children's illustrated encyclopedia

The World of Science

Orpheus

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MATTER

EVERYTHING is made of matter. Every object, substance, chemical and material is matter. This includes not only things you can see easily, like the paper of this page and the ink that forms the words and pictures. It also includes specks of dust too small to notice, houses and cars, living things like trees and your own body, the rocks of the Earth, the clouds in the sky and the invisible air around you. And not only objects and substances on Earth are made of matter. All of the planets and stars in deep space contain matter. In fact everything in the entire Universe is made of matter. All matter is made of tiny building blocks called

Why is a butterfly like a lump of rock whizzing through space? Both are made of atoms. The butterfly is living matter, the rock non-living matter.

There *are* places where there is no matter. If there is no matter then there is nothing at all. The total or complete absence of matter is called a **vacuum.** However a total vacuum is very unusual. "Space" is named because it is supposed to be just empty space, with no matter. But even in the depths of space, a few micro-particles of dust or some wispy bits of gas are floating about. These tiny bits of matter may be several metres apart, instead of crammed together like they are on Earth. But they are still present. Here on Earth, powerful vacuum pumps can suck most of the matter out of a container, but never quite all of it.

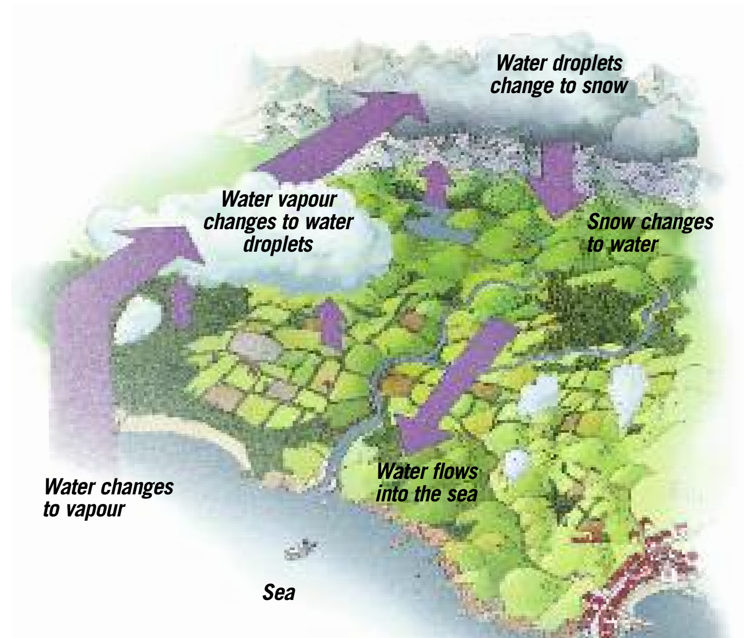
STATES OF MATTER

Matter exists in three main forms, called the states of matter. These are solid, liquid and gas. In a solid such as ice, the molecules (atoms bonded together *see page 12*) are very close together and joined in a rigid pattern. They can hardly move. So a solid object stays the same volume and does not change its shape. In a liquid such as water, the molecules are still quite close together but they are not joined to each other. They can move about, which means the whole liquid can change shape and flow, although, like the solid, it still takes up the same volume. In a gas like water vapour, the molecules can move nearer together or farther apart. So a gas can also get bigger or smaller, to fill the container it is in.

A hot-air balloon contains matter in the form of gas—air. Heat from the burner causes the air's molecules to rush farther apart, so taking up more room. Soon there are fewer molecules in the hot air inside the balloon than in the normal air outside. The balloon is lighter or less dense *(see opposite)* and rises.

CHANGING STATES

Matter or substance can change state from solid to liquid, or liquid to gas. This usually happens by adding heat. Matter can also change state the other way from gas to liquid or liquid to solid. This usually happens by cooling (taking away heat). A common example which is all around us is water. The world's water is always on the move and changing state in a never-ending process, the water cycle *(below)*.



Water changes from one state to another in the water cycle.

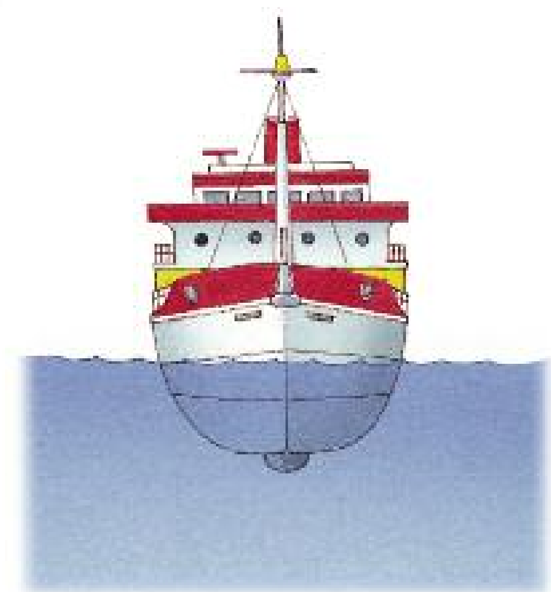
In the water cycle, the Sun warms the sea. The heat makes liquid water turn into a gas, invisible water vapour, which rises into the sky. It is cooler high up so water vapour changes state back into a liquid, forming tiny droplets. These are so light that they float as clouds. Wind blows the droplets over the land. Some clump together, become too heavy to float and fall as rain. Some droplets blow even higher, up over a mountain, and become even colder. They change state again, freezing solid into snowflakes. The snow falls to the ground and melts into liquid water. With the rain, it flows into streams and rivers, and finally into the sea—and so the cycle continues.

We are too big and heavy to float on liquid water. But the insect called the pond skater can do just this. Its body is very light and it slides or skates about on the surface film, which is like a tight skin stretched over the top of the water.

PROPERTIES OF MATTER

Matter has many features, or properties. One of the main properties is its state—solid, liquid or gas. Another property is the type of atoms it is made of. Each kind of pure substance, like iron, carbon, oxygen or sulphur, has a different kind of atom. It is known as a chemical **element** *(see page 6)*.

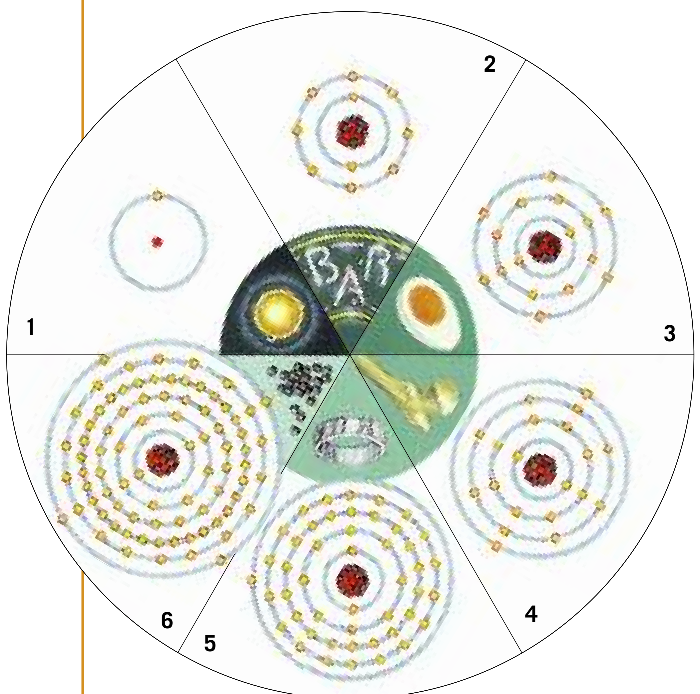
A third property of matter is **density.** This is the amount of matter in a certain place or volume. The more matter within a certain volume, the denser or heavier the substance or object. Dense substances like iron have lots of large atoms packed close together. Density is important because it determines whether things float or sink. If an object is less dense than water, such as a lump of wood, it floats. A lump of iron is more dense than water and so it sinks. But if the iron is made into a boat's hull its shape contains lots of air, which has a very low density and is extremely light. The overall density of the iron-plus-air is less than the density of water, and makes the boat float.



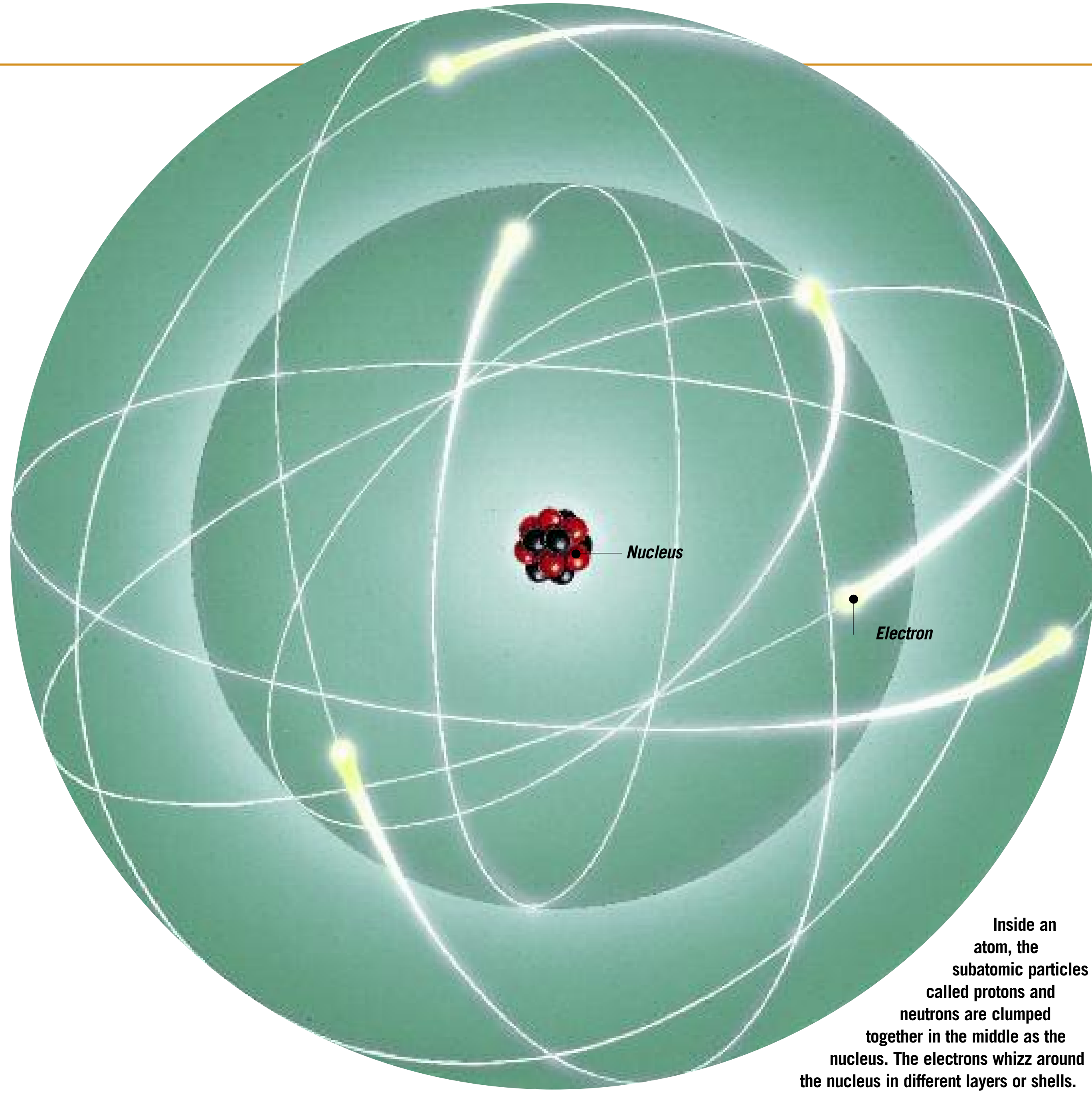
Atoms

ALL MATTER is made of atoms. An individual atom is far too small to see, even with the most powerful microscope. But atoms joined together make up every solid object, substance, chemical and material in the Universe. A pinhead, for example, contains about one billion billion atoms.

Atoms able to move about make up liquids and gases. Atoms which are more fixed and unable to move much make up solids. Not all atoms are the same. There are about 92 different kinds of atoms that occur naturally. Scientists have made another 17 or so artificial kinds in laboratories. Each kind of atom has individual properties that distinguish it in some way from another kind. A substance made from just one kind of atom is known as a chemical **element.** Examples of six elements are shown below.



Atoms of different chemical elements have different numbers of particles. Simplest is hydrogen (1), a very light gas that makes up most of the Sun *(see page 11).* Neon (2) is a gas used in coloured strip-lights. Egg yolks are rich in sulphur (3). Calcium (4) is needed for healthy bones. Silver (5) is a shiny valuable metal. Lead (6) has many particles and so is very heavy. It is used to make small weights or shot.



Inside an atom, the subatomic particles called protons and neutrons are clumped together in the middle as the nucleus. The electrons whizz around the nucleus in different layers or shells.

Atoms are not solid, like marbles. In fact, they are mostly empty space. But this space contains even smaller pieces of matter known as subatomic particles. There are three main kinds of **subatomic particles**—protons, neutrons and electrons. The protons and neutrons are gathered together in the middle of the atom, forming its central part or nucleus. The electrons are much smaller and move at speed around the nucleus. They do not move at random, but stay in certain layers known as shells.

Elements differ in their numbers of subatomic particles. Hydrogen is the simplest because its atom has just two particles, one proton and one electron. In most atoms there are the same number of protons as electrons. This is because a proton has a tiny positive electrical charge *(see page 30)*, and an electron has the same amount of negative charge. The two sets of opposite charges balance each other out so the whole atom has no charge. This makes it stable or unlikely to break up.

The name "radioactivity" was invented by Polish-born scientist Marie Curie (1867-1934). She studied various rocks and minerals from the Earth and gave the name to the invisible rays or particles that some of them gave off, which affected photographic paper and various electrical equipment. In particular Marie worked with the substance pitchblende, a raw material used to obtain the metal uranium. Pitchblende gave off more radioactivity than expected from uranium alone. Marie purified the substances which gave off this extra radiation and so discovered two new elements, polonium and radium.

