has begun, it continues – it is self-sustaining. The reaction creates heat. Scientists call a reaction that creates heat an **exothermic reaction**.

After the reaction is over, the product is a substance called iron sulfide. The equation for this reaction is:

iron + sulfur → iron sulfide

As the table shows, the product of this chemical reaction is different from the two reactants. The iron and sulfur **atoms** in iron sulfide are joined together by strong **chemical bonds**. You can only separate the elements in a compound using another chemical reaction. If you tried to separate these elements by filtering them or passing a magnet over the iron sulfide, they still would not separate.



Iron pyrite is a form of iron sulfide.

The reaction between iron and sulfur is exothermic – it creates heat.

The chemical reaction between iron and sulfur

	REACTANTS		PRODUCT
SUBSTANCE	**iron**	**sulfur**	**iron sulfide**
	 *Iron metal shavings*	 *Powdered sulfur*	 *Iron sulfide*
PROPERTY			
FORMULA	Fe	S	FeS
STATE AT ROOM TEMPERATURE	solid	solid	solid
COLOUR	silvery grey	yellow	black
ATTRACTED TO A MAGNET?	yes	no	no
MELTING POINT	very high	moderate	high
BOILING POINT	very high	high	decomposes rather than boils
HARDNESS	hard	soft	hard
REACTION WITH HYDROCHLORIC ACID	forms hydrogen gas	no reaction	forms smelly hydrogen sulfide gas

LOOK IT UP

atom the smallest particle of a substance that can exist

chemical bond the attraction between atoms that allows the formation of chemical substances that contain two or more atoms

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

exothermic reaction a reaction that releases heat

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

CHECK IT OUT

1 Explain why iron and sulfur in a test tube before being heated is a mixture and not a compound.

2 Name the reactants and the product in the reaction between iron and sulfur when heat is applied.

3 Choosing four of the properties listed in the table, explain the evidence that a chemical reaction takes place between iron and sulfur.

4 How would you show that iron sulfide is not just a mixture of iron and sulfur?

5 The formula for iron sulfide is FeS. What does this tell you about the compound?

5 AMAZING COMPOUNDS

Many common substances are **compounds** formed from atoms of different elements combined chemically.

Wheat can be turned into flour, which is rich in compounds called carbohydrates.

1 Carbohydrates

Flour is the main ingredient of bread and many other baked products. It is made by grinding cereal grains such as wheat. Carbohydrates are the main part of flour. Carbohydrates contain carbon, hydrogen and oxygen atoms. Our bodies can easily digest carbohydrates, turning them into **glucose.**

Glucose is the form of sugar used by our bodies. Glucose and oxygen combine in our bodies to create energy. This process is called cellular **respiration**. (We also use the term respiration in another way, referring to breathing and supplying our body with oxygen while removing carbon dioxide.)

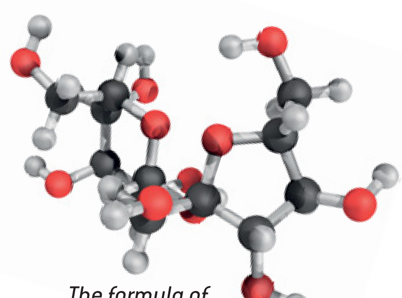
glucose + oxygen → carbon dioxide + water (+ energy)

Sucrose comes from sugar cane or sugar beets.

Harvesting sugar cane in Queensland.

2 Sugar

Sucrose is the chemical name for table sugar. Sucrose is a carbohydrate that occurs naturally in every fruit and vegetable. Sugar is often added to packaged foods such as breakfast cereals to sweeten them and increase their flavour.



The formula of sucrose is $C_{12}H_{22}O_{11}$

3 Eggshells

Eggshells are made of calcium carbonate. The formula of this compound is $CaCO_3$. This means that there is one calcium (Ca) atom and one carbon (C) atom for every three oxygen (O) atoms. Other items made of calcium carbonate include chalk, limestone, cave stalactites, seashells, coral and pearls.

An eggshell is covered with thousands of tiny pores (holes). The pores let air and moisture pass in and out, so that a chick can survive inside.

Calcium carbonate reacts with acetic acid. This means eggshells will dissolve in vinegar, which contains acetic acid. This chemical reaction is written as:

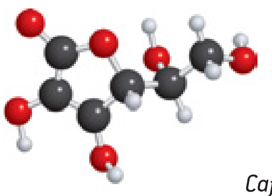
calcium carbonate + acetic acid → calcium acetate + carbon dioxide + water

Eggshells are made almost entirely of the compound calcium carbonate.

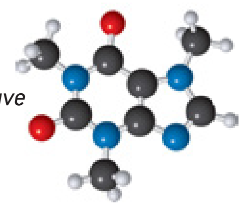
4 Vitamin C (ascorbic acid)

We need **vitamin** C for growth and health. Our bodies can't store it, so we need to get it from food. Citrus fruits such as oranges, grapefruit, limes and lemons are excellent sources of vitamin C. Other foods rich in vitamin C are watermelons, cantaloupes, capsicums, strawberries, kiwi fruit, broccoli and tomatoes.

Citrus fruits are rich in vitamin C.



Vitamin C has the formula $C_6H_8O_6$



Caffeine molecules have the formula $C_8H_{10}N_4O_2$

5 Coffee

Coffee beans contain many different compounds including water, carbohydrates, fibre, fats, oil, proteins, minerals, acids and caffeine. The coffee we drink, called roasted coffee, contains almost 1000 different compounds! Coffee contains **esters**, which are compounds that often have pleasant smells. A cup of coffee will usually contain up to a fifth of a gram (0.2 g) of caffeine.

Caffeine is a stimulant – it wakes up the body and increases the heart rate. Small amounts can make you feel refreshed and focused. Large amounts are likely to make you feel stressed and can make it more difficult to sleep.

Green coffee beans on the branch of a coffee plant.

LOOK IT UP

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

ester a compound that often has a pleasant smell

glucose a simple sugar containing six carbon atoms

respiration the breakdown of glucose and oxygen into water, carbon dioxide and energy; usually occurs in the mitochondria of a cell

vitamin a compound essential in small amounts in the diet for health and development

CHECK IT OUT

1. Name the three elements contained in carbohydrates.
2. Name the two compounds our body produces when we obtain energy from glucose.
3. A small sample of sucrose contains 12 000 carbon atoms. How many oxygen atoms will it contain?
4. Name the gas that forms the bubbles when eggshells are dissolved in vinegar.
5. Why is vitamin C called a compound?

EXPERIMENT #9

SALTY WATER

AIM: TO EXPLORE THE EFFECT OF DISSOLVING SALT IN WATER

MATERIALS

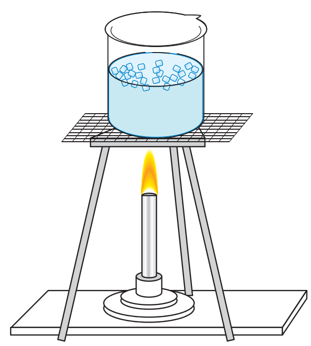
- 10 g common salt
- Beaker (250 mL)
- Bunsen burner
- Heatproof mat
- Tripod stand
- Gauze mat
- Stirring rod
- Scales

SAFETY

- Take great care when working with high temperatures as steam and boiling water can both burn the skin and scald.
- If scalded, immediately place the area of skin under cold running water and tell your teacher.
- Wear safety glasses, enclosed footwear and a lab coat.
- Tie back long hair.
- Never taste anything that you use or make in a laboratory.

METHOD

1 Weigh the empty beaker and record its mass.
2 Add 10 g of salt to the beaker.
3 Add approximately 100 mL of water to the salt in the beaker.
4 Stir the water until all the salt dissolves.
5 Light the Bunsen burner and heat the saltwater solution until nearly all of the water has evaporated.
6 Turn off the burner and let the damp salt dry in the beaker.
7 When the beaker has cooled, weigh it with the dry salt in it.



RESULTS

What was the mass of the salt left in the beaker after the experiment?

DISCUSSION

1 Did a new substance form after the salt was dissolved and the water evaporated? Explain your answer.
2 What mass of salt did you expect to be left in the beaker? Suggest reasons for why the mass may have been different from what you expected.

EXPERIMENT #10

BAKING SODA AND ACID

AIM: TO TEST WHETHER DISSOLVING BAKING SODA IN HYDROCHLORIC ACID IS A PHYSICAL OR CHEMICAL CHANGE

MATERIALS

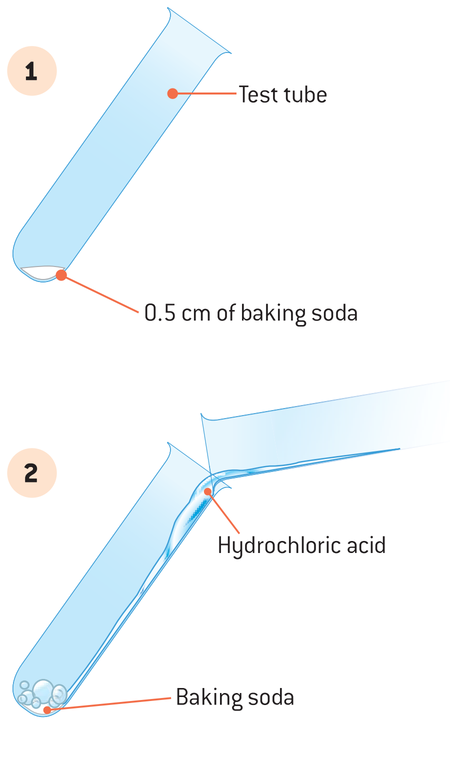
- Baking soda (sodium bicarbonate)
- Dilute hydrochloric acid
- Test tube
- Test tube holder
- Matches

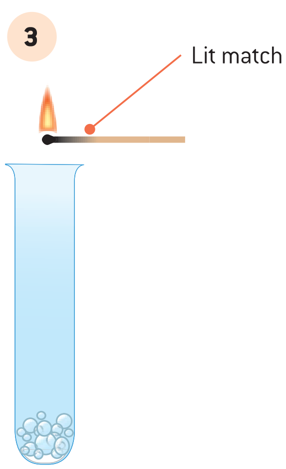
METHOD

1 Place the baking soda in a test tube to a depth of 0.5 cm.

2 Add an equal amount of hydrochloric acid to the test tube and observe.

3 Conduct a test for carbon dioxide gas by holding a lit match above the tube – if the flame goes out, carbon dioxide is one of the products of the chemical reaction.





DISCUSSION

1 Name a substance produced when hydrochloric acid is added to baking soda.

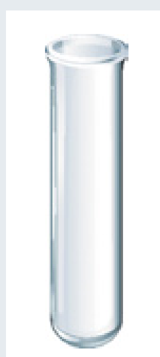
2 Why does the flame on the match go out if carbon dioxide is present?

3 Is adding baking soda to hydrochloric acid a physical or chemical change? Explain your answer.

Bicarbonate of soda (sodium bicarbonate) is often used in cooking as it releases carbon dioxide gas to create the bubbles in pancakes, cakes and bread.

SCIENTIFIC EQUIPMENT

- Test tube
- Test tube holder



EXPERIMENT #11

REACTING METALS

AIM: TO OBSERVE AND RECORD THE REACTION BETWEEN STEEL WOOL AND COPPER SULFATE

MATERIALS

- Small ball of steel wool
- 0.5 M copper sulfate solution
- Test tube and test tube rack
- Stirring rod

Steel wool is made of fine strands of steel. Iron is the main metal in steel.

METHOD

1. Push the steel wool to the bottom of the test tube with the stirring rod.
2. Pour copper sulfate solution into the test tube until it covers the steel wool.
3. After five minutes, remove and inspect the steel wool.

RESULTS

1. Record your observations of what occurred in the test tube.
2. Compare the appearance of the steel wool before and after the experiment.

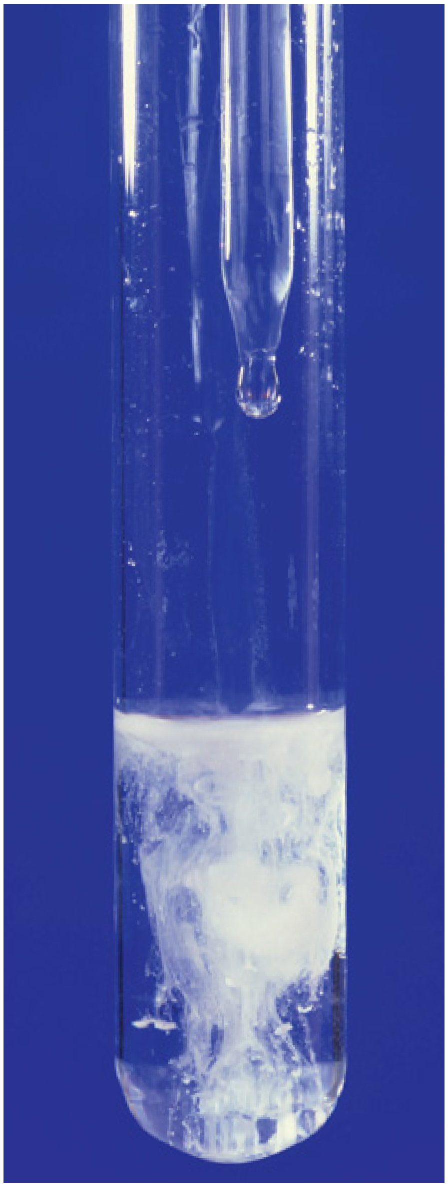
DISCUSSION

1. What evidence is there that a chemical reaction took place?
2. Suggest a name for the brown material that you may have seen coating the steel wool.
3. Suggest why scientists call this a displacement reaction.

EXPERIMENT #12

MAKING A PRECIPITATE

AIM: TO OBSERVE A REACTION THAT MAKES A PRECIPITATE (INSOLUBLE SOLID)



What do you observe when barium chloride solution is added to sodium sulfate solution?

MATERIALS

- 0.1 M sodium sulfate solution
- 0.1 M barium chloride solution
- Test tube and test tube rack

METHOD

1 Add sodium sulfate solution to a depth of 1 cm to the test tube.

2 Add a few drops of barium chloride solution to the test tube.

RESULTS

1 Describe the appearance of the sodium sulfate solution and of the barium chloride solution.

2 What did you observe when the barium chloride solution was added to the sodium sulfate solution?

DISCUSSION

1 What evidence is there that a chemical reaction took place?

2 Suggest how you would separate the precipitate from the liquid in the test tube.

KITCHEN CHEMISTRY

A lot of chemistry happens in preparing food, such as during baking, wine making and heating sugar.

Yeast, a fungus, changes the sugars in the dough into carbon dioxide gas. The bubbles of gas make the dough expand.

Baking bread

The main ingredients in bread are flour, water, sugar and **yeast**. Bakers mix the ingredients together when they knead the dough. When the dough sits, the yeast (tiny organisms) in the dough change the **carbohydrates** in the flour into carbon dioxide gas.

The change in the dough is a chemical reaction known as **fermentation**. Fermentation makes alcohol as well as carbon dioxide. During baking, the alcohol evaporates.

The carbon dioxide gas creates bubbles inside the dough. The bubbles make the dough expand. After an hour or so the dough is ready to go into the oven. Baking the dough makes the gas bubbles expand further, so the dough rises and the loaf of bread becomes larger.

Glucose is a carbohydrate. The fermentation reaction involved in making bread from yeast and flour is:

glucose → carbon dioxide + ethanol (alcohol)

Baking dough makes the gas bubbles expand and the bread rise.

Baking a cake

Like bread, the flour mixture used for making a cake needs to rise. Cooks often use self-raising flour to help make this happen.

Self-raising flour is plain flour combined with a small amount of baking powder. Baking powder contains sodium bicarbonate (often called bicarbonate of soda or baking soda), and an acid, such as cream of tartar. The formula for sodium bicarbonate is $NaHCO_3$.

When sodium bicarbonate reacts with acid in the cake mix, the equation for the reaction that occurs is:

sodium bicarbonate + acid → carbon dioxide + water

Fermentation

The same chemical reaction that causes bread to rise also occurs when making alcoholic drinks. Fermentation is a natural process. People have been using fermentation for thousands of years to make wine and beer.

Grapes contain a lot of sugar, including glucose and fructose. To make wine, winemakers pick and crush the grapes. Yeast is naturally present or can be added. It is the yeast that changes the sugars into alcohol. The sweeter the grape, the greater the percentage of alcohol in the wine. The main alcohol produced by fermentation is called ethanol.

Making caramel

Heating sugar causes a chemical reaction known as **caramelisation**.

Caramel is made by heating sugar to around 180°C in a pan. First the sugar melts, and then it turns brown. Once the sugar melts, the heat makes the sucrose break down into two simpler forms of sugar: fructose and glucose. Next, the fructose and glucose break down into lots of different molecules. Some of them smell sweet.

Grapes fermenting to make red wine.

LOOK IT UP

caramelisation the process of cooking sugar until it browns

carbohydrate a class of compound containing carbon, hydrogen and oxygen atoms

fermentation the breakdown of a substance by microbes such as yeasts and bacteria; the process involved in making alcohol and bread

glucose a simple sugar containing six carbon atoms

yeast a microscopic fungus capable of converting sugar into alcohol and carbon dioxide

CHECK IT OUT

1. Where does the carbon in carbon dioxide come from during bread making?
2. What is the main difference between the process of fermentation in bread making and in wine making?
3. State three pieces of evidence that bread making involves chemical reactions.
4. Name three examples of carbohydrates.
5. Name the two sugars formed from sucrose during caramelisation.

CAR CHEMISTRY

Chemistry is needed for making cars. The metal comes from **minerals** and the plastics come from **fossil fuels**. Starting the car, driving the car and car safety all rely on chemical reactions.

Combustion in the engine

Most cars obtain their energy from petrol. Petrol comes from fossil fuels.

Fossil fuels occur naturally and have formed over millions of years. Heat, pressure and bacteria change plant and animal remains into crude oil – a yellowish black liquid.

Petrol comes from **petroleum**. Petroleum comes from crude oil and is a mixture of many chemicals. Oil refineries separate the petroleum to produce petrol, kerosene, asphalt and compounds used for making plastics and medicines.

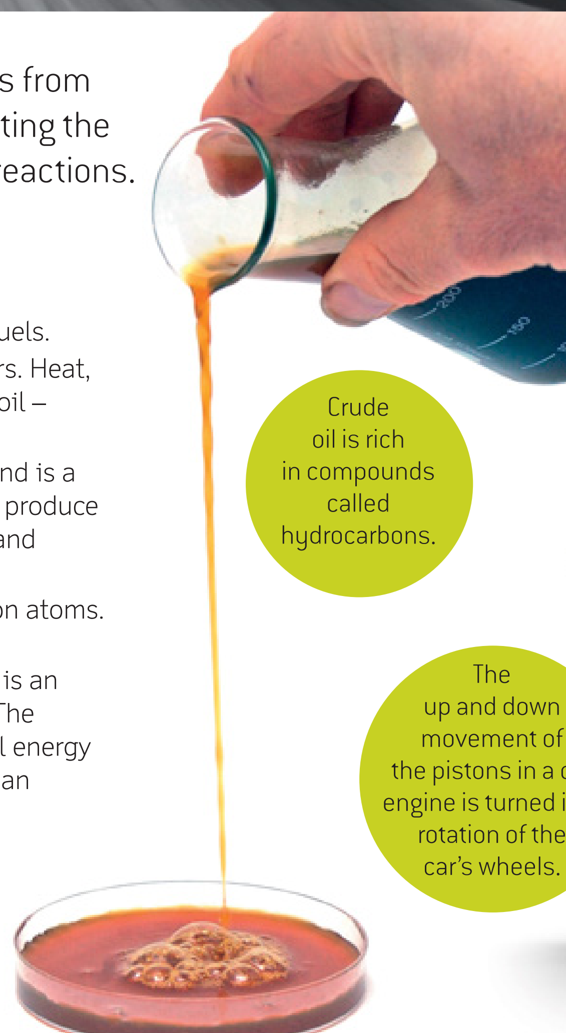
Petrol contains hydrocarbons with between five and twelve carbon atoms. Examples include hexane and octane.

Inside a car engine cylinder, a spark ignites petrol vapour. There is an explosion that pushes down a piston (a cylindrical piece of metal). The reaction produces heat. Inside the combustion engine, the chemical energy from the explosion transforms into the movement of the car. This is an example of energy conversion or transformation.

The word equation for the combustion of octane is:

octane + oxygen → carbon dioxide + water

A fuel-efficient car can travel 25 kilometres from the energy in 1 litre of petrol.



Crude oil is rich in compounds called hydrocarbons.

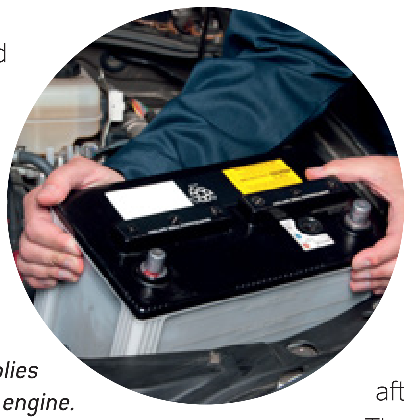
The up and down movement of the pistons in a car engine is turned into rotation of the car's wheels.

Lead acid battery

Most cars have a rechargeable battery. Electricity leaves and enters the battery via the **electrodes.** Car batteries have two electrodes: usually one is made of metallic lead and the other made of lead dioxide. The electrodes are in a sulfuric acid solution.

The lead electrode in a car battery undergoes a chemical reaction. The lead dissolves, releasing electrons. These electrons form the electricity needed to start the car.

When the engine is running, it recharges the battery. A chemical reaction takes place as the engine pushes **electrons** into the lead sulfate, regenerating the lead metal. The battery stores the energy in the charge, ready for use the next time it is needed to start the car.



A car battery supplies power to start the engine.

Air bags

An air bag is an example of chemistry in action. A driver's-side air bag typically contains approximately 50 grams of sodium azide. If a sensor detects a change of movement, such as that in a collision, it creates an electric current. The current causes detonation (explosion) of the sodium azide.

Within just 40 milliseconds (less than one-twentieth of a second), the sodium azide breaks down to produce 60 litres of nitrogen gas. By the time the driver's body hits the air bag, the bag has filled and it is deflating. This means that the bag is soft and does not injure the driver. The bags deflate quickly because they have pores (small holes) and the gas can escape easily.

There are other types of air bags that use different chemicals or produce argon gas rather than nitrogen.

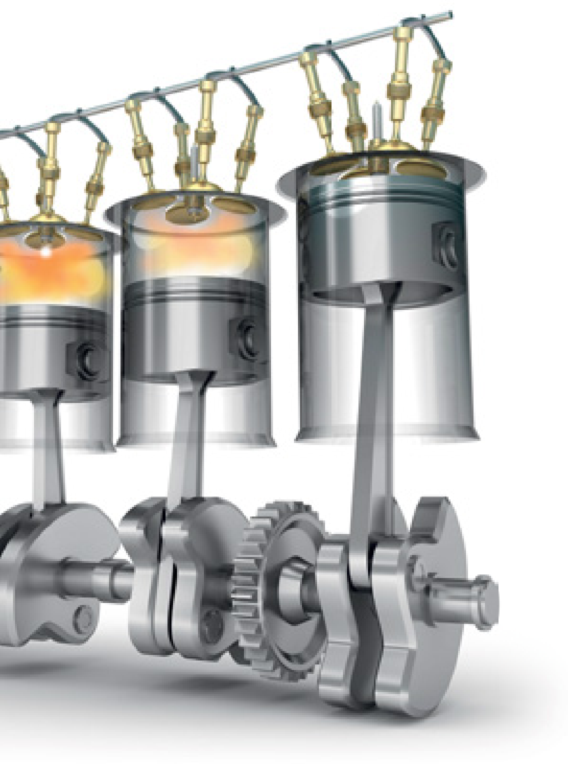
A rapid chemical reaction fills air bags in cars with gas to protect the driver and passengers in a crash.

Rubber tyres

Car tyres are made of rubber. The rubber can be natural or man-made. Natural rubber comes from the sap of a rubber tree. Heating rubber with the element sulfur makes it stronger and more resistant to cuts. It also makes it more elastic, meaning that it returns easily to its normal shape after being stretched or compressed.

The reaction between rubber and sulfur is called vulcanisation. Vulcanisation creates links or bridges between the long rubber molecules. These links help strengthen the rubber.

Chemical reactions strengthen the rubber in car tyres and help it maintain its shape.



LOOK IT UP

electrode a conductor through which electricity enters or leaves an electrolyte

electron a negatively charged particle found in atoms

fossil fuel a fuel such as coal, oil and natural gas that is produced from ancient organisms (mainly plants) that lived millions of years ago

mineral a naturally occurring solid substance with its own chemical composition, structure and properties

petroleum a natural oil that is pumped from the ground; also known as crude oil; a fossil fuel

CHECK IT OUT

1. How is petrol produced and where does it come from?
2. What is a hydrocarbon? Name an example.
3. State the chemical reaction that occurs in air bags.
4. What is vulcanisation?
5. Briefly explain why the four topics discussed on these pages represent chemical rather than physical changes.

EXPLOSIONS

An **explosion** is a sudden, violent change that creates a fast-moving rise in pressure called a blast wave or shock wave. Chemical explosives react rapidly, producing lots of gas.

Gunpowder

Over 1000 years ago, Chinese scientists mixed a mineral called **potassium nitrate** with sulfur and charcoal. They had invented gunpowder. This 'fire drug' became an important part of Chinese celebrations. Stuffing gunpowder into bamboo tubes and then lighting it created sparklers.

Soon, Chinese soldiers began using the explosive power of gunpowder to shoot objects through the air at their enemies.

Igniting gunpowder sets off a very fast chemical reaction that produces a lot of heat and gas. For centuries, gunpowder was the only explosive known. It was used for the military and for mining.

The explosive power of gunpowder comes from the gases nitrogen and carbon dioxide.

Nitroglycerin, dynamite and TNT

The charcoal in gunpowder makes it a messy explosive and it produces lots of smoke when it burns. Scientists in the 1800s discovered explosives that didn't create smoke. **Nitrocellulose** is one example. A German chemist invented nitrocellulose by accident when he spilled a bottle of acid on his kitchen table. He wiped up the acid with a cotton apron. Soon after, the apron exploded! Today, magicians use the product as 'flash paper', which burns brightly and doesn't leave any ash.

An Italian chemist created another explosive, nitroglycerin. It had the problem of sometimes detonating when being touched or moved, which was very dangerous! It was the Swedish chemist and engineer Alfred Nobel who invented the detonator. A detonator creates a small explosion that triggers the explosion of nitroglycerin, allowing the explosive to be more safely controlled.

Alfred Nobel's second important invention was **dynamite**. Dynamite is a mixture of nitroglycerin and other substances such as silica minerals, wood pulp and sodium nitrate. *Dynamis* is a Greek word meaning power. Dynamite is much safer to handle and easier to use than nitroglycerin. There are different strengths of dynamite, created by changing the amount of nitroglycerin.

