

THE SCIENCE YOU NEED TO KNOW

Author: Brian Smith

Editor: Valerie Wood-Robinson

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What this book IS and IS NOT

This book is a reference source for teachers at primary school level who may not be science specialists. It provides information for teachers' background knowledge. It includes much more detail, both in range of topics and depth of coverage, than needs to be taught at primary school level (Key Stages 1 and 2 of the National Curriculum for England or equivalent curricula). This allows teachers an overview of the context of what they are teaching. It enables them to know what they are preparing the pupils for, as they go on to KS3 and beyond. Also it will help to answer pupils' questions that go beyond KS2 coverage. We hope that it will be useful not only to teachers but also to teaching assistants and parents.

The sequence of the text generally follows that of the 1999 National Curriculum for England, Programme of Study: Science, Key Stage 2, Sc2, 3 and 4. Information beyond the scope of Key Stage 2 is included in relevant sections; for example, the concept of the cell (introduced at Key Stage 3) is included with Life processes, and ideas of mass (introduced at Key Stage 3) and inertia (beyond National Curriculum) are included with Forces.

Sc1 is not explicitly addressed in this book. In teaching the relevant concepts elaborated in this book, it is supposed that teachers will also be teaching about ideas and evidence in science, and teaching investigative skills. As implied in the National Curriculum, it is important that primary school pupils learn from personal experience, rather than be overwhelmed by theoretical knowledge. To allow experiential learning, teachers need to feel confident that they can call on scientific knowledge to 'explain and elaborate on the pupils' experiences. We hope that this book will support this confidence.

(Specific support for teaching Sc1 is offered in several publications from ASE, including *Making Sense of Primary Science Investigations*, *Investigations: Getting to Grips with Graphs*, and *Investigations: Developing Understanding in Scientific Enquiry*.)

Some of the scientific 'facts' presented here may be difficult to accept as plausible explanations. Children and adults alike bring to their thinking about the world many deeply embedded popular beliefs that seem to make more sense than apparently far-fetched scientific explanations. These everyday ideas have been called 'alternative conceptions' or even 'misconceptions'. Although we have pointed out a few possible pitfalls or sources of misunderstanding, there is not space in this book to draw attention to many of the probable alternative conceptions that the reader and his or

her pupils may have. You may like to compare your initial ideas on a topic (e.g. how plants get their food, phases of the Moon) with the explanations given here, which will help you to anticipate the difficulties that pupils encounter in accepting some counter-intuitive ideas. (Alternative conceptions are addressed in other resources, including the *QCA Scheme of Work for KS.1 and 2*, and *Making Sense of Secondary Science* published by Routledge.)

Many scientific explanations are models, that is, creative mental constructs that best explain the evidence of the world around us. For example, atomic structure and food chains are models, ways created to visualise complex ideas. Pupils should be introduced to this, and not be led to believe that atoms *are* microscopic balls, nor that a lettuce, a rabbit and a fox actually line up somewhere to eat one another. To quote the National Curriculum: '*Pupils should be taught that science is about thinking creatively to try to explain how living and non-living things work*' (Key Stage 2, Sc1, 1a). This book refers to several historical scientists whose creative insights have contributed to our knowledge.

(The scope of this book does not allow for descriptions of analogies or of demonstration models, which are described in the ASE publication *Analogies & Illustrations: representing ideas in primary science* and other resources.)

This book was originally conceived by the author Brian Smith as a publication to support teachers of the Scottish Environmental Studies curriculum. It has developed into a Scottish version, written and published by Brian Smith, consistent with the content of the 5-14 National Guidelines on Science, and, in collaboration with Valerie Wood-Robinson as editor, into this ASE publication consistent with the content of the English National Curriculum. We have tried to simplify the science while maintaining accuracy, which, in some places, has involved making generalisations without giving examples or exceptions. We would like to thank the following colleagues for their valuable comments that helped to improve the accuracy of the text: Max de Bóo, Colin DuQueno, Phil Ramsden. However, responsibility for the content rests with the author and the editor.

Valerie Wood-Robinson

Editor

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Life processes and living things

As this muscle contracts it squeezes blood out and, as it relaxes, the heart fills up with blood again.

Circulation

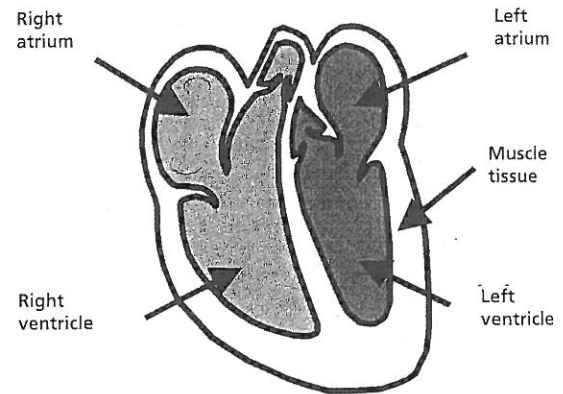
The heart and blood circulation: The circulation system is a continuous series of tubes. The heart is a part of this continuous system. The function of the heart is to pump blood. Blood contains many substances dissolved in it, including oxygen, which are pumped around the body. The heart is divided into four main chambers and has a wall made of thick muscle. As this muscle contracts it squeezes blood out and, as it relaxes, the heart fills up with blood again. The blood is pumped by the right-hand side of the heart to the lungs where the blood absorbs oxygen. The oxygen-rich blood then passes from the lungs to the left-hand side of the heart from where it is then pumped around the body. As the blood passes through all the organs of the body, their cells take the oxygen from the blood. The blood then returns to the right-hand side of the heart where the process repeats itself. Both sides of the heart pump at the same time.

Arteries are the tubes that carry blood away from the heart to the rest of the body and veins are the tubes that carry blood back from the body to the heart. Arteries are divided into smaller and smaller capillaries which deliver the blood to the body's living cells.

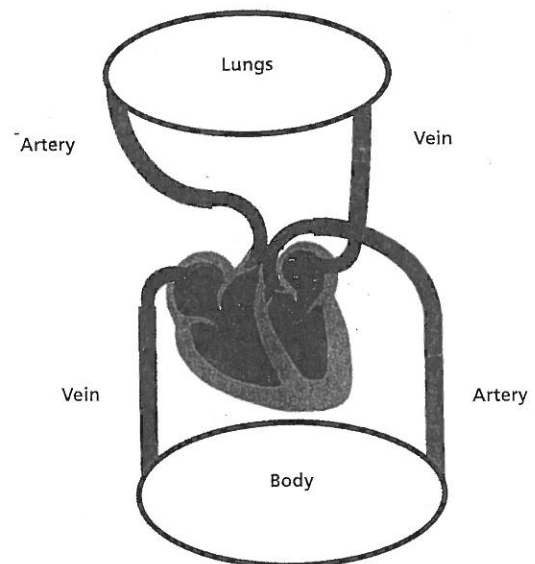
The blood itself is mostly made from a watery liquid called plasma. The plasma contains many dissolved chemicals which have their own particular uses in the body. It also contains red blood cells that carry oxygen to body cells, white blood cells which kill germs, and platelets which form blood clots to reduce blood loss if the body is cut.

A typical pulse rate for someone at rest would be about 70 beats per minute.

When the heart beats, it forces blood through the arteries which swell slightly at each heart beat and causes our pulse. If you put your finger on your wrist you can feel your pulse. You can therefore count how often your heart beats per minute by counting the number of times you feel your pulse each minute. A typical pulse rate for someone at rest would be about 70 beats per minute. When we exercise, our muscles require more energy, which they get from food and oxygen in the blood. To supply more blood our heart beats more often and our pulse rate rises. After exercise the pulse rate returns to normal. The fitter a person is, the quicker their pulse rate will return to normal (recovery time). Also, a fit person's heart can supply larger quantities of blood, so their pulse rate will not increase as much as an unfit person's during exercise.



Lengthwise section of the heart seen from the front.



Movement

The skeletal system: Animals, such as humans, which have an internal skeleton with a backbone are called vertebrates. Animals, such as worms and insects, which do not have a backbone, are called invertebrates.

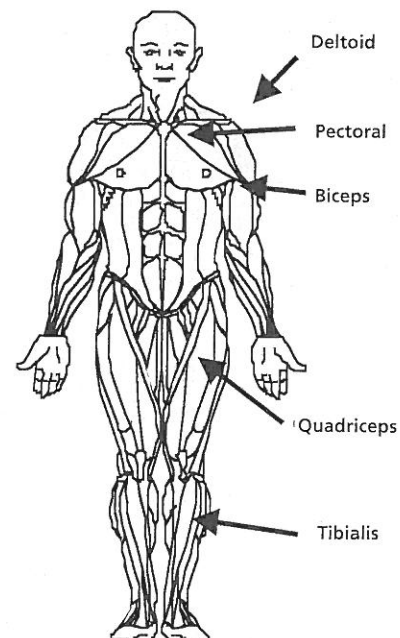
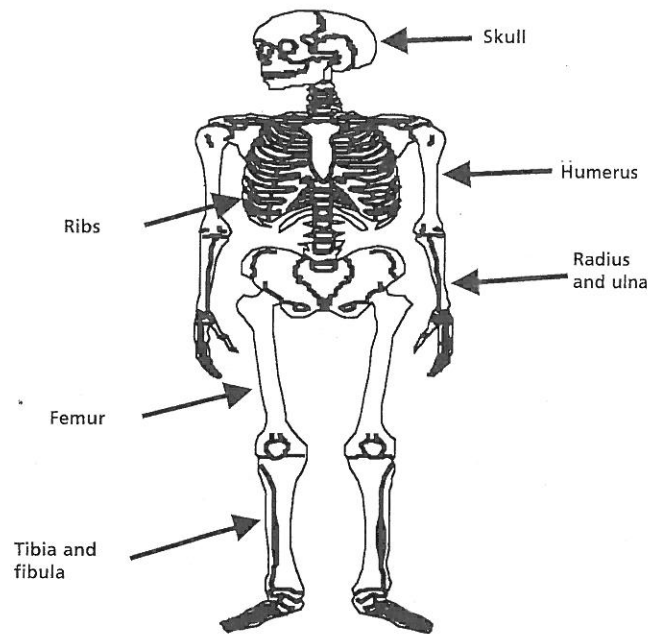
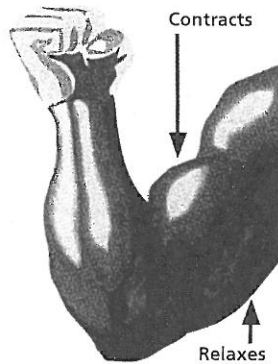
There are over 200 bones in an adult human body. Babies are born with over 300 bones that fuse together as they grow. The smallest bone in the body is the stapes (stirrup) bone that is one of three bones found in the ear.

The skeleton has three main functions:

- 1) To support the body so that it can stand, sit and lie.
- 2) To protect vital organs such as the heart, brain and lungs.
- 3) Along with the muscles, to help us move around.

Joints are where the bones meet and allow the limbs to bend. There are different types of joints. For example, the joint at the elbow is called a hinge joint and the hip joint is called a ball and socket joint. The bones are held together by ligaments.

Muscles: Depending on how you count them, there are between 656 and 850 muscles in the human body. Voluntary muscles, which are connected to the skeleton, allow us to move at will and involuntary muscles, like the ones in our intestines, perform their function on their own without our control. Muscles are connected to bones by tough fibres called tendons. Signals from our brains cause muscles to contract and so they pull the limb, causing movement. In the arm, the biceps muscle contracts and lifts the arm and the triceps muscle contracts and lowers the arm. The biceps and triceps muscles act as an opposite pair to produce movement.



Health

A well-balanced diet and exercise are prerequisites for a young person to grow to be fit and healthy. Smoking and alcohol abuse are very damaging to our bodies and just some of the negative effects of abuse of these drugs are listed below.

Smoking: addiction, lung cancer, bronchitis, asthma, emphysema, heart disease, mouth and throat cancer, bad breath, stunted growth of the young and unborn.

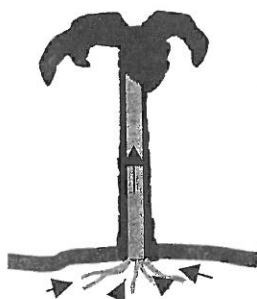
Alcohol: addiction, liver cancer, ulcers, heart disease, kidney damage, depression, birth defects, aggressive behaviour, irresponsible behaviour leading to unplanned pregnancies.

Non-smokers can be passive smokers if they are near to smokers in polluted environments such as pubs. Smoky cities and dusty mines are other environments that can cause lung damage similar to that caused by smoking.

Non-smokers can be passive smokers if they are near to smokers in polluted environments.

Life processes and living things

Light is essential for photosynthesis, the process by which a plant changes light energy into chemical energy in food.



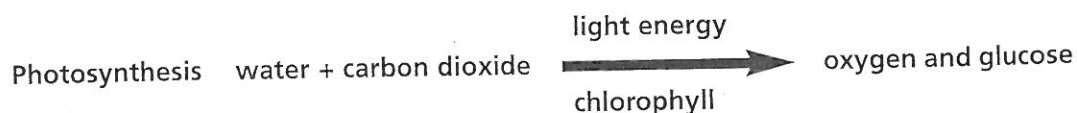
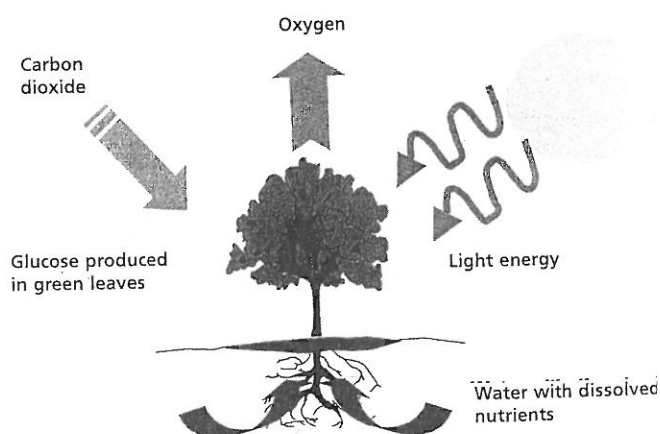
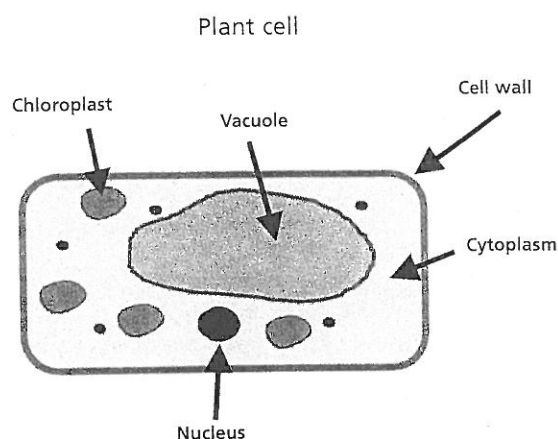
The leaf cells contain a chemical called chlorophyll in structures called chloroplasts.

3. Green plants Growth and nutrition

Factors affecting growth: Light is not normally needed for seeds to germinate but, once the shoot begins to grow leaves, light becomes essential for plant growth and survival. Light is essential for photosynthesis, the process by which a plant changes light energy into chemical energy in food. Living organisms are very sensitive to temperature changes. If the temperature of a plant's surroundings decreases, then the biochemical reactions needed for life to exist begin to slow down. During the cold winter the growth of a tree (caused by cell division and enlargement that happens just underneath the bark) can stop altogether although the tree is not dead, but, when the warmer temperature of spring arrives, the growing restarts. This starting and stopping of the tree's growth results in the formation of annual growth rings. The width of growth rings on a tree trunk are a record of the weather conditions when the tree was growing.

The living cells of a plant need water and food to stay alive. Plants take in mineral nutrients, dissolved in water, through their roots. Examples include nitrates for growth, phosphorus and calcium to build cells and iron and magnesium for making chlorophyll. Water and dissolved minerals are transported up the stem to other parts of the plant. The roots also help hold the plants in the ground, preventing them from being blown down easily.

Photosynthesis: The green leaves of a plant are essential for photosynthesis to occur. Carbon dioxide is absorbed through tiny holes in the leaf surface called stomata and water is taken up through the roots and stem. The leaf cells contain a chemical called chlorophyll in structures called chloroplasts. Chlorophyll absorbs sunlight energy, which then combines the water and carbon dioxide to form glucose and oxygen. The oxygen passes through the stomata in the leaves into the air and the glucose is used as food for the plant. As in animals (including humans) the food provides the plant with energy for growth and reproduction. Some of the glucose is joined together to form starch which is stored in the cells to form a food store.



