DK Pocket Genius

SCIENCE

FACTS AT YOUR FINGERTIPS

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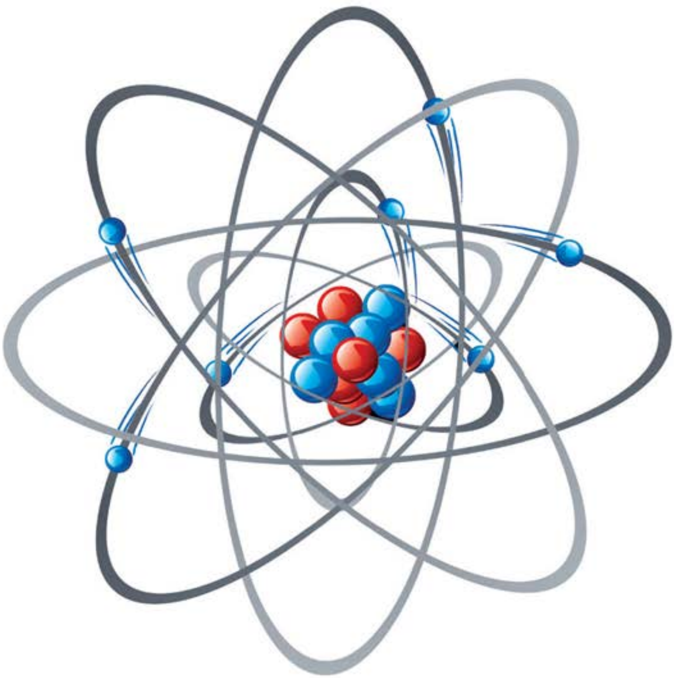

FACTS AT YOUR FINGERTIPS

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What is science?

Science is the study of the universe and everything in it—from the tiny atoms that make up all matter to the forces that build stars and planets. Through the study of science, we have been able to figure out how our planet came to exist and how life on Earth developed. We are even able to work out how the universe might come to an end in the far future.

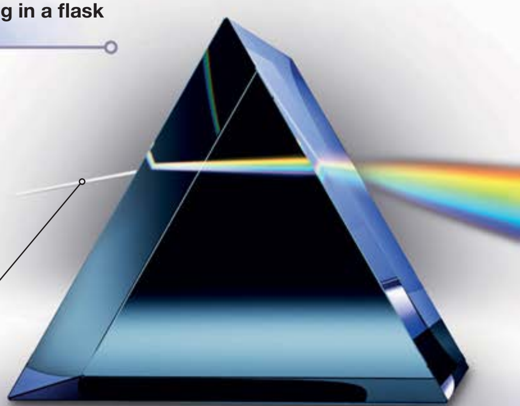
Materials science

Science can be split into three main areas—materials, physical, and life science. Materials science looks at what materials are made of, how they react with each other, how they can be combined to form new materials, and what uses they can be put to. Chemists often conduct research to create useful things rather than simply to learn about the world.

Chemicals reacting in a flask

Physical science

Scientists who study forces, energy, and how they interact try to answer some big questions. How was the universe formed? What are the forces that hold it together? Where does energy come from? What is light made of?



Light is split by a prism

Life science

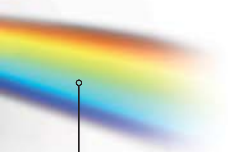
Life scientists study all living things, such as bacteria, fungi, plants, and animals. They observe how organisms live, what they eat, how their bodies work, and how they work together to form different ecosystems.

The eating habits of animals, such as this kingfisher, are studied in life science

What is a scientist?

Scientists discover laws that explain the world around us. They do this by making observations and then coming up with predictions, or hypotheses, for how they think things work. They then test these hypotheses in experiments to see if they fit the evidence.

This scientist is developing new forms of wheat to improve farmers' crops



White light is split into different colors

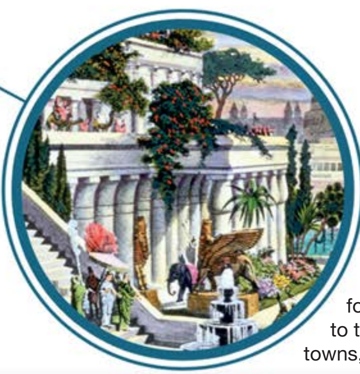
Scientific advances

Some scientific breakthroughs have changed the course of history. Inventions such as the wheel, penicillin, and the World Wide Web have transformed people's lives, while the development of theories on the laws of motion and natural selection have helped build our understanding of the universe.

Inventions and theories

An invention is something that humans have created that did not exist before. But scientists do not just come up with new inventions, they also develop new ways of thinking about how the world works.

c.9000 BCE



Agriculture
The development of farming in Mesopotamia allowed people to settle in permanent communities for the first time. This led to the development of large towns, such as Babylon.

c.3500 BCE

Invention of the wheel
Invented in Mesopotamia, the first wheels were used as potters wheels and were later attached to vehicles for transportation.

c.1200–1000 BCE

The Iron Age
A new method was discovered to extract iron from iron ore through smelting (heating with carbon). Iron tools were harder and sharper than the bronze and stone tools of previous ages.

Invention of paper
The Chinese produced the first paper from a mixture of tree bark, plant fibers, and rags mixed to a pulp and then squeezed flat.

c.50 BCE

c.800 CE

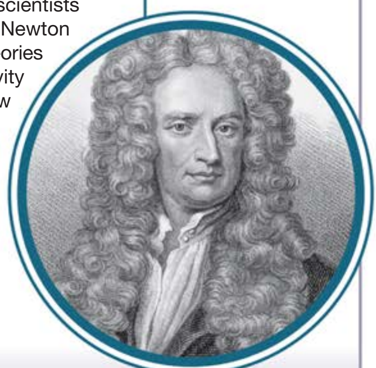
Invention of gunpowder
China was also responsible for gunpowder, an explosive mixture of sulfur, charcoal, and potassium nitrate, which they used in fireworks and firearms.

c.1450

Invention of printing
Johannes Gutenberg invented a new printing process using movable metal letters that made the mass production of books and newspapers possible.

1687

The Laws of Motion
One of the leading scientists of his day, Sir Isaac Newton devised important theories explaining how gravity works and how things move.



1700–1900

The Age of Steam
Steam engines could perform much more work than animals. They were used to power everything from factory machinery to trains and helped kick-start the Industrial Revolution.

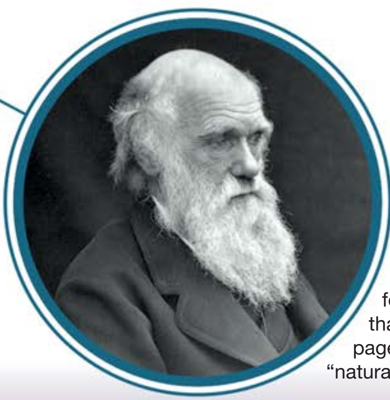
Discovery of polonium and radium
The French-Polish physicist Marie Curie discovered the radioactive elements polonium and radium. Her work on radioactivity paved the way for a new understanding of atoms.

Invention of cars
The invention of the gasoline-powered automobile by Karl Benz at the end of the 19th century eventually brought the Age of Steam to an end.

Albert Einstein
The Theory of Relativity (proposed in 1905 and completed in 1916) put forward by the physicist Albert Einstein fundamentally changed people's understanding of time, space, matter, and energy.

1859 | 1885 | 1895 | 1898 | 1905–16

X-rays discovered
Wilhelm Röntgen discovered X-rays, which can be used to produce images of bones inside the body. This transformed medicine.



Natural selection
In his book *On the Origin of Species*, Charles Darwin put forward the revolutionary theory that species gradually evolve (see page 140) into new forms through "natural selection."

Penicillium mold growing in a Petri dish

Discovery of penicillin
Antibiotics have saved millions of lives. The first antibiotic, penicillin, was discovered by accident by Alexander Fleming, when he noticed a strange mold killing the bacteria in a Petri dish.

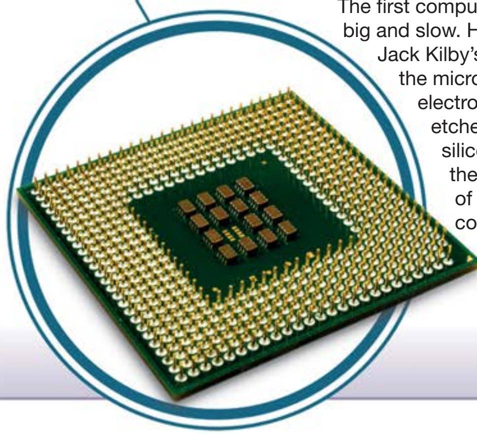
Invention of the World Wide Web
The British computer scientist Tim Berners Lee linked up the world with his invention of the World Wide Web, a global computer communication system that uses the Internet.

1928

1958

1990

Invention of the microchip
The first computers were big and slow. However, Jack Kilby's invention of the microchip (a set of electronic components etched on to a tiny silicon chip) allowed the development of smaller, faster computers.



Everyday science

Science does not just take place in laboratories. It forms part of almost everything we do, whether it is cooking food, playing with plastic toys, speaking to a friend on the telephone, surfing the Internet, or traveling from one place to another.