The inventor of dynamite, Alfred Nobel, was a multimillionaire. He donated money to establish the Nobel Prize. Each year, the prize honours people for outstanding achievements in physics, chemistry, medicine and literature, and for work in peace.

Sticks of dynamite contain the explosive nitroglycerin.

Different metal elements give fireworks their colours. Compounds of the metals release different coloured light when they burn.

TNT is another explosive that was discovered by accident. In 1863, a German chemist was researching dyes. He created one that was yellow, with the chemical name **trinitrotoluene (TNT)**. It was nearly 20 years before scientists realised that TNT was an excellent explosive. TNT was much safer to handle than the explosives that already existed, and it was harder to detonate.

The shock wave from the explosion of TNT can travel at 25 000 kilometres per hour.

The word equation for the explosive reaction of TNT is:

trinitrotoluene (TNT) → nitrogen + carbon monoxide + water + carbon

Today, the mining industry uses modern explosives that are based on different chemicals. They are much safer than TNT and other early explosives.

Fireworks

Fireworks are made of gunpowder or other fuels, as well as binding materials to hold everything together. There is a fuse to ignite the fuel, and an oxidiser and chemicals that produce colours. The word 'pyrotechnics' refers to fireworks, with *pyro* meaning fire.

ELEMENTS	PYROTECHNICS COLOUR
barium	green
calcium	orange
copper	blue
iron or carbon	gold
potassium	pink
rubidium	purple
sodium	yellow
strontium and lithium compounds	deep red
titanium and magnesium compounds	silver or white

LOOK IT UP

dynamite a high explosive made up of a nitroglycerin mixture

explosion a sudden violent change caused by a chemical reaction

trinitrotoluene (TNT) an explosive chemical

CHECK IT OUT

1. Name an element and a compound present in gunpowder.
2. Describe what changes happen when an explosion occurs.
3. List the safety rules you would set in an explosives factory.
4. List five positive ways explosives can be used.

CHEMISTRY AT WORK

People who study chemistry can work directly in this field or they may use the skills they learn to work in other fields of science.

Chemistry career options

Chemists usually complete a university course before starting work. They learn to use a variety of sophisticated equipment. They may perform some of the following activities.

Analysing substances

Analysing substances includes finding out what is in a substance. A food chemist might use special equipment to test vitamins, flavours or minerals to work out how pure they are. An environmental chemist may analyse river water to learn how much lead is present, or check how much smog there is in the air. Chemists might try to find the active compound in a substance found in nature that gives it special properties. For example, the active ingredient in manuka honey is methylglyoxal (MG). MG can be placed on cuts and burns to help reduce inflammation. It is also a natural antibiotic, so it prevents infections.

Testing substances

Chemists measure the physical properties of substances, such as melting points, boiling points, strength and how well they conduct heat and electricity.

Creating new substances

Chemists may make a copy of a substance found in nature or use it to create a new compound. They design new medicines, plastics, paints, perfumes, dyes and electronic parts. They hunt for cheaper, quicker, safer and cleaner ways of making substances. Chemists may control the way in which atoms and molecules act to create new materials, such as membranes, coatings and sensors.

Chemists test and analyse substances, and may also develop materials with valuable properties.

Understanding and predicting chemical behaviour

Chemists test ideas and explanations of how atoms and molecules react. They often use computers and mathematics to study chemical systems and understand how they work. This type of study is called theoretical chemistry.

Chemical engineers develop steps for making chemicals and products, such as medicines, petrochemicals and plastics. They design chemical manufacturing facilities (factories) and decide which steps need to be followed during manufacture. Chemical engineering covers many parts of science, from **nanotechnology** (reactions at almost the level of individual atoms) to processing minerals. Processing minerals such as aluminium and iron includes separating them from the rocks they are found in, by using chemical reactions.

*Chemists use specialised equipment such as this gas **chromatograph**, which separates, analyses and identifies substances present in liquids and gases.*

LOOK IT UP

chromatography a method of separating and analysing mixtures of chemicals

nanotechnology the manipulation of matter on an atomic or molecular level

CHECK IT OUT

1 What work is performed by chemists?

2 Name four activities that chemists may perform.

3 What might be the value of trying to find the active compound in a substance found in nature?

4 Name five substances produced by chemists.

Biochemists study the chemistry of living systems. They develop ways to apply this knowledge in areas such as medicine, veterinary science, agriculture, environmental science and manufacturing.

Ask a scientist

Ms Jenny Powell

Ms Jenny Powell is a chemist tracking levels of air pollution outdoors and in people's homes.

Jenny Powell has a science degree from Monash University in Victoria. She studied chemistry, geography and environmental science before joining CSIRO as a laboratory technician. Today, she is a researcher and is finishing a PhD in chemistry.

Jenny investigates levels of pollutants in the air. Most projects involve a team of researchers. Some take measurements or samples outdoors. Some analyse the samples in laboratories. Other researchers use computer programs to explore and explain their findings.

During a test of air pollution inside people's homes, Jenny and her colleagues measured pollutants such as carbon dioxide, carbon monoxide, nitrogen dioxide and tiny airborne particles. These pollutants come from outdoor sources such as bush fires and the burning of fossil fuels by motor vehicles, industry and power plants. Indoor sources of pollutants include wood heaters, candles, cigarettes, gas stoves and gas heaters.

Jenny's work is important. 'I track how pollution affects people. I feel like I am helping, working through processes and new approaches to better understand air quality', she says.

A video interview with Ms Jenny Powell is available on your obook / assess.

CHEMICAL CHANGE

CHEMICAL AND PHYSICAL CHANGES (PAGES 80–81)

1 What is the difference between physical and chemical changes?

2 In which state of matter (solid, liquid or gas) are mercury atoms held together most strongly?

3 Explain the physical change taking place in the photograph of ice opposite.

4 Copy and complete the table below.

DESCRIPTION	PHYSICAL OR CHEMICAL CHANGE?
Water freezing to form ice	
Baking bread	
Changing colour in autumn leaves	
Melting gold to make gold coins	
Dynamite exploding	
Lighting a match	

5 Using the picture of the candle below to help you, identify each of the following as a physical or a chemical change.

- **a** The solid wax melts.
- **b** Liquid wax evaporates into wax vapour.
- **c** Burning wax vapour reacts with oxygen to create carbon dioxide and water vapour.

CHEMICAL REACTIONS (PAGES 82–83)

6 Methane gas burns in oxygen and forms carbon dioxide and water. Name the reactants and products in this reaction.

7 What does the '+' sign mean in a chemical equation?

8 Give two examples of chemical reactions that happen quickly and two examples of slow chemical reactions.

9 Chemists react 28 kg of nitrogen gas with hydrogen gas to make 34 kg of ammonia. What mass of hydrogen is used in this reaction?

10 Write word equations for the following chemical reactions.

- **a** Iron reacts with copper sulfate to form iron sulfate and copper.
- **b** Sodium reacts with chlorine gas to form sodium chloride.
- **c** Hydrogen and oxygen combine to form water.

HOT REACTION (PAGES 84–85)

11 Describe two ways that you can speed up the rate of a chemical reaction, such as reacting iron with sulfur.

12 Describing the movement of particles, explain why some substances need to be heated before they will react together.

13 What is a melting point?

14 What is a boiling point?

15 When heated, copper carbonate forms copper oxide and carbon dioxide.

- **a** Write a word equation for this reaction.
- **b** Identify the reactant.
- **c** What are the products?

5 AMAZING COMPOUNDS (PAGES 86–87)

16 What is a compound?

17 Look at the coffee opposite.

- **a** List five different compounds found in coffee.
- **b** What special role do ester compounds play?
- **c** Caffeine has the formula $C_8H_{10}N_4O_2$. What information does this formula give you?

KITCHEN CHEMISTRY (PAGES 92–93)

18 Name two products formed from fermentation.

19 What does baking powder do when cooking?

CAR CHEMISTRY (PAGES 94–95)

20 What is petrol?

21 What chemical change happens to petrol in a car engine?

22 What is the source of electricity in a car battery?

EXPLOSIONS (PAGES 96–97)

23 Complete the following word equation.
TNT → ________ + carbon ________ + water + ________

24 How did an exploding apron help in the discovery of explosives?

25 What is an explosion?

26 What produces the different colours in fireworks?

CHEMISTRY AT WORK (PAGES 98–99)

27 Name three common materials in the home that chemists would have helped to produce.

28 Why are computers an important tool in chemistry?

29 What is nanotechnology?

30 Suggest a measurement that an air-quality chemist might take.

KEY IDEAS

1

There are two types of changes: physical and chemical. Physical changes involve changes of state – between solid, liquid and gas forms. Chemical changes lead to the formation of new substances with different properties.

2

Chemical changes happen all around us, in nature, in our bodies and in industry. Without chemical changes, there would be no life on Earth.

3

Chemical reactions involve reactants (e.g. hydrogen gas and oxygen gas) forming products (e.g. water). Reactions can be summarised as word equations like this:

reactants → products

4

Some reactions require a 'kick start', such as heating.

5

The chemical formula of sucrose (sugar) is $C_{12}H_{22}O_{11}$. This formula represents a molecule in which strong bonds hold together 12 carbon atoms, 22 hydrogen atoms and 11 oxygen atoms.

6

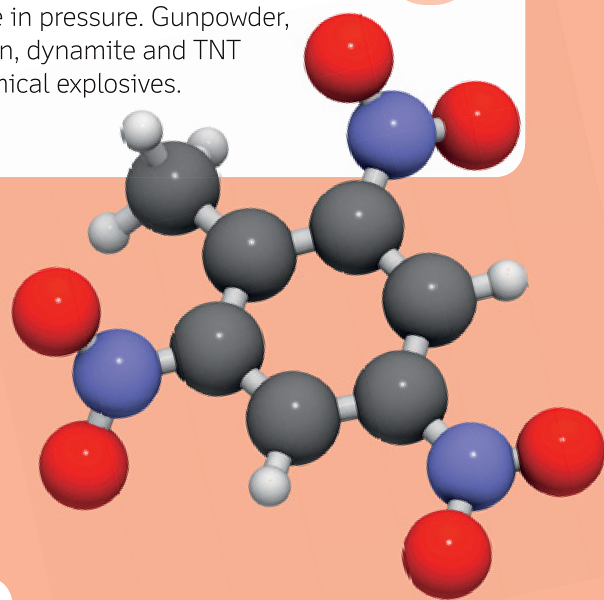
Fermentation is a chemical reaction used for making bread and alcohol. Fermentation produces carbon dioxide gas.

7

Petrol cars rely on a combustion reaction. Hydrocarbons in petrol burn in the engine to produce carbon dioxide gas. The gas moves a piston, which makes the car wheels turn.

8

An explosion is a sudden, violent change that produces lots of gas and a fast-moving rise in pressure. Gunpowder, nitroglycerin, dynamite and TNT are all chemical explosives.



9

The different colours of fireworks come from compounds of metals such as lithium, copper and calcium. Each metal makes its compound burn with a unique colour.

10

Chemists test and analyse substances, and develop materials with valuable properties.

ROCKS AND MINERALS 05

5 AMAZING ROCK RECORDS

Where is the **world's deepest hole?**

WHAT'S AT THE **EARTH'S CORE?**

HOW CAN ROCKS FLOAT?

ROCKS IN YOUR COMPUTER

HISTORY IN OUR ROCKS

THE EARTH'S ROCKS

The Earth has been a rocky planet since its formation. It started as very hot dust and gas surrounding the newly formed Sun. It then gathered in rocky clumps due to **gravity**. Eventually, the clumps became a ball of molten (melted) material. Then, slowly, the outer layers cooled to form the rocky planet we call Earth. Other rocky planets, moons and asteroids also formed.

Planet Earth formed 4.5 billion years ago (that's 4500 million years ago).

Core to crust

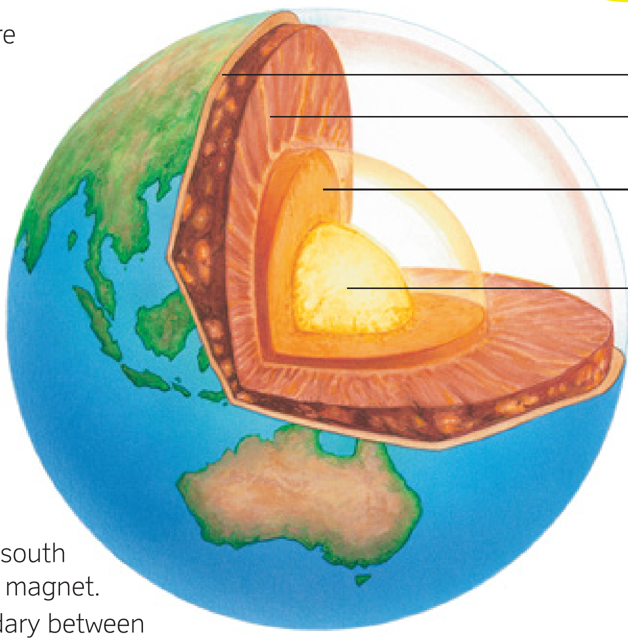
The name Earth means 'ground'. Below the ground are several layers that extend deep inside the Earth.

Core

At the Earth's centre is a 1200-kilometre-wide inner core. The inner core consists mostly of iron (which is metal, not rock). Although it is more than 5000°C (about as hot as the Sun's surface), the solid metal ball does not melt because it is under huge pressure from the weight of the rest of the Earth around it.

Around the inner core is a 2300-kilometre-wide liquid outer core. The outer core consists mostly of the metals iron and nickel, and has a temperature of more than 4000°C. The Earth's **magnetic field** is caused by the liquid metal outer core. The north and south magnetic poles are at the opposite ends of this giant magnet.

Nobody has ever seen the Earth's core. The boundary between the inner and outer core is about 5000 kilometres beneath the ground. Scientists discovered the inner structure of the Earth by studying how shockwaves (seismic waves created by earthquakes) behave when they travel through the Earth's layers.



The internal structure of the Earth is made up of four layers: the inner core, the outer core, the mantle and the crust.

Rocks can be different in how they look and feel.

Mantle

Above the core is a 2900-kilometre-thick layer of rock called the **mantle**. The mantle makes up about 84 per cent of the Earth's volume.

The rock in this layer varies from clay-like, semi-solid rock to soft molten (melted) material. The upper mantle starts between 7 and 35 kilometres below ground and stretches down to about 410 kilometres below ground. Like hot air, heated rock rises and cooler parts sink in this region of the mantle. This movement can contribute to earthquakes and volcanoes.

Crust

Like the crust of a loaf of bread, the Earth's crust is a thin, hard and brittle outer layer. It makes up less than 1 per cent of the Earth's volume.

The crust is between 10 and 75 kilometres thick beneath continents. About 70 per cent of the crust is covered by ocean, beneath which the crust is between 5 and 10 kilometres thick.

Nobody has managed to drill beneath the Earth's crust into the mantle. The deepest mines penetrate less than 4 kilometres below ground. The deepest holes drilled beneath the ocean floor, where the crust is thinner, are 1.5–2 kilometres, still a few kilometres away from the mantle.

Rocks, minerals and crystals

Minerals are the basic building blocks of rocks. Rocks differ in their look and feel because they are made up of different combinations of minerals. Scientists have identified more than 4000 different minerals. A rock is made up of one or more of these.

At an even smaller scale, minerals are made up of crystals. A crystal is a solid substance with its **atoms** organised in a regular pattern with flat surfaces. The structure of a crystal influences a mineral's properties. For example, the minerals called graphite and diamond are both made of pure **carbon** but they have their atoms arranged differently. Graphite has its atoms arranged in a way that means the mineral is soft. Graphite is used in grey lead pencils. Diamond is one of the hardest minerals on Earth.

Diamonds and the graphite in pencils are both made of pure carbon.

LOOK IT UP

atom the smallest particle of a substance that can exist

carbon a non-metallic element occurring in a pure form as graphite and diamond; is in all organic compounds

gravity the force of attraction that objects have towards one another due to their masses

magnetic field the region around a magnetic material or a moving electric charge within which the force of magnetism acts

mantle the 2900-km-thick layer of the Earth that lies beneath the crust

mineral a naturally occurring solid substance with its own chemical composition, structure and properties

CHECK IT OUT

1. Is the Earth's core solid, liquid or gas?
2. Where is the crust thinnest: beneath the land or beneath the ocean?
3. Consider the following layers of the Earth: core, mantle and crust.
   - a Arrange these layers in order of thickness.
   - b Arrange these layers in order of temperature.
4. Which layer beneath the ground causes the Earth's magnetic field, and why?
5. True or false?
   - a Rocks contain minerals.
   - b Crystals contain minerals.
   - c Minerals contain rocks.
   - d Minerals contain crystals.

IGNEOUS ROCK

There are hundreds of different kinds of rocks on the Earth, but they all can be classified into three main groups: igneous, sedimentary and metamorphic rocks. Rocks form in different ways, which causes them to have a different look, feel and composition. **Igneous rocks** are the most common on Earth.

Igneous rock is a type of rock that has formed from **lava**. The word igneous comes from the Latin word *igneus*, which means 'of fire'.

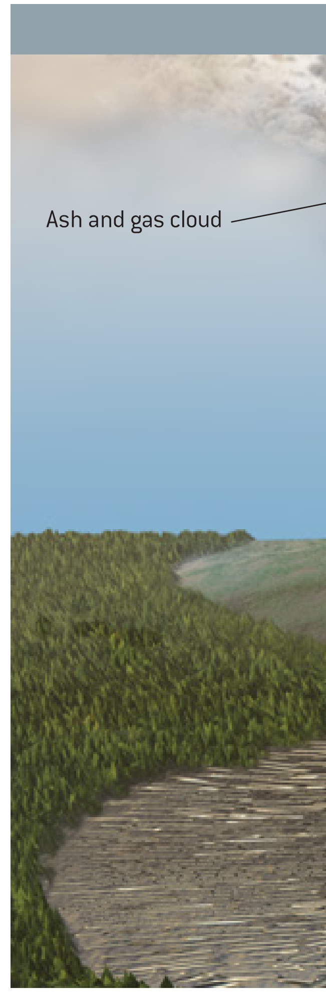
When a volcano erupts, melted rock spews to the surface as lava. The red-hot lava cools quickly on the surface of the Earth and solidifies into rock. These are called **extrusive igneous rocks**. Basalt is a common type of extrusive igneous rock. Igneous rock can also form beneath the Earth's surface. This happens when **magma** (molten rock) cools and solidifies over millions of years, before being pushed to the surface or being uncovered by erosion. These are called **intrusive igneous rocks**. Granite is a common type of intrusive igneous rock.

Igneous rocks are the most common type of rock, making up almost two-thirds of the Earth's crust. Geologists have discovered more than 700 types of igneous rock.

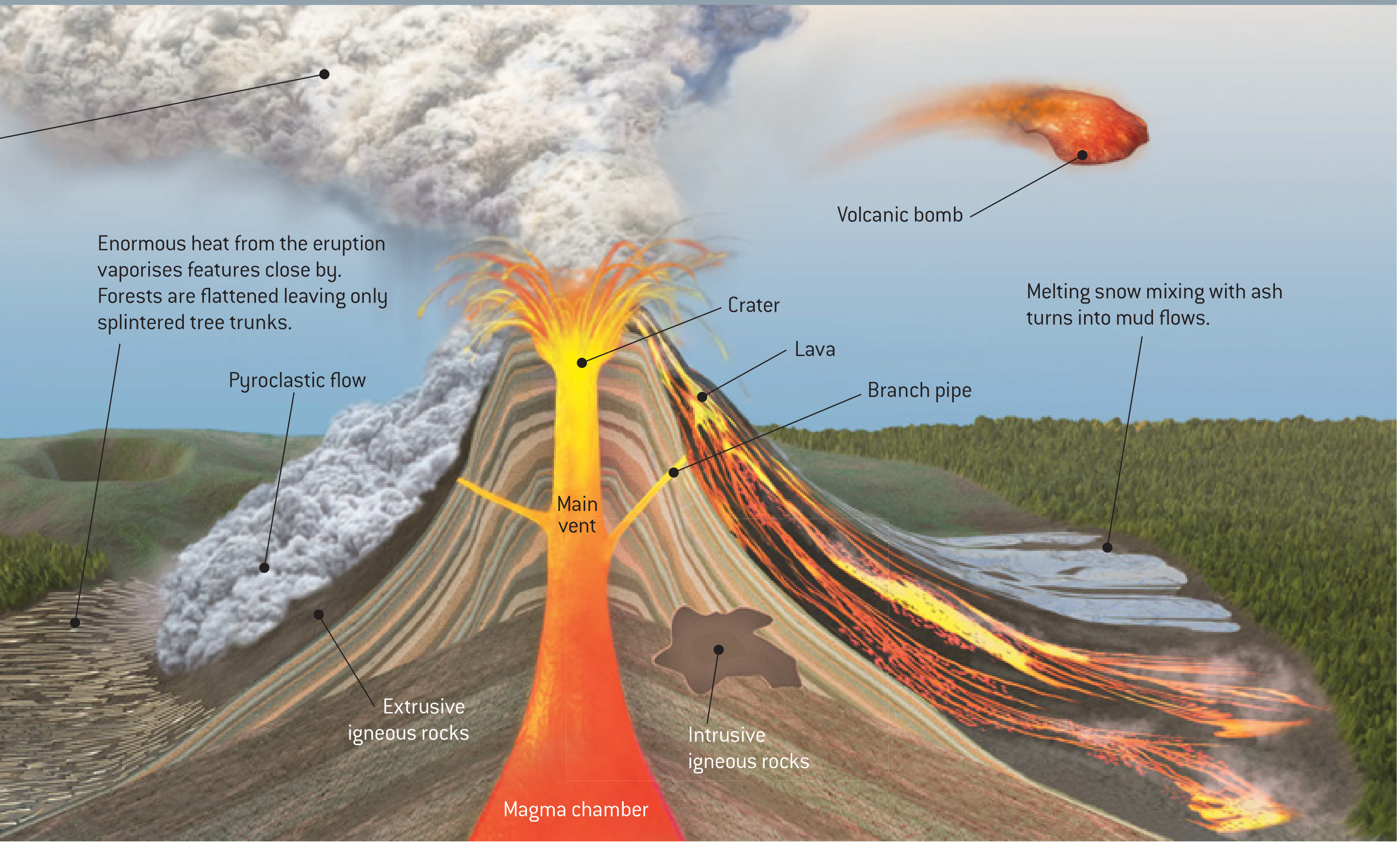
Cradle Mountain in Tasmania is composed of delorite, an intrusive igneous rock. The rock has been exposed after the surface material has eroded away.

Basalt is the most common type of extrusive igneous rock. Large crystals don't form in basalt because the lava cools so quickly.

Granite is an intrusive igneous rock. These very hard rocks are good for use in building, such as kitchen benchtops.



CROSS-SECTION OF A VOLCANIC ERUPTION



LOOK IT UP

extrusive igneous rock rock formed when lava from a volcanic eruption cools quickly on the Earth's surface

igneous rock a type of rock formed from lava on the surface or magma beneath the ground

intrusive igneous rock rock formed when magma cools and solidifies slowly beneath the Earth's surface

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 List the three main types of rock.

2 How are igneous rocks formed?

3 Which igneous rocks form on the surface of the Earth and why are they different to those that form under the Earth?

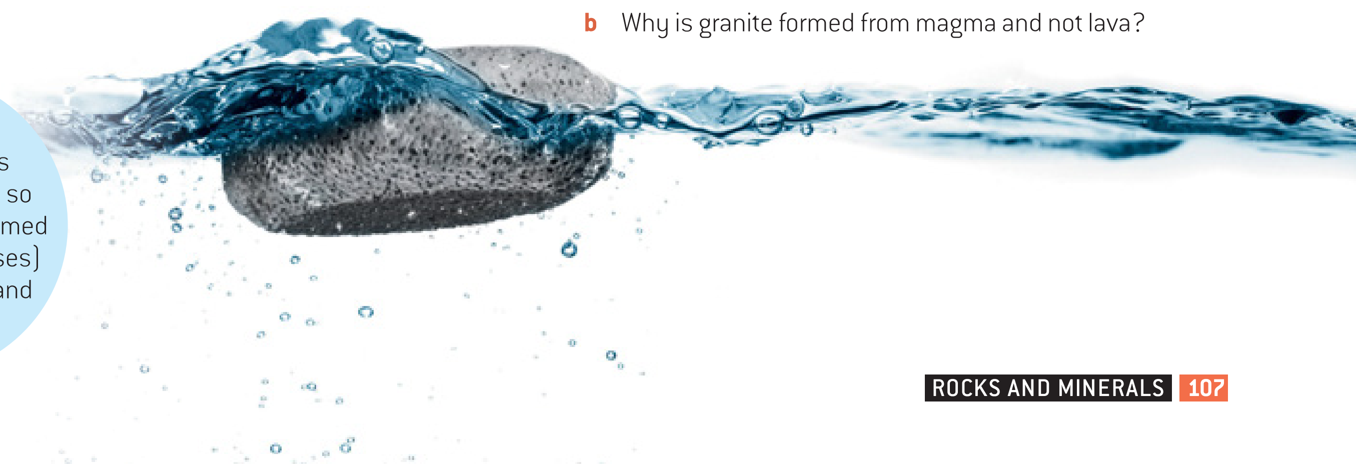
4 How does magma escape onto the Earth's surface?

5 Pumice forms when gas-filled lava cools very quickly. How does it get its holes and what special properties does it have?

6 Look at the photograph of granite opposite.

   a What special properties does granite have that makes it useful?

   b Why is granite formed from magma and not lava?



Pumice is an extrusive igneous rock. It is filled with so many tiny holes (formed by escaping hot gases) that it is very light and floats on water.

The Wave is a sedimentary rock formation located near the Arizona–Utah border in the United States of America. You can clearly see the layers in the sandstone that have been compressed together and eroded over time.

SEDIMENTARY ROCK

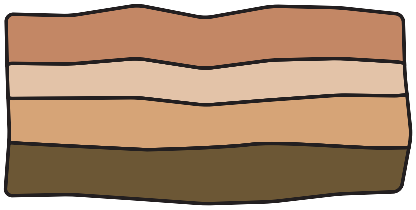
***Conglomerate** is sedimentary rock made up of rounded pebbles of different sizes that have been cemented together. The sediments were deposited by fast-flowing rivers that could transport larger pebbles.*

Sedimentary rock is formed when **sediments** are deposited in layers, such as on a riverbed or the ocean floor. This can take thousands or millions of years. The weight of the overlying rock can cause the formation of hard rock.

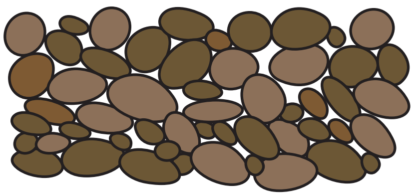
Sedimentary rock forms when particles of eroded rocks are compressed over a long time. The name refers to the particles, or sediments, that make up the rock.

