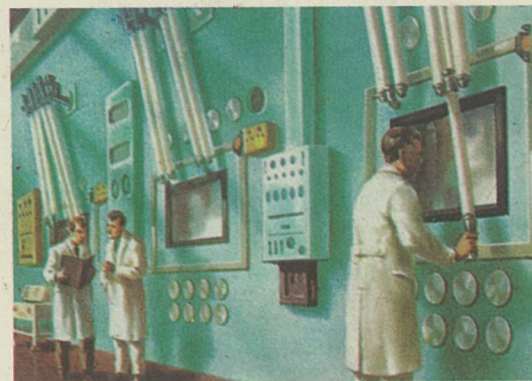
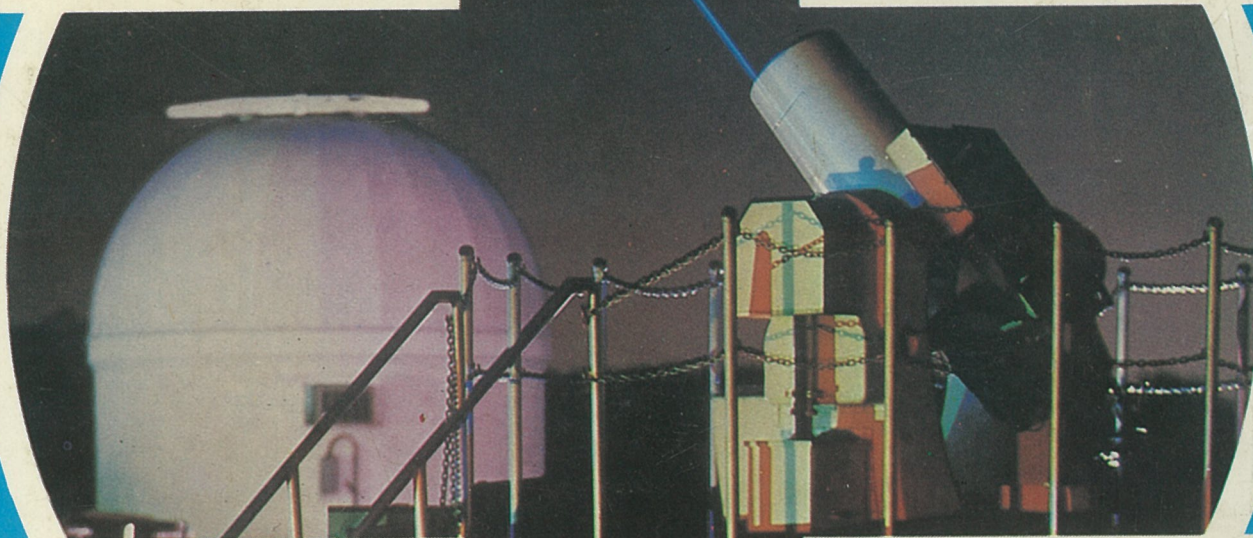
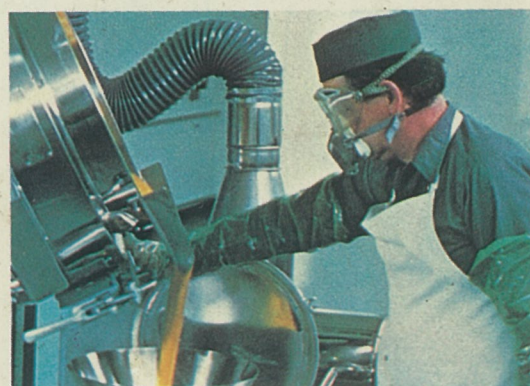
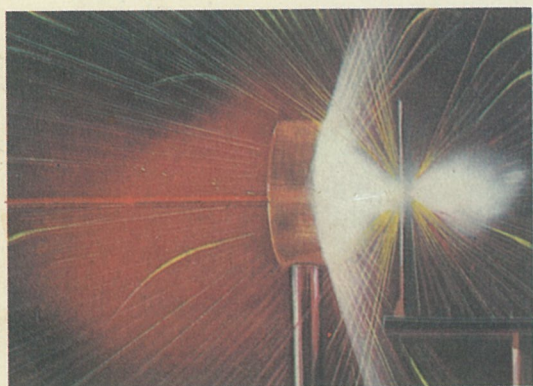


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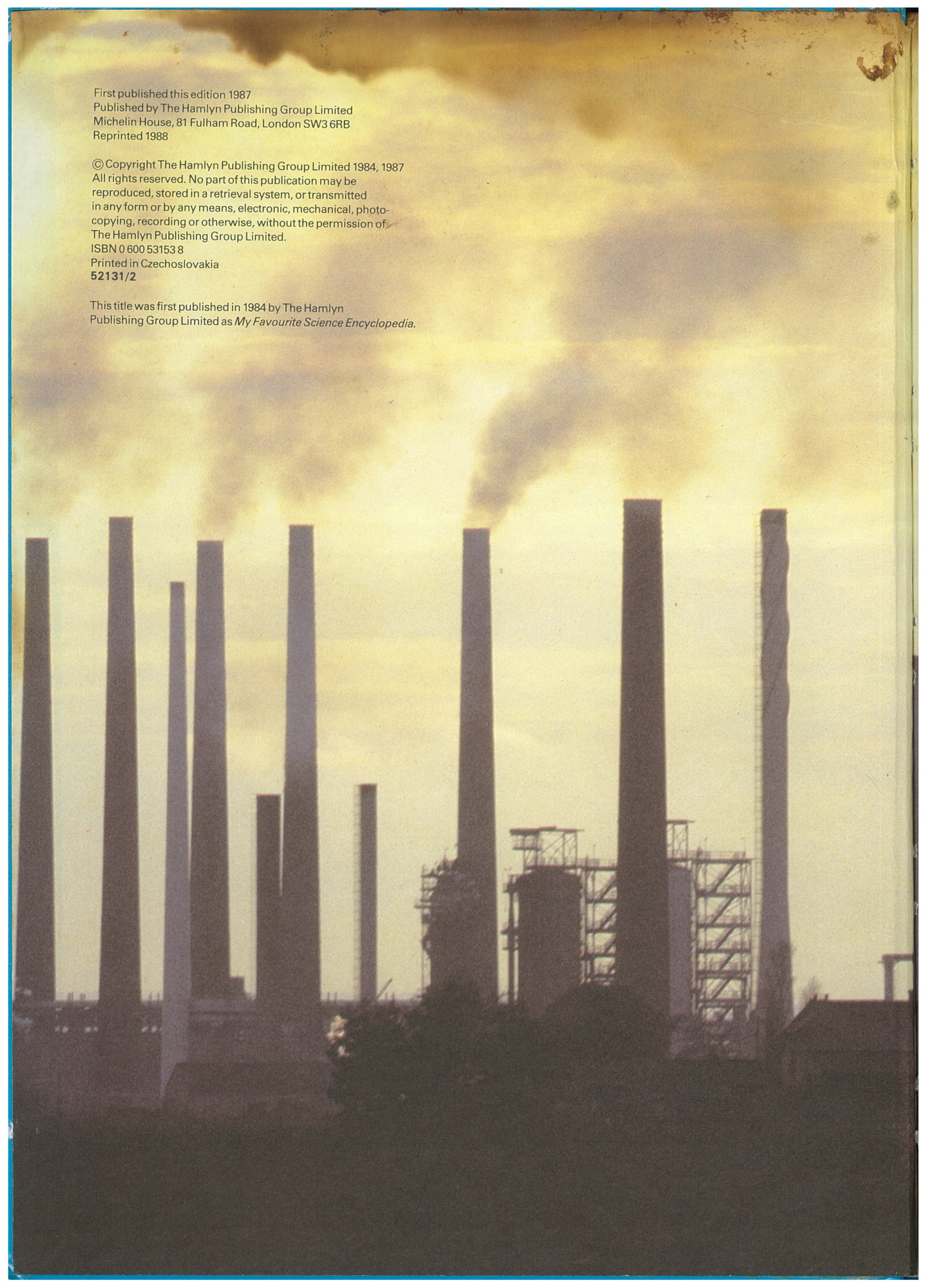


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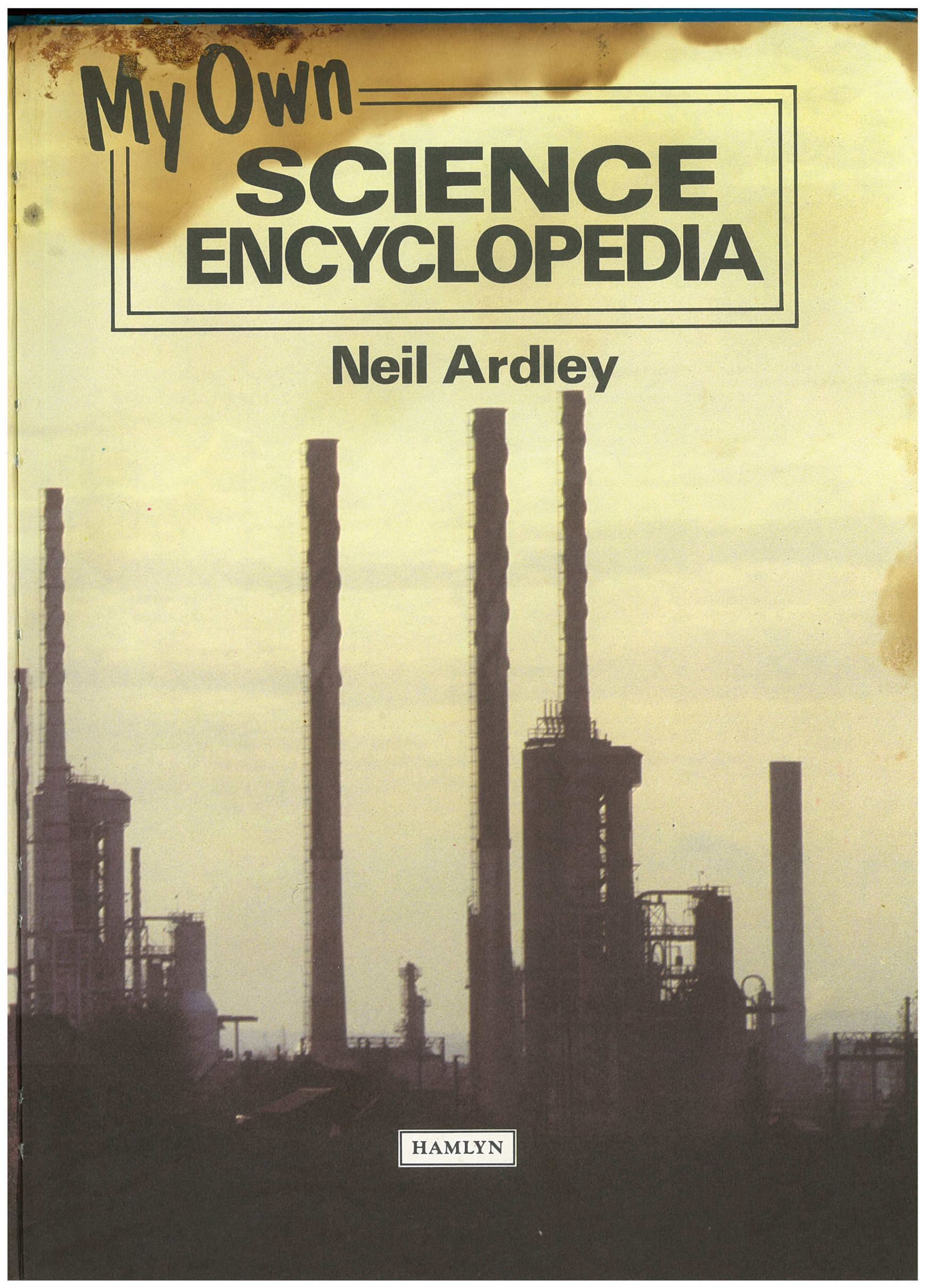
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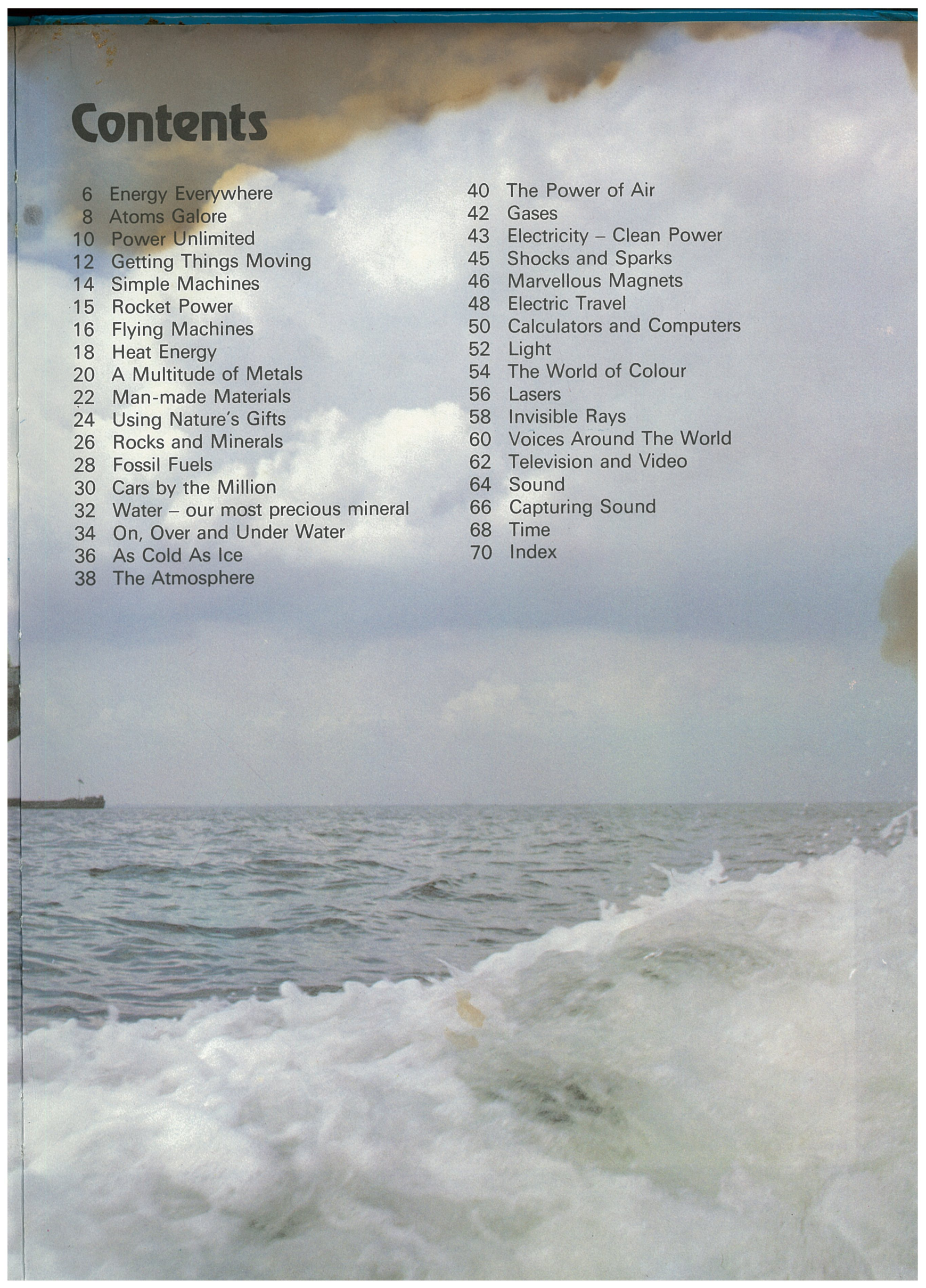
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Energy Everywhere.

All around you, things are moving. Outside the wind may be blowing and cars and people are passing by. Inside you, things are happening too. Your eyes are moving as you read these words, and blood is flowing around your body.

All these activities are happening because of *energy*. Energy is everywhere, and it makes things happen all over the Earth and throughout the entire Universe. Energy drives computers, cars, aeroplanes, lasers, television sets and all the other marvellous machines that science has given us. Energy also keeps all living things alive, from the smallest germ to the

mightiest whale and tallest tree. Without energy, nothing could work and nothing could live.

What is energy then? Energy is not the push you give something to make it move. Energy is the power that goes to your muscles and makes them move and push something. The energy gets to your muscles from the food that you eat. This is why you feel hungry after working hard. You need more food to give you more energy.

Machines need energy to make them work. A car needs petrol, which produces energy in the car's engine so that the engine turns the

The warmth and light of the Sun ripens crops that provide food. In this way, the Sun's energy is changed into energy-rich foods.



By eating foods made from crops, people gain the chemical energy that is in the food. Eating meat provides energy too because the animals we eat feed on crops or grass first.



The chemical energy in the food is changed into kinetic energy (energy of movement) as the muscles of the rider power the bicycle.

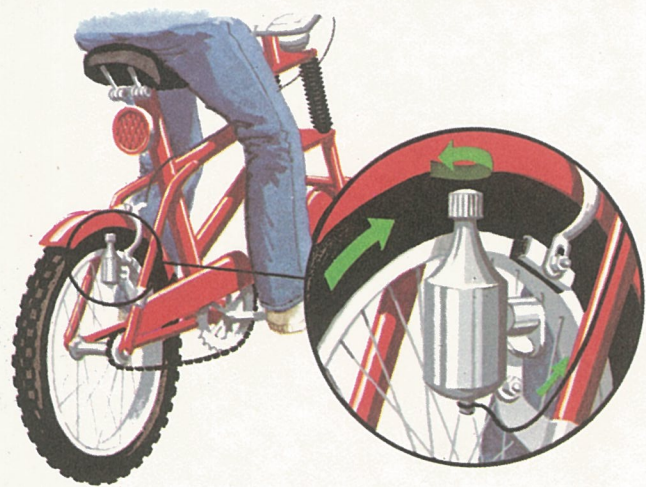
wheels. A television set needs electricity to get energy and light up with a picture.

There are several different kinds of energy. Food and petrol contain *chemical* energy. Electricity is a kind of energy called *electrical* energy. Heat, light and sound are other kinds of energy.

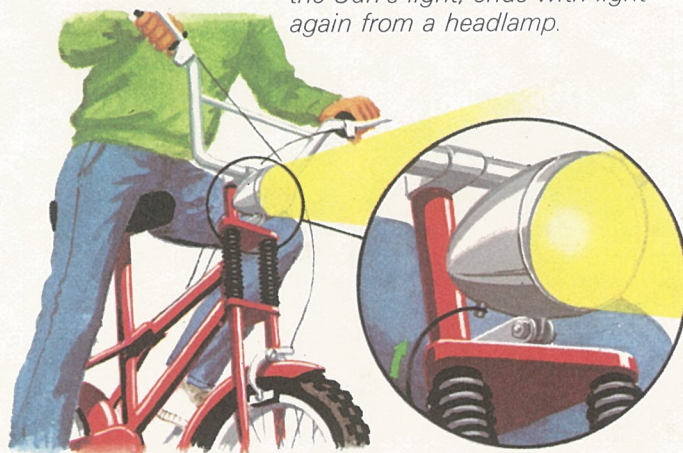
Like you, machines use up energy as they work. But both machines and people also produce energy as they work. When anything moves, it gains a kind of movement energy called *kinetic* energy. If it makes something else move – like a bat hitting a ball – it transfers this

energy. The bat gives kinetic energy to the ball. In a car, the chemical energy in the petrol is changed to heat when the petrol burns in the engine, and the heat energy changes to movement. In a television set, the electrical energy changes into the light of the picture and the sound of voices and music.

Where does energy come from? Most of it comes from other kinds of energy. However, there has to be some beginning to this chain and the beginning is the Sun. All energy, apart from nuclear energy, first comes to us in the form of heat and light from the Sun.



The wheel of the bicycle is connected to a dynamo, which produces electricity. In this way, the kinetic energy of the bicycle is turned into electrical energy.



The electricity goes to the headlamp on the bicycle and lights it, turning electrical energy into light energy. The long chain of energy changes, that began with the Sun's light, ends with light again from a headlamp.

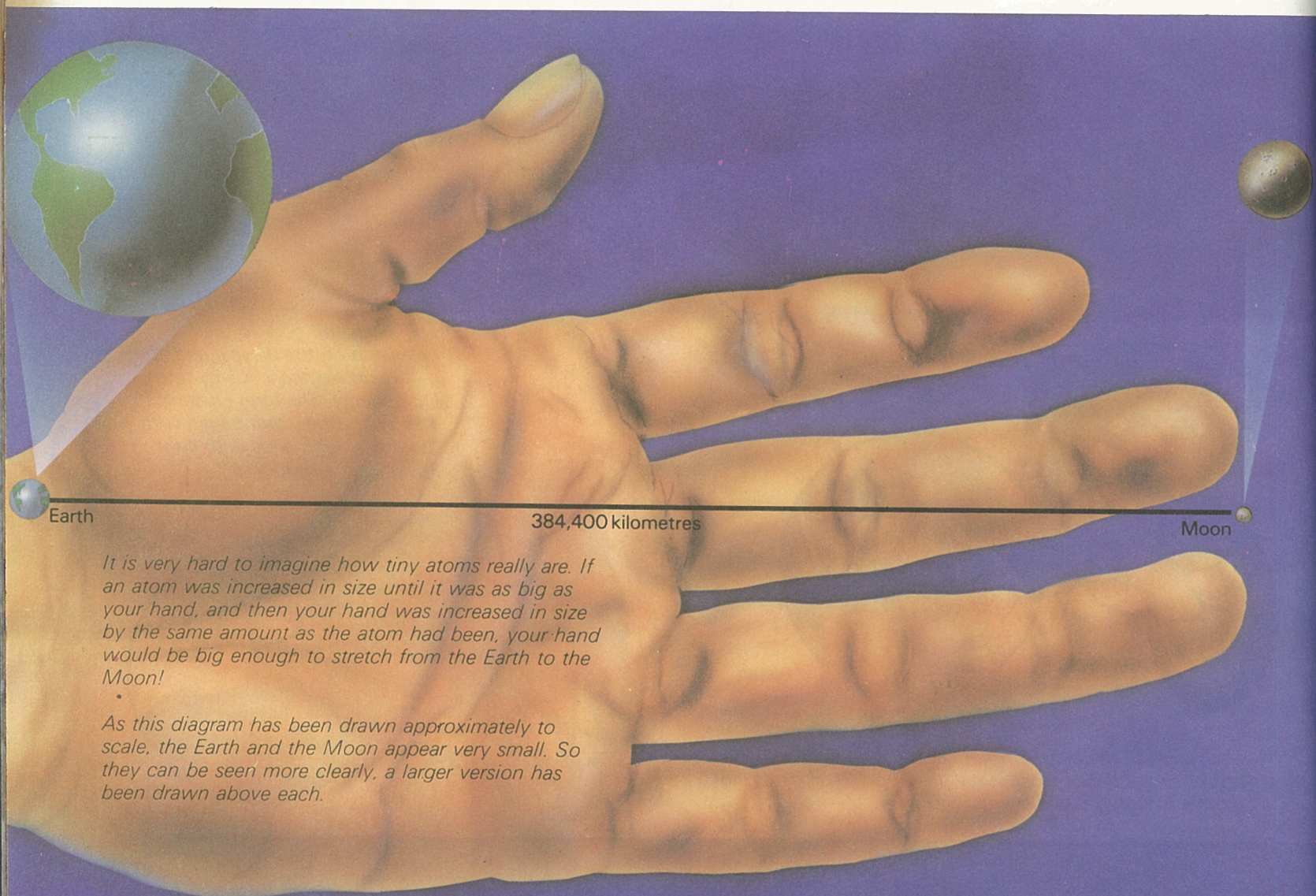
Atoms Galore

Look around you. How many different kinds of things can you see? Paper, wood, metal, cloth, plastics, stone, bricks, grass, trees and soil probably – and then there are the things you see through, like glass, water and air. Everywhere you go, you come across all kinds of different substances.

What are all these things made of? What makes them different from one another? The only way to find out is to cut them into smaller and smaller pieces and see what is inside. If you could keep on breaking them down into smaller and smaller pieces, you would find the answer. Eventually, you would get pieces that could not be made any smaller. These pieces are called *atoms*, a Greek word that means uncuttable. However, you can't just make atoms by chopping up something with a knife! Atoms are very small indeed: you would need to pile 50 million atoms on top of one another to get enough to measure just one centimetre.

There are about a million atoms in the thickness of this page!

If we could inspect the atoms in all the different things we see around us, we would not find more than one hundred different kinds of atoms in all. Some things are made up of atoms that are all the same. These things are called *elements*. Gold is an element because it contains only gold atoms. The metals copper and silver are elements too, and the gases hydrogen and oxygen, and the black solid carbon. As there are about one hundred different kinds of atoms, so there are about one hundred different elements. Everything else we see around us is made up of some combination of two or more types of atoms. Water, for example, is made up of atoms of hydrogen and oxygen. Sugar has carbon, hydrogen and oxygen atoms. If you could break down a drop of water and a piece of sugar into atoms, you would find no difference between a hydrogen



It is very hard to imagine how tiny atoms really are. If an atom was increased in size until it was as big as your hand, and then your hand was increased in size by the same amount as the atom had been, your hand would be big enough to stretch from the Earth to the Moon!

As this diagram has been drawn approximately to scale, the Earth and the Moon appear very small. So they can be seen more clearly, a larger version has been drawn above each.

atom from the water and a hydrogen atom from the sugar.

If everything is made up of tiny particles called atoms, you might wonder why everything isn't rather like sand – lots and lots of tiny grains which fall apart from each other. The reason is that atoms are very much smaller than sand grains and they pull at each other and can grip one another very strongly. In solids like metals, the atoms cling together so tightly that they will not part. This is why many solids are hard and strong.

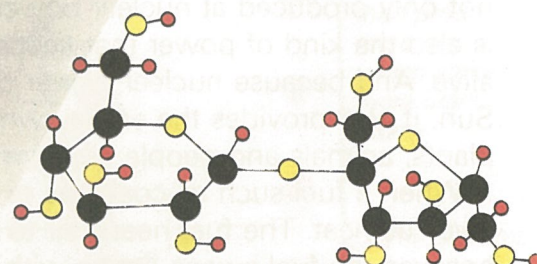
In many things, the atoms form small groups called *molecules*. Molecules do not grip one another as strongly as atoms do. In liquids and gases, the molecules are loose. This is why liquids and gases flow easily.

Inside an atom

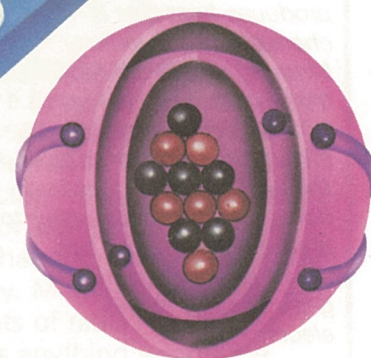
What is inside atoms? Strangely enough, atoms are almost all empty space! The outside of an atom contains one or more particles called *electrons*, which are each 100,000 times smaller than the atom itself. And inside, at the centre, is a tiny *nucleus* made up of particles called *protons* and *neutrons*, which are almost as small as electrons. Each kind of atom has a different number of these particles. So, everything you see about you is basically made up of just three things – electrons, protons and neutrons.



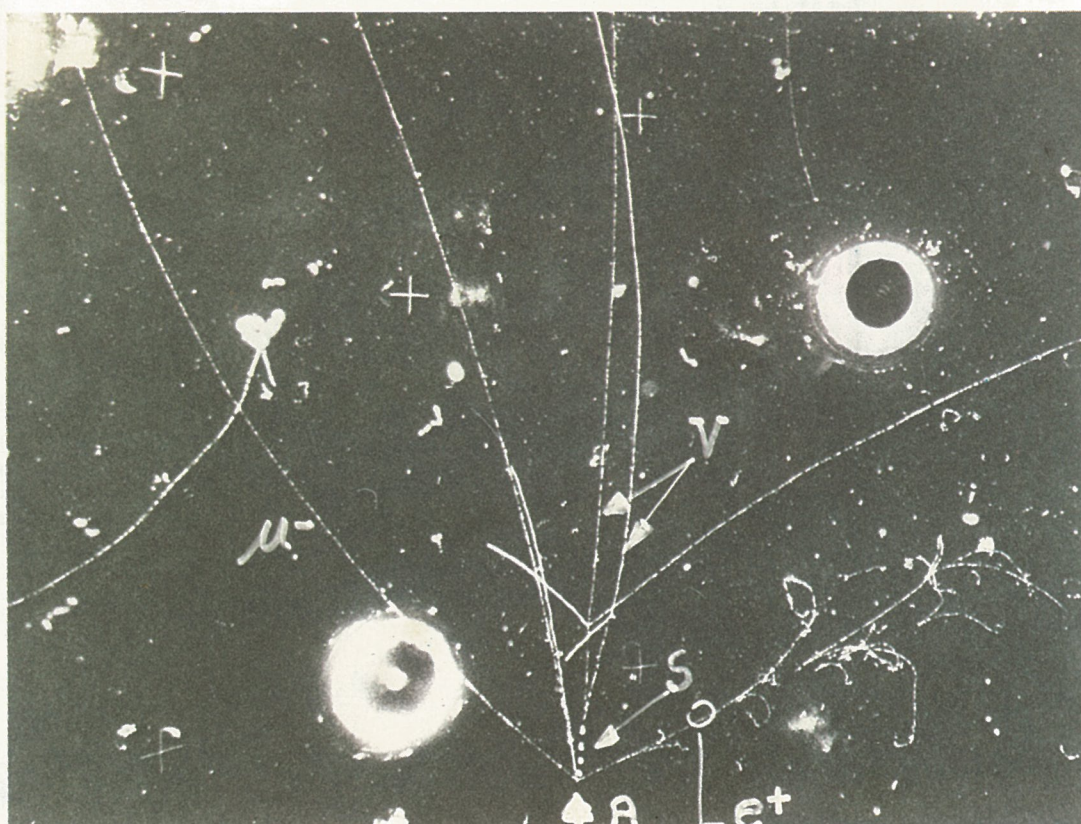
- carbon
- oxygen
- hydrogen



Above: A sugar lump is made up of many tiny sugar crystals pressed together. But inside each crystal are millions of these sugar molecules. Each sugar molecule contains 12 carbon atoms (black), 11 oxygen atoms (yellow) and 22 hydrogen atoms (red).



Above: The black graphite in a pencil lead is made of carbon. Carbon is an element, and contains only carbon atoms. Each carbon atom consists of six electrons (blue), which move around the central nucleus. The nucleus is made up of six protons (red) and six neutrons (black). If each electron were the size of a pencil, then the pencil would be bigger than the entire Solar System!



Left: Scientists can find out about the particles inside atoms by making them break apart. The particles produce tracks of tiny bubbles in a liquid which can be seen in this photograph.

Power Unlimited

Even though the particles inside atoms are so tiny, they can give us enormous power. This power is called *nuclear power*, because the particles are the nuclear particles in the central nucleus of the atom. However, nuclear power is not only produced at nuclear power stations. It is also the kind of power that keeps the Sun alive. And because nuclear power drives the Sun, it also provides the energy which keeps all plants, animals and people alive on the Earth.

When a fuel such as coal, gas or oil burns, it gives us heat. The fuel needs air to burn. This is because the fuel swaps atoms with the oxygen gas in the air. The atoms link up in different patterns, producing ash and smoke. As they do so, the chemical energy in the coal, gas or oil changes to heat.

Nuclear power is different. It is not made by

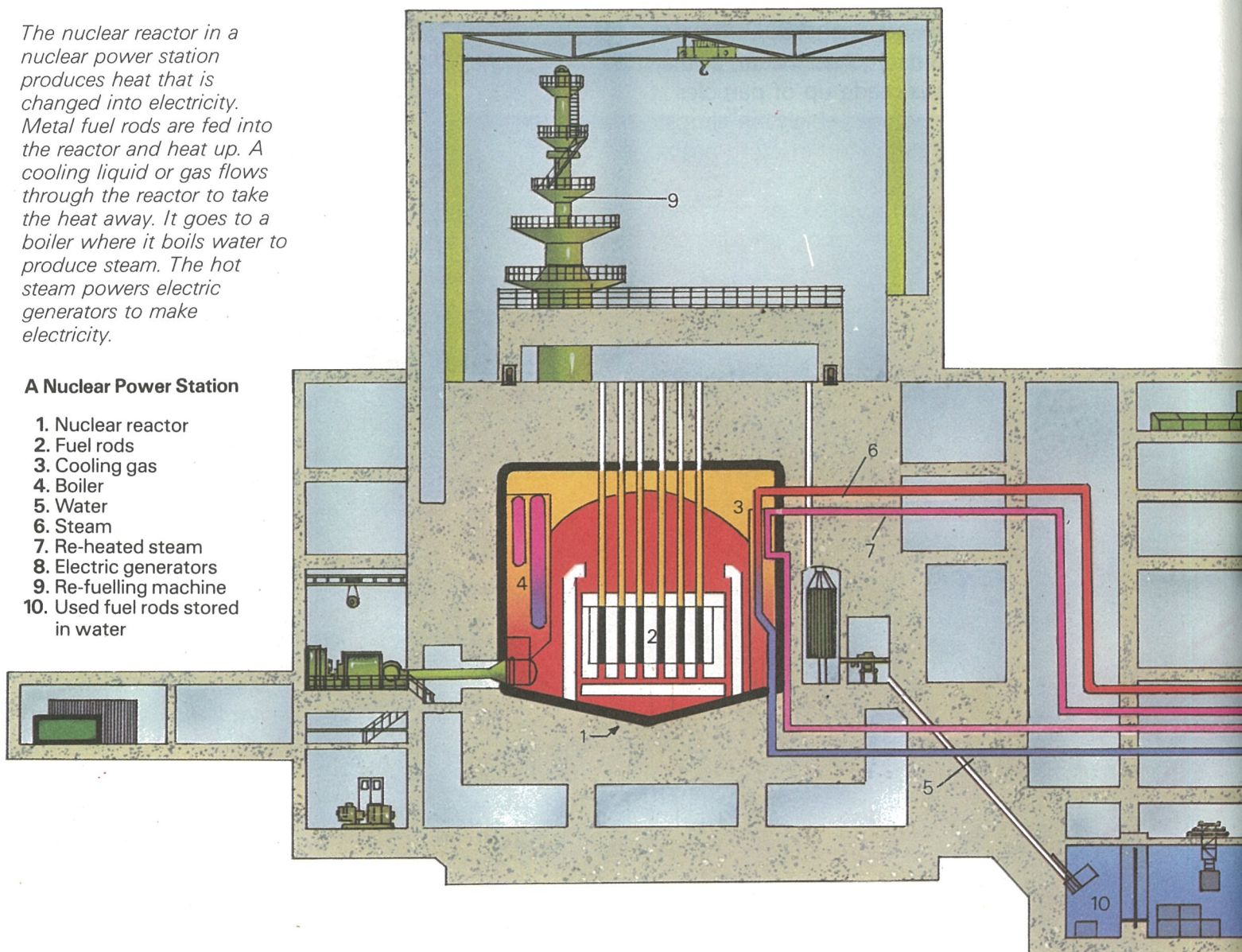
burning a fuel such as coal, gas or oil. It is made in a nuclear reactor inside a nuclear power station. The fuel is a metal called uranium or plutonium. By feeding just the right amount of metal into the reactor, it begins to heat up. Inside the metal, the atoms start to split. The nuclear particles break apart, forming smaller atoms. When atoms change into other atoms like this, enormous amounts of heat are produced. The uranium or plutonium gives many thousands of times more heat than a fuel like coal, gas or oil. In the power station, this heat is turned into electricity.

Atoms only break apart like this in nuclear reactors. But as they do, they produce radiation or rays that can cause illness and death. These rays are harmful because if they strike the human body, they change the

The nuclear reactor in a nuclear power station produces heat that is changed into electricity. Metal fuel rods are fed into the reactor and heat up. A cooling liquid or gas flows through the reactor to take the heat away. It goes to a boiler where it boils water to produce steam. The hot steam powers electric generators to make electricity.

A Nuclear Power Station

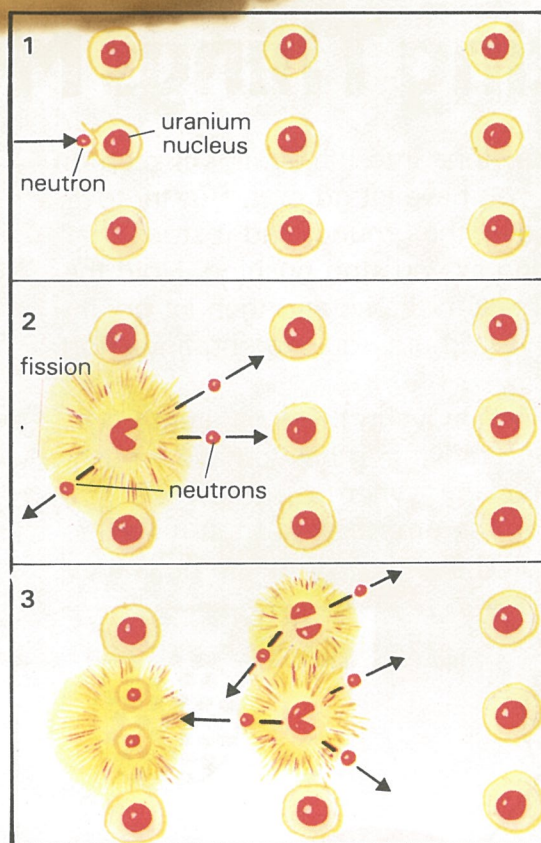
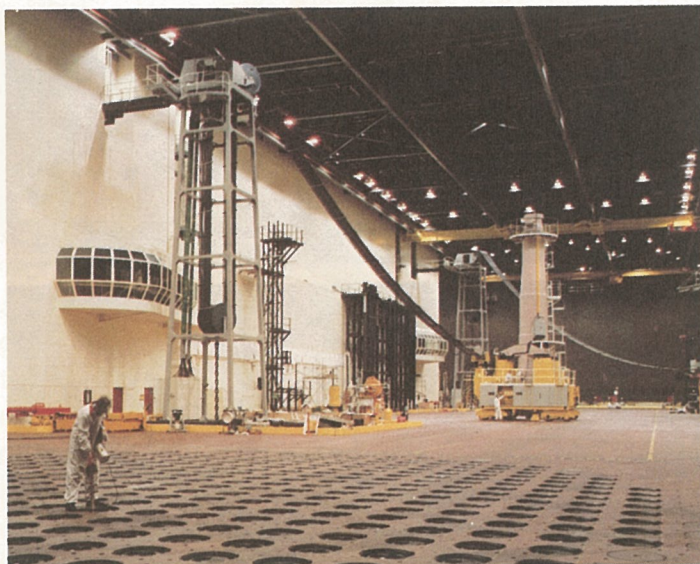
1. Nuclear reactor
2. Fuel rods
3. Cooling gas
4. Boiler
5. Water
6. Steam
7. Re-heated steam
8. Electric generators
9. Re-fuelling machine
10. Used fuel rods stored in water



atoms inside and disturb the delicate balance of all the chemical compounds which keep our bodies working properly. So nuclear power stations have thick layers of shielding around the reactor to prevent these rays getting out.

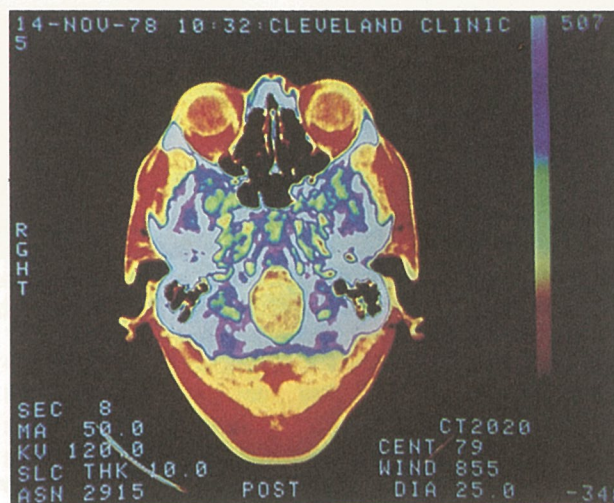
The Sun is like a gigantic nuclear power station in space. However, it works in a different way. Its fuel is the gas hydrogen. In the centre of the Sun, it is so hot that the hydrogen atoms change into bigger atoms. This is because the nuclear particles are forced together. As the atoms change, they give out even more heat, making the Sun a globe of white-hot gas. The heat and light stream through space, warming and illuminating the Earth. Scientists are trying to make power stations that work like the Sun. The stations would use a kind of hydrogen that is found in the sea. If they can be made to work, we would gain an unlimited source of power.