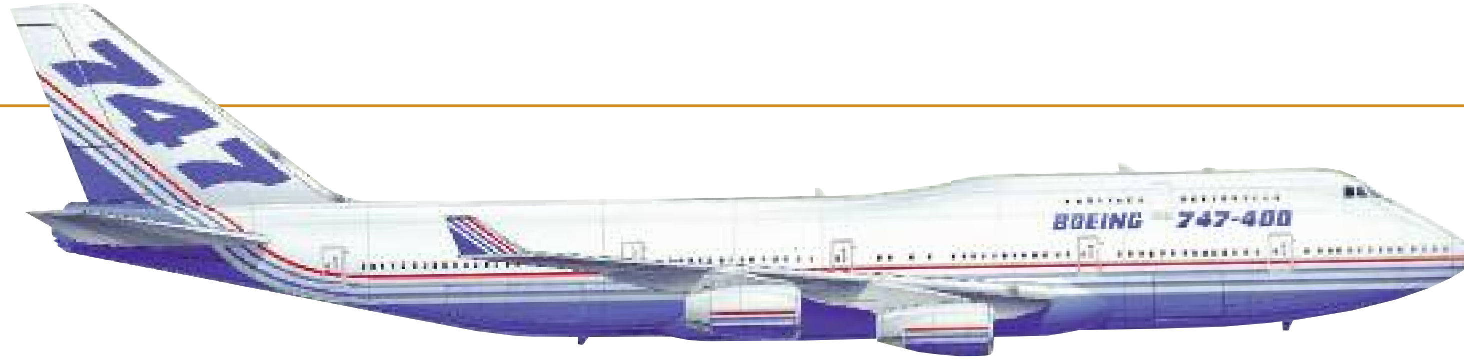
Radioactivity

Most atoms are stable. They remain the same through time. Others are unstable—they are likely to break up. As they do so they give off some of their particles or energy in the form of rays. These particles or rays are known as radioactivity. Examples of chemical elements with radioactive atoms include uranium, plutonium and radium. As atoms give out particles or rays they change into the atoms of simpler elements. For example, uranium changes into lead. This change is called radioactive decay. It happens at different speeds or rates for different radioactive elements. The time taken for half of a number of atoms to decay is known as the half-life of that element. Radioactivity can be dangerous since it harms living things. But under controlled conditions it is very useful in medicine and scientific research.

How do we know the age of mummies from Ancient Egypt? By measuring the tiny amounts of radioactive substances they contain. This is known as radio-carbon dating.

METALS

CHEMICAL ELEMENTS can be divided into several groups. The largest group, forming about three-quarters of all elements, is the metals. Metals have several features that the other elements or non-metals lack. They carry heat and electricity very well compared to non-metals. They are solid at normal or room temperature. They are strong, hard and tough, and they can be polished to give a smooth, shiny surface. When they are squeezed under great pressure, they change shape or deform and become squashed, rather than splinter apart or shatter. These features are true of most metals, but not all. The metal sodium is very soft, while the metal mercury is a silvery liquid at normal temperature.



A modern plane like the Boeing 747 Jumbo *(above)* has more than four million parts, and many of these are made of metals. The main panels of the fuselage (body), wings and tail are aluminium. This metal is strong but very lightweight.

Not all metals stay hard and solid. Some can burn very brightly, especially in powdered form. Fireworks *(below)* contain mixtures of powdered metals such as magnesium as well as other substances, to make them flare up with bright colours.

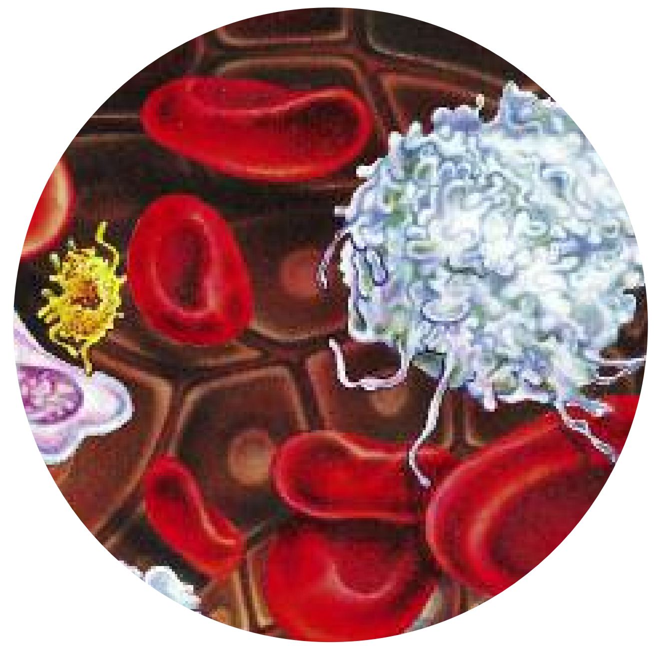
The Statue of Liberty in New York, USA *(left)* is made of a thin shell of copper held up by a framework inside. Copper is shiny brown when clean. After a time exposed to air it develops a greenish covering of the substance copper oxide. Most cars *(below)* have bodywork made of steel plate. This is strong, easy to shape into curved panels and relatively light. But steel is mostly iron, and iron rusts away when exposed to moisture and air. So the steel panels receive an anti-rust coating before they are painted.

Metals are very important in the modern world. Because of their strength and hardness they are used to make all kinds of buildings, structures, machines and engines. The most widely-used metal in industry is iron—but not usually in its pure form. Iron is mixed with small amounts of other substances, especially carbon *(see page 10)*, to form steel. A metal mixed with other metals and substances like this is known as an alloy. There are hundreds of different kinds of alloy steels, each with slightly different amounts of carbon and other elements, and each designed to do a different task. Stainless steel is used for sinks and cutlery. Titanium and vanadium steels resist very high temperatures without melting.

In a suspension bridge, the road or railway is hung from massively thick cables made from steel which is high tensile (resists stretching).

MAKING METALS

Very rarely a lump of pure metal is found lying on the ground, such as a gold nugget. But most metals occur inside rocks. Rock especially rich in a certain metal is called a metal ore. The metal is separated from its ore by various means. Iron is obtained from ores by heating them until they melt, a process called smelting.



Microscopic red blood cells contain tiny particles of iron, part of the oxygen-carrying substance haemoglobin.

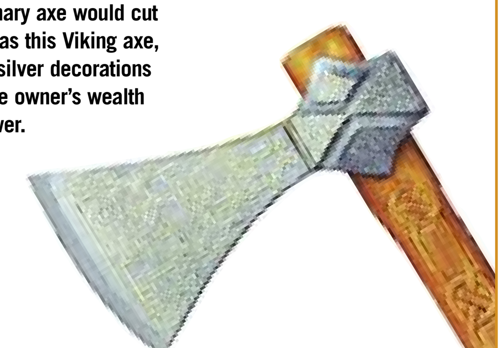
Aluminium ore is known as bauxite. To separate the aluminium, it is treated with chemicals and electricity is passed through it, a process called electrolysis.

PRECIOUS METALS

Certain types of metals are precious or valuable. This may be because they are rare and difficult to obtain from their ores, so owning them has become a symbol of power and wealth. Some metals are prized for their beautiful colours and lustre or sheen. Some are valuable because they are easy to hammer or cast into detailed, intricate shapes such as thin wires or leaves.

Two of the main precious metals are gold *(above)* and silver. People have fought wars and killed for them. These metals have become even more valuable recently because they are excellent carriers of electricity. They are used in switches, circuits and other devices in electrical equipment. Silver is also mixed with another metal, mercury, to make tooth fillings.

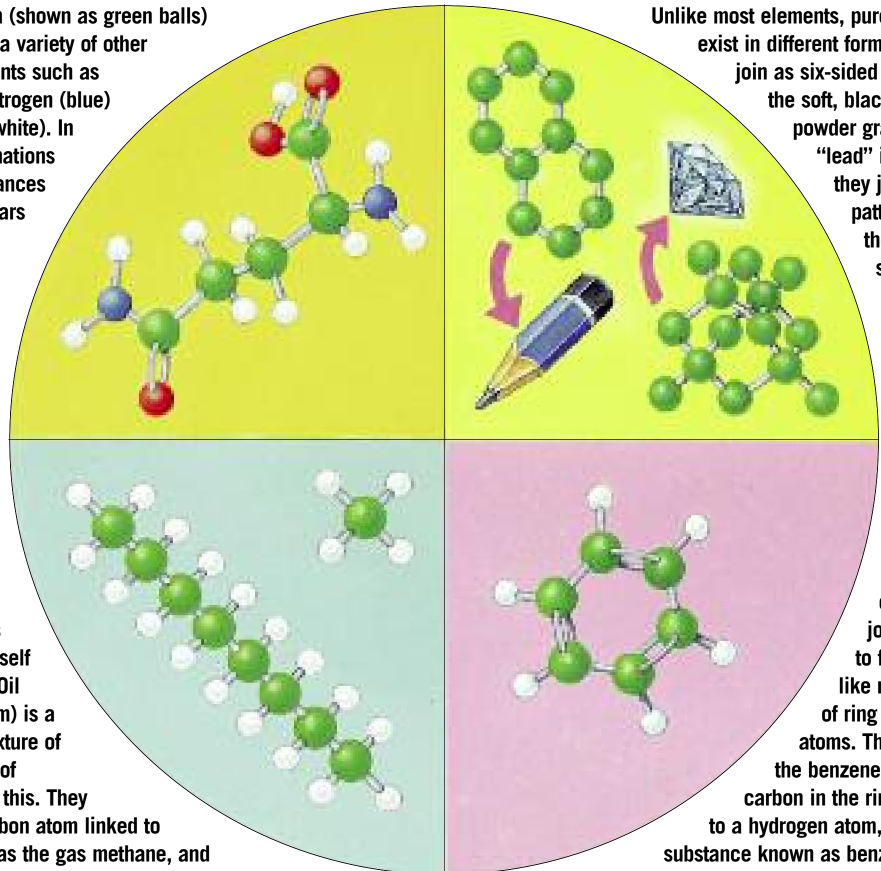
An ordinary axe would cut as well as this Viking axe, but the silver decorations show the owner's wealth and power.



Carbon

ONE OF THE MOST important chemical elements is carbon—partly because it makes up one-fifth of the human body. It is also the main element in all living things and the sixth most common element in the Universe.

Atoms of carbon can join or bond easily with each other and also with numerous other atoms *(see page 12).* This allows carbon to be the basis of a vast variety of substances, from wood to plastics. Indeed carbon is such a common and adaptable element that it has its own branch of science, known as organic chemistry.

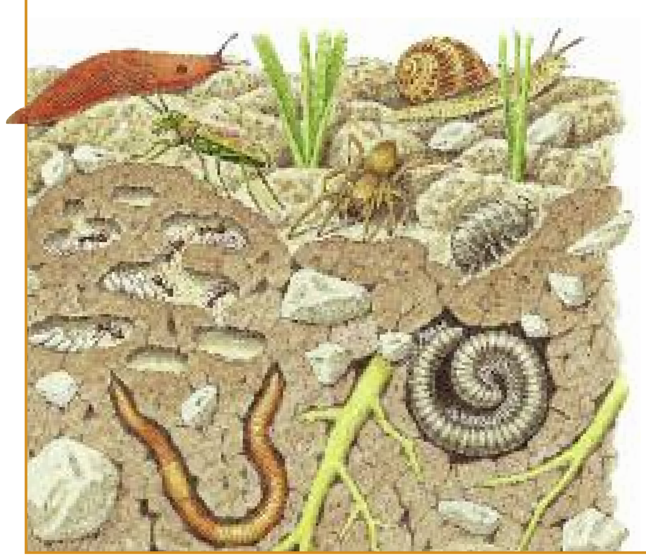


Atoms of carbon (shown as green balls) easily join with a variety of other chemical elements such as oxygen (red), nitrogen (blue) and hydrogen (white). In different combinations they form substances such as the sugars and starches found in living things.

Unlike most elements, pure carbon can exist in different forms. If its atoms join as six-sided rings they form the soft, black, slippery powder graphite, used as "lead" in pencils. If they join in a box-like pattern they form the hardest substance of all, diamond.

One of the carbon atom's main features is that it joins to itself in long chains. Oil (crude petroleum) is a complicated mixture of many hundreds of substances like this. They include one carbon atom linked to four hydrogens as the gas methane, and eight carbons in a row forming the gas octane.

Atoms of carbon can even join to each other to form necklace-like rings. One type of ring has six carbon atoms. This is known as the benzene ring. If each carbon in the ring is also joined to a hydrogen atom, the result is the substance known as benzene. It is a very important chemical in many industries.



The structures and substances in all living things are based on carbon. This includes our own skin, hair, blood, muscles, bones and brain, as well as the body parts of birds, fish, insects and worms, and all the parts of plants. Even the chemicals which form our genes, known as DNA, have carbon as their main element. This is why the chemistry of carbon is often called "the chemistry of life itself".

The entire living world is based on carbon. It joins with other substances to form snail shells, spiders' legs, ants' eggs, plant roots and countless other parts.

Oxygen

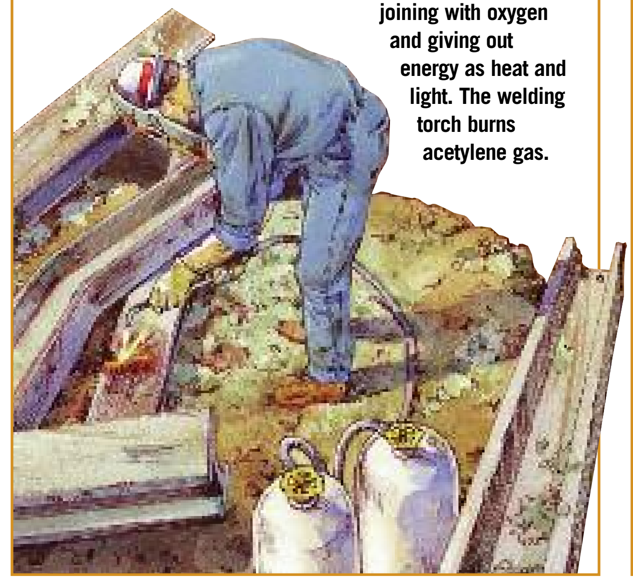
WE CANNOT see, smell or taste oxygen. Yet it forms one-fifth of air and is vital for life. We must breathe oxygen to stay alive. So must all animals and plants.

Oxygen is one of the commonest chemical elements on Earth. It forms about half the weight of the planet's hard outer rock layer or crust. It makes up one-fifth of the air. Joined with hydrogen it forms the water which covers more than two-thirds of Earth's surface.

Oxygen is a vital part of chemical changes inside each microscopic living cell, which break apart food substances to obtain the energy for life. This is why oxygen is essential for all living things (except for a few specialized types of microbes).

Oxygen is also needed for burning. A substance such as coal or wood burns by splitting apart and joining with oxygen to form new substances. It quickly gives out lots of heat and often light in the process. This is known as **combustion** (burning).

Substances burn by joining with oxygen and giving out energy as heat and light. The welding torch burns acetylene gas.



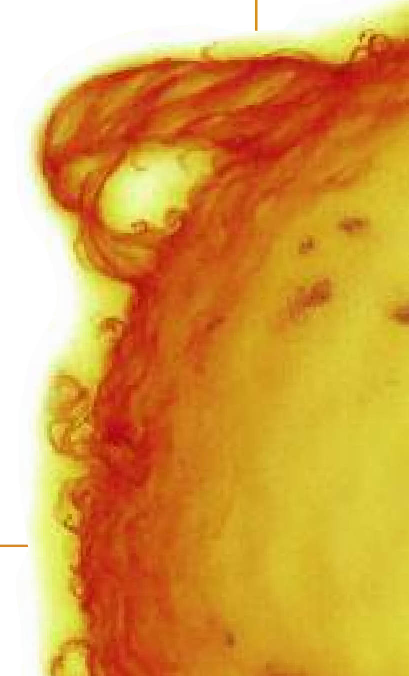
Hydrogen

THE MOST abundant element in the Universe is hydrogen. It forms the bulk of most stars. On Earth, most hydrogen (chemical symbol H) is joined to oxygen (O) to form water (H_2O). Hydrogen is also the simplest and lightest chemical element because each of its atoms has only two sub-atomic particles, one proton and one electron *(see page 6)*.