Glucose can be formed into long chains called cellulose which can be used to construct the cell walls of plant cells. The glucose produced by photosynthesis can also be changed to other carbohydrates, protein and fats. Since all animals, including humans, are dependent on plants for food, then this reaction is fundamental for the survival of all animal life. Fairly recently, however, colonies of small microbes have been discovered living on the chemicals and heat given out by volcanic vents deep under the ocean floor. These support other small animals in a community that does not require the Sun as its primary source of energy (they are so deep that no sunshine reaches them). It is thought that similar communities may exist underneath the surface of other planets and the moon(s) that orbit them that are also volcanically active.

Reproduction

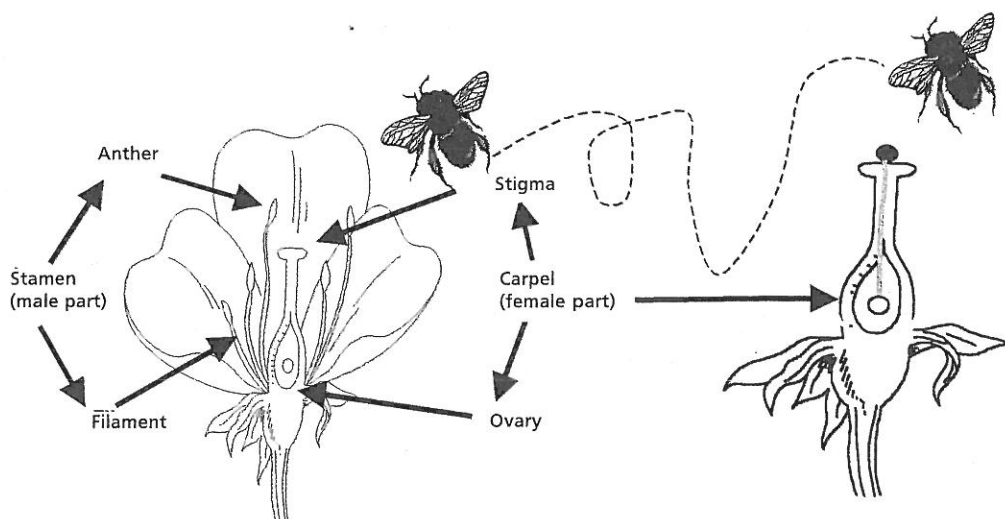
Reproduction by flowers:

Many flowering plants have bright and scented flowers which attract many insects that come in the search of nectar (a sugary liquid). In most flowers the petals provide the colour and a landing stage for the insects. Pollen is a powder produced in a part of the flower called the anther, the top part of the stamen.

The pollen dust consists of pollen grains, each of which represents the male sex cell of the plant. When an insect visits in search of nectar, the plant pollen can stick to it. The pollen can then be carried to another flower where the pollen grains can stick to the top of its stigma. Each pollen grain grows a tube downwards into the ovary. Once this happens the male sex cell, which is contained in the pollen grain, passes down the tube and fertilises the ovule, and a seed develops. Often the wall of the ovary develops into a soft juicy fruit like a plum or cherry or it may become dry like a poppy head or sycamore wing.

Other types of flowering plants including grasses and some trees, such as oak and willow, have other mechanisms to allow pollination to take place. They produce small flowers with lots of pollen which is spread by the wind instead of by insects.

Seed dispersal: After fertilisation (the combining of the male and female sex cells), a seed is produced which contains a young plant and a food store. To help a species of plant to survive into future generations, its seeds must be well dispersed to reduce competition between plants and to spread to other habitats. Some methods of dispersal are shown below. An edible fruit such as an apple or berry attracts animals to eat it. The animal will either spit out the seed or will swallow it. The seed's tough coating prevents it from being digested and allows it to pass through the animal, to be dropped far away from the parent plant unharmed.

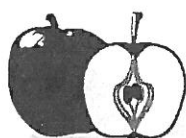


When an insect visits in search of nectar, the plant pollen can stick to it.

An edible fruit such as an apple or berry attracts animals to eat it.



Sycamore: by wind



Apple: by animal



Coconut: by water



Sweetpea: by bursting

Seeds and germination: When a seed is scattered, it has little water in it. For the embryo plant inside the seed to begin to grow into an independent plant (germinate), it must have water, oxygen and a suitable temperature. If the conditions are right, the seed uses its food store to grow a new root to take water in and then a new shoot. Once the new plant has leaves and is exposed to light it will produce its own food through photosynthesis and will no longer be dependent on the seed's food store. If the food store runs out and the plant is not exposed to sunlight then it will die. Seeds which, after germination, continue to grow in dark places can produce long spindly shoots which give the leaves a better chance of reaching sunlight before the seed's food store runs out. When planting seeds a simple and very general rule is that the bigger the seed then the deeper it should be planted and vice versa. A small seed has a small food store and therefore it must be planted near the surface to give the young plant a greater chance of reaching the sunlight before the food store runs out. Light is not essential for seeds to germinate but, once the shoot begins to grow leaves, light becomes essential for plant growth and survival.

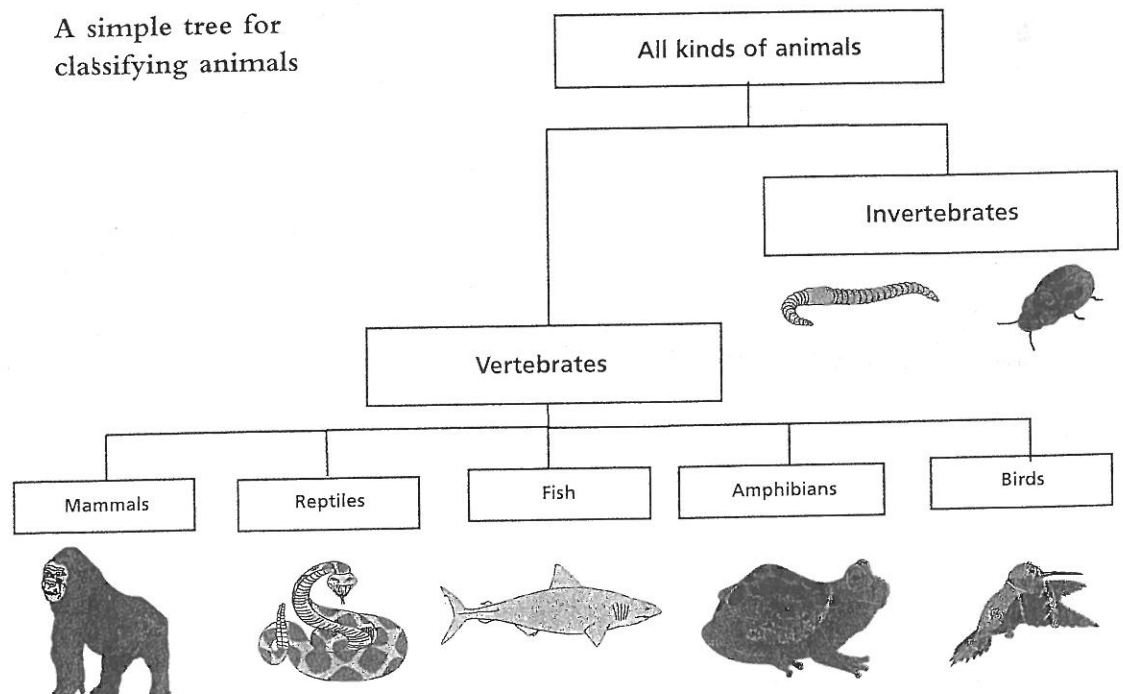
4. Variation and classification

Principles of classification: Things, including living things, can be put into groups based on a variety of criteria, e.g. things that fly, things that are edible. But the scientific classification of living things puts them into groups according to their patterns of similarities, for example, birds can be grouped together because they all have feathers, or fish because of their wet scales and fins. Classification involves placing an organism into a series of groups, according to more and more detailed similarities. This classification is thought to reflect evolutionary relationships. It allows predictions to be made about further characteristics of an organism; for example, if you know that a mullet is a fish, you can predict quite a lot about it.

For our purposes, we can classify all living things as either plants or animals. Plants have green parts, stay fixed and make their own food by photosynthesis. Animals move about and eat food.

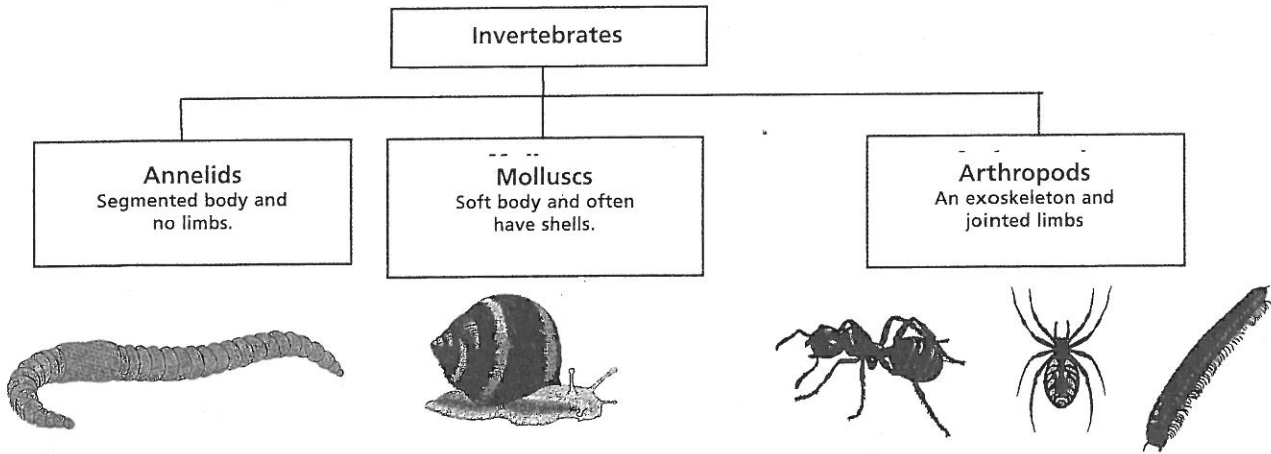
Animal groups: For animals, the first distinction is made between animals that have a backbone (vertebrates) and those that do not have a backbone (invertebrates).

A simple tree for
classifying animals



Vertebrates are separated into five other groups depending on their features. Mammals have hair and supply milk to their young; birds have feathers, beaks and lay hard eggs; reptiles have dry scales and lay soft eggs; fish have wet scales, gills and fins; amphibians have moist skin and live in a land and water habitat.

Invertebrates can also be separated into further groups such as annelids, molluscs, arthropods. Arthropods are separated into insects, arachnids, crustaceans and myriapods.

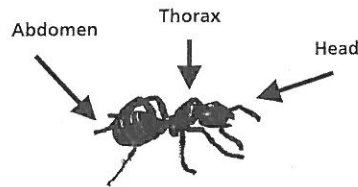


Insects such as ants, bees and beetles have three distinct parts to their body and have six legs. Many have wings. The number of insect species could well be over a million although it is not known how many different species of insects there are in the world as thousands of new ones are discovered each year and many are lost due to the destruction of the tropical rain forest habitat. The desert locust (as mentioned in the Bible) is the most destructive insect to crops, as large swarms can eat thousands of tonnes of crops a day.

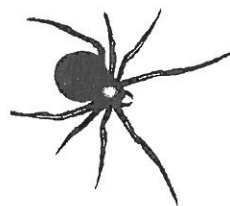
Arachnids such as spiders, ticks, mites and scorpions have a two-part body and eight legs. The silk that makes up a spider's web is stronger than man-made steel of the same weight. Dust mites are thought to be one of the causes of asthma and common allergies.

Crustaceans such as crabs, shrimps and woodlice have a three-part body, with plate-like external skeleton and more than four pairs of legs. Most crustaceans live in water, but woodlice live on land.

Myriapods such as centipedes and millipedes have long bodies with lots of segments and legs on each. Millipedes and centipedes help turn over the soil by their burrowing and their burrows help air and water to circulate in the soil.



The number of insect species could well be over a million.

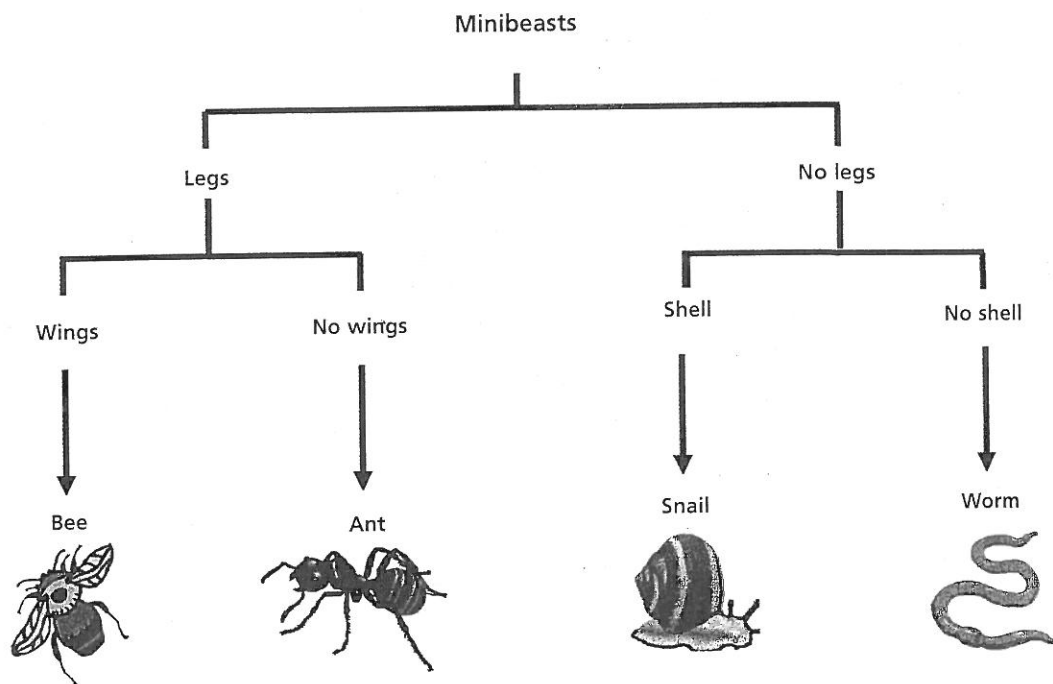


Most crustaceans live in water, but woodlice live on land.



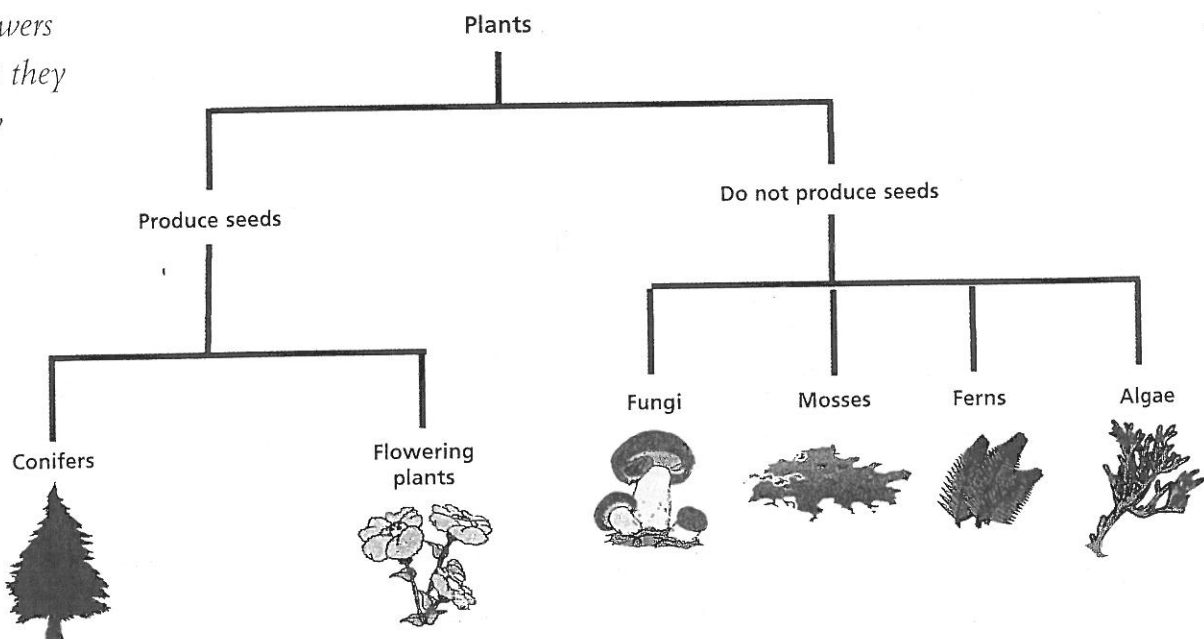
Life processes and living things

Animal keys: Simple keys can be constructed with yes/no questions on the organisms' physical characteristics to help identify them.



Plant groups: Plants can be classified according to their own characteristics. Flowering plants (angiosperms) are plants that, at some time in their life, produce flowers as their reproductive organs. Conifers never have flowers but they produce seeds from cones. Fungi, mosses, ferns and algae do not have flowers or seeds, but they reproduce by spores.