Play

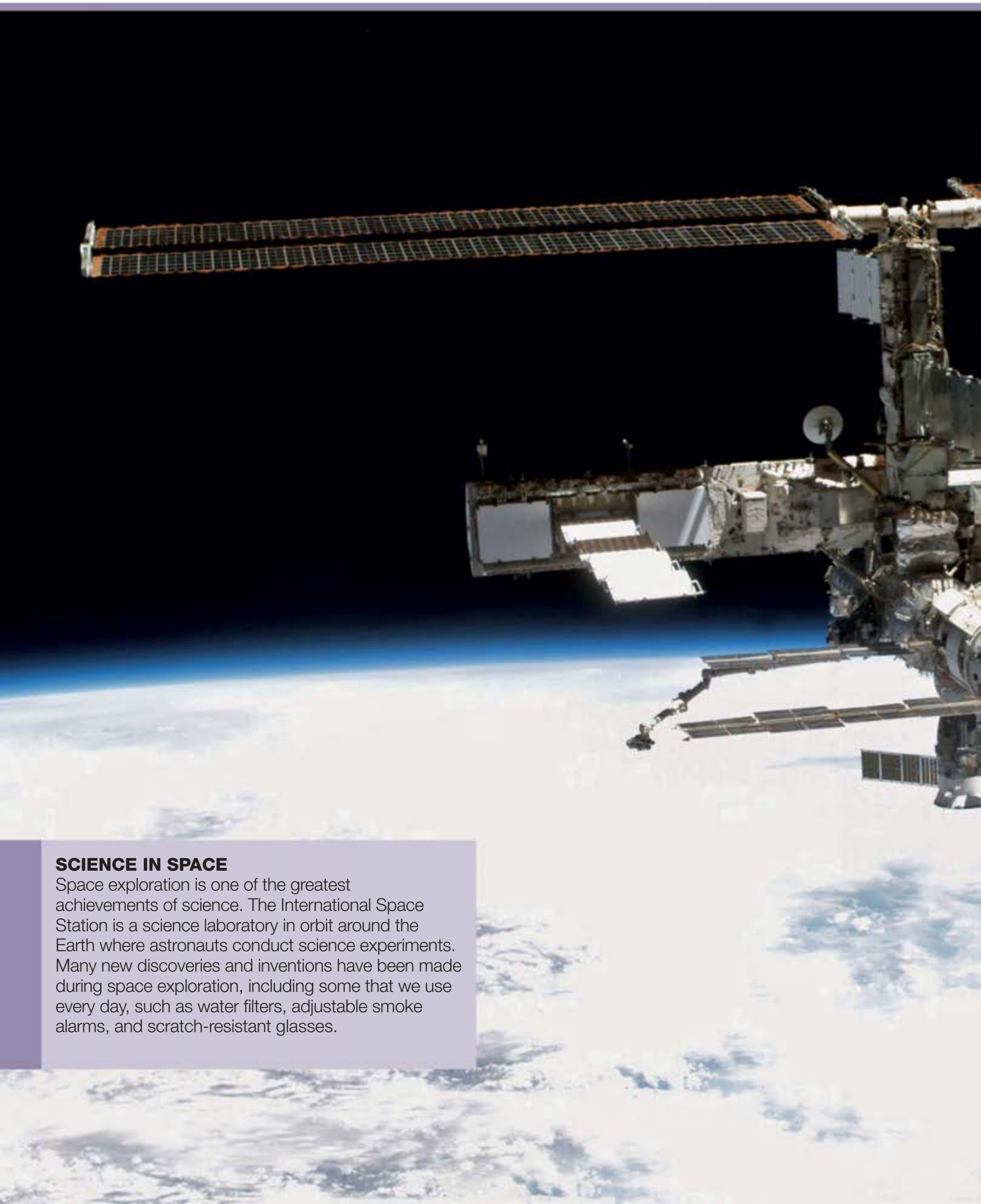
From plastic toys and computer games to the latest cutting-edge sports equipment, science has nearly always been involved in developing and shaping the materials. Science is also used in the design of the equipment.

Work

Science is used in a range of jobs, helping to make them easier and more efficient. Machines can lift heavy objects, computers can process information and send messages, while the latest surgical equipment can help save lives.

Rest

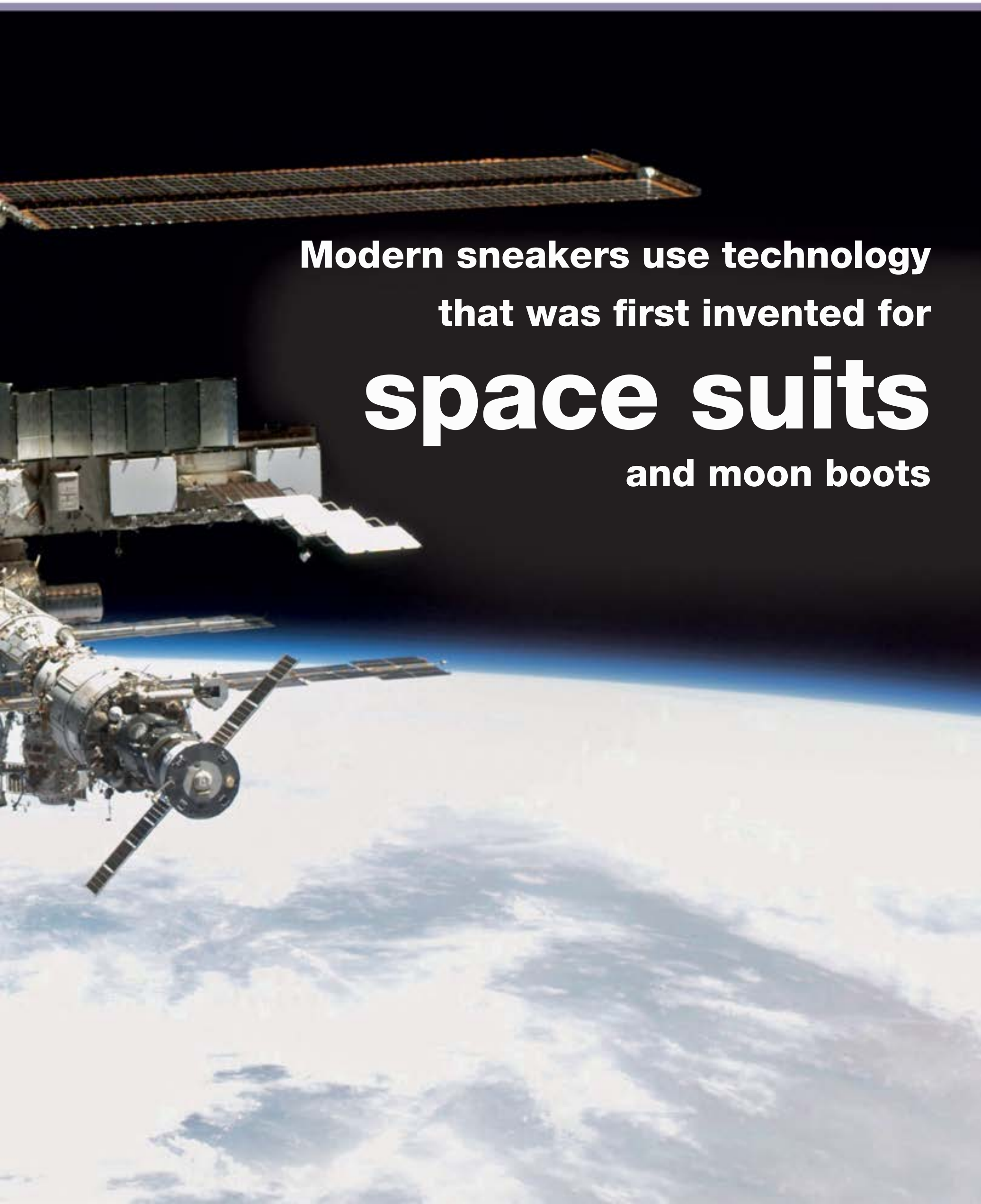
Science even helps us to rest. In our homes, science is all around us. Thermostats control the temperature, ovens turn raw ingredients into tasty meals, while satellites in space beam radio, phone, and TV signals from all over the world into our homes.