The sediments that make up sedimentary rock form when weather erodes the landscape. Water and wind carry these sediments before dropping (depositing) them in a layer such as a riverbed or the seafloor. A layer of sediments builds up as more particles are deposited over thousands or millions of years. If the conditions are right, the layer can become buried and then pressed together by the weight of rock above it, and cemented by water to form hard rock.

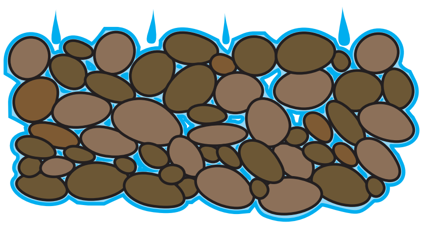
Sedimentary rocks can also form when water evaporates and leaves behind a solid substance, such as salt to form rock salt, or calcium carbonate to form limestone.



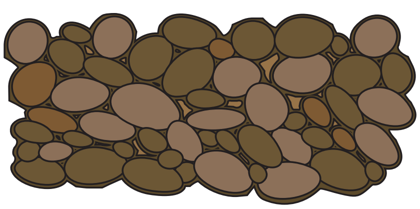
Sediments are deposited in layers.



The grains of sediment in lower layers begin to squash together.



Chemicals that are dissolved in the water can soak into the sediments.



The chemicals help cement the grains together once the water has evaporated.

***Fossils**, the imprints of plants and animals, can sometimes be found in sedimentary rocks. We have learnt about ancient life through the discovery of fossils. The layer they are found in can help reveal how old the fossil might be.*

Biological rocks

Sedimentary rocks are sometimes formed from the remains of plants, animals and other living things. For example, shells and hard parts of sea organisms break down and are deposited in layers on the ocean floor. Eventually they cement together under pressure to form limestone.

Coal is a sedimentary rock formed from dead plants that were buried before they completely decayed. Pressure from the layers above can change the plant material into coal.

Coal is a sedimentary rock formed from the remains of plants under pressure.

LOOK IT UP

conglomerate sedimentary rock made up of rounded pebbles of different sizes that have been cemented together

fossil the imprints of an animal, plant, bacteria or other living organism preserved in rock

sediment particles of rock eroded from the landscape, and then transported and deposited by water and wind

sedimentary rock rock formed when layers of particles (sediments) are pressed together by the weight of the overlying rock, or when water evaporates to leave behind a solid substance

CHECK IT OUT

1. Look at the picture of The Wave on the opposite page.
   - a What type of sedimentary rock is The Wave?
   - b Why did it form in layers?
   - c How did it eventually become a sedimentary rock?
2. What is a fossil?
3. How do you think fossils become preserved in sedimentary rocks?
4. Give two examples of sedimentary rocks that have formed from living things.

METAMORPHIC ROCK

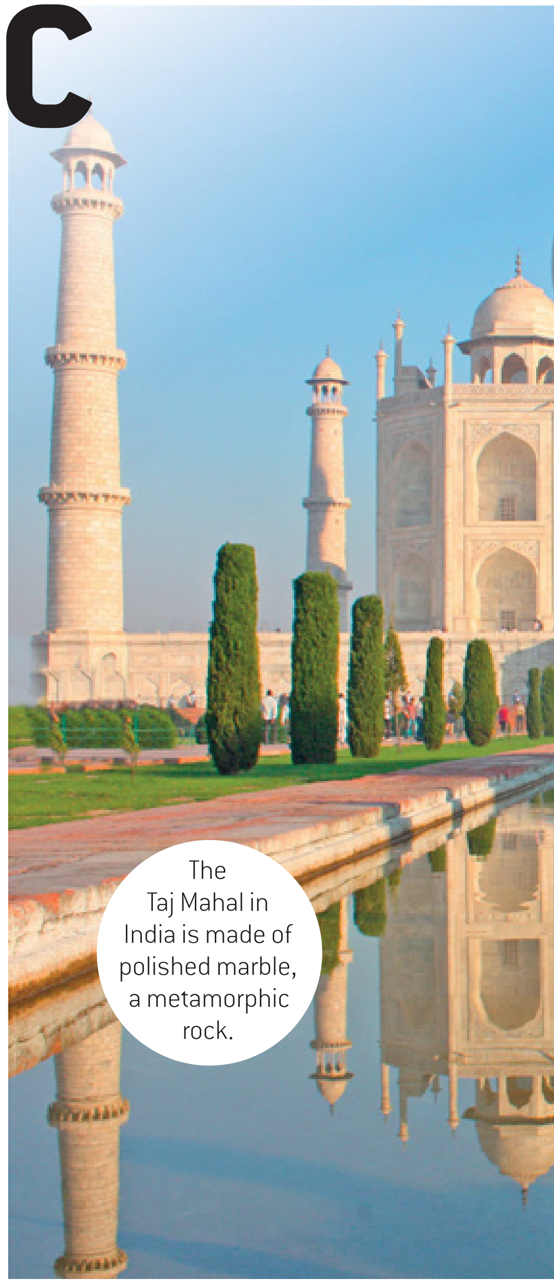
Metamorphic rock is formed when igneous, sedimentary or older metamorphic rocks are changed by intense heat and pressure inside the Earth.

Rocks can be changed from one type into another over millions of years. Metamorphic rock forms when igneous, sedimentary or older metamorphic rocks are heated or squeezed (or both). This can cause them to change into a new type of rock. The name refers to the metamorphosis (meaning 'change in form') of the rock.

The high temperatures and pressure needed to change rocks occur only beneath the Earth's surface. The temperature increases by around 25 degrees Celsius for each kilometre below the Earth's crust.

The intense heat and pressure change the rocks into ones with different physical and chemical **properties**. For example, shale (a sedimentary rock) can be changed under heat and pressure into slate. Slate is stronger than shale and does not absorb water. These properties make slate ideal for floor and roof tiles.

Metamorphic rocks are stronger than the rocks they were formed from because the intense pressure and temperature fuse the particles together.



The Taj Mahal in India is made of polished marble, a metamorphic rock.

granite (igneous rock)

When granite is subjected to high heat or pressure, it can change into the metamorphic rock known as gneiss.

gneiss (metamorphic rock)

limestone (sedimentary rock)

Marble is formed when limestone is placed under extreme temperature and pressure.

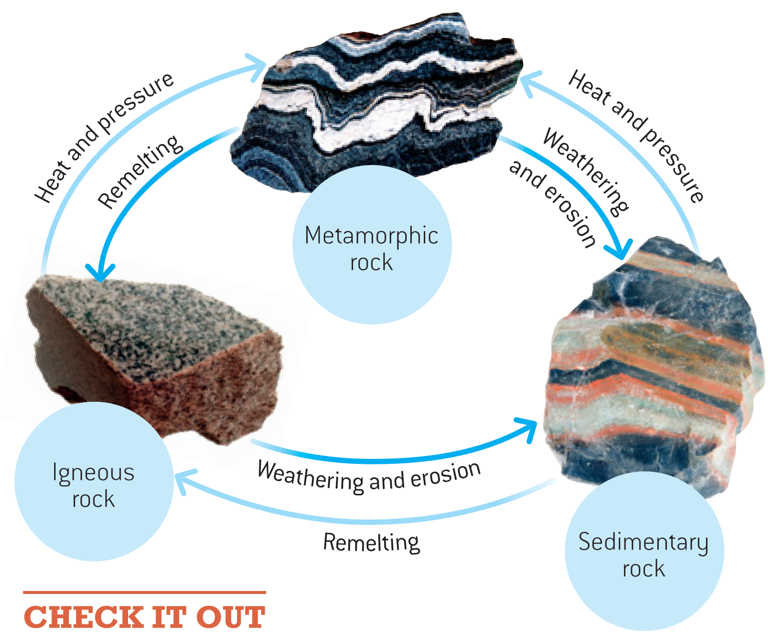
marble (metamorphic rock)

The rock cycle

Rocks in the landscape around us do not seem to change over our human lifetime, but they are always changing. Our lives are very short compared to the history of rocks on Earth. Over millions of years, rocks change from one type into another and back again in an ongoing cycle.

The minerals that form rocks are always being recycled by the Earth. James Hutton, who is considered by many as the founder of geology, came up with the idea of the **rock cycle** in the 1700s. The cycle is driven mainly by **erosion** above ground, and heat and pressure below ground.

For example, magma can erupt from a volcano and cool to form igneous rocks. These rocks can be broken down into particles by the weather, and later deposited and then pressed together to form sedimentary rocks. The sedimentary rocks can be buried deep in the Earth and subjected to intense forces to form metamorphic rocks. These metamorphic rocks can be melted beneath the Earth's surface to form magma. The magma can erupt and then cool to form igneous rocks, beginning the cycle again. This example is just one of the many pathways that rocks can take around the rock cycle.



LOOK IT UP

erosion the carrying away (by water, wind etc.) of particles of the Earth's surface that have been worn away by weathering

metamorphic rock a type of rock formed when igneous, sedimentary or older metamorphic rocks are heated or squeezed

property a characteristic, quality or feature that distinguishes something from other things, e.g. the properties (characteristics) of a mineral

rock cycle a concept explaining how the three rock types (igneous, metamorphic and sedimentary) are related to each other and how they change from one type to another over time

CHECK IT OUT

1. Into which three groups are rocks classified?
2. What two things can cause rocks to change form and become metamorphic rocks?
3. Describe the differences between:
   - a gneiss and granite
   - b marble and limestone.
4. Which properties of slate make it an ideal material for flooring and roofing?
5. Look at the diagram of the rock cycle.
   - a How do igneous rocks become metamorphic rocks?
   - b How do metamorphic rocks become igneous rocks?

EXPERIMENT #13

MAKING ROCKS

AIM: TO MAKE SMALL SAMPLES OF SEDIMENTARY AND METAMORPHIC ROCKS AND COMPARE THEM WITH REAL SAMPLES

MATERIALS

- Dry clay
- Dry sand
- Small, smooth pebbles
- Plaster of Paris
- Mortar and pestle
- Teaspoon
- 4 empty matchboxes
- White tile
- Marker pen

SAFETY

When 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 any hot samples 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

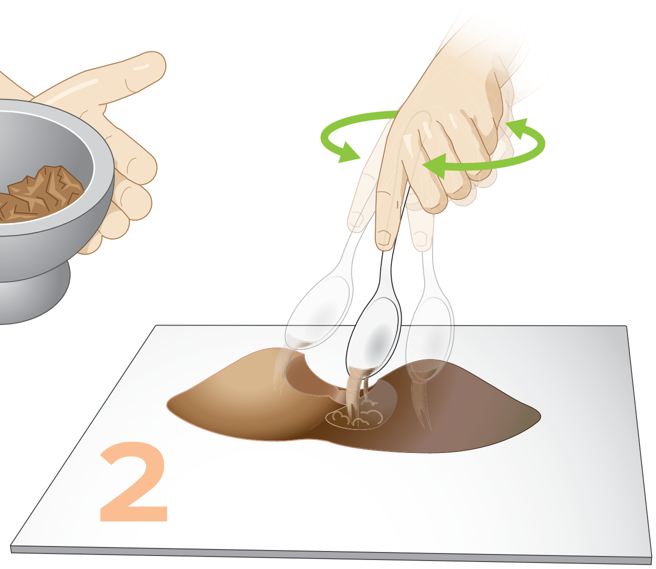
Rock recipes

ROCK	DRY CLAY (teaspoons)	SAND (teaspoons)	PLASTER OF PARIS (teaspoons)	PEBBLES (teaspoons)	WATER (teaspoons)
Sandstone	½	4	½	0	2
Shale	5	½	0	0	2
Conglomerate	½	1	½	4	2

PART A

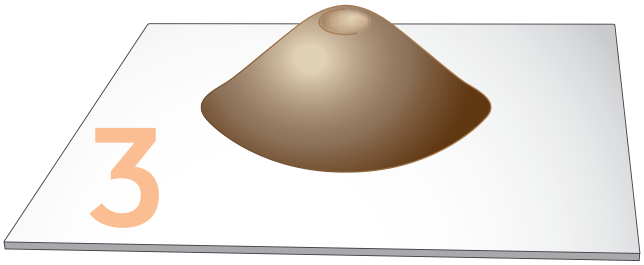
1 Grind a lump of dry clay with the mortar and pestle until it is fine and powdery.

2 On the white tile, use the teaspoon to mix the dry ingredients for a sample of sandstone according to the rock recipe in the table, but don't add the water yet. Repeat for shale and conglomerate. Prepare two shale samples for use in Part B. You should have four separate dry samples on the tile.



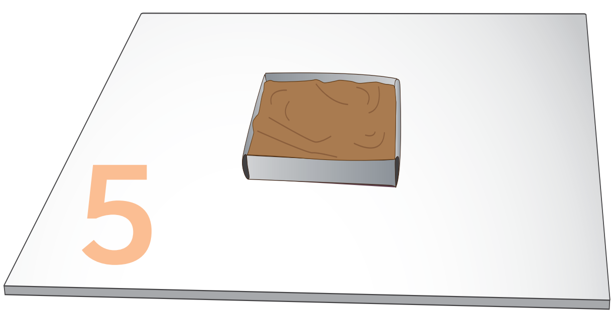
Shale (or mudstone) is the most common sedimentary rock. Shale is a fine-grained sedimentary rock made up of clay minerals or mud.

3 For each sample, pile up your ingredients into a small hill. Make a small dip in the centre for the water.



4 Slowly add the water and stir until the ingredients are evenly mixed. Be careful not to make the mixture too wet.

5 Press your mixture into an empty matchbox, and label it with the rock type and your name.



6 Leave the rock samples to dry for two days.

7 When your rock sample is dry, peel off the matchbox and examine your sample. Take digital photos of your samples and find photos of real rocks online for comparison.

PART B

MATERIALS

- Bunsen burner
- Tripod
- Pipe clay triangle
- Gauze mat
- Evaporating dish
- Tongs
- 2 beakers (250 mL)
- Water

1 Allow your two shale samples to dry for approximately a week.

2 Place one of the shale samples on a pipe clay triangle on top of a gauze mat. Place the evaporating dish upside down over the shale (so it will retain more heat). Heat over a blue Bunsen burner flame for about 30 minutes.

3 After about 30 minutes of heating, carefully pick up the shale sample using the tongs and drop it into a beaker of water. Observe what happens to the rock sample.

4 Drop the second, unheated shale sample into another beaker of water. Observe what happens to the rock sample.

RESULTS

Record your observations in a table. Include images of your rocks. Make statements about the process or products.

DISCUSSION

1 How do your sedimentary rock samples compare with real rocks?

2 What were the differences between your samples and the real rocks?

3 What differences do you notice about the two shale rock samples when they are dropped into the water?

4 Considering Part B of the experiment, can strong heat change the properties of rocks over time?

5 How different was your new metamorphic rock sample from the original shale sample? Was the method successful?

CONCLUSION

What have you discovered about sedimentary rocks and the formation of metamorphic rocks?

USING ROCKS TO BUILD

The hardness, long life and weatherproof nature of stone and rock make them important materials for building. Buildings from around the world have been made of igneous, sedimentary and metamorphic rock.

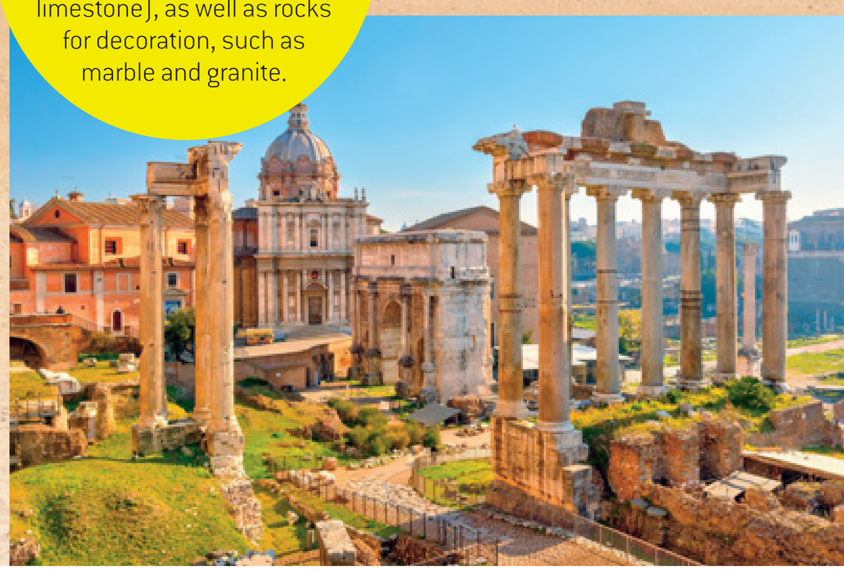
The ancient Egyptians used stone, such as granite and limestone, to build huge pyramids. They built more than 100 pyramids to use as burial tombs for their kings.

Houses of rock

Houses are often built with bricks made of clay and **shale**, the most common sedimentary rock on Earth. To increase strength, the material is shaped into a block and heated at very high temperatures in a kiln.

Buildings can be made from igneous, sedimentary or metamorphic rock. The pylons of the Sydney Harbour Bridge are made from **granite**, an igneous rock. Many early colonial buildings in Sydney, such as the Art Gallery of New South Wales, are made of **sandstone**, a sedimentary rock. Many ancient Roman buildings were made using travertine, a type of limestone common in Rome. Travertine is a sedimentary rock. **Marble**, a metamorphic rock, was a popular building material for ornate buildings such as the Leaning Tower of Pisa in Italy. The Taj Mahal in India was built using marble and other precious stones.

The buildings of the Forum in ancient Rome, Italy, were built from common local rocks, including tufa (a porous volcanic rock) and travertine (a type of limestone), as well as rocks for decoration, such as marble and granite.



Grab the nearest rock

Often, the type of rock found locally determines the type of rock used in the buildings of that area.

The Inca people built the city of Machu Picchu in Peru, South America, in the mid-1400s from local rocks such as granite. The granite rock quarry is still there today in the ruins of the city. They used **dry-stone wall** techniques, building homes without mortar or anything to stick the stone bricks together. This construction technique involves fitting rocks together like a jigsaw puzzle.

The Gunditjmara in western Victoria built fish traps, windbreaks and stone huts using the rock from ancient volcanic lava flows. In the 1800s, European settlers farmed the same land after clearing the ground of the volcanic stones and used them to build dry stone walls.

LOOK IT UP

dry-stone wall a wall constructed by fitting rocks together without anything to stick them together

granite a common, hard igneous rock

marble a hard form of limestone, often used in sculpture and buildings

sandstone a sedimentary rock consisting of sand or quartz grains cemented together

shale a common sedimentary rock

CHECK IT OUT

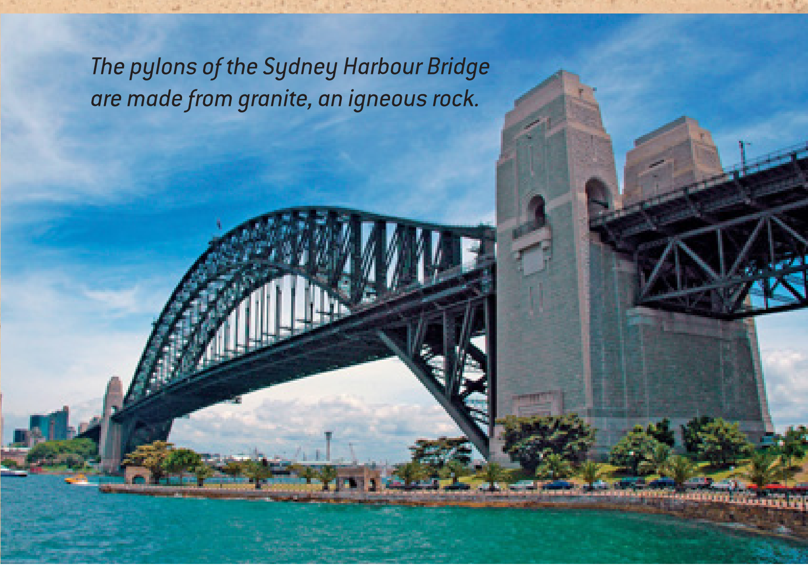
1 Match each of the following building materials with the type of rock (igneous, sedimentary or metamorphic):
   - a marble
   - b clay
   - c granite
   - d sandstone.

2 List three properties of rock that make it an ideal building material.

3 Name one rock used in the construction of the pyramids and identify the main rock group (igneous, sedimentary or metamorphic) to which it belongs.

4 Name a building made of:
   - a marble
   - b limestone
   - c sandstone.

5 Imagine you live in an area that has many small basalt rocks on the surface, crumbling limestone cliffs nearby and granite dug in large blocks from beneath the ground. Describe how you would collect local building materials, and what type of home you would build.



The pylons of the Sydney Harbour Bridge are made from granite, an igneous rock.

People built the city of Machu Picchu by fitting together local stones like a giant puzzle.

PROPERTIES OF ROCKS

Rocks have different characteristics or properties, making them look and feel different. Within each of the three main types of rocks (igneous, sedimentary and metamorphic) there are many types of rocks that are identified by what minerals they are made of and how they look and feel.

Properties of minerals

By looking closely at a rock's properties you might be able to tell how a rock formed, where it came from and what has happened to it. You can also decide from its properties what it could be used for. For example, granite is a very hard type of igneous rock. It does not change when heated, is not damaged by chemicals, does not absorb liquid and comes in large pieces. These properties make it suitable for use in construction, for example as hard floors in buildings and as kitchen benches.

COLOUR

Sulfur (yellow)

Labradorite (blue)

Rhodochrosite (pink)

Fluorite (purple)

LUSTRE

Pyrite (metallic)

Turquoise (waxy)

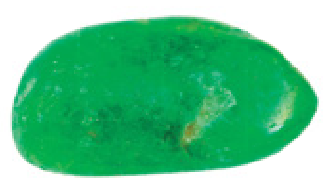
Amber (resinous)

Kaolinite (dull)

TRANSPARENCY

Quartz (transparent)

Moonstone (semi-transparent)



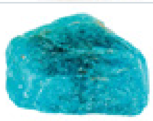
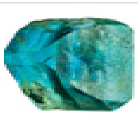
Chrysoprase (translucent)

Malachite (opaque)

Friedrich Mohs, a German scientist, developed a scale in the early 1800s that described hardness.

Talc is the softest mineral as it can be scratched by all others, and has a Mohs scale rating of 1.

Diamond is the hardest as it cannot be scratched by other minerals, and has a hardness of 10.

HARDNESS		
1	Talc	
2	Gypsum	
3	Calcite	
4	Fluorite	
5	Apatite	
6	Orthoclase	
7	Quartz	
8	Topaz	
9	Corundum	
10	Diamond	

Classifying rocks

The first step in identifying a type of rock is to see how it looks. This involves observing a range of visible characteristics of the rock and of the minerals it contains.

» Colour – often the first thing noticed about a rock. Many rocks have minerals in them that affect the colour. For example, pure quartz is colourless and transparent (like glass), but impurities can make it purple, pink, yellow or other colours. Coal is usually black, but can be dark brown. Streak is the term given to the true colour of a mineral when crushed into a powder and other minerals do not affect it.

» **Lustre** – the shininess of a mineral's surface, which depends on how much light its surface reflects. A shiny mineral can appear metallic like a coin, brilliant like a mirror, or pearly like a clean fingernail. A non-shiny mineral can appear dull or earthy.

» **Transparency** – how much light can pass through the mineral. If light can pass right through, the mineral is transparent. If only some of the light shines through, it is translucent. If no light can shine through, it is opaque.

LOOK IT UP

cleavage the way in which a rock splits when hit

composition what something is made of, e.g. a rock's composition includes its crystal structure and crystal size

hardness a measure of the resistance of a mineral to being scratched

lustre a measure of the gloss or brilliance of reflection of light from a mineral's surface

transparency a measure of how much light can pass through a material, such as a mineral

» **Composition** – what it is made of. This includes the crystal structure and size of the grains, which can be observed through a microscope to help classify the mineral type.

» **Hardness** – how easily a mineral can be scratched. If one mineral scratches another, the rock that is scratched is softer than the other.

» **Cleavage** – how rocks cleave (break) along smooth lines when they are hit. One measure is how easily a rock cleaves when hit. Another measure is the shape or direction of the cleave. For example, mica cleaves into flat layers, which is called basal cleavage. Diamond cleaves into an eight-faced shape, which is called octahedral cleavage.

» Other properties include fluorescence (how it emits light), density, magnetism, and even smell and taste.

CHECK IT OUT

1 Name three visible characteristics used to identify mineral type.

2 Which of the following properties is not a physical characteristic? density, cleavage, lustre, hardness

3 Fill in the gaps. If light can pass right through a mineral, it is ________; if only some of the light shines through, it is ________; and if no light can shine through, it is ________.

4 Explain which properties of granite make it suitable for use as a kitchen bench.

5 The mineral fluorite has a hardness of 4 on the Mohs scale, and calcite has a hardness of 3. Explain which minerals would be scratched when you rub the following pairs together: fluorite/talc; fluorite/calcite; fluorite/diamond; calcite/diamond; talc/diamond; talc/calcite.

MINING MINERALS

Diamonds, gold, silver and other **minerals** are highly valuable due to how rare they are and their perceived beauty. Other minerals, such as coal and copper, are valuable because they are used by many people for lots of purposes. Mineral ores contain metals and other materials that are used around the world.

An **ore** (left column) is a mineral containing a large amount of metal or other valuable substances (right column).

Mineral resources

Copper was the first metal ever used, other than gold. Thousands of years ago, early civilisations used copper in jewellery and statues, as the heads of weapons and tools such as axes, and in medical instruments. Today, copper is used in electrical products because it is a good conductor of electricity. It is also used for water pipes because it doesn't easily corrode.

Other important mineral resources include:

» aluminium (in cars, buildings and packaging)
» iron ore (to make steel, magnets and pigments)
» lead (in batteries, electronics, protective coatings and radiation shields)
» quartz or silica (in glass and precision instruments such as watches)
» rare-earth elements (in batteries and electronics)
» silver (in coins and jewellery, electronics and silverware)
» titanium (in jet engines and sporting goods)
» uranium (for nuclear power, medicine and atomic dating)
» zinc (as a protective coating, and in sunscreen, roof guttering and batteries).

ORE	METAL
Malachite, azurite, chalcopyrite	Copper
Haematite, limonite	Iron
Bauxite	Aluminium
Galena	Lead
Rutile	Titanium
Pitchblende	Uranium
Molybdenite	Molybdenum
Cinnabar	Mercury
Sphalerite	Zinc
Pentlandite	Nickel
Cassiterite	Tin

Mineral resources including aluminium and iron ore (to make steel) are used to make cars.

Zinc, which is used in sunscreen, comes from an ore called sphalerite.

The minerals in the ground are limited, so we need to reuse materials such as aluminium and other metals by recycling. Recycling can also supply materials more cheaply. Recycling uses less energy and causes less environmental damage than mining for minerals.

Gold and gems

Gemstones such as diamonds, jade, opals and rubies are used in jewellery and decorations. They are also called jewels, precious stones or gems. Their use depends on their colour, markings, mineral content, beauty, value and rarity. They tend to be colourful, translucent and very hard. Most gemstones are cut and polished before being used.