Fungi, mosses, ferns and algae do not have flowers or seeds, but they reproduce by spores.



Fungi, for example mushrooms, may be considered to be plants although they do not share characteristics such as leaves and roots. They do not make food by photosynthesis. Mushrooms feed off dead organic matter and are also referred to as decomposers. This decomposition of organic matter allows nutrients to be released back into the soil and recycled back into living organic matter.

5. Living things in their environment

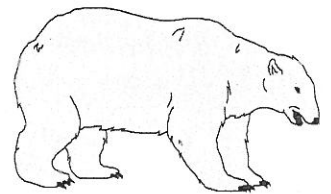
Adaptation

Adaptation to habitats: Where a group of living organisms live is called their habitat. The habitat provides the organisms (collectively known as a community) with food, water and shelter. The community of organisms, the habitat and the environmental factors which affect them, such as the weather, are collectively called an ecosystem.

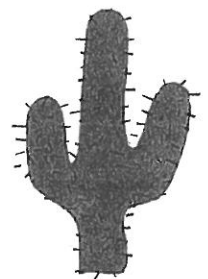
Animals and plants live in habitats that supply their needs for survival and to which they are best adapted to live. Ferns are plants that mostly grow better in damp, shady conditions. Ferns are often found living in a woodland habitat that satisfies the plants' needs. Ferns are not found everywhere because not every habitat is damp and shady. Squirrels are animals which also prefer a woodland habitat as it supplies them with their needs for survival, such as trees to live in and food such as caterpillars and acorns. Squirrels are suited to this habitat as they have sharp claws for climbing and tails to help them balance. Nowadays many squirrels find these conditions in suburban environments. A pond or river will have plants and animals in or around it which are best suited to this habitat. Otters often live around river banks, where they can burrow for shelter and feed on fish. An otter is suited to this habitat as it has webbed feet for swimming, whiskers to help 'feel' for fish, a waterproof coat and sharp teeth to eat fish with. Some animals are adapted to live in habitats with very contrasting and extreme environmental conditions. The polar bear lives in the Arctic where it is mostly freezing and there is little or no vegetation. By natural selection (the process by which animals and plants most suited to their environments are most likely to survive and pass their favourable characteristics to their offspring) the polar bear has adapted to this habitat by evolving a white fur coat for camouflage and insulation on land. (Each hair is hollow and the combined effect of such a coat is superb.) The polar bear has lots of blubber to keep it warm in the water. It has sharp claws and teeth for killing and eating fish and seals. It is an excellent swimmer, but, having fur on the underside of its feet to help it walk on ice, it is also successful on land. Camels can live in a desert habitat where there is little rainfall and it is very hot during the day and cold at night. The camel is covered in fur which keeps heat out during the day and prevents it losing heat at night. The camel has long eyelashes and hair in its narrow nostrils to stop sand and grit entering them especially during sand storms. The camel can go for a long time without eating and drinking which enables it to make long journeys through waterless and foodless landscapes.

Plants such as cacti are also adapted to live in a desert habitat. Cacti can store water in swollen stems and branches and have leaves which are curled up tightly into needles to reduce their surface area and prevent water loss by evaporation. Trees in very cold climates are adapted in a similar way to reduce evaporation from their leaves by growing narrow needle-like leaves.

The polar bear has adapted to this habitat by evolving a white fur coat for camouflage and insulation on land.

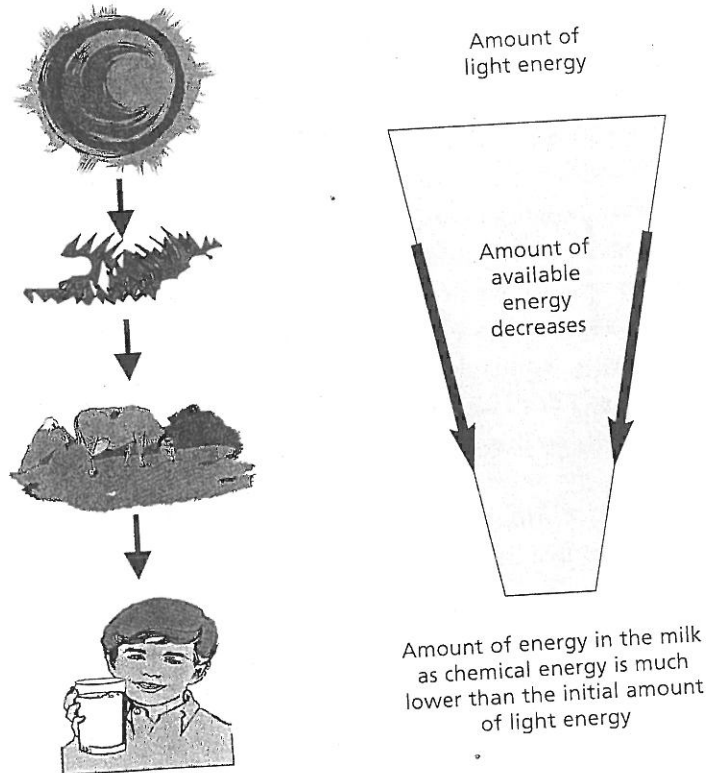


Cacti can store water in swollen stems and branches.



Feeding relationships

Energy relationships: Humans and other animals receive the energy needed to keep them alive and to be active from the food that they eat. We can trace the energy from a glass of milk back through a food chain to its origin as the energy in sunlight.



The cow grazes on the grass and, by the process of digestion, the food is made available to all the cells of the body.

The grass absorbs some of the light energy from the Sun (most of the light is reflected off the grass) and through the process of photosynthesis this energy is changed to chemical energy in the form of food. The cow grazes on the grass and, by the process of digestion (the breaking down of large food particles into small soluble ones), the food is made available to all the cells of the body. Some of the undigested food is passed through the cow and egested.

In the cells, energy is released from the food. The cow 'uses up' some of this energy as it moves around, grows and maintains its body temperature. Some of the food (containing energy) is changed into body material such as muscle (meat) and milk. When the cow is milked the energy becomes available for us, but by this time only a small percentage of the original light energy from the Sun is left.

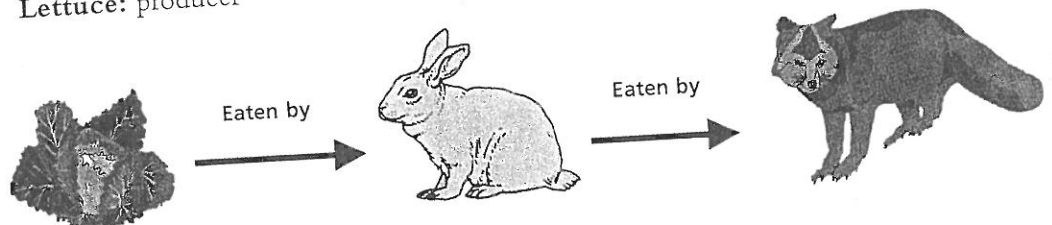
Food chains: The diagram below illustrates the link as a food chain. The arrows indicate the flow of energy along the food chain. The longer the food chain the less energy is available at the end. Short food chains are more efficient as more of the original light energy is available in food at the end.

A food chain

Lettuce: producer

Rabbit: primary consumer

Fox: secondary consumer



Micro-organisms

Microbes (micro-organisms) are very small living organisms and cannot be seen by the naked eye. Due to the differences between microbes and other living things, they are grouped together. The four main types of microbe are viruses, bacteria, fungi and protozoa. (Fungi may also be classified as plants, and protozoa as animals.)

Viruses are the smallest of the microbes and cannot reproduce by themselves. They are parasites and rely on invading animal and plant cells, taking control of them to make them produce more viruses. Viruses cause many diseases, such as flu, chicken pox, cold sores and AIDS.

Protozoa look like individual cells. Some can also cause disease. Malaria is a disease which is caused by protozoa living in a human's red blood cells and is transmitted by the female mosquito.

Fungi are made from long thread-like structures called hyphae. A group of hyphae is called a mycelium. Some fungi can cause disease such as athlete's foot. Other fungi have useful functions. Yeast is a fungus and is used in making bread. Fungi also help decompose the flesh of dead organisms and release the nutrients back into the soil. Plants re-use these nutrients and the cycle begins again.

Bacteria look like living cells but they do not have a nucleus. Certain bacteria are responsible for making foods rot. Others are the cause of some diseases, such as cholera, diarrhoea, leprosy and diphtheria. Some bacteria live in the human intestines (e.g. *E. coli*) and are also present in our mouths. Bacteria are used in sewage works. The bacteria feed on the organic matter in the sewage, making the water cleaner and safer. One useful by-product of this is methane gas which can be used as fuel. Bacteria are also used to produce yogurt and some other food products.

Viruses cause many diseases, such as flu, chicken pox, cold sores and AIDS.

*Some bacteria live in the human intestines (e.g. *E. coli*) and are also present in our mouths.*

Materials and their properties

1. Grouping and classifying materials

Materials: 'Materials' is a general word that includes everything in and on the world that is tangible, including gases. Different kinds of materials are rocks, fabrics, metals, water, flesh and bone, air, wood, plastics, in fact anything that any object consists of. It is important to distinguish objects from the materials they are made from: e.g. chair (wood and metal), book (paper, glue, card, ink), ball (plastics). There are many ways to classify materials depending on the characteristics chosen to separate them and the purpose of the classification.



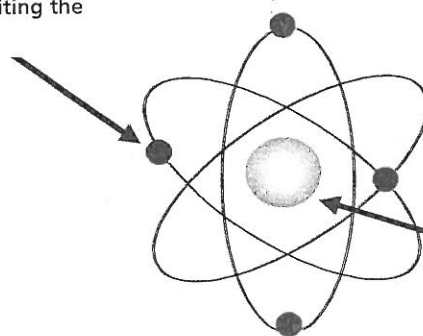
The ancient Greeks (e.g. Empedocles) postulated that all things were made from four basic elements which were Earth, Air, Fire and Water.

Matter: Matter is all the 'stuff' that things are made of, all the different kinds of materials. The ancient Greeks (e.g. Empedocles) postulated that all things were made from four basic elements which were Earth, Air, Fire and Water. These four elements had four possible properties: hot, cold, wet and dry. Combining these elements in different ways with the four properties helped the ancient Greeks explain the physical world around them. At the same time as the Greeks' four-element theory there was also a Greek 'atomic theory' (postulated by Leucippos and his pupil Democritos) in which everything was thought to be made from atoms which were small, hard, indivisible and continually moving in a void in which the atoms existed. According to this atomic theory, substances varied from each other because of the shape of the atoms that made them up and because of the way the atoms were arranged. The word atom comes from the Greek '*atomos*' meaning 'cannot be divided'.

Atoms: Atoms are too small to be seen directly but modern instruments have allowed science to build up an accepted model of the atom based on the results of Ernest Rutherford's (1871-1937) experiments in 1911.

In this model the mass of an atom is concentrated into a central core called a nucleus containing particles called protons and neutrons, around which small particles called electrons 'orbit'.

Negatively charged electrons orbiting the nucleus



Nucleus containing positively charged protons and neutral neutrons

*The word atom comes from the Greek '*atomos*' meaning 'cannot be divided'.*

The different arrangements of electrons within different atoms, give the atoms their chemical, electrical and thermal properties. The electrons also help in binding the atoms together to form solids and liquids. Metals, for instance, which are all good conductors of electricity, have electrons which are free from the rest of the atom and move easily through

the metal causing the metal to be a good conductor. We now know that during the conduction of electricity the energy moves quickly but the electrons themselves move slowly.

When trying to explain the physical world around us it is not normally necessary to think of atoms as having a nucleus and orbiting electrons. Instead, it is only necessary to think of atoms in much the same way that the Greek 'atomic-theorists' thought of them. A molecule is a group of atoms chemically combined together. For simplicity it is convenient to refer to atoms and molecules as particles of their substances (not to be confused with the sub-atomic particles described above, or larger granules such as grains of sand or soil particles).

Elements, compounds and mixtures: In order to understand their chemistry, materials can be distinguished by the chemical particles of which they are composed. There are around 100 naturally occurring elements. They are mostly metals, and around 20 are non-metals. Some materials consist of pure elements; they cannot be broken down or separated into other substances. Although nowadays it has been discovered that the atoms themselves are made from other smaller particles, an atom cannot normally be 'divided' and an atom is the smallest part of an element. The atoms of an element are all the same, and different from the atoms of other elements.

Examples of elements are gold, mercury, iron, oxygen, hydrogen, chlorine, sulphur.

Combining elements produces compounds with quite different properties from the original component elements. For example, sodium is a very reactive metal element. Chlorine is a highly reactive, toxic gas. Chemically combined together they produce common household salt, sodium chloride. Many natural materials are compounds. Many man-made materials are compounds, produced by combining different elements. The smallest part of a compound is a molecule of the compound.

Examples of compounds (with their constituent elements) are water (hydrogen and oxygen), sugar (carbon, hydrogen and oxygen), salt (sodium and chlorine), rust (iron and oxygen), polythene (carbon and hydrogen), nylon (carbon, hydrogen and nitrogen).

Most materials are mixtures of a number of elements and compounds. In a mixture the different elements and compounds are not chemically combined, they can be mixed in varying proportions, and they can often be easily separated into their components.

Examples of mixtures are crude oil, milk, air (mixture of oxygen, nitrogen, carbon dioxide and other gases).

Types of materials based on their general properties: Five basic types of materials and their general properties are listed in the table below.

Metals	Plastics	Fibres	Ceramics	Glass
Strong and hard, conduct heat and electricity well. Some metals are magnetic.	Poor conductors of electricity and heat. Can be soft, flexible and light.	Good heat insulators. Can be made strong and flexible.	Hard, brittle and resistant to heat.	Hard, brittle, resistant to heat and can be transparent.
Obtained from ores dug out of the ground.	Made from crude oil, obtained from the ground.	Obtained from plant and animal fibres. Can be man-made, e.g. plastics from crude oil.	Made from clay and other materials dug out from the ground.	Made from sand and limestone obtained from the ground.

There are around 100 naturally occurring elements.

The smallest part of a compound is a molecule of the compound.

Materials and their properties

Different materials have different physical and chemical properties.

Materials such as plastics, wood and ceramics do not conduct electricity well and are referred to as electrical insulators.

This is not a mutually exclusive way of classifying materials; some metals such as mercury are not hard, fibres can be made from some plastics, and some ceramics can be good conductors of heat.

Naturally occurring and synthetic (man-made) material: Gold, granite, crude oil and wood are naturally occurring materials, whereas plastics are synthetic. There is no rigid distinction; for example, salt can be extracted from rocks or water (natural source) or it can be manufactured synthetically. Iron is extracted from its (natural) ore by smelting (which involves a chemical change), and sugar is extracted from (natural) sugar cane or sugar beet (by physical separation processes), so it is difficult to decide whether iron and sugar are 'natural' or 'man-made'.

Physical and chemical properties: Different materials have different physical and chemical properties. For example, a physical property of iron is its strength, and a chemical property of iron is its rusting. Classifications of materials by some of these properties are described below.

Strength: There are different types of strength but, in general, a strong material will be able to endure large forces on it before it breaks or is deformed. Concrete, brick and stone are considered to be strong materials and will stand large squashing forces. Steel cables and nylon ropes can stand large stretching forces.

Hardness: The hardness of a material is its ability to resist being scratched, dented or worn away. Diamond is a hard material and is very resistant to wear. Friedrich Mohr (1773–1839) devised a scale of hardness (for rocks and minerals) based on a material's ability to scratch another. Diamond is the hardest with a rating of 10, and a soft rock called talc the softest with a rating of 1.

Electrical conductivity: All the metals conduct electricity easily as does the non-metallic element carbon. Materials such as plastics, wood and ceramics do not conduct electricity well and are referred to as electrical insulators. Materials that do conduct electricity easily, such as metals, are called electrical conductors. The plastic casing of a plug is an electrical insulator and the brass pins of the plug are electrical conductors.

Thermal conductivity: Again, metals are good at conducting heat, and materials such as plastics, fibres and wood are not good conductors of heat. Thus materials can be grouped into thermal conductors and insulators. A cooking pot's plastic handle is a thermal insulator and the metal bottom of the pot is a thermal conductor.

Magnetic materials: Magnetic elements are iron, nickel and cobalt. Lodestones that were used for early compasses are made from iron that occurred naturally. Most naturally occurring materials are not magnetic. Very strong magnets are man-made by combining different materials to form mixtures. One of these is the alloy alnico which is mostly made from aluminium, nickel and cobalt.

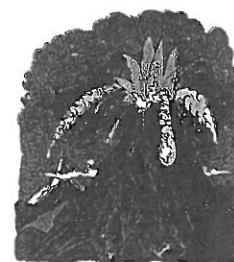
Other properties: There are other headings under which materials could be classified including flexibility, transparency, noise insulation, water resistance, and chemical properties such as reaction with other materials like air and water. It is important to distinguish the properties of objects from the materials from which they are made. For example, a piece of aluminium foil is flexible but a block of aluminium is not, so the property of flexibility should not be attributed to the material aluminium.