Below: The top of a reactor inside a nuclear power station.



Radiation for health

Doctors sometimes use radiation in small amounts to stop cancer, a dangerous illness. The radiation destroys the cancerous tissues when it is directed on to them. Radiation is also used in scanners which help doctors to look inside the body. A brain scanner, for example, shows the interior of the head, so that doctors can see if the brain is working normally. Many scanners work by detecting tiny amounts of radiation coming from the body. If there is anything wrong the amount of radiation may be different from normal. This difference shows up in the picture made by the scanner. The picture below shows a scan across the middle of the head. At the top you can see the nose and eyeballs.



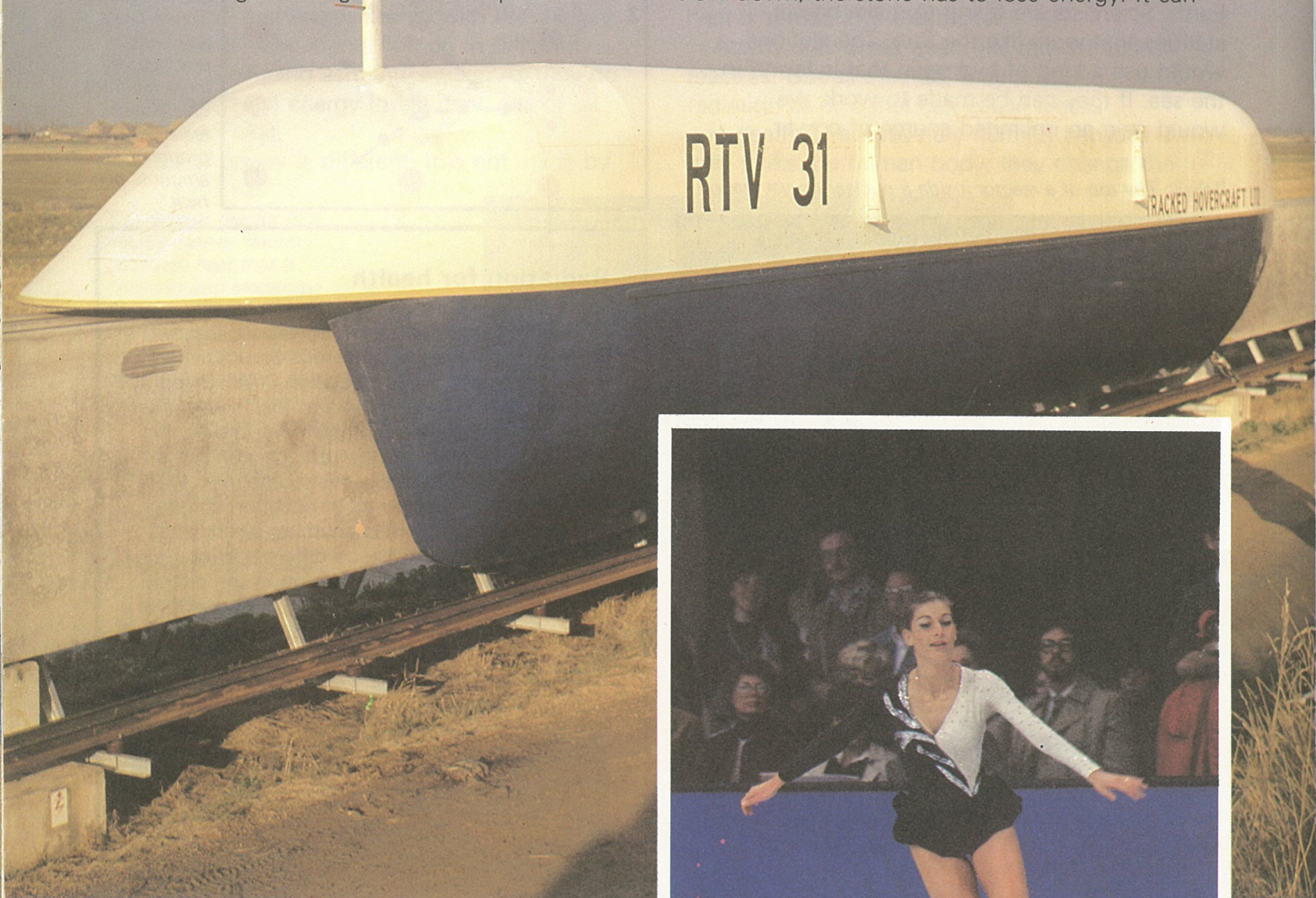
Getting Things Moving

If you throw a stone into the air, it will keep on moving after you have let go of it. But try to push a brick over the ground, and it stops moving as soon as you stop pushing. Hold the stone or the brick in the air and then let go: it begins to move without you exerting any effort at all.

Why do things move in these different ways? To get anything moving, it has to have a push or pull of some kind. When you throw something, your arm muscles push at it and start it moving. The engine of a train pulls the

coaches along. In both cases, a force is produced. The force is the push or pull that gets something moving.

However, strange as it may seem, a force is not needed to keep something moving once it has started going. This is why the stone continues to fly through the air after it has been thrown. The push of the throw gives the stone a certain amount of the energy of movement called kinetic energy. The amount of kinetic energy depends on how fast it is going. To slow down, the stone has to lose energy. It can



Above: This experimental train can travel at 500 kilometres per hour because it has no wheels. Instead it floats over the track, suspended by a strong magnetic field. There is no friction with the track to slow it down, so the train can move very fast indeed.

Right: When a skater moves over the ice, the ice melts beneath the skates making the ice slippery – so the skater moves quickly. When the skater has passed, the ice immediately freezes again.



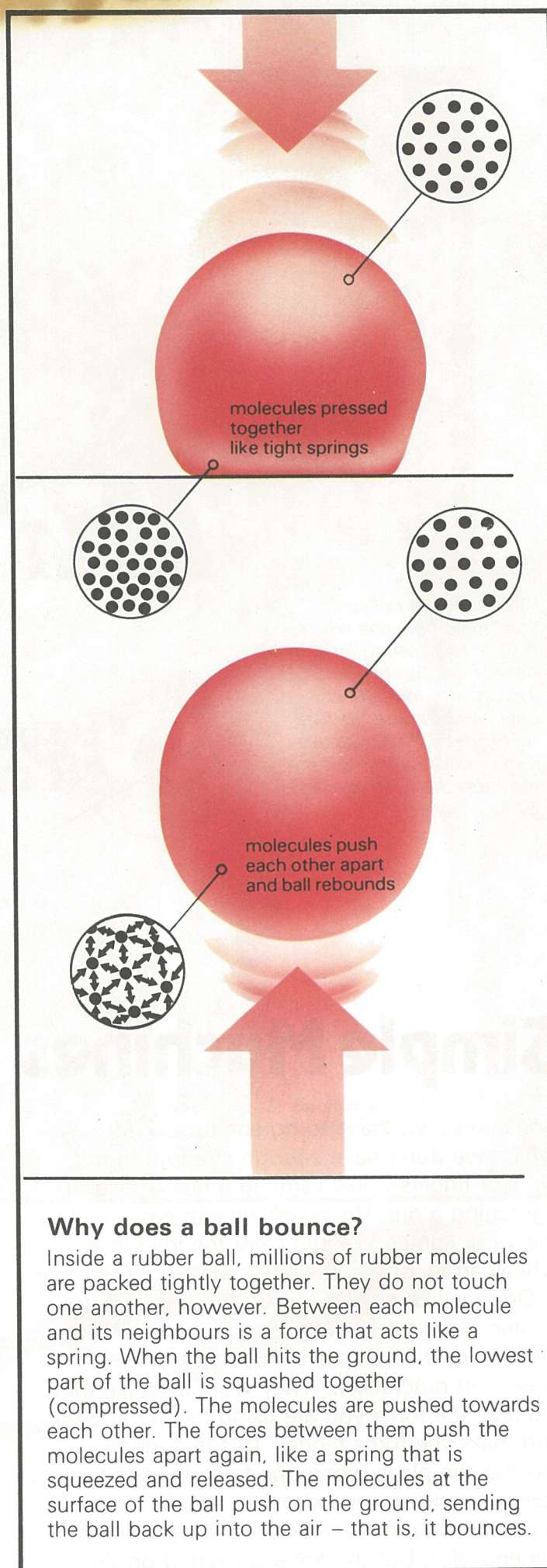
only do this if something else takes the energy away from the stone. If nothing is there to do this, it will carry on moving in the same direction. Of course a stone will fall to earth eventually, no matter how hard you throw it, because it loses energy pushing against the air and because the force of gravity is pulling it downwards.

The brick on the ground also begins to move as it is pushed. But the surface of the ground takes up all its energy so when you stop pushing, the brick does not carry on moving. This happens because the surface of the brick and the ground are both rough. The little bumps in the surfaces catch and rub, stopping them moving over each other. This effect is called *friction*.

Brakes on cars and bicycles work by friction. As the brakes press on a wheel, their surfaces are pushed together and stop the wheel turning. The energy of movement turns into heat and the brakes get warm. However, friction is also needed to get a car and every other vehicle with wheels moving. As the engine turns the wheels, the tyres grip the road surface. Friction stops them slipping and sliding on the road, and the wheels turn and move the vehicle forward.

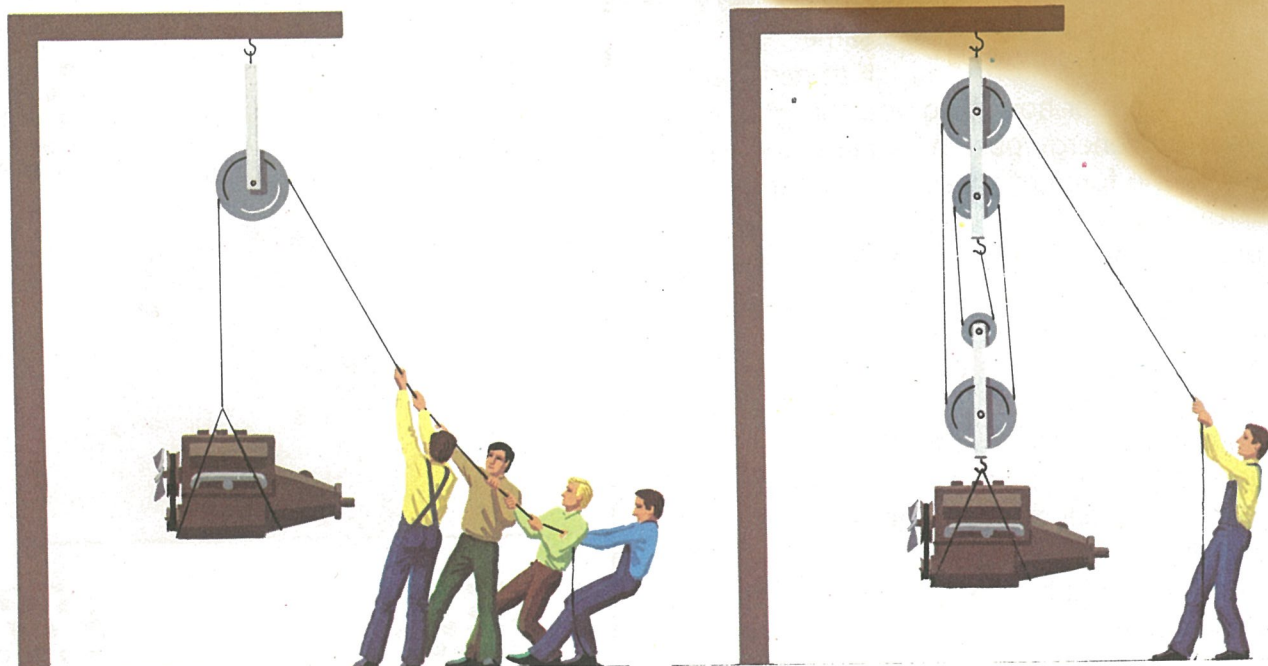
The force of gravity pulls on everything. It works like the way in which a magnet pulls pieces of iron towards it. The Earth's gravitational field pulls everything down towards the Earth's surface. That is why, if you drop a stone or brick, it falls to the ground and doesn't stay put or fly upwards. The Earth's gravitational pull is powerful enough to keep our Moon from drifting off into space. It also holds in place the atmosphere (*see page 38*) which is a layer of gases around the Earth. The Sun has a gravitational pull of its own which keeps the nine planets of the Solar System, including our own planet Earth, in orbit, circling round and round it.

The force of gravity on Earth pulls with six times the force on a man weighing 60 kilograms as it does on a child weighing 10 kilograms. This is why the man weighs six times as much as the child. But on the Moon the force of gravity is six times less than on Earth. This is because the Moon is much smaller than the Earth and so has a much less powerful gravitational pull. The man would weigh only 10 kilograms on the Moon – the same as the child on Earth!

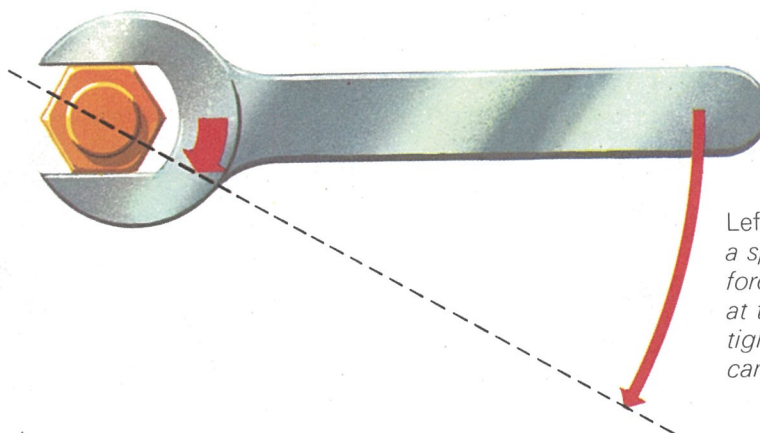


Why does a ball bounce?

Inside a rubber ball, millions of rubber molecules are packed tightly together. They do not touch one another, however. Between each molecule and its neighbours is a force that acts like a spring. When the ball hits the ground, the lowest part of the ball is squashed together (compressed). The molecules are pushed towards each other. The forces between them push the molecules apart again, like a spring that is squeezed and released. The molecules at the surface of the ball push on the ground, sending the ball back up into the air – that is, it bounces.



Above: With a pulley containing only one wheel, it takes four men to lift a heavy load. But by using a system with four wheels, one man can raise the load on his own. This is because a four-wheel pulley system increases the force applied by four times.



Left: Pushing on the end of a spanner increases the force that pushes on the nut at the other end. This tightens the nut so that it cannot come loose.

Simple Machines

Sometimes, we have to do some work for which we don't have enough strength in our arms or fingers – like carrying a heavy load or tightening a nut. However, we can easily make the work lighter. We can carry the load in a wheelbarrow and tighten the nut with a spanner.

Devices like wheelbarrows and spanners that lighten work are known as *simple machines*. Other simple machines include screwdrivers, pliers and nutcrackers. They work because they multiply the force you are using to do the work and make the force bigger. This is done by moving the place where the force is used to some distance away from your hands. When you use a spanner, for example, you push on the end of it. But the force is exerted on the

nut at the other end of the spanner, several centimetres away. Your hand moves much more than the nut turns, making the force exerted much bigger. The farther away it is exerted so that the more it moves, the bigger the force becomes.

Pulleys and gears move to make forces very much bigger in a similar way. One person can use a pulley system to raise loads that would otherwise need several people to lift. The gears on a bicycle and car enable it to go up hills without straining the rider or the engine. Pulleys and gears are also simple machines. The amount by which they multiply forces depends on the number and size of the pulley and gear wheels.

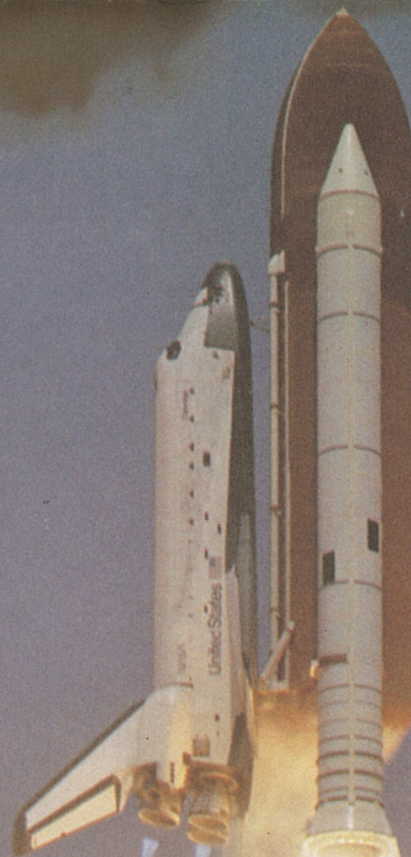
Rocket Power

Have you ever seen a space rocket lift off? Probably you have seen one on television. A huge flame roars from the bottom of the rocket. Then it slowly heaves itself into the air. Gradually it gets faster and faster as it gets higher. Then it disappears from sight, streaking away towards space.

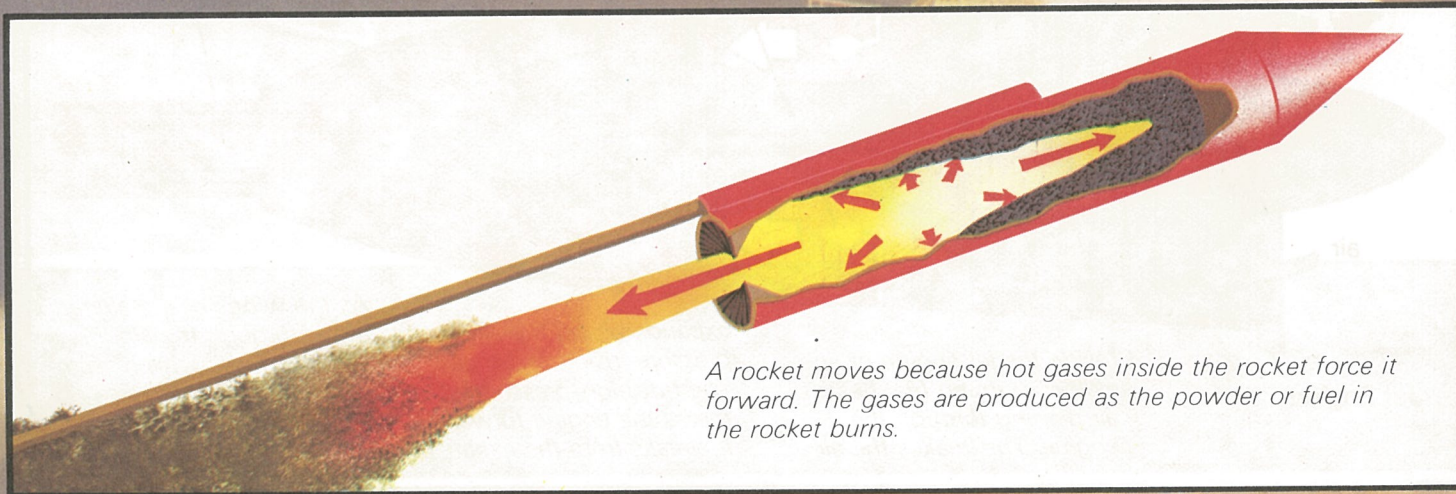
Why do we have to use rockets to fly in space? The reason is that there is no air in space. Aircraft engines need air to burn their fuel, so they would not work in space. Also, rocket engines are very powerful. To get into space, a spacecraft like the space shuttle has to reach a speed of eight kilometres per second. Only rockets can get to this speed.

A space rocket works in basically the same way as a firework rocket. Inside the firework rocket, a powder burns very quickly, producing lots of hot gases as well as flames and smoke. Inside the space rocket, fuels burn in the engine to give hot gases too. Air is not needed. The hot gases push against the inside of the rocket engine. But they do not push at the bottom, because it is open to let the gases out. This causes the gases to exert a force against the top of the rocket engine, and this moves the rocket upwards.

To get back from space, the space shuttle and other spacecraft use the air in the atmosphere (*see page 38*). As they re-enter the atmosphere from space, the air slows the spacecraft. This is just like cycling into a strong wind that slows you down, but a spacecraft hits the air so fast that friction with the air makes it red-hot! Within minutes, the spacecraft is travelling slowly enough to make a landing.



The lift-off of the space shuttle, the first spacecraft in the world to make more than one spaceflight.



A rocket moves because hot gases inside the rocket force it forward. The gases are produced as the powder or fuel in the rocket burns.

Flying Machines

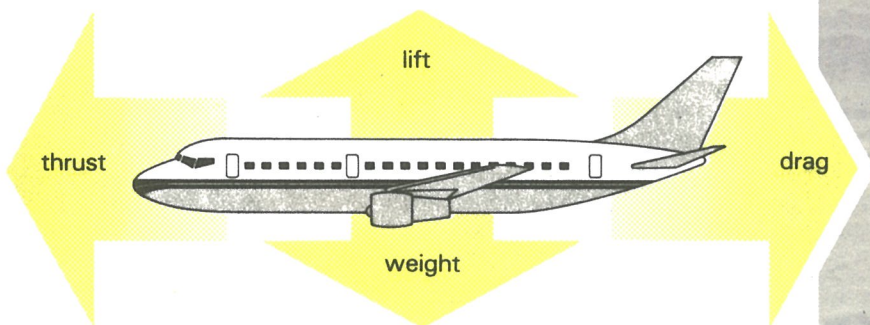
How can machines like aeroplanes and helicopters fly? Like birds, they are heavier than air. Yet they can all stay up in the air, as if they are suspended on an invisible string.

Aeroplanes, helicopters and birds are all supported in the air as they fly. A force called *lift* pushes them up into the air. When the lift is equal to the weight of the bird or flying machine, it stays at the same height in the air. If the lift is greater than the weight, it rises and if the lift is less, it drops.

Lift is produced when the wings of the

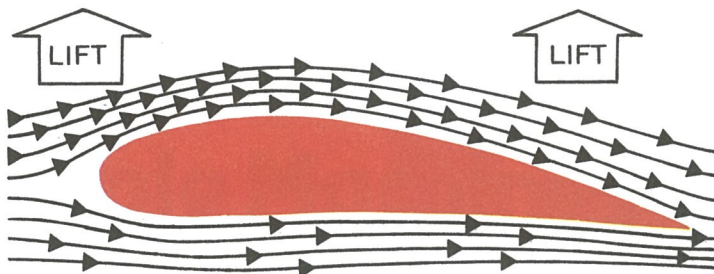
aeroplane or the bird move through the air. The wings have a curved shape called an *aerofoil*. The curve is greater on top of a wing than underneath. As it cuts through the air, the air flows over and under the wing. But because of the shape of the wing, the air moves faster over the top of the wing than it does underneath.

Above the wing, the air molecules space out more as the air moves faster. Beneath the wing, the molecules in the slower air crowd together. This makes the pressure of the air greater beneath the wing than above the wing. As a

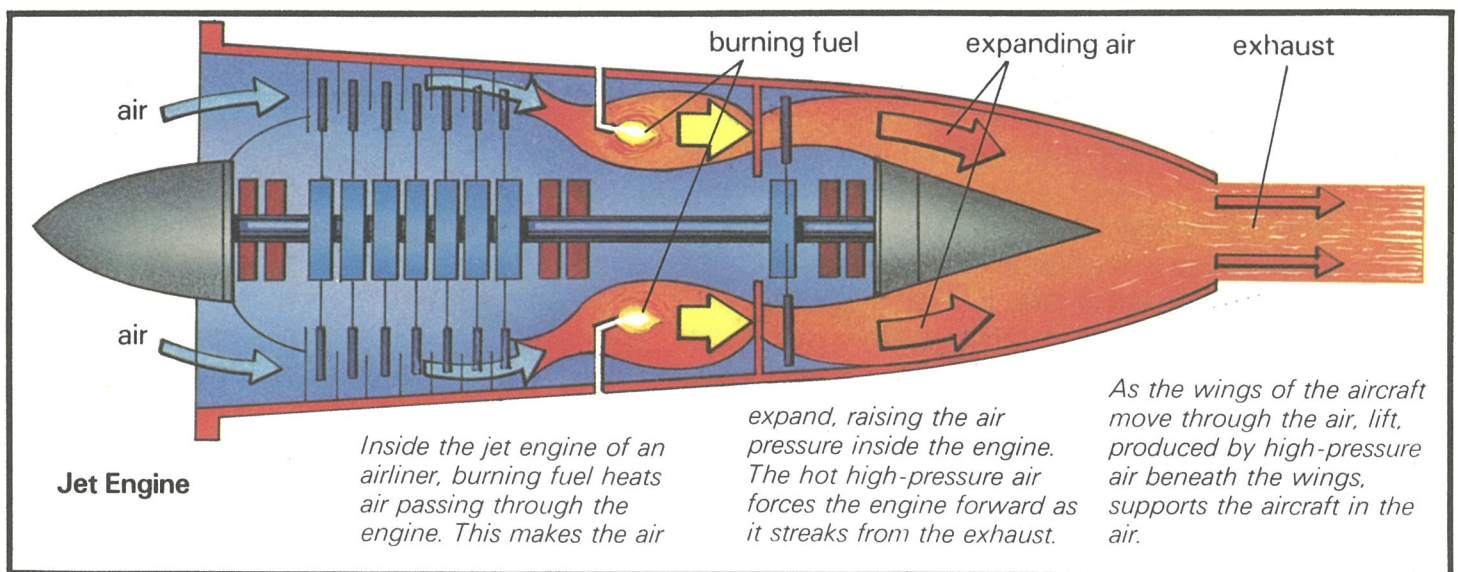


Above: Four forces act on an aeroplane – lift, weight, thrust and drag (air resistance).

Below: Air flows over and under the wings of an aeroplane. Because of the shape of the wing, the air moves faster over the top of the wing than it does underneath.



Above: The fastest aircraft in the world is the Lockheed SR-71, an American military plane. It can fly at more than 3500 kilometres per hour.



Inside the jet engine of an airliner, burning fuel heats air passing through the engine. This makes the air

expand, raising the air pressure inside the engine. The hot high-pressure air forces the engine forward as it streaks from the exhaust.

As the wings of the aircraft move through the air, lift, produced by high-pressure air beneath the wings, supports the aircraft in the air.

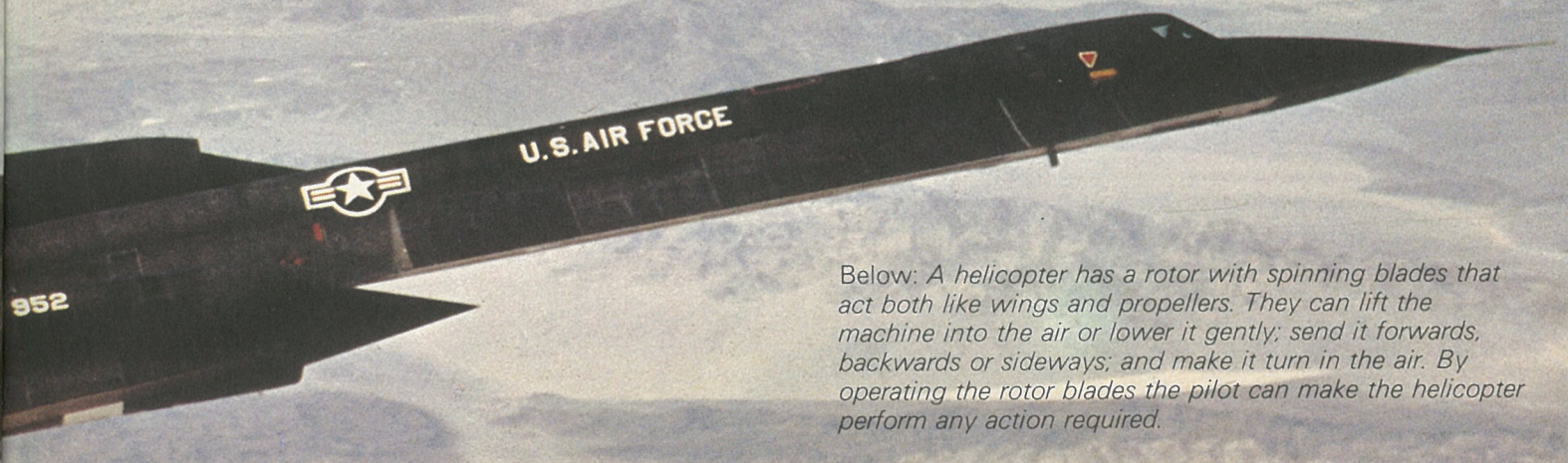
result, the air underneath pushes the wing upwards and lifts the aeroplane or the bird up into the air.

The blades of the rotor that whirls above a helicopter are like moving wings. Lift is created beneath the blades, pushing the helicopter up into the air. Because the blades spin without the helicopter itself moving, the helicopter can rise straight up into the air. An aeroplane has to streak along a runway to get up enough speed and create sufficient lift to get it off the ground. Most birds are much better at flying. They simply jump into the air to get going.

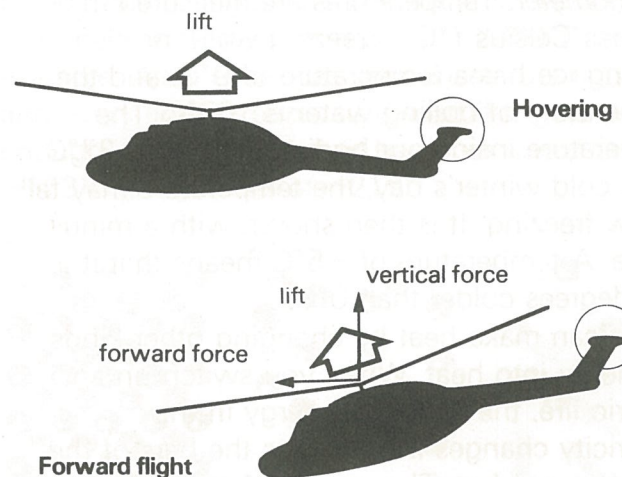
Once they are in the air, how do flying machines and birds move forwards and twist

and turn in flight? Birds flap their wings and helicopters tilt their rotor to make air move backwards. Pushing the air back moves the bird or helicopter forward. Air may also be pushed downwards to increase lift. In an aeroplane a propeller or jet engine pushes the air backwards. This action produces a thrust which forces the aircraft forward.

To turn, the pilot of an aeroplane operates the rudder on the tail and the flaps on the wings. This alters the flow of air around the plane, bringing the nose round so the whole machine turns. Birds use their wings and tail in a similar way. A helicopter has a small tail rotor that acts to turn it in flight.



Below: A helicopter has a rotor with spinning blades that act both like wings and propellers. They can lift the machine into the air or lower it gently; send it forwards, backwards or sideways; and make it turn in the air. By operating the rotor blades the pilot can make the helicopter perform any action required.



Heat Energy

Heat is a kind of energy that everything possesses. Even ice has heat. Ice feels cold because it has less heat than we have. Things that feel hot, like a radiator, have more heat.



We can tell how hot or cold things are by measuring their *temperature*. We do this with a *thermometer*. Temperatures are measured in degrees Celsius ($^{\circ}\text{C}$). Freezing water or melting ice has a temperature of 0°C , and the temperature of boiling water is 100°C . The temperature inside our bodies is close to 37°C . On a cold winter's day, the temperature may fall below freezing. It is then shown with a minus figure. A temperature of -5°C means that it is five degrees colder than 0°C .

We can make heat by changing other kinds of energy into heat. When you switch on an electric fire, the electrical energy in the electricity changes into heat as the bars of the fire glow red-hot. The energy of movement, or kinetic energy, can be converted into heat. Striking a match turns the movement of the match head into heat, causing it to burst into flame. Burning fuel like wood, coal, gas or oil makes heat. In this case, chemical energy in the fuel is turned into heat. This also happens when we eat food. The chemical energy in the food changes to heat as we digest the food.

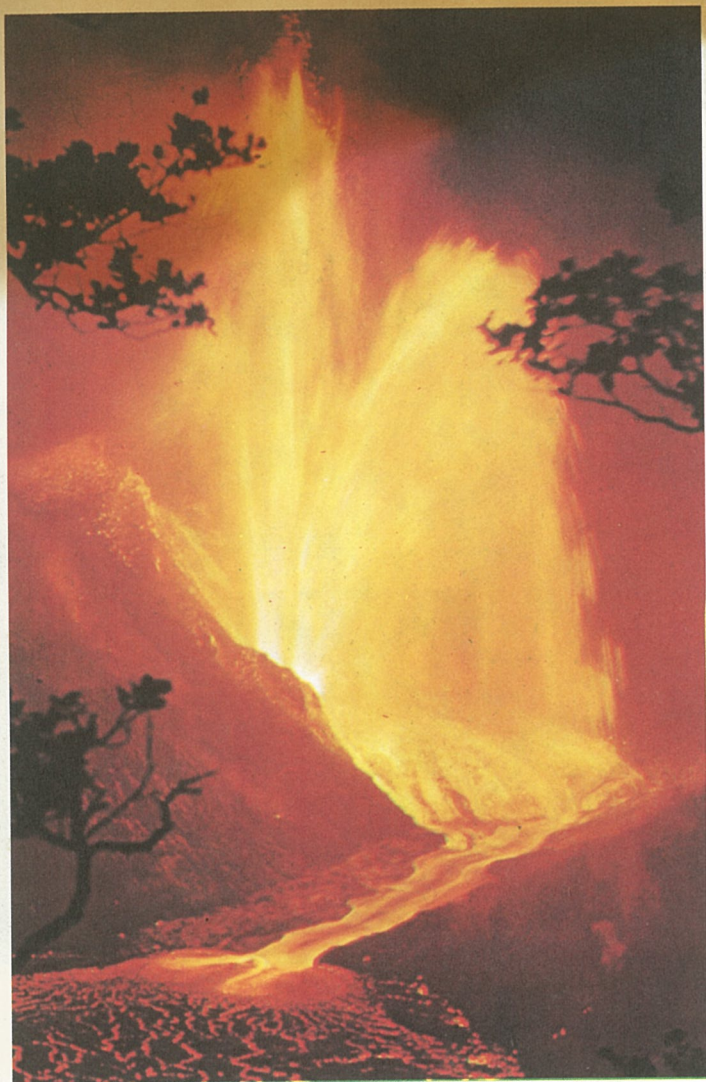
Temperatures

-273°C	Absolute zero, the coldest temperature possible
-230°C	Surface of the planet Pluto
-196°C	Air becomes liquid
-89°C	Coldest temperature recorded on Earth (Antarctica)
-39°C	Mercury becomes solid
0°C	Water freezes
37°C	Normal body temperature
58°C	Hottest temperature recorded on Earth (Libya)
100°C	Water boils
250°C	Wood catches fire
600°C	Gas cooker flame
1063°C	Gold melts
5500°C	Surface of Sun
$16\text{ million}^{\circ}\text{C}$	Centre of Sun

This heat spreads throughout our bodies and keeps us warm.

How heat moves

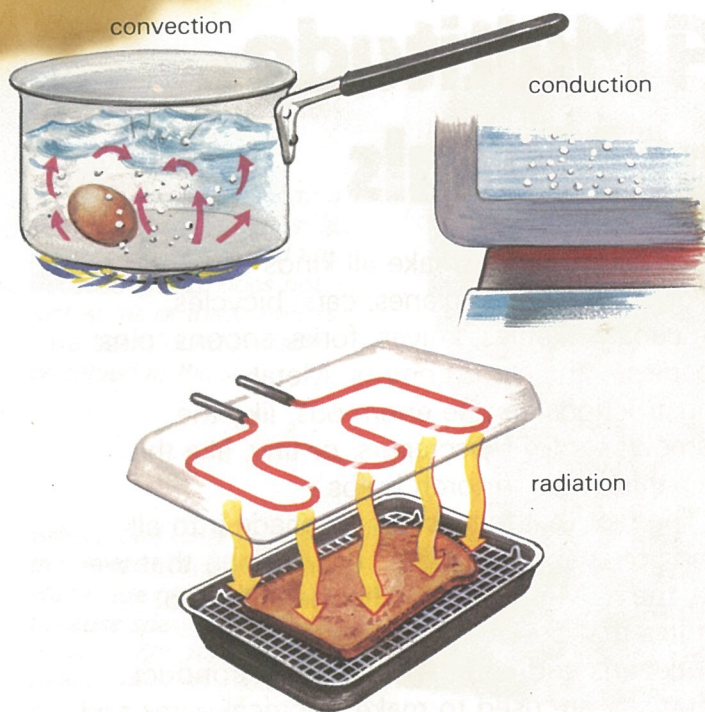
Once heat is produced, it begins to move. Heat moves in three ways. In many metals, heat



spreads through the metal. This kind of heat movement is called *conduction*. Saucepans are made of metal so that lots of heat can move from the cooker through the pan and into the food being cooked. The heat may also move up the handle, making it hot too, so many saucepans have plastic handles. Plastic does not conduct heat well, so the handles do not get hot.

Heat also moves by *convection*. This happens in liquids like water and gases like air. When a part of the liquid or gas becomes hot, it gets lighter and rises. This causes streams of hot liquid or gas to move through the liquid or gas, spreading heat through it. Heaters like radiators warm the air in a room in this way.

When the Sun is out, the sunlight feels warm. This is because heat rays travel through space and pass through the Earth's atmosphere (see page 38-9). When these heat rays strike something like your skin, they make it warm. This kind of heat movement is called *radiation*. Fires that glow red-hot also give out heat rays and toast cooks under a grill by radiation.

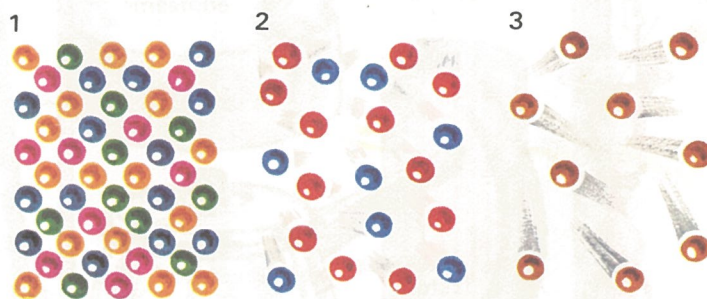


Heat moves through a saucepan on a cooker by conduction. In the saucepan, convection currents of hot water flow and heat the water. Under the grill, heat rays from the grill heat the toast by radiation.

Far left and left: Even ice has heat, but an erupting volcano is much, much hotter.

Solid, liquid, gas

If you heat water in a kettle, it boils. The water which is liquid becomes steam which is a gas. But if you put water in a refrigerator it freezes to ice. The liquid water has now become a solid. Every solid melts to a liquid, and every liquid boils to a gas, if it becomes hot enough. Iron melts at 1540°C and boils at 2800°C , for example. Also, every gas condenses to a liquid and every liquid freezes to a solid if it gets cold enough. Oxygen in the air becomes liquid at -183°C and freezes at -219°C .