Pure hydrogen gas is much lighter or less dense than air *(see page 5).* It filled the great airships of the early 20th century to keep them aloft. However hydrogen also burns very easily. After several disasters where airships caught fire, hydrogen was no longer used. Today airships use another light gas, helium, which does not burn.

Hydrogen joins with carbon to form the substances known as hydrocarbons. Many of the fuel gases obtained from natural gas or crude oil, such as propane and butane, are hydrocarbons. Hydrogen also joins with carbon and oxygen to form carbohydrates. Starches in foods like potatoes and rice, and sugars in cane or beet, are carbohydrates.

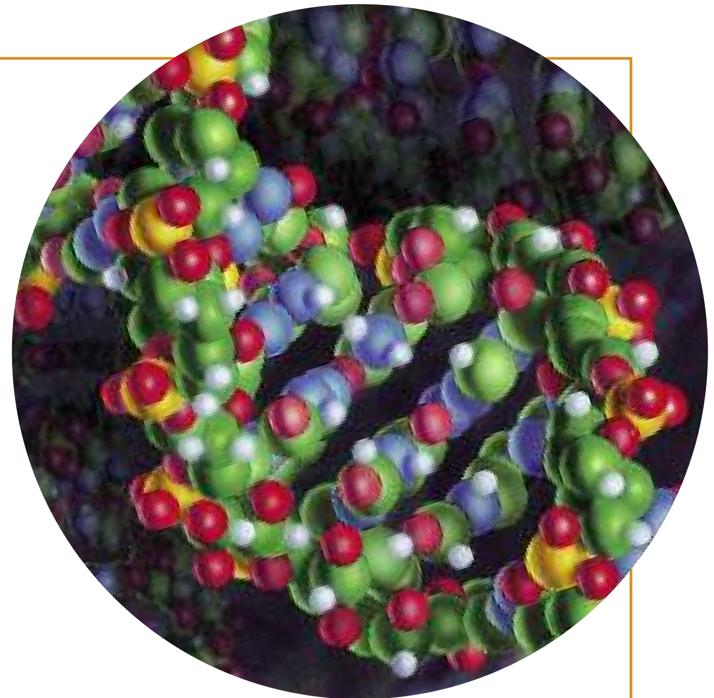
The Sun and other stars are mostly mostly made of hydrogen. In the star's centre, tremendous temperatures and pressures squash hydrogen atoms together to form atoms of the gas helium. As this happens, huge amounts of energy are released as heat and light. The energy travels up to the Sun's glowing surface and then passes through space to Earth. This is known as nuclear fusion *(see page 21)* because the centres, or nuclei, of the hydrogen atoms join or fuse together. Nuclear energy on Earth is obtained by splitting nuclei apart, known as nuclear fission.



Molecules

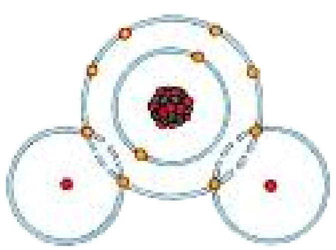
ATOMS make up all the objects and substances in our world. But they are rarely single atoms, alone or unattached. They are usually attached or joined to other atoms. For example, the oxygen gas that makes up one-fifth of the air does not float about as single atoms of oxygen, O. It is in the form of oxygen atoms joined together in pairs, O_2. Two or more atoms linked or joined together make a molecule. O_2 is a molecule of oxygen.

If atoms of one chemical element join or combine with atoms from other elements, this forms a **compound.** O_2 is a molecule of oxygen but not a compound. Two atoms of hydrogen and one of oxygen form H_2O, which is a molecule and a compound. Some compounds, like minerals in rocks, have 50 or 100 atoms in each molecule from 15 or 20 different elements. Other compounds, like certain plastics, have millions of atoms in each molecule but usually from only a few elements, mainly carbon, hydrogen, oxygen and nitrogen. The links between atoms are called **bonds.** There are different types of bonds depending on the atom's structure and the conditions such as temperature and pressure.

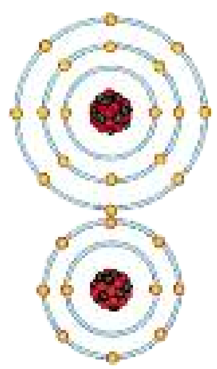


The molecule known as DNA, found in our genes, is based on a group of atoms called ribose sugar, which is repeated millions of times in a long, coiled chain.

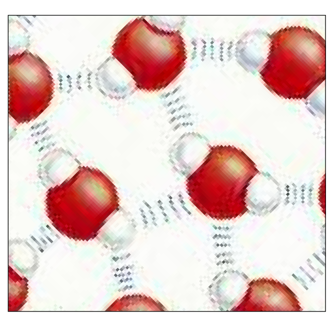
One of the main features of the chemical element carbon is that it joins or bonds easily with many other types of atoms and also with itself *(see page 10).* Carbon atoms can join like links in a chain to form enormously long molecules. Often the chain is made of the same groups of atoms, called sub-units, which are repeated hundreds or thousands of times along its length. This type of molecule is called a polymer and the repeated sub-units are monomers. Many types of plastics and artificial fibres like rayon, acrylic and nylon are polymers. So are molecules in living things like cellulose in plants, chitin in insect body casings and the carrier of genetic information, DNA *(see above).*



In a covalent bond one atom shares an outer electron *(see page 6)* with the next atom. Here, two hydrogen atoms are bonded covalently to one oxygen to form water, H_2O.



In an ionic bond an atom loses or gains electrons, which are negative. An atom that loses one becomes positive while an atom that gains one becomes negative. Atoms which are positive or negative are known as ions *(see opposite).* Positive and negative attract and form an ionic bond. Here sodium and chlorine bond as sodium chloride, or common salt.



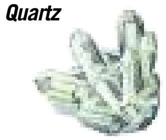
An inter-molecular bond is a weak attraction between the positive part of a molecule and the negative part of its neighbour. The weak attractions between hydrogen and oxygen in water molecules are shown here.

CHEMISTRY

Crystals

IN MANY SOLID substances, the atoms or molecules are fixed in place but they are not positioned at random. They are arranged in an orderly or regular pattern known as a crystalline framework. The result is that the substance forms crystals. These are not irregular lumps but orderly, geometric shapes with sharp edges and flat sides at certain angles to each other. Many pure metals have a crystalline structure. So do minerals in the rocks, and sugar and salt.

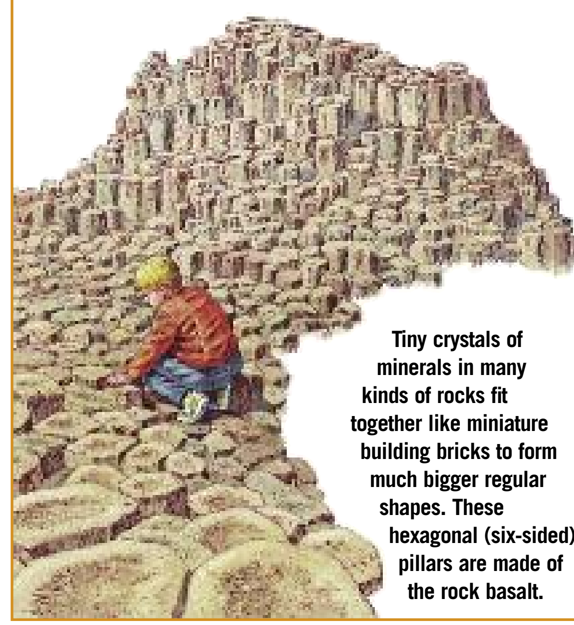
Quartz



Ice

Crystals of quartz in sand grains have a triangular shape. Ice crystals form snowflakes and are six-sided.

There are seven basic shapes or systems of crystals. Simplest is the cubic shape which is like a box. Diamonds are cubic crystals. The monoclinic system is like a matchbox which has been squashed slightly flat. The calcium-rich mineral gypsum has this shape. Some natural minerals like ruby and emerald form large, shiny crystals with beautiful colours. They are cut and polished as gemstones.

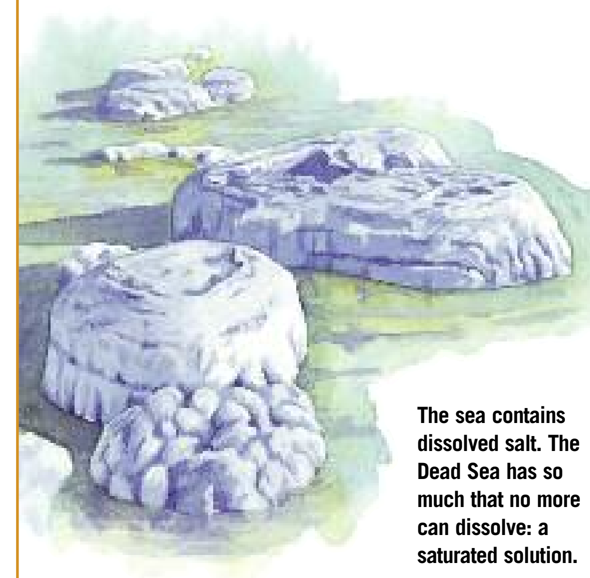


Tiny crystals of minerals in many kinds of rocks fit together like miniature building bricks to form much bigger regular shapes. These hexagonal (six-sided) pillars are made of the rock basalt.

Solutions

STIR A TEASPOON of table salt into a glass of water—and the salt disappears. However, tasting the water shows the salt is still there. It has dissolved. The large grains or crystals of salt have broken down into their individual atoms. These are too small to see and float about freely among the molecules of water. The substance which dissolves, which is usually a crystalline solid, is the solute. The substance it dissolves in, usually a liquid, is the solvent. The solute in the solvent is known as a solution.

When substances dissolve, their atoms or molecules usually gain or lose electrons *(see page 6).* For example table salt, sodium chloride (NaCl), dissolves and breaks apart into its atoms of sodium (Na) and chlorine (Cl). Sodium loses an electron and becomes positive (Na^+), while chlorine gains an electron and becomes negative (Cl^-). Atoms which are positive or negative are known as **ions** *(see opposite).* Many solutes form ions.



The sea contains dissolved salt. The Dead Sea has so much that no more can dissolve: a saturated solution.

Shaking salt and sand together produces a **mixture,** which is different from a solution. In a mixture two or more substances intermingle but they do not dissolve and their molecules do not alter by becoming ions. Add water to the mixture and the salt dissolves. It is soluble. The sand grains do not dissolve. They are insoluble.

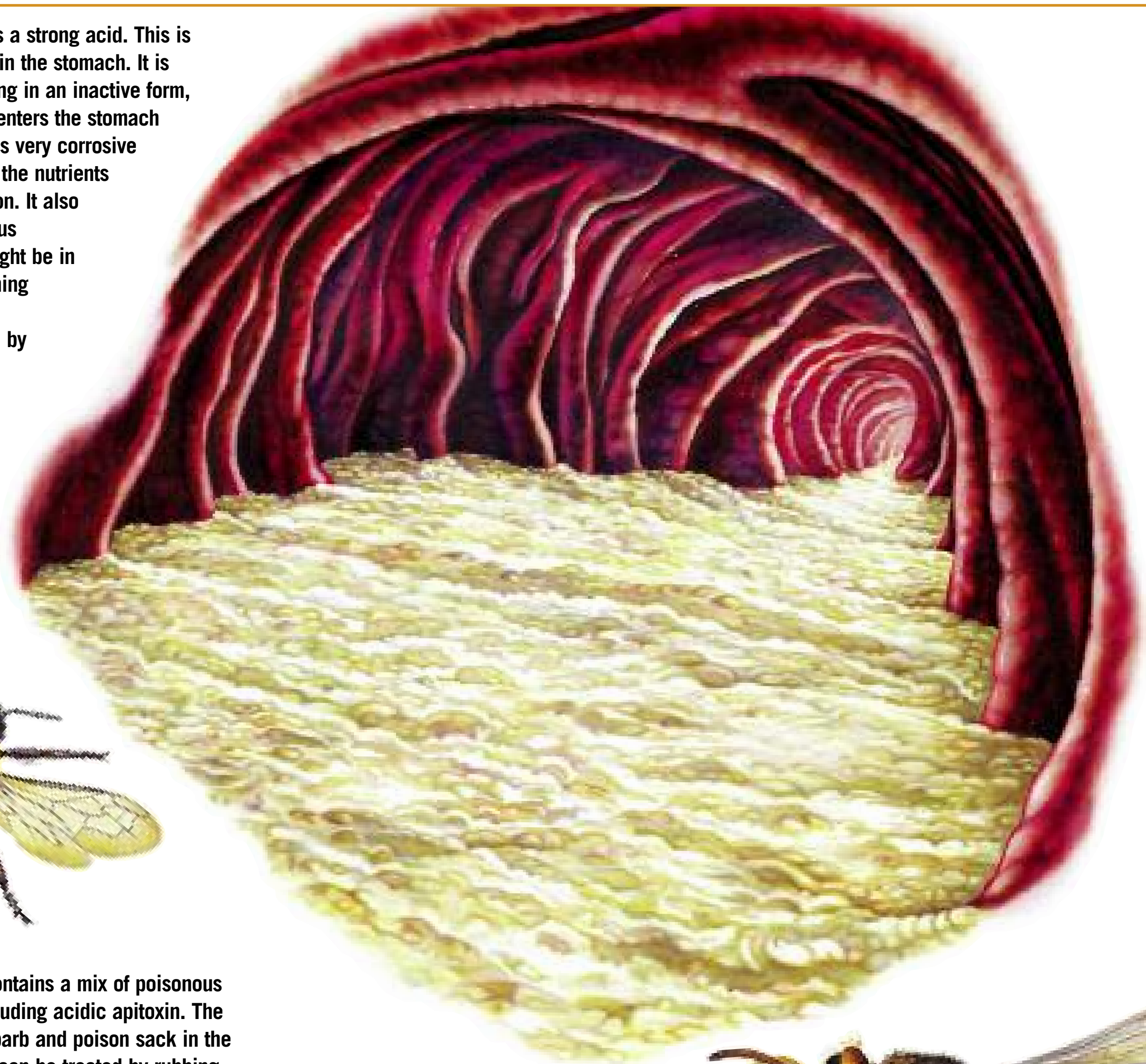
Acids and Bases

SOME SUBSTANCES and chemicals are very reactive. This means they easily combine or join with other substances in chemical reactions, to form new substances. Two types of reactive chemicals are acids and bases. Many bases dissolve in water: these are called **alkalis.** Strong or concentrated acids and alkalis are so reactive that they are corrosive. This means they break down and dissolve substances, including human skin, to cause severe chemical burns. Examples are the sulphuric acid in a car battery and the alkali sodium hydroxide, which is used as a drain-cleaner. Strong alkalis may also be slippery or slimy, almost like thin jelly.