Building materials: A building such as a house is built from many different materials that are used for their own particular properties. Just some of the materials used in a modern home are listed below.

Material	Where it is used	Useful properties
Slate or concrete	Tiles on the roof of buildings.	Waterproof and hardwearing.
Brick	Walls.	Hardwearing and water-resistant (not completely waterproof). Strong.
Plastics	Insulation on electrical house wiring, window frames, water and sewage pipes, central heating pipes and damp insulation.	Good electrical and heat insulator. Waterproof.
Metals	Electrical house wiring, central heating pipes and some water pipes. In old houses toxic lead pipes were used to carry drinking water. Used to make photovoltaic cells for generation of electricity.	Good electrical conductor. Copper piping will not be corroded by the water
Wood	Floors, inside walls, roof rafters, doors, and skirting, etc.	Good heat insulator and fairly hard.
Glass	Windows and solar panels.	Transparent and weather-tight. Allows light radiation in for seeing and heat for warmth.

Types of rocks: The three types of rocks obtained from the earth are igneous, sedimentary and metamorphic.

Igneous rock starts deep beneath the Earth's crust. As molten magma, it pushes up through the crust, where it cools and solidifies. There are many different kinds of igneous rocks formed, depending on the composition of the magma and the way it cools and forms crystals. Examples of igneous rocks are granite and basalt.



Sedimentary rocks are usually formed when rock of any type is weathered down into fine particles which are then re-deposited under water and compacted. Sandstone and limestone are common examples of sedimentary rocks. Limestone is made from fine shell and skeleton fragments of microscopic sea animals.

Metamorphic rocks can be formed from igneous or sedimentary rock which has been subjected to high pressure and/or temperature to change its nature. Marble is an example of a metamorphic rock formed from the change of limestone, while quartzite is formed from the change of sandstone.

Rock type	Structure	Porous	Hardness	Examples
Igneous	Small grained if cooled quickly and large grained if cooled slowly when forming.	Impervious to water.	Very hard.	Granite, pegmatite and basalt.
Sedimentary	Loose grained in most cases.	Porous.	Soft.	Sandstone, limestone and chalk.
Metamorphic	Often with layered appearance.	Impervious to water.	Hard.	Marble, slate and quartzite.

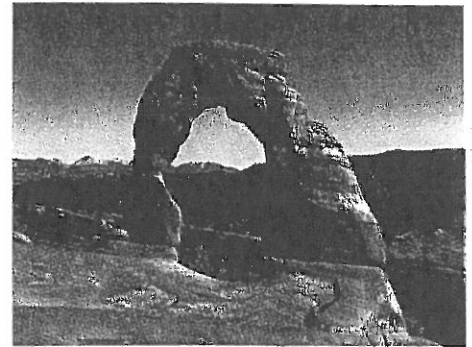
Materials and their properties

Earthworms burrow through the soil creating tunnels for water and air to reach the roots of plants.

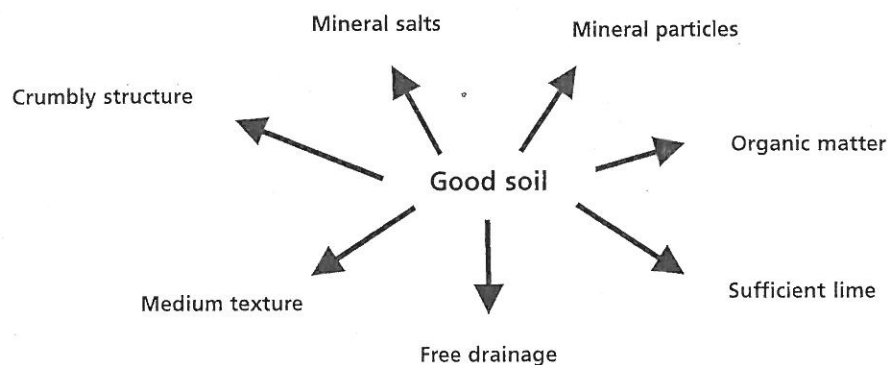


Minerals and ores: We acquire the materials we need for building and manufacturing from the first few miles into the Earth's crust. As well as the fossil fuels, oil, coal and gas, we get other useful materials such as iron and aluminium, which are found combined with other materials as ores, and also building materials such as stone, sand and gravel. Some materials such as gold are so unreactive that they are often found in their natural states as elements and not combined with other materials.

Soils: All soils are composed of four basic components: mineral particles, organic matter, air and water. Mineral particles are the non-living skeleton of the soil and come from the decomposition of rocks caused by erosion due to weathering. Organic matter is a mixture of living organisms and dead, decomposed organisms (both animal and vegetable) which form humus. Bacteria in the soil decompose the humus material to form mineral salts that dissolve in the water and are taken up by the roots of the plants as nutrients. Earthworms burrow through the soil creating tunnels for water and air to reach the roots of plants. The worms also help to churn up the soil as they burrow, bringing new soil to the surface. They also add nutrients to the soil by dragging leaves into their burrows where they are digested and their mineral salts eventually reintroduced to the soil.



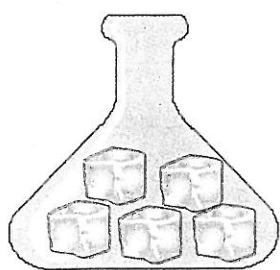
Particles from this stone will end up in the soil as a result of erosion.



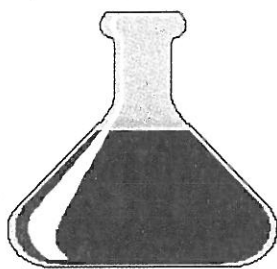
Different soils suit different purposes. Two extreme soils are listed below. Most soils are a mixture of these two extremes, in different proportions.

Type of soil	Properties	Uses
Sandy soil	Feels gritty. Good drainage and easily worked.	Ideal for early crops but a lot of nutrients need to be added to replace those lost because of good drainage.
Clay soil	Feels sticky when moist, has poor drainage and becomes waterlogged easily. It can be hard work to dig.	Not suitable for certain crops because poor drainage causes waterlogging. Better for use in the building industry.

The states of matter: Solids, liquids and gases are the three states of matter. If a solid, liquid and gas are placed in three containers then the following will happen.



The solid retains its own shape and volume.



The liquid flows into the shape of its container but its volume doesn't change. the liquid has a surface.



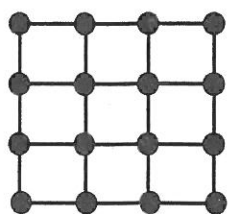
The gas flows into the shape of its container and will spread out until it has the same volume as the container.

Liquids and gases can flow and spread out leaving no gaps between them and the sides of the container they touch. The distinguishing question is how well does the substance hold itself together when it is released from the container? Solids keep their shape, liquids run, gases spread out everywhere. Some thick liquids like syrup and sauce flow very slowly. Very fine solids such as sugar and sand seem to flow but are not liquids. When these are studied under a hand lens they can be seen to be made up of very small solid lumps. There are gaps between these lumps of solid and the sides of the container they touch, and they tumble over each other if they are tipped out.

Solids keep their shape, liquids run, gases spread out everywhere.

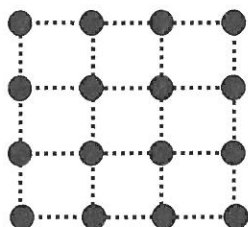
The different states can be explained by the strength of bonds between the particles of the substance. In a solid the bonds are strong and the particles' movement is limited to small vibrations. In a liquid the bonds are weaker and allow more movement. There are very weak, negligible, bonds in the gaseous state and the particles can move in any direction independently of each other.

Solid



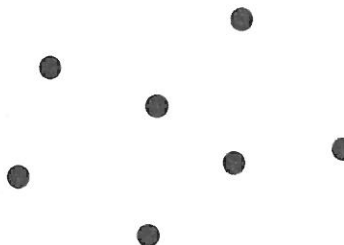
Ice: strong bonds between particles

Liquid



Water: weaker bonds

Gas



Steam: negligible bonds

Although the spaces between the particles may increase and decrease (expansion and contraction) when the substance is heated or cooled, the particles themselves do not change size or shape.

Materials and their properties



Steam is an invisible colourless gas and should not be confused with the 'steam' we can see from a bath or kettle, which is mostly liquid water droplets suspended in the air.

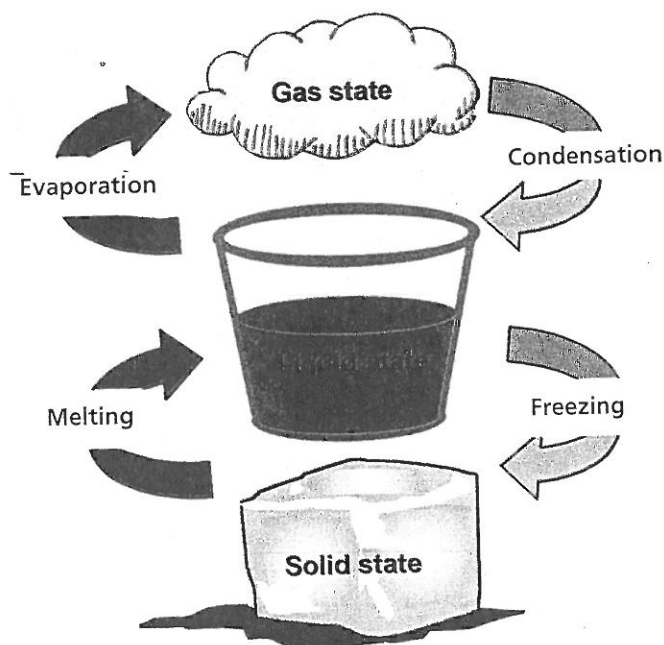
2. Changing materials

Heat and temperature: Temperature is a measure of how hot a thing is and heat is a form of energy. A cup of tea at 60°C is more likely to burn you than a spark from a fire at 800°C because the tea has a greater amount of heat energy in the greater mass of material, although it is at a lower temperature. Hot things cool down because heat energy always flows from a higher temperature to a lower temperature. Since our bodies are 'normally' at the fairly high temperature of 37°C and our surroundings are normally at a lower temperature we lose heat to our surroundings. When we touch objects at lower temperatures than ourselves we lose heat to them. If the material is a good conductor of heat (like metal) it takes heat from us quickly, and as we lose heat to it we perceive the object as being cold. Objects made of poor conductors of heat like woods, plastics and textiles do not take heat away from us and so they feel warm. A very low temperature of -88.3°C has been recorded in Antarctica and a very high temperature of 58°C was once recorded in Libya. The lowest temperature possible is thought to be -273°C . This low temperature could only be achieved in a laboratory or in very deep space far away from any heat and light from stars. At this temperature the particles (atoms) would have absolutely no energy at all and even the electrons that normally orbit the outside of an atom would not be able to as they would have no movement energy. There is no theoretical upper limit to temperature that we know of yet.

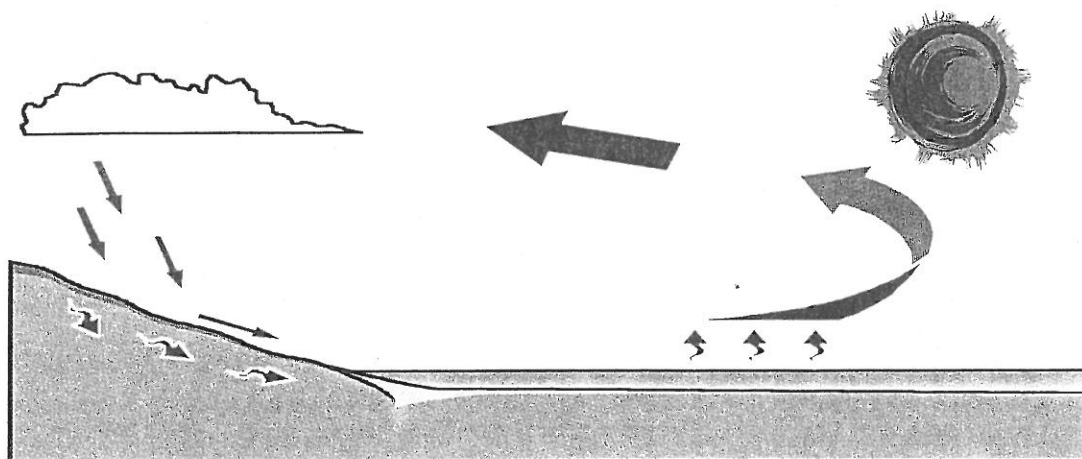
Physical changes: Changes to materials can be physical or chemical. A physical change like squashing a piece of paper only alters the shape of the object while the material remains the same, and it can usually be reversed.

Changes of state are reversible, physical changes. The chemical composition of the substance remains the same, although it can exist in three states. Water is the most available and familiar example for considering change of state, but there are pitfalls in discussing it, as the same word 'water' applies both to the chemical substance and to the liquid state of this substance. Water is always the chemical compound H_2O , although it can exist in three states, ice, water and steam. (Steam is an invisible colourless gas and should not be confused with the 'steam' we can see from a bath or kettle, which is mostly liquid water droplets suspended in the air.)

When ice is heated enough it will eventually melt, change state and form (liquid) water. If the water is then heated it will evaporate, change state and form steam. These physical changes of state are reversed when the steam cools (loses heat), condenses and forms water. If the water continues to cool it will freeze and form ice.

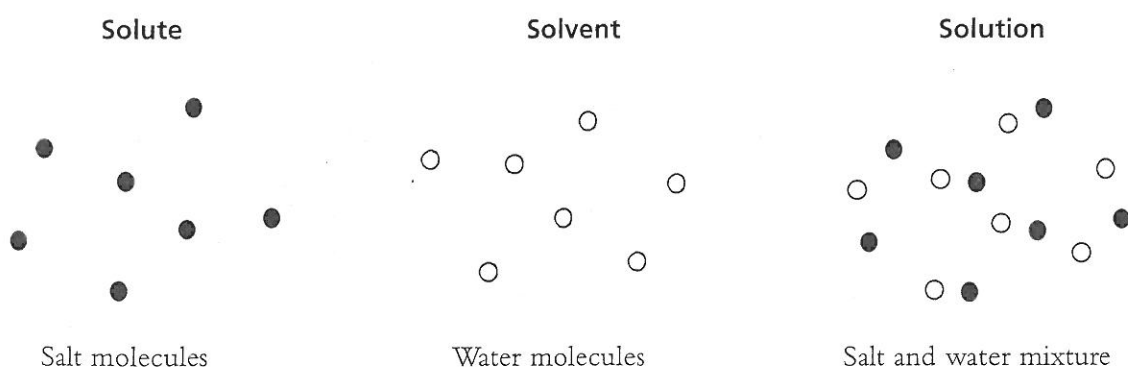
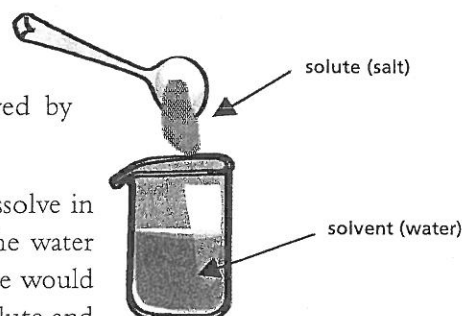


The water cycle: The water cycle is an example of a series of reversible changes. The water in the seas evaporates into the air as it is heated by the Sun and then it condenses to form water droplets and forms clouds. It rains and the water falls back to the seas or land.



Solubility and insolubility: Dissolving is another kind of physical change. A solid is added to a liquid (solvent) to produce a solution. The solid is also known as the solute. The process is reversible: the solvent can be removed by evaporation, leaving the solute.

Some solids dissolve in water and are therefore soluble; other solids do not dissolve in water and are insoluble. In the case of salt and water, salt can be dissolved in the water easily. If we could take a look at what the salt and water particles were doing, we would see that the salt particles fit into the spaces between the water particles. The solute and the solvent can be made from particles of different sizes and the particles of the solvent can be smaller than those of the solute, for example sugar.



It is possible to keep adding a soluble solid like salt to water until all the spaces between the water particles are full. When this happens the solution becomes 'saturated' and any more salt that is added will sink to the bottom.

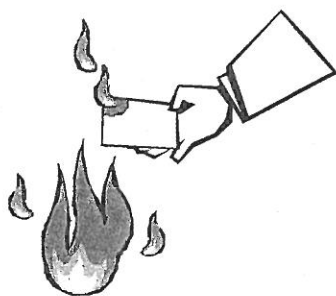
Soluble in water	Insoluble in water
salt sugar 'health' salts	sand flour plaster of Paris

Materials and their properties

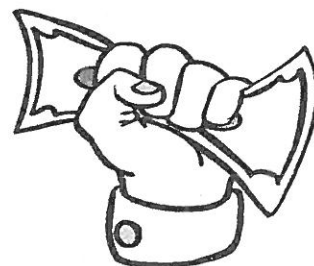
Dissolving involves two substances, the solvent and the solute interacting, whereas melting is the change of state of one substance on its own.