1 In a solid such as ice, the molecules are arranged in neat rows, rather like soldiers on parade.

2 In a liquid like water, the molecules move about slowly in groups, rather like couples dancing.

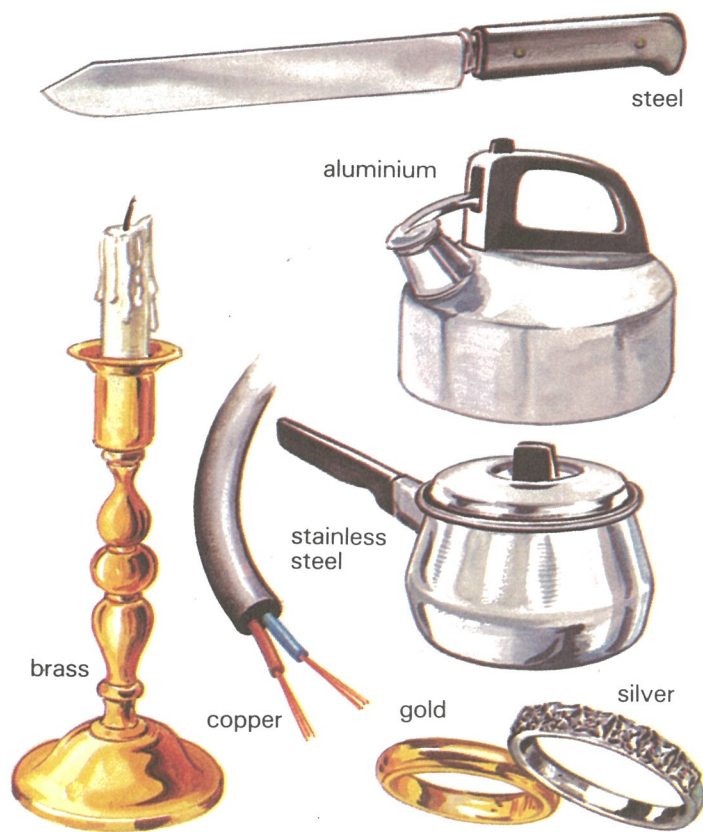
3 In a gas like steam, the molecules dash about on their own, rather like people in a busy street.

A Multitude of Metals

Metals are used to make all kinds of things – bridges, ships, aeroplanes, cars, bicycles, saucepans, kettles, knives, forks, spoons, pins, needles – the list is endless. Metal constructions can be enormous, like the frameworks for skyscrapers, or tiny, like the hair-thin wires in torch bulbs.

The fact that metals can be made into all kinds of shapes is not the only reason that we use them. Metals have other benefits too. Metals that conduct heat are good for saucepans and kettles. Metals that conduct electricity are used to make electrical wires and cables. Light metals are needed to construct aeroplanes and spacecraft, while strong metals make bridges and frameworks for buildings. Some metals bend easily without breaking, making them useful for milk bottle tops and toothpaste tubes. Some metals can be heated without harming them, so they can be used to make things like jet engines and the filaments in light bulbs. A few metals are magnetic.

The most common metal that we use is steel. It is a very strong metal and it is cheap to make. Most common metal objects like cutlery,



pins, tools of all kinds, vehicles like cars, bicycles and ships, and large structures such as building frames and bridges are made of steel. Steel is not a pure metal. It is mostly made of the metal iron, but it also contains some carbon to make it strong.

Another common metal is aluminium, which is light but strong, and is therefore used to make frames for aeroplanes. But it also has other useful characteristics: it does not rust, it conducts heat and electricity, and is flexible. So it is used to make window frames, saucepans and kettles, electric cables and kitchen foil.

Copper is a beautiful red-brown metal used to make electrical wiring because it is a good conductor of electricity. Silver and gold are good conductors too, but they are rare and therefore also used to make jewellery.

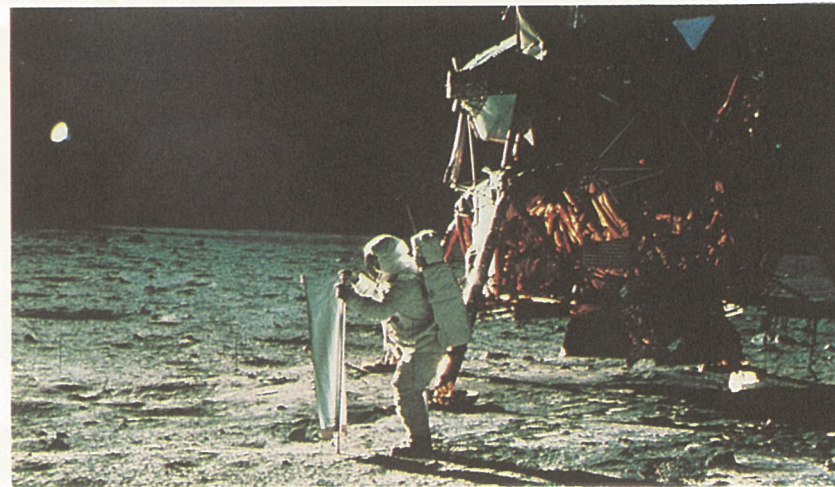
We use many metals that are not pure metals like aluminium and copper, but mixtures of metals. These mixtures are called *alloys*. When steel is made, other metals are often added. Stainless steel, which does not rust, is an alloy of steel containing chromium. Copper has several useful alloys, including cupronickel, (a nickel alloy used to make coins), brass (copper and zinc) and bronze (copper and tin). Alloys of iron, nickel and cobalt make strong magnets.



Right: Bronze was the first metal that people used to make vessels, tools and weapons. The ancient Greeks also made beautiful statues in bronze, which is an alloy of copper and tin. Because bronze does not rust, some of these statues have been found perfectly preserved in the sea.

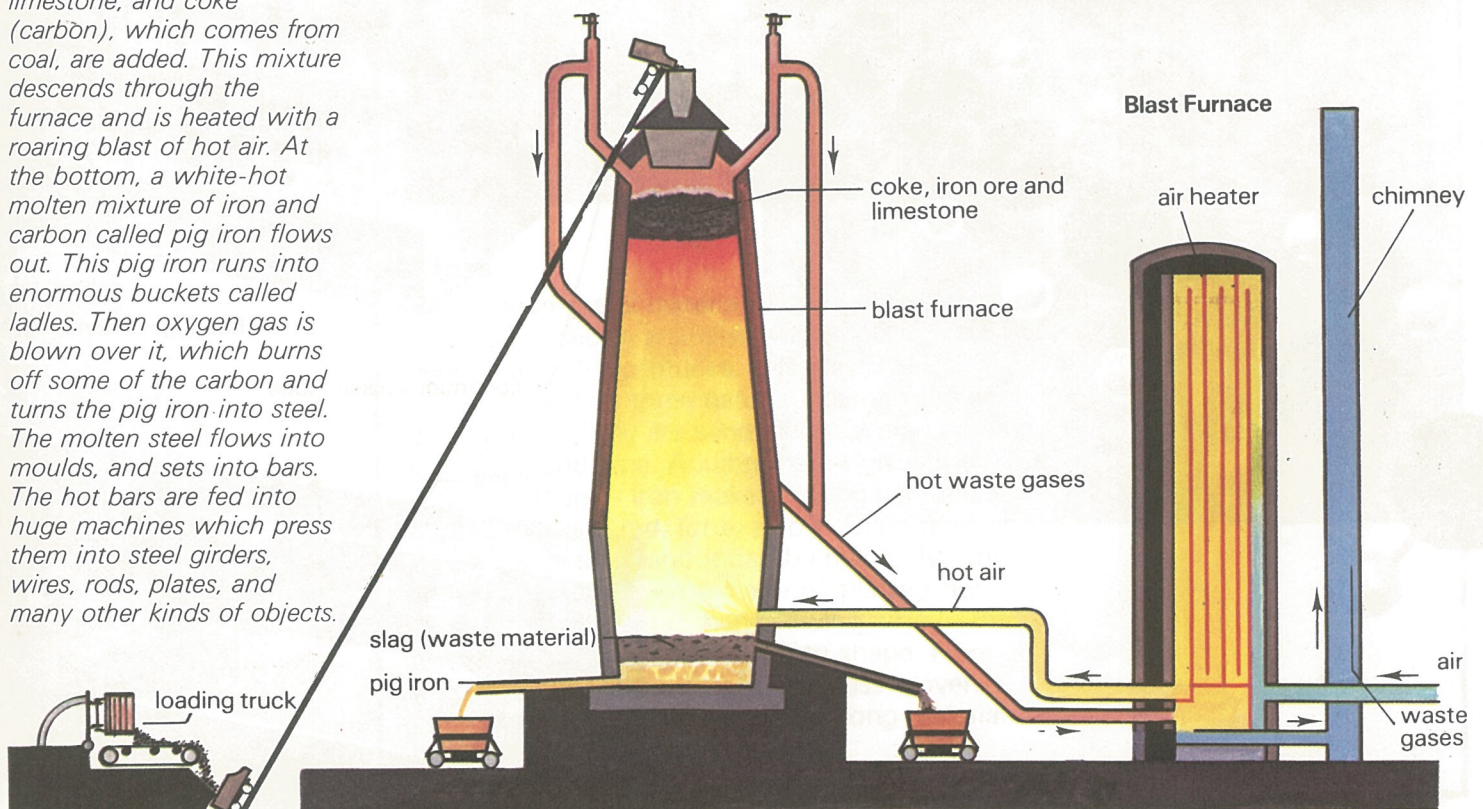


Below: The lunar module that landed on the Moon was made of aluminium, because spacecraft have to be very light. Its walls were only as thick as a kitchen saucepan.



Below: Steel is made in huge fiery furnaces. First iron ore (a mineral containing iron) is fed into the top of a high, tower-like furnace called a blast furnace. A rock called limestone, and coke (carbon), which comes from coal, are added. This mixture descends through the furnace and is heated with a roaring blast of hot air. At the bottom, a white-hot molten mixture of iron and carbon called pig iron flows out. This pig iron runs into enormous buckets called ladles. Then oxygen gas is blown over it, which burns off some of the carbon and turns the pig iron into steel. The molten steel flows into moulds, and sets into bars. The hot bars are fed into huge machines which press them into steel girders, wires, rods, plates, and many other kinds of objects.

Above: A steel foundry is a hot and noisy place. The steel is heated until it is white-hot so that it becomes soft and can be forged into any shape required.



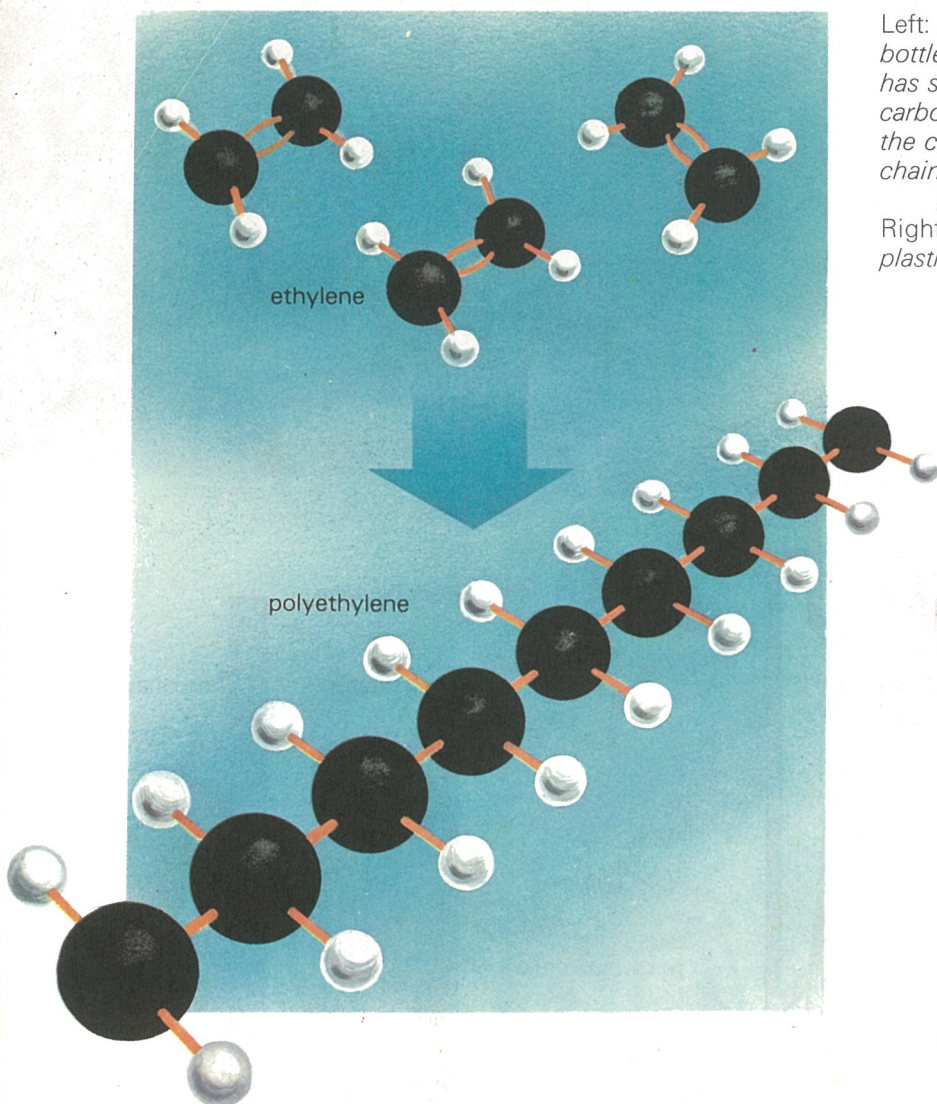
Man-made Materials

Many of the things we use every day are made of plastics. In your home, you probably have a radio, television set, telephone, clothes, carpets, curtains, bottles, cups, saucers, bowls, pens, and many more things that are completely or partly made of plastics. We use plastics so much for several reasons. Plastics are cheap to manufacture and they can be easily made in any shape. They can be flexible or hard and they do not rust or rot. They don't conduct electricity so they are useful for electrical fittings like plugs and switches.

Plastics are man-made or artificial materials. Unlike wood, cotton, wool or leather, they do not come from plants or animals. Plastics are

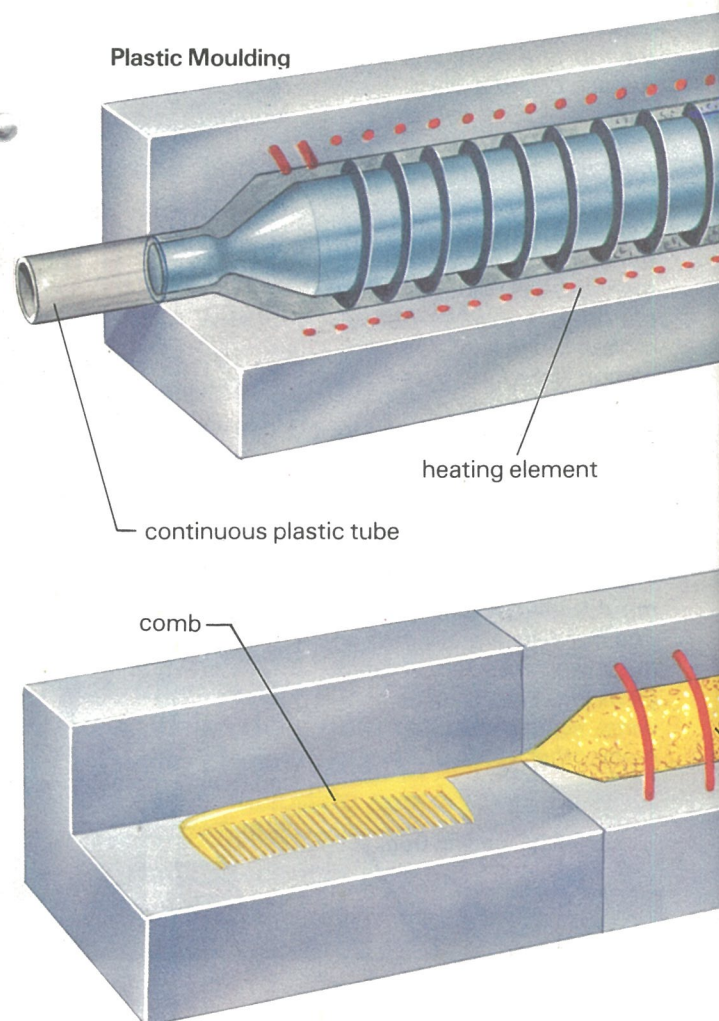
made in factories from chemicals. These chemicals are obtained from coal, oil and natural gas and they contain small molecules. To make plastics, the chemicals are heated. This makes the small molecules join together to form very big molecules. By selecting different chemicals, big molecules of all shapes and sizes can be obtained. This gives plastics of many different kinds.

Plastic objects are made in two ways. The plastic may be placed in a mould and heated to make it soft. The plastic then fills the mould and hardens as it cools, taking up the shape of the mould. These plastics go soft or melt if they are heated. They are used to make such things



Left: Polyethylene is a common plastic used to make plastic bottles and bowls. It is made from the gas ethylene, which has small molecules containing only six atoms – two carbon atoms and four hydrogen atoms. In polyethylene, the carbon atoms join to form molecules containing large chains of hundreds or thousands of atoms.

Right: Two types of plastic moulding machines – producing plastic tubing (top) and combs (bottom).



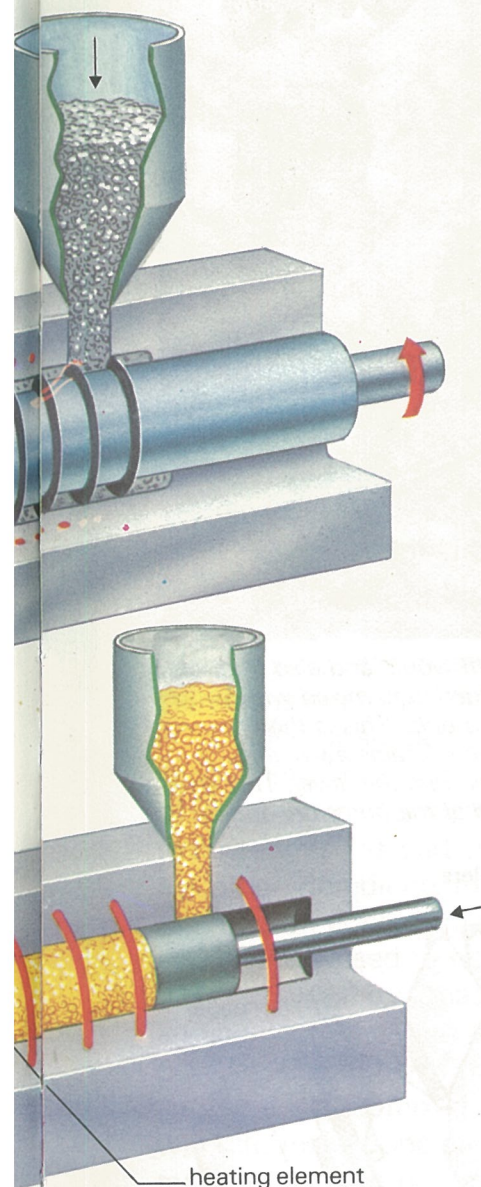
as plastic bowls and bags. Other plastics go hard when they are heated. They are often used to make very strong glues and varnishes and paints for tough coatings.

Artificial fibres like nylon are made by forcing plastic through very small holes to produce thread, which is then woven to make cloth.

Plastics are made by a science called *chemistry*. Other new substances, which can be made from chemicals in similar ways to plastics, have been discovered by chemists. These man-made materials include the dyes that colour our clothes, our furniture, the pictures in this book and many of the things we use every day. Drugs that help to prevent and cure illness, fertilizers and pesticides, and explosives and fuels, can all be made by chemists from chemicals found in natural gas, oil and coal.



Above: Superglue is a kind of plastic that sets to form a very, very strong join!



Glass

Not all man-made materials are new. One that is made and used in a similar way to plastics has been around for centuries. It is glass. Glass is made by heating three natural materials together in a furnace. They are sand, soda (which comes from salt) and lime. Adding metals gives the glass certain colours – iron makes glass green and copper makes it red, for example. Glass goes soft when it is heated, and it can be made into any shape. Glass bottles are made by placing hot glass in a mould, and then blowing air into the mould to push the glass out into shape. Fibre glass is made of thin threads of glass woven tightly together. It is a light but strong material often used for making small boats.

A glass blower makes beautiful glass objects by blowing down a tube into a 'gob' of soft hot glass. As the glass fills out, the glass blower twirls it and trims it with a tool to fashion it into shape.

Using Nature's Gifts

Not all the materials that we use are artificial and man-made. Many occur naturally on or under the Earth's surface. You're holding one of these natural materials right now. It is paper. And you're probably wearing something made of cotton or wool, which are two other natural materials. Is your house or school made of brick, and do you eat and drink from china plates and cups? Bricks and china are two more materials that we make with things that nature provides for us.

Woollen clothes come from the woolly fleece that grows on sheep. Cotton is a cloth that

comes from the cotton plant, which grows large white tufts around its seeds. The sheep's fleece and cotton tufts both contain masses of thin fibres all tangled together. To make cloth, the fleeces and cotton tufts are gathered and combed in machines. The combing straightens out the fibres. Then a spinning machine twists the fibres so that they form long threads, which are wound on to reels.

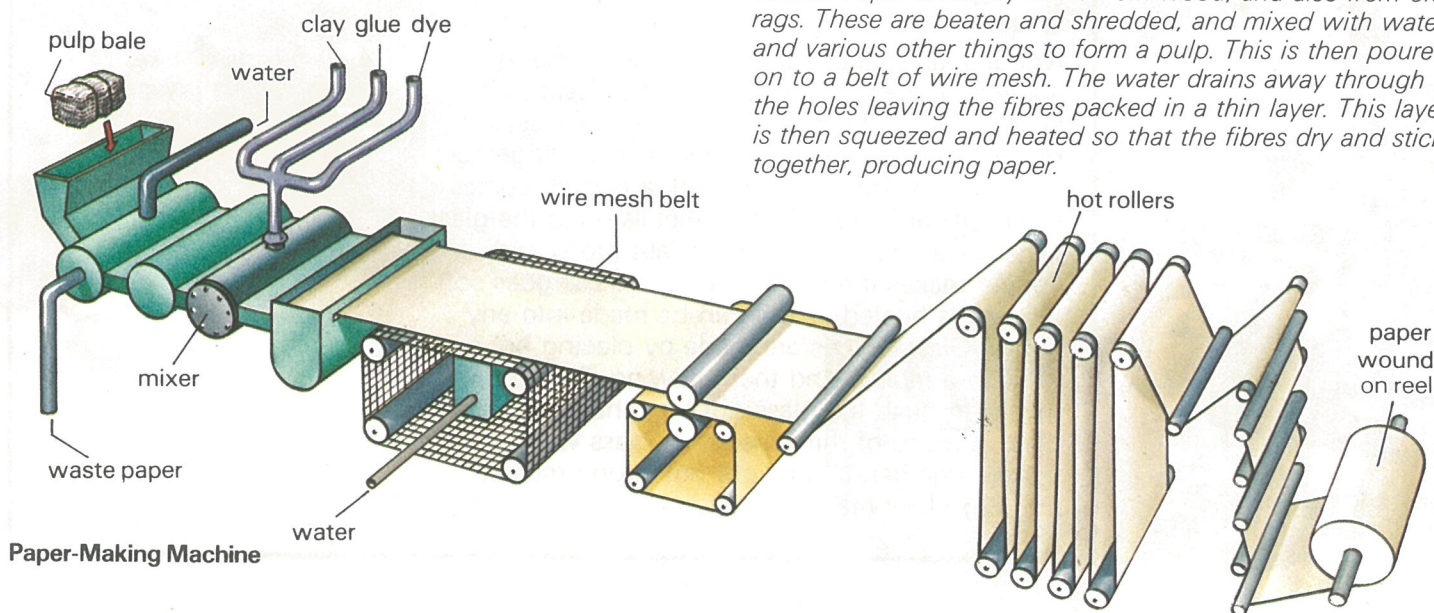
Most cloth is made by weaving or knitting threads of cotton or wool. Linen is a strong cloth woven with thread made from the flax plant. Thread made from artificial fibres such as

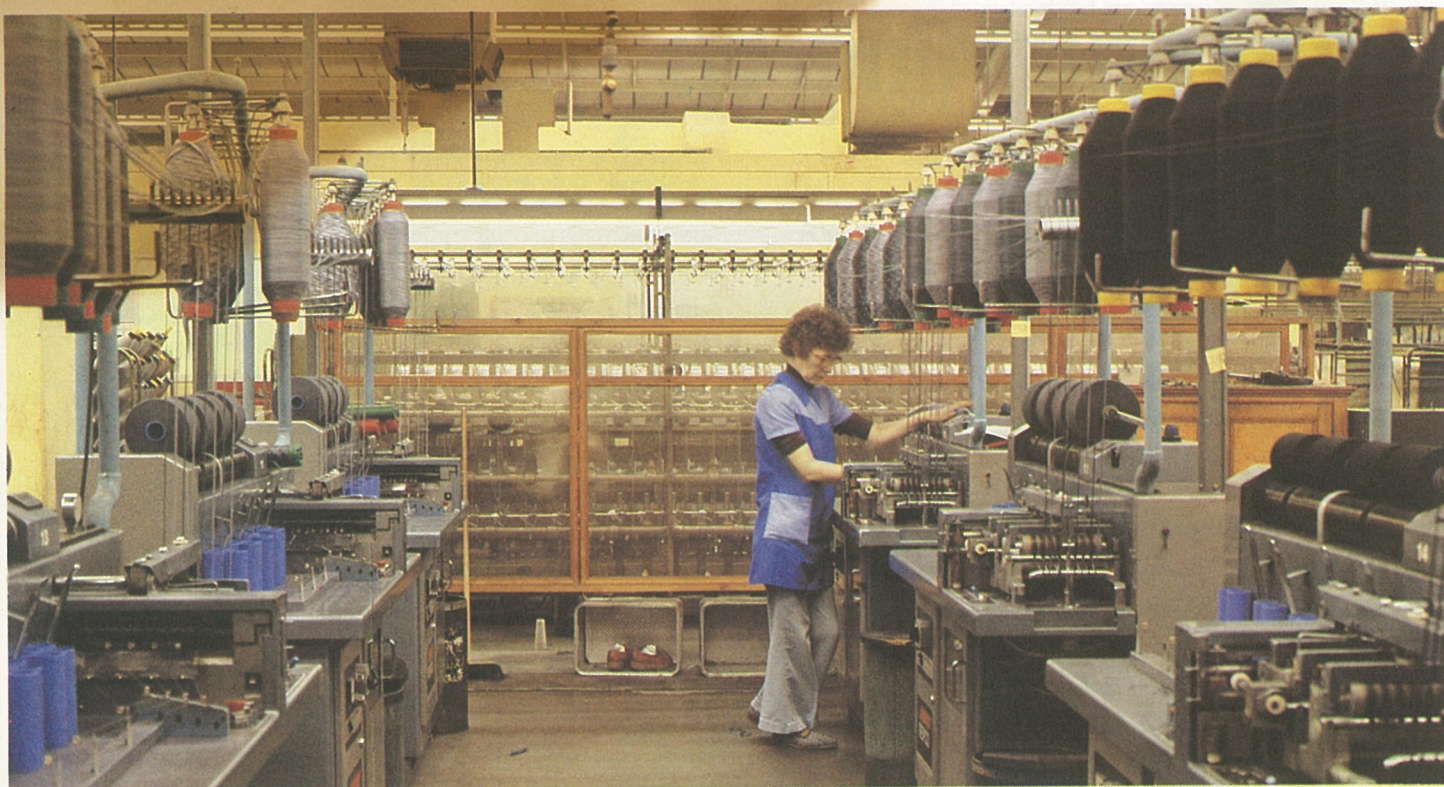


Above: Picking cotton by hand in China.
Right: A sheep is sheared to remove its fleece.



Below: Paper is mainly made from wood, and also from old rags. These are beaten and shredded, and mixed with water and various other things to form a pulp. This is then poured on to a belt of wire mesh. The water drains away through the holes leaving the fibres packed in a thin layer. This layer is then squeezed and heated so that the fibres dry and stick together, producing paper.





Above: Spinning yarn in a factory.

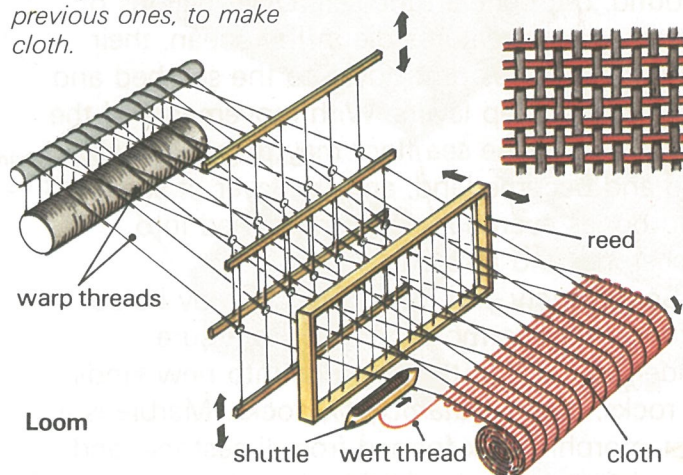
polyester may be included with natural thread. Look and see if you have any labels on your clothes telling you what they are made of.

Weaving is done on a loom by passing one thread over and under a line of other threads. Knitting is more complicated, and the threads interlock in stitches. If the threads are coloured, the weaving or knitting makes a pattern in the cloth. But often the cloth is white and a pattern is printed on it. Weaving and knitting can be done by hand, but most cloth is made by powered looms and knitting machines.

Bricks, china (porcelain) and pottery are all made from different kinds of clay. Clay is a heavy, sticky variety of soil. It is mixed with some water to soften it, and other ingredients such as sand and minerals may be added. Then the clay is cut into blocks to make bricks, or it is moulded or shaped by hand or machine to make china or pottery. These then go to a kiln, where they are heated to a very high temperature. The particles of soil in the clay and the other ingredients melt, and then bind together on cooling to give a hard material.

Cement is used to hold bricks together in building walls. It is made by heating limestone and clay together and then grinding it to a powder. Cement sets hard when water is added. It is also mixed with sand, stones and water to make concrete, a strong building material that can be formed into any shape required.

Below: A loom. The reed presses the newly woven line tightly against the previous ones, to make cloth.



Above: Using concrete to make strong foundations.

Rocks and Minerals

The Earth is like a great treasure house.

Beneath our feet are immense riches – not just precious metals and stones, which are rare, but vast quantities of valuable rocks and minerals.

Deep down inside the Earth, it is so hot that everything is molten. Where there are cracks in the Earth's surface this liquid material sometimes comes to the surface. It cools on or near the surface and solidifies to give a kind of rock called *igneous* rock after the Latin word for fire – indicating that these rocks had a fiery beginning. Granite and basalt are igneous rocks.

Over millions of years, rocks on the surface of the Earth are worn away by the wind and rain, which dislodge tiny particles of sand and soil. These particles can collect in layers, become buried, then get squeezed together and form rocks again. Rocks formed like this are called *sedimentary* rocks. Sandstone and clay are sedimentary rocks. One important sedimentary rock is limestone, which forms, not under the ground, but beneath the sea. Over millions of years, as sea creatures die in the ocean, their shells and bones drift down to the sea bed and build up in deep layers. With movements of the Earth's crust, the sea floor may then gradually rise and become land, and the layer of shells and bones eventually be compressed into limestone, and also chalk.

Sedimentary and igneous rocks may be so affected by enormous heat and pressure underground that they change into new kinds of rocks, called *metamorphic* rocks. Marble is a metamorphic rock formed from limestone, and slate forms from clay in this way.

All rocks are made from *minerals*. For example, limestone, chalk and marble are made of the mineral calcite. Minerals always have the same composition no matter where they are found, while rocks are usually made up of a mixture of minerals and the minerals are not always present in the same proportions. Rocks that contain valuable minerals are called *ores*. The minerals are often valuable because they contain useful metals like iron and aluminium. The metals are not found underground as pure metals. Instead, they are combined with other elements in the minerals. The ores go to factories and refineries to extract the metals.

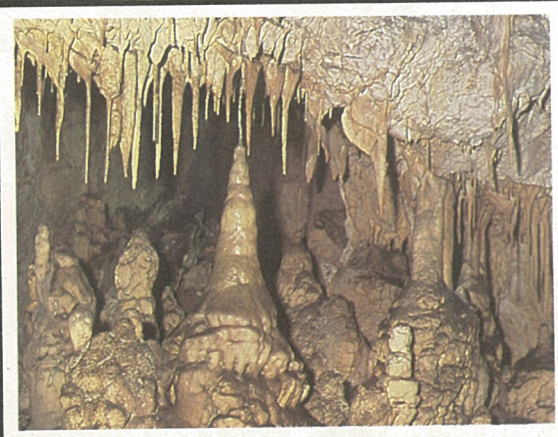
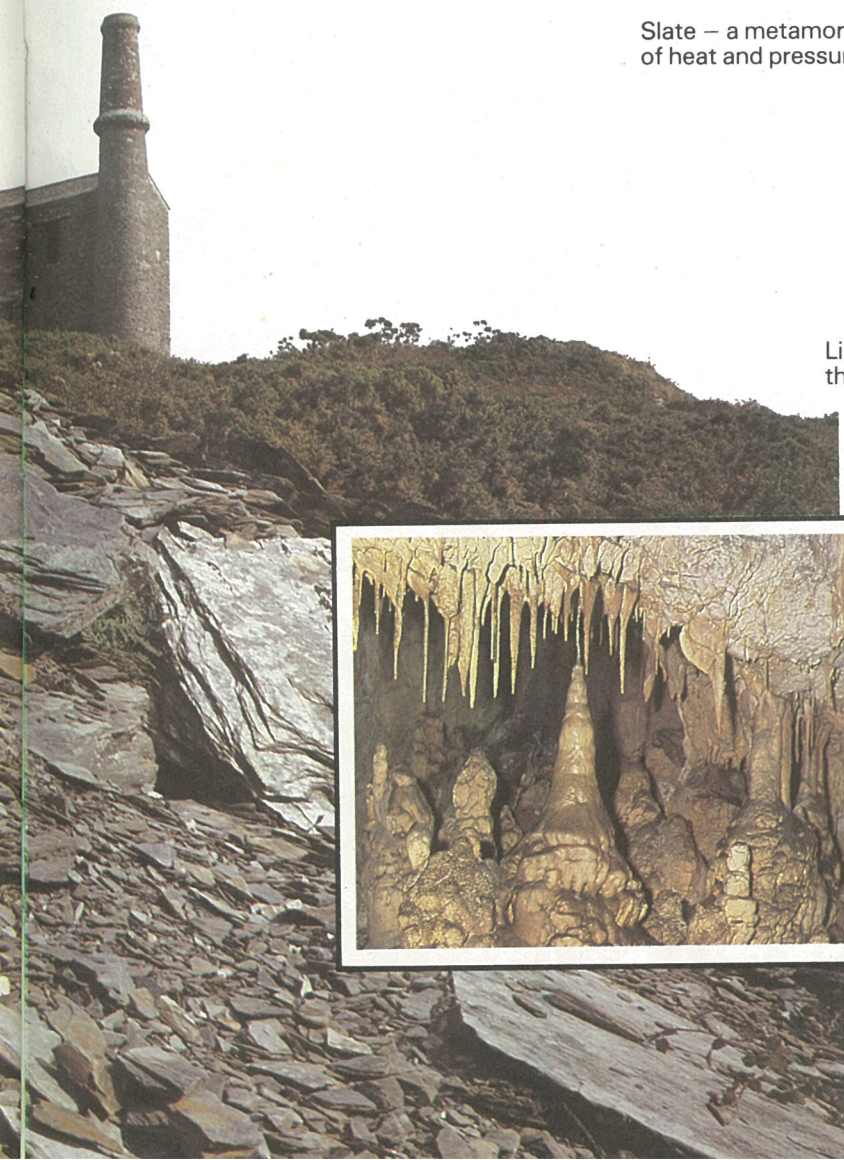
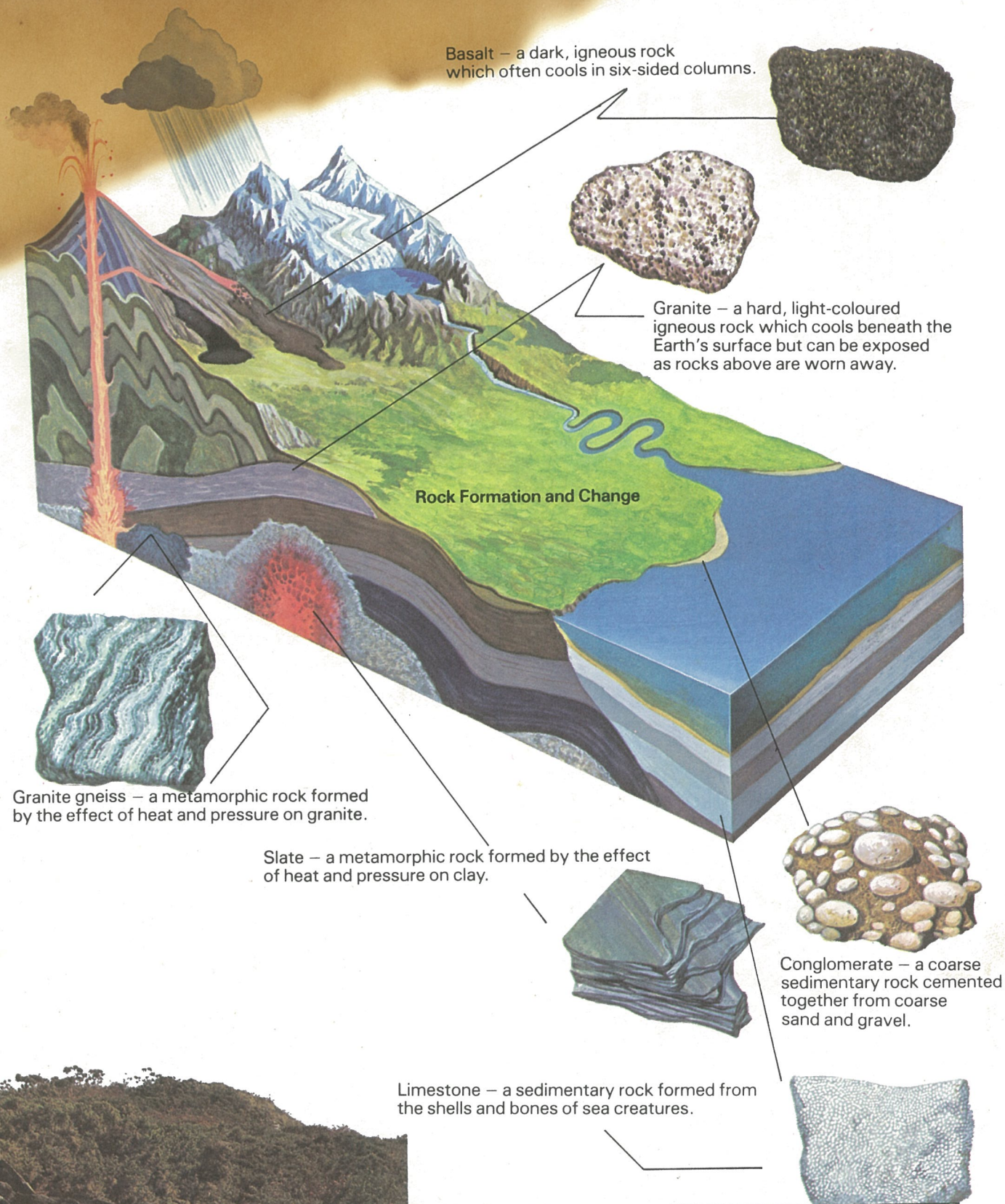
Gold is found in the ground as a pure metal. Precious stones are also found in rocks. They

are pure minerals that have formed as large crystals. This only happens when the conditions underground are just right. For example, diamonds form when carbon slowly crystallizes under intense heat and pressure. Inside crystals, the atoms or molecules line up in neat rows. The pattern of the rows give the crystal a certain shape. Quartz crystals, for instance, are six-sided. However, gemstones are usually cut by jewellers into shapes to make them fit ornaments and look attractive.

Right: A crown encrusted with precious stones.

Below: A slate mine. Slate is sometimes used to make tiles for roofs.





Stalactites and stalagmites

Stalactites and stalagmites are often found in caves formed in limestone, which consists of the mineral calcite. They grow as water containing calcite drips from the roof of the cave. The calcite dissolves as water drains through the limestone above. Then it forms tiny crystals on the roof of the cavern, and these slowly grow into a column of calcite, producing a stalactite. Stalagmites grow up from the cave floor where water drips on to the ground. It takes thousands of years for stalactites and stalagmites to form.

Fossil Fuels

Perhaps the most important of the riches that the Earth provides is one that we never keep. We don't throw it away though; we burn it. From the Earth we obtain our most important fuels, which are coal, oil and natural gas. These at present provide almost all the energy on which our civilization depends.