A weak acid usually has a sharp or sour taste, like the natural citric acid in citrus fruits such as lemons and grapefruits. A weak alkali has a bitter taste, such as the caffeine in coffee. Caffeine is an example of an alkaloid—a natural alkali found in certain plants. Many plants make alkaloids in their leaves and stems. These are poisonous so that animals avoid eating them. Some animals have bites or stings that inject poisonous acid into prey or enemies.

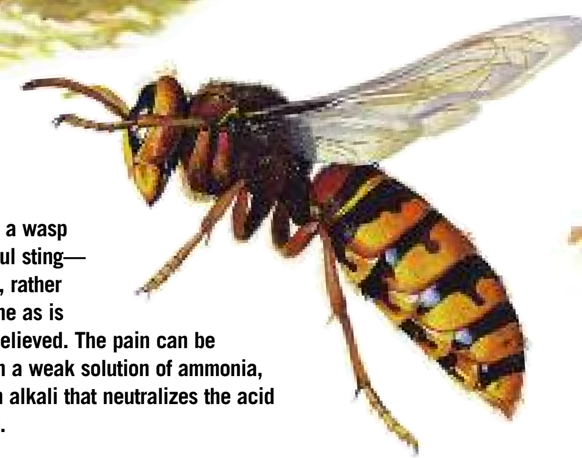
The fumes from vehicle exhausts, factories and power stations contain nitrogen and sulphur chemicals. These dissolve in the drops of water in clouds to form nitric and sulphuric acids which fall as acid rain.

The human body contains a strong acid. This is hydrochloric acid, found in the stomach. It is made in the stomach lining in an inactive form, and released when food enters the stomach during a meal. The acid is very corrosive and helps to break down the nutrients in food as part of digestion. It also helps to kill any dangerous microbes (germs) that might be in the food. The stomach lining protects itself from being dissolved by its own acid by making a thick layer of slimy mucus.



A bee's sting contains a mix of poisonous substances including acidic apitoxin. The bee leaves its barb and poison sack in the skin. The sting can be treated by rubbing on a weak solution of bicarbonate of soda, an alkali that counteracts the acid.

Acids are substances with hydrogen in their molecules. For example, sulphuric acid is H_2SO_4 and hydrochloric acid is HCl. In solution with water, the hydrogen forms a positive ion, H^+ *(see page 13)*. This hydrogen ion is, in fact, a hydrogen atom without its electron—that is, it is just a proton *(see page 6)*. An acid is reactive because it is always ready to give up, or donate, this proton in a chemical change, in order to rid itself of the positive charge and become neutral. Alternatively, the acid can accept an electron, which is negative, to achieve the same result. This is why acids are known as proton donors or electron receptors. An alkali does the opposite and so is a proton receptor or electron donor.



Like a bee, a wasp has a painful sting—also acidic, rather than alkaline as is popularly believed. The pain can be treated with a weak solution of ammonia, which is an alkali that neutralizes the acid in the sting.

Acids and alkalis are widely used in industry. Millions of tonnes of sulphuric acid are produced every year, not only for vehicle batteries but for processes such as making detergents, explosives, fertilizers and dyes for colouring. Sulphuric acid is also used in the splitting or refining of crude oil (petroleum) to make petrol, diesel, plastics, paints and other petroleum products.

CHEMISTRY

Acid or Alkali?

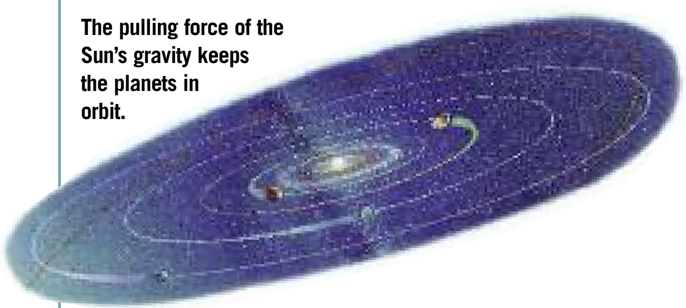
Touching or tasting an unknown liquid to find out if it is an acid or alkali is far too dangerous—even deadly. The usual way is to use an indicator. This is a substance which changes its colour when added to an acid or alkali. One of the best-known indicators is litmus. It can be used as a liquid or on a dry paper strip. Normally litmus is a pinky colour. When it is added to an acid it turns red. Added to an alkali it becomes blue. If litmus does not change colour when added to a substance then the substance is neither acid or alkali but neutral. Normal rainwater is a very weak natural acid because it contains tiny amounts of dissolved carbon dioxide, one of the gases in air, which forms carbonic acid. Acid rain from pollution is much stronger *(see opposite)*.

In medieval times the terrible disease plague killed millions. The dead bodies were sprinkled with lime, a strong and corrosive base. It helped to kill the germs in the bodies and make them rot faster.

Acids and alkalis are very important in farming and forestry. Some soils are naturally slightly acidic, others are slightly alkaline. Each type of plant grows best in a certain type of soil, acidic or neutral or alkaline. To grow a certain plant the soil can be changed using additives. Adding alkaline lime to an acidic soil makes it more neutral.

GRAVITY

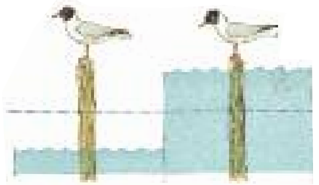
THE UNIVERSE is made of matter. Matter is held together and moved by **forces.** One of the basic or fundamental forces is the gravitational force. Any piece of matter from a pinhead to a planet has this gravitational force. It pulls or attracts other matter. The biggest large lump of matter in our daily lives is the Earth. Its gravitational force pulls us and other objects towards it, keeping our feet on the ground. The Earth's gravitational force is also called gravity.



The pulling force of the Sun's gravity keeps the planets in orbit.

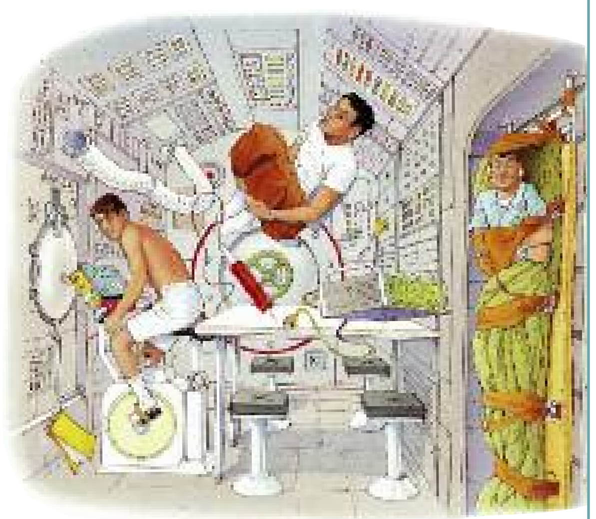
Gravity means that all matter, from the minute particles that make up atoms to the biggest stars, attracts each other. The nearer an object, the stronger its gravitational force on other objects. But the force becomes weaker with increasing distance. Earth is very big and very near, so for us its gravity is very strong. However, a few hundred kilometres above the surface its gravity is weak and objects may drift off into space.

It is said that English scientist Isaac Newton (1642-1727) had the idea for gravitational force when he saw an apple fall from a tree. Why did it fall straight down towards Earth's centre? Newton suggested that the Earth pulled it down by gravity. He extended this idea to all matter and into space. He proposed that the Earth's gravity attracted the Moon and kept it in orbit around the Earth. Newton's ideas began a new era in science.



Moon's gravity pulls the water of Earth's oceans and makes it bulge outwards. As the Earth spins this causes the rise and fall of tides.

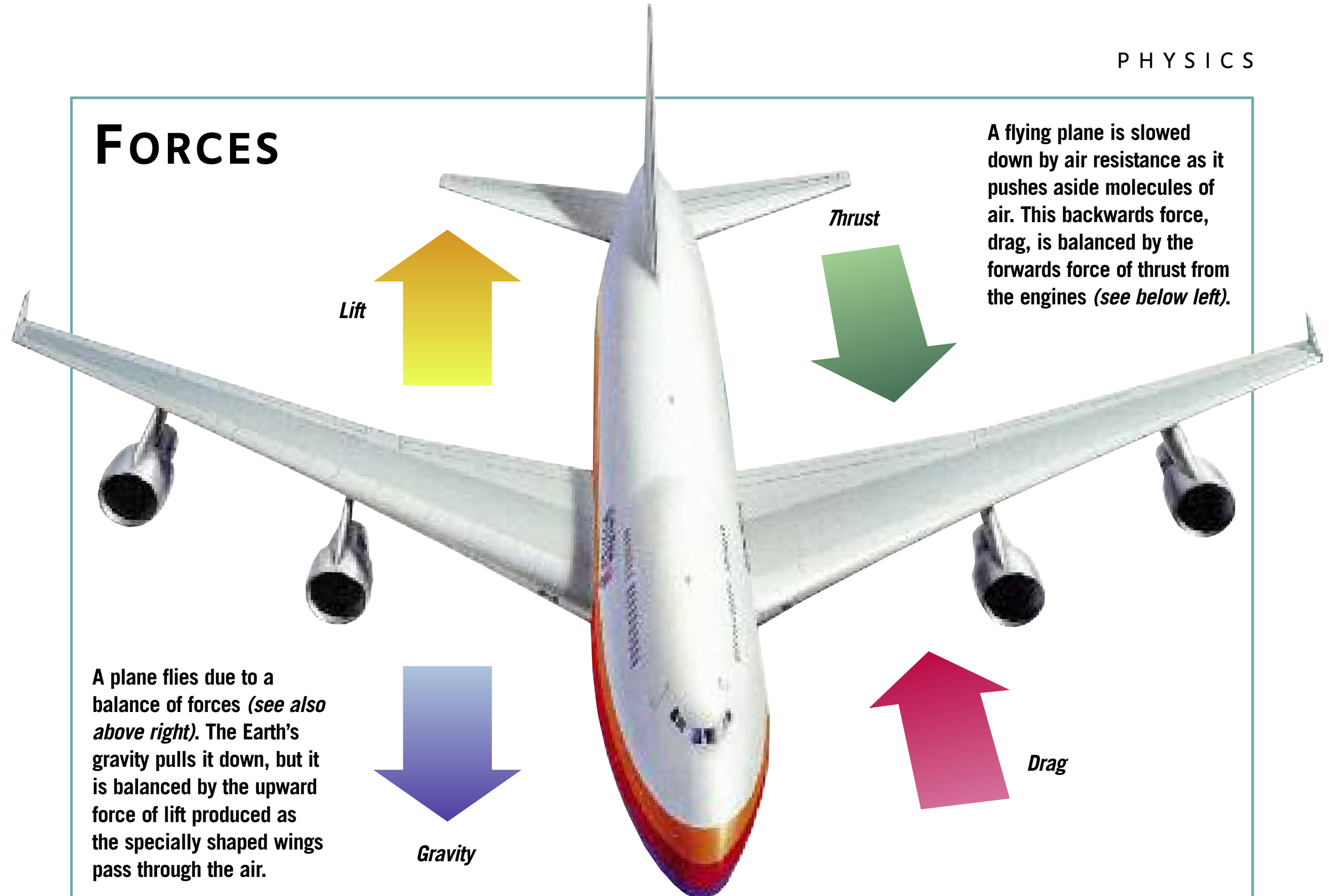
The Earth's gravity gives matter and objects what we call **weight.** A big book is weighty because it is being pulled downwards by Earth's gravity and we have to counteract this force with our muscles when we pick up the book. However, weight varies according to the strength of gravity, and the strength of gravity depends on the amount of matter (and its density) in the two objects that attract each other. We are used to the weight of objects on Earth. The Moon has less matter than Earth, so its gravitational force is less. On the Moon the book would weigh less—about one-sixth of what it weighs on Earth. On a star consisting of vast amounts of matter the book would weigh many tonnes.



In space, Earth's gravity is weak. These astronauts are therefore "weightless".

Weight varies with gravitational force but mass does not. Weight is a measure of the gravitational force pulling on an object. **Mass** is a measure of the amount of matter in the object—the numbers and types of atoms. On the Earth, Moon or a star, the book would weigh different amounts, but it would always have the same mass.

FORCES



A flying plane is slowed down by air resistance as it pushes aside molecules of air. This backwards force, drag, is balanced by the forwards force of thrust from the engines *(see below left).*

A plane flies due to a balance of forces *(see also above right).* The Earth's gravity pulls it down, but it is balanced by the upward force of lift produced as the specially shaped wings pass through the air.

A FORCE pushes or pulls. It squashes or stretches. It presses on an object or any other form of matter. It may make the object move in a certain way (motion) or change its shape (deform). One of the main forces that acts throughout the Universe is the gravitational force *(see opposite).* Another is the electromagnetic force *(see page 30).* These two forces can act at a distance. That is, they do not have to be in contact with an object or touching it.

Physical forces act when two objects are in contact. Hammer a nail into wood, and the force of the hammer hitting the nail makes it push down into the wood's fibres. This is a force causing motion. The wood pushes back with its own resisting force. As the nail goes deeper the resisting force of the wood increases. It may eventually become equal to the force of the hammer hitting the nail. At this stage the nail stops moving. The next blow may bend the nail. This is a force causing deformation.

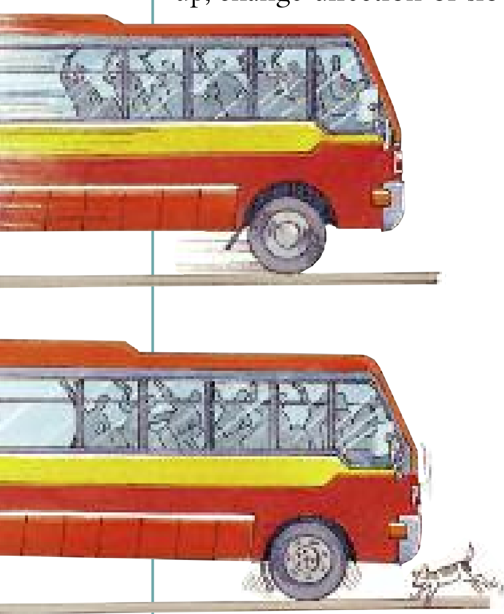
A lilytrotter (jacana) has wide, splayed toes which spread the force of its steps. It can easily run over floating lily leaves.

PRESSURE

The force of a hammer blow pushing a nail into wood acts over a tiny area—the nail's point. The same hammer blow might not make a blunt nail enter the wood because the force is spread out over a larger area. The amount of force for a certain area is called pressure. A sharp knife cuts because the force moving the blade is concentrated into the tiny area of the blade's edge, giving very high pressure. Force is measured in units called newtons after scientist Isaac Newton *(see opposite).* Pressure is measured in newtons per square metre.