Precious metals include gold, silver and platinum. Gold was once used as money in many countries. It is now used in jewellery due to its bright colour, shininess and its high resistance to being corroded or tarnished by air and water.

Some minerals occur in the ground as crystals and can be simply separated from the rock in which they are found, such as gold, platinum, and sometimes copper and silver. Some materials need to be processed using heat, chemicals or electricity to separate them from the rock. This is the case with aluminium from bauxite. Aluminium was once a precious metal because it was difficult to extract (take out) of rocks, but once smelting (separating minerals by heating) was invented its price decreased.

An opal gemstone set in a silver ring. Precious metals and stones are important in the jewellery industry.

LOOK IT UP

mineral a naturally occurring solid substance with its own chemical composition, structure and properties

ore a mineral containing a large amount of metal or other valuable substance

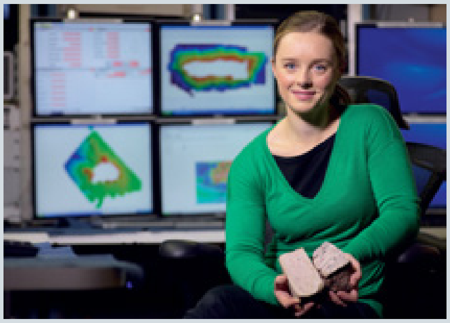
CHECK IT OUT

1. Name three mineral resources and suggest a use for each.
2. What properties of gold make it a valuable and useful mineral?
3. In what way is gold easier to mine that aluminium?
4. Which two precious minerals have been used to make the ring above?
5. From which ore did sunscreen originate?

Gold is chemically stable, so it can be collected from the ground without having to be smelted or treated. This gold mine in Kalgoorlie, Western Australia, is the biggest open-pit gold mine in Australia. It produces up to 24 000 kilograms of gold every year.

Ask a scientist

Dr Jo Whittaker



Dr Jo Whittaker's geology research helps us learn how the Earth's geography and climate have evolved over millions of years. This helps us understand how it may change in future.

Jo Whittaker's research into rocks beneath the ocean helps identify new locations where we might find natural resources such as oil and gas.

Her geology research also helps us learn how the Earth's geography and climate have evolved over the past 200 million years. This helps us understand how it may change in future and improves our ability to simulate ancient climates using computer models.

Jo attended the University of Sydney and earned a double degree in geology and economics. After earning a Masters of Geophysics in New Zealand, she completed a PhD in Geophysics in Sydney.

Her work these days at the University of Tasmania is on plate tectonics – the slow movement of the Earth's upper layers. She says that many natural resources form on the continental margin, which is the submerged shelf and slope that make up the outer edge of a continent. Therefore the oil and gas industry needs to know where the continents once were, and how the margins have evolved over millions of years.

Jo says she likes to solve jigsaw puzzles, which is lucky because understanding how the continents formed is one of the biggest puzzles on the planet.

o a

A video interview with Dr Jo Whittaker is available on your obook / assess.

ROCKS IN YOUR COMPUTER

A computer contains more than 50 different minerals. These include gold, silica, nickel, aluminium, zinc and iron. Minerals also are used to make laptops, mobile phones, tablets, and other hand-held devices. Without minerals, these devices could not be made, and we wouldn't have cars, aeroplanes or most other things we see and use in the world today.

Gold in the wires

Gold conducts electricity, it can be twisted easily without breaking and it does not get rusty. These properties make it an ideal mineral for coating the thin wires in computer circuit boards. Because of its value, gold and some other precious metals are recycled from old computers. About 0.5 grams of gold can be recycled from the parts of a computer, whereas just 0.03 grams can be recovered from a mobile phone.

Other minerals have properties that make them suitable for use in electronic equipment. Mica, a mineral containing the element silicon, does not conduct electricity and has a high melting point. It is used as an insulator to prevent short circuits – the mica around the wire stops the electricity flowing across the wrong connections. Lithium is the lightest metal; it is used in lithium batteries in laptops, phones and other portable devices. Tantalum releases heat easily and is flexible, so it is used to make capacitors to store electricity in laptop computers.

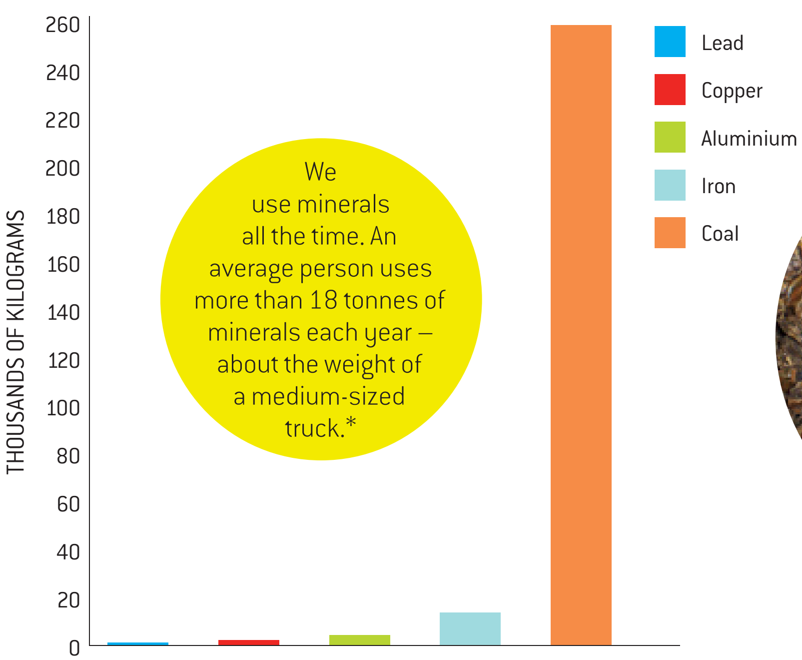
Staring at the screen

The monitor of a computer is made of glass, which is made using quartz sand. The mineral quartz is hard, waterproof and transparent. These are the ideal properties for a computer screen.

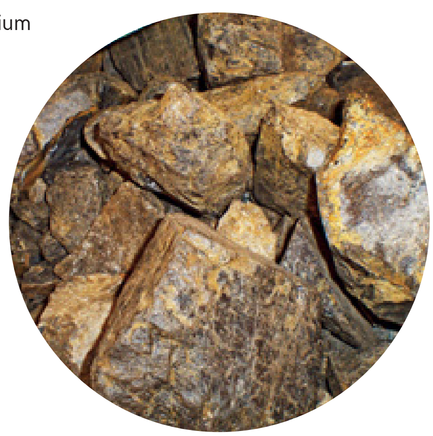
Computers use a chip made of **silicon** to process information. Silicon comes from quartz.

Tungsten, a rare metal found in the Earth as a chemical **compound** (combined with other elements), is also used in laptop screens and light bulbs because it has a high melting point. Tungsten is also used to make mobile phones vibrate because it is very dense and a small amount is heavy.

AVERAGE MINERAL USAGE PER PERSON PER LIFETIME

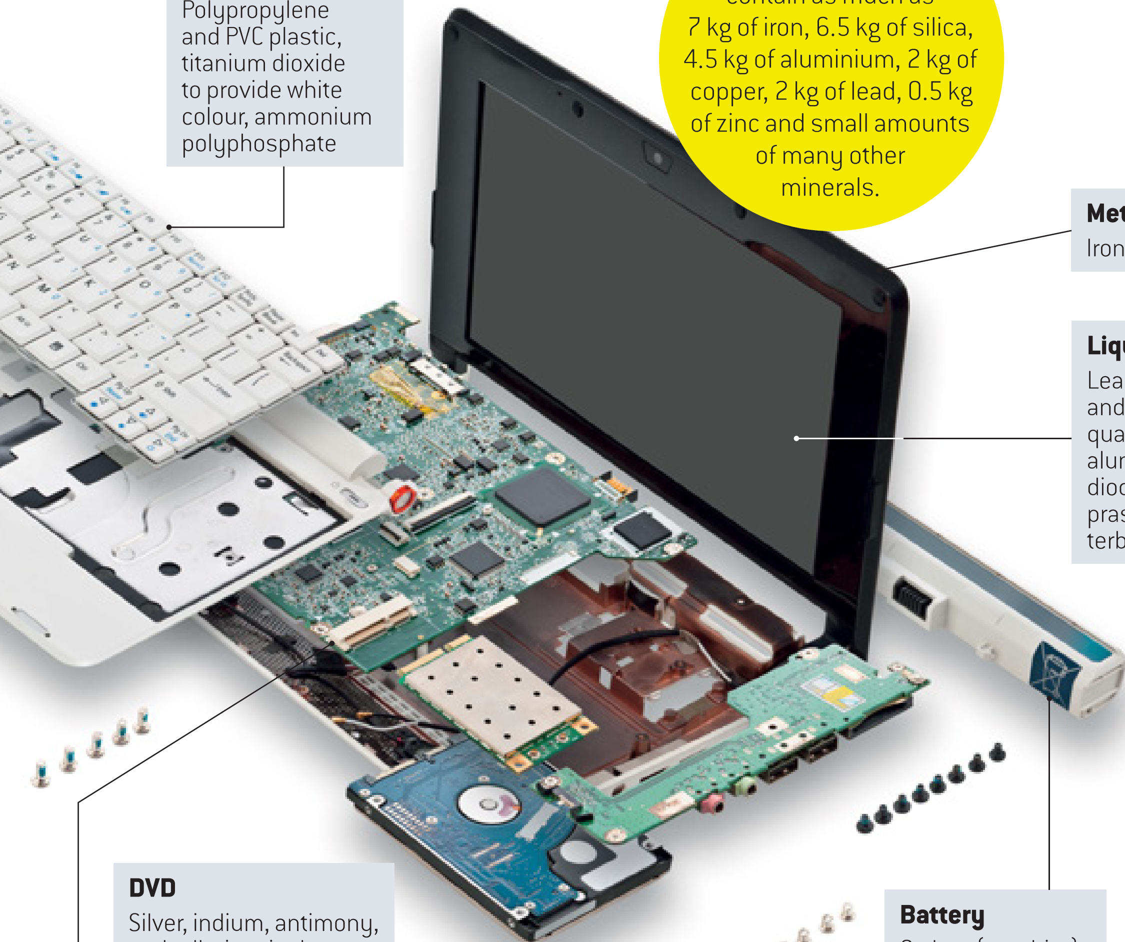


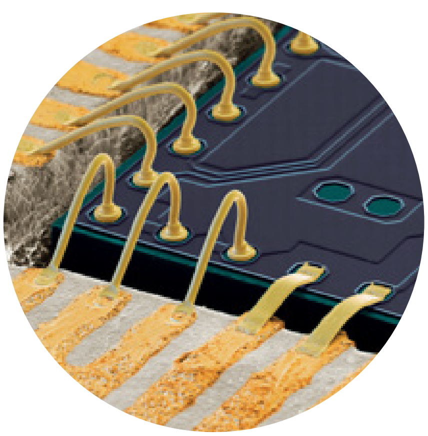
*Figures refer to typical industrialised countries.



Tantalum, an element that comes from the mineral tantalite (left), is used in capacitors (right) that store electricity in laptop computers.

A 30-kg computer can contain as much as 7 kg of iron, 6.5 kg of silica, 4.5 kg of aluminium, 2 kg of copper, 2 kg of lead, 0.5 kg of zinc and small amounts of many other minerals.





A scanning electron microscope (SEM) image of gold wires connecting a computer chip to a circuit board.

You'll be amazed how many minerals taken from the Earth are used inside electronic devices.

LOOK IT UP

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

silicon a non-metallic element used in making electronic circuits

CHECK IT OUT

1. Why are computer chips sometimes referred to as 'silicon chips'?
2. Name three minerals that you would find inside a computer.
3. List three properties of gold that make it suitable for use as a coating for electric wires in a computer.
4. List three properties of quartz that make it suitable for use in a computer screen.
5. Look carefully at the column graph on the previous page.
   a. How much aluminium, on average, do people in industrialised countries use in a lifetime?
   b. List three different uses for aluminium.
   c. Which mineral is used most by people in a typical industrialised country? Suggest which activities would be likely to use large amounts of this mineral.

STORIES IN STONE

Earth's 4.5-billion-year history of **bacteria**, early life forms, plants and animals is recorded in rocks. The remains of living things can leave fossils. These can be petrified remains of bones, insects trapped in sap or animals preserved beneath frozen ground. These pieces of evidence tell a story about how life on Earth has evolved over millions of years.

Much of what we know about dinosaurs is based on fossils in rock.

Fossils

Fossils form when sediments cover the remains of an animal; for example, if an animal died in a river or became stuck in mud. Any soft tissue, such as skin and internal organs, rots and breaks down (decays), while the hard bones, teeth or shells remain. More sediment builds up over the remains over millions of years, forming rock containing the fossilised remains.

Bone and other hard material can be **petrified** (which means to make like stone). Water containing dissolved minerals seeps into the remains. Over time, these minerals replace the original material, converting it to stone.

Rocks with fossils may rise and be weathered away over millions of years. This can uncover fossils, or sometimes people dig up fossils.

A petrified tree – water has dissolved the wood, which has been replaced over a long time by minerals, and a stone replica of the original tree has been formed.

Era	Period (millions of years ago)	
CENOZOIC (recent life)	Quaternary	2
	Tertiary	65
MESOZOIC (middle life)	Cretaceous	142
	Jurassic	206
	Triassic	248
PALAEOZOIC (ancient life)	Permian	290
	Carboniferous	354
	Devonian	417
	Silurian	443
	Ordovician	493
	Cambrian	545
PRECAMBRIAN	Ediacaran	600
		2500
	Archaean	3800
	Hadean	4500

Scientists called **palaeontologists** study fossils to understand ancient life. Palaeontologists compare fossilised remains with others found in the past, and try to piece together what an animal or plant may have looked like. They can find out the age of the fossil by studying the layer of rock it was found in, because older layers of rock will be beneath newer layers of rock. Palaeontologists can also find out the age of a fossil by studying the radioactivity of rocks. With this information, they can calculate how long it has taken for the uranium in the rock to have decayed to the amount present now (because uranium decays at a known rate).

Geological timescales

We use a calendar to divide short periods of time. Palaeontologists divide much larger time periods into eras, periods, **epochs** and ages.

Rock that has formed in different time periods contains different types of fossils and has experienced different events. For example, the Cenozoic era contains the Quaternary period when humans developed, which contains the current Holocene epoch. Dinosaurs became extinct in the Cretaceous period after living in the Triassic and Jurassic periods, all of which are in the Mesozoic era. The first land plants and animals appeared in the Silurian period. The Earth formed, bacteria appeared, and multicellular life and algae developed through the periods of the Precambrian era.

This geological timescale lists the name and chronological order of the major eras and the periods within them.

In Atapuerca, Spain, palaeontologists and volunteers dig for fossilised human remains and stone tools belonging to the earliest known humans in western Europe.

LOOK IT UP

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

epoch a particular span of time in history, shorter than a geological era or period, and longer than an age

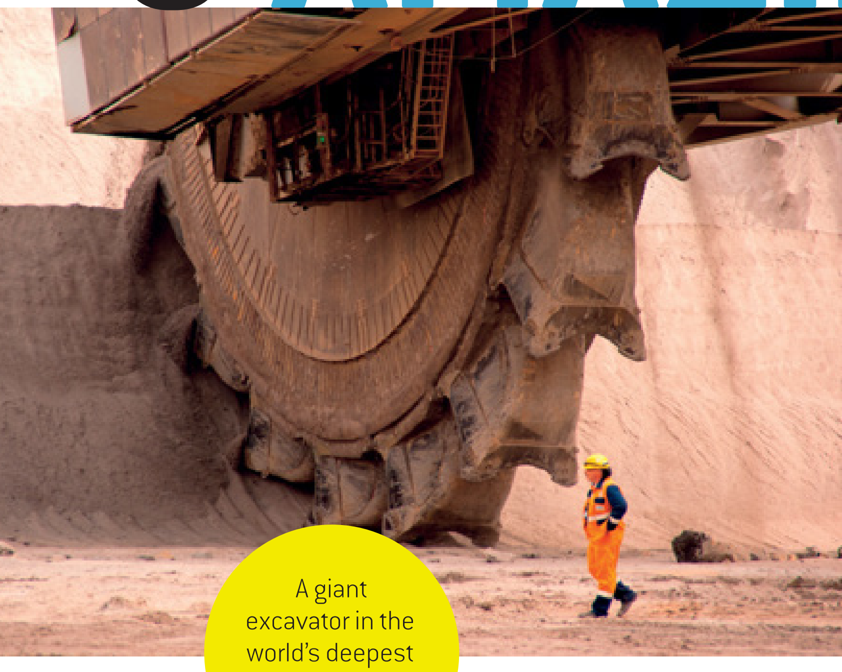
palaeontologist a scientist who studies fossils to understand ancient life

petrification the chemical replacement of wood, bones, teeth and shells by minerals dissolved in water

CHECK IT OUT

1. List the following in order of length of time from longest to shortest: epoch, period, era, age.
2. In which era and period did dinosaurs become extinct?
3. How many millions of years ago did the first plants and animals appear on the land?
4. Considering how fossils are formed, which of the three main types of rock (sedimentary, igneous or metamorphic) would most likely contain fossils?
5. Suggest two ways that palaeontologists may have worked out the skin type and skin colour of the *Tyrannosaurus rex*.

5 AMAZING ROCK



A giant excavator in the world's deepest open-cut mine in Germany.

The heaviest boulder ever moved sits above a walkway at an art gallery in Los Angeles.

1 That's deep

The world's deepest open-cut mine is the Tagebau Hambach brown coal mine in Germany. It lies across the two towns of Niederzier and Elsdorf and extends nearly 300 metres below sea level.

The world's deepest mine is the Mponeng gold mine in South Africa. The tunnels are 3.9 kilometres below the surface.

People have dug much deeper than the Tagebau Hambach and Mponeng mines. The world's deepest hole in the ground is 12.3 kilometres deep. It was dug in Koba, Russia, between 1970 and 1994. But the hole doesn't reach the mantle, because the Earth's crust is so thick beneath the continents.

Over the next few years, scientists plan to reach the Earth's mantle by drilling a hole 6 kilometres beneath the ocean crust, which is thinner than **continental crust**. The deepest hole in the ocean crust so far is called Hole 504B in the Pacific Ocean, which extends more than 2 kilometres beneath the sea floor.

2 That's heavy

The heaviest boulder lifted since ancient times weighs more than 300 tonnes. In 2011, it was moved to the Los Angeles County Museum of Art to form part of a sculpture by artist Michael Heizer. The huge granite boulder is 6.6 metres high.

3 That's far out

Not all of the planet's rocks were formed on Earth. Some came from space.

During the Apollo space missions, astronauts brought 382 kilograms of rock samples back to Earth from the Moon. But rocks have come to Earth from further away than that – meteorites are rocks that have come from space. The world's largest known meteorite is located in Namibia in south-western Africa, weighing about 55 tonnes. It is also the largest known natural piece of iron in the world.

RECORDS

The Hoba meteorite in Namibia is the largest meteorite ever found.

Red beryl, found in a white rhyolite host rock, is a rare gem.

An up-close view of Uluru, the world's largest rock.

4 That's rare

In 2005, *The Guinness Book of World Records* described **painite** as the world's rarest mineral. It was discovered in 1951 in Myanmar (then Burma). For many years, there were only two crystals of this rare gemstone. In 2005, when the record was set, there were fewer than 25 crystals. Since then, more have been discovered in Myanmar.

There is no agreement on what is the rarest gemstone today. There are only eight musgravite gemstones, all found in South Australia. Black opal, found in Lightning Ridge, New South Wales, is rare and is as valuable as rare diamonds. The Argyle Mine in Western Australia produces a small number of red diamonds, which sell for millions of dollars. Other rare gems include red beryl, benitoite, jeremejevite, tanzanite, poudretteite, grandidierite, jadeite and serendibite.

5 That's big

The world's largest rock is Uluru in Central Australia. The giant sandstone rock rises 348 metres above the ground. Like an iceberg, most of Uluru lies beneath the surface.

Mount Augustus (or Burringurrah, as it is called by the Wajarri Yamatji Traditional Owners) in Western Australia is sometimes called the world's largest rock. However, Mount Augustus is not a single rock (unlike Uluru). Rather than being a giant rock, it is a **monocline**.

LOOK IT UP

continental crust a relatively thin, hard and brittle outer layer of the Earth beneath a continental land mass

monocline a fold in a rock layer

painite one of the world's rarest minerals

CHECK IT OUT

1. List the following in order of depth: the deepest hole on land, the deepest open mine, the deepest hole beneath the ocean and the deepest mine.
2. Uluru is the world's largest rock. True or false?
3. Almost all rocks on Earth formed on the Earth. Where are two other places rocks on Earth have come from?
4. Name two rare gemstones found in Australia.
5. Explain why scientists would dig a hole to reach the Earth's mantle from beneath the ocean rather than from land.

ROCKS AND MINERALS

THE EARTH'S ROCKS (PAGES 104–105)

1 Look at the cross-section of the Earth below.

a Match the letters a, b and c with the following labels: crust, mantle, outer core

b Match the part of the Earth with a description of its state.

crust	liquid
outer core	semi-solid
mantle	solid

2 What is the thickness of the Earth's crust:

a beneath the ocean?

b beneath continents?

3 What temperature is the Earth's inner core?

A −2000°C

B 0°C

C 35°C

D 5000°C

4 Complete the following sentences:

________ are the basic building blocks of rocks.

Minerals are made up of ________.

IGNEOUS ROCK (PAGES 106–107)

5 What are the three main types of rock on Earth?

6 How do igneous rocks form?

7 Identify the formation shown at d in the diagram below. What is the name of the pipe that allows the magma to rise up through it?

8 How do intrusive igneous rocks form? Give an example of an intrusive igneous rock.

9 Name three igneous rocks.

SEDIMENTARY ROCK (PAGES 108–109)

10 How can you tell that the rock above is sedimentary?

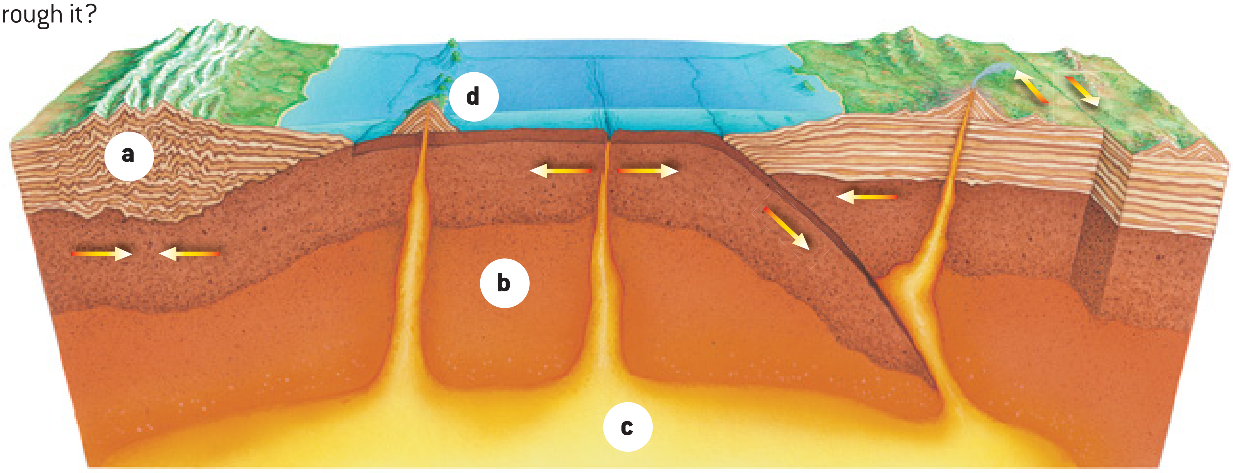
11 How do sedimentary rocks form?

12 Look at the photograph of the crocodile fossil opposite.

a What is a fossil?

b Why are fossils such as this found in sedimentary rocks?

13 Limestone is a common sedimentary rock. Give one example of how limestone can form.



METAMORPHIC ROCK (PAGES 110–111)

14 True or false: metamorphic rocks can form at the Earth's surface.

15 Give an example of an igneous or sedimentary rock that has changed into a metamorphic rock.

16 Look at the photograph of slate floor tiles opposite.

- **a** Slate is formed from which sedimentary rock?
- **b** What properties of slate make it useful as a floor or roof tile?

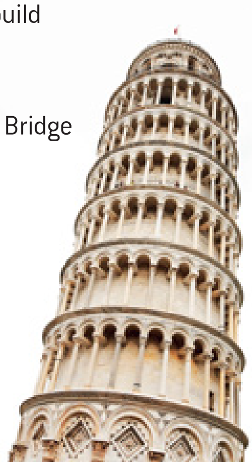
17 Why are metamorphic rocks stronger than the rocks they were formed from?

18 Using the rock cycle, explain how sedimentary rocks change into metamorphic rocks, and metamorphic rocks change into sedimentary rocks.

USING ROCKS TO BUILD (PAGES 114–115)

19 Name the main type of rock used to build each of the following:

- **a** the pyramids in Egypt
- **b** the pylons of the Sydney Harbour Bridge
- **c** the Taj Mahal in India
- **d** the Leaning Tower of Pisa in Italy (pictured).



20 Why did the Inca people use granite to build the city of Machu Picchu in Peru, South America?

21 Houses are often built with bricks. What minerals are bricks made of?

PROPERTIES OF ROCKS (PAGES 116–117)

22 Name three characteristics of rocks used to identify mineral type.

23 Look at the photograph of the diamond ring (top right).

- **a** List the two key minerals used in making this ring.
- **b** Describe the transparency and colour of diamonds.
- **c** Where are diamonds rated on the Mohs scale of hardness? What does this rating mean?

MINING MINERALS (PAGES 118–119)

24 Look at the photograph of the diamond ring above.

- **a** What properties of gold make it a good choice for making rings?
- **b** How is gold mined?

25 Name a mineral that can be used:

- **a** in the state it is dug from the ground.
- **b** after being separated from the rock in which it is found.
- **c** after slight cleaning.
- **d** after processing to take it from the ore in which it is found.

26 What is the name given to scientists who study rocks?

ROCKS IN YOUR COMPUTER (PAGES 120–121)

27 How is gold used in computers?

28 What properties of lithium make it a good choice for batteries in mobile phones?

29 What is the main mineral used in computer screens?

STORIES IN STONE (PAGES 122–123)

30 How do fossils form?

31 What type of scientist studies fossils?

32 How can scientists work out how old a fossil might be?

33 Which of the following would not leave a fossil?

- **A** petrified remains of bones
- **B** insects trapped in sap
- **C** the contents of a dinosaur's stomach
- **D** animals preserved beneath frozen ground

34 When bone or hard material is replaced by minerals dissolved in water that has seeped into them, they are referred to as p _ _ _ _ _ _ _ _ rock.

5 AMAZING ROCK RECORDS (PAGES 124–125)

35 What type of rock is Uluru mainly composed of?

36 Have people ever drilled to:

- **a** the Earth's mantle?
- **b** the Earth's core?