These fuels are known as fossil fuels because they formed, like fossils, from the remains of prehistoric plants and animals. Coal now lies where huge forests once covered the land. As the trees and other plants died, their remains built up in layers on the ground. Then they were buried and, over many millions of years, changed into coal.

Oil formed in a similar way, except that it comes not from forests but from the remains of sea creatures that collected on the sea bed. The decaying remains of plants and animals also changed in places into gas, which was trapped in layers of rock.

In the long ages since these prehistoric times, movements of the Earth's crust have caused land to sink beneath the sea, and the ocean floor has risen to become land in places. Coal, oil and gas are therefore now found below the ground and under the sea bed.

Coal is mined from huge pits if it is near the surface, or in deep mines underground. A coal mine is like a maze of tunnels. It often stretches for many kilometres, sometimes out under the sea. Miners cut and blast the coal from the rock, and conveyor belts and trains carry it to a lift that brings it to the surface. Huge fans suck fresh air into the workings to keep the miners alive.

Oil is obtained by drilling holes down from

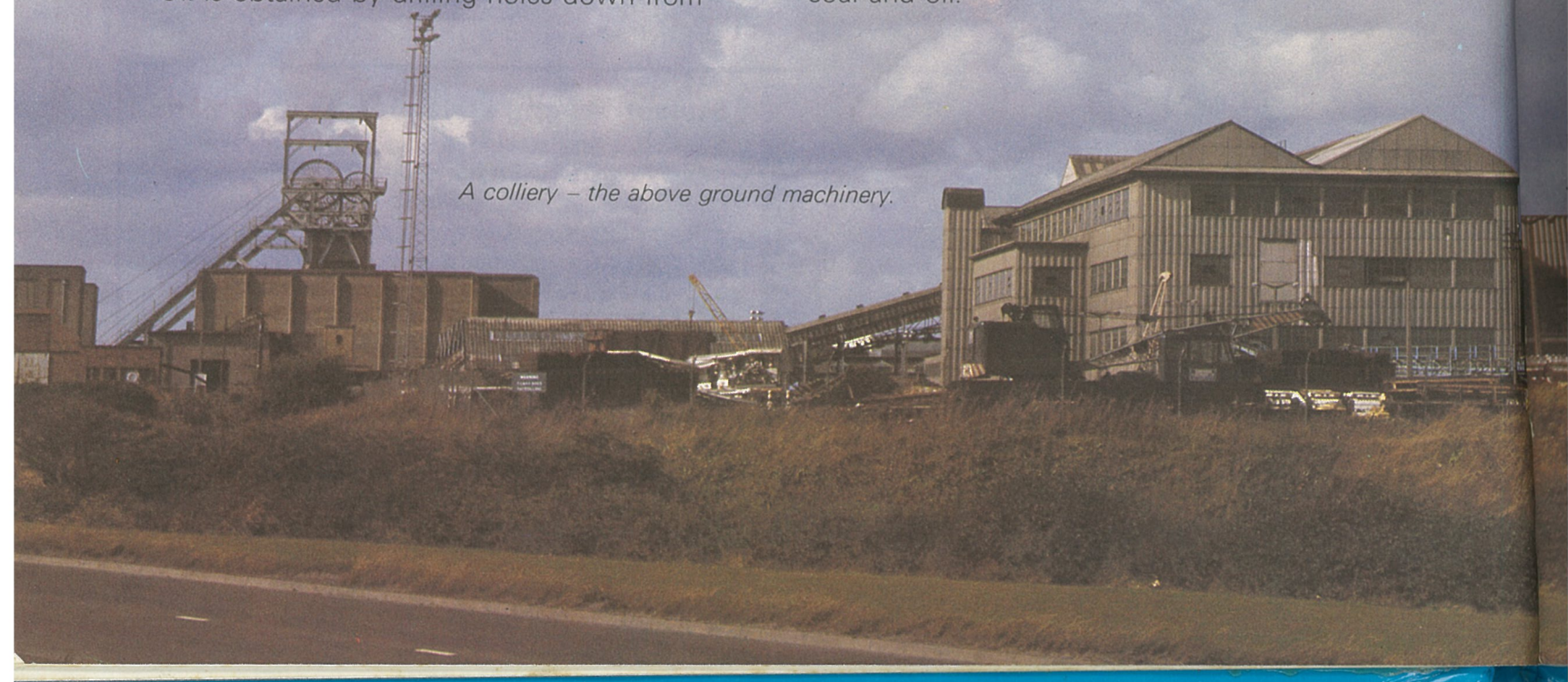
oil rigs to the oil deposits trapped below the Earth's surface. The oil may be trapped under pressure and come bursting up to the surface or it may have to be pumped instead. Then it flows through pipes or is carried by tankers to refineries. Natural gas is drilled for in much the same way as oil and piped to terminals for processing.

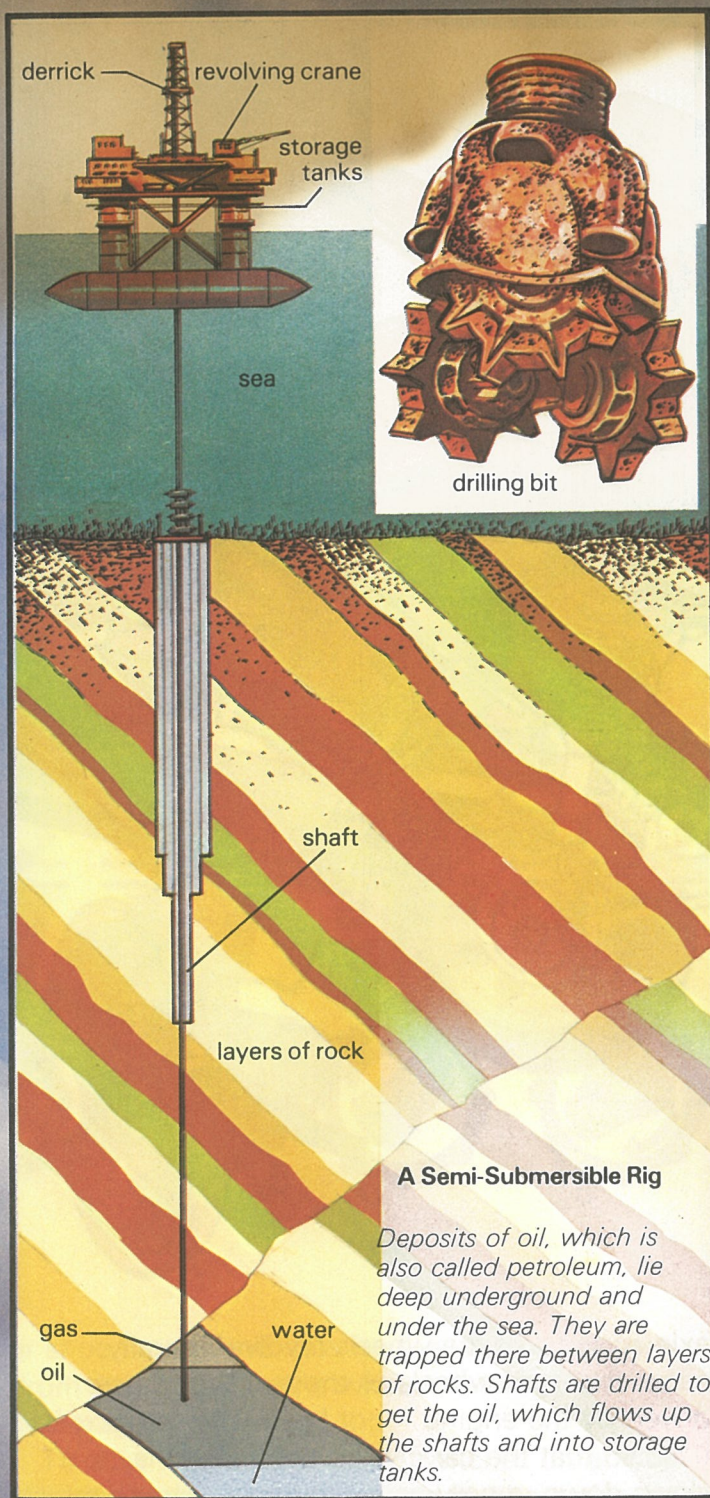
We burn coal in fires to provide heat, but coal is also very useful to us in other ways. If coal is 'cooked' to an immense heat, it gives off coal gas, which is used as a fuel and a source of chemicals. (The solid left behind – coke – is a very good fuel which burns without a lot of smoke.) From coal gas we get coal tar, benzole and ammonia. Coal tar is used to make road tar, bitumen, asphalt and pitch. Benzole is used in the chemical industry to make paint, detergents and even some drugs. Ammonia can be used to make explosives and fertilizers. Coal can even be used to make petrol – a process which is particularly important in countries with no oil reserves of their own.

In refineries, oil is treated to make petrol, fuel oil, lubricating oils and chemicals for plastics and other products. It is even used to make food for farm animals.

Not surprisingly, as coal, oil and gas were formed in similar ways, natural gas gives us much the same range of products as coal and oil – fertilizers, dyes, detergents and protein for foodstuffs. It is also an important fuel, keeping us warm, firing furnaces and kilns and powering cars and vans. Coal, oil and gas are all also burned in power stations to make electricity, and gas can be 'manufactured' from coal and oil.

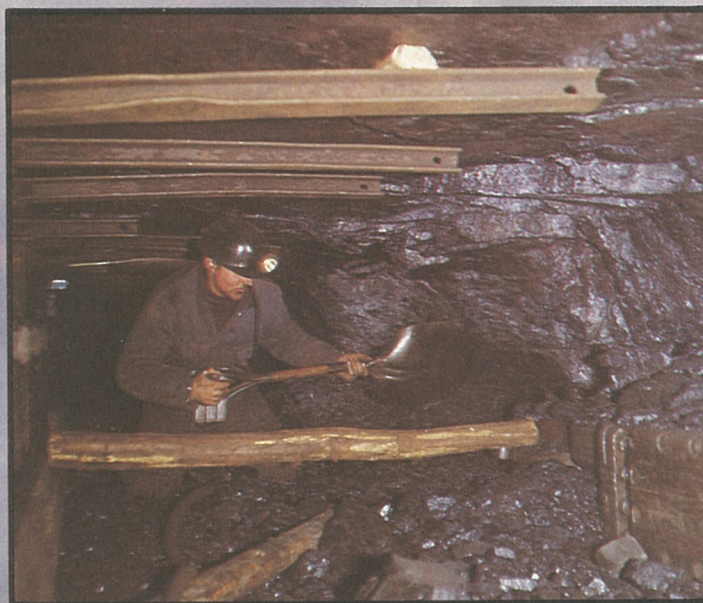
A colliery – the above ground machinery.





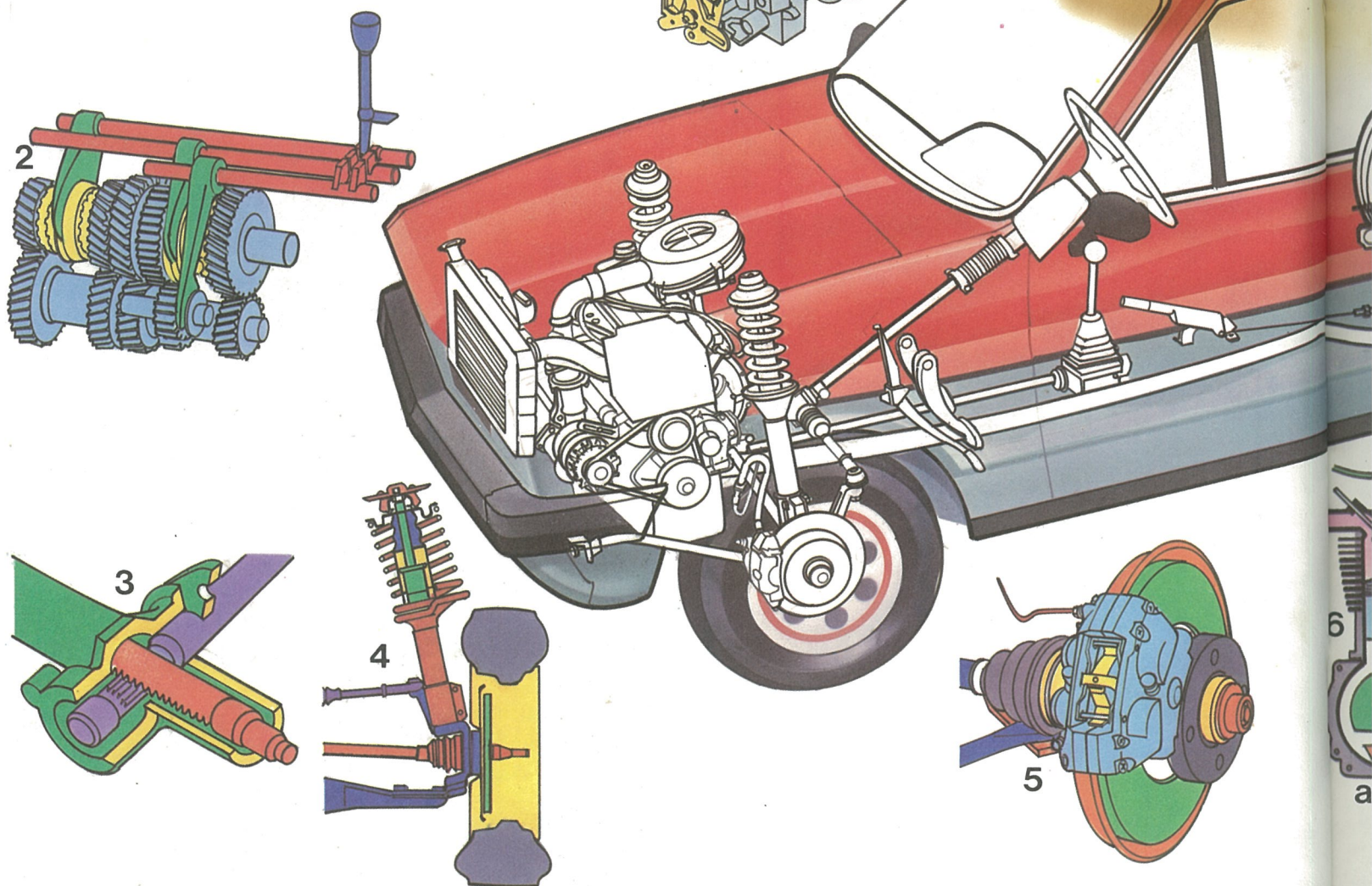
Above: An oil production platform (rig) in the North Sea. These platforms have to be able to withstand winds of up to 200 kilometres per hour and waves up to 30 metres high.

Below: A coal miner cuts away at a coalface deep underground. Most coal mines have powerful machinery to help miners dig out the coal. But it is still a dangerous job.



Cars by the Million

Every year, about 27 million new cars are made. Throughout the world, there are about 350 million cars in use, one car for every 13 people.



There are also millions of lorries, buses, vans and motorcycles, some of which have petrol engines like cars and some of which have kinds of petrol engines called diesel engines. Many trains are driven by diesel engines or carry a diesel-powered electric generator.

The petrol engine was invented a century ago, and it has brought easy travel to almost everyone. It actually goes with a bang, for it works by exploding petrol vapour. However, the silencer swallows the noise so that the engine runs quietly. As the vapour explodes, it forces a set of pistons to move up and down in the engine's cylinders. This happens many times a second. At the bottom of the engine, the pistons make a crankshaft spin round.

When the car is moving, the crankshaft turns a set of gears in the gearbox. These are connected to the drive shaft, which turns an

axle and makes the wheels revolve. Usually, either the front wheels or the rear wheels are driven by the engine – not both. The gearbox is used so that the car can go uphill. As the car slows down, a new gear allows the engine to keep working at the same speed. This gives the car enough power to climb the hill.

To change gear, to move away, and to keep the engine going when the car is at a standstill, the driver operates the clutch. This is a pair of circular plates between the engine and the gearbox. The plates move apart to disconnect the engine from the gears. They move back together to turn the gears and through them, the wheels. The steering wheel turns the front wheels to make the car change direction.

Brakes in the wheel hubs stop the car. The driver presses the brake pedal, which is linked to a brake pad or shoe in each wheel. The pad

Left: A typical car, cut-away to show the insides. Parts of the car have been drawn on a larger scale so they can be seen more clearly.

1. Carburettor – the central part of the car's fuel system. It is here that the fuel, which is stored in the petrol tank and pumped to the carburettor, is mixed with air and vaporised. The resulting mixture of fuel vapour and air then enters the cylinders through the inlet valve.

2. Gear box – the power created by the engine reaches the wheels via the gear box. This allows the car to move at different speeds while the actual engine speed stays more or less steady.

3. Steering mechanism – a car's steering system consists of a steering wheel, the steering box or rack-and-pinion (illustrated) and track rods linking the rack-and-pinion to each of the front wheels. When the steering wheel is turned, the steering column also turns. The toothed pinion at the end of the column engages with a rack, moving it from side to side. Track rods at the ends turn the wheels.

4. Suspension unit – to give the passengers a smooth ride, a car must have a suspension system. This is made up of various arms and springs between the wheels and frame of the car.

5. Disc brake assembly – most cars now have disc brakes on the front wheels. When the brake pedal is pressed, a pair of brake pads clamp against a cast-iron disc fixed to the wheel, which stops the wheel rotating.

6. The four-stroke cycle – Most cars contain four-stroke engines. This means that each piston makes four actions to produce power.

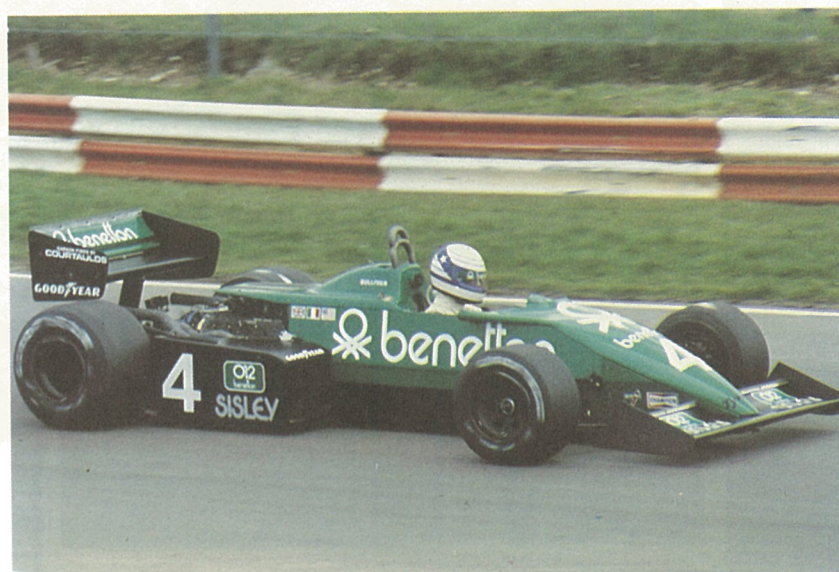
- The piston moves down and petrol vapour enters the cylinder through the inlet valve.
- The piston moves up and compresses the vapour.
- In petrol engines a spark ignites the vapour and the piston is forced down. In diesel engines the vapour ignites without a spark.
- The piston moves up and pushes the exhaust gases out of the cylinder through the outlet valve.

or shoe moves and rubs hard against a disc or drum connected to the wheel, slowing and stopping the wheel.

To start the car, the driver switches on an electric starting motor powered by the car's battery. This sets the pistons going up and down in the cylinders. An electric generator connected to the engine makes a spark fire in the spark plug in each cylinder. This explodes petrol vapour fed to the cylinders, and the engine starts. The vapour comes from the carburettor, which sucks air in to produce vapour from petrol pumped from the petrol tank.

In a petrol engine, the spark plugs continue to fire to keep the engine going. A diesel engine has no spark plugs. Instead, the pistons compress the vapour in the cylinder so that it heats up and explodes on its own.

Below: Racing cars have large engines and travel so fast that they are likely to take off. An upside-down wing is often attached to the car to keep it on the ground.



Water-our most precious mineral

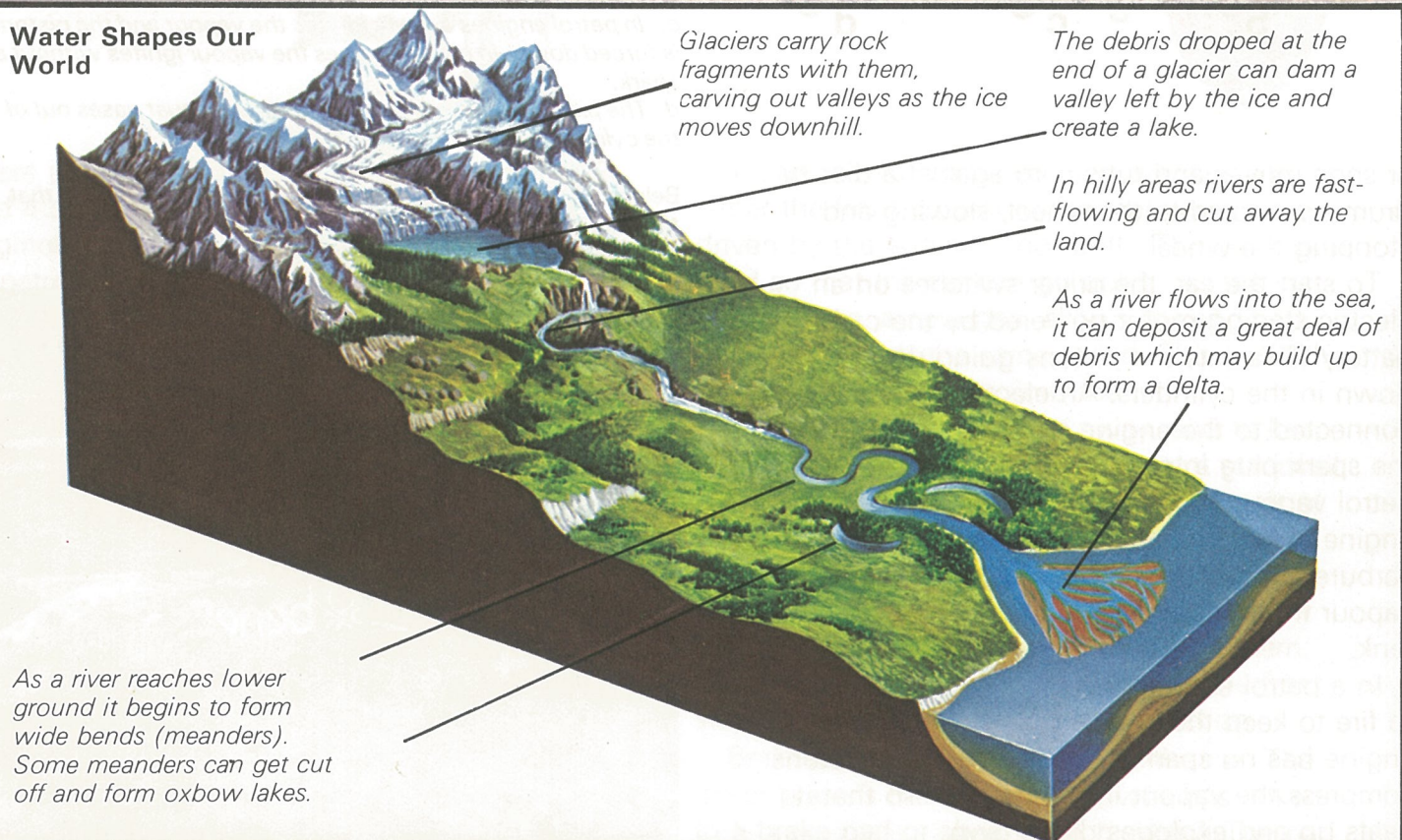
We sometimes speak of any non-living thing that we take from the land or sea for our benefit as being a mineral. Coal and oil are considered to be minerals as useful as iron ore and limestone. But none of these are absolutely essential to us; prehistoric man survived without them. One mineral, however, is absolutely necessary – water. Our bodies are more water than anything else, and we need to keep up our water content by drinking. Plants require water to grow, and plants give us food and maintain the oxygen level in the air (see page 38-9).

The water we need must be liquid too. Plants and animals cannot live at the North and South Poles because it is too cold there for water to stay liquid. No other world in the Solar System

has liquid water – and no other world in the Solar System appears to have life.

Water does not only sustain life on Earth. It also shapes the face of our world. As rain water falls on the land and runs into streams and rivers, it carries particles of soil with it. When winter comes, water freezes in small cracks in the rocks. The ice expands (takes up more room than the water) and breaks small fragments away from the rocks. In these ways, water acts, over millions of years, to change the face of the land. It carves out valleys and smooths away hills, slowly moulding the landscape to its will. In mountains, glaciers (frozen rivers of ice) gouge deep troughs in the rock. At the coast, waves pound at cliffs and eat them away. Fortunately, movements in the

Water Shapes Our World

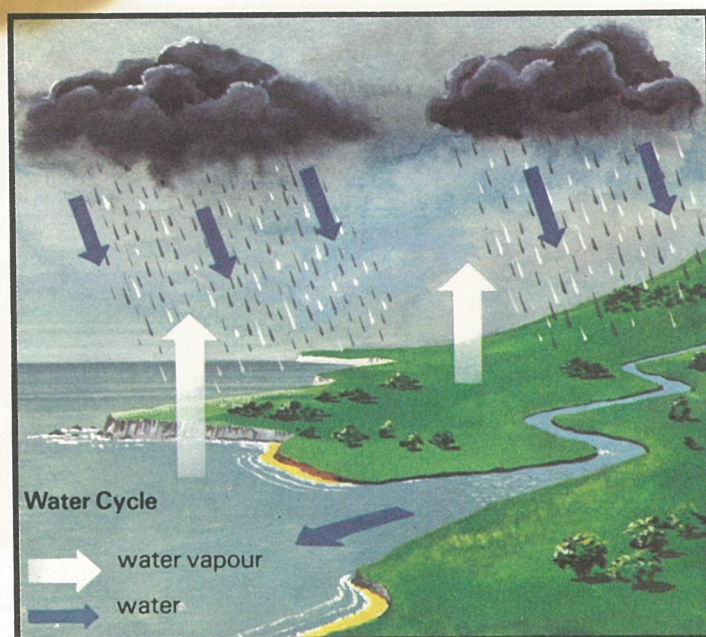


Earth's crust slowly raise new mountains, or water would long ago have made our world as smooth as a billiard ball!

The water cycle

Water travels between land, sea and air in a huge continuous movement called the water cycle. The water in lakes and rivers, and in the sea, evaporates all the time. Water vapour rises into the air from the water, leaving any salt that is in the water behind. Water vapour also rises into the air from plants, and animals, including people, breathe some out.

As the water vapour rises, it cools because the air higher up is colder. It condenses into water droplets, forming clouds, then the droplets gather into drops that fall as rain. If it is very cold, the drops freeze and form snowflakes. In this way, the water returns to the land and sea and the cycle begins again.



Why is the sea salty?

Salt gets into the sea from rivers, which dissolve the salt from rocks on land. It spreads throughout the oceans, but warm waters are generally more salty than cold seas. This is because the Sun's warmth makes more water evaporate, leaving more salt behind. On average, every litre of sea water contains 36 grams of salt. In many places, salt is obtained by allowing shallow pools of sea water to evaporate away completely. Elsewhere, salt is mined underground.

Below: Saltpans in New Zealand. Seawater is trapped in shallow lakes and the heat of the sun evaporates the water leaving the salt behind. Great piles of salt can be seen in the middle of the picture.



On, Over and Under Water

Why do pieces of wood and plastic, apples and oranges, packs of butter and many other things float on water? And why do metal objects sink, even if they are small and light – like pins and needles? Floating has nothing to do with the weight of an object. It all depends on *density*. If an object has a smaller density than water, it floats. If its density is greater than water, it sinks.

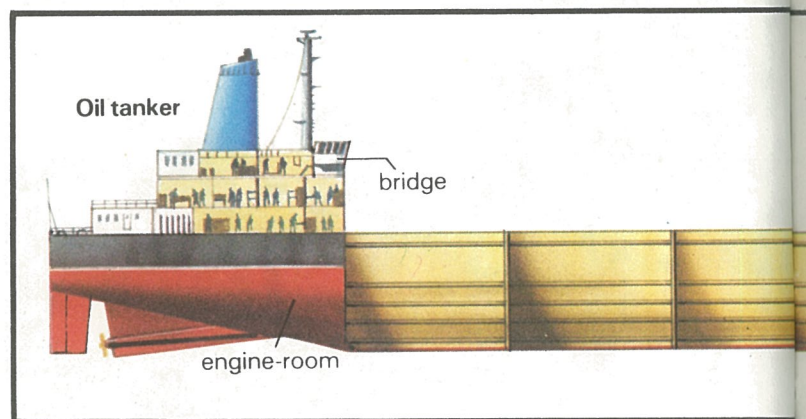
When anything enters water, it pushes some water aside. The water pushes back on the object. You can feel this push by wrapping a plastic bag around your hand and wrist and plunging it into some water. The force with which the water pushes back depends on how much water is pushed aside to begin with. In fact, the force is equal to the weight of the water pushed aside. If an object is less dense than water, it weighs less than the amount of water it pushes aside. The water pushes back with a force greater than the weight of the object. It holds up the object in the water and makes it float. If the density of the object is greater, the water does not push back with enough force to support it, and the object sinks. So wood floats because it is less dense than water, and metal sinks because it is denser.

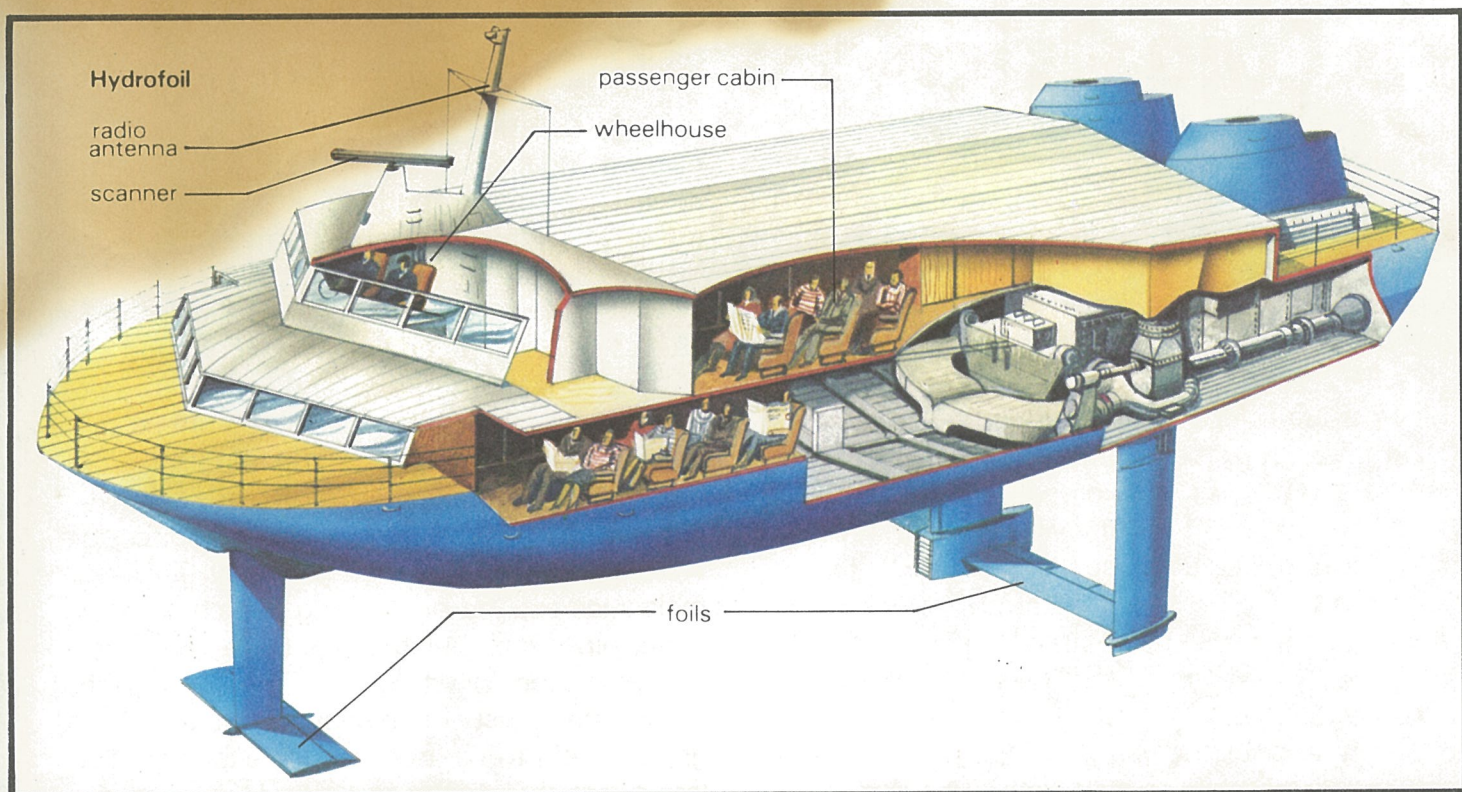
You might now wonder why metal objects like boats float. The reason is that the whole boat has to be considered, not just the metal hull. Inside the boat is a lot of air, so it is much lighter than if it were a solid block of metal. However, the same amount of water is pushed aside as if the boat were a solid block so enough force is produced in the water to hold up the light hollow boat and it floats. You can float and swim in water for the same reason. The air in your lungs makes you light enough to float.

We do not only travel on the sea's surface. Submarines venture beneath the waves. To dive, compartments in the submarine open and fill with water. This makes the submarine so heavy that its density becomes greater than water, and it sinks. To return to the surface, compressed air blasts the water out of the compartments.

Right: Hydrofoils and hovercraft (see page 40) race over the waves. Hydrofoils have blades like wings beneath their hulls. As they begin to move, the blades rise and lift the hull out of the water. This is why hydrofoils can travel so fast: speeds of 100 kilometres per hour or more are common.

Below: Oil tankers can be enormous. They are single-decked ships with the engine-room, bridge and crew's quarters situated aft. This is British Patience, a 250,000 tonne tanker owned by British Petroleum.





An oil tanker cut-away to show the huge tanks where the oil is stored.



Make metal float

If you are careful, you can get a metal needle to float on the surface of some water. The reason it does not sink is that it is held in the surface of the water. The molecules of water in the surface grip it with a force called *surface tension* and stop it sinking. The surface tension is not very strong and supports only very light objects like needles. Small insects like pond skaters use surface tension to move about on the surface of water.

As Cold As Ice

When you touch a metal object, it usually feels cold. This is because metal is a good conductor of heat – heat moves easily through it. So some heat flows from your fingers into the metal, and your fingers get cold.

To make anything cold, heat has to flow out of it. In a refrigerator, cold vapour circulates in pipes around the freezing compartment inside. Heat flows from the food and drinks in the refrigerator into the cold pipes, making the vapour inside them slightly warmer as the food and drinks get colder. Usually, placing something cold next to a warm object will cool the object, because heat can only flow in one direction – from something hot to something cold.

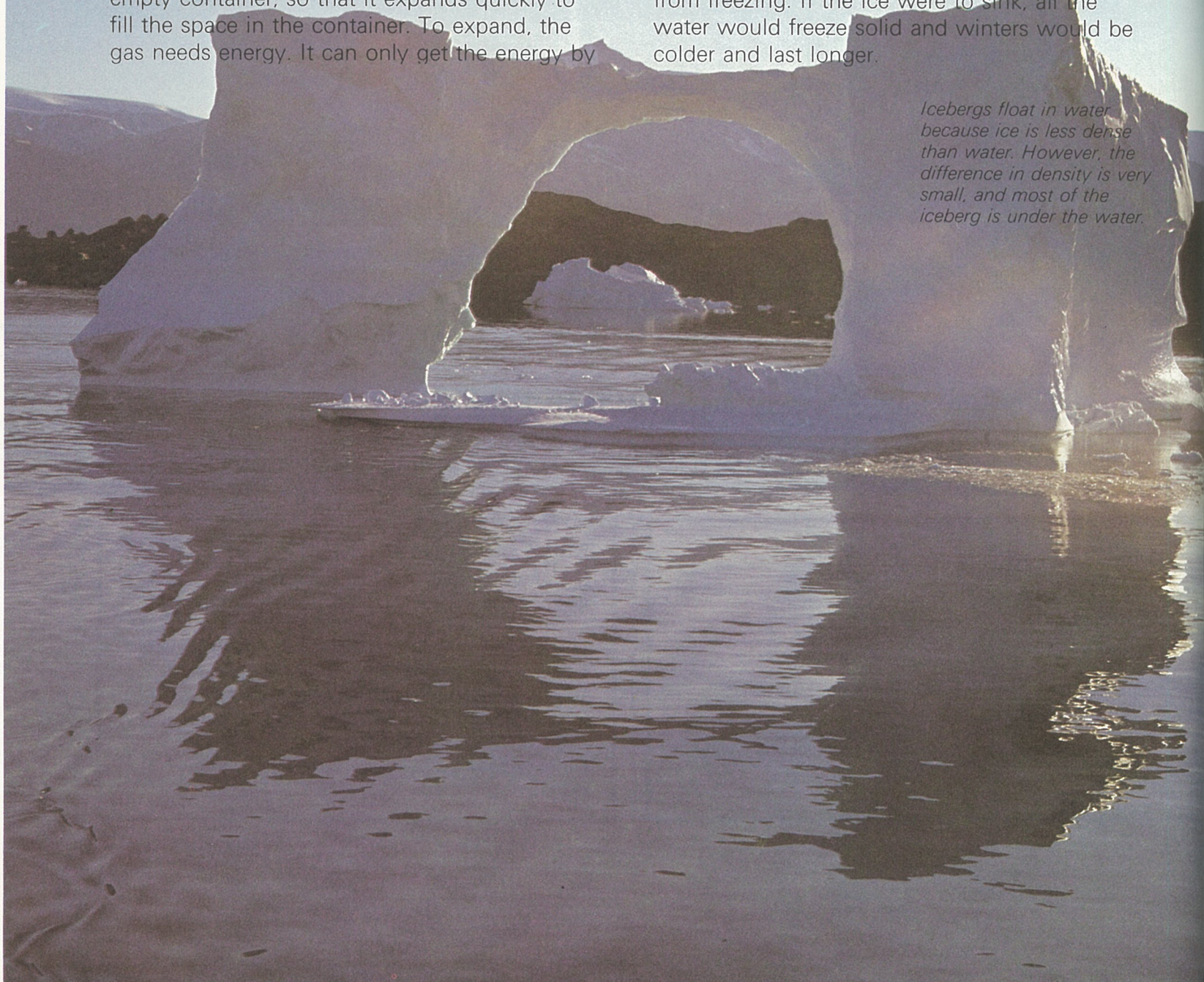
But how does the vapour in the pipes of the refrigerator get cold to start with? This is done by making the vapour expand before it enters the pipes. It goes through a nozzle into an empty container, so that it expands quickly to fill the space in the container. To expand, the gas needs energy. It can only get the energy by

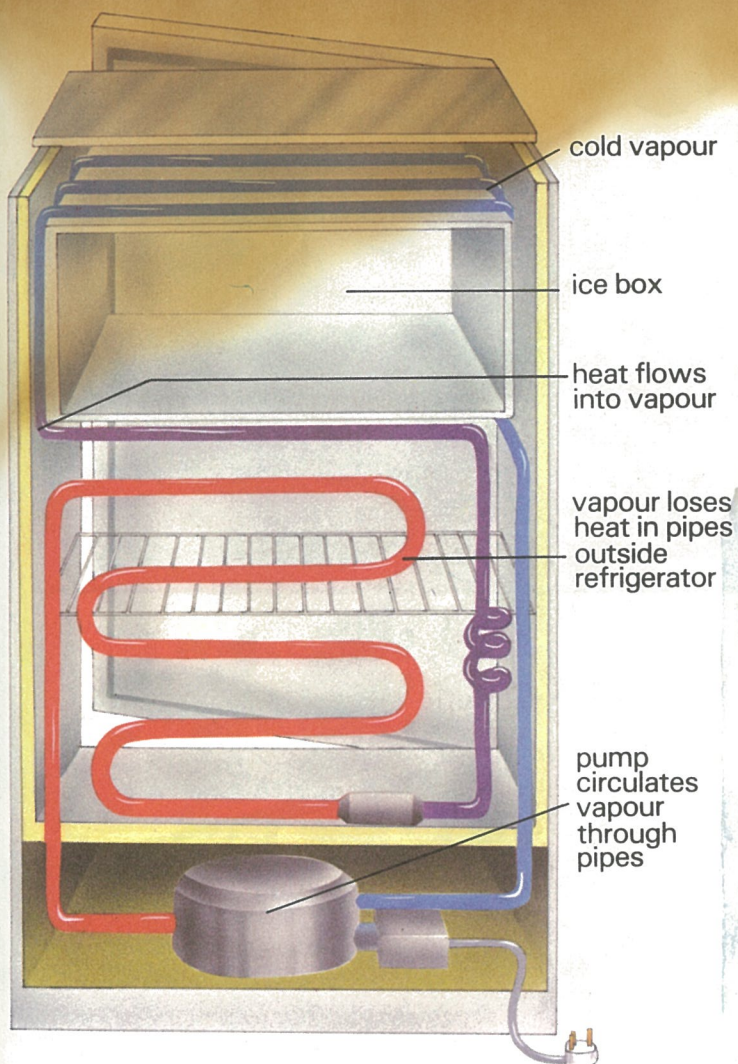
using its heat, so it loses heat as it expands and cools. The cold vapour then flows into the refrigerator pipes and takes up heat again inside.