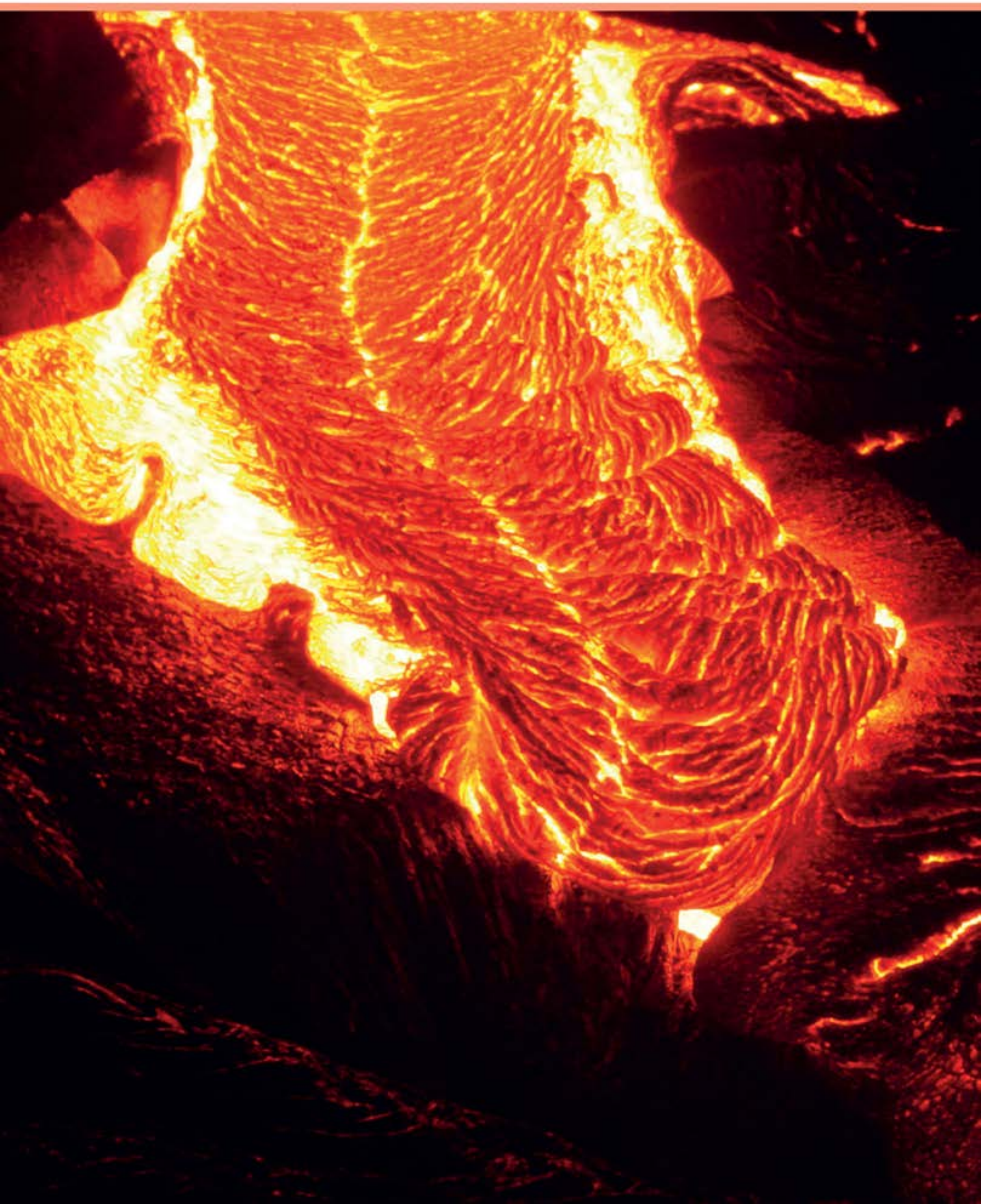


SCIENCE IN SPACE

Space exploration is one of the greatest achievements of science. The International Space Station is a science laboratory in orbit around the Earth where astronauts conduct science experiments. Many new discoveries and inventions have been made during space exploration, including some that we use every day, such as water filters, adjustable smoke alarms, and scratch-resistant glasses.

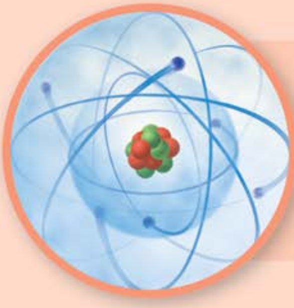
Modern sneakers use technology that was first invented for space suits and moon boots





Matter and materials

Everything on Earth is made from different types of matter, which behave in different ways, depending on the conditions. Rock, for example, can form solid mountains, but at high temperatures it melts and flows as lava. Exploring the way matter changes its form under different conditions of heat or pressure reveals how the universe works at its most basic level. Understanding how materials behave in different situations shows how they can—and cannot—be used.



ATOMS
All matter is made up of tiny particles called atoms. At the center of each atom is a nucleus, made up of protons and neutrons, and this is surrounded by a cloud of electrons.

States of matter

Matter is everywhere, but you cannot always see it. There are four main types, or states, of matter—solid, liquid, gas, and plasma. Each state is made up of moving particles, but they look and behave very differently.

Solids

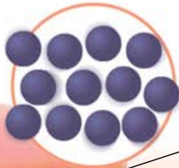
In solids, the particles are packed together so tightly that they vibrate rather than move around. Solids can be hard or soft, huge or tiny, and everything in between, but they always have a fixed shape and volume and occupy a definite space.

Particles are packed together in a solid

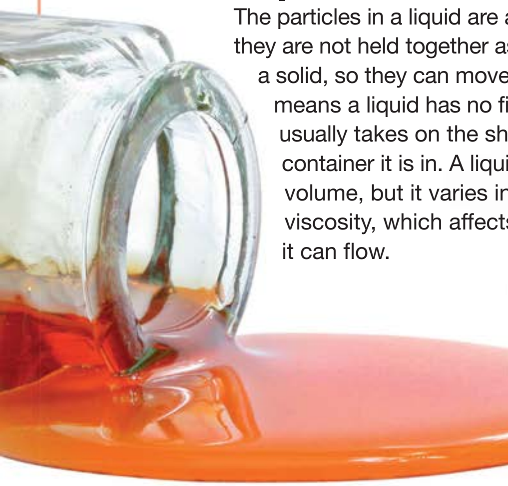
Rocks and minerals are solids

Liquids

The particles in a liquid are also close, but they are not held together as strongly as in a solid, so they can move around. This means a liquid has no fixed shape and usually takes on the shape of whatever container it is in. A liquid has a fixed volume, but it varies in thickness, or viscosity, which affects how freely it can flow.



Particles are close in a liquid



Honey has **high viscosity**, which means it flows slowly

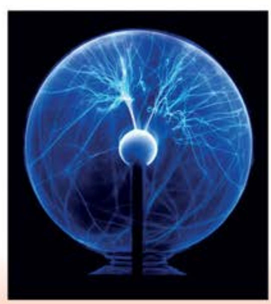
Hot air, an example of a gas, expands to fill these hot-air balloons

Particles are spread apart in a gas

Gases

The particles in a gas are far apart and can move freely, so gases have no fixed shape or volume. Gases can be compressed (squeezed so the space between the particles decreases) or expanded (the space increases) to fit a container. Most gases are invisible.

Plasma



Plasma is rarely seen on Earth, but it is found throughout the universe. Like a gas, it has no fixed shape or volume. However, it contains electrically charged particles (see pages 56–57) and exists only under certain conditions, such as in places with high temperatures or radiation. Streams of plasma can be seen in this plasma lamp.

Sulfur crystal embedded in rock

Changing states

A substance may not always remain in the same state of matter. It can change state when it is at different temperatures. For example, a solid can become a liquid if it becomes hot enough and a liquid may become a solid if it is cooled enough.

Boiling and evaporation

When water is heated to boiling point, bubbles appear. These bubbles are made because some of the liquid has changed to an invisible gas called water vapor, or steam. Water boils at 212°F (100°C). The water vapor escapes into the air in a process called evaporation. Evaporation can also occur more slowly. For example, wet hair dries because of evaporation.

Hot thermal spring in New Zealand

Condensation

The opposite of evaporation is condensation and this process occurs when a gas cools and becomes a liquid. When water vapor comes into contact with something cool, it turns back into a liquid. Condensation often forms on windows as the temperature drops overnight.

Freezing

When a liquid becomes cold enough, it will freeze and become a solid. The temperature at which a substance turns into a solid is called its freezing point. Water freezes at 32°F (0°C) and its solid state is called ice. Jet fuel freezes at around –52°F (–47°C).

Melting

When a solid is heated to a high enough temperature, it becomes a liquid, or melts. The increase in temperature causes the particles in the solid to move more freely until eventually they achieve a liquid state. The temperature at which a solid becomes a liquid is known as its melting point. The melting point and freezing point of a substance are the same temperature.

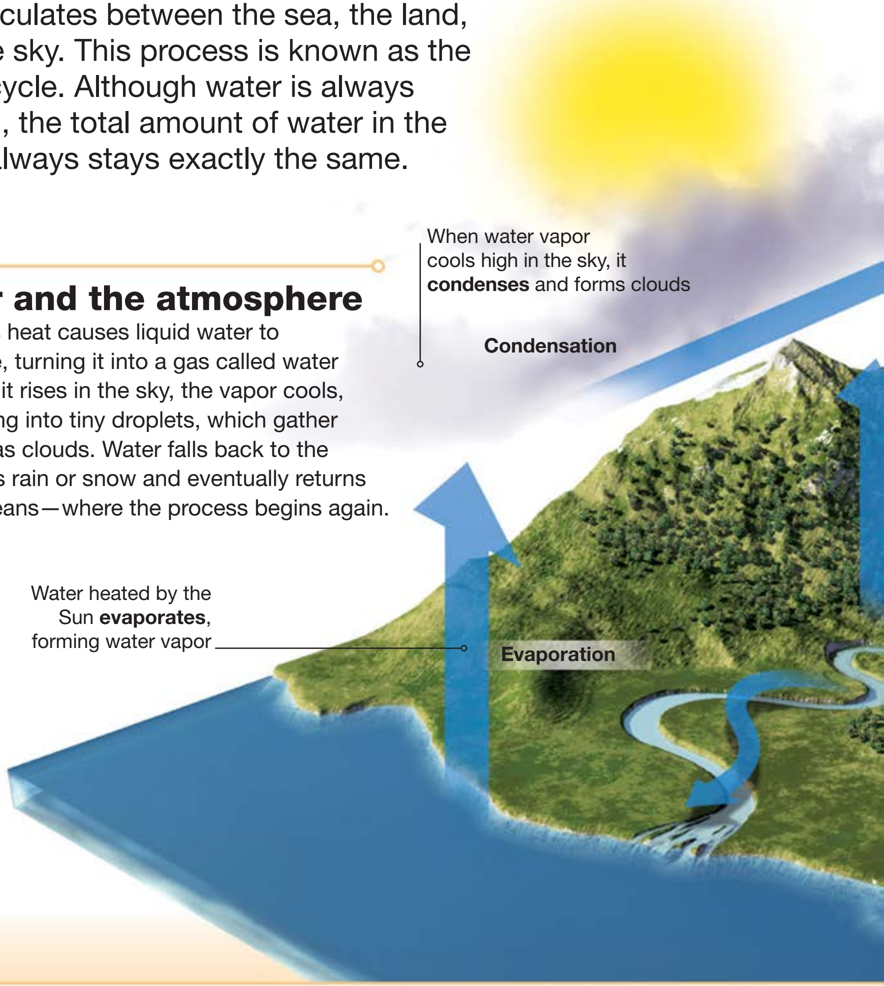
Solid ice pops melt to form a liquid

The water cycle

Earth's water is constantly changing state as it circulates between the sea, the land, and the sky. This process is known as the water cycle. Although water is always moving, the total amount of water in the world always stays exactly the same.