KEY IDEAS

1 Earth and its rocks formed 4.5 billion years ago.

2 The internal structure of the Earth is made of layers called the inner core, the outer core, the mantle and the crust.

3 A rock is made up of minerals, which are made up of crystals that influence minerals' properties.

4 Rocks on the Earth can be classified into three main types: igneous, sedimentary and metamorphic.

5 Igneous rocks are formed from volcanic activity. Extrusive igneous rocks cool quickly from lava flowing onto the surface of the Earth. Intrusive igneous rocks form from magma solidifying under the Earth's surface.

6 Sedimentary rocks form when rock particles are compressed, or when water evaporates leaving behind a solid. Sedimentary rocks form in layers and can sometimes form from the remains of living things.

7 Metamorphic rocks form when rocks are heated and/or squeezed, such as limestone (sedimentary rock) changing into marble.

8 Rocks are constantly changing in an ongoing cycle over millions of years. For example, igneous rock can be eroded to form sedimentary rock, which in turn can form metamorphic rock under pressure.

9 The hardness, long life, and weatherproof nature of rock make it an important building material. The type of rock used in buildings often reflects what is available locally.

10 Minerals are the basic building blocks of rocks. Rocks are identified based on what minerals they are made of and how they look and feel.

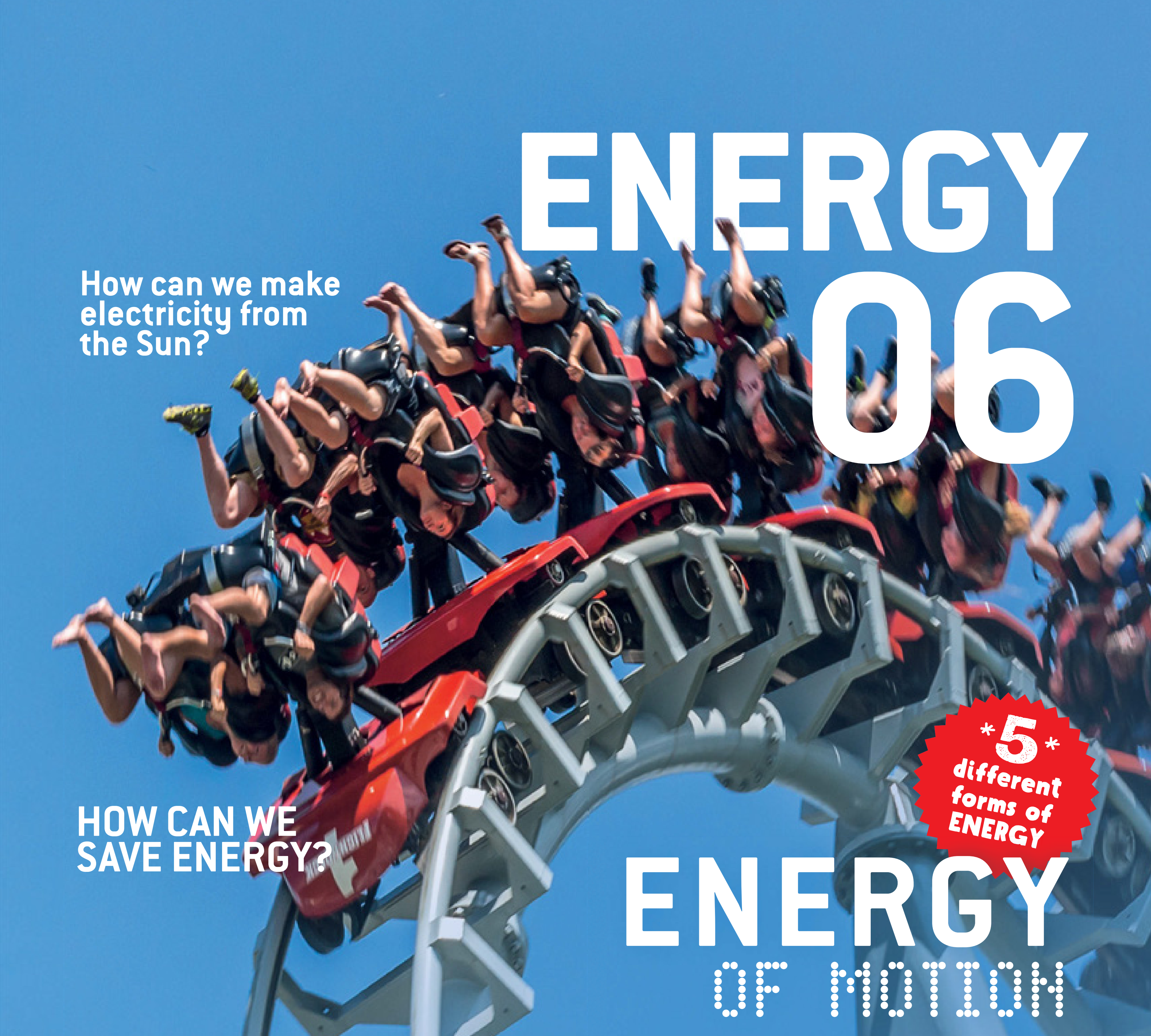
11 The properties of a rock give clues about how it formed, where it came from, what has happened to it, and how it could be used. Examples of rock properties are hardness, colour and lustre.

12 Some minerals, such as diamond and gold, are valuable due to their rarity and perceived beauty. Some minerals, such as coal and copper, are valuable due to their high demand by many people for many purposes.

13 Recycling is a way to conserve finite or limited mineral resources.

14 Earth's 4.5-billion-year history of bacteria, early life forms, plants and animals is recorded by fossils. Palaeontologists study fossils to understand ancient life.

15 Geological time is divided, from longest to shortest, into eras, periods, epochs and ages.



ENERGY 06

How can we make electricity from the Sun?

HOW CAN WE SAVE ENERGY?

5 different forms of ENERGY

ENERGY OF MOTION

ENERGY IS ALL AROUND US

Energy is everywhere. You use energy to get out of bed. You use energy to walk, to climb stairs and to digest food. You use energy to think and to speak. You even use energy when you are asleep.

Turning on a light, boiling water, travelling in a car or train, sending an email or listening to music – all of these activities use energy. Put simply, energy lets us do things.

Types of energy

Energy exists in many different forms.

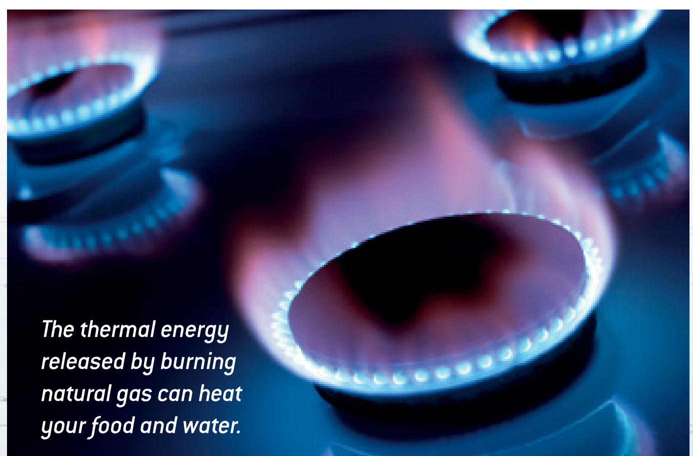
Electrical energy powers appliances in homes, schools and work places. Batteries supply the electricity to operate laptop computers, mobile phones, music players and torches.

Chemical energy in petrol powers cars. Chemical energy in food powers people. Explosives release vast amounts of chemical energy.

Thermal energy (heat) from a flame or a hot plate heats your food. Burning gas or oil provides heat to keep you warm in winter.

Sound is a form of energy.

Electrical energy travels along wires from power plants to appliances.



The thermal energy released by burning natural gas can heat your food and water.

Sound energy carries music and speech to your ears.

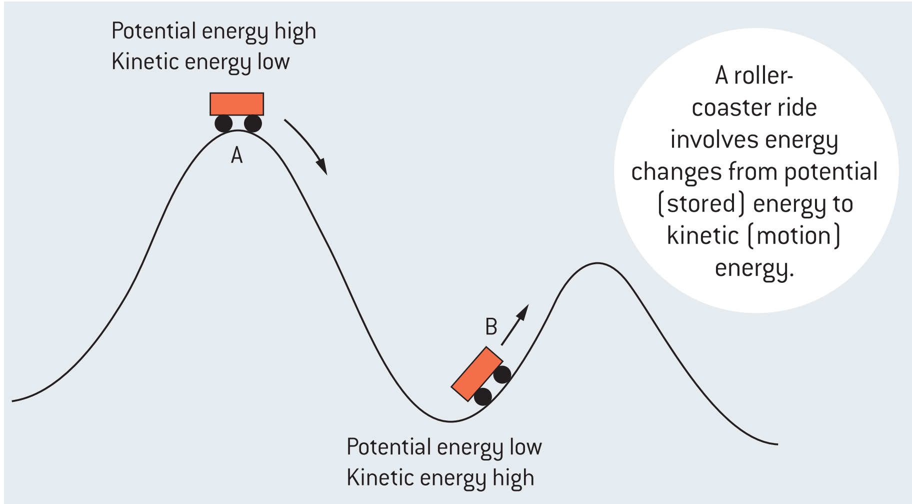
Almost all life on Earth relies on energy from the Sun. The Sun's energy comes from nuclear reactions in its core. These reactions produce hot gases at the Sun's surface. Solar energy travels through space to Earth.

Roller-coaster ride

Imagine yourself on a roller-coaster ride. You climb into your seat. The safety bar clicks into place. The attendant checks that all is secure and presses the 'go' switch. With a whoosh, hooks under your roller-coaster train attach themselves to a chain running under the track.

The chain pulls the train upwards towards the top of the hill. Already an energy change is taking place. As you move higher, you gain **potential energy**. Any object above the ground has the potential to fall due to the force of gravity. The larger the mass and the greater the height, the more potential energy the object gains.

You pass over the top of the hill and the chain releases. The train starts to fall down the track. As it does so, you move faster and faster. Gravity makes your train accelerate. You build up **kinetic energy** (energy of motion) as you lose potential energy.



A roller-coaster ride involves energy changes from potential (stored) energy to kinetic (motion) energy.

At the bottom of the hill, you are moving at peak speed. This is when your kinetic energy is greatest.

LOOK IT UP

chemical energy energy stored in chemicals, e.g. in food, fuel and explosives

electrical energy energy associated with electric charge, either stationary or moving

kinetic energy energy of motion or moving objects

potential energy energy stored in objects available for use

sound energy vibrations passing through solids, liquids and gases

thermal energy heat energy

CHECK IT OUT

1. List four sources of energy.
2. Where does most of the energy come from that supports life on Earth?
3. What is the difference between potential and kinetic energy?
4. At what point does a skydiver have the greatest:
   - **a** potential energy?
   - **b** kinetic energy?
5. What measure during a roller-coaster ride represents the amount of kinetic energy?

ENERGY OF MOTION

The energy of motion is called kinetic energy. Heavy, fast-moving objects have the greatest kinetic energy.

Kinetic energy

Anything that moves has energy. A fast train, a plummeting roller-coaster train, a person walking down the street and the Earth revolving around the Sun are all examples of the energy of movement. This is known as kinetic energy. The word 'kinetic' comes from the Greek word *kinesis*, meaning 'motion'.

The heavier an object is and the faster it is moving, the more kinetic energy it has. A truck travelling at 60 kilometres per hour has more kinetic energy than a motorbike travelling at the same speed. The truck travelling at 100 kilometres per hour will have more kinetic energy than when it was moving at 60 kilometres per hour.

A fast-moving object has a lot of kinetic energy and can exert a great force. A high-speed collision causes much more damage than a low-speed collision. Even a small increase in speed can cause a large increase in kinetic energy.

A bowling ball moving quickly down a lane in a bowling alley has kinetic energy. At the end of the lane, the ball exerts a force on the pins, knocking them over. The ball does **work**, causing movement and noise.

A moving bowling ball has kinetic energy. The energy is converted into the work of knocking down pins.

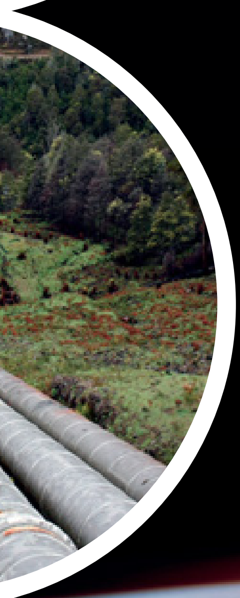
Hydroelectricity

The kinetic energy of falling water can be used to generate electricity. The falling water pushes on huge turbine blades. The blades rotate, driving an electrical generator that converts the rotation into **electrical energy**.

Australia has more than 100 **hydroelectric power** stations. The largest Australian hydroelectric scheme is in the Snowy Mountains in south-eastern New South Wales. At the Murray 1 and Murray 2 power stations, water falls about 750 metres before its kinetic energy is converted into electricity by the turbines.

The kinetic energy of falling water is the energy source in hydroelectric power stations.

A speeding train has lots of kinetic energy – energy due to movement.



Collision with planet Earth

An asteroid (or a comet) with massive kinetic energy slammed into Earth 65 million years ago in what is today Mexico.

The asteroid was around 15 kilometres wide, almost the size of the city of Cairns.

It hit Earth 20 times faster than a speeding bullet and struck with a force one billion times more powerful than the atomic bomb explosion at Hiroshima during World War II.

The asteroid blasted soil and rocks high into the atmosphere, blanketing out the Sun. The climatic changes destroyed much of life on Earth in just days.

The asteroid collision wiped out more than half of all species.

LOOK IT UP

electrical energy energy associated with electric charge, either stationary or moving

hydroelectric power the production of electrical power from falling or flowing water

work occurs when a force moves an object

CHECK IT OUT

1. Which has greater kinetic energy when moving at the same speed: a cannonball or a golf ball? Explain your answer.
2. In terms of kinetic energy, explain why a bullet can cause so much damage despite being small.
3. Name the force acting on water falling though the turbines in a hydroelectric power station.
4. Use kinetic energy to explain why the asteroid striking Earth 65 million years ago caused so much damage.

An artist's impression of the huge asteroid travelling at thousands of kilometres per hour that smashed into Earth 65 million years ago.

POTENTIAL ENERGY

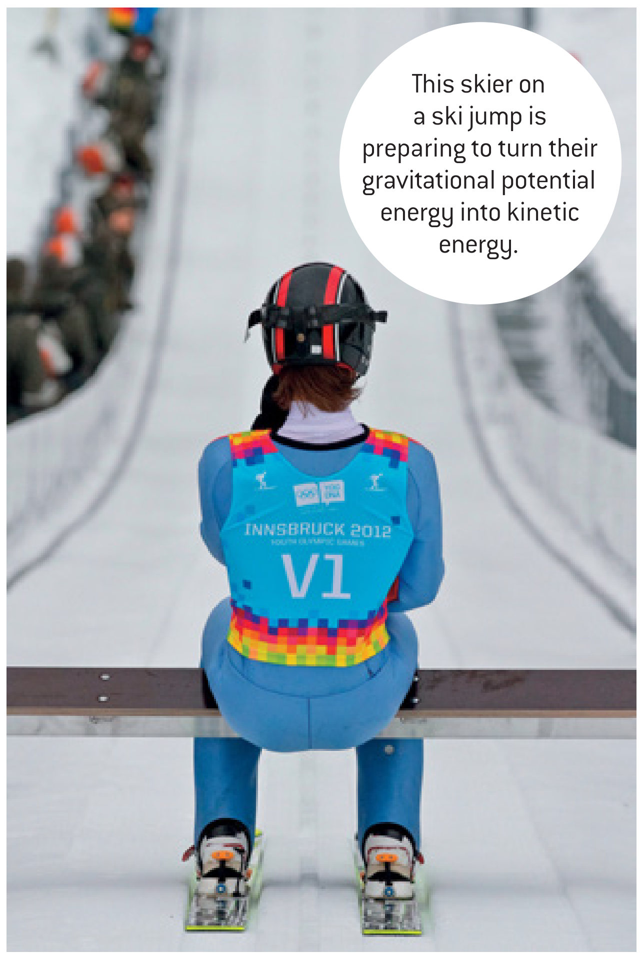
Blast off! With a mighty roar, 100 tonnes of liquid hydrogen reacts with 600 tonnes of liquid oxygen to power the space shuttle engines. The energy stored in the two chemicals provides the huge thrust force needed to propel the space shuttle. Stored energy can be harnessed to do work. Energy that is stored in objects and available to be used is called **potential energy**.

Launch of the Space Shuttle Columbia from Kennedy Space Centre, USA

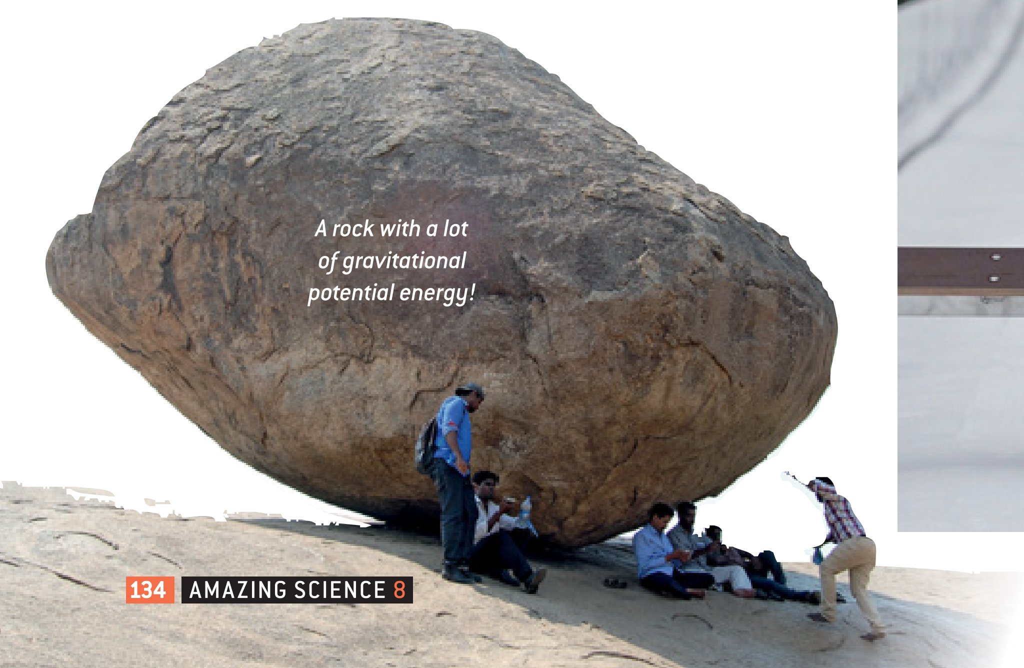
Gravitational potential energy

A brick lying on the ground has no potential energy. It cannot do any work. If you lift it a few centimetres, you transfer energy to it. The brick gains gravitational potential energy. Any object in the air has the potential to fall due to the force of gravity. If you drop the brick, it may make a small mark where it lands. If you lift the brick a metre and drop it, it will probably make a larger mark.

The larger the mass and the greater the height, the more potential energy an object has.



This skier on a ski jump is preparing to turn their gravitational potential energy into kinetic energy.



A rock with a lot of gravitational potential energy!

Chemical potential energy

Fuel reacting to launch a rocket is an example of the conversion of **chemical potential energy** into motion. There is energy stored within chemical substances.

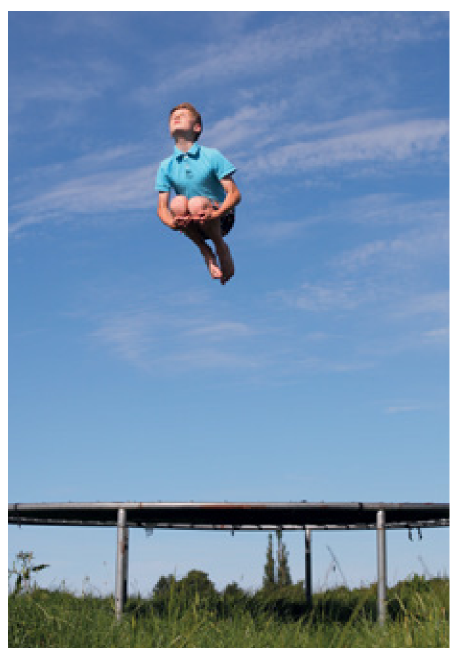
- The explosive TNT contains vast amounts of chemical energy. This energy has the potential to do a great deal of work such as blasting out a section of a mine.
- Fuels, such as oil, natural gas and petrol, contain chemical energy. A stovetop burner converts the energy in the chemical bonds in natural gas into heat for preparing food. A car engine converts petrol's chemical energy into motion.
- Your body takes the chemical energy from the food you eat. Digestion involves chemical reactions that break down food into smaller molecules such as glucose. These molecules can then enter the bloodstream and be taken up by cells. Within cells, a chemical reaction called aerobic respiration breaks bonds within glucose molecules to release energy.
- A battery is a device that turns chemical potential energy into electrical energy.

Energy stored in chemical bonds in an explosive can be used in a quarry to break up rocks.

Releasing the bowstring converts its elastic potential energy into the arrow's kinetic energy.

Elastic potential energy

Think about using a bow and arrow. As you draw back the arrow and stretch the bowstring, you are giving the bowstring **elastic potential energy**. The further you stretch the bowstring, the more potential energy it has. When you release the bowstring, all that energy goes into propelling the arrow through the air.



LOOK IT UP

chemical potential energy energy that is stored in atoms and the bonds between them

elastic potential energy energy stored in elastic materials, such as springs, as the result of stretching or compressing

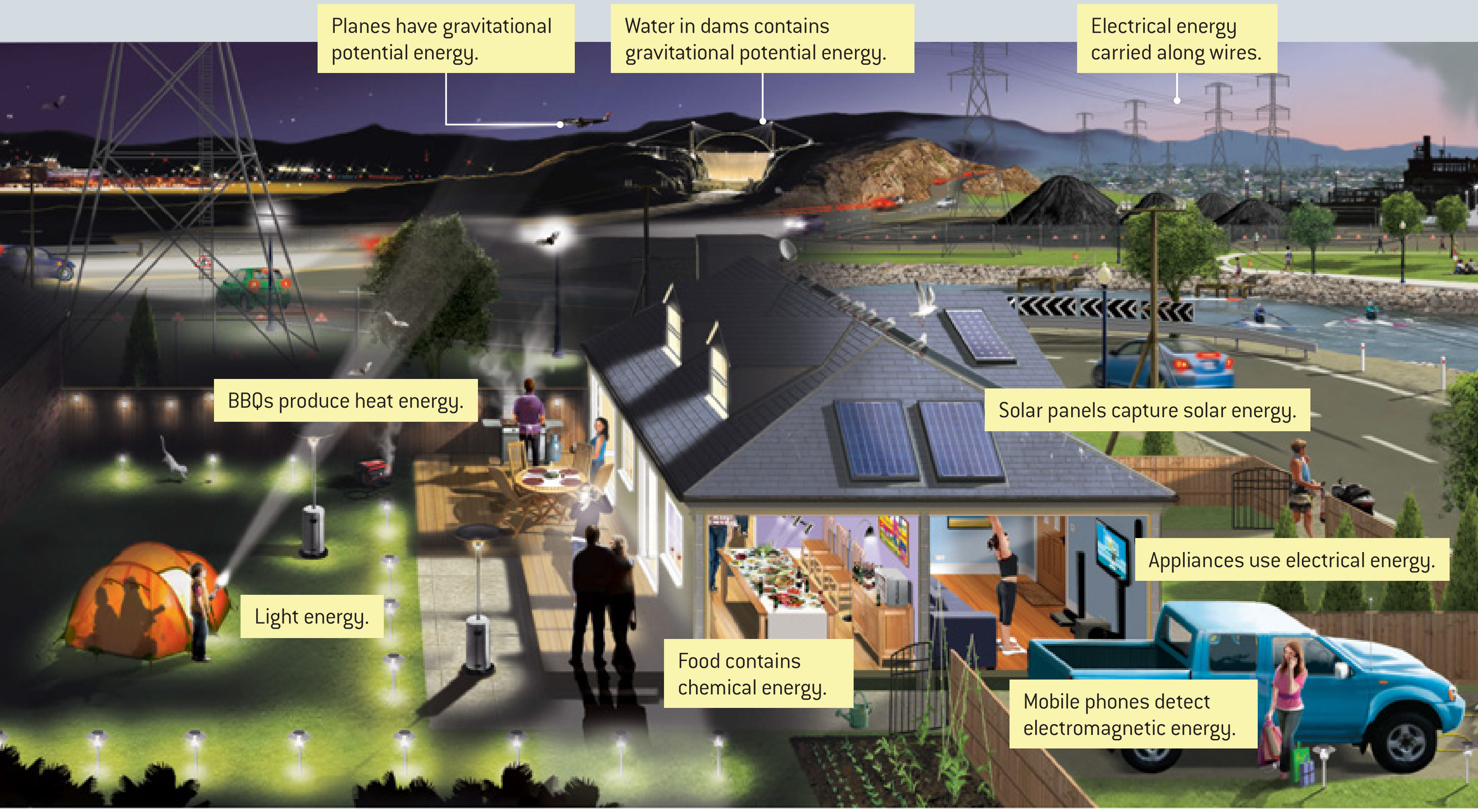
potential energy energy stored in objects available for use

CHECK IT OUT

1. Define potential energy.
2. List three forms of potential energy and give two examples of each.
3. What form of energy does an inflated balloon have?
4. Describe a time in your life when you had a great deal of potential energy.
5. Describe the energy changes of the trampolinist shown in the photograph, starting at the peak of his jump through to his return to a similar height.

5 DIFFERENT FORMS OF ENERGY

Energy exists in many forms. Energy is needed to make things happen. Physicists, who are scientists who study force, motion and energy, describe energy as the ability to do work.



1 Electrical energy is used to keep food cool and to cook it. Electricity powers refrigerators, ovens, lights, TVs, sound systems, computers, phones and fans.