When liquids get cold, their molecules move more slowly. At a certain temperature, the molecules line up in rows and the liquid freezes into a solid. This temperature is the liquid's freezing point. Usually, a liquid shrinks as it freezes, but water behaves differently. As it approaches freezing point and turns to ice, the water molecules move apart slightly. This makes ice expand on freezing, which is why water pipes may burst if they freeze in winter.

If your pipes burst you may not think so, but in fact this unusual behaviour of water is of great benefit to us. Because ice expands, it is less dense than water and therefore floats on water. During cold winters, a layer of ice forms on top of water and stops the water beneath from freezing. If the ice were to sink, all the water would freeze solid and winters would be colder and last longer.

Icebergs float in water because ice is less dense than water. However, the difference in density is very small, and most of the iceberg is under the water.





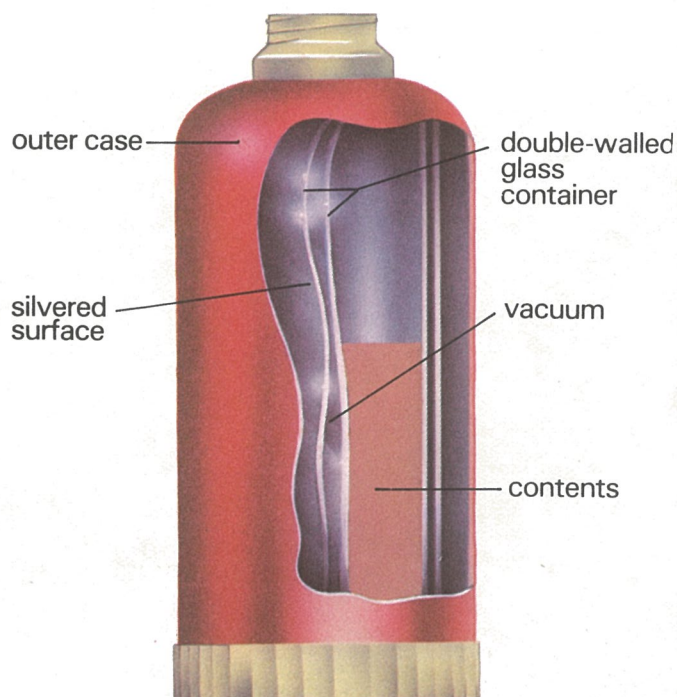
Above: In a refrigerator, vapour flows through pipes and takes heat from the inside to the outside, keeping the food and drink cold. If you look at the back of a fridge you will see the pipes from which heat is lost.

Top right and below: Ducks keep warm in winter because they have a layer of air beneath their feathers. Heat does not easily move through the air so the layer of air keeps the heat in and makes the ducks warm. Coats keep us warm for the same reason.



Vacuum flask

A vacuum flask keeps drinks hot for a long time. Inside the flask is a container with double walls. All the air is removed from between the walls, leaving a vacuum. A vacuum does not conduct heat at all so the heat stays inside the flask, keeping the liquid hot. You may have noticed that the inside of the flask is silver-coloured. This helps stop heat loss by radiation (see page 19).



The Atmosphere

We live on the surface of the Earth. Above us there is the atmosphere – a layer of air that surrounds the Earth just as a layer of peel surrounds an apple or an orange. In fact, if the Earth were the size of an apple or an orange, the atmosphere would be only about as thick as the peel. This layer is vitally important to us: without the atmosphere there would be no life on Earth. And this is not only true because we

need air to breathe. The atmosphere also protects us from the scorching heat of the Sun during the day and keeps us warm, like a blanket, at night. Without it the surface of the Earth would be as hot as boiling water by day and far colder than freezing at night.

The bottom part of the atmosphere, which is the air we breathe, is called the *troposphere*. It goes up to a height of about 10,000 metres

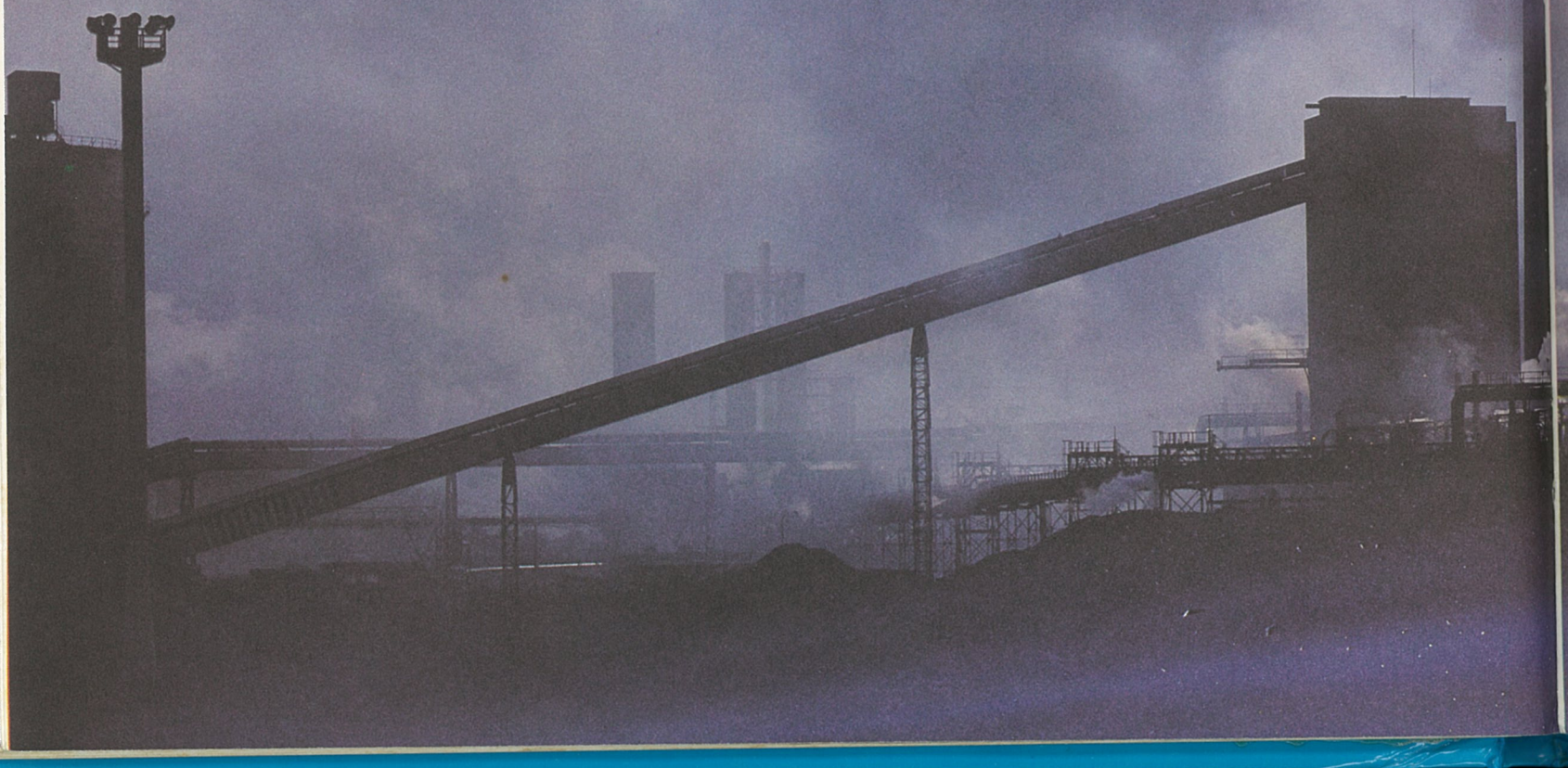


Above: A photograph of a hurricane taken from the Apollo 7 Spacecraft. Hurricanes are violent winds that blow at speeds reaching 200 kilometres per hour. They destroy almost everything in their path. In hot places like the tropics, the Sun's rays warm the land and sea which heats the air above. The warm air rises and moves out, causing winds to blow. Fortunately it is rare for the winds to be of hurricane strength.



Above: Damage caused by a hurricane.

Below: The air we breathe may also contain gases that come from factories, heating systems and car exhausts. Factory chimneys are a major cause of air pollution. Burning fuel produces sulphur dioxide, a gas that rots the stonework of old buildings and may affect people's lungs.



above the ground. As you get higher in the atmosphere, the air gets colder. This is why there is snow at the summits of high mountains. The air also becomes thinner as you get higher, which makes it hard to breathe at great heights. Mountaineers have reached the top of Mount Everest, which is nearly 9000 metres high, without using breathing apparatus. But no one could survive much higher than this. Above the troposphere is the *stratosphere*. This is a layer of air that goes up to a height of about 50 kilometres. It is very cold (about

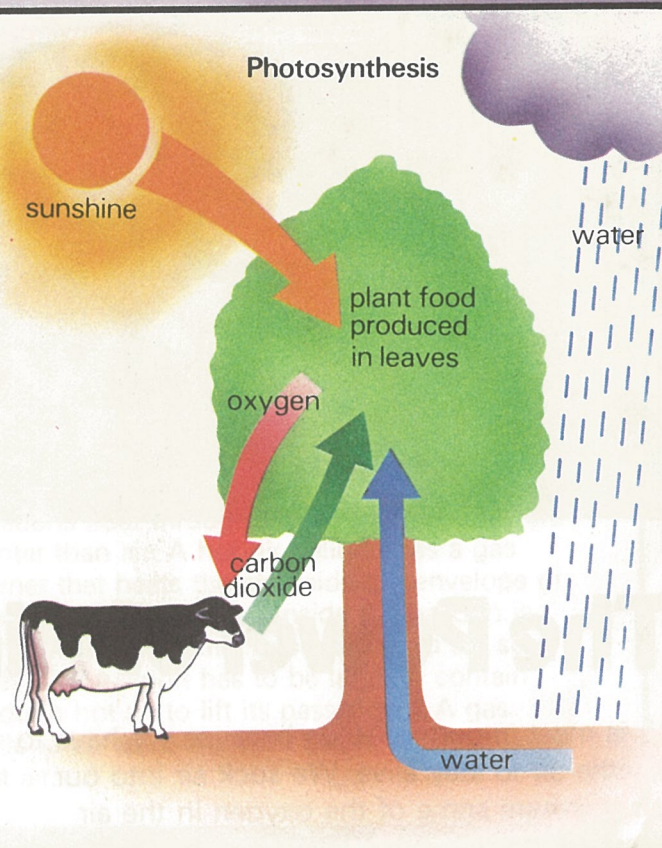
-50°C) but the air is mainly calm. Aeroplanes fly in the lower part of the stratosphere, well above the clouds and winds below.

Above the stratosphere comes a layer containing *ozone*, a gas similar to oxygen. The ozone layer is like a shield because it stops harmful rays reaching us from the Sun. Then comes the upper atmosphere. The air gets thinner and thinner, until there is virtually no air left about 200 kilometres above the ground. This is where space starts and satellites and spacecraft can orbit the Earth.

The air we breathe

Air is not one gas, but a mixture of gases. About one-fifth of air is the gas oxygen and one-hundredth is argon, while almost all the rest of the air is nitrogen. This mixture is the same throughout the world. This is very important, because we need just this much oxygen to live. The argon and nitrogen are harmless gases that dilute the oxygen to the right amount for us to breathe easily. The air also contains some water vapour. The amount of water vapour changes from place to place, depending on how wet it is.

When people and animals breathe, they use up oxygen in the air. However, the amount of oxygen in the air always stays the same. This is because green plants, like grass and trees, replace the oxygen that is used up, keeping the air fresh everywhere and at all times. In the process of breathing people and animals change some of the oxygen they breathe into the gas carbon dioxide which they breathe out. The plants take in the carbon dioxide and use sunlight to change it and water back into oxygen and plant food. This process is called *photosynthesis*.





The Power of Air

Air is most important to us because we have to breathe air to stay alive. We suck air into our lungs, where some of the oxygen in the air dissolves in our blood. This oxygen-rich blood is pumped by the heart around the body, which uses it to produce energy. Oxygen also dissolves in the water of seas, lakes and rivers, which is why fish and other animals can live underwater. They are adapted to take oxygen from the water.

However, we also make use of air in several other ways. We live at the bottom of the atmosphere, and the air presses down on us. We do not feel the pressure of the air because it is the same inside our lungs and outside our bodies. In fact, the air pressure is strong – equal to a force of about 20 tonnes over the whole surface of the body.

We put this air pressure to use to raise liquids. When you suck up a drink through a straw, you decrease the air pressure in your mouth by expanding your lungs. The air

pressure on the drink in the bottle or glass is stronger than the air pressure in your mouth. It therefore pushes some of the drink up the straw into your mouth. Pumps may use air pressure to raise water in a similar way. The pressure of the air is sufficient to lift water by as much as 10 metres.

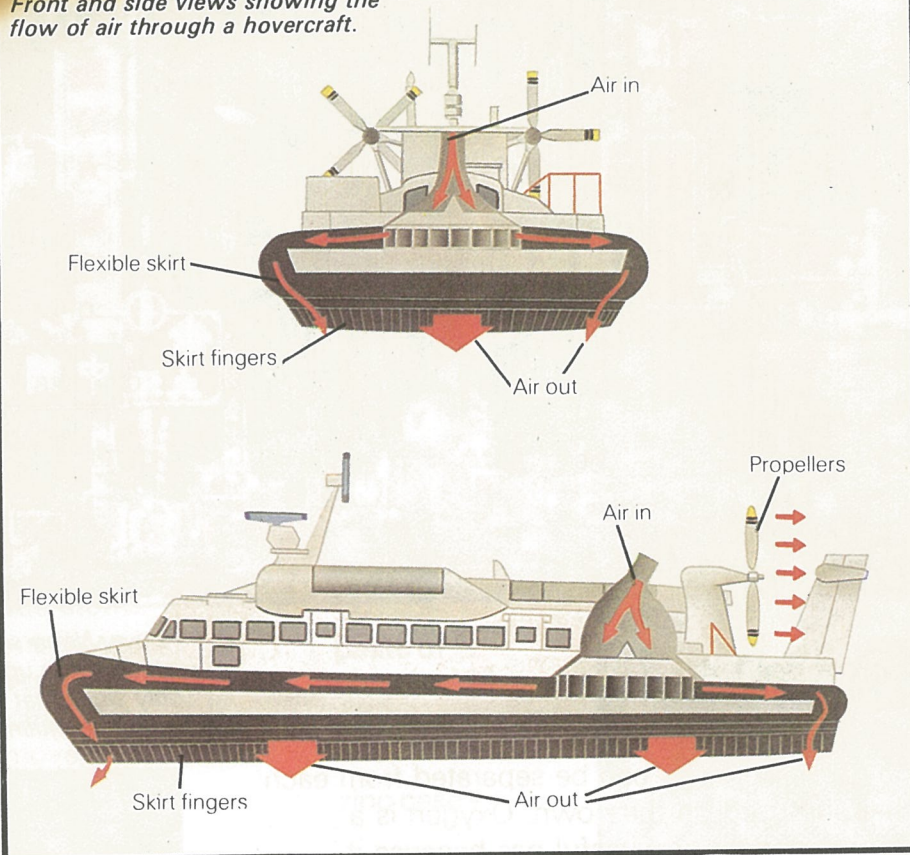
Air is also put to use by increasing its pressure with a *compressor*. Compressed air is a very useful way of producing power. Dentists use drills that are powered by compressed air. The air is fed to the drill through a tube and spins the vanes of a tiny fan that turns the drill. The big pneumatic drills used by road menders also work by compressed air, which drives the blade of the drill up and down to dig into the road surface.

Air is pumped into an air bed and a tyre to compress it. It can then push against the walls of the bed or tyre to give enough force to support the weight of the person resting on the bed or the vehicle riding on the tyres.

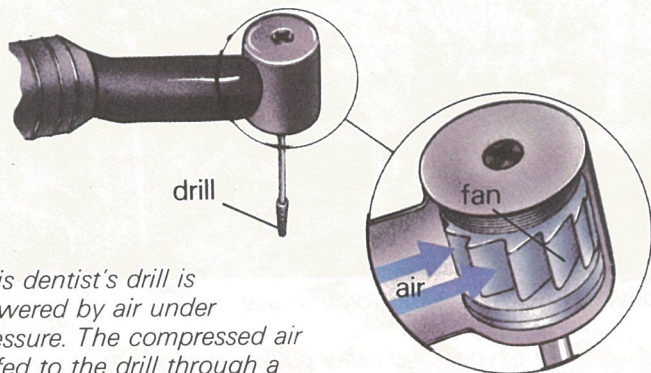
Right: The most dramatic use of air pressure is the hovercraft. Fans inside a hovercraft produce a cushion of high-pressure air beneath it. The hovercraft rests on this cushion of air, which is usually kept inside a flexible skirt around the vehicle. In this way, the hovercraft is raised above the water and, because it does not have to push itself through the water, it can move very fast. The hovercraft is driven by propellers like an aircraft, and it can travel over flat ground as well as water.

Left: The world's biggest hovercraft can carry more than 400 passengers and 60 cars. They operate as ferries between England and France, travelling at speeds of up to 120 kilometres per hour.

Front and side views showing the flow of air through a hovercraft.



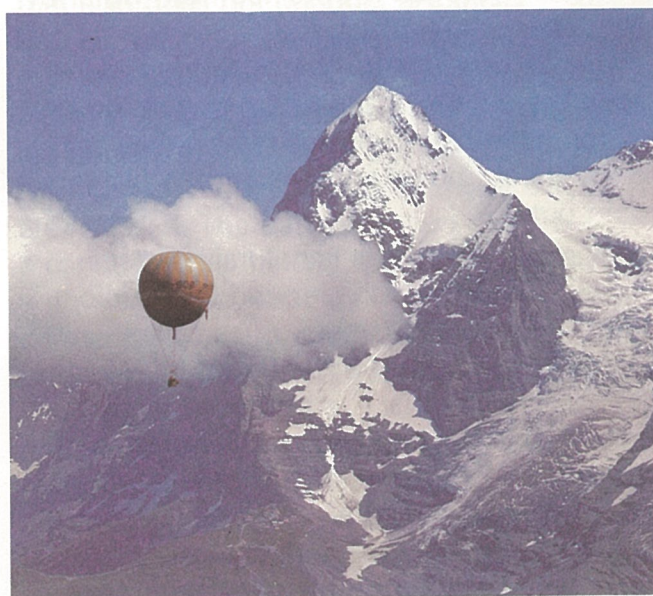
Below: A road mender uses a pneumatic drill to break up the road surface. The drill is fed with compressed air produced by a petrol-driven compressor.



This dentist's drill is powered by air under pressure. The compressed air is fed to the drill through a tube and makes the vanes of a tiny fan turn very fast. The fan then turns the drill.

Lighter than air

Balloons float through the air because they are lighter than air. A hot-air balloon has a gas burner that heats the air inside the envelope of the balloon. The hot air inside the balloon is lighter than the same amount of cold air, so it rises. The balloon has to be large to contain enough hot air to lift its passengers. A gas balloon contains the light gas helium instead of hot air.



Hot-air ballooning is a popular, but expensive, sport.



Gases

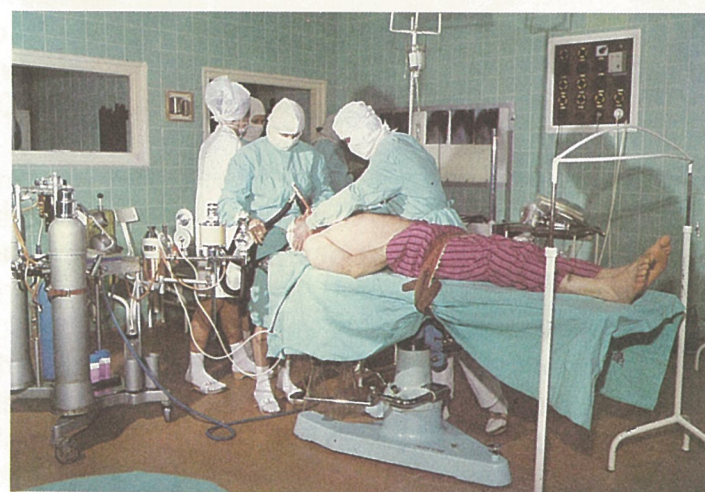
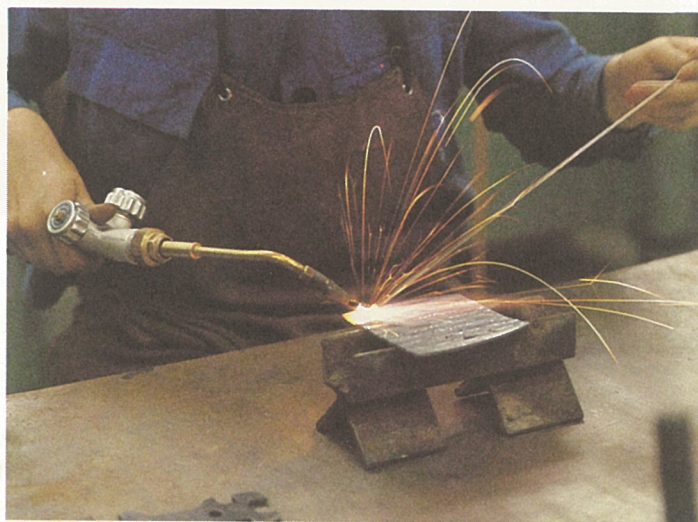
The gases in the air can be separated from each other and used on their own. Oxygen is a vitally important and useful gas because it supports life and allows things to burn. Oxygen, stored in cylinders, is used to help people who have difficulty in breathing. Welding torches burn an inflammable gas (such as hydrogen) together with oxygen because using pure oxygen makes them burn with much more heat. Space rockets also burn hydrogen and oxygen to give great heat and produce enormous power in their engines. Hydrogen is a light gas that is combined with oxygen in water. Pure hydrogen is obtained from water by passing electricity through it.

Oxygen is essential for things to burn. Other gases in the air, like argon and nitrogen, do not allow things to burn. For this reason they are used to fill light bulbs and prevent the filament burning out.

Another important gas is natural gas (see also pages 28-9), which is found below the ground. It consists mostly of a gas called methane, which burns with a bright blue flame in gas cookers. Methane is also used to make chemicals that are then used to manufacture products such as fuels and plastics. Natural gas may also contain the light gas helium, which is used to fill large balloons and airships.

Many useful gases can be made from other gases. Ammonia is made from nitrogen and hydrogen. It is important because it is used to make fertilizers that help crops to grow.

Above: Neon signs are named after a rare gas called neon which lights up when electricity passes through it. In fact, only signs that glow red contain neon. Signs in other colours contain different gases.



Above centre: A welding torch in use.

Above: Pure oxygen and other gases are given to patients during operations in hospital. The gases enable the doctors to control the patients' breathing and may keep them asleep.

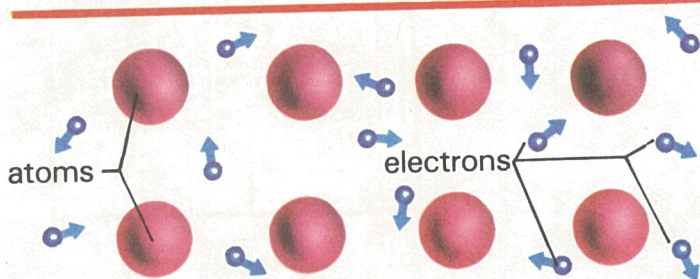
Electricity - Clean Power

Of all our sources of energy, none is more easy or convenient to use than electricity. It can be led along a wire to be put to use wherever it is required, or it can be stored in a battery and carried about. Electricity can be made powerful enough to drive trains and lifts, or made in amounts just sufficient to light torch bulbs. It can be used to power machines such as radio and television sets and computers that extend our ears, eyes and brains. In addition, electricity is a clean source of power that causes no pollution.

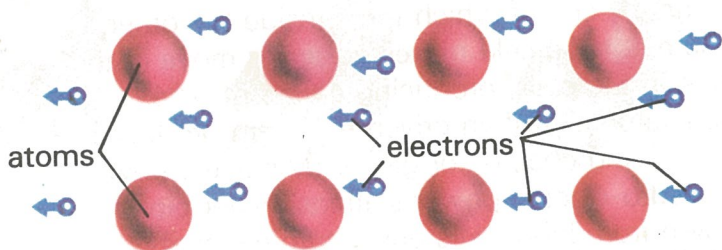
Electricity consists of a movement of the tiny particles called electrons that are inside atoms (see page 9). When an electric current flows through a wire, electrons move between the atoms of metal in the wire. Each electron has an electric charge. As the electrons move, electric charges travel along the wire at very high speed. As the charges arrive, they provide electrical energy that is ready to be used.

A battery has a negative terminal and a positive terminal. Electrons each have a negative electrical charge, which means that when a wire is connected to the terminals of a battery, electrons flow out from the negative

Inside a Wire

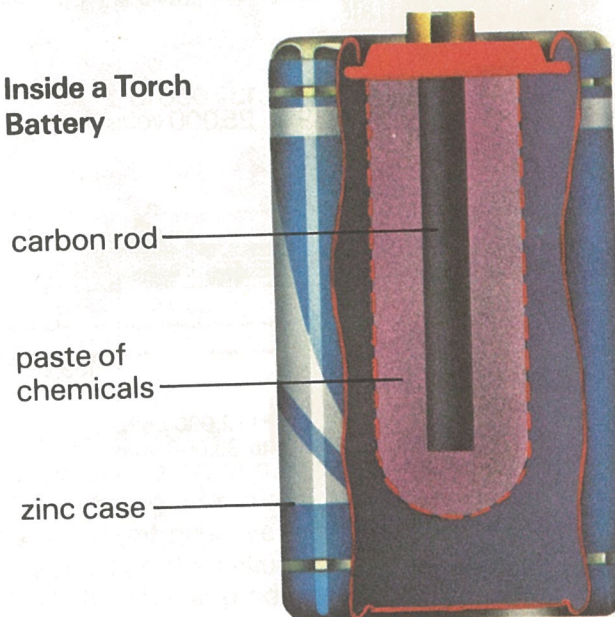


Inside a wire, electrons normally drift about in all directions between the atoms of metal (above). When the wire is connected to a source of electricity, the electrons begin to move in one direction and an electric current flows along the wire (below).



Inside a torch battery is a rod of carbon surrounded by a paste of chemicals. The case is made of the metal zinc. When the torch is switched on, the top of the rod is connected through the bulb to the case. This makes the chemicals produce electrons. A current flows through the bulb and the filament lights up.

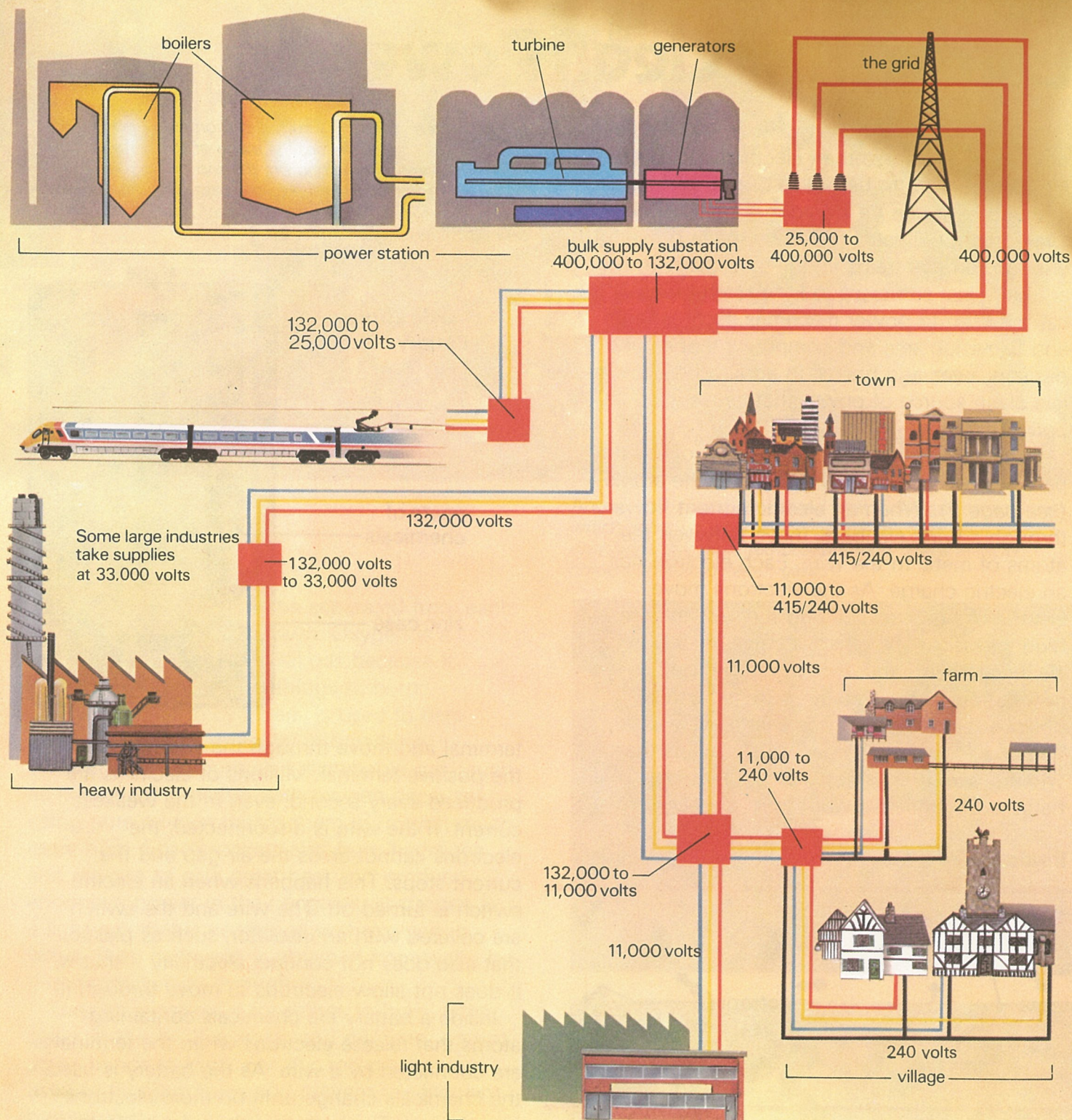
Inside a Torch Battery



terminal and move through the wire towards the positive terminal. Millions of electrons are produced every second, even in the weakest current. If the wire is disconnected, the electrons cannot cross the air gap and the current stops. This happens when an electric switch is turned off. The wire and the switch are covered with an insulator, such as plastic, that also does not conduct electricity – that is, it does not allow electrons to move through it.

Inside a battery are chemicals containing atoms that release electrons when the terminals are connected by a wire. As the battery is used, the chemicals change until no more electrons are released. The battery is then dead. However, a car contains a battery that can be recharged with electricity. A supply of electricity is connected to the battery, and electrons are fed back into the atoms so that the battery can be used again.

Batteries produce direct current (d.c.), which means that the electrons move in only one direction. The supply of electricity in the mains is usually alternating current (a.c.). In this kind of current, the electrons constantly move forwards and backwards many times a second. This still produces energy, because it doesn't matter in which direction the electrons flow.



Above: How Electricity is Made and Distributed

Inside the power station, steam is produced in boilers that burn a fuel such as coal. The steam goes to steam turbines that drive the electricity generators. After it is used, the steam condenses to water in a cooling system and then returns to the boilers to be used again.

The electric current produced by the generators is sent out at 25,000 volts to the power station substation where it is stepped up to 400,000 volts for transmission over the grid system. This is done because less electric power is lost at high voltage. The transformers inside substations can increase or decrease the voltage of electricity being fed through them. The voltage has to be lowered by substations to 132,000 volts for main distribution. For general use a 415/240 volt service is provided by small substations.

The mains electricity which you use in your house is produced not by batteries, but by huge electric generators in power stations. The generators contain large coils of wire and magnets, one of which turns inside the other. The magnetic field makes electrons move in the wire in the coils, producing a current. The generators are often driven by steam produced by burning coal, oil or gas or by nuclear power. In hydro-electric power stations, water piped down from high lakes drives turbines that power the generators.

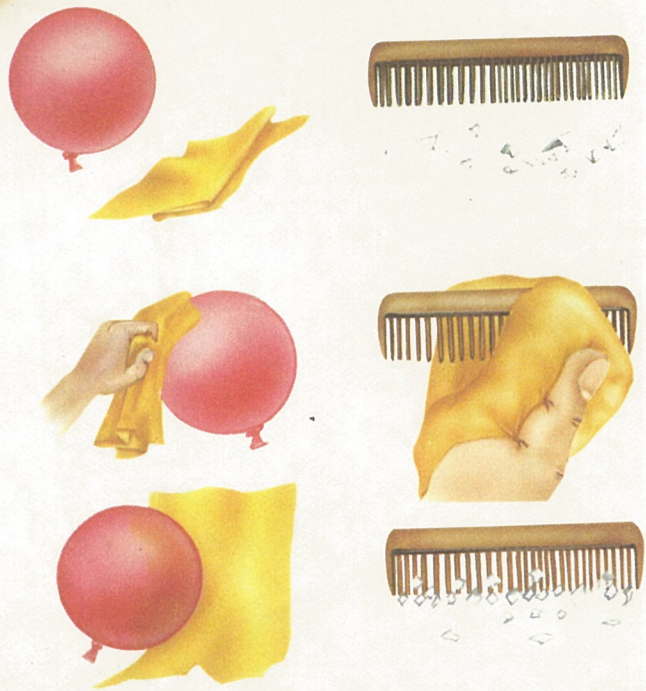
Shocks and Sparks

Mains electricity can give you a dangerous shock if you touch bare wires connected to the mains. This is why you must handle electricity with care. You can sometimes also get a mild, harmless electric shock simply by stroking a cat or walking across a fluffy carpet, especially if it is very dry. If you looked closely at your fingers as you felt the nip of the shock, you might see a tiny electric spark. Both this shock and the spark are caused by a kind of electricity called *static electricity*. This kind of electricity also causes lightning to strike.

As you stroke the cat, you rub electrons off the atoms in its fur. These electrons cross into your fingers, and build up a big electric charge on them. When the charge gets too big, it leaps back and produces the shock and the spark.

Static electricity is different from electric current. The electrons do not continue to flow as in a current. Instead, they move into another object and stay there, building up a greater and greater electric charge if more and more electrons arrive. This kind of electricity is called static electricity because the charge is produced by electrons that are still. Static means still.

Below: The photograph shows a storm moving across country.



Sticky balloons

You can stick a balloon to a wall or the ceiling by first rubbing it with a cloth. The rubbing causes a slight negative charge of static electricity to build up on the balloon. As it nears the wall or ceiling, this charge produces a positive charge on the surface. The two charges attract each other like magnets, causing the balloon to cling to the surface. A rubbed comb will pick up pieces of paper for the same reason.

Left: Thunder and lightning

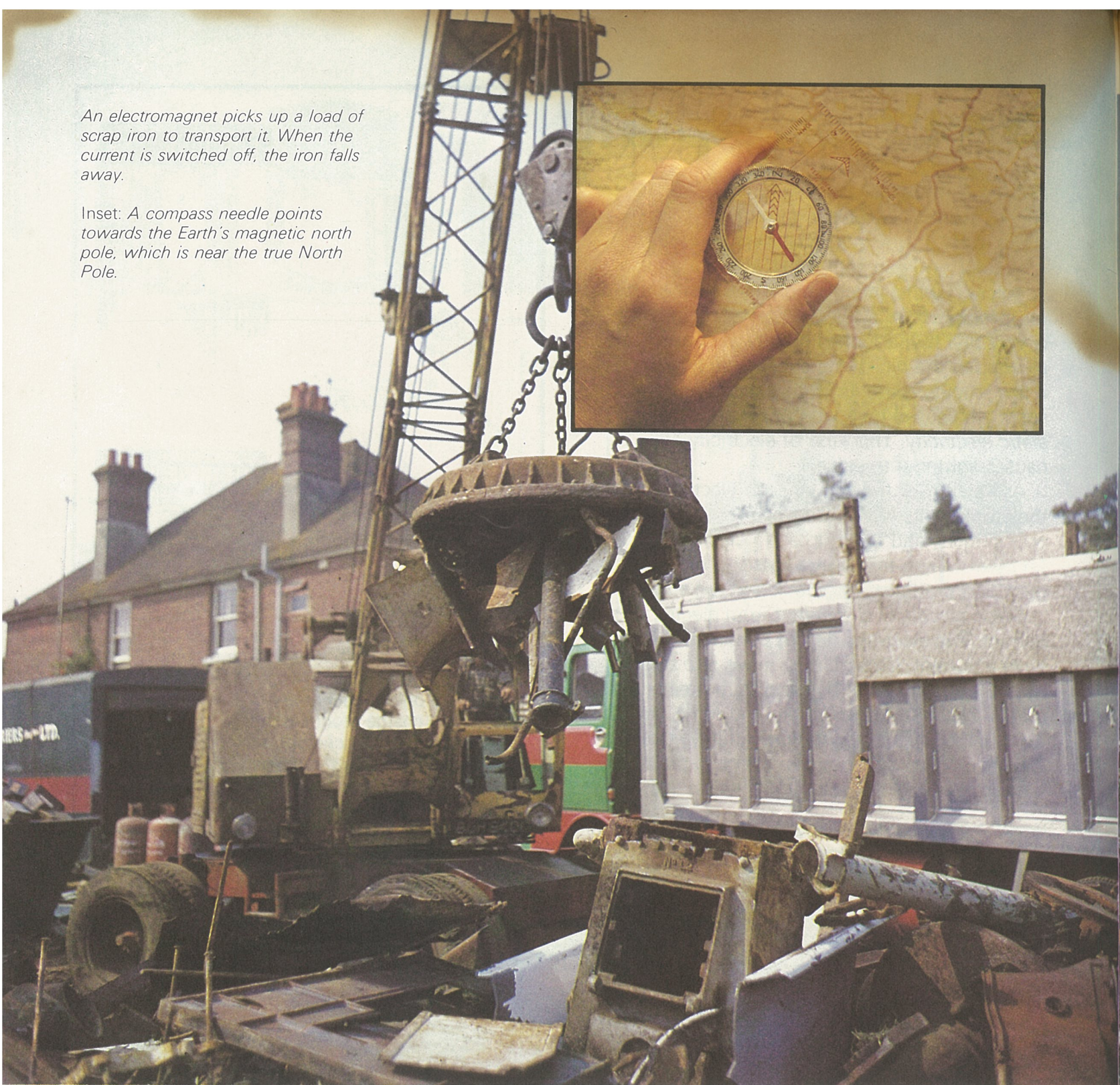
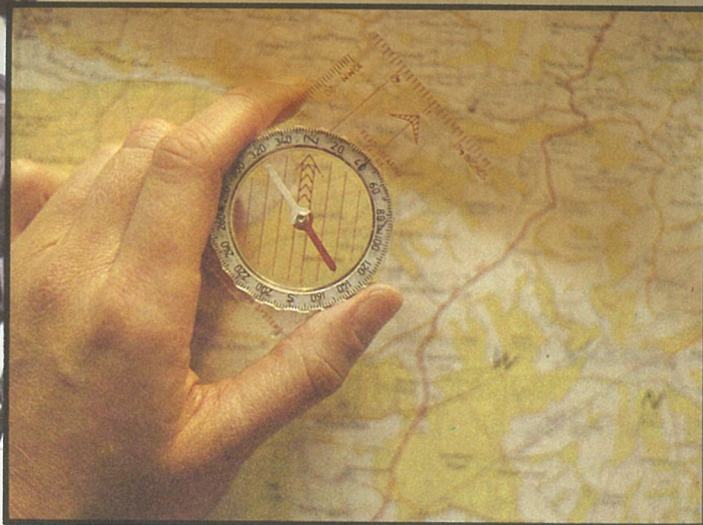
1 In a thunderstorm, large negative electric charges build up in the clouds and large positive charges on the ground. If the two charges become very strong, the negative charge suddenly moves towards the ground to neutralize the positive charge. As the charge moves through the air, it

heats the air so much that a flash of lightning occurs. It may also set fire to any object it strikes on the ground.
2 A lightning conductor helps to neutralize the charges so that lightning does not strike.
3 If it does, the lightning strikes the conductor and not the building.