Water and the atmosphere

The Sun's heat causes liquid water to evaporate, turning it into a gas called water vapor. As it rises in the sky, the vapor cools, condensing into tiny droplets, which gather together as clouds. Water falls back to the surface as rain or snow and eventually returns to the oceans—where the process begins again.




Small water droplets in clouds merge together to become larger ones, eventually falling to Earth as **precipitation**, such as rain and snow, when they become too big
Liquid water that has fallen as **rain** or melted from **snow** collects in rivers and streams
At low temperatures, water **freezes** into solid snow as it falls
Freezing
Precipitation
Melting
Some water sinks into the Earth as **groundwater**, and eventually returns to the surface as springs or marshes
Over time, flowing groundwater can slowly wear away rocks, forming **underground caves** and **pools**

Properties of matter

Different substances have different properties. They might be hard or soft, flexible or rigid, flammable or not. Testing the properties of a particular substance helps in determining what it can, and cannot, be used for.

Mass and density

The amount of matter within an object is known as its mass. On Earth, the force of gravity (see page 84) pulls on the mass of an object to give it weight. An object's density is how much mass it has for its size. For example, a piece of iron weighs more than a feather of the same size because it is a denser material.

A feather has a low density

An iron bell has a high density

Plasticity

Some materials can be shaped into a different form. This property is known as plasticity. Modeling clay, for example, can be shaped into various objects. Special types of plasticity include malleability, where a material such as metal can be beaten into thin sheets, and ductility, which allows a material to be pulled into a thin wire.

Modeling clay has high plasticity, but the knife is less elastic and breaks easily


1. Talc


2. Gypsum


3. Calcite


4. Fluorite


5. Apatite


6. Feldspar


7. Quartz


8. Topaz


9. Corundum

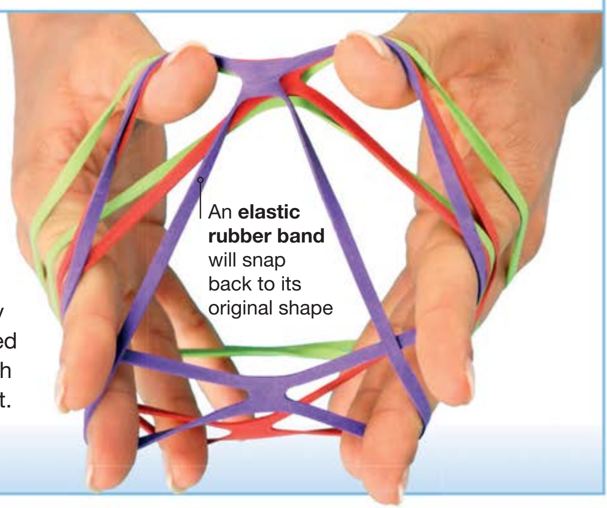

10. Diamond

Hardness

The hardness of minerals is measured using the Mohs scale. Ranging from 1 (soft) to 10 (very hard), the scale measures how well one mineral can resist being scratched and shaped by another. A diamond could scratch any other mineral, but talc can easily be scratched by any mineral, or even a human fingernail.

Elasticity

Some materials are very flexible and have the ability to bend. Some are so flexible that they can bend or stretch in different directions, but still return to their original shape, size, or position. This property is known as elasticity. A rubber band is an elastic object. Many materials cannot be stretched beyond a certain point, which is called the elastic limit.



Flammability

If a material is flammable, it catches fire (ignites) easily and then burns (combusts). Highly flammable materials, such as gasoline, can be dangerous, but also very useful. Flammable materials produce heat as they burn. A material that will not burn is known as nonflammable.

Solubility

If a material can dissolve in a liquid, it is known as soluble. The liquid into which the soluble material dissolves is a solvent. Water is often called the universal solvent because so many materials can dissolve in it. Soluble materials include solids, liquids, and gases.

Potassium permanganate is a solid compound that **dissolves** in water

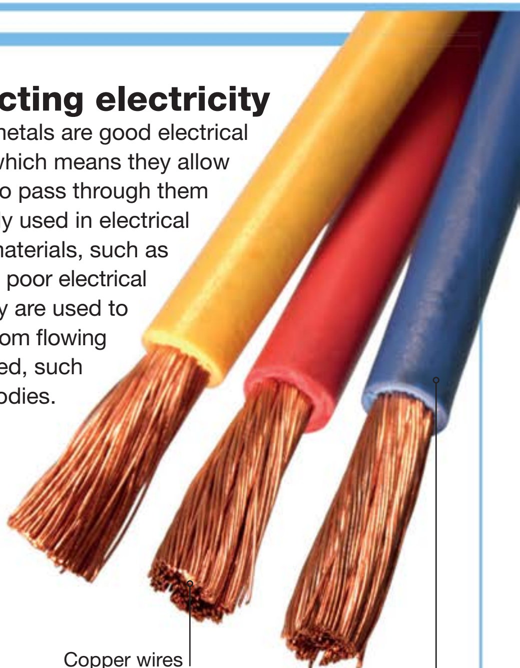
Stone is **nonflammable** and does not catch fire

Wood is a **flammable** material and catches fire easily

Conducting electricity

All metals are good electrical conductors, which means they allow electrical currents to pass through them easily. Copper is widely used in electrical wiring. Insulating materials, such as glass and plastic, are poor electrical conductors. They are used to prevent electricity from flowing where it is not needed, such as through our bodies.

A special nonflammable fabric called CarbonX does not burn even when heated to an incredible 5,500°F (3,000°C).



Copper wires

Plastic insulator covers

Conducting heat

Metals conduct heat well and are known as thermal conductors. Other materials, such as glass and plastic, do not conduct heat easily. They are called thermal insulators and they are very useful as they prevent heat from escaping.

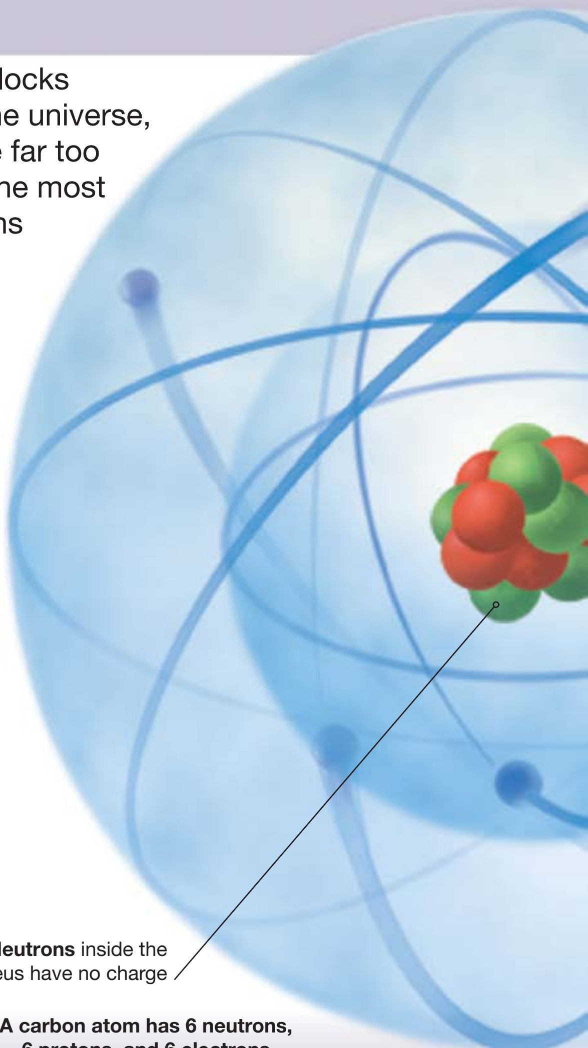
A metal pan conducts heat from the burner to the food inside the pan

Atoms

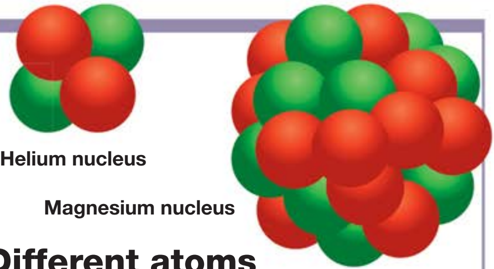
Atoms are the tiny building blocks that make up everything in the universe, including ourselves. They are far too small to be seen, even with the most powerful microscopes. Billions of them could fit on the dot of this "i." Yet atoms are themselves made up of even tinier subatomic particles called protons, neutrons, and electrons.

Inside an atom

Atoms consist of three types of particle. At the center is a nucleus made up of protons, which have a positive electric charge, and neutrons, which have no charge. This is orbited by some even smaller negatively charged particles called electrons, which spin around the nucleus at great speeds. These particles are so tiny that most of an atom is actually just empty space.