Sand is not soluble in water at all. We can think of the sand particles as being too large to fit into the spaces between the water particles, although the explanation of it is really more complex. When an insoluble material like flour is added to water and mixed, it turns the water milky white. The flour has not dissolved in the water or fallen to the bottom of the container; it is actually suspended in the solvent. This type of mixture is called a suspension. Milk is formed by tiny droplets of white fat suspended in water that are too small to sink to the bottom (due to being continually 'bumped' by the movement of the water particles) and too large to dissolve. This type of mixture (liquid suspended in liquid) is called an emulsion, like emulsion paints. Dissolving is often confused with melting: dissolving involves two substances, the solvent and the solute interacting, whereas melting is the change of state of one substance on its own. Heat is essentially absorbed by a substance for it to melt. Warming a solution can help the dissolving but it is not an essential part of the process.

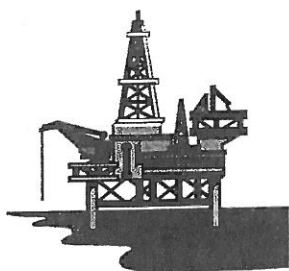
Chemical changes: A chemical change produces a new substance and cannot be reversed, for example burning a material like wood or paper.



Burning money is a chemical change that cannot be reversed, but squashing money is a physical change that can be reversed.



Fossil fuels: Burning of fossil fuels is also an example of irreversible change. Oil and gas are made from the remains of tiny animals and plants that lived up to 500 million years ago. Coal is formed from the remains of plants and very small animals that lived on the land around 250 million years ago. When fossil fuels burn in air they are reacting with the oxygen in the air to form new substances and releasing energy as heat and light. This is a chemical reaction and cannot be reversed. Fossil fuels are in danger of being completely used up. Fossil fuels are burned in power stations to release heat energy to turn water into steam that turns turbines and produces electricity. Carbon monoxide, sulphur dioxide and nitrogen oxide are examples of substances released when fossil fuels burn. All these substances are pollutants. Sulphur dioxide can form sulphuric acid which, when released into the atmosphere, increases the acidity of rain which is then known as 'acid rain'. It is predicted that the global supply of fossil fuels will largely run out by 2050.



3. Separating mixtures of materials

Mixtures and separation: Mixtures can be solid-solid, liquid-liquid, gas-gas or any combination of each state. Mixtures can be returned to their original constituents by a variety of physical means.

Magnetically: A simple bar magnet can be used to separate a mixture where one of the constituents is magnetic, e.g. iron and wood.

Sieving: A sieve can be used to separate any solid-solid mixture where the constituents are different sizes, e.g. sand and peas.

Flotation: Adding water to a mixture of solids may allow one solid to float and then it can be skimmed off, e.g. sand and sawdust.

Filtering and evaporating: A mixture of two solids can be separated if one of them is soluble in water, such as a mixture of salt and sand. Water is added and the soluble solid (salt) dissolves; the insoluble solid (sand) sinks to the bottom. It can then be removed by passing the mixture through filter paper (paper with very small holes in it). The insoluble solid is trapped on the paper and the soluble solid passes through with the water. This can then be separated by allowing the water to evaporate, leaving the solid behind.

Decanting: A mixture of liquids of different densities can sometimes be separated by pouring off the layers in order, e.g. oil and water. A solute which dissolves in one layer can similarly be removed and separated from its solvent by evaporation.

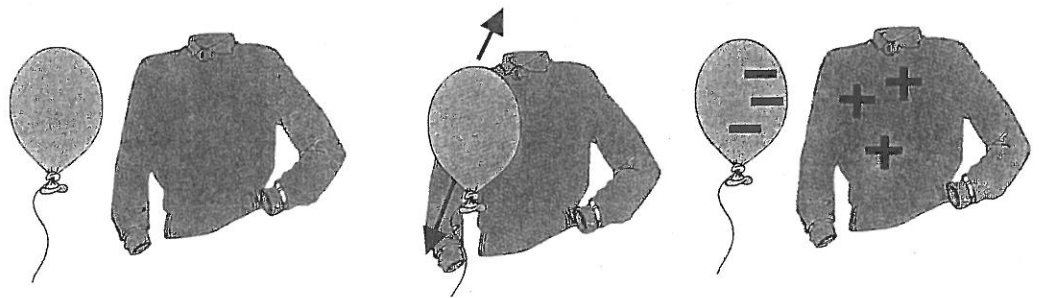
Distillation: This technique makes use of the fact that different liquids in a mixture of liquids, e.g. water and alcohol, have different boiling points. The mixture is heated. When it reaches the boiling point of one of the components, that liquid evaporates and the gas is led off to a cold part of the distillation apparatus. There the gas condenses back to the pure liquid (e.g. alcohol), separate from the other liquid (e.g. water) of the mixture. Crude oil contains many dissolved solids and liquids which can be separated by fractional distillation. This involves the oil being heated, gradually raising the temperature. Each component is tapped off as it reaches its boiling temperature, evaporates into a gas, is piped away, and then cooled to condense and form a liquid.

Crude oil contains many dissolved solids and liquids which can be separated by fractional distillation.

Physical processes

1. Electricity

Static electricity: Rubbing a balloon on a jumper can cause some of the electrons from the jumper to be rubbed onto the balloon. This leaves the jumper with a positive charge and the balloon with a negative charge. This type of electric charge is called 'static electricity'. Some uncharged materials, such as paper, will now be attracted to these 'extra' charges on the balloon and jumper; the balloon and jumper would also be attracted to each other.



Lightning and thunder: Lightning is thought to be caused by the movement of tiny ice particles in clouds. Very large charges build up and the negatively charged electrons can then be conducted through the air to the ground as lightning. The thunder is caused by the rapid expansion, due to heating, of the air created by the speeding electrons passing through it.

Lightning was shown to be electricity by Benjamin Franklin (1706–1790). Franklin invented the lightning conductor, which is a piece of metal fastened to the top of a roof and connected to the ground by a metal cable. The lightning conductor attracts lightning, as it is a better conductor than air, preventing it from hitting the roof and from passing through building materials. The lightning is conducted safely through the cable to the ground.



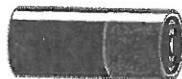
The flow of electrons as a current is what we would normally consider to be 'electricity'.

Current electricity: Electrons in the orbits of metal atoms can be made to move and 'flow' very easily when they are 'pushed' by the electric force from a battery or another electrical source such as a dynamo or van de Graaff generator. The flow of electrons as a current is what we would normally consider to be 'electricity'.

Electrical circuits: Electricity is the most commonly used form of energy to power appliances in the home. Electricity can be transmitted down cables from power stations to our homes, where the most common access to electrical energy is via electrical sockets. Appliances in the home change electrical energy into useful forms of energy. For example, a toaster changes electrical energy into heat (and light) energy, and a light bulb changes electrical energy into light (and heat) energy. Batteries (a single battery is sometimes referred to as a cell) are a source of portable electrical energy. Technically, the battery stores chemical energy that is converted to electrical energy when the battery is used. Solar cells change light energy directly into electrical energy. Electricity flows from these sources in the form of an electric current.

To build a working electrical circuit the following components would be needed:

1. A source of electrical energy such as a battery.



2. A component such as a bulb to indicate the flow of electricity.

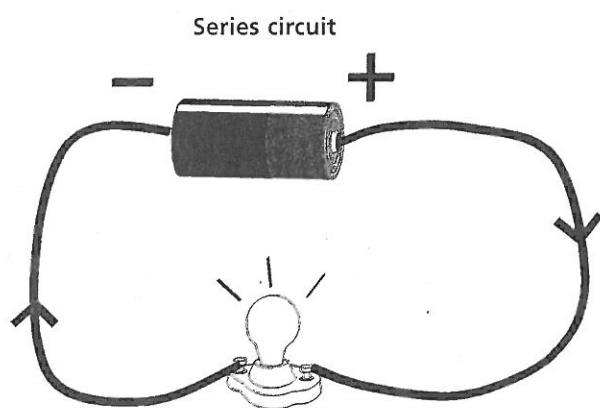


3. Metal wires so that we can construct a complete path of conductors from one side of the battery to the other side.

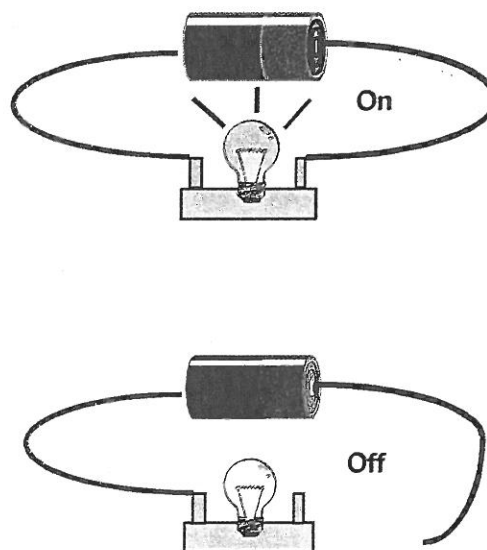


Current: The flow of electricity around a circuit is normally called an electric current. The unit of electrical current, the ampere or amp, is named after the Frenchman André Ampère (1775-1836). In circuit diagrams we put arrows to show the flow of current from the positive side of the supply to the negative side; this is the 'conventional' current direction, which was arbitrarily decided long ago. It is now known that electrons flow from the negative to positive sides. The electrical current, measured in amperes, is a measure of this flow of electrons. This will only happen if there is a complete path of conductors connecting both sides of the battery. If the circuit is not complete, because of an air gap caused by an unconnected wire or component, then the electrical current will not flow at these low voltages. If the voltage is large enough then electricity will flow through virtually any material. This is why we only experiment with low voltages up to a maximum of 12 V. Mains electricity is very dangerous and does kill.

If the voltage is large enough then electricity will flow through virtually any material.



The arrows indicate the flow of current (opposite to direction of electron flow)



Voltage: Voltage can be thought of as the push which forces the electric current around a circuit. The greater the supply voltage pushing the current then the more energy it will have and the bigger the electrical current will be. The unit of voltage, which is the volt, is named after the Italian physicist Alessandro Volta (1745-1827).

Conductors and insulators: Switches can be used to control the flow of current by either completing a circuit and allowing the current to flow, or by breaking the circuit by introducing an air gap. Under normal conditions air is not considered to be a good conductor and it stops the flow of current. By the correct use of switches, any electrical device can be switched on or off. Copper is used for household electrical wiring because it

The unit of voltage, which is the volt, is named after the Italian physicist Alessandro Volta (1745-1827).

Physical processes

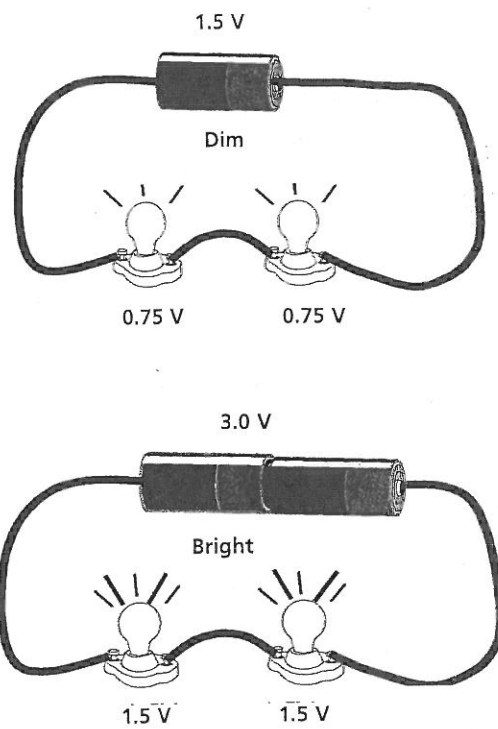
The more components that are connected in series, the less energy will be available for each one.

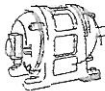
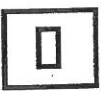
if too many batteries are connected to a bulb, then the bulb will 'blow'.

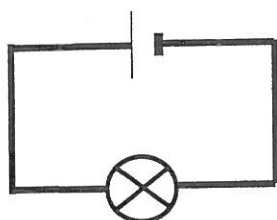
is a good conductor of electricity and is soft enough to be drawn into long cables. Materials that do not allow an electrical current to flow through them easily are called insulators. Air, wood, fabrics, ceramics and plastics are insulators. Household plugs and electrical cables are surrounded by plastic casings and sheathing to insulate people from the electricity flowing in the copper cables. Many household electrical appliances, such as hair driers, alarm clocks and table lamps, have a completely plastic casing to prevent electrical shocks.

Series circuits: When bulbs (or any other components) are connected in series as shown, it is more difficult for the battery to push the electrical energy (that is carried by the electric current) around the circuit. The more components that are connected in series, the less energy will be available for each one. In the case of bulbs, this is indicated by the brightness of all of them decreasing as more bulbs are connected in series. The current remains the same at all parts of the circuit. If two or more batteries are connected in series with each other, they provide more 'push', and the electrical current flowing through the circuit increases. Voltage is a measure of the 'push'. Increasing the number of batteries increases the voltage across the bulb. Two 1.5 V batteries will produce 3 V across a component. If more than one battery is connected to a bulb, then the bulb will become brighter. However, if too many batteries are connected to a bulb, then the bulb will 'blow'. This happens because the filament heats up when the electricity flows through it. If it gets too hot, the metal filament simply melts and breaks the circuit.

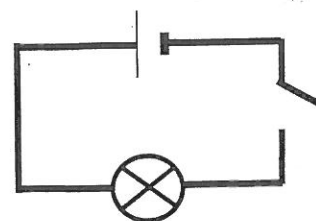
Often symbols are used to represent electrical components such as bulbs, bells and batteries. Some of these symbols are shown below.



Name	Battery	Lamp	Motor	Bell	Switch
Component					
Symbol					

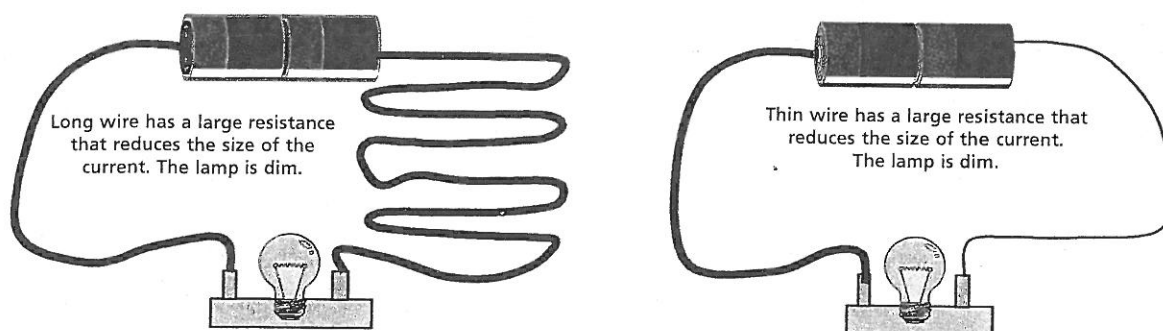


A series circuit drawn using symbols



A series circuit with a switch, drawn using symbols

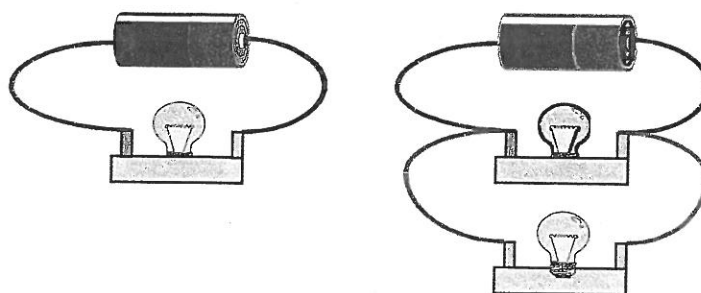
Varying the current in a circuit: Electrical devices such as bulbs and motors can be controlled by switches and batteries. They can also be controlled by changing the characteristics of the wire conductor used in the circuit. Normally the wires that make up an electrical circuit are designed to have as little effect as possible on the current flowing through them. In practice, however, the electrical current loses some energy as heat as it flows through wires. The amount of difficulty experienced by the current as it flows through a wire is called resistance.



Using a long or thin wire will decrease the size of the current and the brightness of the bulb. Longer wires have more resistance than short ones and thin wires have more resistance than thick ones. Long thin wires will therefore have the greatest resistance.

The greater the resistance a wire has, then the smaller will be the size of the current flowing through it. The thinner and longer the wire is, then the more resistance it will have. Wires made of different materials have different resistance. These wires can be used to control electrical components such as the brightness of a bulb or the speed of a motor, by varying the length of the wire in the circuit, by a rheostat (variable resistor).