MOTION

MOTION is any kind of movement. Motion is caused by forces. A still or stationary object does not move unless a force acts on it to start it going. Once it is moving it carries on at the same speed in a straight line unless a force makes it speed up, change direction or slow down and stop.



An object stays still or keeps moving in a straight line, unless forces act on it. A bus will not start to move unless the engine provides a force to make it do so. This tendency of an object's motion to stay the same is called inertia. Once the bus is moving, the force of air resistance tries to slow it down. The engine keeps the bus going forward. If the bus stops suddenly, people on it fall forward because there is nothing to stop them moving.

There are many kinds of movement. An object going in a straight line like a rocket shooting through deep space has linear motion. An object going around a central point like a ball swung round on a string has circular motion. An object moving to and fro like a pendulum has reciprocating motion. An object that twists around like a wheel or a screwdriver has rotary motion.

FRICTION

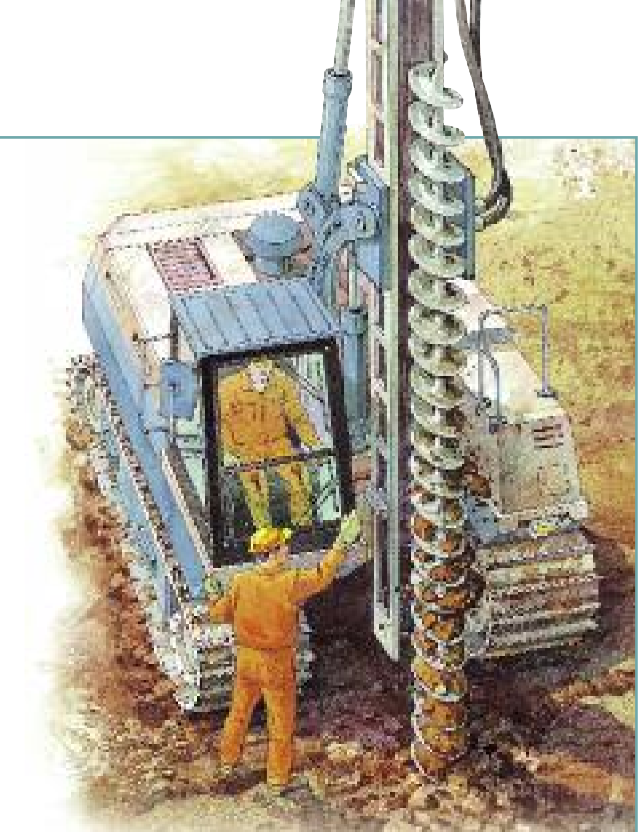
When two objects which are touching try to move past each other, they rub against each other. This produces a force called friction which tries to stop the movement. If the surfaces of the objects are rough, like sandpaper, then friction is greater. If they are smooth and slippery, especially if lubricated with oil or grease, then friction is less. Friction is "the enemy of machines": it opposes movement, causes wear and tear, and changes useful energy into waste heat. But friction can also be helpful. A vehicle slows down suddenly because of friction provided by its brakes. A bulldozer's tracks dig into the earth with so much friction that they cannot slip *(above)*. So the bulldozer can push huge mounds of soil.

People on a "Chair-o-Plane" ride *(left)* have several forces acting on them. As always, Earth's gravity pulls them down towards the ground. The chair holds them up and pushes them forwards. Its cable pulls them around in a circle.

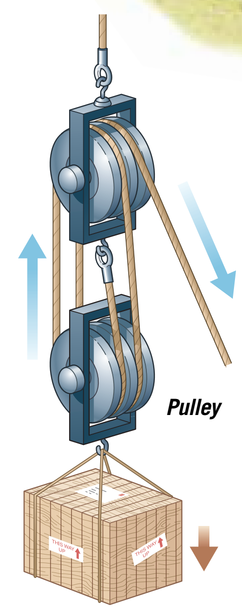
A skier slides easily over snow and ice because the skis press down and rub hard on them. The friction makes them heat and melt into water, which is very slippery with low friction. After the skis have past, the snow and ice freeze again.

MACHINES

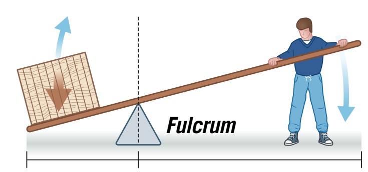
OUR WORLD runs on machines. They make work easier for us. A machine uses physical efforts, forces and work to get a job done. It can be as complicated as a jet engine or a combine harvester to gather crops. Yet it can be as simple as a crowbar used to lift heavy stones or a wheel on an old cart. Even the most complicated machines are combinations of a few kinds of simple machines.



Ancient structures like the Egyptian pyramids *(left)* were built using simple machines such as ramps and rollers. The driving force came from humans. The ground drill, or auger *(above)*, is a modern machine, an engine-driven screw.



A rope and pulley *(left)* changes the direction of a pulling force. It is usually easier to pull down on a rope than to pull up. Loop the rope around two pulleys and it can lift a heavier weight than with one. But the rope must be pulled further. Adding more pulleys to the system makes the lifting even easier, but the rope has to be pulled yet further. The total work done to move the weight is the same in each case.



A lever is a stiff bar that pivots at a fulcrum. If the fulcrum is near one end then a small force at the other end moves a heavy weight but not very far.

The main kinds of simple machines are:
- **Inclined plane** A slope or ramp to drag or roll heavy objects upwards.
- **Wedge** Two ramps back to back as used in knife and axe blades.
- **Lever** A rigid bar or beam that pivots on a hinge or fulcrum, like a crowbar.
- **Screw** A wedge twisted into a corkscrew shape forces its way through a substance.
- **Wheel and axle** An endless curved ramp turning on its central point, the axle.
- **Pulley** A wheel with a groove in its rim for a rope, chain or cable.

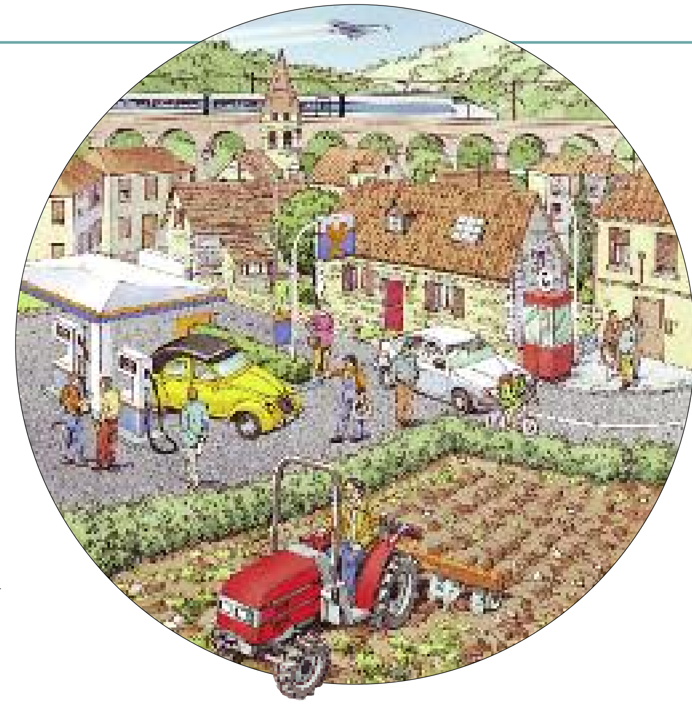
These machines make tasks easier. But they do not give something for nothing. Usually the task takes longer and involves more movement, so the total work at the end is the same as doing the task without it.

ENERGY

ENERGY is the ability to make things happen, cause changes and carry out work. Any change anywhere in the Universe, from a tiny meteorite hitting a planet to an exploding star, means that energy is at work. In daily life, energy is all around us in many different forms. Light and sound energy travel through the air as waves. Heat is a form known as thermal energy. Movement or motion is, too, and is called kinetic energy. Objects even have energy because of their place or position. This is called potential energy. A boulder on a hilltop has potential energy because gravity tries to pull it down. As the boulder begins to roll its potential energy changes into kinetic energy.

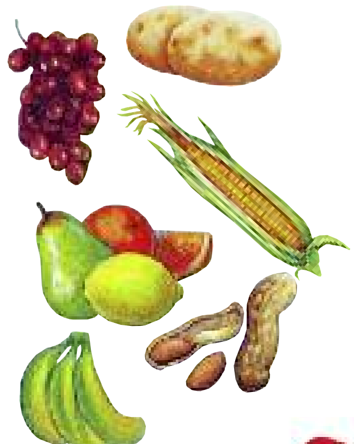
Energy from the Sun bathes our world. It is in two main forms, light and heat. It takes more than 8 minutes to travel nearly 150 million kilometres through space to Earth.

Energy can cause changes and it can change itself. It can convert between one form and another. The boulder rolls down the hill, converting some of its potential energy to kinetic energy. Water also flows downhill with kinetic energy. We can harness this kinetic energy in a hydro-electric power station and convert it into electrical energy *(see page 30)*, yet another form of energy. Electricity is very useful in our modern world. It can be transported long distances along wires. It can be converted to other forms of energy, like light from a light bulb, heat in an electric kettle and sound from a loudspeaker.



Energy is all around, present in different forms and changing from one form to another. Without energy our world would be completely dark, cold, still and silent.

Matter contains chemical energy, in the links or bonds between atoms *(see page 12)*. The bonds need energy to form and they release this energy when they are broken. We make use of chemical energy in fuels such as petrol. The bonds break as the fuel burns and releases heat.

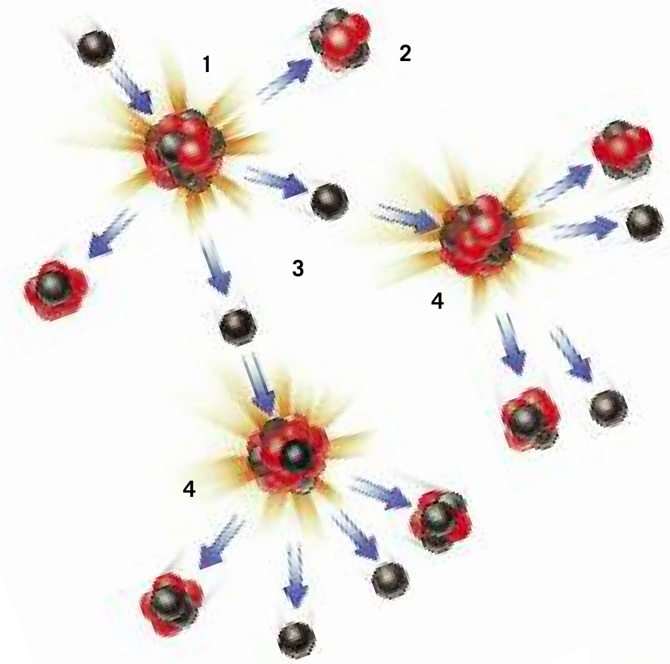


The human body needs energy to drive its life processes like heartbeat, breathing and movement. The energy is present in chemical form as the nutrients in our food. We digest the food to obtain the energy and store it as body starches and sugars.

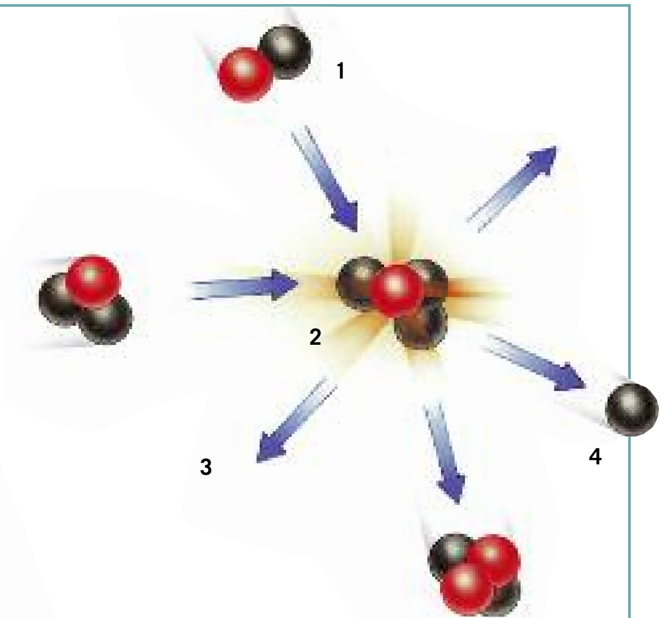
Chemical energy in the body in the form of blood sugar is taken to muscles. The muscles convert it into the energy of motion so we can move about.

CONSERVING ENERGY

Energy can be changed or converted from one form to another. But it is never destroyed or created, lost or gained. It is conserved—the amount stays the same. At the end of a process or event, the total amount of energy is the same as at the beginning. For example, the chemical energy in a car's petrol is converted into the same amount of energy as the car's motion, heat and sound. The principle of energy conservation means the total amount of energy in the Universe is always the same.



Another form of energy is matter itself. Matter can be converted into energy and energy can be changed into matter. This conversion is used in nuclear power stations *(see above)*. A nuclear particle called a neutron smashes into the nucleus of a uranium atom (1). The nucleus breaks into two parts (2). This releases large amounts of heat and other energy and also two more fast-moving neutrons (3). These smash into more uranium nuclei and so on in a chain reaction (4). Splitting of nuclei is known as **nuclear fission.** During the process bits of matter cease to exist and become vast quantities of energy instead.



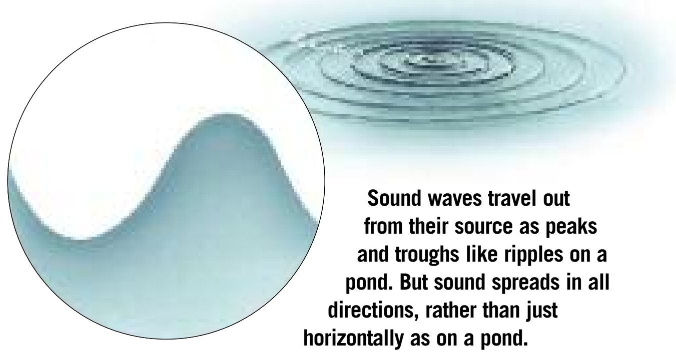
A similar process of changing matter into energy happens naturally in the Sun *(above)*. The Sun is made mainly of hydrogen. Tremendous temperatures and pressures at its centre squeeze or fuse together the nuclei of the atoms (1) to form the nucleus of a helium atom (2). Vast amounts of energy are given off (3) which emerge from the Sun mainly as light and heat. A neutron may also be given off to continue the reaction (4). Since the nuclei join or fuse, this is called **nuclear fusion.** Compared to fission used in our nuclear power stations, fusion power would cause less radioactive wastes and pollution. Fusion power may be the energy source of the future.