A carbon atom has 6 neutrons, 6 protons, and 6 electrons

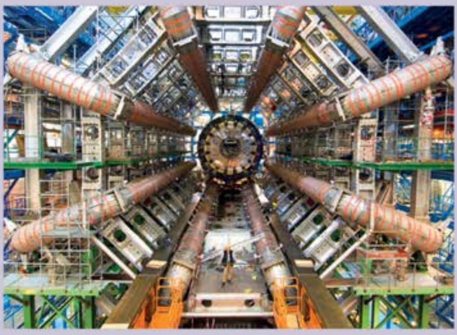


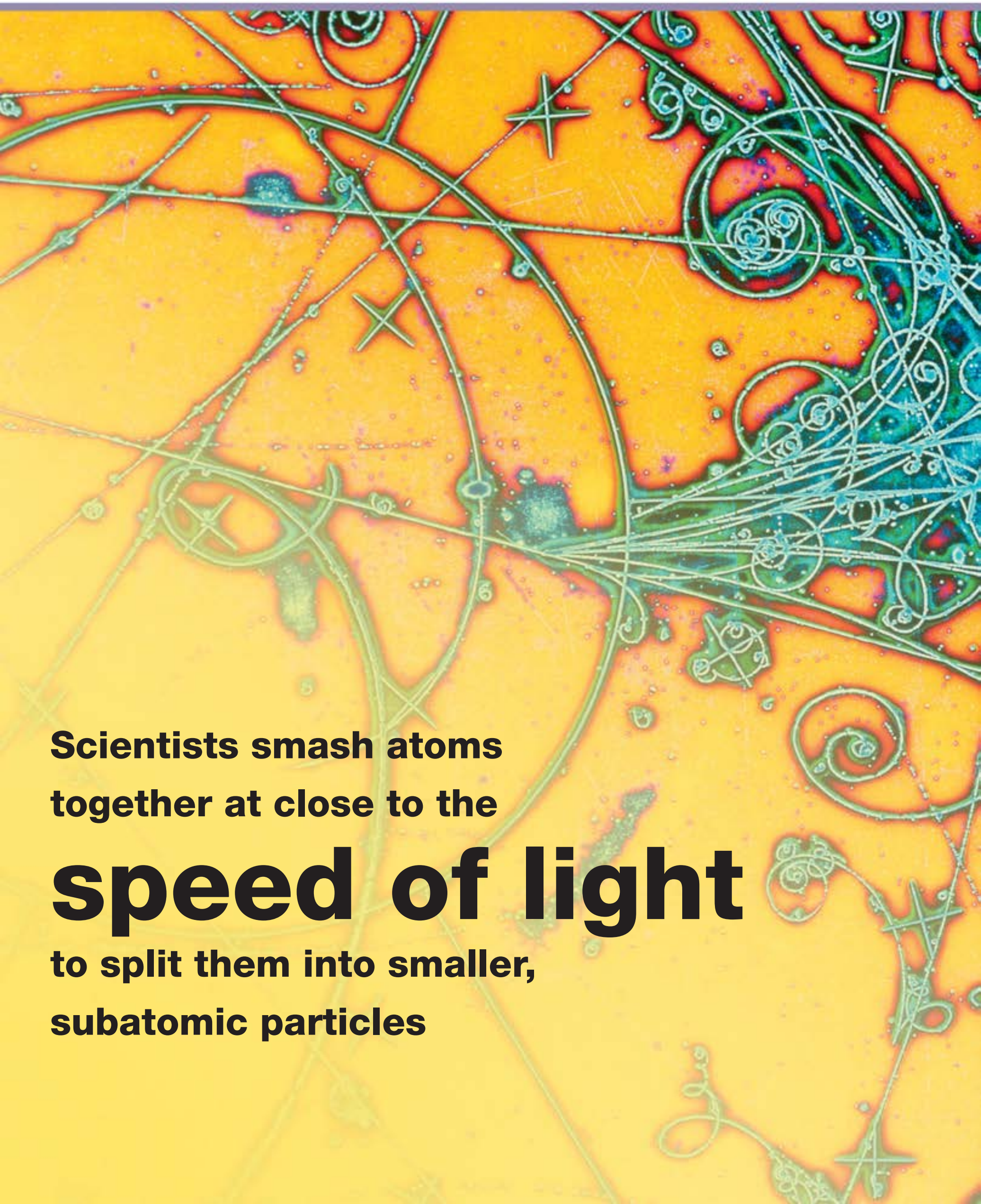
Different atoms

A helium atom has just 2 protons, 2 neutrons, and 2 electrons, while a magnesium atom has 12 of each. Sometimes atoms can lose or gain electrons to become a special type of atom called an ion. When an atom loses electrons, it becomes a positively charged ion. If it gains electrons, it becomes a negatively charged ion.

PARTICLE ACCELERATOR

Scientists can learn more about atoms by smashing subatomic particles into each other at high speeds and then studying the results. They do this using machines called particle accelerators, such as the Large Hadron Collider (below) at CERN in Switzerland.





Scientists smash atoms together at close to the

speed of light

to split them into smaller, subatomic particles

PARTICLE TRACKS
Subatomic particles, such as electrons, are not usually visible. However, inside this special bubble chamber filled with liquid hydrogen, the electrons leave behind tracks as they move, creating intricate spiral patterns.

Molecules

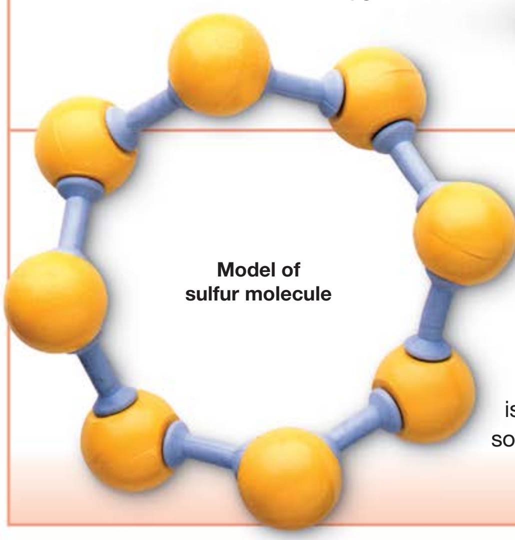
Most atoms do not exist on their own, but bond with other atoms—either ones of their own type or of another element—to form molecules. Atoms join together by sharing their electrons, a process known as chemical bonding.

Simple molecules

The natural state of oxygen is nearly always as a molecule, not an atom. An oxygen molecule is made up of two oxygen atoms, chemically bonded together. The oxygen in the air consists of molecules, not single atoms.

Oxygen atom

Model of oxygen molecule



Model of sulfur molecule

Complex molecules

A sulfur molecule is made up of eight sulfur atoms bonded together in a ring. The structure of a molecule can be shown by a formula. For example, sulfur has the chemical symbol S and is made up of eight atoms, so its chemical formula is S_8.

Diamond

Pencil “lead” is made of graphite

Model of graphite’s atomic structure

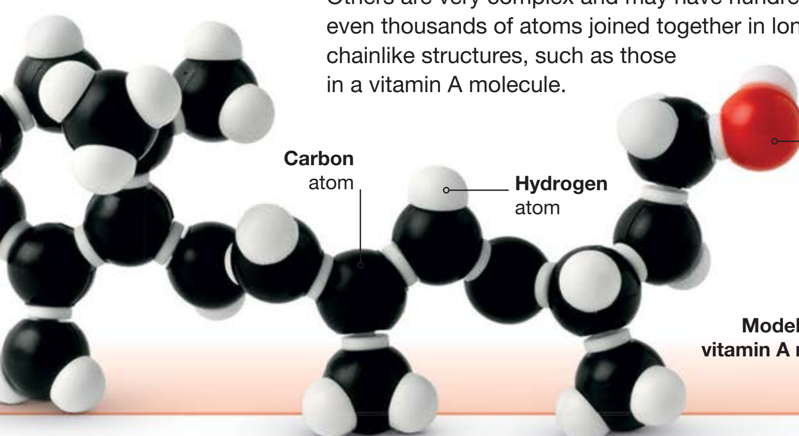
Model of diamond’s atomic structure

Different arrangements

Atoms of some elements can join together in different ways to create different substances. For example, carbon atoms can join together in sheets to form graphite or in a lattice shape to form diamond.

Complex chains

Some molecules are simple, containing just a few atoms. Others are very complex and may have hundreds or even thousands of atoms joined together in long chainlike structures, such as those in a vitamin A molecule.



Carbon atom

Hydrogen atom

Oxygen atom

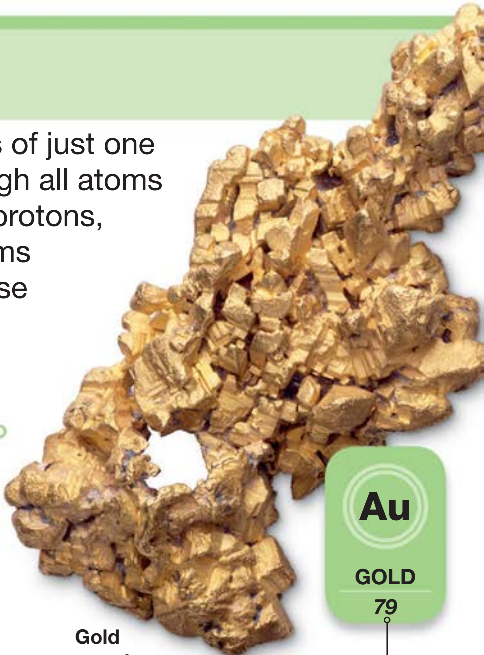
Model of a vitamin A molecule

Elements

A chemical that is made up of atoms of just one type is known as an element. Although all atoms are made of the same basic parts—protons, neutrons, and electrons—not all atoms are the same. It is the number of these parts that gives the atom—and the element—its properties.