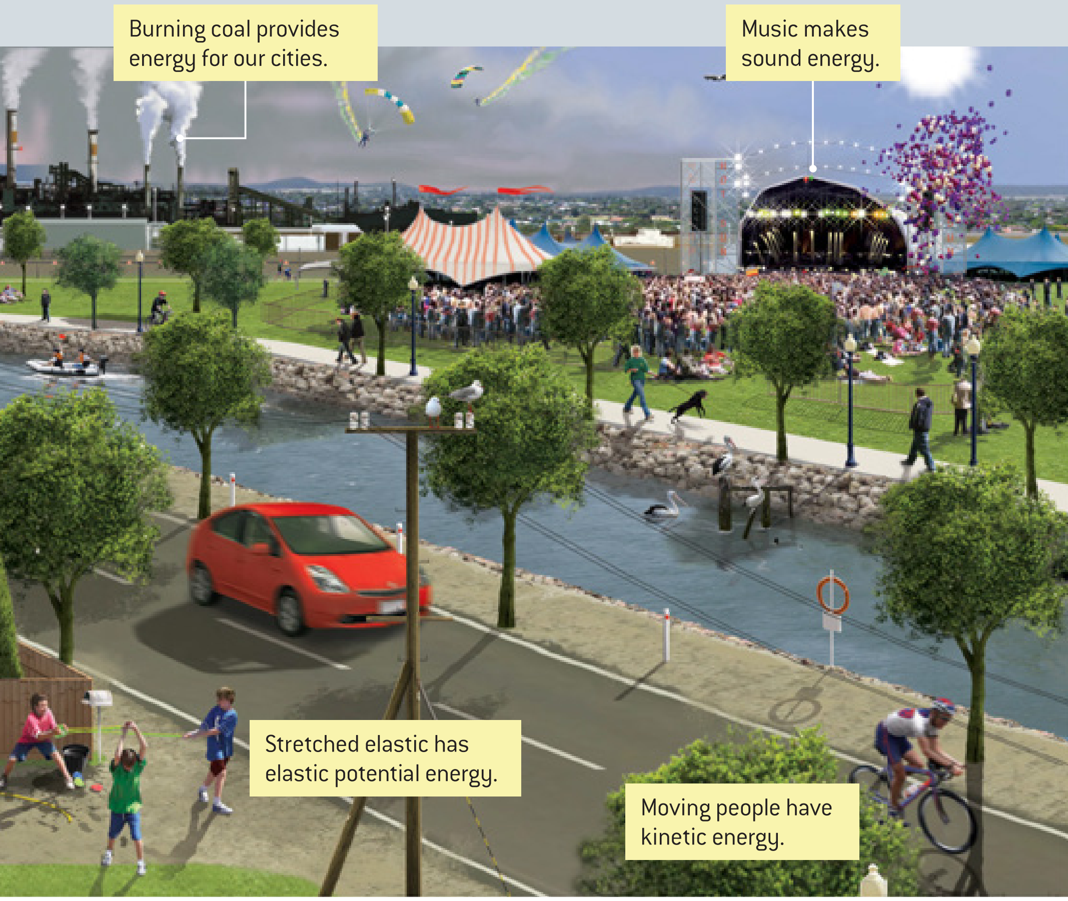
2 Thermal energy (heat) is used to cook food, to warm water and to warm your home. It is the energy of moving and vibrating atoms and molecules. As an object is heated, its particles move and collide faster. Geothermal energy is the thermal energy in the Earth.

3 **Radiant energy** includes light and radio waves. Energy from the Sun is radiant energy that provides the fuel and warmth that make life on Earth possible. Light globes, lasers, stovetops and radiators emit radiant energy.

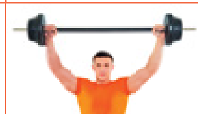
4 Sound energy transfers via vibrations. Vibrations are tiny movements back and forth. Vibrations can occur in gases, liquids and even in solids. The larger the vibrations, the louder the sound will be.

Sound travels faster through liquids and solids than it does through gases such as air. For example, sound travels through air at approximately 1230 kilometres per hour. It travels through solid aluminium at almost 20 times this speed. This is because the closely packed particles in a solid can transfer vibrations between each other much more quickly than the widely spaced particles in a gas.

Vibrations of speaker cones transmit sound energy through the air. These vibrate your eardrums, moving tiny bones in your inner ear that allow your brain to process sound.



Examples of energy use

TYPE OF ENERGY	HOW IT WORKS	EXAMPLE
Kinetic	Motion	
Gravitational potential	Height above the ground	
Chemical potential	Chemical bonds in molecules releasing heat	
Elastic potential	Stretching or compressing	
Electrical	Electricity passing through wires	
Thermal	Heat	
Radiant	Objects releasing light and heat at a distance	
Sound	Vibrations passing through solids, liquids and gases	
Nuclear	Energy in the nucleus (core) of an atom	

5 **Nuclear energy** holds together the particles in the small, dense core (nucleus) of atoms. This energy can be released during changes to the nucleus. In nuclear power stations, uranium atoms are bombarded with particles called neutrons. When a neutron hits a nucleus, the nucleus splits into two smaller nuclei, releasing lots of energy.

LOOK IT UP

nuclear energy energy stored in the nucleus of an atom; released in nuclear reactors or explosions of nuclear weapons

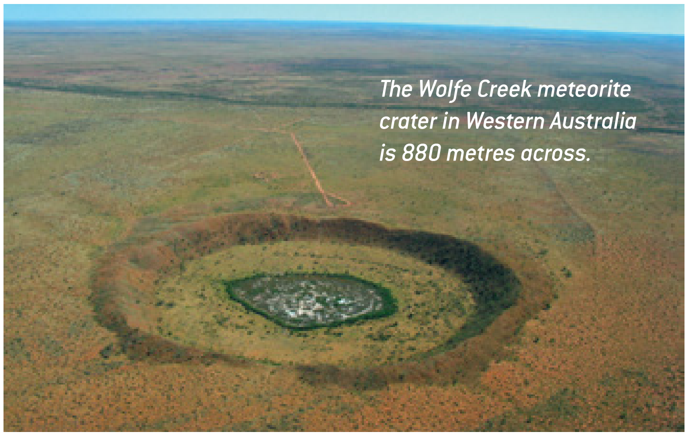
radiant energy energy that travels by waves; can travel through space

CHECK IT OUT

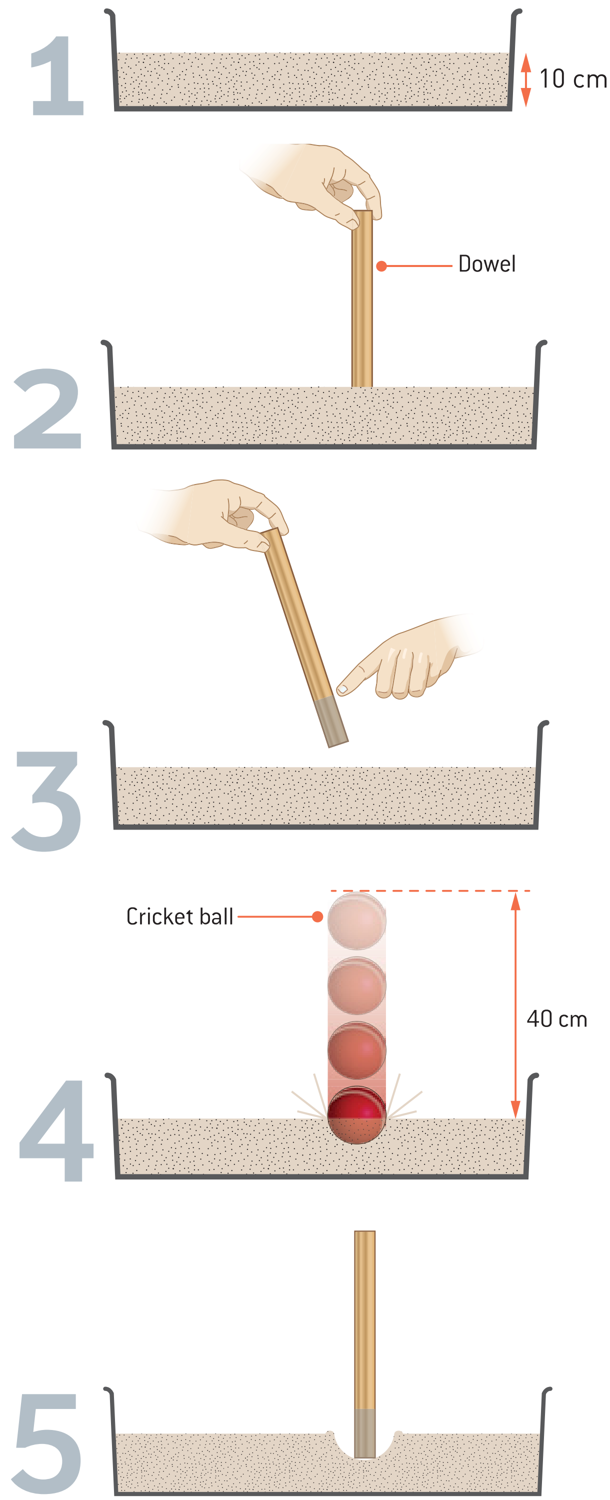
1. List five forms of energy that you have experienced today.
2. In terms of particles, what is thermal energy?
3. Light and radio waves are a form of _______ energy.
4. How does sound energy travel?
5. What is the source of energy in nuclear power stations?

EXPERIMENT #14

CRICKET BALL DROP



The Wolfe Creek meteorite crater in Western Australia is 880 metres across.



AIM: TO INVESTIGATE THE EFFECT OF DROPPING A BALL FROM DIFFERENT HEIGHTS

MATERIALS

- Large tray
- Dry sand
- Ruler
- Tape measure
- Cricket ball
- Thin wooden dowel

METHOD

1. Fill the tray with loosely packed dry sand to a depth of about 10 cm and lightly smooth the surface.
2. Insert the dowel vertically into the sand to the bottom of the tray. Mark the level of the sand on the dowel.
3. Remove the dowel and measure and record the height of the sand.
4. Hold the cricket ball 40 cm above the sand. Gently release the ball.
5. Use the dowel to measure the height of the sand at the deepest point in the crater made by the ball. Subtract this measurement from the original height of the sand to determine the crater depth.
6. Repeat the drop from 40 cm twice and calculate the average of the three crater depths. Smooth the surface between each drop.
7. Continue the experiment by dropping the ball from all the heights indicated in the table, repeating each drop height three times.

DROP HEIGHT (CM)	TRIAL	CRATER DEPTH (CM)	AVERAGE CRATER DEPTH (CM)
40	1		
	2		
	3		
80	1		
	2		
	3		
120	1		
	2		
	3		
160	1		
	2		
	3		
200	1		
	2		
	3		

RESULTS

Record all your measurements in a table similar to the one shown.

DISCUSSION

1 What did you observe about the crater height as the drop height increased?

2 Were the crater depths from each of the three trials at a particular height exactly the same? If not, suggest reasons for the differences.

3 Why do scientists often repeat experiments a number of times?

4 Draw a graph of your results with drop height on the horizontal axis and average crater depth on the vertical axis.

5 Describe the appearance of the graph.

CONCLUSION

1 At which height does the ball have the greatest potential energy?

2 Describe the conversion between potential and kinetic energy in this experiment.

3 How does the sand show the amount of work done by the falling ball?

Ask a scientist

Dr Niraj Lal

Dr Niraj Lal is working to make solar panels more efficient so that they generate more power from sunlight.

Niraj Lal is a physicist doing research on solar cells. Niraj and his colleagues at the Australian National University in Canberra have discovered that changing the shape of solar cells can make a big difference to their performance.

There are more than one million solar panels in Australia, each one generating pollution-free electricity. Around 8 per cent of Australia's electricity comes from solar cells.

'Current standard solar panels lose a large amount of light energy as it hits the surface, making the panels' generation of electricity inefficient', says Niraj. 'But if the cells are bowl-shaped, then the light bounces around inside the cell for longer.'

The researchers have discovered that by layering two different types of solar panels on top of each other, the cells can capture the energy from the blue part of sunlight, not just the red part.

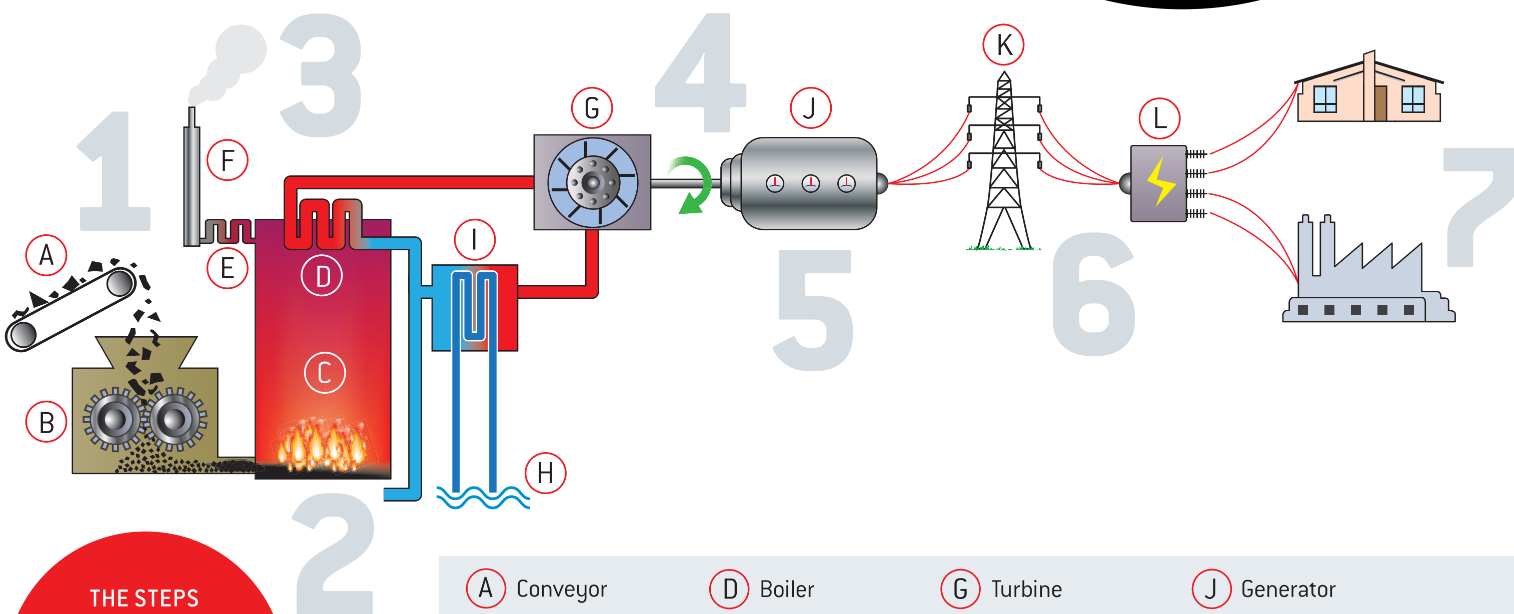
'If we can make a solar cell that "sees" more colours and keeps the right light in the right layers, then we could increase efficiency even further', says Niraj. 'Every extra per cent in efficiency saves you thousands of dollars over the lifetime of the panel.

A video interview with Dr Niraj Lal is available on your obook / assess.

FROM COAL TO ELECTRICITY

Coal has been formed over millions of years from the remains of plants and animals. A thermal power station can convert the energy stored in coal into electricity.

Power stations convert the chemical energy stored in coal into electricity.



THE STEPS INVOLVED IN GENERATING ELECTRICITY FROM COAL IN A POWER STATION.

(A) Conveyor	(D) Boiler	(G) Turbine	(J) Generator
(B) Coal crusher	(E) Precipitator	(H) Cooling pond	(K) Power lines
(C) Furnace	(F) Stack	(I) Condenser	(L) Substation transformer

1 Transport and crushing

A conveyor belt (A) takes the coal that has been dug from the mine and drops it into crushers (B). The crushers break up the coal. It is then further pulverised into a fine powder that will burn easily.

2 Burning and boiling

Hot air from nearby fans blows the powdered coal into a huge furnace (C). The powdered coal burns at a high temperature (around 1100°C). The heat quickly boils the water inside the boiler pipes (D), changing it into steam.

3 Smoke stack

Coal contains **carbon**. Burning the coal in the furnace creates **carbon dioxide** gas. This is the main product of the combustion reaction. The hot gas passes through a precipitator (E). The precipitator gives the dust an electrical charge and then removes it from the gas. The gas escapes into the atmosphere via the tall smoke stack (chimney) (F).

4 Spinning the turbine

The steam passes along the boiler pipes at high speed into the turbine (G). The jets of steam strike the blades of the turbine. Like a massive fan, the turbine spins rapidly.

After passing through the turbine, the steam comes into contact with pipes full of cold water (H). The cold pipes cool the steam so that it condenses (I) back into water. The water is piped back to the boiler, where it is again heated to form steam to keep the turbine turning.

5 Creating electricity

The generator (J) contains a strong magnet surrounded by coils of wire. The spinning turbine makes the magnet spin. The spinning causes **electrons** (negatively charged particles that form part of an atom) to move about inside the coils of wire, creating electricity.

6 Transmitting the power

The generator feeds electricity to a transformer. A transformer changes **voltage** from one value to another. The transformer boosts the voltage to between 130 000 and 500 000 volts. Voltage is a measure of electrical force.

The high voltage reduces the loss of energy as electricity passes long distances along electrical cables. Large steel towers support these power lines (K).

7 Power to your home

The transmission lines transport power to substations (L). Finally, a transformer reduces the voltage to 240 volts for use in homes and industry.

LOOK IT UP

carbon a non-metallic element occurring in a pure form as graphite and diamond; is in all organic compounds

carbon dioxide a colourless, odourless gas with formula CO_2

electron a negatively charged particle found in atoms

voltage a measure of electrical force

CHECK IT OUT

1 Fill in the gaps to complete the summary of how a power station works:

Coal is finely _______ and then blown into a _______ to be burnt. The heat boils _______, turning it into _______ that turns the blades of a _______. The rotating blades make a _______ spin inside a _______, in turn causing _______ to move to create _______.

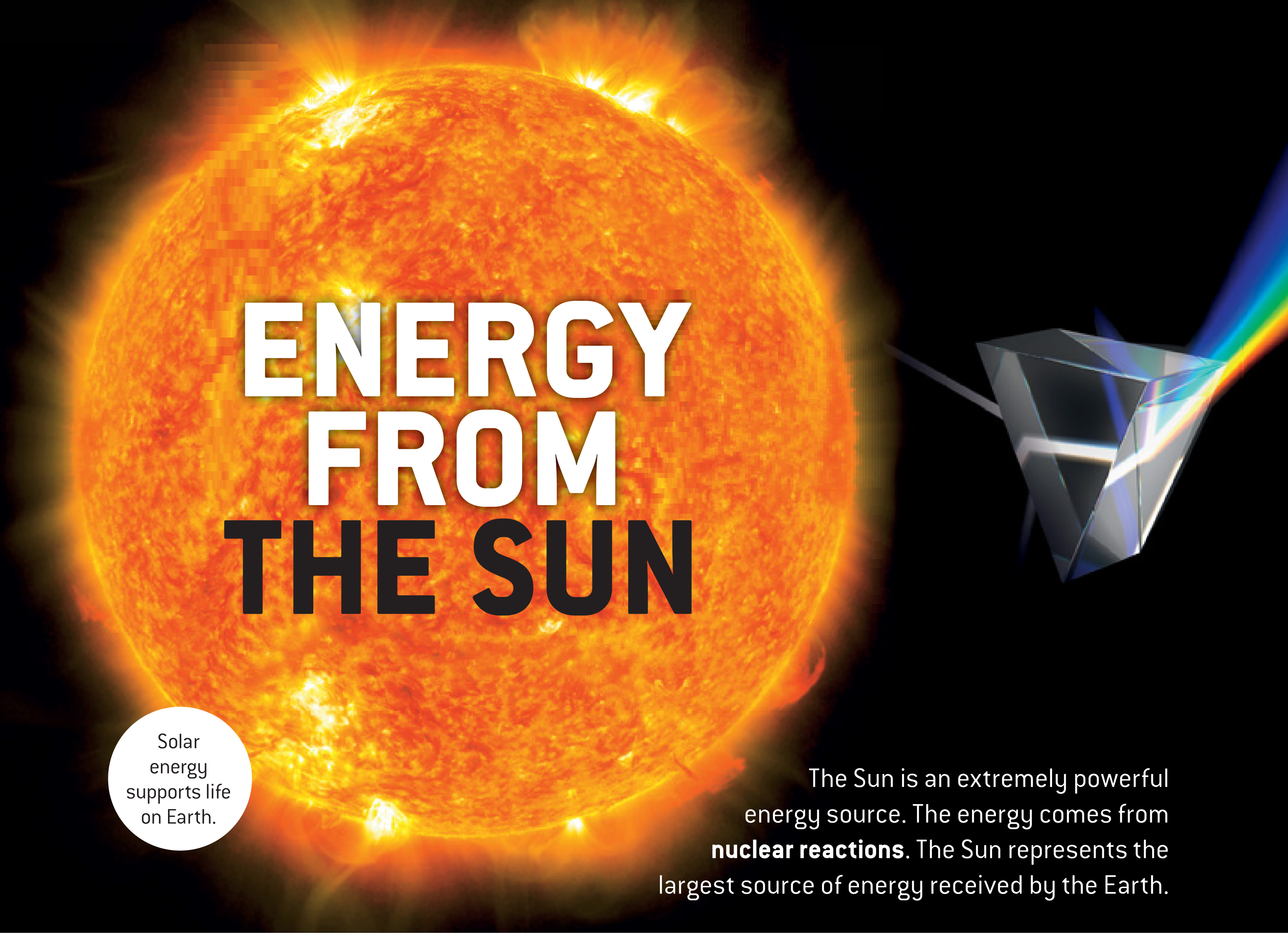
2 Why is coal crushed before it enters the furnace?

3 What is the function of water in the power station?

4 What is the main gas released by a coal-fired power station?

5 Describe the energy conversions that occur in the power station generator.

Victoria's Loy Yang power station burns over 2000 tonnes of brown coal every hour. The station's four turbine generators supply electricity to more than 2 million homes.



ENERGY FROM THE SUN

Solar energy supports life on Earth.

The Sun is an extremely powerful energy source. The energy comes from **nuclear reactions**. The Sun represents the largest source of energy received by the Earth.

Nuclear reactor

At an average distance of 146 million kilometres from Earth, the Sun blasts out vast amounts of energy.

At its core, the Sun's temperature is at least 15 000 000°C (which is 15 million degrees Celsius). The temperature at its surface is 5800°C. At these temperatures, the **nuclei** (cores) of hydrogen atoms smash into each other. As they do so, they form helium atoms and release energy.

Every second, the Sun converts over 500 million tonnes of hydrogen into helium, which releases massive amounts of energy. More than 5 billion years from now the Sun will have used up most of its hydrogen and will get larger and cooler.

The Sun releases its energy into space. We call this energy solar radiation. The radiation includes light energy, X-rays, ultraviolet and infrared (heat) **radiation**. The energy travels at 300 000 kilometres per second. This is the speed of light. It takes just 8 minutes for the Sun's energy to reach us on Earth.

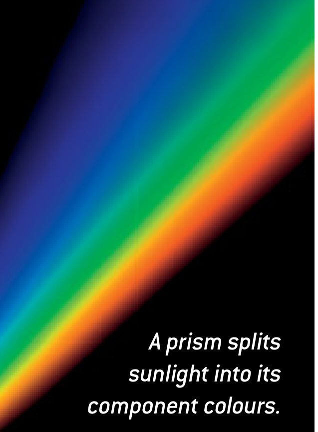
Solar cells

The Earth's atmosphere and clouds scatter about half of the incoming sunlight, reflecting it back into space. The remaining energy that reaches the ground consists of nearly 50 per cent visible light and 45 per cent infrared radiation. The rest is ultraviolet radiation and other forms of energy.

Plants convert the Sun's light energy to chemical energy, producing sugars and other compounds in a process called photosynthesis.

The simplest form of solar energy to collect is heat. If you stand in the Sun on a cold day you can feel the warmth. Solar water heaters are common. Simple ones have water travelling through pipes on a dark absorber plate covered with glass. As the plate heats up, the water is warmed.

Solar cells convert solar radiation directly into electricity. These cells are called photovoltaic cells ('photo' means light; 'voltaic' means electricity).



A prism splits sunlight into its component colours.

Photovoltaic cells are made of elements such as silicon or germanium. A pure silicon crystal, such as glass, is an insulator. Very little electricity will flow through it. However, adding a small amount of impurity (such as phosphorus or arsenic) to the crystal can transform the silicon crystal into a good, but not great, conductor of electricity. Silicon and germanium are called semiconductors.

When light strikes a photovoltaic cell, some of the light's energy knocks electrons loose in the semiconductor, allowing them to flow freely. This movement of electrons is electricity. It can be used to power appliances such as calculators and watches. On a larger scale, lots of solar cells connected together can help power homes, offices and factories.

Solar energy has many advantages over energy from coal, oil and natural gas. Solar energy is non-polluting and freely available. Every day, enough solar energy hits the Earth to meet the world's total daily electric-generating capacity 200 000 times over. Australia receives the highest solar radiation per square metre of any continent.

Solar panels convert solar energy into electricity.

LOOK IT UP

nuclear reaction a reaction that changes the number of protons or neutrons in the nucleus of an atom

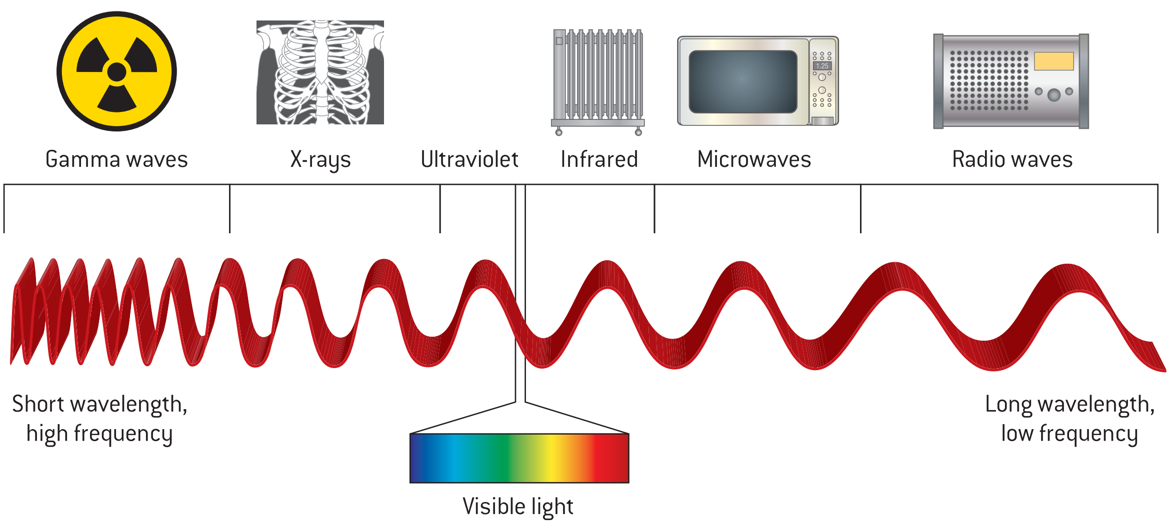
nucleus (chemistry) the positively charged central part of the atom that contains protons and neutrons (plural: nuclei)

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

CHECK IT OUT

1. How is energy produced within the Sun?
2. Name some of the forms of radiation released by the Sun into space.
3. What is the distance of the Sun from Earth?
4. Name three ways in which solar energy is captured and used on Earth.
5. What name do scientists give to solar cells?

THE ELECTROMAGNETIC SPECTRUM



Electromagnetic energy is the term used to describe all the different forms of energy released into space by stars such as the Sun. Most of the Sun's energy is in the form of light and heat.