Parallel circuits: Connecting bulbs in parallel with each other also connects the bulbs directly to the battery. The more alternative routes, the easier it is to push, there is more flow and all the bulbs are bright. The brightness of the bulbs is not affected by adding more bulbs to the circuit as long as they are in parallel with each other. House lights are connected in a parallel arrangement. This has the advantage that if one goes out, or is removed, then the others stay on and are unaffected, i.e. the electrical current flowing to a bulb does not have to flow through any of the others.



The lamps in each circuit will shine equally bright.

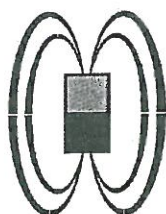
2. Forces and motion

Types of force

Forces: Forces can be described as either pushes or pulls. For example, we push children's swings to move them forward and we pull doors closed. Both these phrases describe forces. We often use alternatives to 'push' and 'pull' to describe forces. Some of these are twist (a push and pull), tear, drag, squash and squeeze. If we push something to try to move it, even if it does not move, we are still exerting a force. If a book is resting on a table, it is pushing downwards, exerting a force on the table.

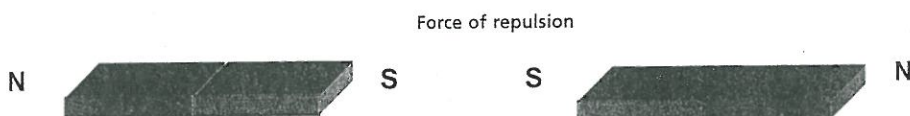
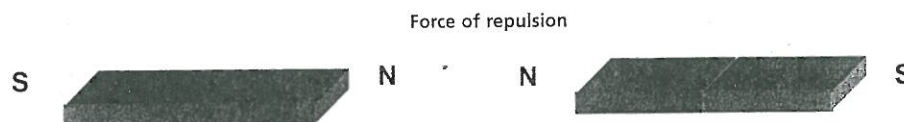
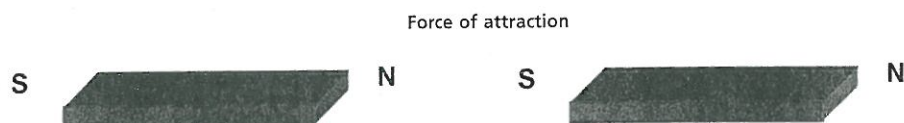
Physical processes

Magnetism: Of the one hundred or so elements known, the only ones which are attracted to magnets are iron, nickel and cobalt, which are all metals. Steel is mostly made from iron and so objects made from, or containing, steel will be attracted to magnets. A lot of the metal objects in a room will consist of steel, including desk and chair legs, scissors, sharpener blades, and radiators. Coins do not normally contain iron, nickel or cobalt, so these will not be attracted to the magnets. Some newer coins are magnetic as they include a steel core.



If a magnet is broken in two, then two magnets, each with a north and south pole, will be created.

The area around a magnet where it has an effect is called its 'magnetic field'. This magnetic field stretches out from the magnet forever, but the strength of this magnetic field decreases with the distance from the magnet. The ends of a magnet are called poles, a north pole and a south pole. If a magnet is broken in two (not necessarily equal halves) then two magnets, each with a north and south pole, will be created.



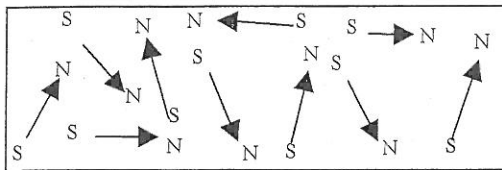
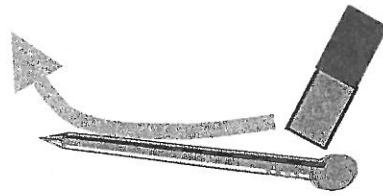
The magnetic force produced by a magnet is strongest at its poles and becomes weaker the further away from them. 'Opposite' poles of magnets produce a force of attraction between them and 'like' poles produce a force of repulsion between them.



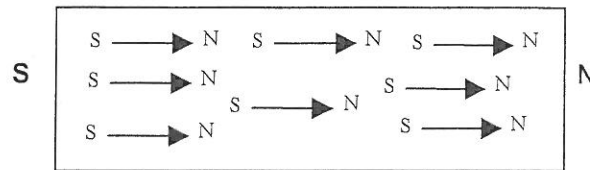
The Earth also has a magnetic field similar to a bar magnet. If a magnet is allowed to swing freely as in a compass, the force exerted on the compass needle by the Earth's magnetic field will force it to orientate itself in a north-south direction. The full names of the poles of a magnet are 'north-seeking pole' and 'south-seeking pole', as the N and S poles seek, or are attracted by, those respective poles of the Earth. The first compasses were made from a naturally occurring magnetic material (iron oxide) called lodestone that was used for navigation by the Chinese long ago.

Making magnets: A magnetic material such as an iron nail can be magnetised by repeatedly passing a magnet along it in the same direction. It is thought that the atoms making up the nail are themselves magnetic but they are positioned in a random way and their magnetic poles point in all different directions, cancelling out the effects of each other. When a magnet is used to magnetise the material, its magnetic field pulls these 'atomic' magnets into

alignment, enabling the effects of their magnetism to add together creating a magnet. Magnetised nails do not retain their magnetism for very long. Magnets that are bought from suppliers are made by placing iron bars in very strong magnetic fields created by powerful electromagnets.



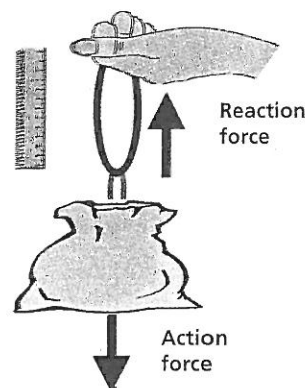
An unmagnetised magnetic material. The atoms' individual poles are pointing at random.



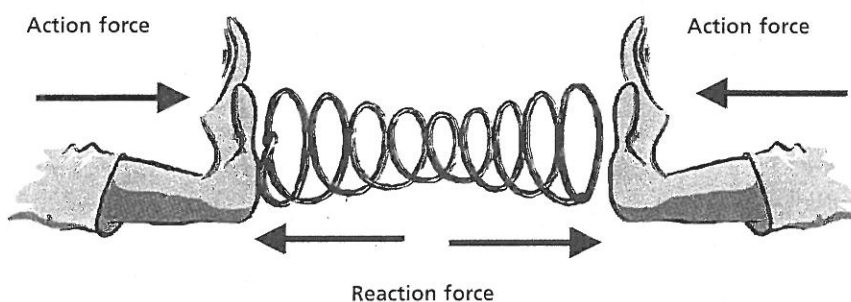
A magnetic material after stroking has caused the individual atoms' poles to line up.

Measuring forces: Forces are measured in units called newtons, named after Sir Isaac Newton (1642-1727). Springs are good for measuring the size of pulling forces because they stretch when pulled. The length of the stretch is proportional to the size of the pulling force and the spring will return to its original length when the force is removed. A spring used in a forcemeter to measure the size of pulling forces works in this way.

When springs are compressed they exert a pushing force on whatever is compressing them. The extent of the spring's compression could be used to measure the size of a pushing force, as in a compression forcemeter.



The length of the stretch is proportional to the size of the pulling force and the spring will return to its original length when the force is removed.



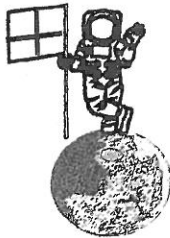
Gravity and weight: Objects are pulled downwards because of an attraction between them and the Earth. This force of attraction is called gravity. Our weight is a result of the Earth's gravity pulling us downwards towards the centre of the Earth. Every object has mass. Its mass is a measure of the object's inertia, that is how difficult it is to start or stop the object moving. You can think of mass as the amount of 'stuff' in the object; it depends on the quantity and types of atoms that make up the object. Mass is measured in kilograms and it remains the same wherever the object is. Weight is the pull of the Earth on the object; it is a force, so it is measured in newtons. For each kilogram of our mass there is a force of around 10 newtons (N) pulling us downwards. Thus, someone with a mass of 65 kg will be pulled by a force of 650 N.

If an astronaut with a mass of 65 kg went to the Moon he would still have a mass of 65 kg but his weight (the Moon's pull of gravity on him) would be around 110 N. The Moon's pull

Physical processes

of gravity is around 1/6th of the Earth's because the mass of the Moon is smaller than the mass of the Earth. The astronaut's weight on the largest planet, Jupiter, would be 1690 N. Normally we do not describe our weight in newtons. We tend to use our mass to describe our weight, that is, if our mass is 65 kg we will say our weight is 65 kg instead of 650 N.

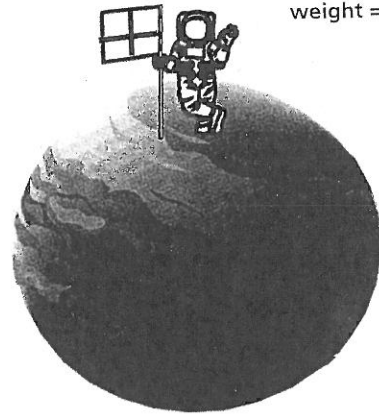
On the Moon
mass = 65 kg
weight = 110 N



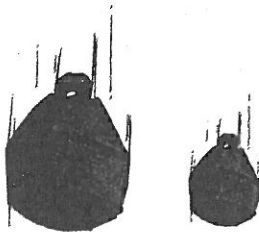
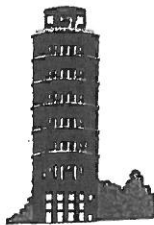
On the Earth
mass = 65 kg
weight = 650 N



On Jupiter
mass = 65 kg
weight = 1690 N



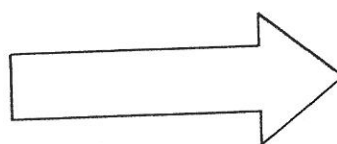
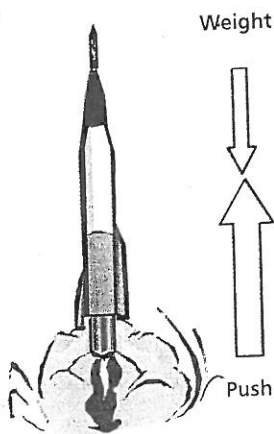
If air resistance is ignored, then all objects, regardless of their mass, will fall towards the Earth at the same rate.



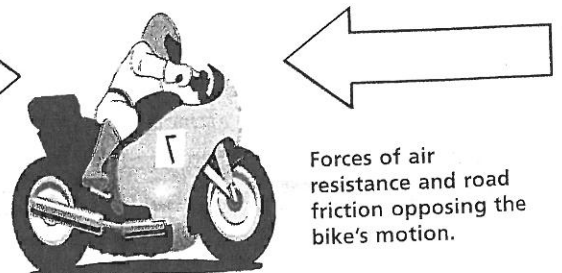
Each kilogram of mass has 10 N pulling it downwards. Both masses therefore fall at the same rate.

If air resistance is ignored, then all objects, regardless of their mass, will fall towards the Earth at the same rate. This was demonstrated by the famous experiment of Galileo (1564-1642) when he allegedly dropped different masses from the tower of Pisa. They both hit the ground at the same time after falling from the same height. This was evidence that they fell at the same rate. This happens because each kilogram of mass within each object has the same force of 10 N pulling it downwards.

Effects of forces: Objects have several forces acting on them at the same time. When one of the forces acting on an object is larger than the other force(s) acting on the object, then the object will accelerate in the direction of the larger force.



Larger engine force causes the motor bike to speed up.



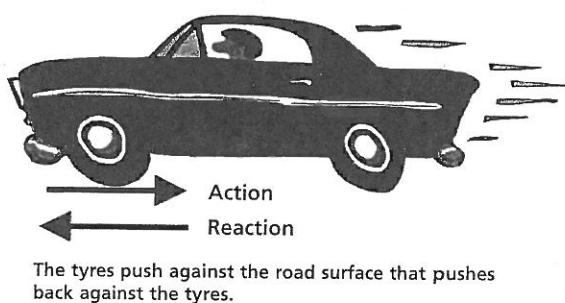
Forces of air resistance and road friction opposing the bike's motion.

The upward force from the rocket's engine is larger than the downward force of gravity. The rocket accelerates upwards. The force pushing the bike to the right (in picture above) is larger than the resistive forces to the left. The bike will therefore accelerate to the right. If the larger force is in the opposite direction to the object's motion then the object will slow down (decelerate).

When one force is larger than the others (as above), then this is often referred to as an unbalanced force. An unbalanced force can also cause an object to change direction and change its shape. For example, volleying a tennis ball applies a force that changes the ball's direction and squashing a can applies a force that changes the shape of the can.

When forces are acting on an object, but no movement results, the forces are said to be balanced. When a cup is on a table, the weight of the cup is pushing down on the table, but the table is pushing up with an equal force. If you lean, pushing against a wall, you can feel the wall pushing back on you, and neither you nor the wall fall over.

Force pairs: Whenever there is a force which makes something move (an action force) there is always another force acting in the opposite direction to this force (a reaction force). For example, if you hit an object forward (an action force) then you feel the object exert a force on you (a reaction force). A car moves forward because the tyres push the road surface backwards and, in return, the road surface pushes the car forward.

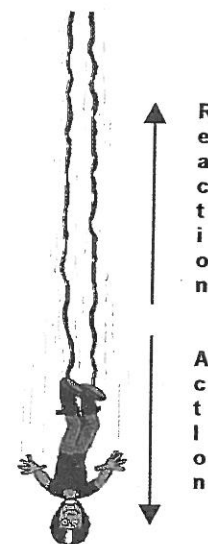


A propeller-driven boat works by pushing water back and, in return, the water pushes the propeller (and boat) forward.

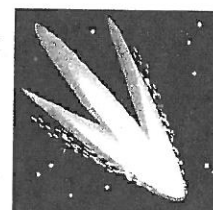
When an elastic band is stretched, it exerts a force in the opposite direction (pushing on the bundle of papers held by the band, for example) but this is equal in size to the force causing the stretch. When a spring is compressed it also exerts a force in the opposite direction but equal in size to the force causing the compression.

Friction: The force of friction occurs when two surfaces rub against each other. Friction is a force that tends to oppose any moving object's motion, slowing it down. For example, if you push a coin, which is lying flat, across a table it will soon come to a halt. This is because of the friction between the coin and the table's surface as they rub against each other. If you could throw the same coin in space, where there are no particles to cause friction, the coin would continue to travel away from you. The planets continue to travel around the Sun without any noticeable slowing down because there is no friction to oppose their motion. They do not travel in straight lines because of the effect of the Sun's gravity pulling on them.

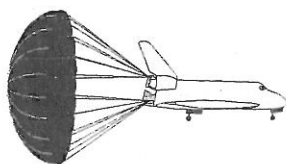
Friction can be reduced by the use of wheels or rollers and by the use of oil and other lubricants. These reduce the amount of surface area of the two materials rubbing together. Friction may prevent an object from starting to move. Friction is useful if you want to get a grip on something, start moving or stop. It is not useful if you want to slide quickly down a slide or if you want to 'free wheel' on your bicycle. Friction is also the force that rubs the graphite off pencils and sticks it to paper when we write. If you rub your finger against a desk top, the skin on your finger begins to feel as if it's burning. When a space ship or meteor enters the Earth's atmosphere the friction caused by it rubbing against the air (air resistance) causes much of the object's movement energy to turn to heat. This causes meteors to burn up and fall as shooting stars. It is also the way the space shuttle's speed is reduced for landing.



Friction is a force that tends to oppose any moving object's motion, slowing it down.



Physical processes



Many fast-moving animals have become streamlined over time due to natural selection.



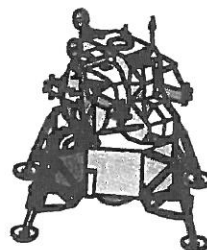
The space shuttle has special heat-resistant tiles on its outside to prevent the enormous amount of heat energy produced being conducted to the inside.

Air resistance and streamlining: Air resistance is caused by the surface of a moving object moving through the air. As the air rubs or pushes against the moving surface, a force is produced which pushes against the object's motion. Air resistance is a force that opposes the motion of objects as they move through the air. You can feel the effects of air resistance on your movement when travelling quickly on a bicycle or roller skates. The amount of air resistance pushing against a moving object depends mostly on the speed of the moving object and its surface area. The faster the object, then the greater will be the air resistance pushing against it. Cars use up more fuel when they travel quickly because, as they travel faster, the force of air resistance pushing against them increases. More fuel is needed by the engine to produce a larger force to compensate for this and keep the car from slowing down. Parachutists can make use of air resistance to make their jumps last longer. They can change the shape of the parachute to capture as much air underneath them as possible. Fast aircraft and cars sometimes use a parachute which captures air, increasing the air resistance on the vehicle and slowing it down, thus making use of the force of air resistance.