Grouping elements

The number of protons in an atom of an element gives it its atomic number. Scientists arrange elements according to their atomic numbers in a chart known as the periodic table (see pages 144–45). Although each element is unique, many have similar properties. Those that share certain properties are grouped together.



Gold nugget

The atomic number of gold is 79

Alkali metals

The first group of similar elements in the periodic table is known as the alkali metals. These elements, which include sodium and lithium, are soft and react with water, forming alkaline solutions.

Sodium gets hot and melts when it reacts with water, producing hydrogen, which burns

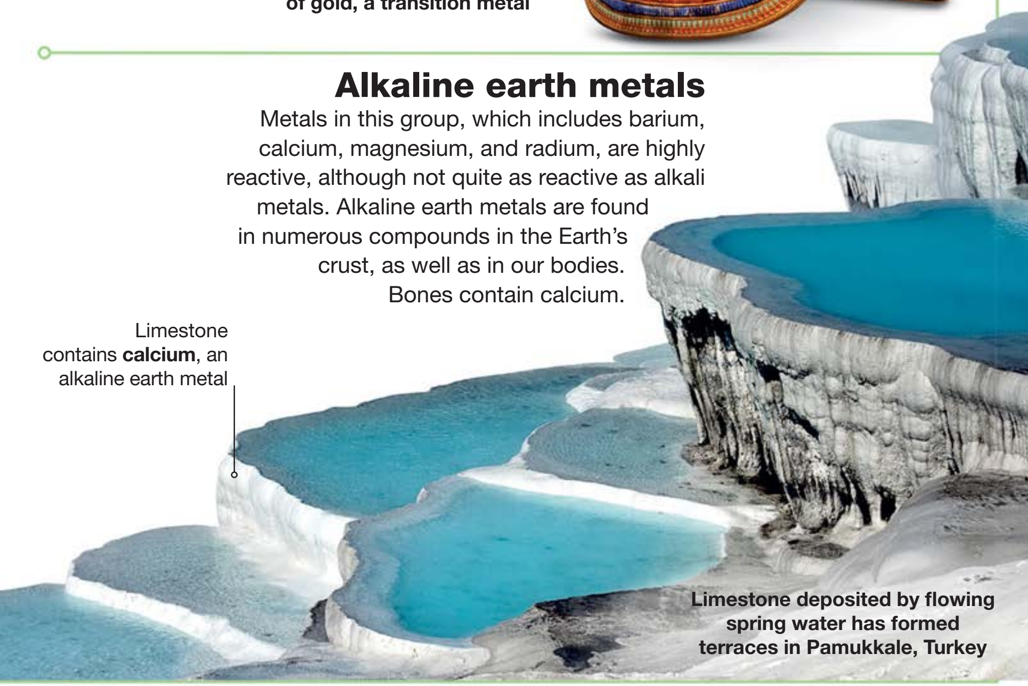
Transition metals

Most of the metals we use in everyday life, such as gold, iron, and copper, are grouped together as transition metals. This group contains metals that can create magnetic fields (see page 63) and are good conductors of heat and electricity.

The mask of the Egyptian pharaoh Tutankhamun is made of gold, a transition metal

Alkaline earth metals

Metals in this group, which includes barium, calcium, magnesium, and radium, are highly reactive, although not quite as reactive as alkali metals. Alkaline earth metals are found in numerous compounds in the Earth's crust, as well as in our bodies. Bones contain calcium.

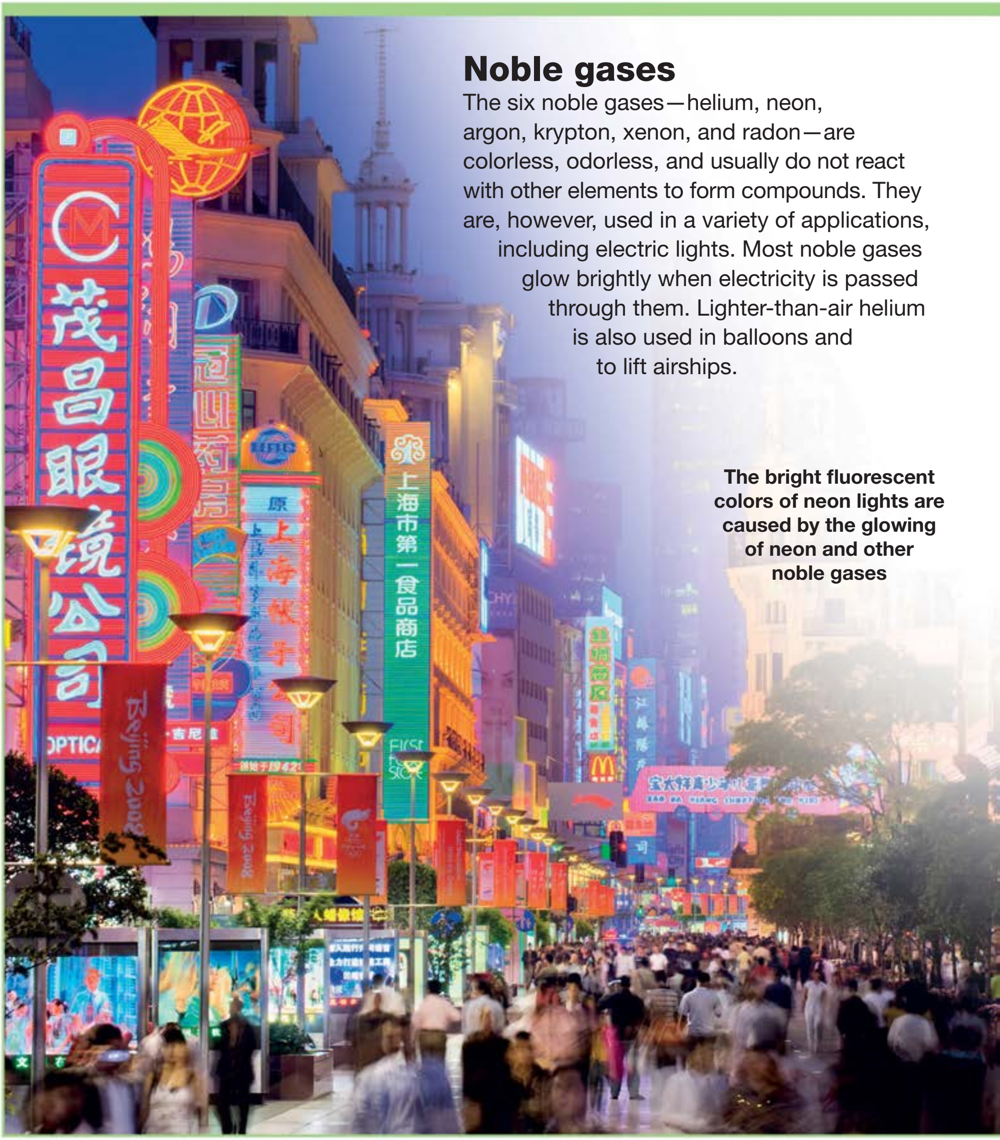


Limestone contains **calcium**, an alkaline earth metal

Limestone deposited by flowing spring water has formed terraces in Pamukkale, Turkey

Noble gases

The six noble gases—helium, neon, argon, krypton, xenon, and radon—are colorless, odorless, and usually do not react with other elements to form compounds. They are, however, used in a variety of applications, including electric lights. Most noble gases glow brightly when electricity is passed through them. Lighter-than-air helium is also used in balloons and to lift airships.

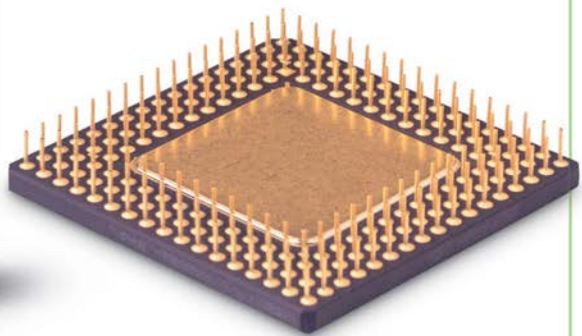


The bright fluorescent colors of neon lights are caused by the glowing of neon and other noble gases

Poor and semimetals

Poor metals have lower melting points than most transition metals. They are often used in alloys, such as bronze—a mixture of copper and tin. Semimetals have some metallic and some nonmetallic qualities. For instance, silicon is shiny like a metal, but brittle like a nonmetal.