Geothermal energy from hot rocks deep in the Earth causes geysers, jets of hot water and steam. This form of energy will last millions of years.

SOUND

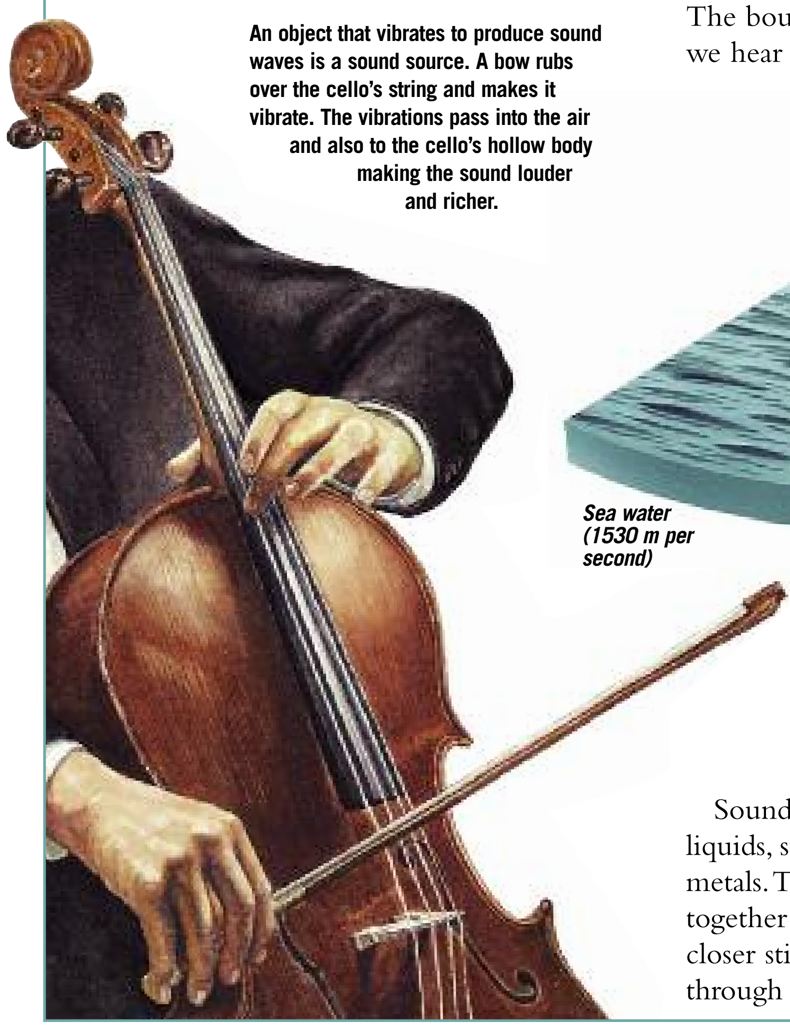
ONE OF THE MOST familiar forms of energy in daily life is sound. We hear natural sounds like birdsong and wind. We hear the noise of vehicles and machines, and sounds such as speech and music from radios, televisions and stereo systems. We also rely on sounds to communicate when we talk to others.

Sounds are made by objects that vibrate (move to and fro rapidly). As an object vibrates, it alternately pushes and pulls at the air around it. The air is squashed and stretched as the molecules of the gases in air are pressed close together and then pulled farther apart. These are regions of high and low air pressure. They pass outwards away from the object in all directions. They are called sound waves.



Sound waves travel out from their source as peaks and troughs like ripples on a pond. But sound spreads in all directions, rather than just horizontally as on a pond.

Sound waves start as the energy of movement in the vibrations. This is transferred to the energy of movement in air molecules. As the sound waves spread out they widen and disperse, like the ripples on a pond after a stone is thrown in. So the sound gradually gets weaker and fades away. However if there is a hard, smooth surface in the way, such as a wall, then some sound waves bounce off it and come back again. The bouncing is known as reflection and we hear the returning sound as an echo.



An object that vibrates to produce sound waves is a sound source. A bow rubs over the cello's string and makes it vibrate. The vibrations pass into the air and also to the cello's hollow body making the sound louder and richer.

The speed of sound varies depending on the substance it travels through. Atoms in steel are closer than molecules in air, so the vibrations of sound move faster and further.

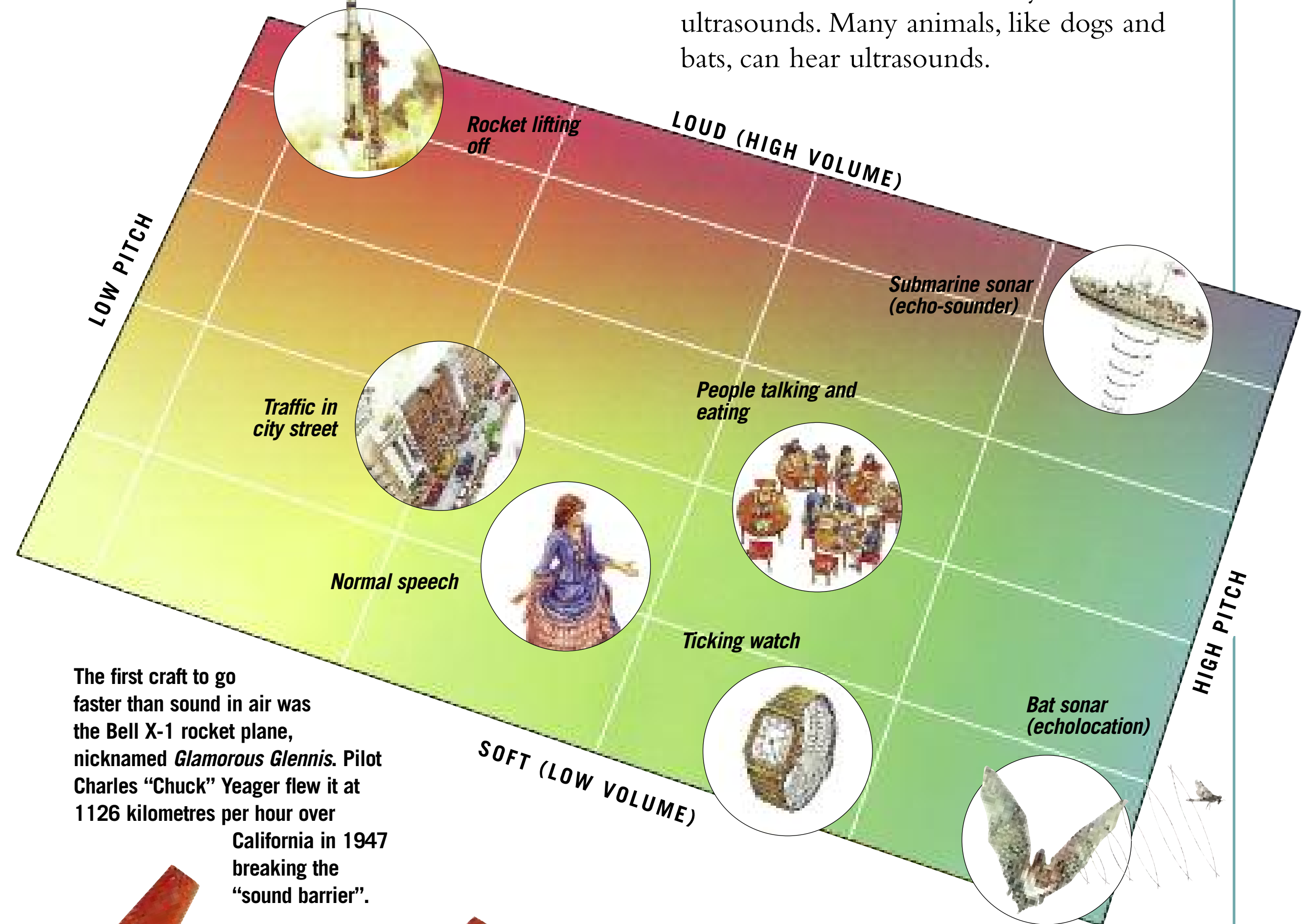
Sounds also travel as vibrations through liquids, such as water, and solids, such as metals. The atoms or molecules are closer together in liquids than in air, and even closer still in solids. So sounds travel through them much faster.

PITCH AND VOLUME

Sound has two important features *(see chart below)*. One is pitch. A low-pitched sound is deep, like a roll of thunder or a booming big drum. A high-pitched sound is shrill, like a snake's hiss or the tinkle of a triangle. Pitch depends on the frequency of sound waves—the number of waves per second. High-pitched sounds have high frequencies.

An ultrasound scanner beams very high-pitched sound waves into the body. The echoes are analysed by a computer to form an image, like this baby in the womb.

Some sounds are so high-pitched that our ears cannot detect them. They are known as ultrasounds. Many animals, like dogs and bats, can hear ultrasounds.

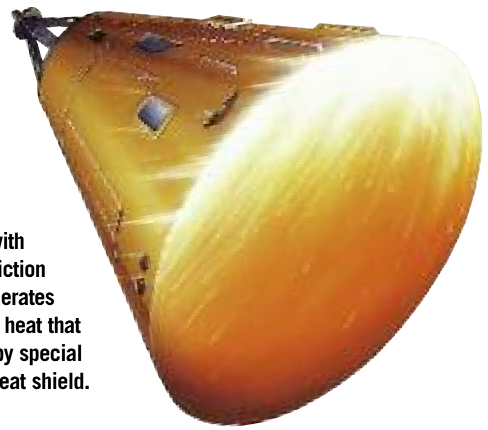


The first craft to go faster than sound in air was the Bell X-1 rocket plane, nicknamed *Glamorous Glennis*. Pilot Charles "Chuck" Yeager flew it at 1126 kilometres per hour over California in 1947 breaking the "sound barrier".

The second important feature of sound is its loudness or volume. Some sounds are so quiet that we can only just hear them, like a ticking watch or the rustling of leaves. Other sounds are so loud, like the roar of engines or the powerful music in a disco, that they may damage the ears. Sound volume, or intensity, is measured in units called decibels (dB). Sounds of more than 80-90 decibels can damage our hearing.

HEAT

HOW WARM is the weather today? It may be cold and wintry or hot and summery. Heat is a vital part of our lives. We need to keep our bodies comfortably warm with clothing, especially in cold conditions. If body temperature falls from its normal 37°C to below about 30°C, fatal hypothermia may set in.

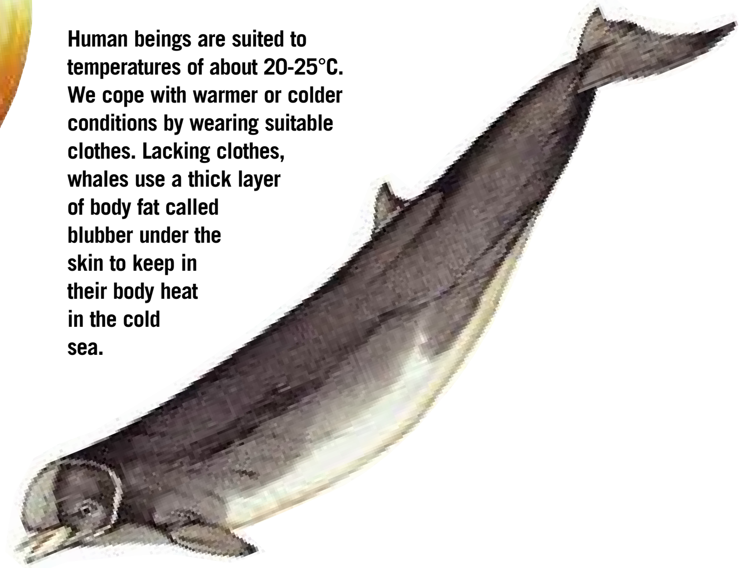


A spacecraft re-entering Earth's atmosphere glows red with heat. The friction with air generates tremendous heat that is resisted by special insulating heat shield.

We cook our food with heat using gas or electricity. Countless machines and industrial processes use heat, from making pottery or a photocopy to a steelworks or power station. Heat is also given off as a waste form of energy by many processes. In a power station most of the heat is used to generate electricity, but some is released as clouds of steam from huge cooling towers.

Heat almost any solid and it will eventually melt into a liquid. Even solid rocks melt or become molten at above about 800-1000°C. The liquid rock that oozes or spurts from volcanoes is called lava. The temperature and pressure inside some volcanoes are so great that some types of rock not only melt, they boil and bubble as they give off the gases trapped inside them.

Heat is a type of energy—the vibrations of atoms and molecules. The more an atom moves or vibrates, the more heat or thermal energy it has. In a solid, the atoms have fixed central positions but each atom vibrates slightly about its central position, like a ball tied to a nail by elastic. Heat the solid and the atoms vibrate more. When they have enough vibrations, the atoms break from their fixed positions (the "elastic" snaps), and they move about at random. The solid has melted into a liquid. Heat it more and the atoms fly further apart. The liquid becomes a gas.



Human beings are suited to temperatures of about 20-25°C. We cope with warmer or colder conditions by wearing suitable clothes. Lacking clothes, whales use a thick layer of body fat called blubber under the skin to keep in their body heat in the cold sea.