Streamlining is a term used to describe a process of reducing the amount of air resistance acting on an object. Streamlining can be achieved by minimising the surface area facing into the air in the direction of movement by using smooth polished surfaces, and by making the surfaces curved so that air flows around them smoothly to reduce resistance. Streamlining is also used on boats to reduce the effect of water resistance acting against their motion. This not only helps them move more quickly but also reduces the amount of fuel they use. Many fast-moving animals have become streamlined over time through natural selection.



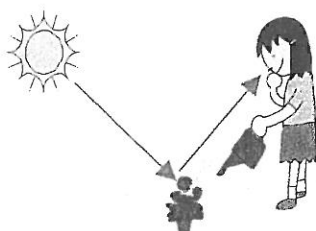
Submarines are very streamlined. It has been suggested that the military study animal shapes to help design the most streamlined craft.



Space craft do not need to be streamlined because there is no air or water in space to resist their movement.

3. Light and sound

Light: Hot objects can be used as sources of light; for example, a filament bulb has a fine piece of metal which becomes 'white hot' when a large enough current of electricity is passed through it. The elements of an electric cooker or toaster glow 'red hot' when an electrical current flows through them. Sources of light can also be created by chemical changes, such as when gas, oil and wood react with oxygen to produce a flame. The light from the Sun is a result of nuclear reactions. Fluorescent tube lighting works on a very different principle from filament bulbs. The electrical current causes the gas in the tube to give off ultra-violet light (invisible to us), which is in turn absorbed by a coating on the inside of the tube which converts the ultra-violet light to white light.



Most objects, such as ourselves, plants or books, are not sources of light. Objects are seen only because they reflect light, say from the Sun, which then enters the eyes of those who can then see the objects. Light reflected off most objects is scattered in all directions, so the objects can be seen by people all around them.

The Sun radiates all the visible colours (red, orange, yellow, green, blue, indigo and violet). If we are seen to be wearing a red jumper, then this is because the jumper's material absorbs the orange, yellow, green, blue, indigo and violet colours of light and reflects only the red light.

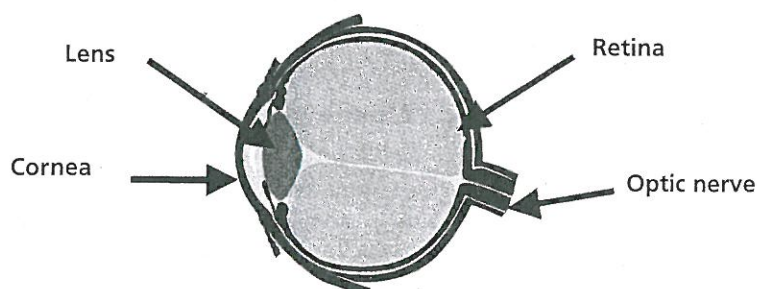
When sunlight, or artificial 'white' light, is shone through a triangular prism the light can be separated into its component colours. The fact that 'white' light was a mixture of other colours was first demonstrated by Isaac Newton. Light travels from a source, such as a flame, in straight lines and at the fantastic speed of around 300,000,000 metres per second (approximately equivalent to 8 times around the world in a second). The Sun is so far away from the Earth that, even at this speed, the sunlight that we see left the Sun nearly nine minutes ago.



Shadows are created behind objects that do not allow light to pass through them, such as a stick or person. These types of objects are made of materials called opaque materials. Materials that allow all or a great deal of the light to pass through them are called transparent materials. Materials, such as grease-proof paper, which allow some of the light to pass through them are called translucent materials.

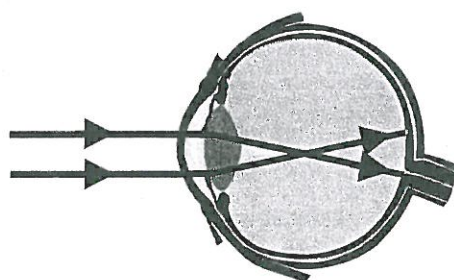
Almost all materials reflect some light from their surface (except for purely black materials) and even black objects reflect some light. Highly polished materials and mirrors reflect light regularly from their surfaces, that is all the light is reflected back in the same pattern and all in the same limited direction. This enables you to see a reflection in a shiny surface, but only from a particular position. Dull or rough surfaces scatter the reflected light in an irregular way, so they do not allow us to see reflected images.

Seeing: Living things have senses that allow them to gain information about the world and to react to changes in their environment. A human has five biological senses: sight, touch, hearing, smell and tasting.



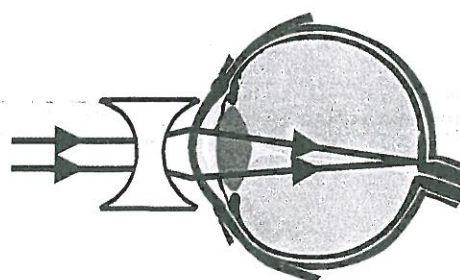
Light enters the eye through the pupil, which is a hole surrounded by the iris. The light is brought to focus by the cornea (in front of the pupil) and the lens (behind the pupil) to give a sharp image on the retina. Light-sensitive cells on the retina change the light energy falling on them into small electrical signals. These travel along the optic nerve to the brain which then turns the signals into an image. The shape of the lens can be changed by muscles around it. This allows us to focus clearly on objects that are close or far away. If these muscles are unable to change the shape of the lens adequately then the image can become blurred. This can be corrected by using artificial lenses such as spectacles or contact lenses.

The first diagram illustrates what happens when someone is short-sighted. The image would be blurred. In the second diagram the diverging lens helps focus the image on the retina giving a clear image. To correct long-sight, a converging lens is used.



Short-sighted eye

The cornea and the lens of the eye bend light too much, so it is brought to a focus in front of the retina, and the image is blurred on the retina.



Corrected with a diverging lens

The diverging lens (glasses) bends light outwards, counteracting the excessive bending inwards by the eye. So light is focused on the retina.

Physical processes



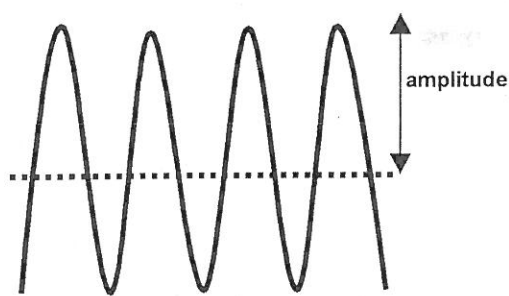
Loudness and pitch of sound: When an object shakes or vibrates in air it causes vibrations in the air itself. We hear sounds because the air vibrations set up similar vibrations in the ear. The vibrations in the air travel outwards, in all directions, at around 330 metres a second (around 740 mph). Sound cannot travel through a vacuum, such as space, as there are no particles to vibrate (or they are too few and far apart). Sound travels most quickly through dense solid materials such as metals, more slowly through liquids such as water and the most slowly through gases such as those making up air.

Musical instruments produce sounds by the use of vibrating strings, as in a guitar, vibrating surfaces, like drums or cymbals, and vibrating air columns as in a flute.

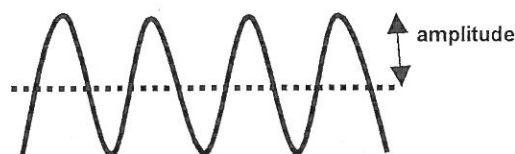
The loudness of these sounds depends on the amplitude of these vibrations (the amplitude is the distance that the air particles move in each vibration). The larger the amplitude of the vibration, as when a drum skin is hit with a large force, then the louder the produced sound will be.

Computer Images

Loud sound



Quiet sound



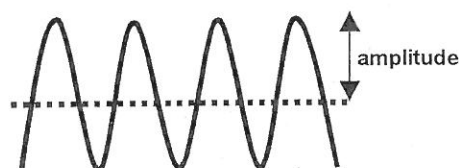
The pitch of sound depends on the number of vibrations per second (the more vibrations per second the higher the pitch of the sound).

A microphone can be used to convert the energy contained in the sound vibration into an electrical signal which can then be displayed as an image on a computer monitor. The images displayed by the computer can be useful in visualising the loudness and pitch of sound.

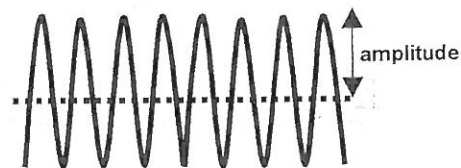
The pitch of sound depends on the number of vibrations per second (the more vibrations per second the higher the pitch of the sound). The pitch of a drum skin will depend on the tightness of the drum skin, and the pitch of a stringed instrument will depend on the length of the string, the thickness of the string and the tightness of the string. The pitch of a wind instrument depends on the length of the vibrating air column (which can be changed by covering up the holes).

Computer Images

Low-pitched note
(low frequency)

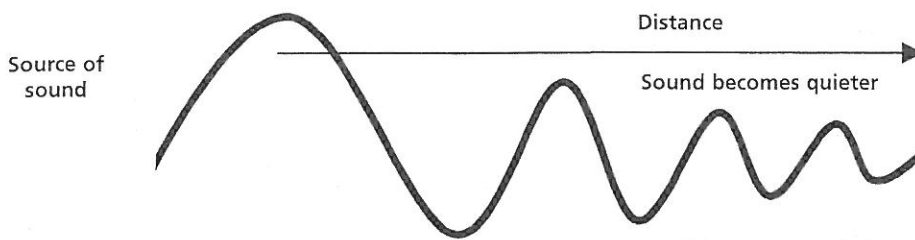


High-pitched note
(high frequency)



The loudness of a sound at a particular point will decrease the further away the point is from the source of the sound. If the distance from the source of the sound is doubled then the loudness of the sound will be reduced to 1/4 of its original level.

Computer Images



Like light, sound can be reflected off surfaces to varying degrees. This is called an echo. Hard, smooth surfaces like stone and metal are good sound reflectors. Soft, rough materials such as fabrics are good at absorbing sound energy.

Hearing: Having two ears helps us to identify from which direction sound is coming. Sound travels through the air as vibrations. These vibrations are absorbed by the ear drum which vibrates in tune with the sound. The vibrations then pass through the middle ear (the smallest bone in the body, the 'stirrup' bone, is found here) and into the inner ear. Cells in the inner ear change the energy of vibration into small electrical signals that travel along the auditory nerve to the brain, which turns the signals into the sensation of sound.

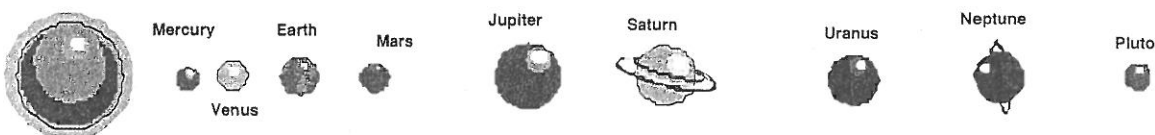
The diaphragm on the bell of a doctor's stethoscope causes air inside the tube to vibrate when it is placed against a patient's body. The sound travels up through the air in the tubes of the stethoscope and eventually reaches the ear pieces and travels into the doctor's ears.

Cells in the inner ear change the energy of vibration into small electrical signals that travel along the auditory nerve to the brain, which turns the signals into the sensation of sound.

4. The Earth and beyond

The Sun, Earth and Moon

The solar system: The Earth is the third planet orbiting a star that we call the 'Sun'. It is thought that the nine planets, the Sun and the moons were created from a swirling cloud of dust around 4600 million years ago. The particles that made up the dust cloud that formed our solar system are thought to have been the remains of stars that had existed long ago and had eventually blown apart as supernovae. (The universe is thought to be between 10,000 million and 20,000 million years old.) The force of gravity pulled the particles of matter together into larger clumps of matter to eventually form our solar system. As the planets originated from the same swirling mass of dust they travel anti-clockwise around the Sun, which is thought to be the original direction of the dust cloud. The Sun, planets and most moons are almost spheres because, as they were forming out of the dust cloud, they were soft and gaseous and the force of gravity pulled them into near-spherical shapes. As the Earth formed from the dust cloud, it was like Jupiter: large and composed mostly of gas, and very hot. As the Earth cooled, it solidified on the outside but it still remains very hot and liquid below the crust.

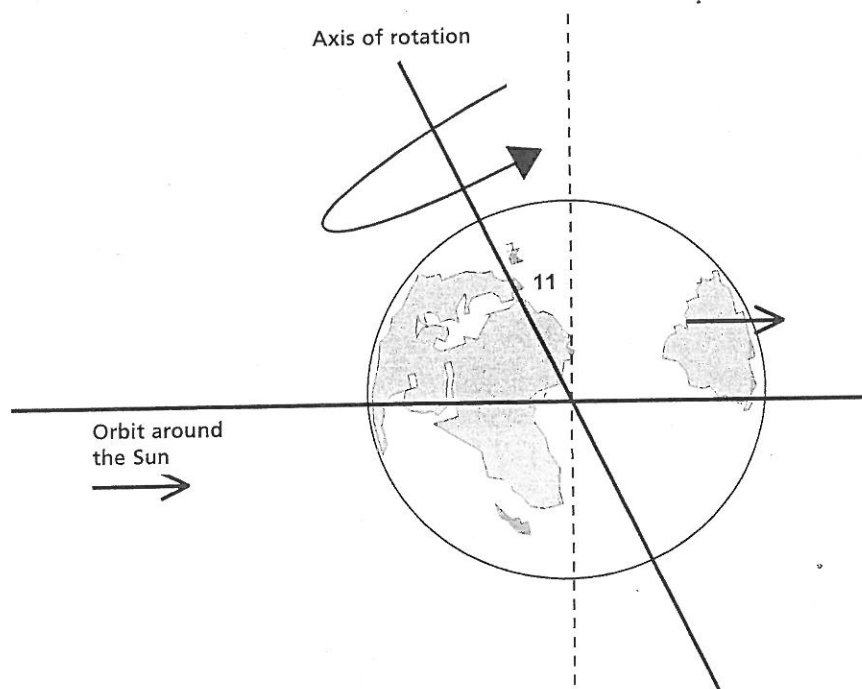


Physical processes

Periodic changes

Night and day: The Earth spins on its axis completing one revolution every 24 hours. It is this spinning that gives us night and day. When the side of the Earth that we are on is facing the Sun, then it is day for us. When the side of the Earth that we are on is facing away from the Sun, then it is night. There are 24 time zones around the Earth. Since the Sun appears to rise in an east to west direction (due to the Earth's rotation), it is morning in Japan before morning in Britain. East coast USA is 5 hours behind, and central Australia is 9 hours ahead, of UK time.

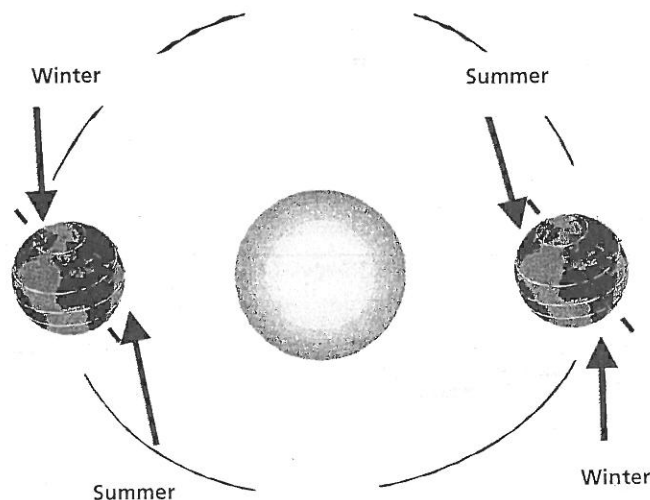
The seasons: The Earth's axis of rotation is tilted at about 11° from its orientation in its orbit of the Sun. As the Earth orbits around the Sun this tilt remains constant.



During our summer the northern part of the Earth that we are on is tilted towards the Sun during the day. The Sun appears to take a long time to cross the sky, and appears high in the sky overhead in the daytime. Due to the angle at which the rays hit the Earth, we receive a lot of the Sun's light and heat energy. In winter the northern part of the Earth is tilted away from the Sun and the Sun appears to be low in the sky, crossing the sky in a short day. We receive less of the Sun's light and heat energy, because of the narrow angle of incidence of the rays.

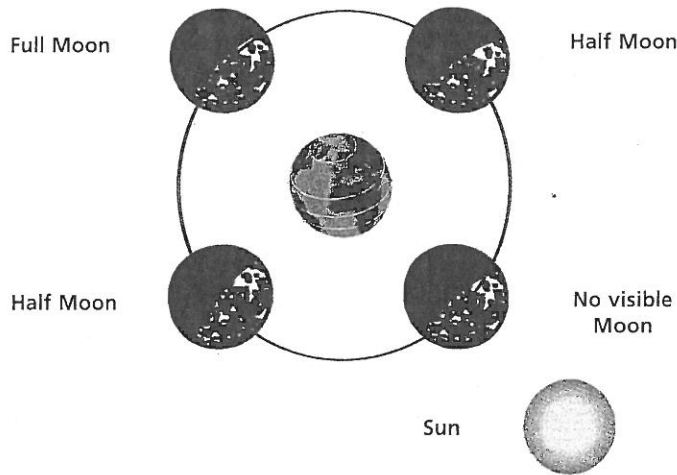
(The actual brightness and temperature of any day in summer or winter also depends on other factors such as cloud cover.)