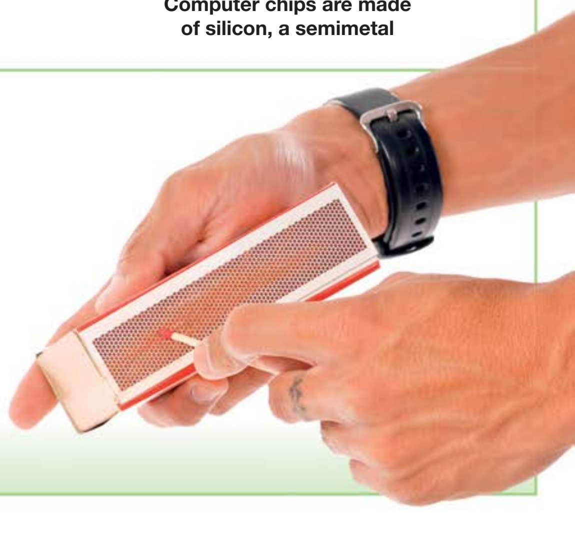
Tin, a poor metal, does not rust, and so it is often used as a coating for cans



Computer chips are made of silicon, a semimetal

Nonmetals

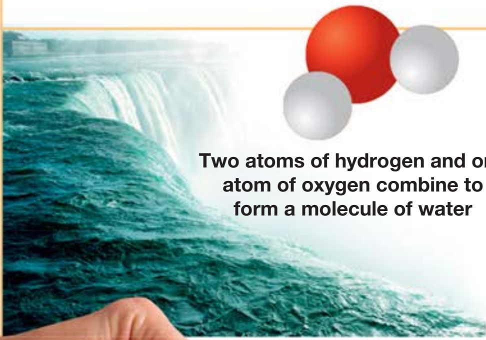
Nonmetals are so called because they do not share physical or chemical properties with metals. Nonmetals do not conduct heat or electricity well, and the solid forms of most nonmetals are soft and brittle. The atmospheric gases nitrogen and oxygen are nonmetals.



The striking surface of a matchbox is coated with phosphorus, a nonmetal

Mixtures and compounds

Different elements can be combined to create new substances. When atoms and molecules chemically combine to form a substance, it is called a compound. If no chemical reaction takes place—as when mud is added to water—a mixture is formed.



Two atoms of hydrogen and one atom of oxygen combine to form a molecule of water

Compounds

These are often very different from the elements that make them up. Hydrogen and oxygen are invisible and odorless gases. However, when chemically combined, the two create a simple compound called water.

Water flowing at Niagara Falls, Canada

Mixtures

There are two main types of mixture: solutions and suspensions. In a solution, a substance breaks up into individual atoms or molecules and mixes evenly in another substance, known as the solvent. In a suspension, a substance does not break up completely and may still be floating in the liquid as solid particles.

Ink will **mix evenly** in water to form a solution

Mud **dissolves unevenly** in water

Solution **Suspension**

Alloys

Metals can be mixed with each other, or with other substances, to create a new substance called an alloy. Alloys have different properties from the substances they are composed of. For example, the alloy bronze is much harder than the metals that make it up—copper and tin.

Car wheels are often made of alloys

Separating mixtures

Several methods can be used to separate substances in a mixture, including evaporation, spinning, filtration, and distillation. The last method involves heating a mixture so that a substance with a lower boiling point can be collected as a gas from the mixture, leaving behind the substance (or substances) with the higher boiling point. Pure water can be obtained from salty water by distillation.

Oil refineries use distillation to separate gas from crude oil

Reactions and changes

Physical changes occur when substances change state. Chemical reactions occur when the atoms in molecules are rearranged to create different molecules. Changes caused by physical reactions are usually easy to reverse, while chemical changes are not.

Chemical reactions

These reactions can be caused by various factors, such as heat or contact with other substances. When food is cooked, heat causes the ingredients to react together chemically, altering their appearance, texture, temperature, and taste.

Flour

Butter

Eggs

Physical changes

Some changes are physical, not chemical. When candle wax is heated, it melts and changes to a liquid. However, its molecules do not change, just their physical state. The change can be reversed by remolding and cooling the candle wax.

Sugar

Baking powder

Melting candle wax

Fast changes

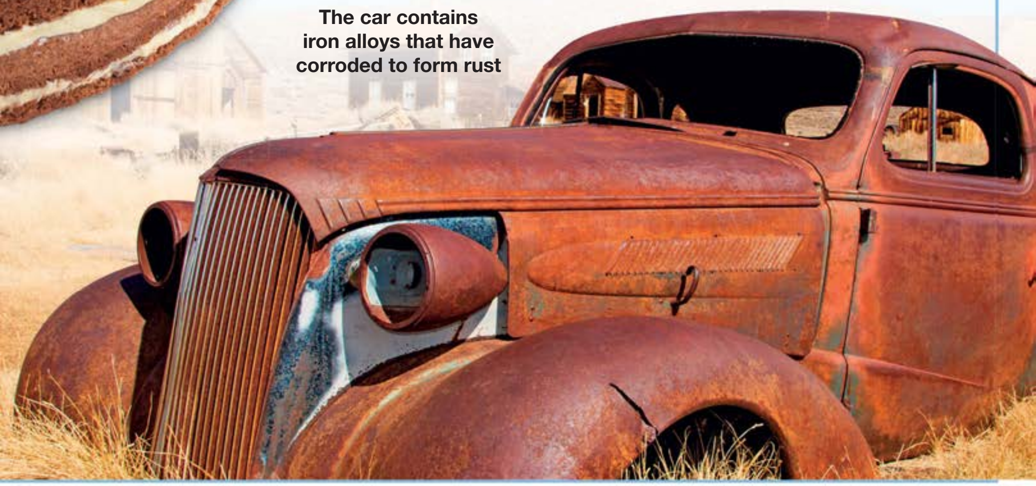
Some changes can happen suddenly. When baking soda and vinegar are mixed, the two substances react, causing the liquid to erupt. The speed of change can also be altered: if a potato is cut into small pieces and heated in boiling water, it will change (soften) faster than if it were a single, large piece because the heat has less far to travel to get to the center of the potato pieces.

Baking soda mixes with vinegar to form a gas called carbon dioxide, causing the cork to pop

The baked cake is chemically different from its ingredients

Slow changes

Certain reactions happen over a long period of time—days, weeks, or even years. Corrosion, such as rusting, occurs when metal objects are exposed for too long to the oxygen and moisture present in air, or other corrosive substances.



The car contains iron alloys that have corroded to form rust

A catalytic converter from a car

Catalysts

Some substances, called catalysts, change the rate at which a reaction occurs, although the catalyst itself is not changed in the reaction. Most cars are equipped with a catalytic converter, which helps the polluting gases that fuel the car to react and create less harmful gases. Many catalysts speed up reactions, but others, called inhibitors, slow down reactions. Preservatives, added to food in order to keep it fresh for a longer period, are examples of inhibitors.

Giving off heat

Some reactions release heat, light, or both. These are called exothermic reactions and include the burning of wood or other fuels and reactions between acids and bases (see pages 44–45), resulting in the formation of a salt. The burning of fuel is also known as a combustion reaction and can give off enough energy to power a car or a house.

The burning of a wick soaked in oil gives out light and some heat

Cool reactions

Endothermic reactions are the opposite of exothermic reactions. They absorb heat, rather than releasing it, to change the molecules. Special instant ice packs, used to treat sports injuries, contain water and ammonium chloride. When the pack is activated, the substances mix and react, causing an endothermic reaction which cools the affected area.

An ice pack being applied on the hand

Man-made materials

Sometimes chemical reactions are used to create substances that do not occur naturally. Man-made materials are often used for outdoor clothing. These breathable, waterproof materials are made when certain molecules are combined in a process known as polymerization.

Man-made waterproof clothing is popular with skiers and climbers

REACTIONS AT WORK
Firework displays are an example of exothermic reactions. They release heat and light. When a spark is applied, the fuse burns down, causing the gunpowder and metal stars within the firework to explode in a spectacular mix of bangs, crackles, and light.

The largest firework display ever, in Madeira, Portugal, in 2006 used

66,326

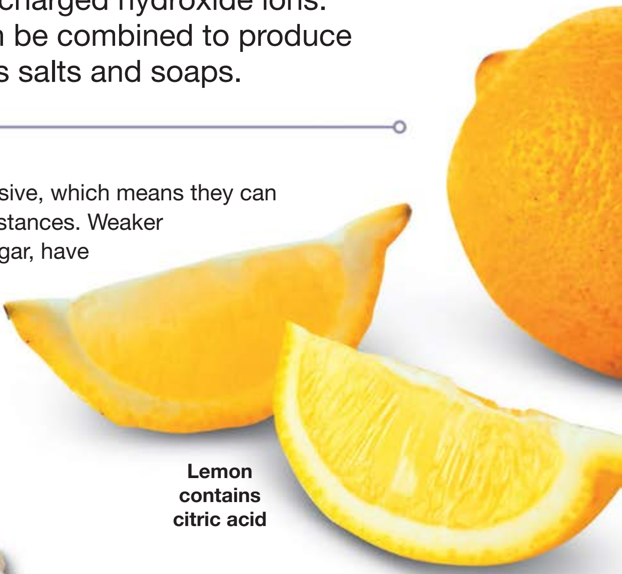
separate fireworks

Acids and bases

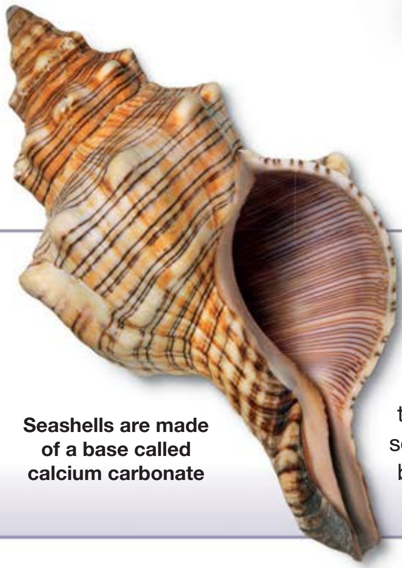
Acids and bases are chemical opposites: acids produce positively charged hydrogen ions and bases produce negatively charged hydroxide ions. Many acids and bases can be combined to produce useful substances, such as salts and soaps.