ENERGY FLOWS

Modern society requires a lot of energy. We regularly change energy from one form into another to meet our needs. For example, a hairdryer turns electricity into heat or thermal energy. A battery converts chemical energy into electricity. A power station converts the chemical energy in fuels into electricity through a number of steps.

When a jet plane takes off, it is converting chemical energy in its fuel into the kinetic energy of motion.

Energy conversions

Energy constantly changes from one form to another. Solar energy heats water in the sea. Heated water molecules move around more quickly, gaining kinetic energy. Some of the molecules move fast enough to form water vapour (a gas).

Water vapour rises into the air. As it rises, the water vapour cools and condenses to form clouds. Clouds contain liquid water and ice. A single cloud can weigh many tonnes. Clouds have potential energy. They release this energy when the water falls to the ground as rain.

Flow diagrams can be used to represent energy conversions.

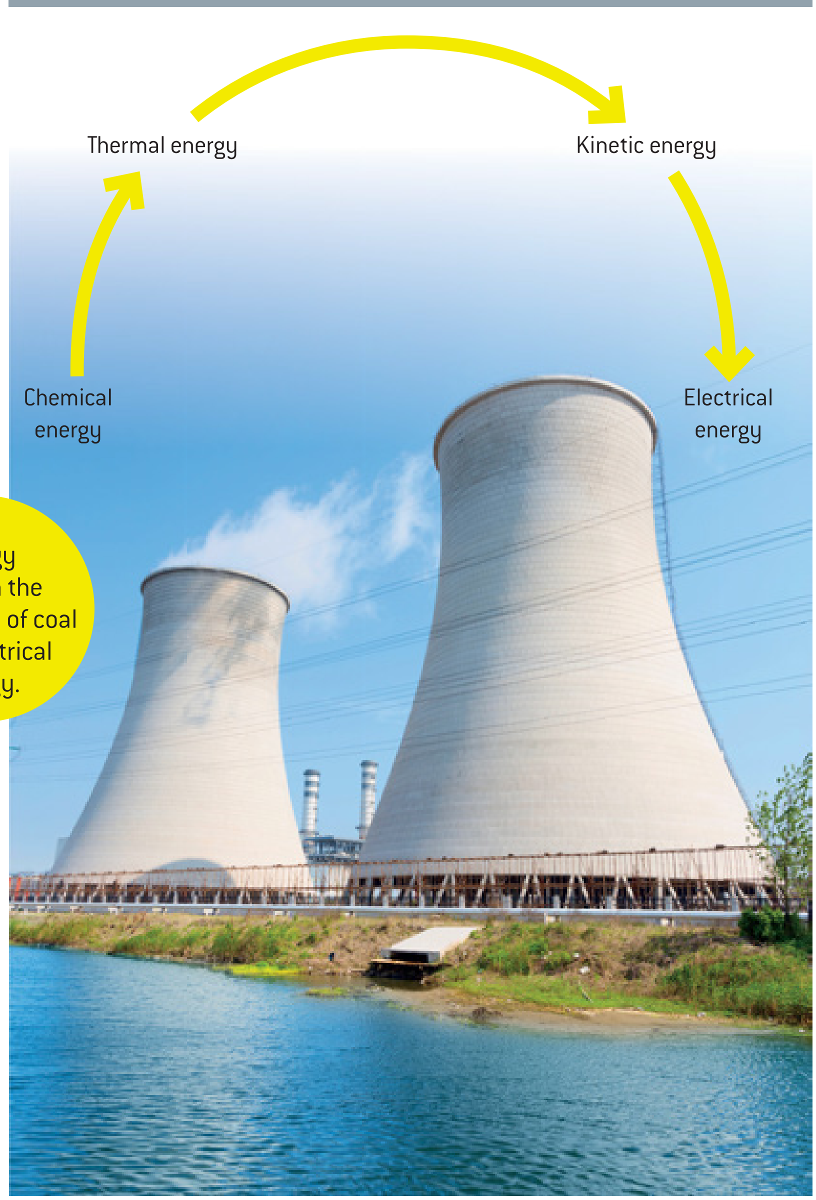
Turning chemical energy into electricity

A power station converts the chemical energy stored in coal into electrical energy.

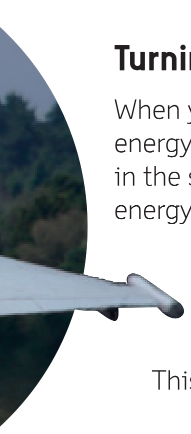
Burning the coal releases the chemical energy as heat (thermal) energy. Water absorbs the heat, turning into steam. The steam moves at high speed, with great kinetic energy. The energy turns a turbine, which converts the kinetic energy into electrical energy.

This energy chain is shown in the flow diagram to the right.

ENERGY CHAIN: ELECTRICITY FROM COAL



The energy chain in the conversion of coal into electrical energy.



Turning chemical energy into sound

When you listen to music on a smartphone, a number of energy conversions occur. The chemical energy stored in the smartphone battery is converted into electrical energy. The electrical energy flows through the wires to the headphones where it is turned into kinetic energy as the speakers in the headphones vibrate. The vibrations are sound energy, which we hear as music.

This energy chain is shown in the diagram below.

Heat is the transfer of energy from an object with a higher temperature to an object with a lower temperature. The heat energy from this hot coffee mug will transfer to the surrounding air and bench top.

ENERGY CHAIN: SMARTPHONE

The energy chain in listening to music on a smartphone.

Heat flow

What will happen to a mug of coffee with a temperature of 80°C if it is sitting on a bench in a room that has a temperature of 20°C?

The answer, of course, is that the mug and coffee will cool. Eventually the coffee will reach room temperature. The mug of coffee is transferring heat to its surroundings. As the coffee cools, the average speed or kinetic energy of its particles decreases. You can think of heat as the transfer of energy from a hot object to a colder object.

What will happen to a glass of lemonade with a temperature of 10°C in the same room? The glass of lemonade will warm until it is the same temperature as the room. In this example, heat from the room is transferred to the lemonade.

CHECK IT OUT

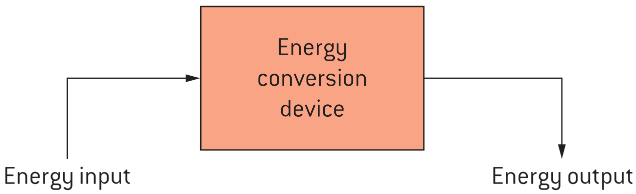
1 What information is provided by an energy chain flow diagram?
2 Draw a flow diagram showing the energy changes when:
   a a cricket player hits the ball high into the air
   b a person bungee jumps from a bridge
   c a person uses a toaster powered by electricity from a nuclear power plant.
3 Why will a hot object cool down to reach the temperature of its surroundings?
4 Draw a flow diagram showing the energy changes for the following conversions:
   a speaking to a friend
   b boiling water in an electric kettle
   c generating electricity in a hydroelectric power station.
5 Name a device that will convert:
   a electricity into chemical energy
   b kinetic energy into potential energy
   c electricity into sound.

ENERGY EFFICIENCY

Energy conversions produce waste energy. The waste energy is usually heat.

Losing energy

The total amount of energy always stays the same during an energy conversion. This is known as the First Law of Thermodynamics.



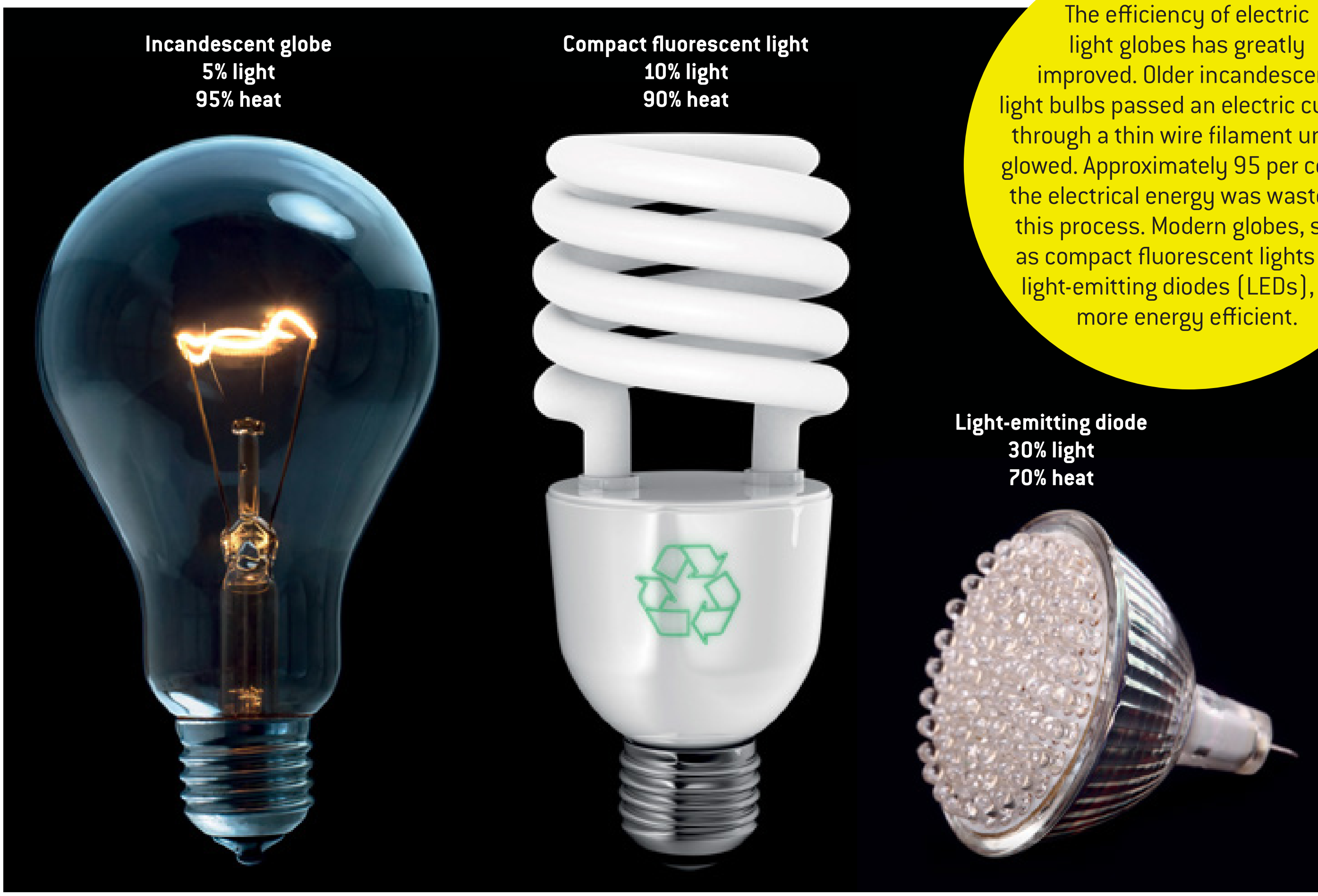
The First Law of Thermodynamics states that energy input = energy output.

However, energy conversions are inefficient and produce some waste energy. This means energy conversions occur at less than 100 per cent efficiency.

Think about the conversion of electrical energy into light in a light globe. A light globe that is 100 per cent efficient would convert all of the electricity into light. We know that globes don't do this because they get hot. Some of the electricity is being wasted as heat.

An energy conversion can never be greater than 100 per cent. Energy cannot be created during a conversion. For example, a car engine can never produce more power than the chemical energy contained in the petrol that goes into it.

An average car engine operates at only about 25 per cent efficiency. This means that 75 per cent of the chemical energy in the petrol is wasted, mostly as heat. Heat is the most common form of wasted energy. TVs, refrigerators and car engines all get hot when they are being used.



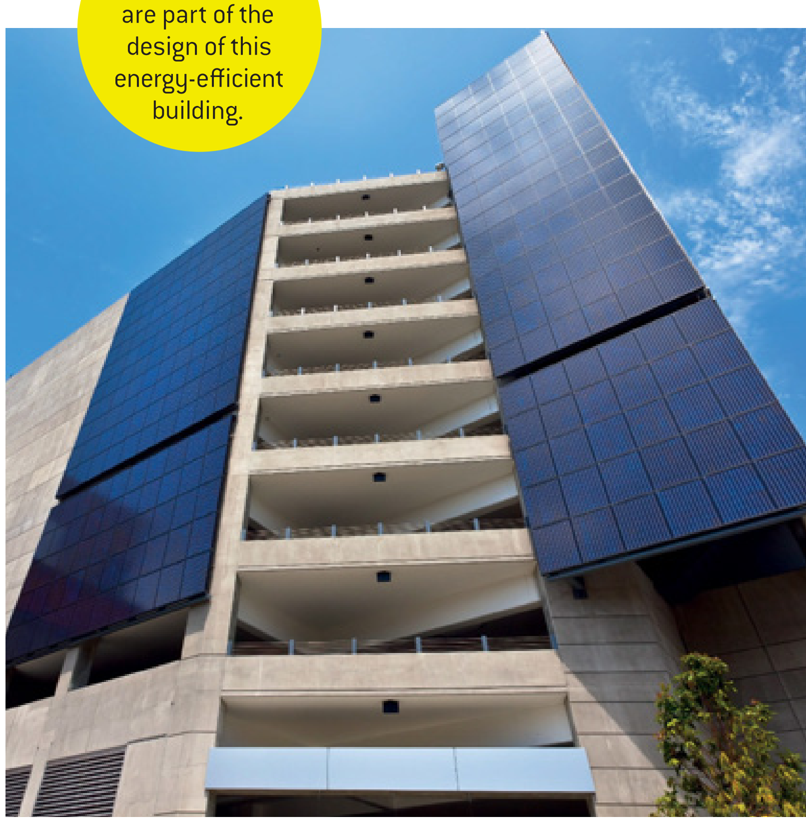
The efficiency of electric light globes has greatly improved. Older incandescent light bulbs passed an electric current through a thin wire filament until it glowed. Approximately 95 per cent of the electrical energy was wasted in this process. Modern globes, such as compact fluorescent lights and light-emitting diodes (LEDs), are more energy efficient.

The energy efficiencies of common devices

ENERGY CONVERSION DEVICE	TYPICAL EFFICIENCY (%)
Hair dryer	Almost 100
Electric heater	Almost 100
Electric generator	95
Battery	90
Steam turbine	45
LED (light-emitting diode) globe	30
Refrigerator	30
Car engine	25
Fluorescent globe	25
Human muscle	20
Incandescent (traditional) globe	5

More stars mean a more energy-efficient appliance, which will be cheaper to operate.

Solar panels are part of the design of this energy-efficient building.



Scientists and engineers are trying to design products that are more **energy efficient**. These are cheaper to run as you are not paying for energy that is being wasted.

Measuring energy efficiency

$$\text{Energy efficiency} = \frac{\text{useful energy output}}{\text{energy input}}$$

Scientists measure power in watts. For example, a battery may consume chemical energy at the rate of 100 watts every second and produce electricity at a rate of 90 watts.

$$\text{Battery energy efficiency percentage} = \frac{90}{100} \times 100 = 90\%$$

From power station to our homes

A lot of energy is lost, usually as heat, in generating power and supplying it to homes and industry.

» When coal burns, 90 per cent of its energy is transferred to making steam – 10 per cent of the coal's energy is lost at this point.

» Just 45 per cent of the steam's energy is converted into spinning the turbine.

» Almost all of the spinning turbine's energy gets turned into electricity.

» Sending electricity long distances via transmission lines can lose 10 per cent of the energy.

Individual appliances, such as TVs, washing machines and ovens, also waste energy. That is, not all of the energy supplied to them is turned into useful output. Traditional incandescent globes are very inefficient and waste lots of energy as heat. An incandescent globe typically turns less than 1 per cent of the original energy stored in the coal into light energy. Australia is phasing out incandescent globes, replacing them with energy-efficient ones.

LOOK IT UP

energy conversion the process of changing one form of energy into another

energy efficiency how much of the energy used by a device is useful

CHECK IT OUT

1 What happens to the total amount of energy during a conversion from one energy form to another?

2 What evidence is there that car engines do not convert all the chemical energy in petrol into motion?

3 A jackhammer wastes 80 per cent of the supplied energy. What is its energy efficiency?

4 What is the energy efficiency of a machine that turns 50 watts per second of electricity into 20 watts of useful work?

EXPERIMENT #15

MEASURING ENERGY EFFICIENCY

AIM: TO INVESTIGATE THE ENERGY EFFICIENCY OF A TENNIS BALL BOUNCING ON DIFFERENT SURFACES

MATERIALS

- Tennis ball
- 1-m ruler
- A range of different surfaces such as concrete, dirt, grass and sand

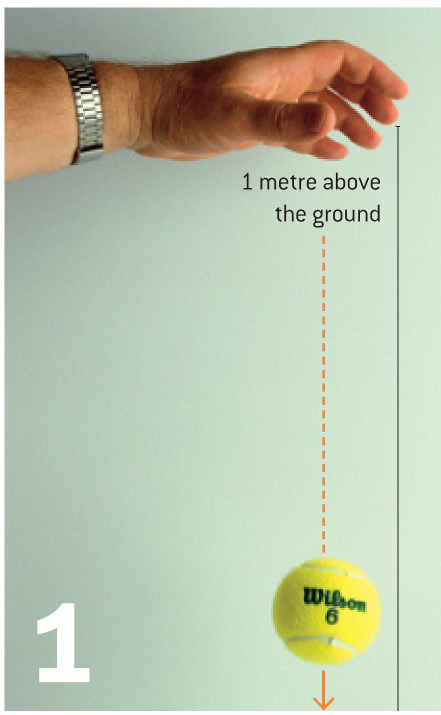
METHOD

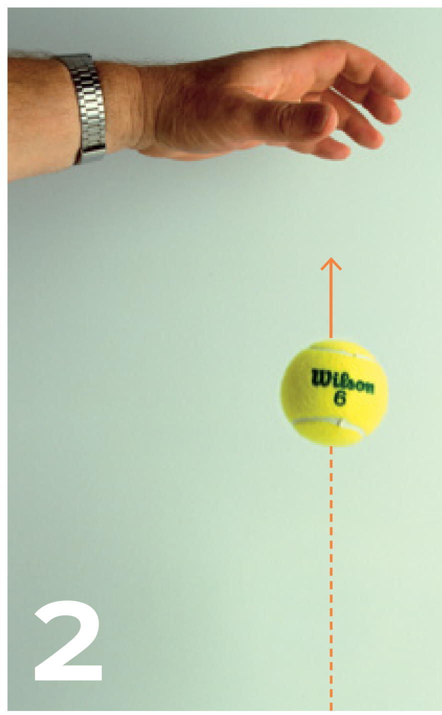
1 Drop the tennis ball from 1 m above the concrete.

2 Measure how high the ball bounces and record your result in a table similar to the one in the Results section.

3 Repeat the measurement four times and calculate the average height of the bounce.

4 Repeat the above steps for the other surfaces. Record the results for each different surface in a separate table.





RESULTS

1 Calculate the percentage energy efficiency of each surface. The percentage energy efficiency of the tennis ball's bounce is

$$\frac{\text{bounce height}}{\text{starting height}} \times 100.$$

If the starting height is 1 m (100 cm), the bounce height in centimetres is equivalent to the energy efficiency.

SURFACE TYPE:		
TRIAL NUMBER	BOUNCE HEIGHT (CM)	AVERAGE BOUNCE HEIGHT (CM)
1		
2		
3		
4		
Percentage energy efficiency for this surface:		

DISCUSSION

1 Name the main form of energy that the tennis ball has:

a before it is dropped

b just before it hits the ground

c when it is in contact with the ground

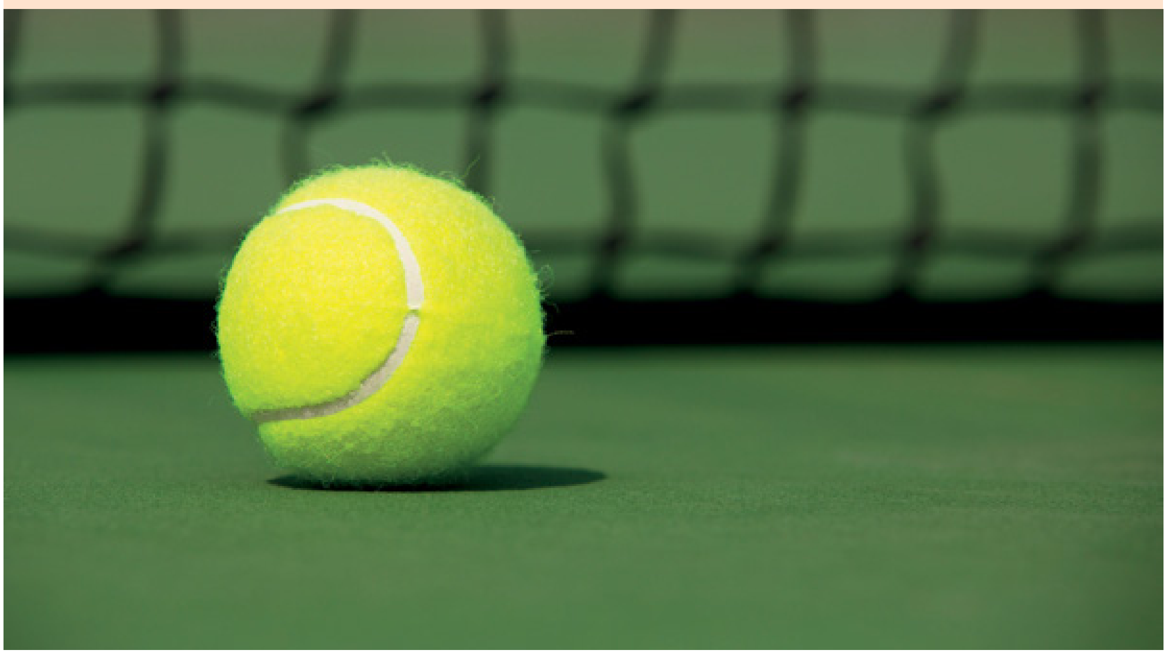
d just before it reaches its maximum height again.

2 Discuss any errors you noticed in the experiment and suggest how they could be reduced.

CONCLUSION

1 Which surface is most energy efficient? Suggest reasons why.

2 Which surface is least energy efficient? Suggest reasons why.



EXPERIMENT #16

EFFICIENT LIGHTING

AIM: TO CALCULATE THE COST OF BUYING AND RUNNING EACH OF THREE TYPES OF LIGHT GLOBE

METHOD

On average, a traditional incandescent globe lasts for 1000 hours before needing to be replaced. So, 50 globes will be needed for 50 000 hours of use. The cost of buying these globes would be:

$$50 \times \$1.50 = \$75$$

1 Copy the table into your workbook.

2 Calculate the number of CFL and LED globes needed for 50 000 hours of use. Enter these values into the table.

3 Calculate the cost of CFL and LED globes and enter the values into the table.

Incandescent globes use 60 watts or 0.06 kilowatts of electrical energy. The number of kilowatt hours (the unit we use to pay for electricity) is:

$$0.06\,\text{kW} \times 50\,000 \text{ hours} = 3000\,\text{kWh}$$

4 Calculate the number of kilowatt hours of electricity required by the CFL and LED globes and enter the values into the table.

The cost of a kilowatt hour of electricity is approximately 30 cents. So, the cost of running incandescent globes for 50 000 hours is:

$$3000\,\text{kWh} \times \$0.30 = \$900$$

5 Calculate the cost of running CFL and LED globes for 50 000 hours and enter the values into the table.

The total cost of the incandescent globes is equal to the cost of the globes plus the cost of the electricity:

$$\$75 + \$900 = \$975$$

6 Calculate the cost of the CFL and LED globes and enter the values into the table.

	INCANDESCENT GLOBE	COMPACT FLUORESCENT GLOBE (CFL)	LIGHT-EMITTING DIODE GLOBE (LED)
Power (watts)	60	14	10
Life (hours)	1000	10 000	50 000
Cost per globe	$1.50	$3.50	$35.00
Number of globes needed for 50 000 hours of use	50		
Cost of globes	$75		
kWh of electricity used over 50 000 hours	3000		
Electricity cost for 50 000 hours of use	$900		
TOTAL COST (ELECTRICITY COST + COST OF GLOBES)	$975		

7 Calculate the savings associated with replacing an incandescent globe with an LED globe over 50 000 hours of use.

8 Calculate the savings associated with replacing 25 incandescent globes in a home with LED globes for 50 000 hours of use each.

9 Assuming that a light is turned on for 8 hours a day, calculate how many years it will take to achieve 50 000 hours of use.

CONCLUSION

Summarise your findings about the cost of buying and running these three types of light globes.

Incandescent light globes are inefficient, wasting a lot of energy as heat.

LED light globes are efficient and much cheaper to run than incandescent globes.

ENERGY

ENERGY IS ALL AROUND US (PAGES 130–131)

1 List eight different forms of energy.
2 Describe three ways in which we use energy from the Sun.
3 What is kinetic energy and when do objects have a lot of it?
4 What is potential energy? State an example of an object having a lot of potential energy.
5 List examples of how you have used thermal energy today.

ENERGY OF MOTION (PAGES 132–133)

6 Define the term 'work'.
7 Explain why, according to the scientific definition of work, the beams holding up the roof of a house are doing no work.
8 Which has more kinetic energy: a 600-kilogram car travelling at 55 kilometres per hour or a 10 000-kilogram truck travelling at 55 kilometres per hour? Explain your answer.
9 How does hydroelectricity work?
10 Describe a situation in your favourite sport that involves high kinetic energy.

POTENTIAL ENERGY (PAGES 134–135)

11 Describe the main form(s) of potential energy (gravitational, chemical or elastic) of each of the following:
  a a sling shot ready to be fired
  b a tonne of coal in a power station
  c a monkey sitting in a tree
  d an arrow moving at its highest point
  e a car battery.

5 DIFFERENT FORMS OF ENERGY (PAGES 136–137)

12 Describe thermal energy in terms of the behaviour of particles.
13 What is sound energy?
14 Briefly describe the source of nuclear energy.
15 Name the form of energy emitted by stovetops.
16 How far does sound travel through air in one minute?

17 What is the main form of energy in each of the following situations?
  a crops growing in the fields
  b the Sun shining through a window on a sunny day
  c a girl riding her skateboard
  d a stretched rubber band
  e a train travelling along a track
  f a litre of petrol
  g a mobile phone battery
  h a clap of thunder
  i a stick of dynamite.