Our solar system is only one of many star systems in our galaxy, called the Milky Way.



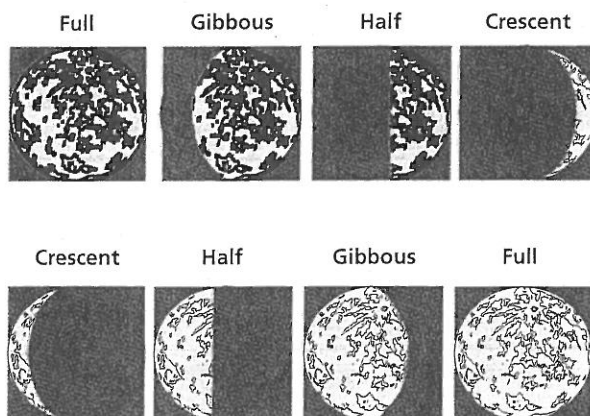
The Earth takes 365 and a $\frac{1}{4}$ days to orbit the Sun. Since we only have 365 days in our 12-month calendar, then each year our dates are a $\frac{1}{4}$ day out. Every 4 years an extra day is introduced on February 29th to compensate for the extra $\frac{1}{4}$ days and that year is called a Leap Year. Our solar system is only one of many star systems in our galaxy, called the Milky Way. There are billions of stars in our galaxy and billions of galaxies like the Milky Way make up the observable universe.

Phases of the Moon: We see the Moon because it reflects light from the Sun. The Moon, whatever it looks like to us, is always half in light and half in dark. The Moon orbits the Earth and is seen from the Earth in different positions relative to the Sun. Sometimes we can see all of the light side, and the Moon is said to be 'full' (when the Sun is behind us on the other side of the Earth). At a later phase we can see half of the illuminated side of the



The amount of the Moon's surface that can be seen from Earth changes over 28 days. The diagram is not to scale.

Moon (when the Sun is over to the side of us, relative to the Moon). The visible area of illumination gets smaller as the Moon goes between the Earth and the Sun, until we are facing the dark side of the Moon. Then, as the Moon continues its orbit we can see increasingly bigger areas of the illuminated side until we see the whole full Moon again. Thus we see varying amounts of the Moon's surface over a 28-day cycle. Certain shapes in the continuous sequence of the changing apparent shape of the Moon are called Phases of the Moon.



The Moon completes one complete orbit of the Earth every 28 days

GLOSSARY

These definitions, while accurate, are by no means comprehensive. If you require a more exact definition, you should consult a scientific dictionary.

Adaptation	The process by which living organisms become fitted to their environments.
Air resistance	The force which pushes against a moving object as it moves through the air.
Ampere (amp)	Unit of measurement of electrical current.
Amphibians	The group of vertebrate animals with smooth damp skin, living on land and in water, such as frogs.
Amplitude	The distance that the air particles move in a vibration.
Angiosperm	Plants that produce flowers as their reproductive organs.
Annelids	The group of invertebrate animals with segmented bodies and no limbs, such as earthworms.
Annual rings	Concentric rings found on the cut trunk of a woody plant, showing yearly growth.
Anther	The end of the stamen (male part of flowering plant) where pollen is produced.
Arachnids	A sub-group of arthropods that have two parts to their body and have eight legs, including spiders and ticks.
Arteries	Tubes through which blood is pumped from the heart to other areas of the body.
Arthropods	The group of invertebrate animals with an exoskeleton and jointed limbs; insects, spiders, crabs and myriapods are examples of arthropods.
Atom	The smallest building block of matter, i.e. all matter is made up of a number of atoms.
Attraction	A word used to describe a force which pulls objects together, for example the magnetic force between a paper clip and a magnet, gravitational force between any object and the Earth.
Bacteria	Microscopic forms of life often associated with disease, although many types of bacteria are harmless and useful.
Battery (cell)	A portable source of electricity, a battery contains chemical energy which is converted to electrical energy when it is used in a complete circuit.
Bell	A device which changes electrical energy to sound energy. A lot of movement energy is also produced.
Boiling	The process of a liquid changing into the gas state, when it is heated to a particular temperature. A rapid form of evaporation in which bubbles of gas are formed in the liquid and they escape at the surface.
Bulb (lamp)	A device which changes electrical energy into light energy. A lot of heat energy is also produced.
Buzzer	A device for changing electrical energy into sound energy.
Canines	Teeth which are found near the front of a human's and other mammal's mouth, which are normally pointed and used for tearing.
Capillary (blood)	Minute subdivisions of arteries or veins carrying blood to and from cells.
Carbohydrate	A food group which is associated with providing the body with energy.

Carbon dioxide	A gas which is found in the Earth's atmosphere and is essential for photosynthesis.
Carnivore	Animals that feed on meat only.
Carpel	The collective name for the female parts of a flowering plant.
Cell	The smallest unit of life. All living things are made up of one or more cells.
Chlorophyll	The chemical which gives plants their green colour and which is essential for photosynthesis to occur.
Chloroplasts	Structures in a plant cell which contain chlorophyll.
Circuit	A system in which a source of electrical energy and one or more component are connected together into a continuous pathway to enable electricity to flow.
Component	Devices such as bulbs, buzzers, bells, motors and switches.
Compound	Two or more different elements joined together to form a new substance.
Condensation	The process of a gas changing into a liquid when it cools. An everyday example is steam from a kettle of boiling water cooling on a cold window and forming water that runs down the window.
Conductor (electrical)	A material, such as a metal, that allows electricity to flow through it easily, without the generation of too much heat.
Conductor (thermal)	A material that allows heat to flow through it easily.
Conifer	Woody plants that produce seeds from cones.
Consumer	An organism which eats another organism. Normally a primary consumer eats plants and a secondary consumer eats animals.
Crustaceans	A sub-group of Arthropods, mostly aquatic, that have a very hard external skeleton and several pairs of legs, such as crabs, shrimps, woodlice.
Current	The flow of electrons around an electrical circuit.
Crystallisation	Formation of crystals by evaporation of a saturated solution.
Cytoplasm	The complex of materials that makes up the structure (other than the nucleus) of a living cell.
Decomposer	Organisms that feed on dead plants and animals and thus recycle nutrients back into the soil.
Dentine	The material making up the main, living, part of the tooth.
Diet	The variety of foods eaten by an organism.
Dissolve	To make a solid or a gas apparently 'disappear' by mixing it with a liquid.
Distillation	A method of separating different liquids by using their different boiling points, collecting each evaporated gas and separately cooling it to form a liquid.
Dynamo	A device that turns movement energy into electrical energy.
Ecosystem	An interactive collection of interdependent organisms and the components of their surroundings.
Electricity	A form of energy which is used to power many devices and appliances such as computers, washing machines, televisions, lights and fridges.
Electron	A small negatively charged particle that orbits the nucleus of an atom.

Element	A substance made up of only one type of atom, e.g. gold, oxygen, iron.
Emulsion	A mixture of liquids where one remains suspended as droplets in the other, as in milk.
Enamel	The hard white material forming the outer part of a tooth, surrounding and protecting the living part of the tooth.
Energy	Energy is not something that can be detected or defined. It is energy changes or transfers that can be detected and which enable machines or living things to do work. For example we receive our energy from the food we eat which contains chemical energy. We are then able to change this energy to do work.
Environment	All the conditions and features, for example, temperature, rainfall, vegetation, of the surroundings of living things.
Evaporation	The process of a liquid changing into a gas when it absorbs heat. For example, water in a kettle evaporates as it is heated, but puddles also evaporate after a time due to heat from the atmosphere.
Fat	Material stored around the body as a reserve energy store and which also helps to keep animals warm. A food group derived from this material from animal and plant sources.
Fertilisation	The process of a male cell joining with a female cell to produce a new organism.
Filtering, filtration	The means by which an insoluble solid and a liquid can be separated through a porous paper. A soluble solid can be dissolved in a liquid and thus separated from an insoluble solid, by filtration followed by evaporation of the filtrate.
Fluoride	A chemical which hardens the enamel and helps protect the tooth from decay.
Food chain	A sequence of living organisms dependent on each other as food.
Food web	A network of two or more interconnected food chains.
Force	An influence which can change an object's shape, direction or speed.
Forcemeter	A device for measuring the size of a force.
Freezing	The process of a liquid changing into a solid when it cools. Different liquids freeze at different temperatures.
Friction	The force which pushes or pulls against a moving object's motion.
Fungi	A group of micro-organisms made from long thread-like structures called hyphae, such as mushrooms, moulds, dry-rot fungus.
Galaxy	A large congregation of stars held together by the force of gravity, for example, our own galaxy, the Milky Way, containing over 100 billion stars.
Germination	When an embryo plant within a seed begins to take in water and grow.
Glucose	A type of sugar. The simplest carbohydrate found in living things. Made in photosynthesis in plants. In humans it is carried in the blood. It is the source of energy for the body when used in all the cells.
Gravity	The force of attraction between objects with mass. For example the Earth's gravity attracts other masses down towards its centre.
Habitat	The place in which an organism lives, for example a woodland or a desert or a more specific location.
Heart beat	The vibration made by the heart as it pumps blood around the body.

Herbivore	Animals that feed on vegetation only.
Humus	Organic material contributing to the structure of soil, resulting from the decomposition of organisms and their products.
Igneous	A type of rock which is formed by its liquid form pushing its way from beneath the Earth's crust, as in the action of volcanoes. On the surface it cools and solidifies.
Incisors	Teeth at the front of the mouth used for cutting food.
Insects	A sub-group of arthropods that have three distinct parts to their bodies and six legs, including ants, bees, flies and beetles.
Insulator (electrical)	A material that does not allow electricity to pass through it easily.
Insulator (thermal)	A material that does not allow heat to pass easily through it, so keeps contained things either hot or cold.
Invertebrates	Animals without backbones, such as insects, worms and snails.
Joint	The place where two bones meet. Joints allow animals to move their limbs.
Ligament	Strong tissue that holds bones together at joints.
Loudness	The intensity of sound due to the amplitude or displacement of a sound wave.
Mammals	The group of vertebrate animals which have a body covering of hair.
Man-made	Any material which is not found naturally, but which uses natural materials in its construction.
Mass	The amount of matter making up an object. A measure of an object's inertia, that is how difficult it is to start it moving or stop it moving.
Melting	The process by which a solid changes to a liquid when heated. Different solids melt at different temperatures.
Metamorphic	A type of rock which has been changed from its original state by being squeezed or being heated to a high temperature.
Microbes	Small living organisms that can only be seen by using a microscope.
Minerals (in diet)	Elements such as iron and calcium which are required for a healthy body.
Mineral particles (in soil)	Very small particles of weathered rock that make up the structure of the soil.
Mineral salts (in soil)	Compounds, such as calcium phosphate, dissolved in water in the soil, needed for healthy plant growth.
Mixture	Combination of two or more substances, not involving any chemical change.
Molars	Teeth at the back of the mouth used for chewing. The smaller molars are called premolars.
Molecule	The smallest particle of a substance that can exist as that substance. Composed of the same (e.g. oxygen molecule composed of 2 oxygen atoms) or two or more different atoms (e.g. water molecule composed of hydrogen and oxygen atoms).
Mollusc	The group of invertebrate animals with unsegmented soft body and often shells, including slugs and snails.
Moon	A natural mass which orbits a planet.
Motor	A device for changing electrical energy, or another form of energy, into movement energy.

Muscles	Organs, which are attached to bones by tendons, which can cause movement of the bones by contracting and relaxing.
Myriapods	A sub-group of arthropods that have long bodies with many legs, including centipedes and millipedes.
Natural materials	Any substances found on Earth which are not man-made.
Natural selection	Process by which living organisms most suited to their environments are most likely to survive and pass on favourable characteristics to their offspring.
Nerve	A collection of specialised cells which allow signals to be passed to and from the brain or spinal cord.
Neutron	A small uncharged particle found in the nucleus of atoms.
Nucleus (of cell)	The control centre of the cell. It contains DNA, the genetic code directing the cell's functions.
Nucleus (of atom)	The central part of an atom composed of protons and neutrons.
Nutrient	Chemicals such as iron and calcium which are essential to life of plants and animals.
Omnivore	Animals that eat both meat and vegetation.
Opaque	Describes materials that do not allow light to pass through them.
Orbit	The circular or elliptical motion of planets around stars, and moons around planets, or electrons around a nucleus.
Ore	A rock containing compounds of metals from which useful metals can be extracted.
Organism	Any living thing, plant or animal or bacterium.
Ovary (of plant)	The female part of the flower where the female eggs are produced. Develops into the fruit after the eggs are fertilised and become seeds.
Ovule	Female egg in ovary of plant, which develops into a seed after fertilisation.
Oxygen	An atmospheric gas. Plants give out oxygen during photosynthesis. Humans and other animals take oxygen from the air they breathe in.
Parallel circuit	An electrical circuit with two or more components such as bulbs connected separately to a source of electricity. Each component can be switched on or off independently of the other.
Particles	Small pieces of materials. Can be used to mean visible pieces, such as grains of salt. Can be used to mean atoms and molecules. Can be used to mean sub-atomic components.
Phases	The sequence of apparent changes in the shape of our Moon during the Moon's monthly orbit, due to the changing visibility of the illuminated area.
Photosynthesis	The process by which plants make food, turning light energy into chemical energy in food.
Pitch (high or low)	The tone of a sound. The pitch of a sound is directly related to the number of vibrations per second produced by the source which is creating the sound.
Planet	A natural body which orbits a star such as our Sun.
Plasma (blood)	Watery liquid containing chemicals in which blood cells and platelets float.
Platelets	Minute particles in blood which form clots and stop bleeding.
Pollen	Grains produced by plants. Each grain contains a male sex cell.

Predator	An animal which kills other animals for food.
Producer	Normally a green plant, which produces food using the Sun's light.
Protein	A food group which is associated with the growth and repair of the body.
Proton	A positively charged particle found in the nucleus of atoms.
Protozoa	A kind of micro-organism, some of which can cause disease.
Pulp	The living inner part of a tooth.
Pulse	The swelling of arteries which can be felt every time blood is pumped through arteries by the heart.
Red blood cells	Carry oxygen to the body cells.
Reflection	The phenomenon of light bouncing off a material. Most objects are 'seen' because light reflects off them, scattered in all directions. A 'reflection', as seen in a mirror, is due to regular reflection of light from a polished surface.
Reproduction	The process by which living organisms produce others like themselves.
Reptiles	A group of vertebrate animals with dry scales.
Repulsion	A word used to describe a force which is pushing objects apart, for example two like poles of magnets will repel each other.
Resistance (electrical)	Opposition experienced by current flowing through an electric circuit.
Rotation	The spin of an object such as a planet around its axis, as in the 24-hour spin of the Earth on its axis.
Saturated solution	A solution that has dissolved as much solute as possible, so that further solute added to it will not dissolve.
Sedimentary	A type of rock which has been formed from another type of rock which was eroded, sunk beneath water and then compressed.
Series circuit	An electrical circuit with two or more components arranged so that the same current flows through each of them in turn.
Shadow	The area behind an object on which no light has fallen.
Solute	A substance which can dissolve in a liquid.
Solution	An intimate mixture of a solute and a solvent, where the solute apparently 'disappears'.
Solvent	A liquid in which a solute can dissolve.
Solar system	One or more planets orbiting a star.
Space	The volume between particles of matter, and between astrological bodies. There is nothing in space.
Stamen	The male part of the flower consisting of the filament and the anther which produces pollen.
Starch	A complex carbohydrate which provides the body with energy.
Stigma	The top of the female part of a flower (carpel).
Stomata	Tiny holes in plant leaves.
Streamlining	The shaping of objects, intended to reduce the force of friction acting against them when they are moving.

Sun	The star at the centre of our solar system.
Suspension	Mixture of insoluble material in a liquid or gas, which remains suspended.
Switch	A device used to control the flow of electricity.
Tendon	Tissue which attaches muscles to bones.
Translucent	Describes materials that allow some light to pass through them.
Transparent	Describes materials that allow all or most light to pass through them.
Vacuole	The part of a plant cell which contains cell sap.
Veins	Tubes which lead blood from all parts of the body back to the heart.
Vertebrates	Animals with a backbone, including amphibians, birds, fish, mammals and reptiles.
Vibration	The regular motion of a moving object (such as a string) which produces sound.
Virus	A type of micro-organism that cannot reproduce by itself, but only by taking over a host cell. Viruses cause many diseases such as flu, chicken pox, cold sores and AIDS.
Vitamins	Chemicals which are required in small quantities for the body to function normally.
Voltage	The force which causes an electric current to flow. Voltage is measured in volts.
Weight	The force of gravity on a mass.
White blood cells	Destroy harmful bacteria in the body.
Wire	A metal conductor used to connect electrical components together to form a circuit.

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