An electromagnet picks up a load of scrap iron to transport it. When the current is switched off, the iron falls away.

Inset: A compass needle points towards the Earth's magnetic north pole, which is near the true North Pole.



Marvellous Magnets

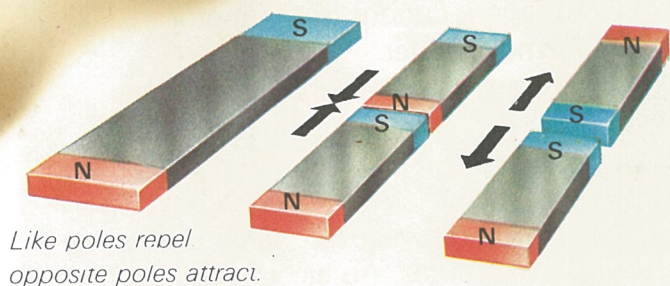
Magnets are amazing things. They pull or push on one another with a strong force that never lessens, and they can pick up iron and steel objects simply by touching them. Magnets lie at the heart of many machines on which we now depend. Without them, we would have no supply of electricity, no telephones, no radios, no televisions and no record or cassette players.

Around a magnet is a magnetic field. The field consists of an invisible force that reaches

out from each end of the magnet. The centre of the magnetic field in each end of the magnet is called a *pole*. One end of the magnet contains a north pole and the other a south pole, and they produce different kinds of magnetic force.

If two magnets are placed close together with both north poles near each other or both south poles, then the magnets push each other apart. But if the north pole of one magnet comes close to the south pole of another, then

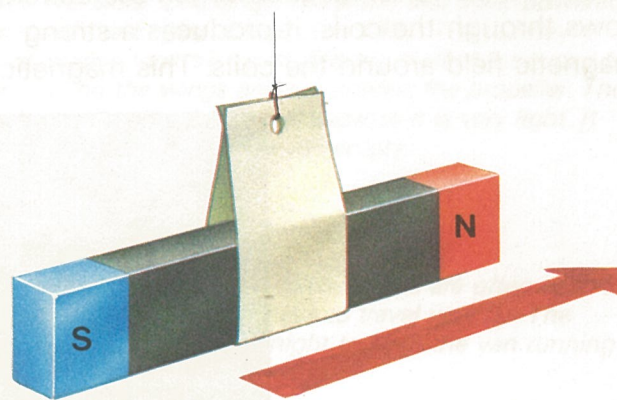
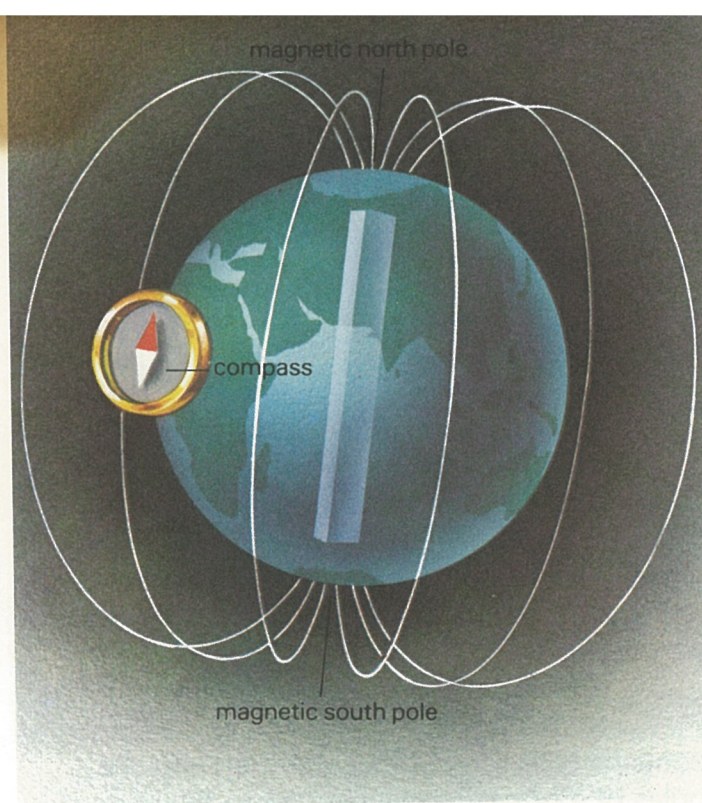
the magnetic force of the two fields pulls the two magnets together. So, if the two poles are the same – either north-north or south-south – then the magnets *repel*. If they are different – either north-south or south-north – then the magnets *attract* each other.



Like poles repel
opposite poles attract.

Only the metals iron, nickel and cobalt, and mixtures of them like steel, can be made magnetic, and all magnets are made of these metals. However, one other thing is also magnetic and that is an electric current. When an electric current flows through a wire, a magnetic field is produced around the wire. If the wire is twisted to form a coil, then the field around the coil is like that of a bar-shaped magnet. Most magnets are made by putting a bar of steel into a coil and passing a current through the coil. A strong magnetic field is produced in the coil, and it magnetizes the steel bar to give a magnet.

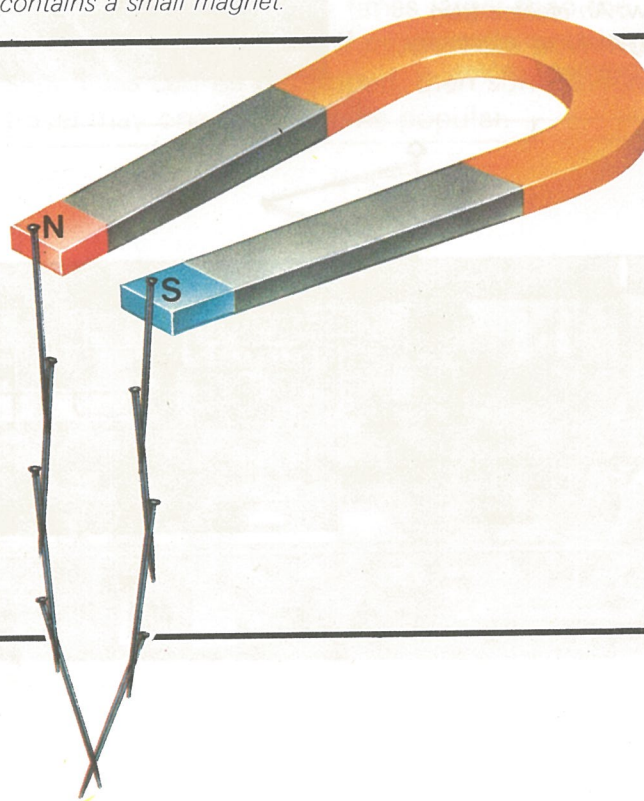
If a bar of iron is placed in the coil instead of steel, it also becomes strongly magnetic. But when the current is switched off, the iron bar loses its magnetism. This device is called an electromagnet. It has many uses. Electric bells, microphones, loudspeakers and electricity generators all work by electromagnets.



It is easy to find out which is the north pole of a magnet. If the magnet is hung from a piece of string, one end swings round to face north. This end contains the north pole of the magnet and the other end contains the south pole. This happens because the Earth acts as if it has a huge magnet inside and its magnetic field extends all over the world. The magnetic poles are near the North Pole and the South Pole, and a compass needle points towards the north because it contains a small magnet.

Picking up pins

If you lower one end of a magnet into a box of pins, it picks up a whole line of pins that cling to each other. This is because the magnetic field of the magnet turns each pin into a weak magnet. If the end of the magnet contains a north pole, the field magnetizes the pin so that a south pole is formed in the end touching the magnet. This pulls the pin to the magnet. At the lower end of the pin a north pole is formed, which produces a south pole in the next pin and makes it cling to the first pin. In this way, a chain of several pins can be picked up. A horse-shoe magnet, like the one illustrated, will pick up two lines of pins which will eventually attract each other. Can you work out why?



Electric Travel

Electricity is an ideal source of power for transport because it is powerful and silent, and because it produces no pollution. If a current can be fed to a vehicle in some way, then it does not need to carry its own electricity supply. This leaves more room for passengers. In electric trains, electricity is fed to the train along overhead wires or through special rails beside the track. Some cities have trams or trolley-buses which pick up current from wires above the road.

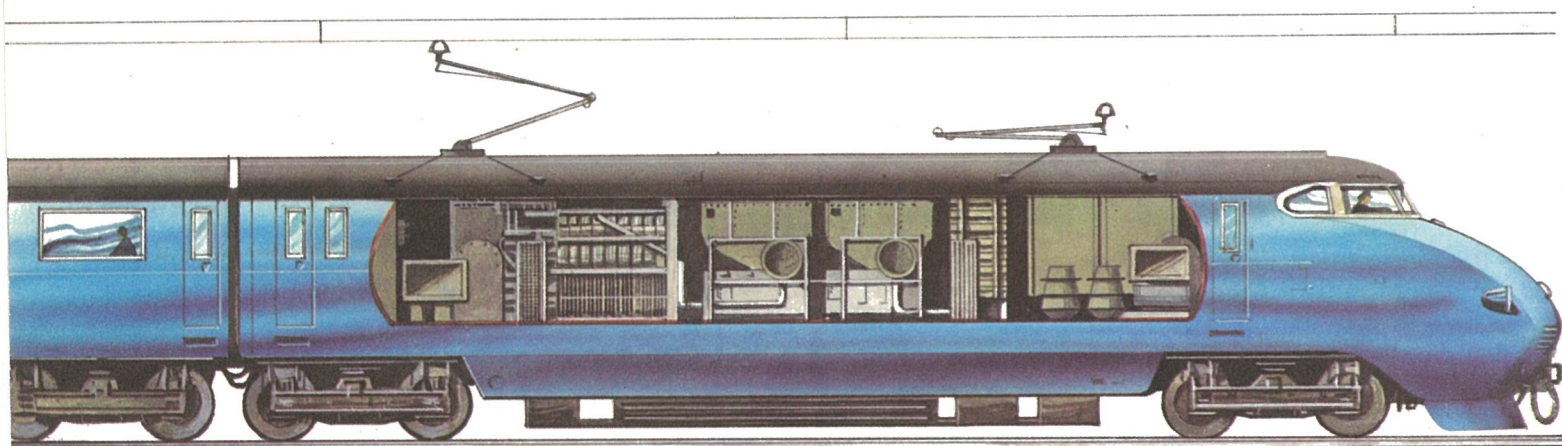
The electric current goes to an electric motor that turns the wheels of the vehicle. The motor contains coils of wire that spin between the poles of a powerful magnet. When the current flows through the coils, it produces a strong magnetic field around the coils. This magnetic

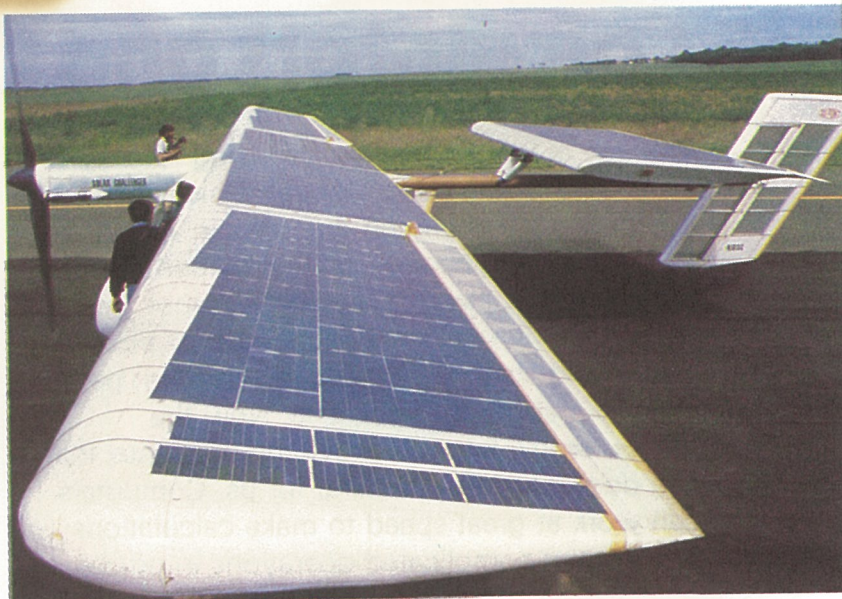
field is placed so that its force pushes and pulls on the poles of the magnet and makes the coils turn. The coils are connected to the wheels, and feeding more current to the motor makes the vehicle move faster.

In cities served by electric transport, the electricity needed to run it is generated in power stations. Feeding it to the vehicles through wires or rails means that the transport must always run between the same places along the same routes. An electric vehicle that can travel anywhere needs to carry its own supply of electric current to power its motor. There are electric cars that carry batteries to supply power. However, they are not very popular because the batteries are large and expensive, and because they do not give

Right: *An electric train in Japan. Electricity is fed to the train through special rails beside the track.*

Below: *An electric train which picks up electricity from overhead cables.*





Above: *The Solar Challenger made the first solar-powered crossing of the English Channel in 1981. The journey of 260 kilometres took 5½ hours. Electric current produced by solar cells on the wings and tail powers the propeller. The aircraft can fly on solar power because it is very light. It weighs only 59 kilograms when empty.*



Above left and left: *Electric delivery vans are often used in cities because they do not have to travel very far. The batteries are recharged overnight to keep the van running during the day.*

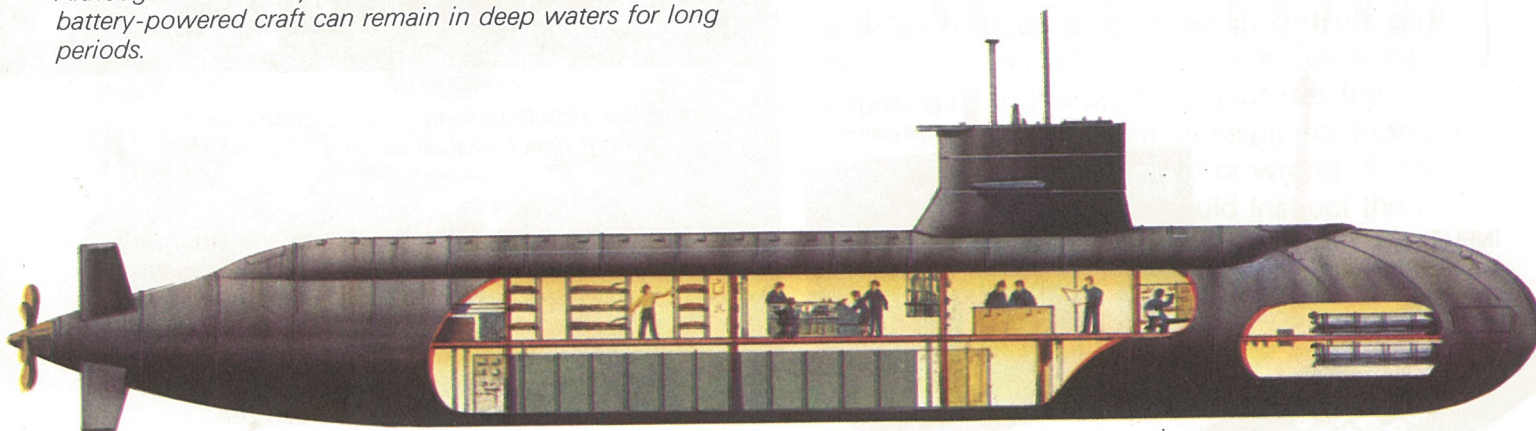
enough power to travel either very fast or very far. If batteries improve in the future, then electric cars may become common.

One kind of transport that does work with batteries is the conventional submarine (but not the nuclear submarine). Submarines cannot use petrol engines underwater because there is no air to burn the fuel. Instead conventional submarines use electric motors powered by batteries. The batteries are recharged at the surface using petrol-driven electric generators.

Below: *A Störmén class submarine from Sweden. Although used mainly for inshore coastal work, this type of battery-powered craft can remain in deep waters for long periods.*

Nuclear submarines have nuclear reactors, which do not require air to operate.

Another possible source of power for travel is solar power. Solar means belonging to the Sun. A solar-power cell turns sunlight into electricity. A panel of cells can provide a strong electric current, but to drive a vehicle, the solar panel would have to be many times larger than the vehicle itself. However, if much more powerful solar cells can be developed, then sun-powered travel may one day become popular.



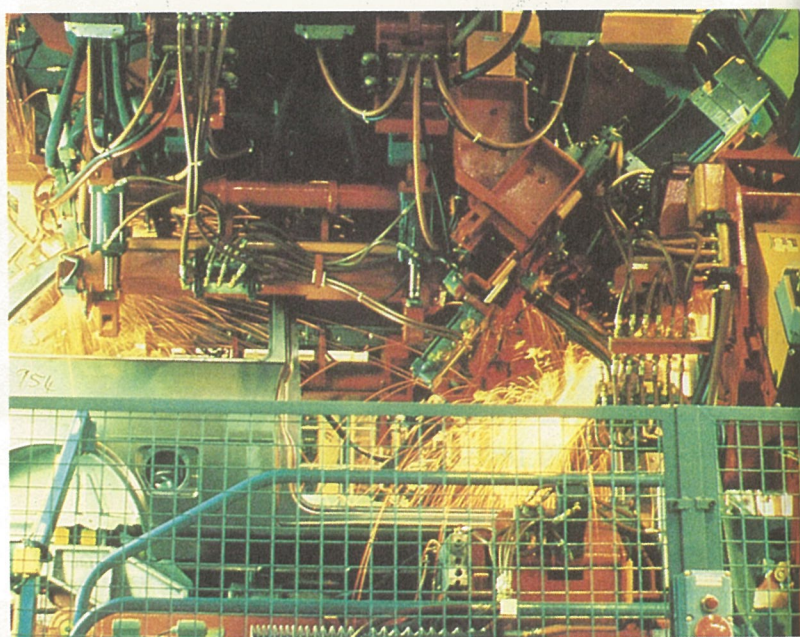
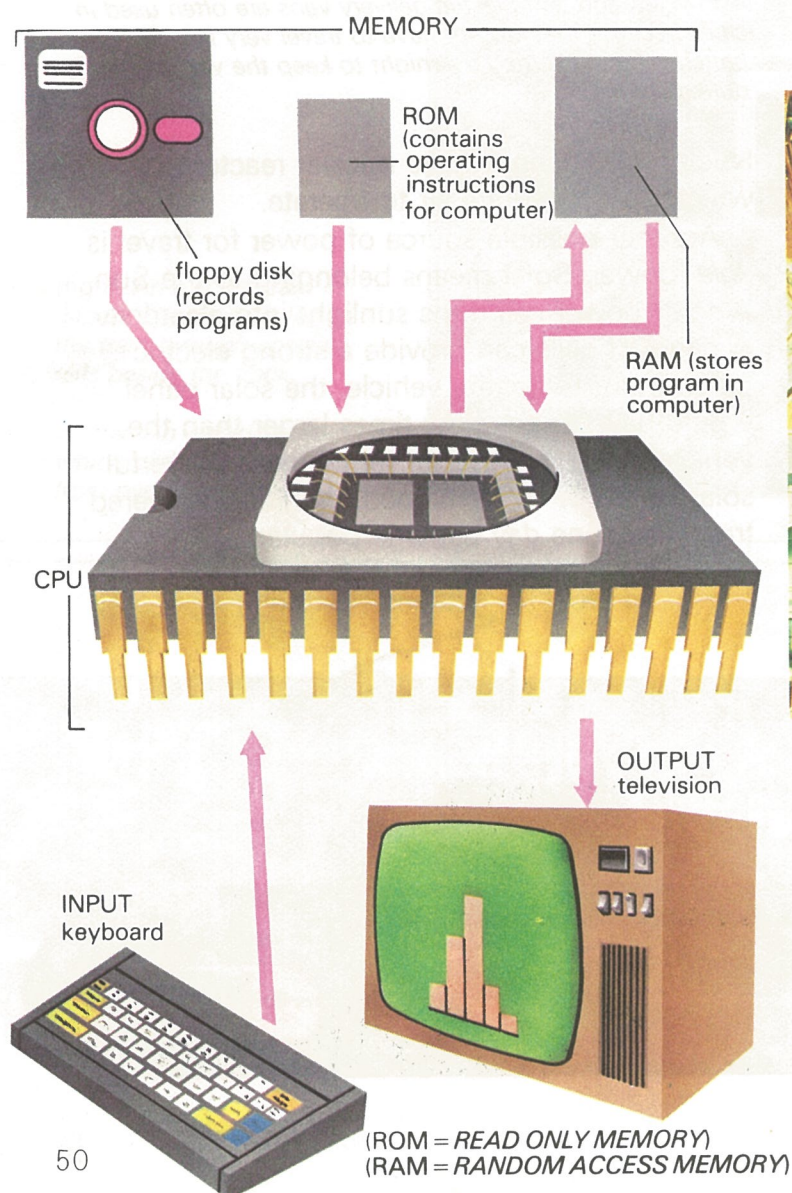
Calculators and Computers

The age in which we are now living is likely to be known as the computer age. This is because computers are changing the ways in which we live and work. The industrial revolution of two centuries ago altered the world because machines were invented that could produce power and also make things quickly that people used to make slowly by hand. Now the computer revolution is providing machines that can do a lot of our thinking for us. Computers can work at great speed to make calculations and control complicated operations in offices, factories and hospitals, on ships and spacecraft, at school and in the home.

The pocket calculator is a kind of small computer that can do instant calculations with numbers. When you press the keys of the calculator, the numbers are changed into on-off electric signals. Each number has a different signal. Then the 'brain' of the calculator adds the signals together to produce another signal,

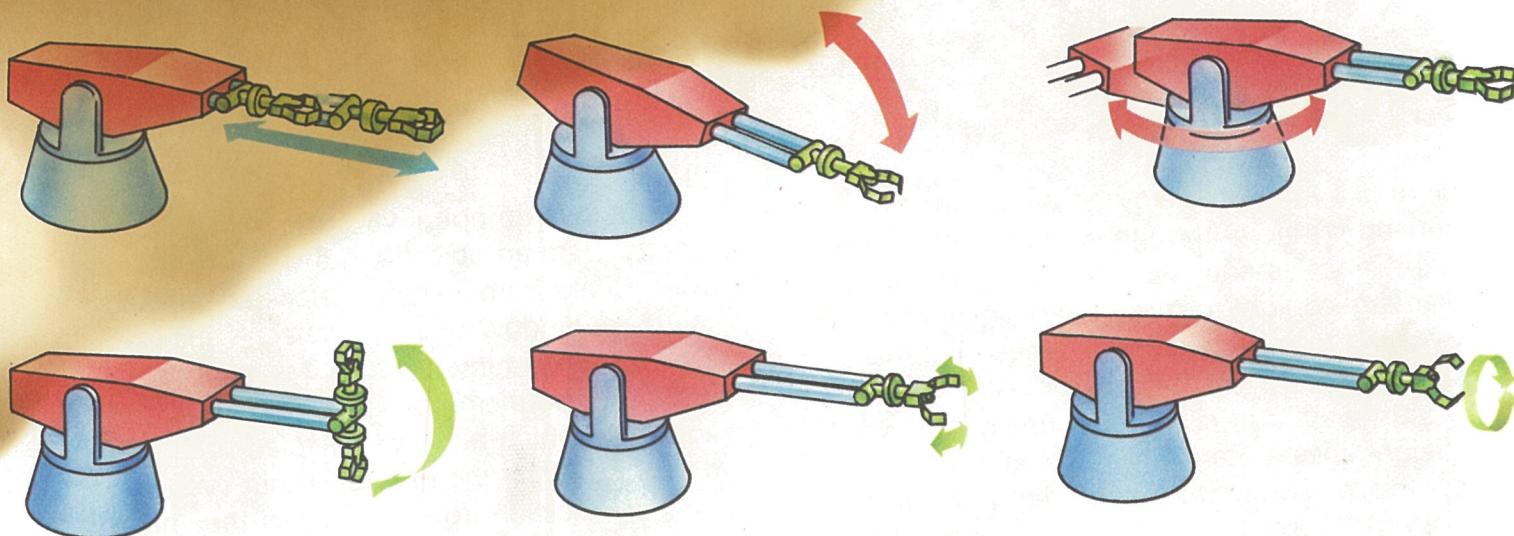
which is then changed back into a number that gives the answer. The brain of the calculator is a *microchip*, which is a tiny device containing thousands of electric circuits that handle the signals. Because it is very small and the signals travel around the circuits very quickly, the calculator does additions very fast indeed. More difficult calculations are done by making additions one after the other, and the calculator carries them out so fast that it appears to get an instant answer.

The computer works in a similar way, but it can do many more tasks. This is because the computer can be given instructions to carry out a particular operation. The instructions are called a computer *program*. A computer can be given many different programs to carry out a wide range of tasks. The program can use the on-off electric signals not just to represent numbers, but words, pictures and even sounds. In this way, you could get a home microcomputer to play games and music, teach you a subject of your choice, work out how



Above: These robots making cars are controlled by computers that direct all their actions.

Left: The 4 main units of a computer are the input unit, in which information is fed into the computer; the memory, which stores the information and the computer program that tells the computer how to use the information; the central processing unit (CPU), which processes the information to get results; and the output unit, which produces the results in a form that we can use.

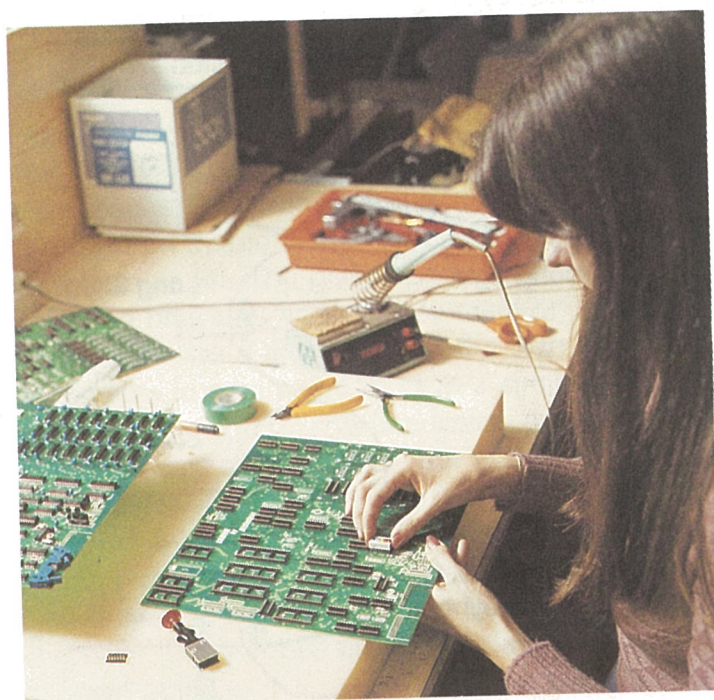


Above: A robot can be programmed to make a variety of movements. The arm (top left) can move in and out, the 'shoulder' (top centre) allows the arm to be raised and lowered, and the 'waist' action (top right) allows the robot to swing from side to side. The 'hand' can move in lots of different ways too. Robots can be programmed to make a sequence of movements and so can be used on assembly lines to do repetitive jobs.

Right: A computer in use. Computers are now very important in business and industry. They check and calculate sums of money, for example in banks, and control machinery, for example in supplying power and in manufacturing products so that high quality is always maintained. Computers can also make accurate weather forecasts from weather reports and can calculate the best routes for aeroplanes to take in flight – tasks too difficult for people to do in the short time available.



Below: The manufacture of a circuit board. The girl is soldering the components to the circuit board.



much money you will need for projects, keep a diary, print out letters and bills, and so on.

The program – say a quiz game – is fed into the computer's *memory*, where it is stored in the form of electric signals. To use the computer, an *input unit* like a keyboard is operated. This sends information, such as answers to questions, to the computer's *central processing unit* (CPU). This unit obeys the instructions in the program and uses the information to get a certain result, for example whether the answer is right or wrong. At the same time, the program could instruct the processor to add up the score and ask a question again if the answer is wrong. These results go to the computer's *output unit*, which is often a video screen or printer, that displays or prints the results.

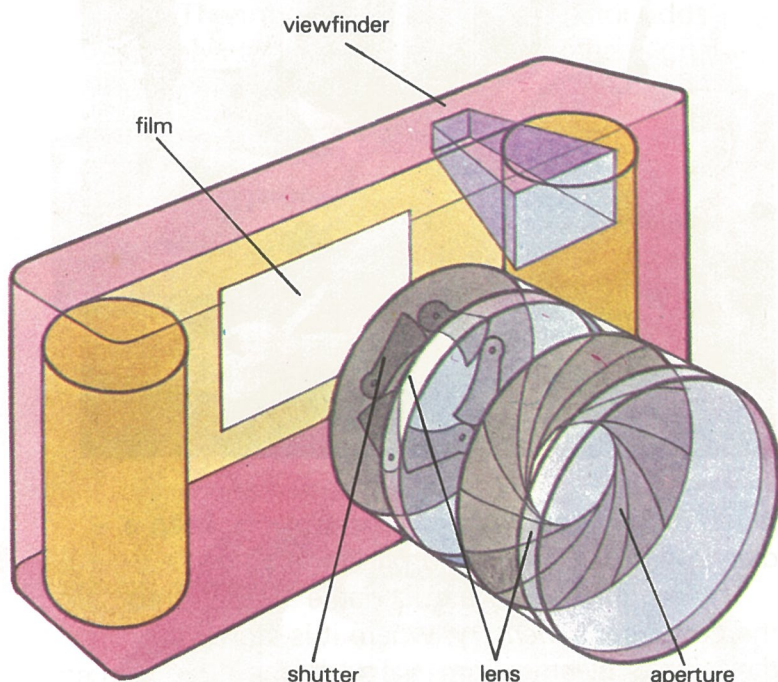
Light

Light is a form of energy on which we all depend for life. Although we use light to see, sight is not essential for us to live. However, plants need light to make the oxygen in the air we need to breathe, so we all need light to survive whether we can see or not.

Light travels in rays that normally follow straight lines. When we see something – another person for example – light rays travel from the person to our eyes. The person has to be lit up by a source of light, such as the Sun or an electric light. The light rays come from the source and travel to the person. Then the rays are reflected by his or her skin and clothes. They bounce off in all directions, and some of these rays reach our eyes so that we see the person.

Light rays do not always reach our eyes directly from an object. On the way, they may be *reflected* from a shiny surface such as a mirror, a window or some water. A shiny surface looks shiny because it is smooth, so, instead of bouncing off in all directions, the light rays which hit it are reflected in the same direction. When the rays reach our eyes, our eyes are tricked into thinking that they have come in a straight line directly from the shiny surface. We therefore see the object in the direction of the shiny surface – that is, as an image in the mirror, window or water. If the shiny surface is curved, the light rays are bent away from a straight line. This tricks our eyes so that we see an image that is larger or smaller than the object. Distorting mirrors make comic

Camera

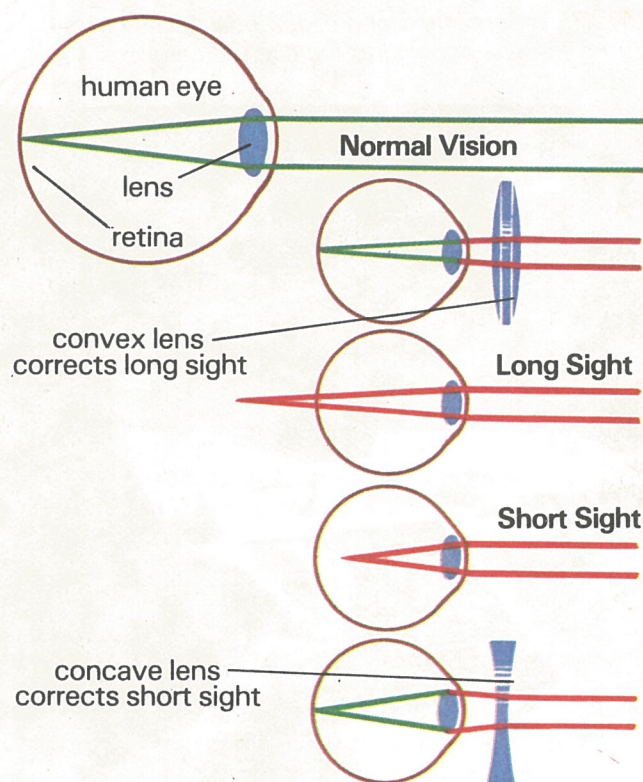


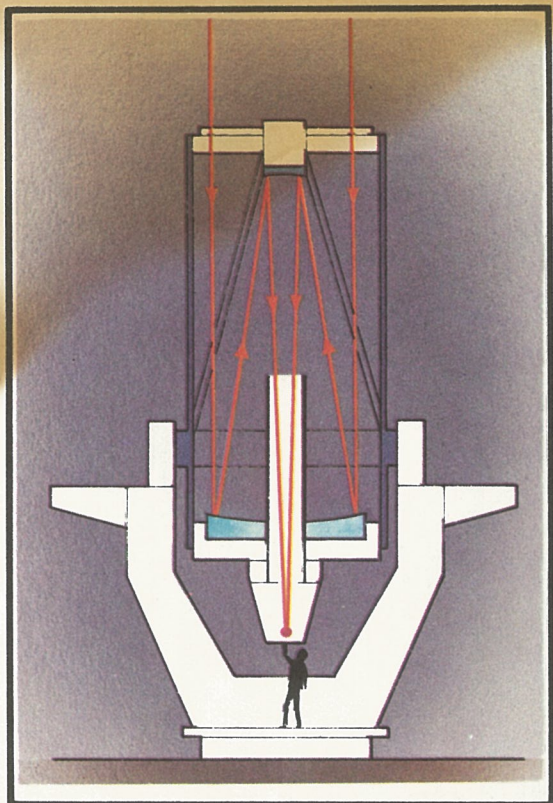
Above: In a camera, the lens forms an image of an object on the film. The shutter opens for a fraction of a second to produce a still image on the film. The aperture can be changed to let more or less light in through the lens, so that a good picture is obtained.

Right: The human eye contains a lens which can alter its shape to focus images from near or far on the retina. Some people's eye-lenses focus the light before it reaches the retina. These are short-sighted people. Others focus light beyond the retina and are long-sighted. Spectacles containing specially made lenses can correct these problems.

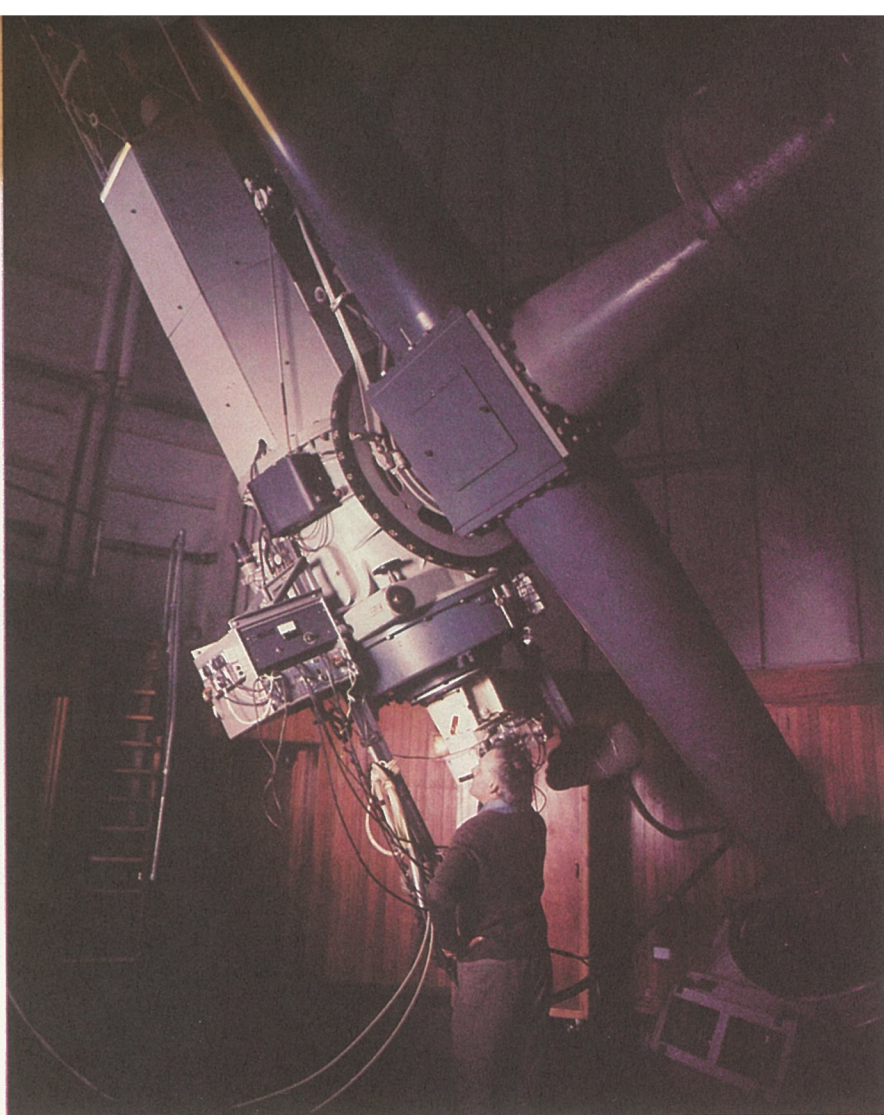
What is light?

Light is produced in the Sun and in electric light bulbs because they glow white-hot with heat. In strip lights, electricity passes through gas in the tube. In both cases, the heat or electrical energy makes electrons jump about in the atoms. As the electrons jump, they give out light rays, changing the heat or electricity into light energy. The rays consist of electric and magnetic waves travelling out in all directions at a speed of 300,000 kilometres per second





Above and right: Astronomers use huge telescopes to take pictures of the stars and other objects in the night sky. The telescopes are made big so that they can gather lots of light from the sky.