FROM COAL TO ELECTRICITY (PAGES 140–141)

18 Draw a simple diagram showing the steps involved in converting the energy stored in coal into electricity.

19 What is the function of the following parts of a coal-burning power station?

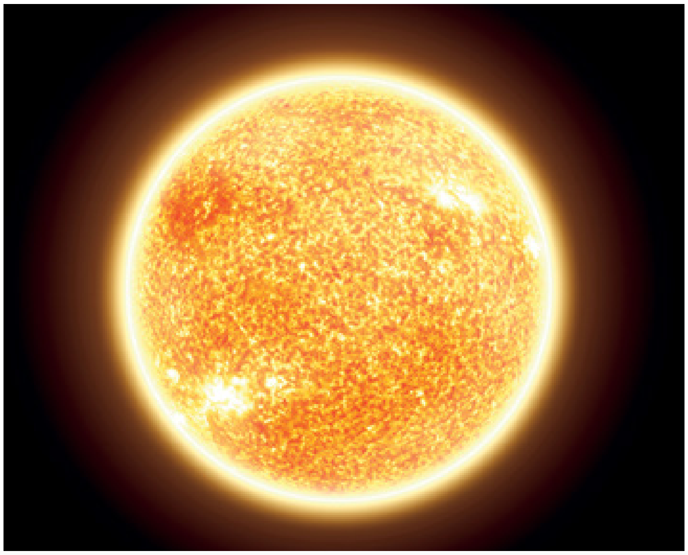
- **a** furnace
- **b** turbine
- **c** smoke stack
- **d** generator

ENERGY FROM THE SUN (PAGES 142–143)

20 What is the source of the Sun's energy?

21 What is the term used to describe all the different forms of energy released by stars such as the Sun?

22 List two advantages and two disadvantages of electricity supplied by solar cells rather than from coal-fired power stations.



ENERGY FLOWS (PAGES 144–145)

23 Draw a flow diagram showing the energy changes for the following conversions:

- **a** hitting a drum
- **b** blasting a rock face with TNT explosive
- **c** kicking a football.

24 Name a device that will convert:

- **a** electricity into kinetic energy
- **b** sound into electricity
- **c** electricity into sound
- **d** potential energy into kinetic energy.

ENERGY EFFICIENCY (PAGES 146–147)

25 Calculate the efficiency of an amplifier that converts 1000 watts per second of electricity into 400 watts per second of sound.

26 What is the most common form of wasted energy?

27 Do you agree with the following statement: 'It is always better to buy an energy-efficient appliance than one that is inefficient'? Give reasons for your answer.

KEY IDEAS

1 Energy lets us do things. It exists in many different forms.

2 The energy of motion is called kinetic energy. Heavy, fast-moving objects have the greatest kinetic energy.

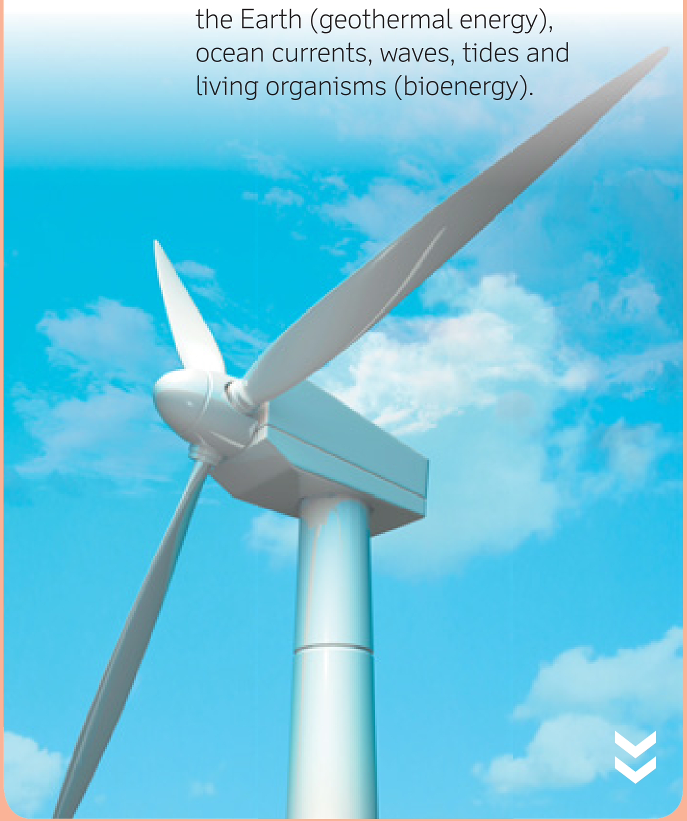
3 Energy that is stored in objects and is available to be used is called potential energy. Three types of potential energy are gravitational, chemical and elastic energy.

4 Other forms of energy include electrical, thermal (heat), radiant, sound and nuclear energy.

5 A thermal power station can convert the energy stored in coal into electricity. Burning the coal produces steam, which spins a turbine that then generates electricity.

6 The Sun represents the largest source of energy received by the Earth. The Sun's energy comes from nuclear reactions.

7 Coal, natural gas and oil are non-renewable energy sources. Eventually they will run out. Renewable sources of energy include the Sun, wind, heat in the Earth (geothermal energy), ocean currents, waves, tides and living organisms (bioenergy).



8 We regularly change energy from one form into another to meet our needs. All around us are devices and appliances that do this.

9 Energy conversions lead to the production of wasted energy. The wasted energy is usually heat.

10 The energy efficiency of a device is the useful energy output divided by the amount of energy originally provided.

$$\text{Energy efficiency} = \frac{\text{useful energy output}}{\text{energy input}}$$

GLOSSARY

air pressure
the force of air pushing against an object

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

amino acid
a small compound that makes up a protein; building block of proteins

amoeba
a single-celled organism that can change its shape

anatomy
the study of the bodily structure of animals and plants

anus
the opening at the end of the digestive system through which solid waste matter leaves the body

aorta
the largest blood vessel in the body, which starts at the top of the heart and extends downwards

aortic valve
a one-way valve (flap of tissue) in the main artery of the body

apoptosis
the controlled death of cells as part of an organism's development

artery
a thick, muscular-walled blood vessel that carries oxygenated blood away from the heart

arteriole
a small branch of an artery leading into capillaries

asexual reproduction
to reproduce without a mate

atmosphere
the layer of gases surrounding the Earth and other planets

atom
the smallest particle of a substance that can exist

atrium
each of the two upper cavities of the heart from which blood is passed to the ventricles (plural: atria)

axon
the part of a nerve cell (neuron) that carries a nerve impulse away from the cell body

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

bauxite
a clay-like mineral ore containing alumina and other minerals

binocular
adapted for using both eyes

bioenergy
a renewable energy produced by organisms that are living or were once alive

bladder
a hollow organ in the pelvis that stores urine

blood vessels
arteries, veins and capillaries that transport blood around the body

body system
a group of different organs working together, e.g. digestive system

calcium carbonate
a white, insoluble solid occurring naturally as chalk, limestone and marble

capillaries
small blood vessels connecting arteries and veins

caramelisation
the process of cooking sugar until it browns

carbohydrate
a class of compound containing carbon, hydrogen and oxygen atoms

carbon
a non-metallic element occurring in a pure form as graphite and diamond; is in all organic compounds

carbon dioxide
a colourless, odourless gas with formula CO_2

carcinogen
a cancer-causing substance

cells
the building blocks of living things

cell membrane
the barrier around a cell that controls the entry and exit of substances into and out of a cell

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

change of state
the transformation of matter from one form to another, i.e. solid to liquid (melting), liquid to gas (evaporating), solid to gas (sublimation), liquid to solid (freezing), gas to liquid (condensation)

chemical bond
the attraction between atoms that allows the formation of chemical substances that contain two or more atoms

chemical change
where a new substance is formed with different properties

chemical digestion
the breakdown of food by enzymes and acids

chemical energy
energy stored in chemicals, e.g. in food, fuel and explosives

chemical potential energy
energy that is stored in atoms and the bonds between them

chemical property
a property used to characterise materials in reactions that change their identity

chemical reaction
a process in which one or more substances are converted to different substances

chemotherapy
the treatment of disease, such as cancer, by the use of chemical substances

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

chloroplast
a structure (organelle) mainly found in large numbers in the leaf cells of plants; contains chlorophyll

chromatography
a method of separating and analysing mixtures of chemicals

chromosome
a structure made of DNA that contains all of the information used to help a cell grow and reproduce; located in the nucleus of animal and plant cells

classify
to arrange things into categories depending on the properties they share

cleavage
the way in which a rock splits when hit

combination reaction
a reaction in which two reactants combine to form one product

composition
what something is made of, e.g. a rock's composition includes its crystal structure and crystal size

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

compress
to reduce in volume

condensation
the change of state from a gas to a liquid

conductivity
how easily something moves through a substance

conglomerate
sedimentary rock made up of rounded pebbles that have been cemented together

continental crust
a relatively thin, hard and brittle outer layer of the Earth beneath a continental land mass

corpse
a dead body

cover slip
a thin, flat piece of transparent material placed over an object for viewing with a microscope

crystal
a solid substance with its atoms organised in a regular pattern with flat surfaces; the structure of a crystal influences a mineral's properties

cytoplasm
the material found inside the cell; includes fluid (cytosol) and mini organs (organelles)

cytosol
the fluid in cells

dendrites
short branched projections of a neuron's cell body; receive impulses from other neurons and transmit these to the cell body

density
the mass per unit volume

deposition
the change of state from a gas to a solid

diaphragm
the muscle that lifts the rib cage to increase suction of air into the lungs

diffusion
a movement of gas or dissolved substance from a region of higher concentration to a region of lower concentration

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

digestive system
the organs and glands in the body responsible for digesting food

DNA
deoxyribonucleic acid; the carrier of genetic information

dry-stone wall
a wall constructed by fitting rocks together without anything to stick them together

dynamite
a high explosive made up of a nitroglycerin mixture

elastic potential energy
energy stored in elastic materials, such as springs, as the result of stretching or compressing

electrical energy
energy associated with electric charge, either stationary or moving

electrode
a conductor through which electricity enters or leaves an electrolyte

electron
a negatively charged particle found in atoms

electron microscope
a microscope with high magnification and resolution; uses an electron beam instead of light

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

energy conversion
the process of changing one form of energy into another

energy efficiency
how much of the energy used by a device is useful

enzyme
a substance produced by living organisms that helps make chemical reactions happen

epiglottis
a flap that closes during swallowing to cover the windpipe

epoch
a particular span of time in history, shorter than a geological era or period, and longer than an age

erosion
the carrying away (by water, wind etc.) of particles of the Earth's surface that have been worn away by weathering

ester
a compound that often has a pleasant smell

ethanol
an alcohol formed from fermentation of sugars

evaporation
the change of state from liquid to a gas

excretion
the removal of waste products from the body

exothermic reaction
a reaction that releases heat

explosion
a sudden violent change caused by a chemical reaction

extrusive igneous rock
rock formed when lava from a volcanic eruption cools quickly on the Earth's surface

fermentation
the breakdown of a substance by microbes such as yeasts and bacteria; the process involved in making alcohol and bread

fluid
a substance with no fixed shape that is capable of flowing; liquid or gas

foetus
a stage in the development of a mammal, particularly an unborn human more than 8 weeks after conception

fossil
the imprints of an animal, plant, bacteria or other living organism preserved in rock

fossil fuel
a fuel such as coal, oil and natural gas that is produced from ancient organisms (mainly plants) that lived millions of years ago

freezing
the change of state from liquid to a solid

fructose
a sugar found in honey and fruits

gall bladder
the small organ under the liver that stores bile; part of the digestive system

gallium
a soft, blue-grey metallic element

gemstone
a precious or semi-precious stone, especially one that is cut, polished and used in jewellery

genetic
relating to genes or passing on of features from one generation to another

geothermal energy
the heat generated and stored in the Earth

gestation
the process or period of developing inside the womb between conception and birth

gill
an organ in fish that extracts dissolved oxygen from water and releases carbon dioxide

glucose
a simple sugar containing six carbon atoms

granite
a common, hard igneous rock

graphene
a one-atom thick sheet of pure carbon

graphite
a pure form of carbon; used in pencils

gravity
the force of attraction that objects have towards one another due to their masses

hardness
a measure of the resistance of a mineral to being scratched

heart
a muscular organ that pumps blood through blood vessels

hydroelectric power
the production of electrical power from falling or flowing water

hydrogen
a colourless, gaseous element; the smallest atoms in the periodic table

igneous rock
a type of rock formed from lava on the surface or magma beneath the ground

intrusive igneous rock
rock formed when magma cools and solidifies slowly beneath the Earth's surface

kinetic energy
energy of motion of moving objects

lava
melted rock (magma) that has reached the surface when a volcano erupts

lens
(biology) a curved, transparent structure that focuses light on the retina

limestone
a hard sedimentary rock composed of calcium carbonate ($CaCO_3$)

lungs
a pair of breathing organs that bring oxygen to the blood and remove carbon dioxide

lustre
a measure of the gloss or brilliance of reflection of light from a mineral's surface

magma
molten rock beneath the Earth's surface

magnetic field
the region around a magnetic material or a moving electric charge within which the force of magnetism acts

magnify
to increase the size of an image

mantle
the 2900-km-thick layer of the Earth that lies beneath the crust

marble
a hard form of limestone, often used in sculpture and buildings

matter
a substance with mass and volume

melting
the change of state from solid to a liquid

membrane
a sheet-like structure acting as a lining or boundary in an organism

metamorphic rock
a type of rock formed when igneous, sedimentary or older metamorphic rocks are heated or squeezed

methane gas
an odourless, colourless, flammable gas; compound of carbon and hydrogen

microbiology
the study of microscopic organisms

micrometre (μm)
one millionth of a metre

microscope
an instrument that magnifies (increases) the size of objects

mineral
a naturally occurring solid substance with its own chemical composition, structure and properties

mitochondrion
a powerhouse organelle of a cell; the site of energy production (plural: mitochondria)

mitosis
the process of cell division to provide growth or repair; results in two daughter cells identical to the parent cell

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

monocline
a fold in a rock layer

monocular
with or for one eye

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

mutagen
an agent promoting mutation, e.g. radiation

nanotechnology
the manipulation of matter on an atomic or molecular level

nephrons
tiny structures in the kidneys that filter the blood; functional units of the kidney

nerve impulse
an electrical signal that travels along an axon

nerves
the fibres in the body that carry messages to and from the brain, so that parts of the body can feel and move

nervous system
the brain, spinal cord and sense organs, as well as all of the nerves that connect these organs with the rest of the body

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

nuclear energy
energy stored in the nucleus of an atom; released in nuclear reactors or explosions of nuclear weapons

nuclear reaction
a reaction that changes the number of protons or neutrons in the nucleus of an atom

nucleus
(chemistry) the positively charged central part of an atom; contains protons and neutrons; (biology) the control centre of the cell, providing instructions for every job that the cell needs to do (plural: nuclei)

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

oesophagus
a part of the digestive system; a tube that carries food from the mouth to the stomach

operculum
a hard bony flap that protects the gills

ore
a mineral containing a large amount of metal or other valuable substance

organ
a group of tissues that work together, e.g. liver, heart, eyes, brain, skin

organelle
a part of a cell with a special function

ovaries
female reproductive organs; contain egg cells

oxygen
a colourless, odourless reactive gas; the life-supporting component of air

painite
one of the world's rarest minerals

palaeontologist
a scientist who studies fossils to understand ancient life

particle
a building block of matter

particle model
a model in which all matter is made up of tiny particles that behave in different ways depending on whether the substance is a solid, liquid or gas

penis
the male organ for mating and urinating

periodic table
an ordered table of the elements

petrification
the chemical replacement of wood, bones, teeth and shells by minerals dissolved in water

petroleum
a natural oil that is pumped from the ground; also known as crude oil; a fossil fuel

pharynx
the cavity with muscles behind the nose and mouth, connecting them to the oesophagus

physical change
a change in state between solid, liquid and gas form

physical properties
properties that can identify substances, e.g. appearance, texture, colour, odour, melting point, boiling point and density

placenta
an organ in the uterus of pregnant mammals for nourishing the foetus

plasma
(physics) an electrically charged gas, occurring at very high temperatures or low pressures; (biology) the colourless liquid part of blood

plate tectonics
the slow, long-term and large-scale movement of the Earth's upper layers, called plates

pollination
the process that occurs in flowering plants when pollen lands on the stigma

potential energy
energy stored in objects available for use

precipitate
an insoluble solid substance

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

property
a characteristic, quality or feature that distinguishes something from other things, e.g. the properties (characteristics) of a mineral

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

pumice
a light, porous volcanic rock used in cleaning or polishing

radiant energy
energy that travels by waves; can travel through space

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

rare-earth element
a group of chemically similar metallic elements; despite the name, some are quite common in the Earth's crust although not in high concentrations

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

respiration
the breakdown of glucose and oxygen into water, carbon dioxide and energy; usually occurs in the mitochondria of a cell

ribosome
a cell organelle where protein production takes place

rock cycle
a concept explaining how the three rock types (igneous, metamorphic and sedimentary) are related to each other and how they change from one type to another over time

ruminant
mammal that chews cud regurgitated (brought up again) from its four-compartment stomach to further break down the cellulose, which is difficult to digest

sandstone
a sedimentary rock consisting of sand or quartz grains cemented together

scanning electron microscope (SEM)
a type of electron microscope that bounces a beam of electrons off the surface of a specimen to create a 3D image

sediment
(chemistry) matter that settles to the bottom of a liquid; (geology) particles of rock eroded from the landscape, and then transported and deposited by water and wind

sedimentary rock
rock formed when layers of particles (sediments) are pressed together by the weight of the overlying rock, or when water evaporates to leave behind a solid substance

seismic waves
waves in the Earth produced by an earthquake

semen
the male reproductive fluid, consisting of sperm in suspension

sexual reproduction
the production of new living organisms by combining genetic information from two individuals of different sexes

shale
a common sedimentary rock

silicon
a non-metallic element used in making electronic circuits

sound energy
vibrations passing through solids, liquids and gases

spawn
the eggs of fish, frogs and other aquatic organisms

specimen
a small sample to be studied or displayed

sperm
male reproductive cells

sternum
(breastbone) the bone to which the ribs are attached

stigma
a component of the female reproductive part of a flower

stimulant
a substance that raises levels activity in the body, e.g. caffeine

sublimation
the change of state straight from a solid to a gas

substance
a matter that has a specific composition and specific properties

sweat gland
a small tube in the skin that releases sweat

thermal energy
heat energy

tissue
a group of cells that do a similar task

trachea
the windpipe through which air passes to the lungs

transmission electron microscope (TEM)
a type of electron microscope that sends a beam through a specimen to form a highly magnified image

transparency
a measure of how much light can pass through a material, such as a mineral

trinitrotoluene (TNT)
an explosive chemical

tumour
a growth caused by faulty cells growing out of control

unicellular
consisting of just one cell, e.g. bacteria

ureters
a pair of tubes through which urine passes from the kidneys to the bladder

urethra
the tube that leads from the bladder; transports and discharges urine outside the body

urine
a pale yellow fluid stored in the bladder and discharged through the urethra

uterus
the hollow muscular organ in the pelvic cavity of female mammals; the site where a fertilised egg implants and develops into a foetus

vacuole
the space within the cytoplasm of a cell, enclosed by a membrane

vagina
the canal between the cervix and vulva of a female mammal

valve
a flap present in veins and the heart that allows blood flow in only one direction

vapour
a visible gas to which some substances can be converted by heat

vein
a thin blood vessel that carries blood towards the heart

ventricle
a lower chamber of the heart

vitamin
a compound essential in small amounts in the diet for health and development

voltage
a measure of electrical force

volume
the space occupied by a solid, liquid or gas

vulcanisation
the hardening of rubber by treating it with sulfur at high temperature

water vapour
an invisible, gaseous form of water

weathering
the process by which rocks are broken down into small grains and soil by natural processes caused by wind, acid rain, plants and animals etc.

work
occurs when a force moves an object

yeast
a microscopic fungus capable of converting sugar into alcohol and carbon dioxide

zygote
a fertilised egg cell; develops into an embryo

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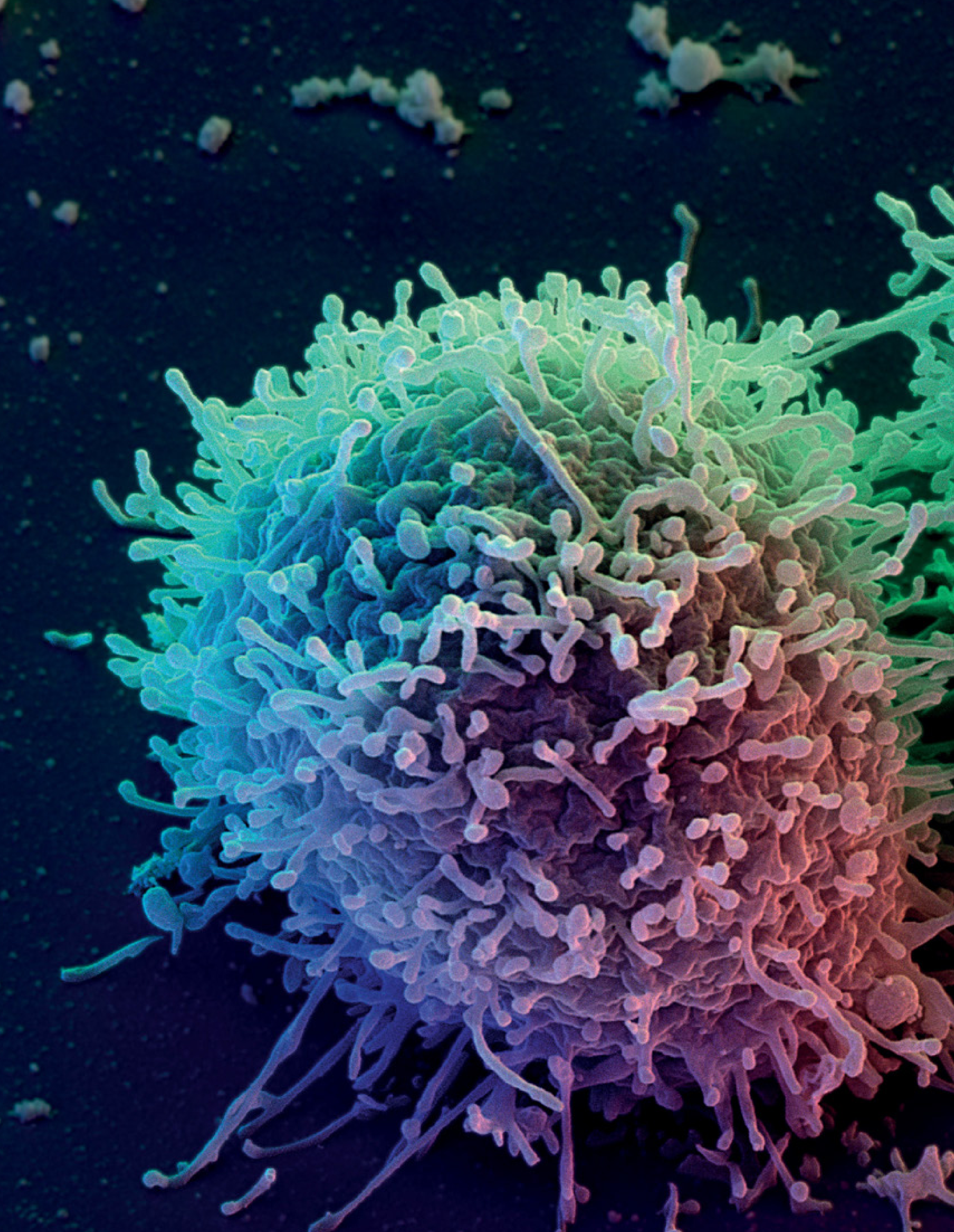

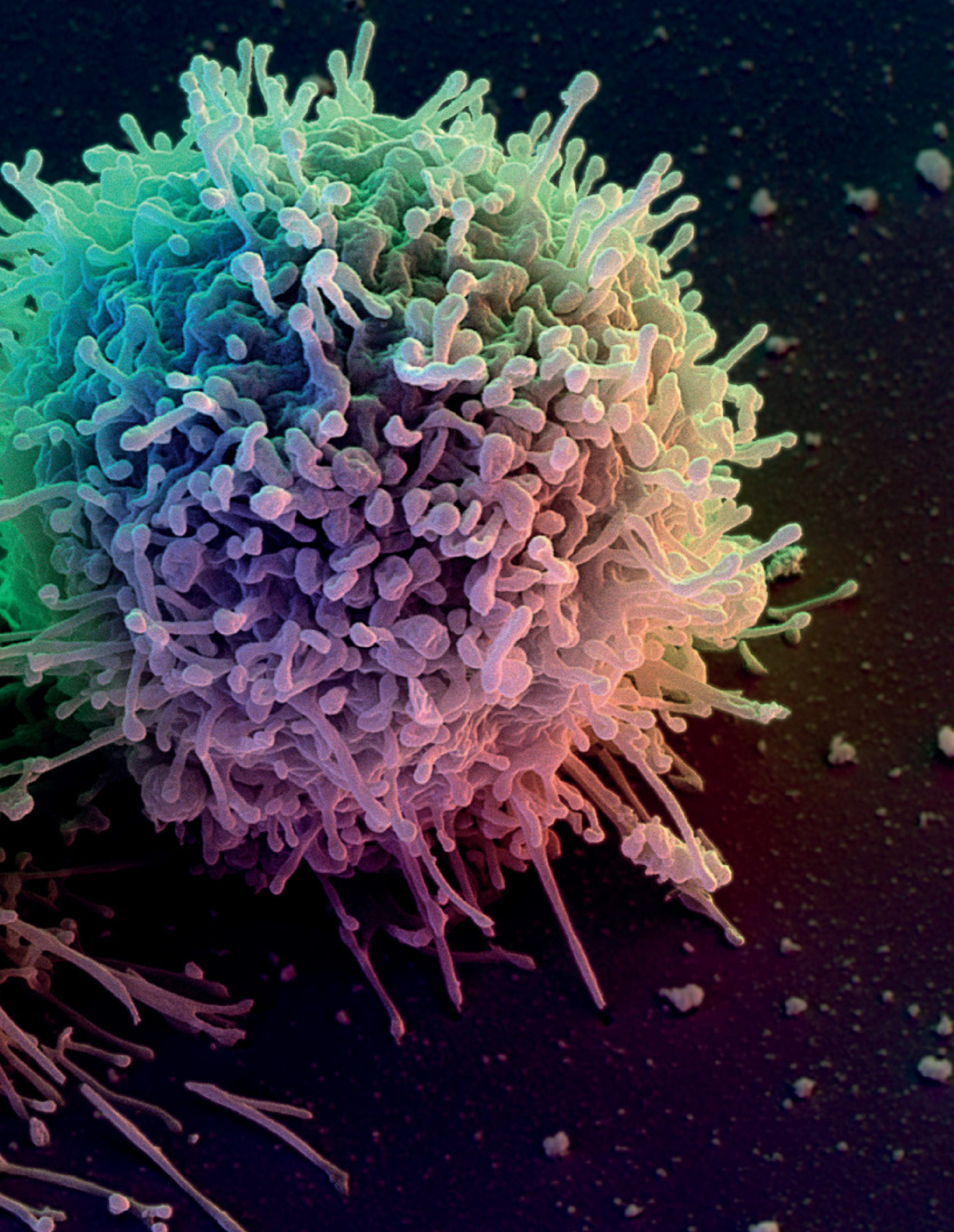

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