TEMPERATURE

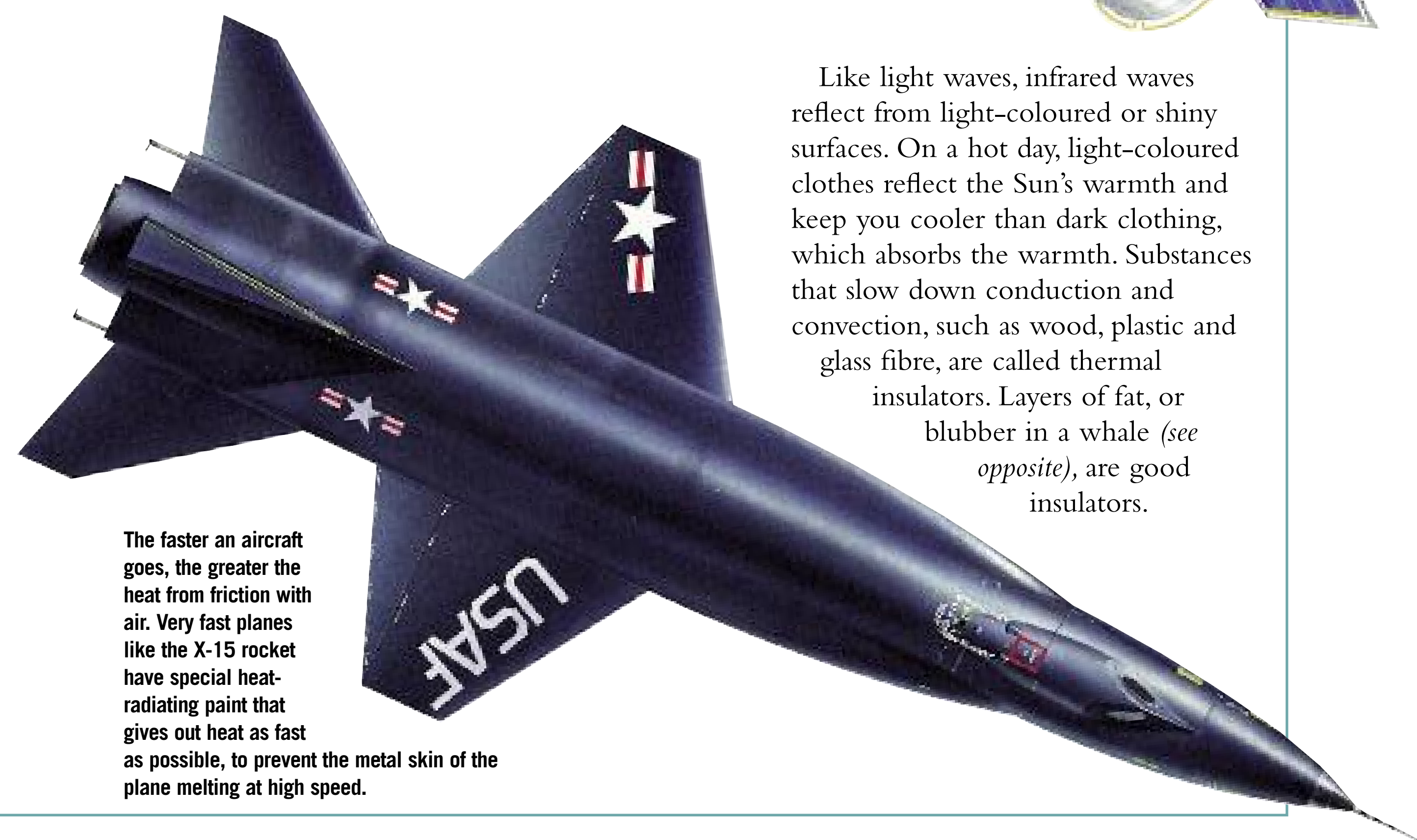
Cold is not the presence of something that opposes heat, but simply the lack of heat. Temperature is not the same as heat. Heat is a form of energy, while temperature is a measure of how much heat energy a substance or object contains. A slice of apple pie at 40°C contains more heat energy than a same-sized slice of the same pie at 30°C. We can judge its temperature quite accurately when we touch the slice with our skin, and especially with our fingertips or lips. But this judgement is only safe within a certain range. Temperatures greater than about 50°C or lower than about -10°C cause pain and may damage the skin. We measure temperatures accurately using devices called thermometers.

PHYSICS

Birds glide and soar in the convection currents rising from areas of sea and land warmed by the Sun.

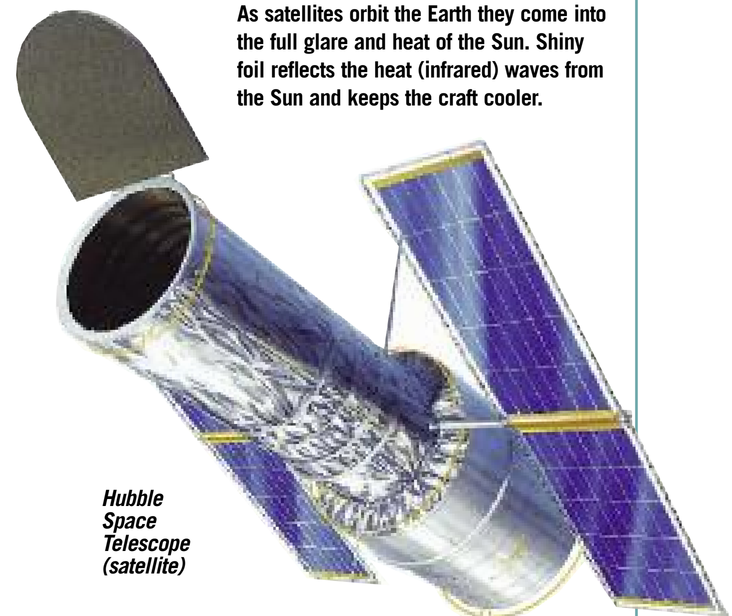
HOW HEAT MOVES

Heat can move around and between objects in three main ways. One is **conduction,** when heat energy passes between two objects in physical contact. When you touch an object to see how warm it is, you receive some of its heat by conduction. A second way is by **convection.** This only happens in liquids and gases. As some of the atoms or molecules receive heat energy and become warm they spread out more. The heated part of the liquid or solid is now less dense than its cooler surroundings so it rises or floats *(see page 5)*. As it rises, it carries its heat energy in the form of a convection current. You can feel this as warm air rising from a central heating radiator.



The faster an aircraft goes, the greater the heat from friction with air. Very fast planes like the X-15 rocket have special heat-radiating paint that gives out heat as fast as possible, to prevent the metal skin of the plane melting at high speed.

The third way that heat moves is by **radiation.** It is in the form of infrared waves which are part of a whole range of waves, including radio waves, light and X-rays, known as the electromagnetic spectrum. Conduction and convection both need matter to transfer heat. Radiation does not. Infrared waves can pass through space, which is how the Sun's heat reaches Earth.



As satellites orbit the Earth they come into the full glare and heat of the Sun. Shiny foil reflects the heat (infrared) waves from the Sun and keeps the craft cooler.

Hubble Space Telescope (satellite)

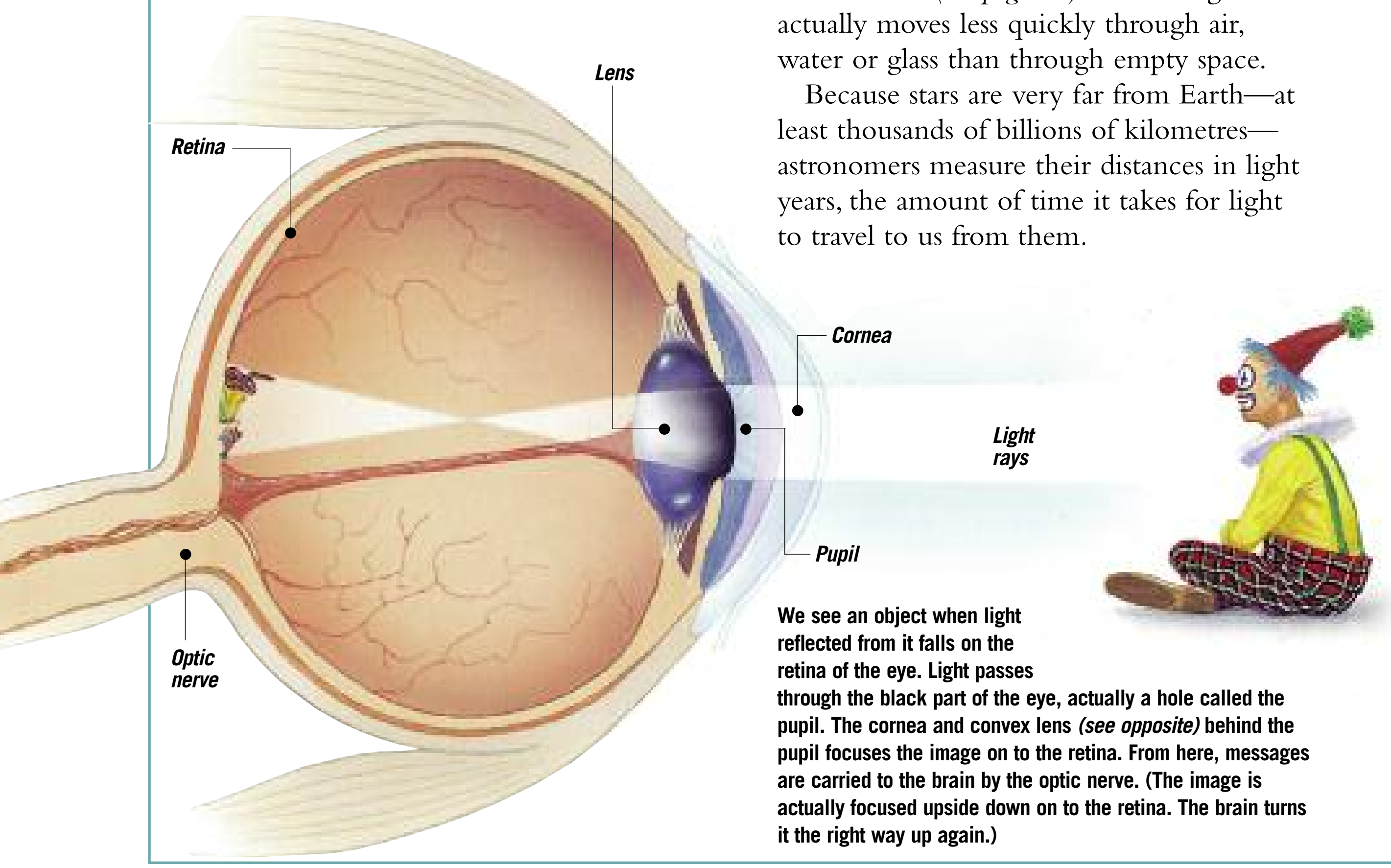
Like light waves, infrared waves reflect from light-coloured or shiny surfaces. On a hot day, light-coloured clothes reflect the Sun's warmth and keep you cooler than dark clothing, which absorbs the warmth. Substances that slow down conduction and convection, such as wood, plastic and glass fibre, are called thermal insulators. Layers of fat, or blubber in a whale *(see opposite)*, are good insulators.

Light

LIGHT is a kind of energy *(see page 20)*. It is the form of energy that our eyes can detect, enabling us to see. It is produced by very hot things—the Sun, fire and the tiny wire inside electric light-bulbs. Certain animals also have light-producing organs.

Light from the Sun is essential to life on Earth. Some creatures live off minerals in the ocean depths but these are exceptions. Most plants use sunlight to make their food. All plant-eating animals, together with other animals that eat plant-eaters, also therefore depend on sunlight.

Light rays can only travel in straight lines. If they strike an object which does not allow light to pass through it (an opaque object), a shadow is cast on the unlit side. Light can be reflected, however. Light reflected from objects allows us to see them. Light rays strike and bounce off a flat, shiny surface like a mirror at the same angle. This enables us to see our reflection.



We see an object when light reflected from it falls on the retina of the eye. Light passes through the black part of the eye, actually a hole called the pupil. The cornea and convex lens *(see opposite)* behind the pupil focuses the image on to the retina. From here, messages are carried to the brain by the optic nerve. (The image is actually focused upside down on to the retina. The brain turns it the right way up again.)

Light from the Sun drowns out all other stars during the day.

Below 1000 metres, the ocean waters are completely without light. Here, fish have special light-producing organs.

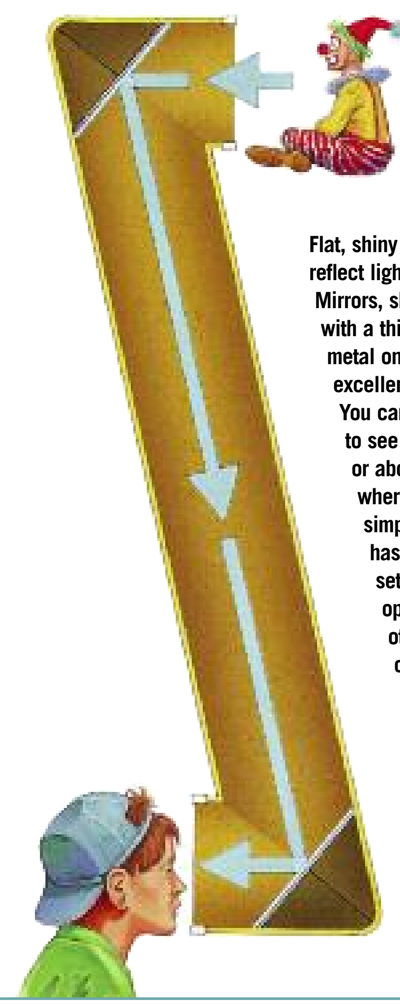
The Speed of Light

When we switch on an electric light, it seems that the room is filled with light instantaneously. But light rays do take time to travel from their source. They travel extremely quickly: about 300,000 kilometres (or seven-and-a-half times around the world) per second in outer space. The speed of light is, in fact, the speed limit for the Universe: nothing can travel faster. Light waves are able to travel through empty space—a vacuum—whereas sound waves *(see page 22)* cannot. Light actually moves less quickly through air, water or glass than through empty space.

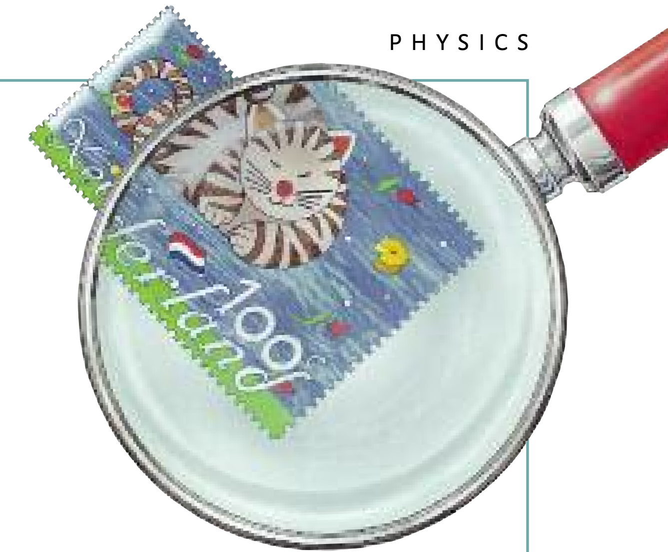
Because stars are very far from Earth—at least thousands of billions of kilometres—astronomers measure their distances in light years, the amount of time it takes for light to travel to us from them.

An electric light-bulb contains a filament made of tungsten, wound in a tight coil. When electricity passes through the coil it becomes white hot (about 2500°C). Argon gas in the bulb prevents the filament from burning out.

Some animals are able to produce light, a feature called bioluminescence. It is generated by chemical reactions in living cells. Female glow-worms (really beetles, *right*) emit light when they are ready to mate.



Flat, shiny surfaces reflect light best of all. Mirrors, sheets of glass with a thin layer of metal on the back, are excellent reflectors. You can use mirrors to see round corners or above or below where you are. A simple periscope has two mirrors set at an angle opposite each other. Light coming in at one end can be reflected through to an observer at the other.



Refraction of Light

Light rays bend, or refract, when they pass through different transparent materials. This is because light travels at different speeds through different materials. At the boundary between two materials, for example, air and water, the light changes speed slightly and is refracted from its straight path. You can see this effect when looking at the bottom of a swimming pool. It looks much shallower than it really is.

Focusing Light

A lens, a shaped piece of glass or plastic, can bend light, either spreading it out or bringing it closer together. A **convex lens,** one that is thicker in the middle than at the edge, brings light rays together at a single point called a focus. The eye contains a natural convex lens which focuses an image on to the retina at the back of the eye. If you hold a convex lens so that the object you are looking at lies between the lens and the focus, the object will appear larger and further from the lens than it really is. A simple magnifying glass *(above)* is a convex lens, and is useful for studying minute detail as, for example, on a postage stamp or a tiny insect or flower.