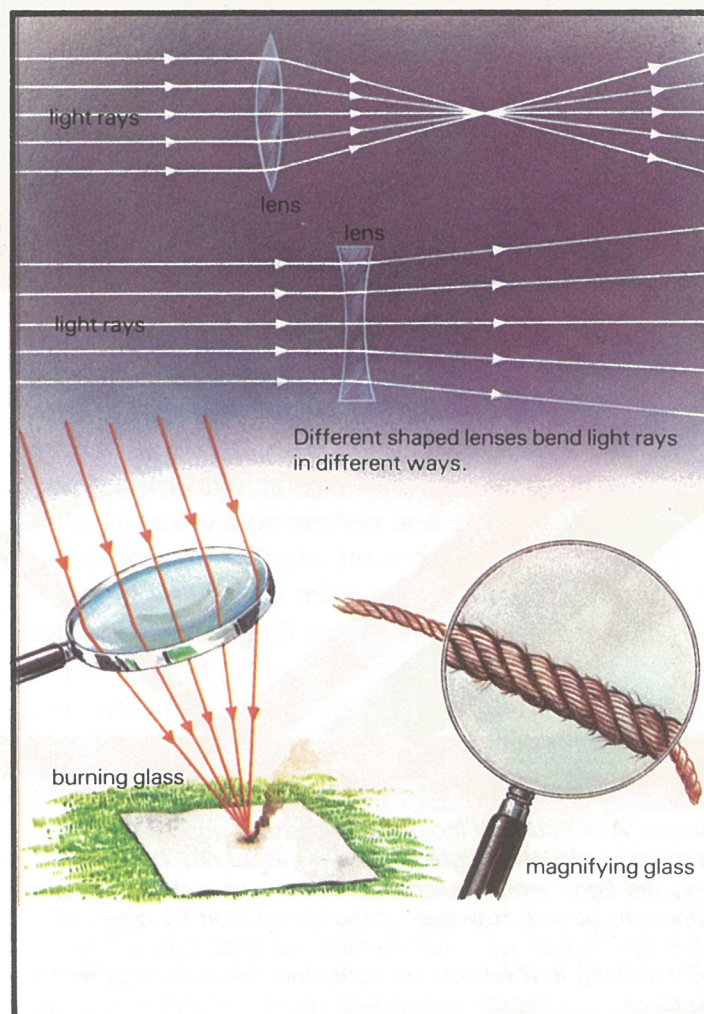
images of people by having curved surfaces.

Light rays also bend as they enter or leave transparent materials like air, glass and water. This is called *refraction*. But, as with mirrors, we always think that the rays have travelled in a straight line. We therefore see an image shifted to one side of the object. Look at your legs when they are half in and half out of the bath water and you will see this effect!

Lenses

Lenses are pieces of glass (or other transparent material) which bend light rays by refraction to give images. A burning glass is a lens which can form an image of the Sun so hot that it can set fire to paper. The glass bends the Sun's light and heat rays so that they meet on the paper and form a tiny image of the Sun.

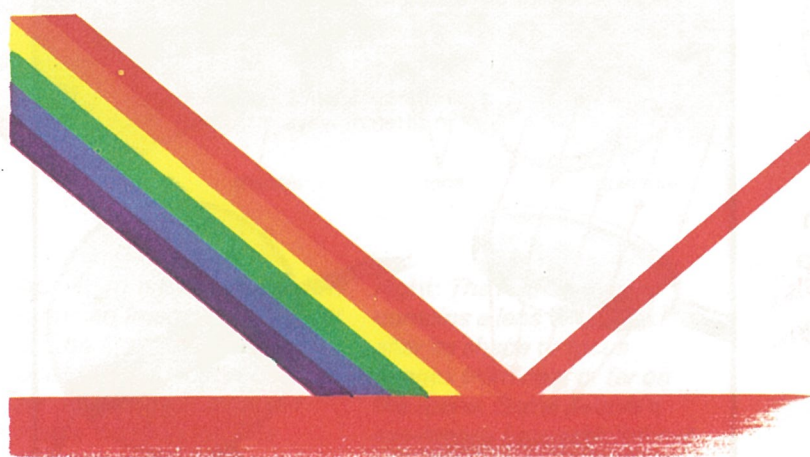
The lens in a camera works in a similar way. It forms an image on the film inside the camera. In a telescope or binoculars, the front lens produces an image of a distant object inside the tube. By looking through the eyepiece, we see this image very close, so that it looks large. This is how telescopes magnify distant objects, and how microscopes produce enlarged images of small objects.



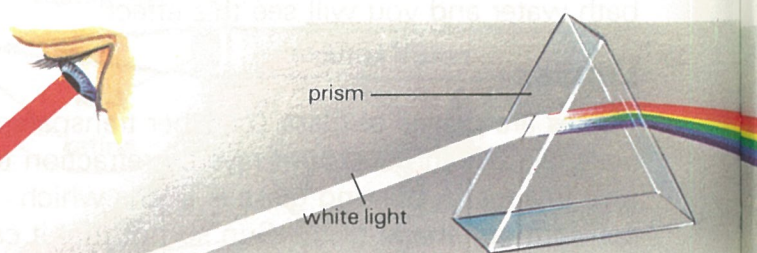
The World of Colour

Light rays consist of waves of energy. Every second, about 1000 million million waves of light energy enter our eyes. Each colour has a different number of waves. Blue light has more waves per second than red, for example.

White light is a mixture of all colours. You can see this by using a glass prism to split white light into its colours. A band of colours called a *spectrum*, which is like a rainbow, is produced. When white light strikes green grass, for example, the grass absorbs all the colours in the white light except green. Green light is reflected, and reaches our eyes so that the grass looks green. The same thing happens with all other colours. A white surface reflects all the colours so that they stay mixed together to give white. A black surface absorbs all the colours and reflects none. You see black where there is no light at all.

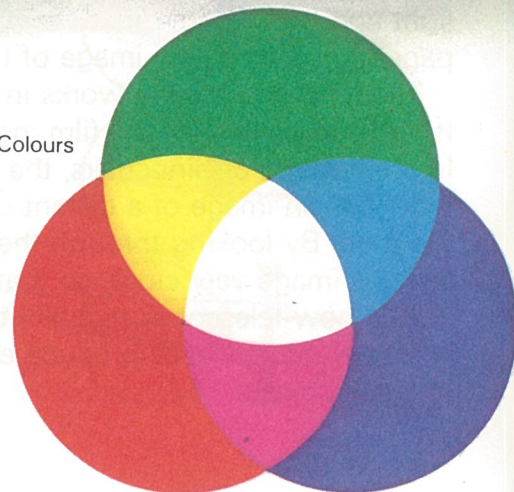


Above: A red surface looks red because it absorbs all the colours in the white light striking it except red. It reflects only red light, which reaches our eyes and makes the object appear to be red. However, if the object is lit by green or blue light, which does not contain red, it absorbs all the light striking it. It reflects no light, and therefore appears to be black.



Primary Colours

Light



The colours of the rainbow

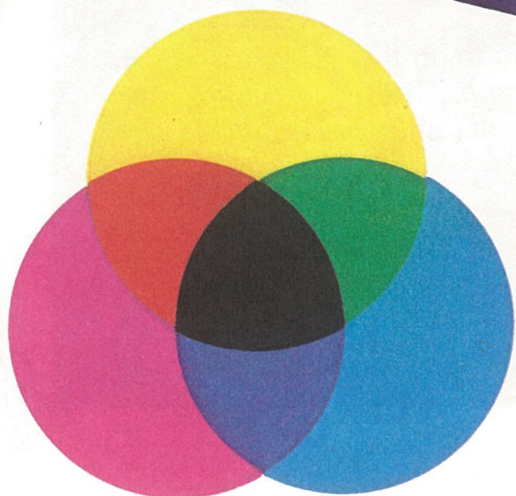
You can see a rainbow in the sky when a shower of rain is lit up by the Sun. What happens is that the Sun's rays strike the raindrops and are reflected by them to reach your eyes. The rays enter the raindrops and bounce off the back surface of the drops, which act like lots of tiny mirrors. However, as the rays come out of the raindrops, the white light splits up into colours – just as a prism splits sunlight into a spectrum of colours. The colours come together to form a curved band in the sky, and we see a rainbow.



Above: In colour printing, the three primary colours – yellow, cyan and magenta – are printed on paper as tiny coloured dots. The dots merge together in the eye to form a coloured picture. A fourth colour – black – is also used to make the black parts of the picture darker. Each colour is printed separately so the paper has to go through the printing machine four times.

A glass prism splits white light into a band of colours called a spectrum

spectrum



Paint

Although our eyes can see many different colours, any colour can in fact be made by mixing together just three colours in different amounts. These three colours are called *primary colours*. In objects that emit coloured light, like a colour television screen and stage lights, the three primary colours are red, green and blue. You get yellow by mixing green and red, and white by mixing all three primary colours.

Paints and printing inks work differently because they reflect light from a surface and do not emit light. The three primary colours in paints and inks are yellow, cyan (usually called blue, but actually blue-green) and magenta (usually called red but in fact red-blue). You get green by mixing yellow and cyan, and black by mixing all three colours. White is given where there are no paints or inks because white light is reflected from the blank paper.

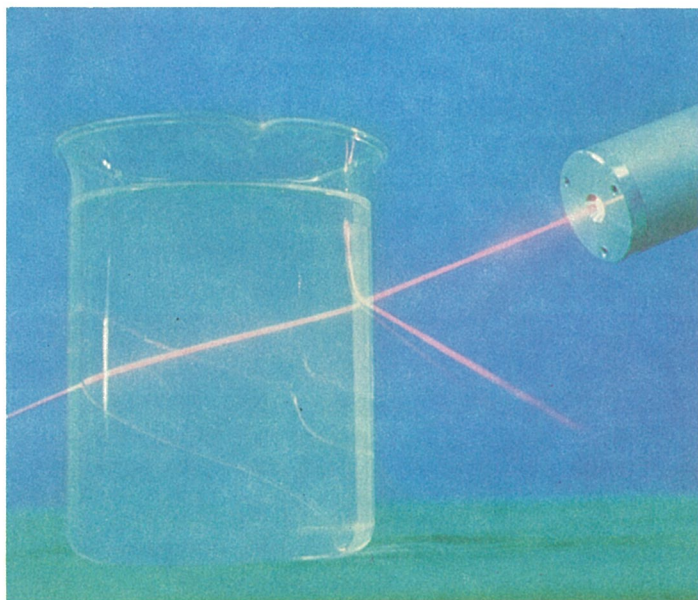
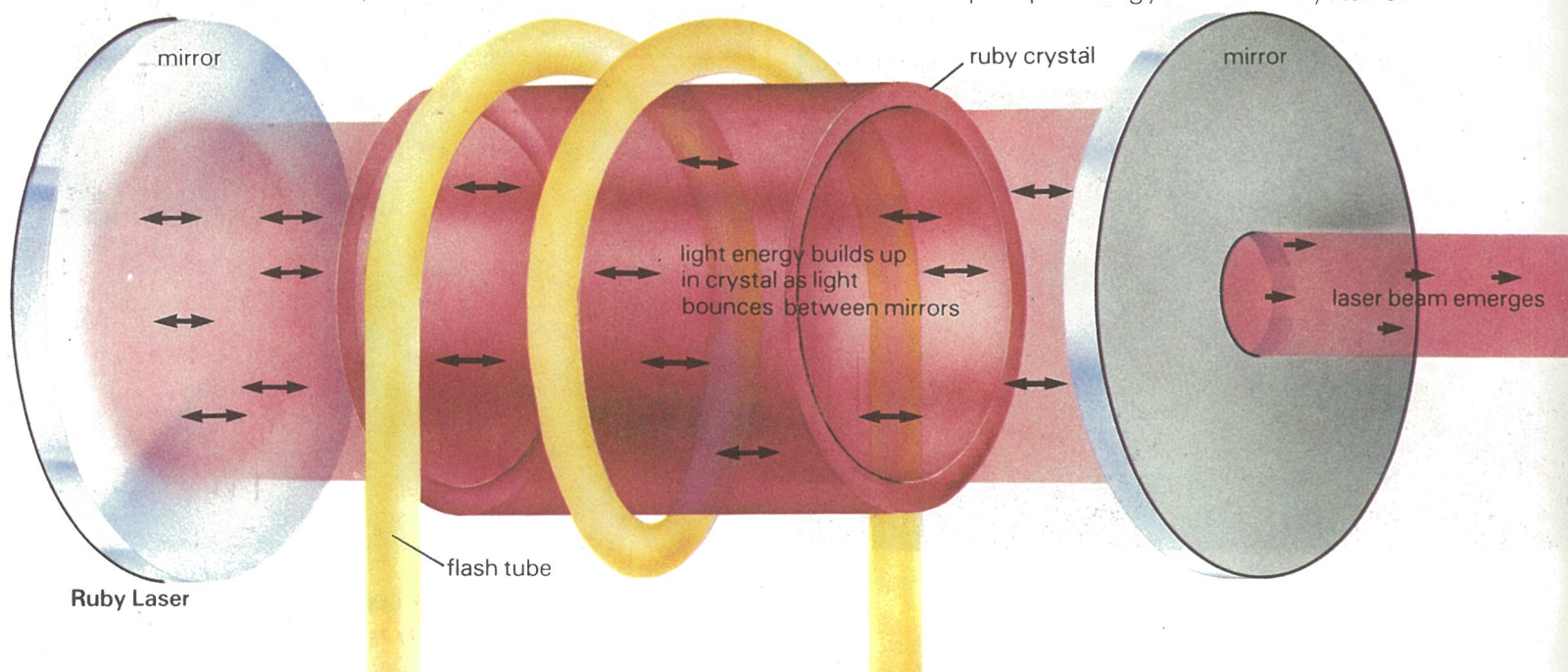
Lasers

If you have ever seen the needle-thin beam of a laser cutting through the air, you will know that lasers do not produce ordinary light like a torch or car headlight. Laser light is amazingly powerful. A laser beam can melt a hole in a steel plate in seconds, and it is possible that lasers may one day be used as weapons, particularly in space. However, we have several peaceful uses for lasers. Laser beams can be used by doctors to repair damage to eyes without having to cut the eye open. The straight narrow beam can be used to measure long distances with great accuracy – even the distance from the Earth to the Moon. Lasers are used to mark dates on cans of food and drink because they instantly burn letters and numbers

into the metal of the can. Laser beams can also carry signals; they are used in compact disc players to carry a sound signal and in videodisc players to carry a picture signal.

Lasers can do all these things because laser light is different from ordinary light. In ordinary light, the light waves overlap one another as they strike an object. But in a laser beam all the waves arrive exactly together. This makes laser light very powerful because it concentrates the energy in the light.

Lasers produce light in a different way to light bulbs and strip lights. Inside a laser is a crystal or a tube of gas, around which a source of energy such as a flashing light is placed. This source pumps energy into the crystal or



the tube. The energy rapidly builds up inside it, then suddenly all the energy that has built up is released at once as light. This is why lasers produce such powerful light. This takes place over and over again very quickly, giving a beam of light.

Another amazing thing that lasers can do is to produce *holographs*. These are pictures that have depth, unlike flat photographs. When you

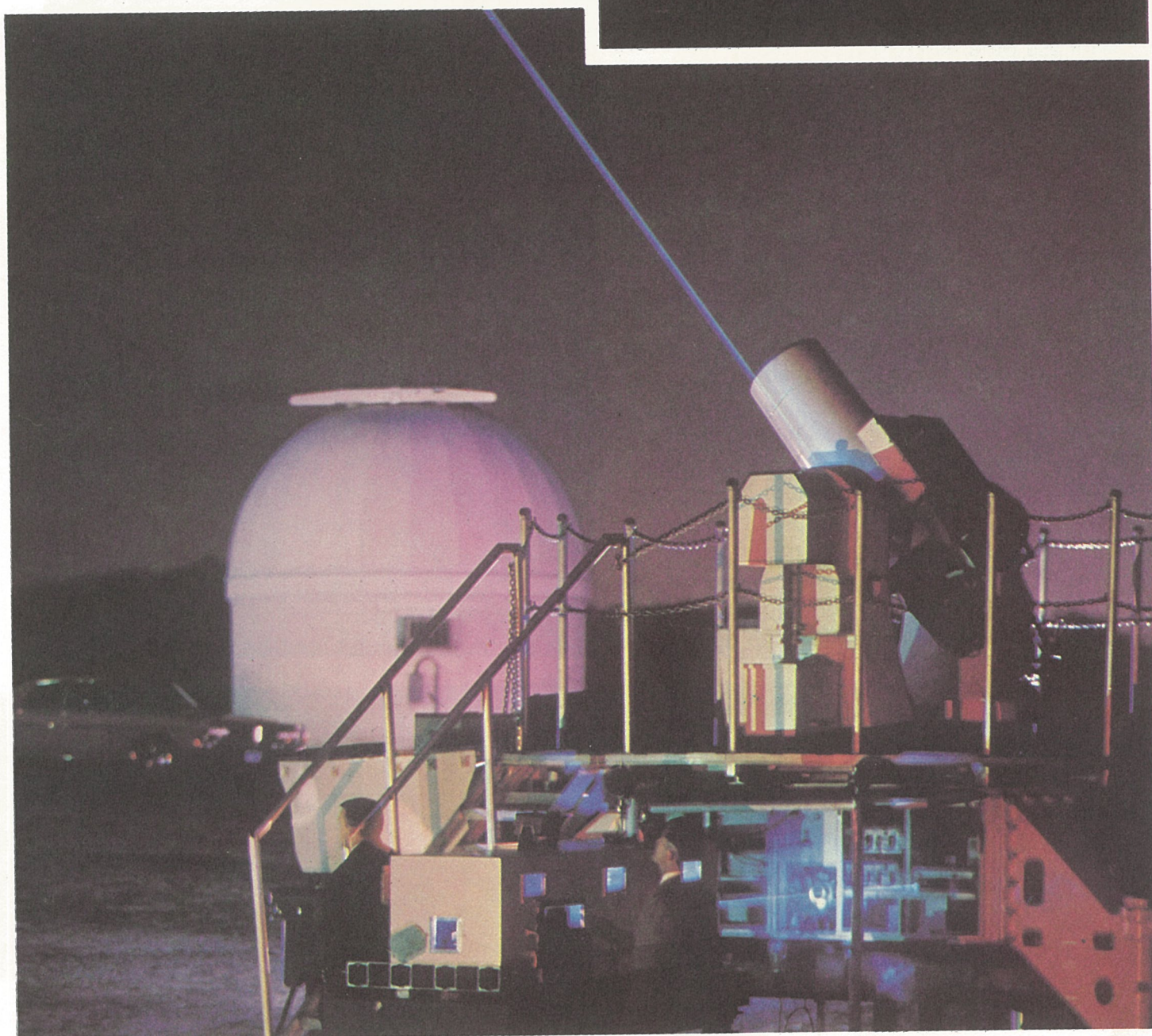
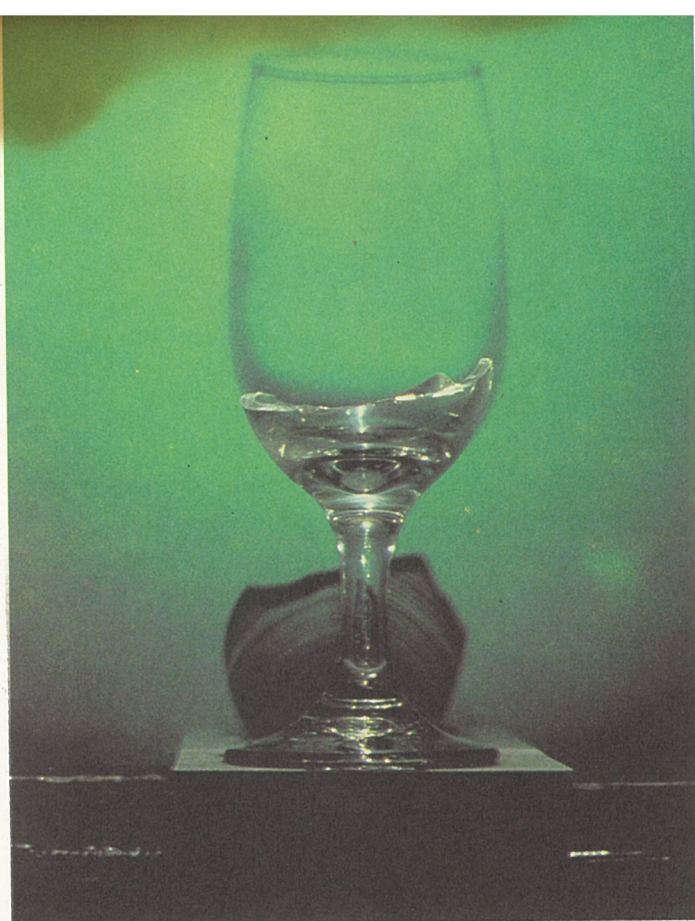
Left: A laser beam has so much energy that the light rays can be seen quite clearly. Here, part of the beam is reflected off the glass, and part refracted through it.

Right: A laser beam has been used to calculate exactly the distance from the Earth to the Moon.

see a holograph and walk past it, you see round the sides of the object in the holograph as if the solid object were actually there in front of you.

A holograph is made by placing a photographic plate near the object to be photographed and shining laser light on the object and the plate. When the plate is developed, it forms a pattern called a *hologram*. The pattern depends on the shape of the object from which the laser light is reflected to strike the plate. When light is shone through the hologram, it is changed into exactly the same kind of light rays that normally come from the object, which depend on its shape. We therefore see a solid image of it suspended in the air.

Right: *The whole glass is a hologram.*



Invisible Rays

Light rays consist of waves of light energy that travel through space and through transparent materials like air, water and glass. We see light when the rays enter our eyes because the energy they contain makes our eyes send signals to the part of the brain that detects vision.

Light waves are *electromagnetic waves*, which means that they are made up of electric and magnetic fields. There are several other kinds of electromagnetic waves that are similar to light rays. They travel at the speed of light, and can move through space and through some materials, though not necessarily the same materials that are transparent to light. Like different colours, they differ from light rays in the number of waves that arrive every second.

All these other kinds of rays are invisible. They include radio waves, radar waves, microwaves, infra-red rays, ultra-violet rays, X-rays and gamma-rays. All of these rays are useful to us in many different ways.

Man-made radio waves carry radio and television signals through the air and space. Radio telescopes can detect radio waves that come from space. These waves are sent out naturally by stars and galaxies, and radio astronomers have made many discoveries about stars and galaxies by studying their radio waves.

Radar waves are similar to radio waves but, like light rays, they are reflected from solid objects. So radar systems can detect distant objects and measure how far away they are and how fast and in which direction they are moving. At airports, radar systems check the movements of all the aircraft approaching and departing from the airport so that the controllers can guide the

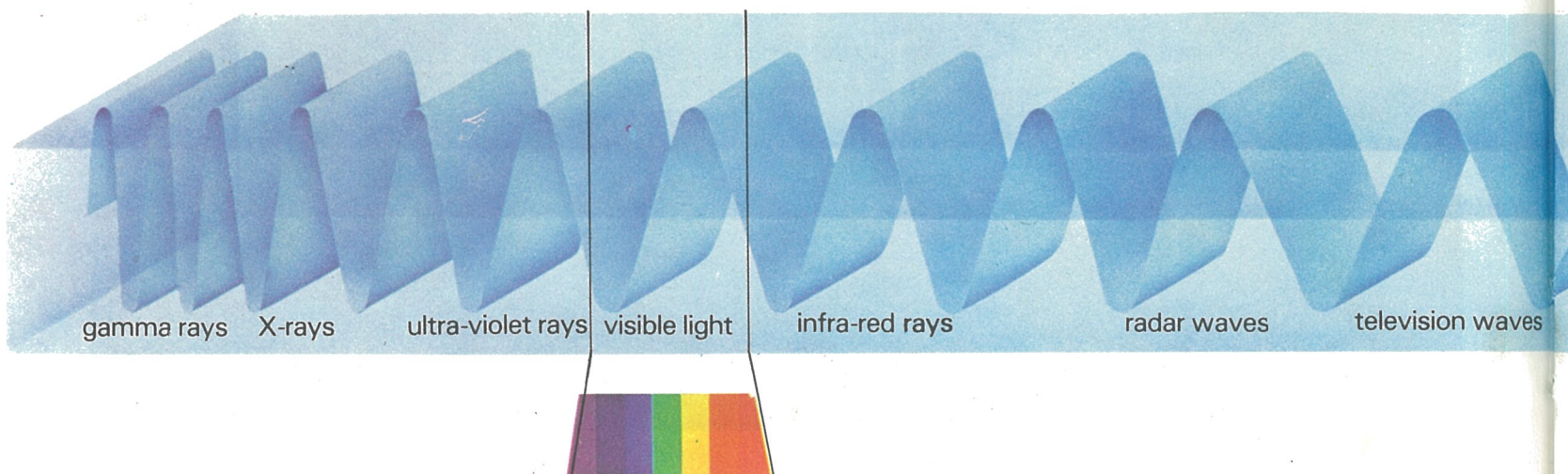


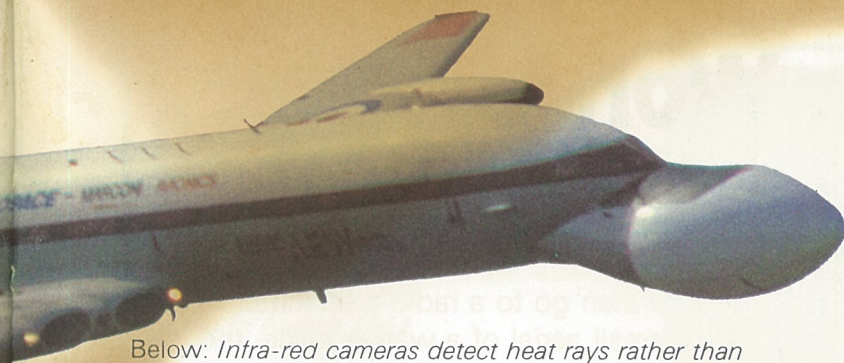
Above: The strange radar nose on this aeroplane allows it to keep track of other aeroplanes over a very wide area.

aeroplanes and make sure that none collide.

Microwaves are used in special ovens that cook food very quickly. The microwaves penetrate the food and heat the inside of the food as much as the outside. This is why the food cooks quickly. Infra-red rays are similar because they too heat things. In fact, when you feel heat rays coming from a fire, a radiator or the Sun, you are being struck by the infra-red rays that they produce. Satellites can detect infra-red rays coming from the Earth below and produce infra-red pictures of the land and sea. This is very useful because the pictures can show up diseased crops and ocean currents that cannot be seen in photographs taken by visible light. Infra-red cameras can also 'see' in the dark, because they detect the heat rays that things produce.

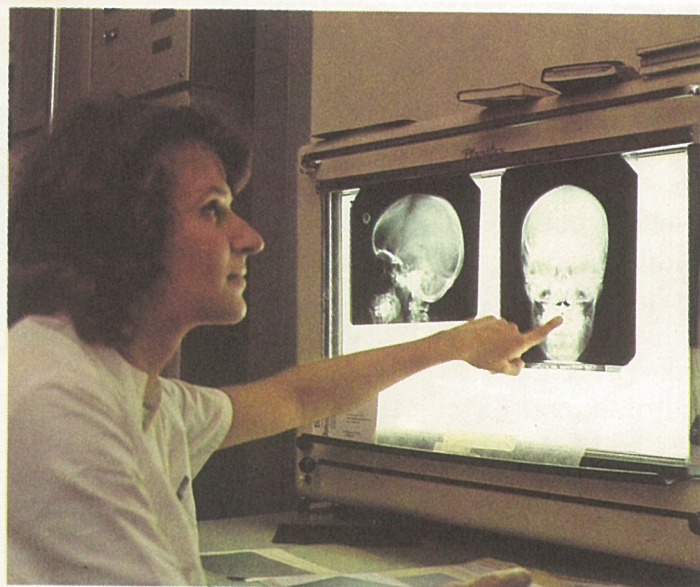
Ultra-violet rays reach us from the Sun and help to tan our skins as well as produce vitamins for health. Substances called





Below: Infra-red cameras detect heat rays rather than light rays and can therefore 'see' in the dark – producing pictures showing objects which give off different amounts of heat in different colours.

Bottom: Air traffic controllers at airports can check the exact position of aircraft on radar screens.



Above: X-rays penetrate flesh, giving a picture of hard substances like bones or teeth.

phosphors glow like luminous paints when ultra-violet light shines on them. This is used for spectacular 'black light' effects in theatres and discos, and post-codes are printed on envelopes with phosphors so that ultra-violet detectors can automatically sort letters.

X-rays are able to penetrate soft materials like flesh but not hard substances, so they are used in medicine to show up the organs inside the body. However, care is to be taken to avoid large doses of X-rays because they begin to destroy the living cells in the body. Gamma-rays are similar to X-rays but have even more penetrating power. They are present in radiation from nuclear reactors, and because the rays also kill body cells, the reactors have heavy shielding to protect nuclear workers. However, small doses of X-rays and gamma-rays are useful in treating cancer, when the rays are used to destroy cancerous tissue.

The Family of Electromagnetic Rays

radio waves

Left: The family of electromagnetic rays extends from radio waves through visible light to gamma-rays. The various kinds of rays differ only in the number of waves that pass every second – gamma rays highest, radio waves lowest.

Voices Around The World

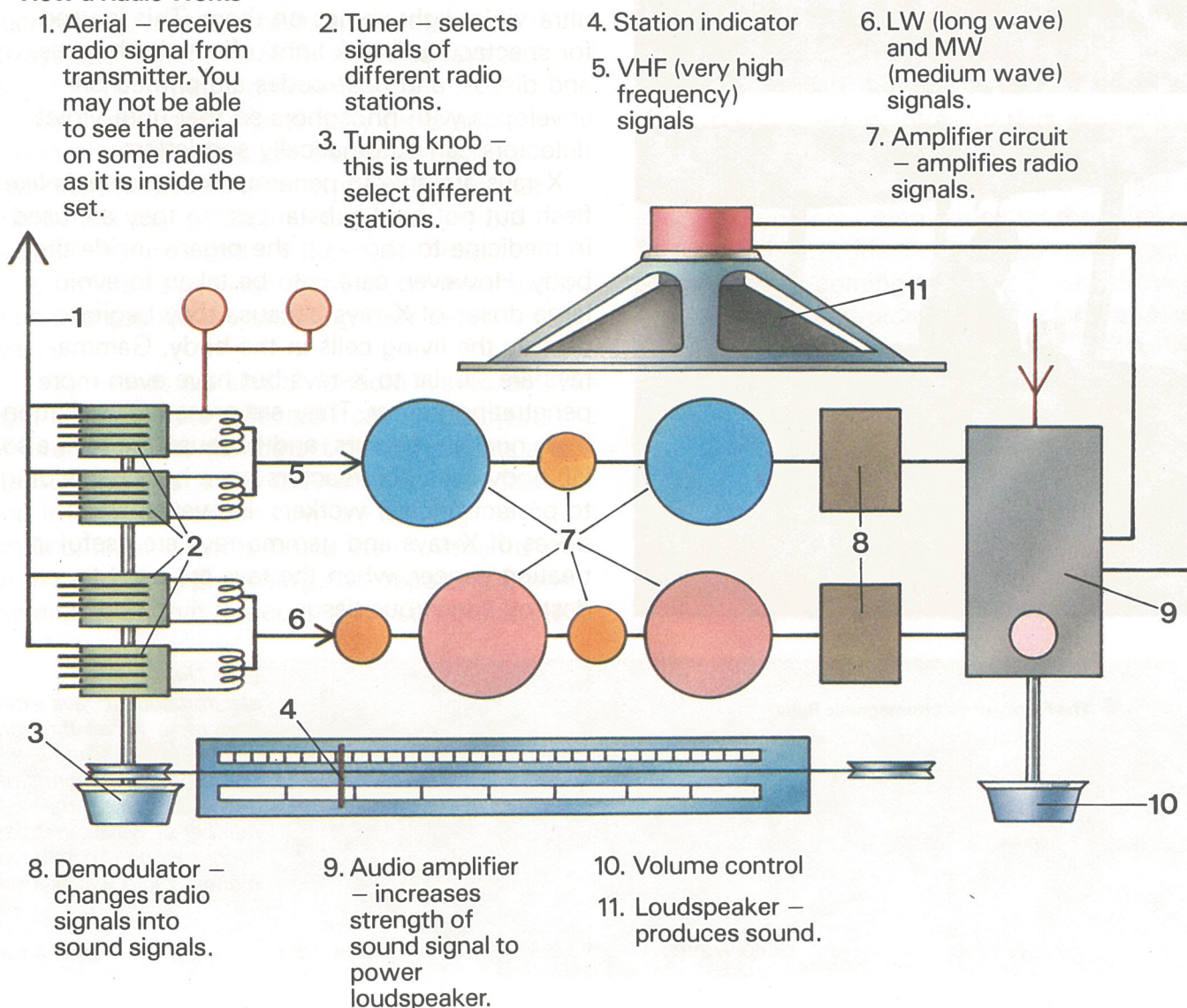
If you turn the tuning controls of a radio set, you will hear voices and music coming from all over the country and perhaps several other countries as well. If you have a very good radio, you may be able to get stations all over the world. Radio also reaches up into space, linking the Earth to satellites and spacecraft. At the other end of the scale, small walkie-talkie sets and CB radios enable us to talk to people a short distance away. The police and taxi drivers also have short-range radios to talk to their headquarters.

How does radio carry voices around the world and out into space? Let's start at the beginning with the person talking. A

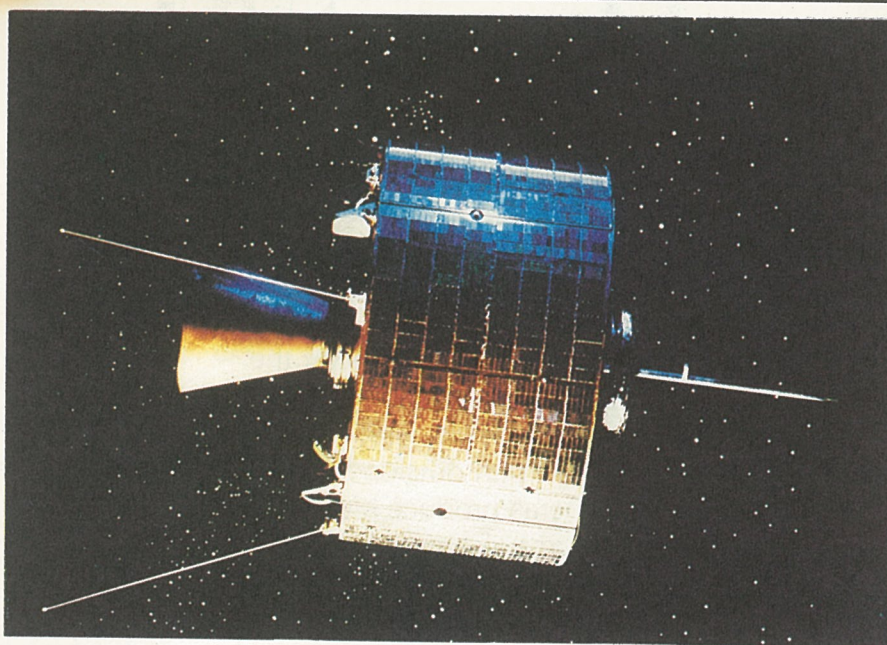
microphone picks up the sound waves that come from the speaker. The microphone turns the sound waves into electrical signals, and these signals then go to a radio transmitter. This may be the small aerial of a walkie-talkie, the big mast of a radio station, or even the enormous dish of a satellite ground station.

The electric signals are turned into radio waves at the transmitter. The waves are produced by feeding an electric current into the transmitter that makes the electrons in the metal atoms of the aerial, mast or dish jump about very quickly. This makes the transmitter send out radio waves, and they spread out through the air and into space at the speed of light,

How a Radio Works



Right: Syncom 3 was the world's first true geostationary communications satellite. It was put into a 24-hour orbit above the earth's equator over the Pacific Ocean in August 1964.



Communications satellites

Even though radio waves travel in straight lines, a good radio set can pick up distant radio stations on the other side of the world. This is because the radio waves do not go out into space, but are reflected back to the ground by the upper atmosphere.

Communications satellites orbit the Earth to do a similar job. They receive radio transmissions

from the ground that can penetrate the atmosphere. Then they send the transmissions back to a ground station elsewhere on Earth. This method gives much better quality than long-distance radio transmission through the atmosphere. The satellites are mainly used to send telephone calls and television programmes around the world.

which is 300,000 kilometres every second.

To receive radio transmissions, a radio set has to be connected to an aerial. Portable radios contain an aerial inside the set, but a large aerial may be needed to get distant stations. To receive signals from satellites, which are very weak, large dish-shaped aerials are used.

When the radio waves strike the metal of the aerial, they make a weak electric signal flow along the aerial. This signal is amplified and then fed to the loudspeaker in the radio. The loudspeaker converts the electric signals into sound waves, and we hear the voice of the speaker far away.

However, the aerial is bombarded with radio waves coming from many stations, both near and far. The radio set needs to sort out which station to receive. This is done by the tuner inside the radio which can detect individual stations because each station broadcasts radio waves with a different *frequency*. The frequency of the radio wave is the number of waves of energy that arrive every second. They go from thousands up to millions of waves a second, and the frequency is indicated in *hertz (Hz)* on the dial. The tuner in the radio cuts out all the frequencies except that of the required station.

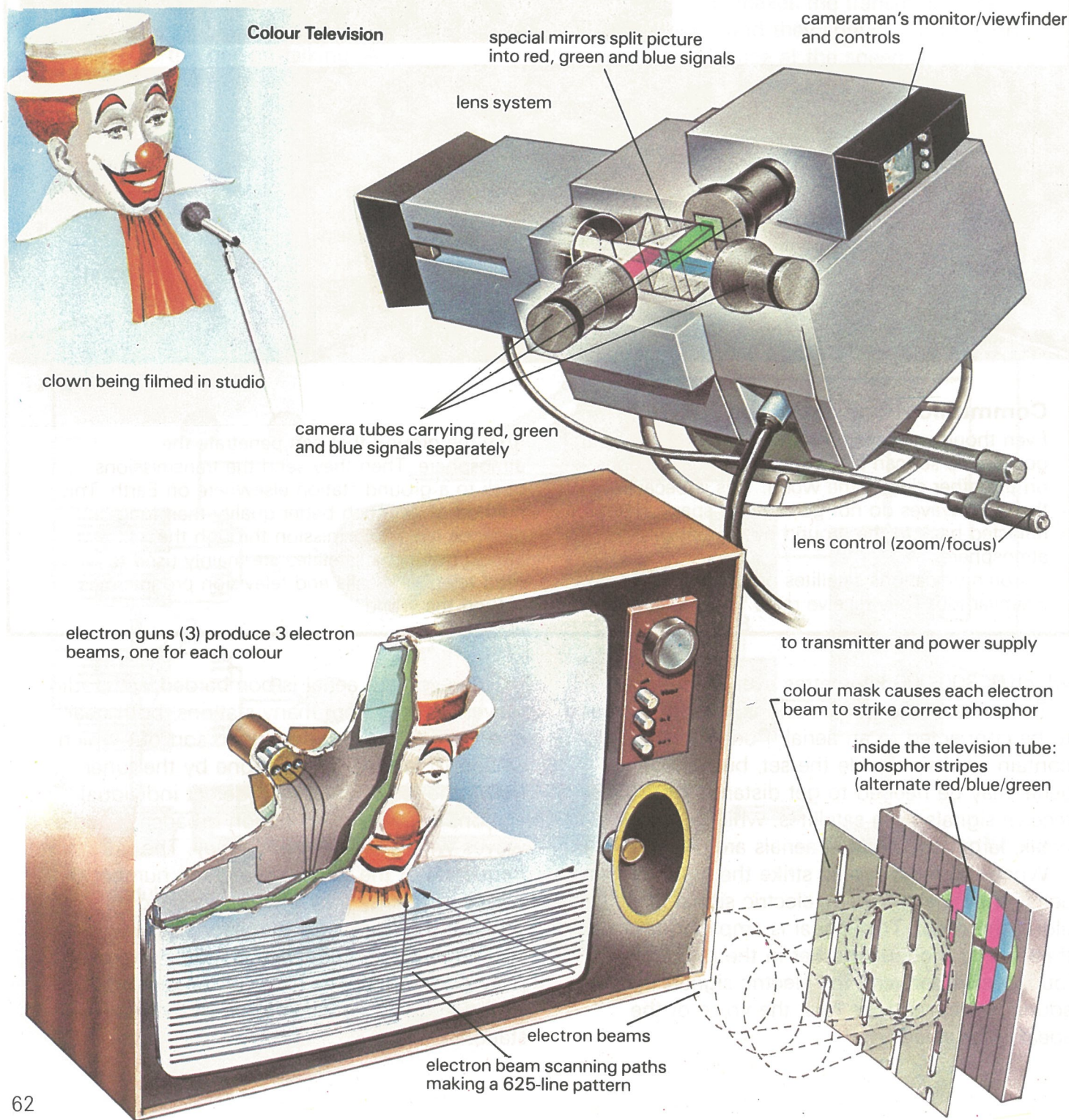
Television and Video

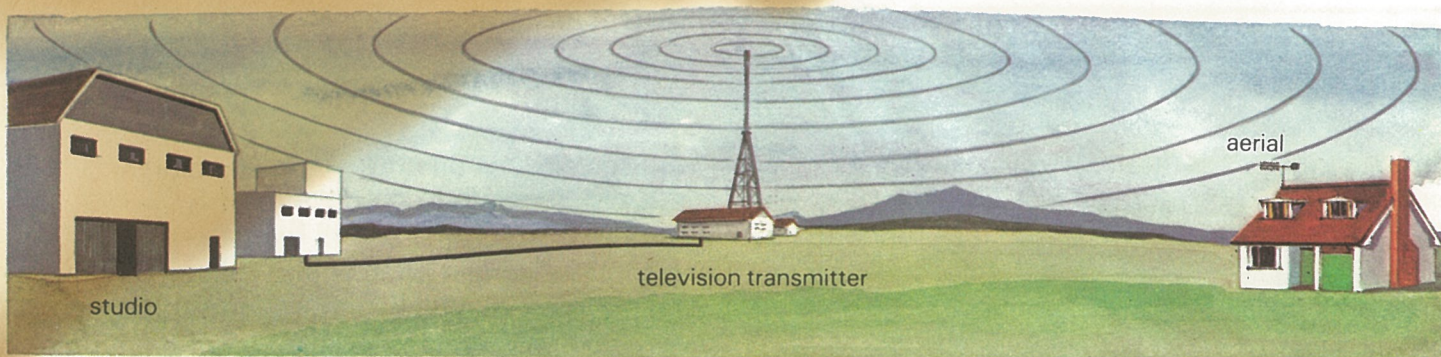
Radio waves do not only carry voices and music from one place to another. Television uses radio waves to send full-colour pictures from transmitters to homes, and radio signals from satellites beam television broadcasts around the world. A television set produces the sound that goes with the pictures in exactly the same way as a radio set. But how can radio waves carry the pictures to our homes?