A **concave lens** is the opposite of a convex lens: it is thicker around the edge than in the middle. This kind of lens diverges (spreads out) light rays. It is used in glasses to correct short-sightedness.

COLOUR

ONE OF THE MAIN features of light *(see page 26)* is colour. If light were just pure white, our whole world would be black and white and shades of grey. But white light is not pure. It is a mixture of all the colours of the rainbow which are known as the spectrum of light.

Colours exist because light is in the form of waves and not all the waves have the same wavelength. Some are slightly longer than others, and these we see as red. Light waves of medium wavelength appear to our eyes as green. We see the shortest light waves as violet. A leaf is green because its surface absorbs all the colours in white light except green, which it reflects into our eyes. A red flag absorbs all colours except red. Objects that reflect all colours are white.

A rainbow forms across the sky when the Sun shines from behind you at rain falling in front of you.

The different colours of light are seen when white light is split up using a prism, an angled block of transparent material such as clear glass or plastic. As the light waves pass into and then out of the prism they are bent or refracted *(see page 27)*. Longer waves of red light refract least. Shorter waves of violet light refract most. The other colours spread out between. A raindrop works as a natural prism. Millions of raindrops split sunlight and form a rainbow in the sky.

The colour wheel *(above)* shows how the different colours of light add up to make white light. When you spin the wheel the colours whirl around so fast that the eye cannot follow them. Inside the eye each colour merges with the others so the eye sees all the colours at once—and all colours of light added together make white light.

The three primary colours of light add together to make white light.

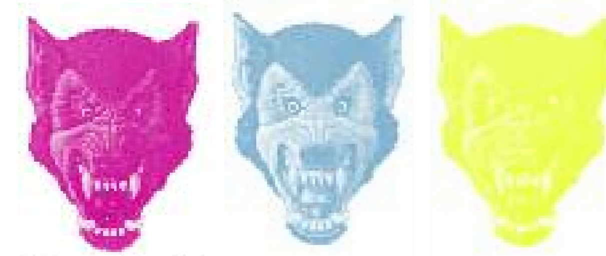
ADDING COLOURS

We see colours in books like this, and on screens such as the television, in different ways. A television or computer screen has thousands of tiny dots that glow and give out light. These dots have actually only three colours—red, green and blue. These colours are known as the primary colours of light. Added to each other in different combinations and brightness they can make any other colour. For example, red and green together make the colour yellow. Red and blue produce the pinky colour known as magenta. Blue and green form cyan, a type of turquoise. The three primary colours of red, blue and green added together make white light.

On the screen of a computer or TV the dots are arranged in groups known as pixels. The different colours of dots flash on and off in different combinations and shine with different brightnesses. From a distance, the eye cannot see the individual dots. They merge to produce larger areas of colour. When all the red dots on an area of the screen shine, that area looks red. When all three colours of dots in an area of the screen shine brightly, that area looks white. Also the dots flash on and off many times each second, again too fast for the eye to follow. So they merge together in time to produce multi-coloured, moving pictures.

SUBTRACTING COLOURS

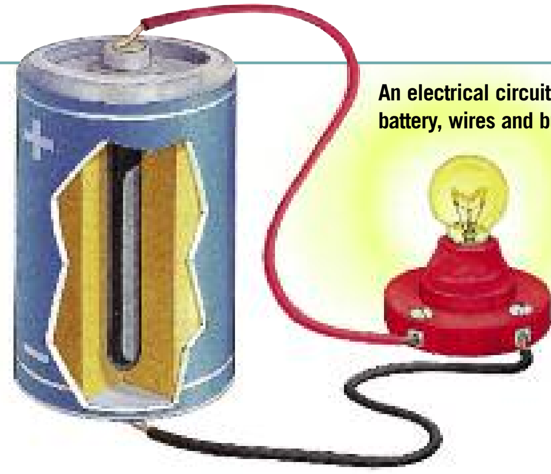
Coloured pictures in a book are made like those on a screen, using tiny coloured dots that merge together. The dots are inks made with coloured substances called pigments. There are three primary pigment colours—yellow, magenta and cyan. They work in the opposite way to light colours. They do not add together, but take away or subtract. A yellow dot takes away all colours of light except yellow which it reflects. The other two dots do the same for their colours. By taking away individual colours, the dots merge to produce areas of other colours. All three dots together make black.



The wolf's mask *(below)* is realistic and frightening. Yet it is printed using tiny dots of only three colours. They can be separated as magenta, cyan and yellow *(above)*. To save on coloured inks some parts of the page, like these words, are printed with ready-made black ink *(left)*.

Electricity

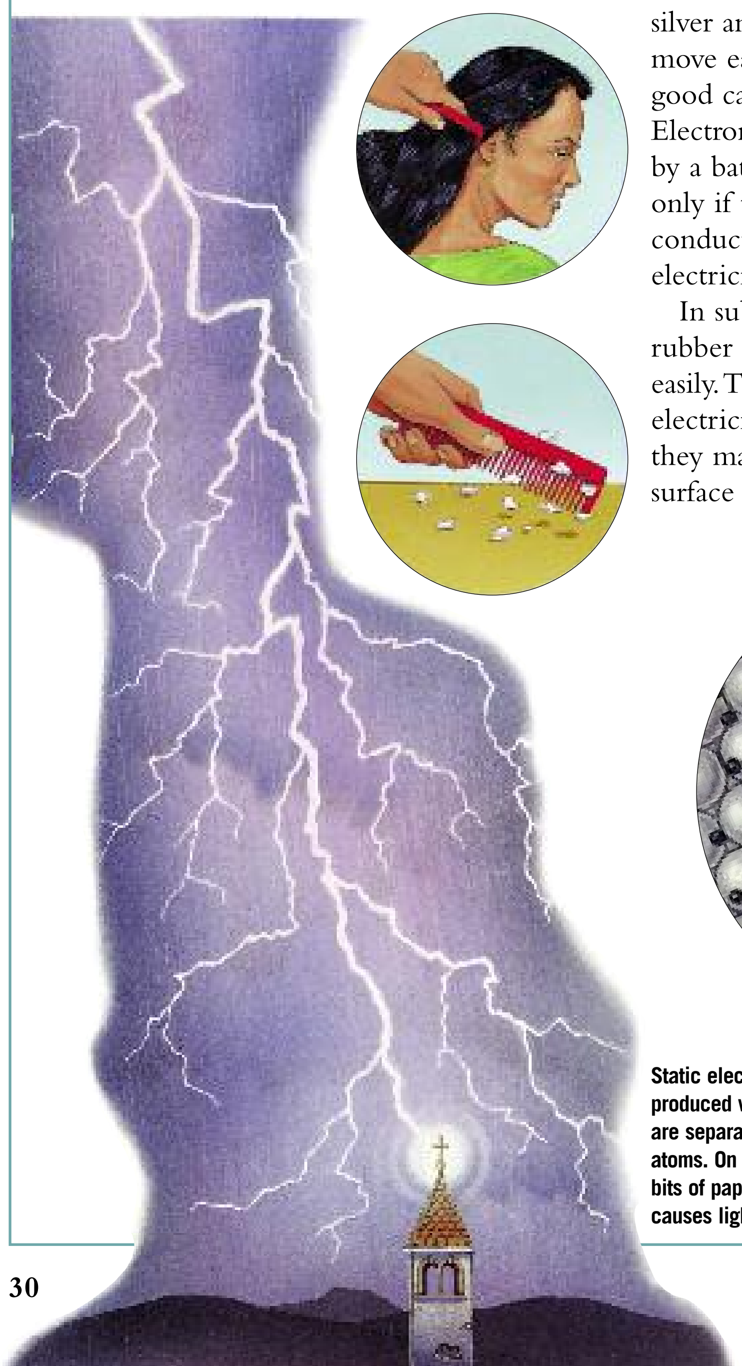
One of the most useful forms of energy in today's world is electricity. It is transportable, which means it can be carried long distances by wires and cables. It is convertible, being changed into many other forms of energy, such as light from an electric light-bulb, and movement in an electric motor. It is also controllable. We can turn it on and off with a switch, or up and down with a knob. When a city suffers a power cut and falls still and silent, we realise how much we depend on electricity.

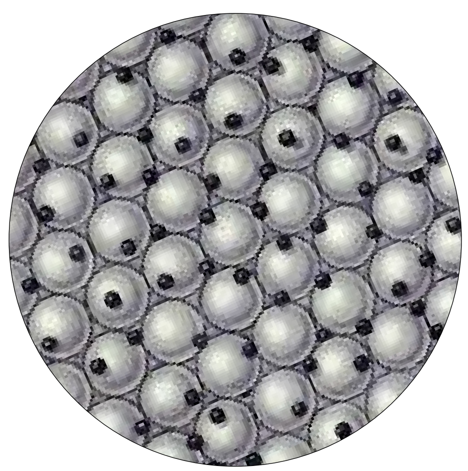


An electrical circuit of battery, wires and bulb.

Electricity is the movement of electrons, the negative particles around the nucleus of an atom *(see page 6)*. Most metals, especially silver and copper, have electrons that can move easily from atom to atom, so they are good carriers or conductors of electricity. Electrons are pushed along the conductor by a battery or generator. But they flow only if they have a complete pathway of conductors called a circuit *(above)*. Flowing electricity is known as electric current.

In substances such as rocks, wood, plastics, rubber and glass the electrons do not move easily. These materials prevent the flow of electricity and are known as insulators, but they may gain or lose electrons on their surface as a static electric charge *(below)*.



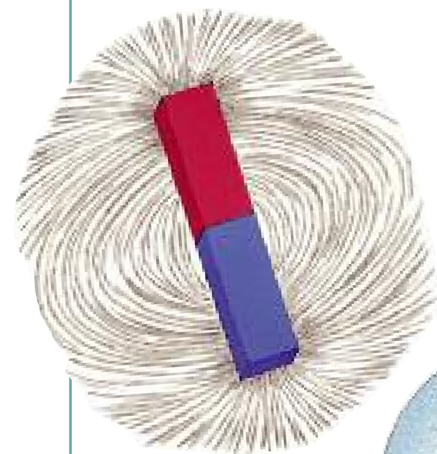


Static electricity is produced when electrons are separated from their atoms. On a comb it attracts bits of paper. In the sky it causes lightning!

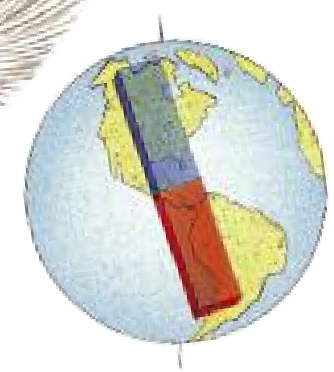
Electric current flows along a wire as electrons which detach from the outermost parts of their own atoms and jump or hop along to the next available atoms.

Magnetism

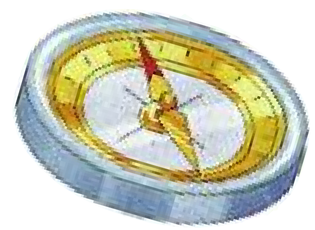
We cannot see or feel the force of magnetism. But it is all around us since the Earth is itself a giant magnet. A magnetic force affects mainly objects and substances that contain the metal iron. It pulls or attracts them. The force is present as a magnetic field around a magnet, which is itself usually made of iron.



A bar magnet is a strip of iron or steel in which the atoms are lined up in a certain way. Its magnetic force is strongest at its two ends or poles.



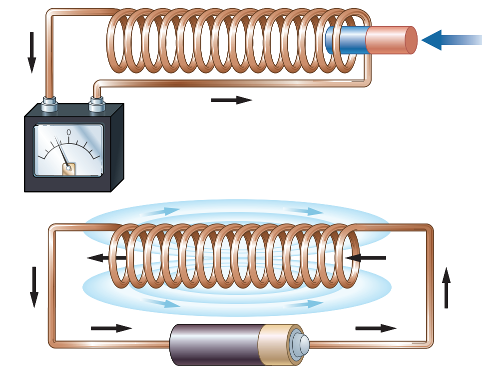
The Earth has a magnetic field and two magnetic poles, north and south, almost as if it had a giant bar magnet inside.



A magnetic compass is a needle-shaped magnet. Its poles are attracted to the Earth's poles so it always turns to point north-south.

Magnets of different sizes and shapes have hundreds of uses, from holding notes on a refrigerator to being vital parts in electrical generators, motors and loudspeakers.

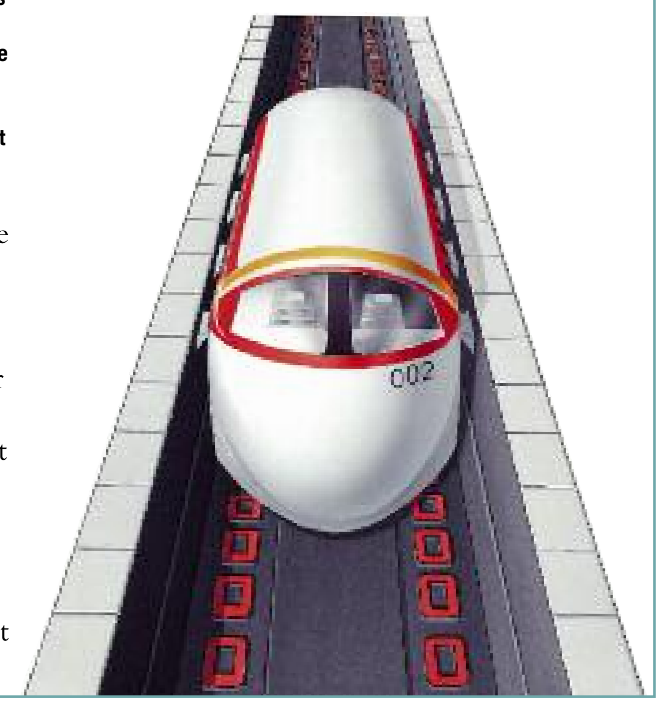
A magnet does not always attract another magnet. Its magnetic force is strongest at two areas called its poles. These are different from each other and known as north and south poles. The north pole of one magnet attracts the south pole of another magnet. But it pushes away or repels the other magnet's north pole. The general rule is that unlike poles attract, like poles repel.



Electromagnetism

Electricity and magnetism are two aspects of the same force, called the electromagnetic force. They are so closely linked that one can produce the other. A magnetic field moving near a wire causes electricity to flow in the wire *(top)*. An electric current flowing in a wire makes a magnetic field around the wire *(above)*. Twist the wire into a coil and it produces a stronger magnetic field. It can be turned on and off by switching the electricity on and off. This is an electromagnet. Electromagnetism is the basis of electric motors and generators.

A maglev (magnetic levitation) train uses the pushing force between the like poles of magnets in the train and track. The force holds the wheel-less train above the track.



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