In a television studio or at an outside broadcast, television cameras produce electronic pictures of a scene. The lens in a camera sends

light from the scene through three coloured glass prisms or filters to produce three images of the scene – one in red, one in green and one in blue. The coloured images fall on three metal plates, which convert the light in each image into electric signals. In this way, the camera gives three signals – one produced by the red, one by the green and one by the blue light in the scene.

These three signals go to the television transmitter, which is a big mast placed high up near a city or several towns. The transmitter





turns the electric signals from the camera into radio waves. The waves spread out from the mast, and go to the television aerials connected to the sets in nearby homes. As the radio waves strike an aerial, they produce in it the same kind of electric signals that are given by the camera. A tuner detects the signals of a particular television channel, just as a radio tuner selects a particular radio station. The three colour signals then go to the screen in the television set to give a picture.

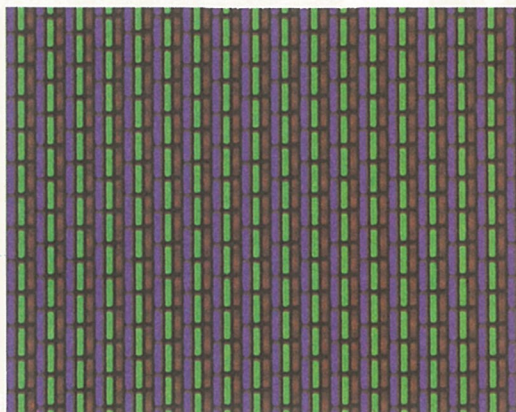
The screen is at the front of a large glass tube in the set. It is covered with a pattern of very small dots or stripes of materials called *phosphors*. At the back of the tube, the three electric signals are converted into beams of

electrons. The beams strike the phosphors and make them glow red, green or blue. In this way, three images made of red, green and blue dots or stripes are formed on the screen. These images merge together in our eyes to give a full-colour picture. The images are transmitted many times every second, so that we see a moving picture on the screen.

Television pictures also reach some homes through cables. The cables are wires that connect the studio to the home. The electric signals travel directly to the television set without being turned into radio waves on the way. Information services can also feed pictures to television sets along telephone wires in the same way.

Far right: A television screen being used to receive an up-to-date information service in the home.

Right: A colour television screen showing the red, green and blue stripes.



Video recording

Many television programmes you see are video recordings, and programmes can also be recorded on a home video cassette recorder. This kind of video recording works like tape recording (see page 66). The electric signals that make up the picture and the sound are changed into magnetic signals in a video recorder. These signals are then recorded on tape as magnetic patterns in the tape. When the tape is played, the magnetic patterns produce the original electric signals, and these go to the set to give a picture and sound in the normal way.

A videodisc contains the same signals in the form of tiny holes in the surface of the disc. A laser beam detector produces the electric



signals when the disc is played, and these go to the television set to give a picture and sound. Unlike a video recorder, new programmes cannot be recorded on a videodisc player. Only the show already recorded on the disc can be played.

Sound

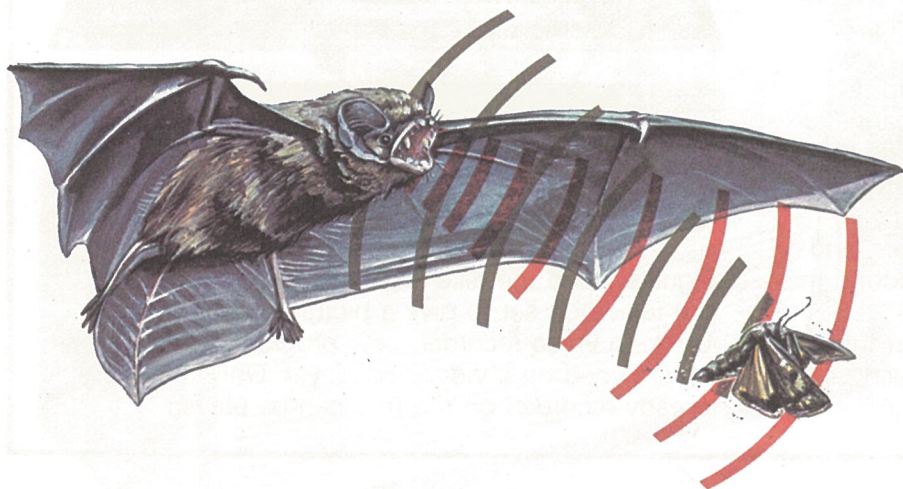
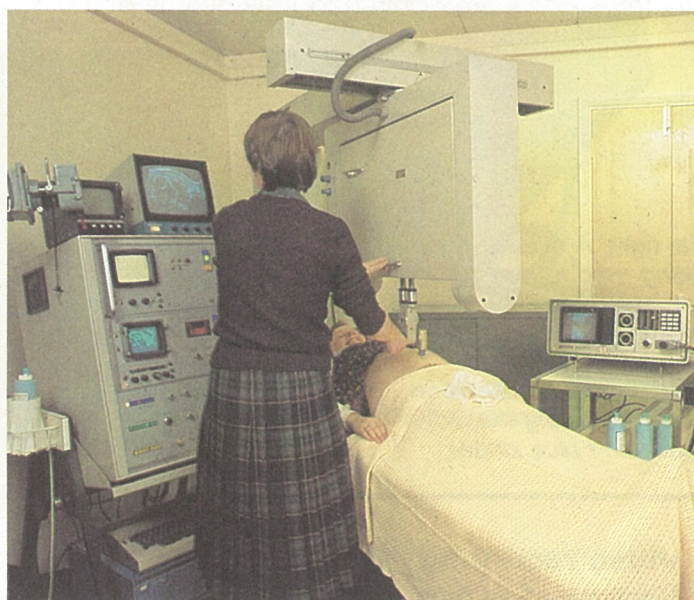
Sound is the last form of energy that we shall explore in this book. It may not appear to you that sound is energy. It seems to have none of the power that other forms of energy, such as kinetic, chemical, heat, light and electrical energy, exert on us. If you shout as loudly as possible at someone, they don't fall over – though they might put their hands over their ears. This is because we are very, very sensitive to sound. A loud sound does not contain very much energy – if it were converted into heat in an electric fire, the fire would hardly get warm. But sound is very important to us, because we live in a world of sound during our waking hours. We depend on sound to talk with and listen to other people, we use sound for warnings in bells and other devices, and most of us gain great pleasure from making or listening to music.

To make a sound, something has to vibrate – that is, it has to move to and fro rapidly, like a rubber band twanging. When we talk, the vocal cords in the throat vibrate. As they vibrate, they produce sound waves, which are alternate bands of high and low pressure in the air. As the waves reach our ears, the bands of air pressure set the eardrums vibrating. The eardrums send signals from the ears to the brain, and we hear the sound.

Right: Doctors now use ultrasound to give a picture of an unborn baby. Ultrasound is sound which is so high that we cannot hear it. To make the picture of the baby, ultrasound (which is harmless) is bounced off the baby in its mother. The sound comes back to the receiver at slightly different times, depending on the shape of the baby. The receiver detects the different times and builds up a picture of the baby from them.

In musical instruments, strings, skins or the air in pipes vibrate to produce sound waves. The rate at which the sound waves arrive gives the sound a certain pitch – that is, a sense of whether it sounds high (treble) or low (bass). A slow vibration produces a low sound, and a fast vibration gives a high sound. You can see this happening by twanging a ruler on a desk or table-top. The rate varies from about 20 waves a second for the lowest sound we can hear up to about 20,000 waves a second for the very highest.

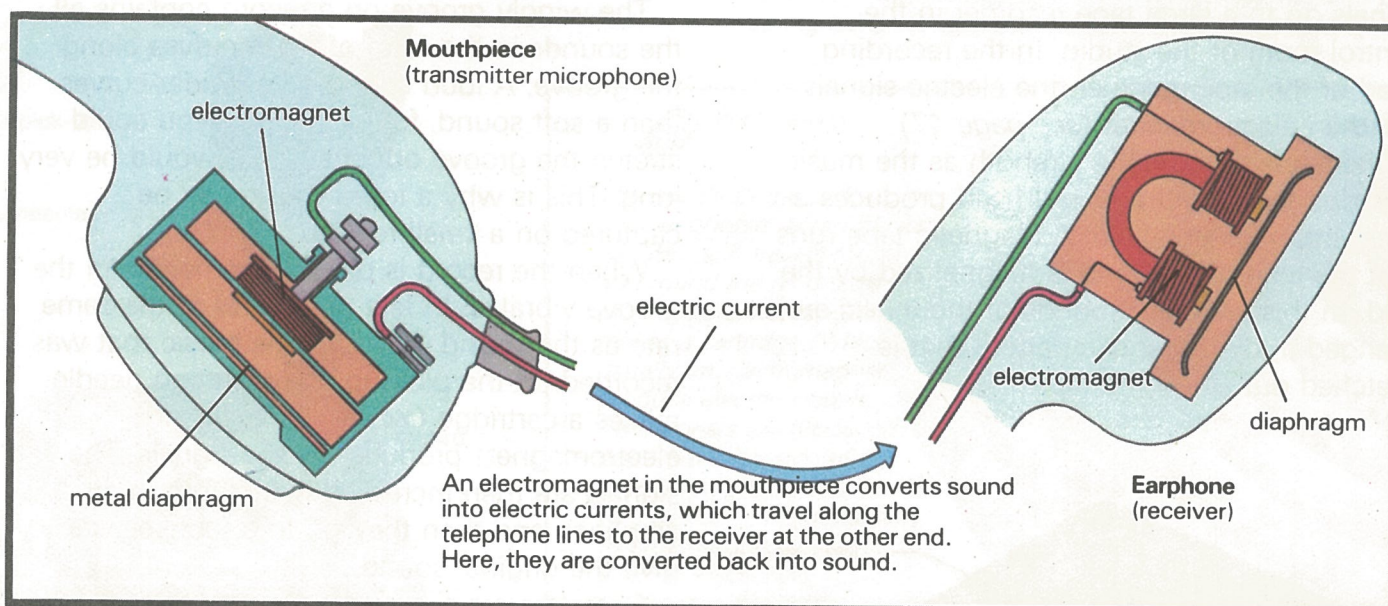
Unlike light and electricity, sound does not travel very fast. In air, it moves at a speed of about 340 metres per second. This is slow enough for us to detect. When we hear an echo, we are listening to a reflection of the sound from a wall or cliff. The delay is the time it takes for the sound to get there and back. You can work out the distance of a flash of lightning in this way. The light of the flash



As bats fly they emit powerful bursts of very high frequency sound. The sound waves travel out and the bats listen for echoes bouncing off anything in their path. This system, which is similar to sonar, but called echolocation, allows bats to fly about in the dark without bumping into anything. Bats also use echolocation to catch their food. In the picture echoes bounce back off the moth to the bat, enabling the bat to locate the moth exactly.

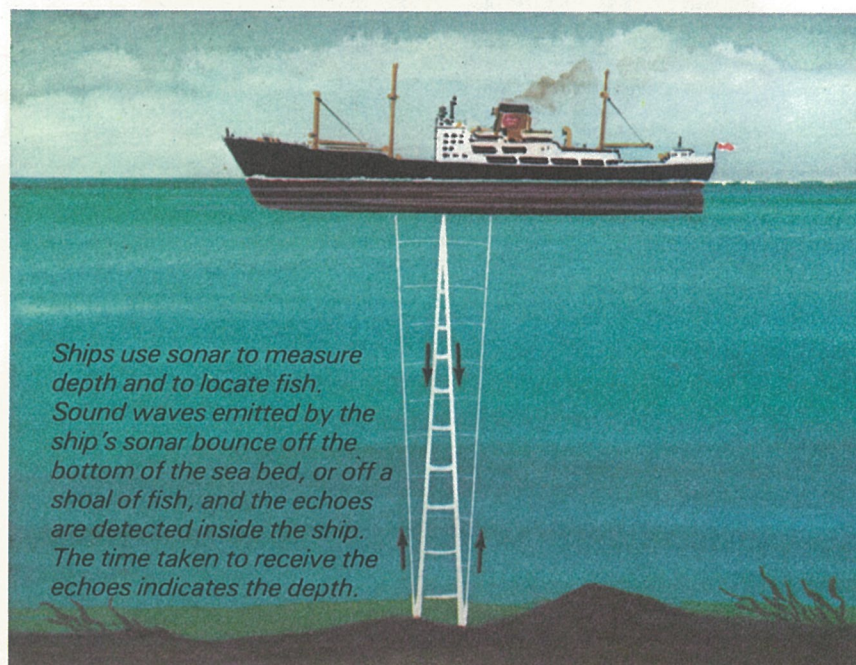
Talking by telephone

On the telephone, you can talk instantly to someone even though they are a long way away from you. In the mouthpiece of the telephone is a small microphone. It turns the sound waves of your voice into electric signals. These signals travel along the telephone wires to the earpiece of the other telephone. The earpiece contains a tiny loudspeaker that turns the electric signals back into sound waves, and your caller hears your voice. He or she then talks to you in the same way. The electric signals travel along the wires between the two telephones at such a high speed that there is no delay.



travels almost instantly to the eyes, but we hear the thunderclap it causes later because the sound takes some time to reach us. Time the delay in seconds and divide the time by three; this is the distance of the lightning in kilometres.

Sound moves much more quickly through liquids and rigid solids. It travels nearly five times as fast through water and 18 times faster through steel, for example. This is why sound goes through walls. However, sound does not easily penetrate soft materials like cloth because they soak up the sound waves. This is why curtains and carpets help to make a room quiet. Sound does not travel at all through a vacuum. On the Moon, where there is no air, astronauts had to talk to one another by radio for this reason.



Capturing Sound

Many of us get great pleasure from listening to records and cassette tapes, and also a lot of fun from recording ourselves on cassettes. With portable cassette players, we can even carry our favourite music about with us. But how does recording work? How can as much as one hour's music be squeezed on to a record or a cassette?

Most of the music that you can buy on a record or cassette is recorded in a recording studio. The same kind of studio is used for both records and cassettes. The singers and musicians perform in front of microphones. The microphones pick up the sound of the music, and convert it into electric signals. These signals go to a large tape recorder in the control room of the studio. In the recording head of the tape recorder, the electric signals go to an electromagnet (*see page 47*).

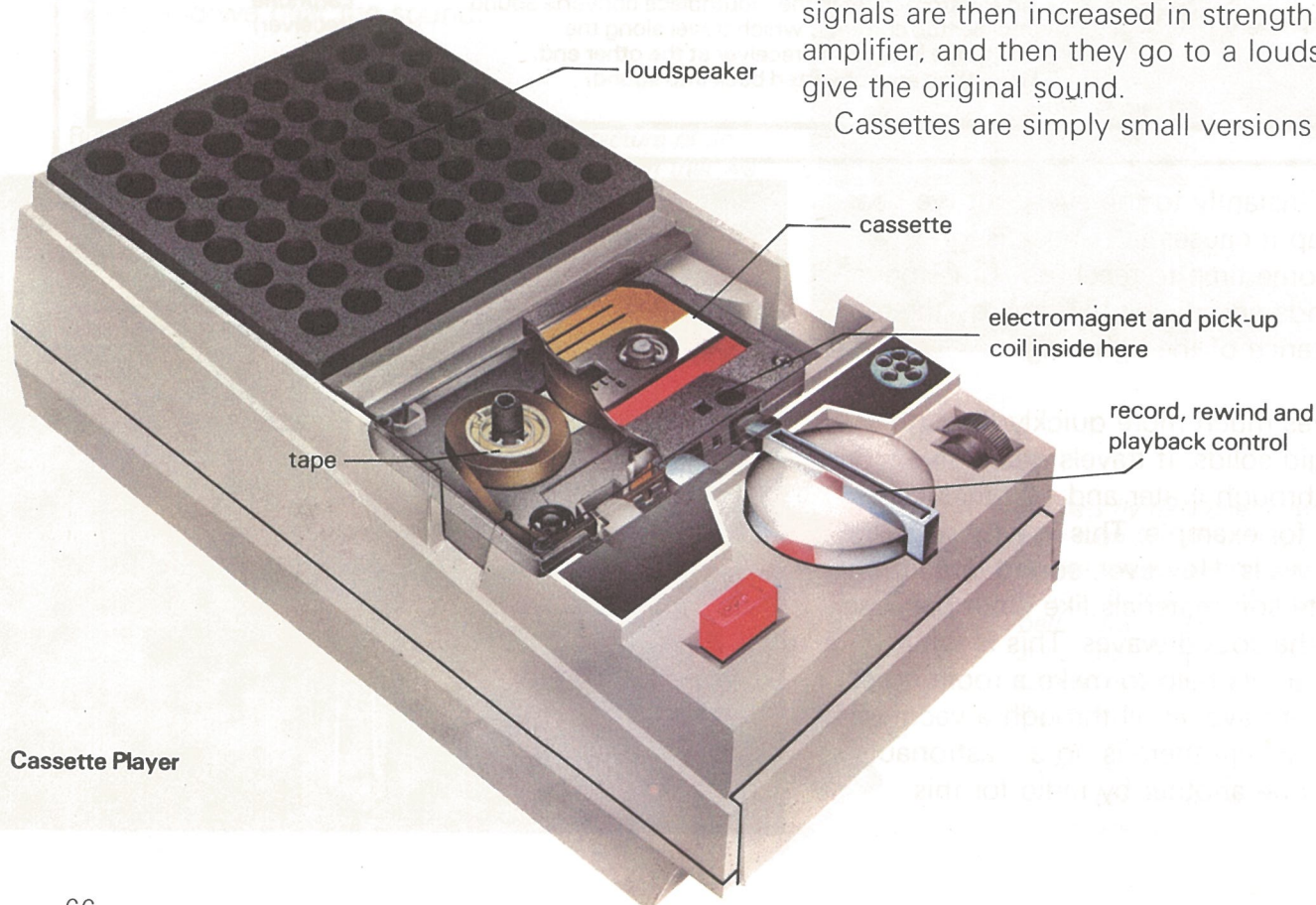
The signals change in strength as the music is performed, and the record head produces a changing magnetic field. A magnetic tape runs past the record head and is magnetized by the field. In this way, the sounds of the music are changed into a magnetic pattern that is stretched out along the tape.

Often, different tapes are put together to make the final master tape of the music. Then this tape is used to manufacture the discs or cassettes. To make discs, a master disc is first produced from the tape. The tape is played back on a tape recorder. It moves past the playback head, which is also a kind of electromagnet, and electric signals are produced as the magnetic pattern on the tape passes the head. The signals go to the cutting head of a disc cutter. The head vibrates, cutting a groove in a spinning disc of plastic. Copies of this master disc are then made by pressing them in moulds. These copies are the records that are sold in shops.

The wiggly groove on a record contains all the sounds in the form of small curves along the groove. A loud sound gives wider curves than a soft sound, for example. If you could stretch the groove out straight, it would be very long. This is why a lot of music can be captured on a small record.

When the record is played, the needle in the groove vibrates. In fact, it vibrates at the same rate as the sound waves of the music that was recorded. In the pick-up, the vibrating needle makes a cartridge (which is usually an electromagnet) produce electric signals. The signals are then increased in strength in an amplifier, and then they go to a loudspeaker to give the original sound.

Cassettes are simply small versions of the



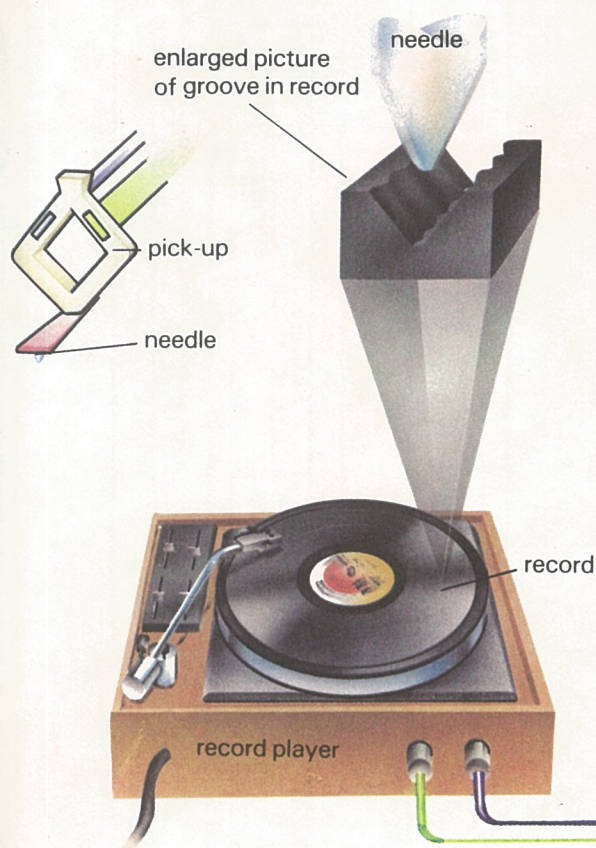
Cassette Player

Stereophonic sound

Most record players and many cassette players have two loudspeakers. The music is spread out between them as if you were in front of the performers. This is called *stereophonic sound*, or *stereo* for short. A stereo disc or cassette in fact contains two separate signals, one for each speaker. In a disc, the signals are recorded in the two walls of the groove. In a stereo cassette, there are two separate magnetic patterns or tracks along the tape.



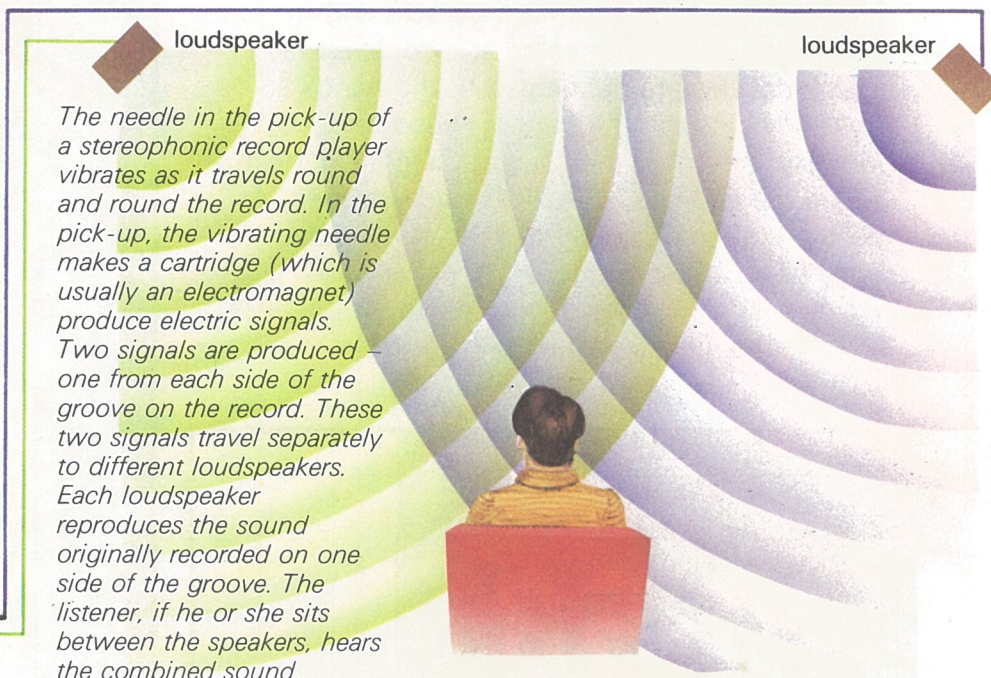
Above: Compact discs are read by a laser beam rather than by a needle. This means the disc is not actually touched by anything except a light beam and so is very long lasting.



Stereophonic Sound

original master tape recorded in the studio. They run slowly so that a lot of music can be got on to a small tape. Cassettes are made on special cassette recorders similar to the studio tape recorder. You can record yourself on cassette and play back cassettes on a cassette player in the same way as a tape recorder. The electric signals produced by the head in the player go to an amplifier and loudspeaker as in a record player or to earphones.

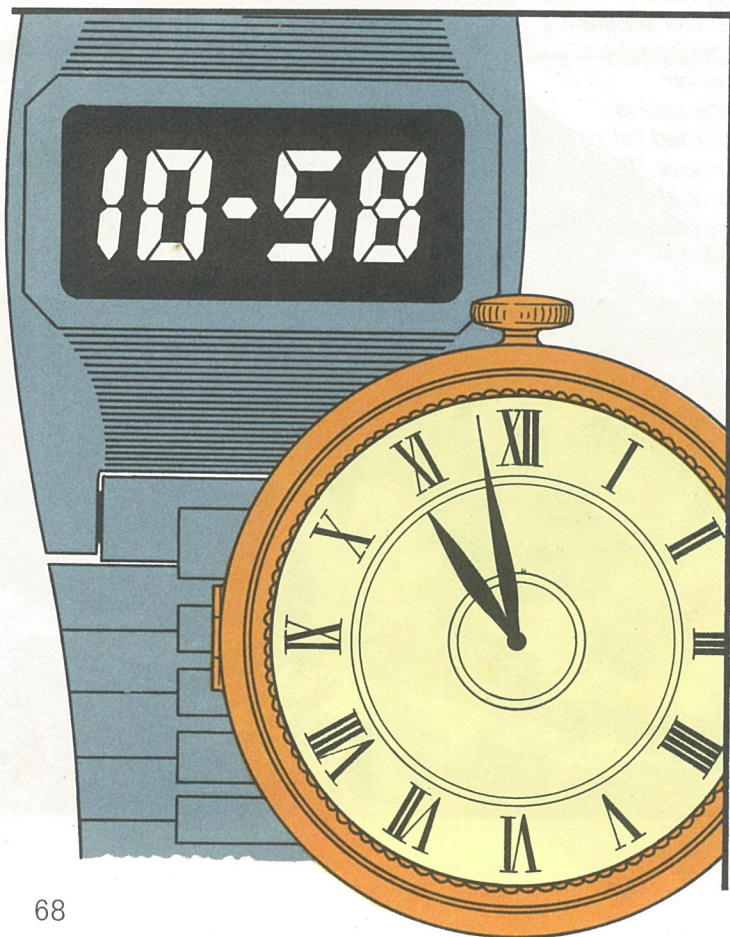
Right: In a recording studio, the musicians perform in front of microphones that pick up the music. In the control room behind the window, engineers check the quality of the sound as it is recorded.



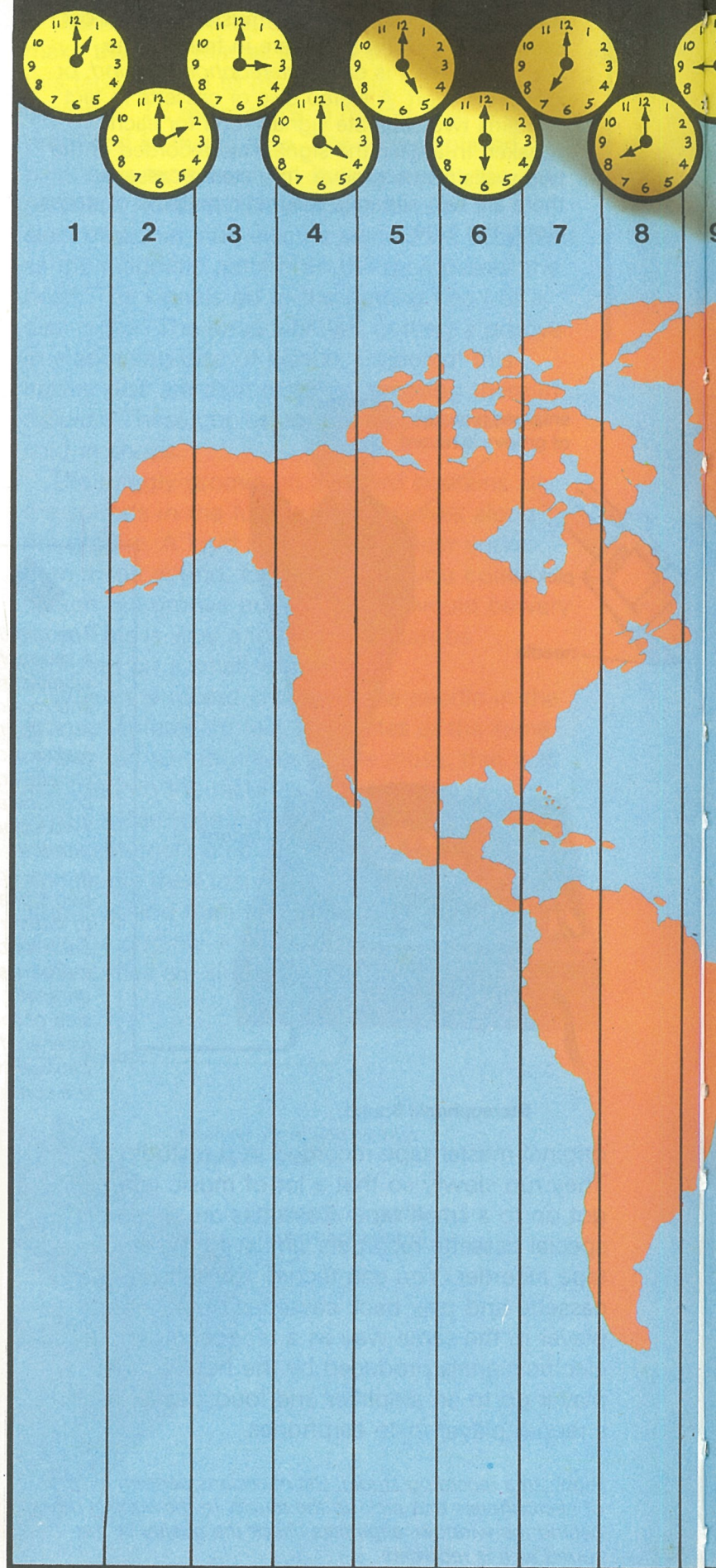
Time

We all need to measure time. Most people carry watches or use clocks so that they can make the best use of their time. Scientists often have to be able to measure time with great accuracy to do experiments. Our method of measuring time is based on the movement of the Earth. One day of 24 hours is the time it takes the Earth to rotate once. A year is the time it takes the Earth to move once around the Sun. Because this is not a whole number of days but nearly $365\frac{1}{4}$ days, we have an extra day every leap year. Dividing a day into hours, minutes and seconds is done for simplicity so that we can easily measure short periods of time.

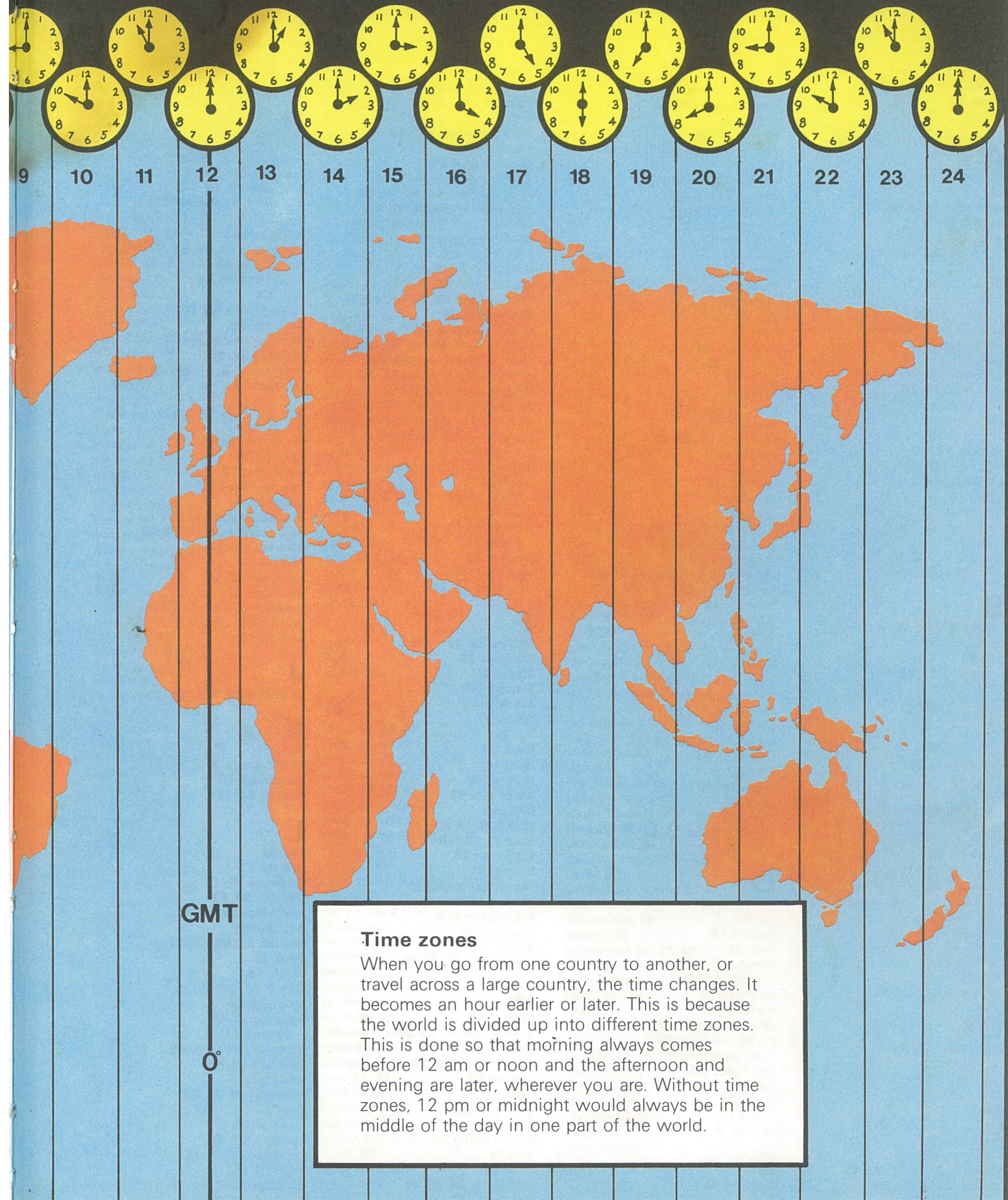
All clocks and watches can measure time because they contain a device that works at a precise unchanging rate. In a clock, this is a pendulum or a spring that moves to and fro or an electric motor that spins at a constant rate. These devices are connected to the hands so that they move at the correct speed and indicate the right time. Digital watches contain electronic controls. All clocks and watches need a source of power to keep them going. They have to be wound up to either raise weights or wind up a spring inside, or they use electricity either from the mains or from batteries.



Hours earlier than GMT



Hours later than GMT



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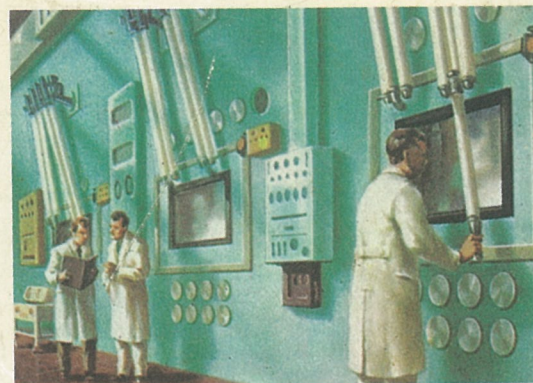
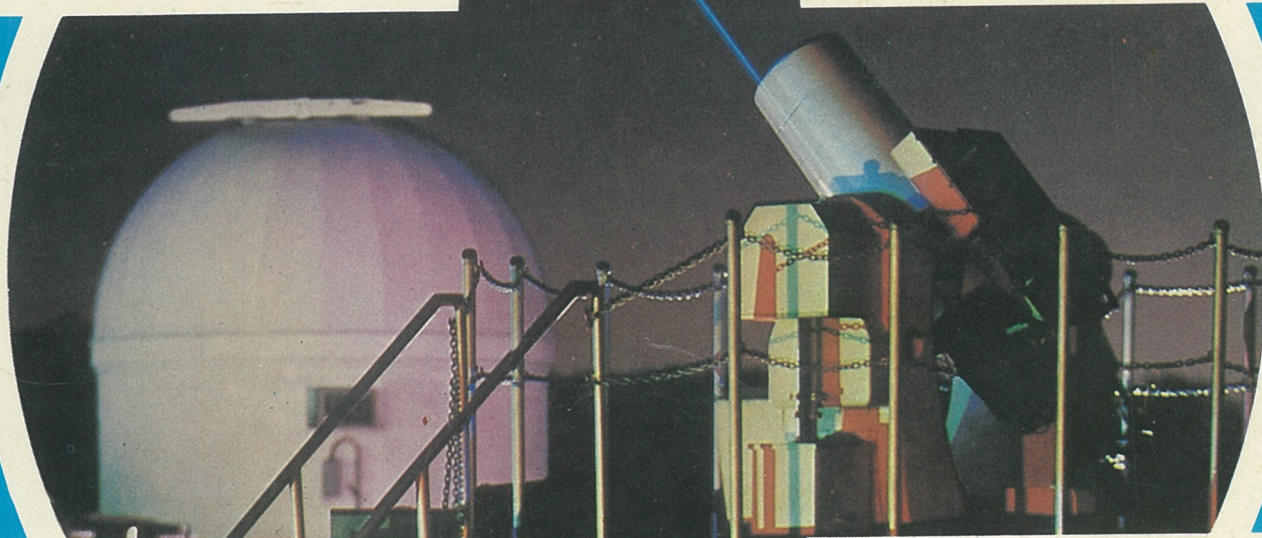
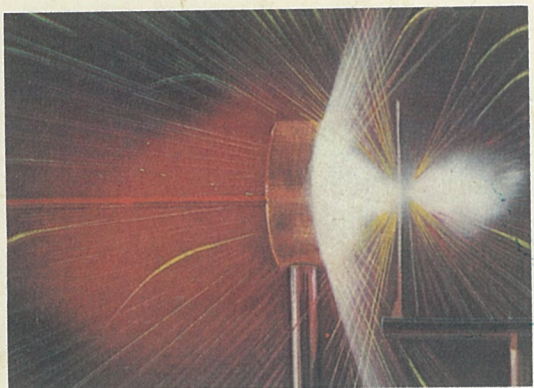
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This book has been specially written for the 7 to 11 age range to provide children with an introduction to basic scientific principles. Its clear, simple text and large full-colour pictures and diagrams will give them every help and encouragement to learn more about the many fascinating topics they meet here.



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