Acids

Some powerful acids are very corrosive, which means they can destroy, or "eat through," other substances. Weaker acids, such as lemon juice and vinegar, have a strong, sour taste. These are often used to flavor food and can also be found in many household cleaning products.



Lemon contains citric acid



Seashells are made of a base called calcium carbonate

Bases and alkalis

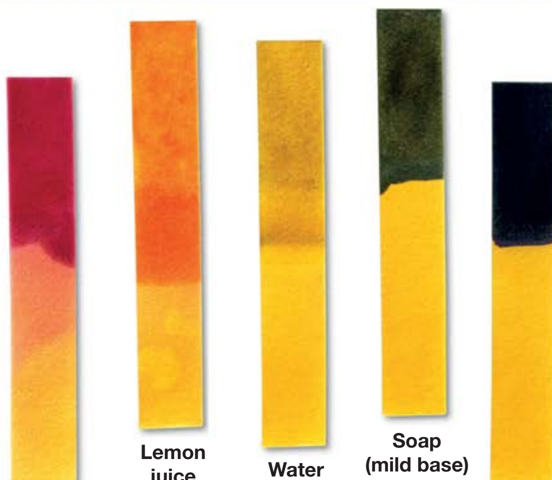
Strong bases can be as dangerous as strong acids, although a base that destroys other substances is usually known as caustic rather than corrosive. Sodium hydroxide (caustic soda) can eat through some metals. Sodium bicarbonate, or baking soda, is a weak base, often used in cooking. Some bases are water-soluble and are called alkalis.

Mixing acids and bases

When certain acids and bases are mixed, they can react to produce water and a salt. Soap is made when a strong base is added to a fatty acid (a building block of fats found in our bodies and food), breaking it down to form a hard or soft soap (depending on the base).

Measuring acids and bases

The strength of acids and bases is measured using the pH (power of hydrogen) scale. It ranges from zero (strong acid) to 14 (strong base). Pure water is seven on the pH scale, which is neutral—neither acid nor base. The pH of a substance can be measured using a pH indicator such as litmus paper. The color of the indicator changes according to the pH of the substance.

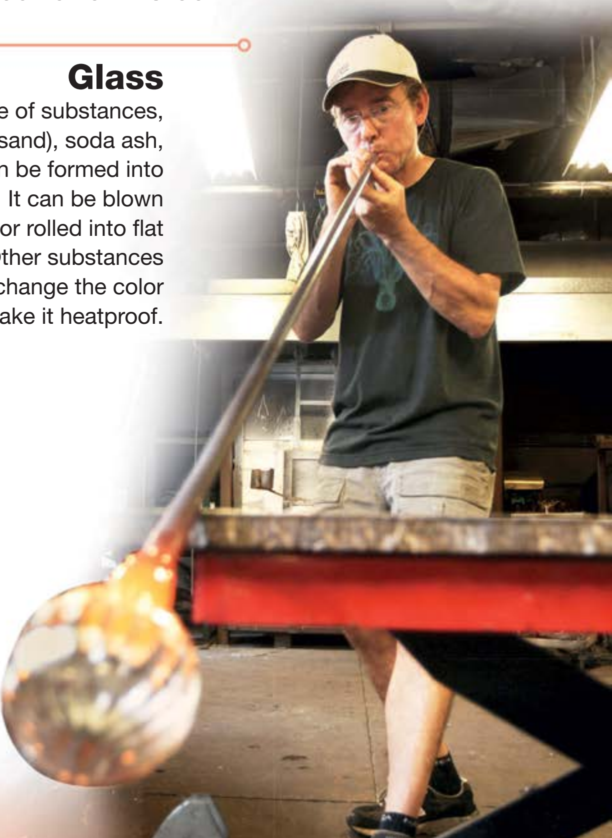


Using materials

Throughout history, people have used and reused materials. Many natural substances can be adapted or changed to produce new substances. For example, soft clay can be turned into hard pottery, sand can be transformed into glass, and iron and carbon can be combined to form steel.

Glass

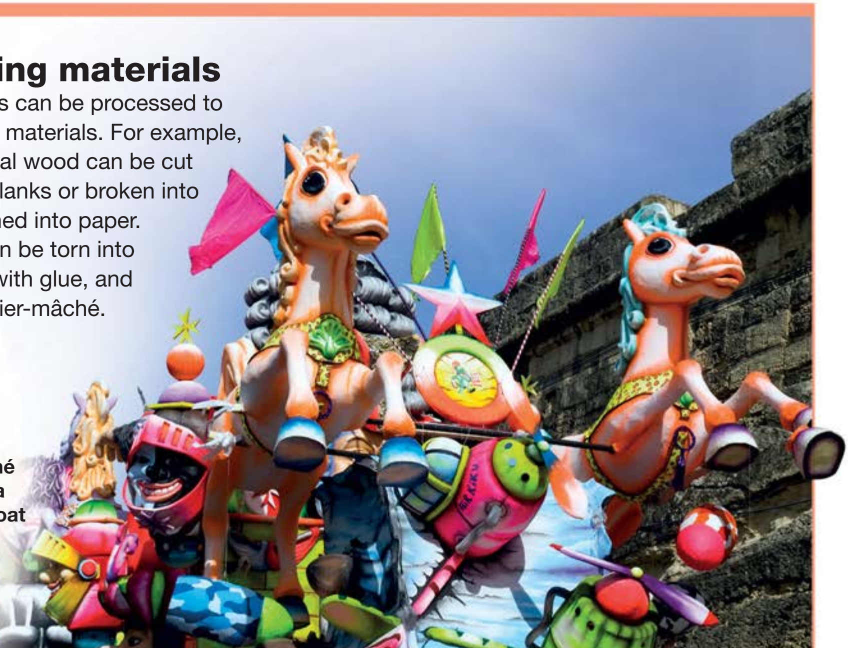
Glass is a mixture of substances, including silica (from sand), soda ash, and limestone. Glass can be formed into many different shapes. It can be blown into bottles and jars or rolled into flat sheets for windows. Other substances can be added to change the color of the glass or to make it heatproof.



Molten glass can be blown or molded into different shapes

Processing materials

Many materials can be processed to make different materials. For example, the raw material wood can be cut into building planks or broken into fibers and turned into paper. Paper itself can be torn into strips, mixed with glue, and reused as papier-mâché.



Colorful papier-mâché figures on a Mardi Gras float

Recycling

Many objects and materials can be used more than once, even when they wear out. For example, tires can be reused by adding new tread. Some objects can also be recycled—their materials turned into new objects. Aluminum cans, newspapers, glass bottles, and even electronic equipment are all regularly recycled.

Old computer circuit boards piled up in a recycling container

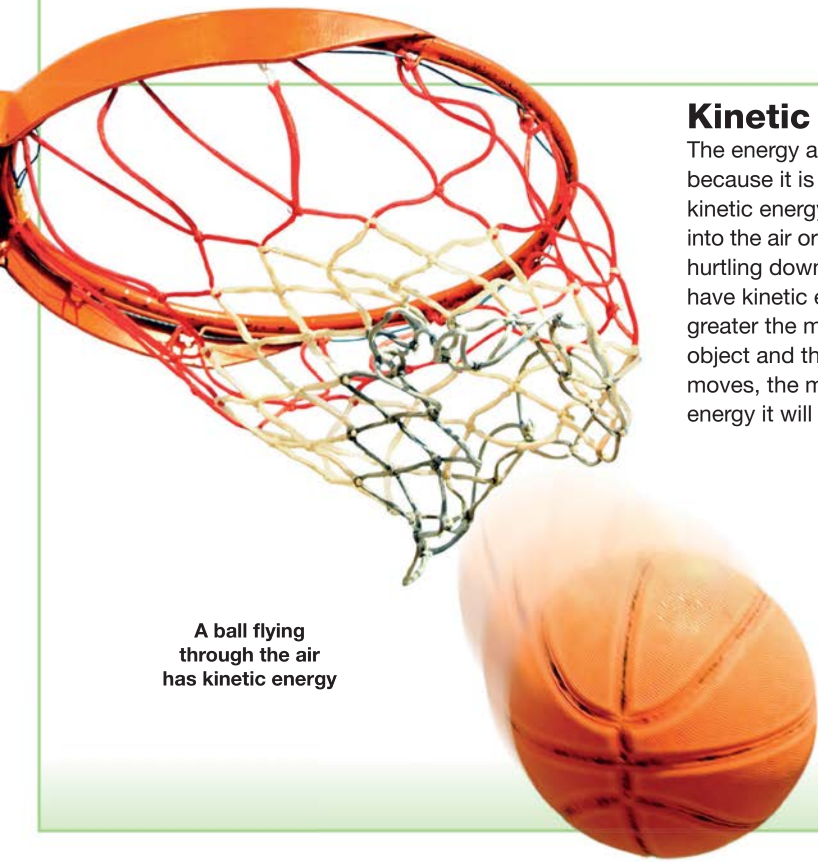
Energy and forces

Everything in the universe is constantly affected by energy and forces. A roller coaster is a good example of energy and forces in action. Fuel provides the energy needed to generate the force that pulls the roller coaster to the top of the slope. The stored potential energy the roller coaster has at the top is transferred to kinetic (movement) energy by the force of gravity as it runs downhill.

ELECTRICAL ENERGY Computers use electrical energy to perform a range of tasks and to generate light. When you touch the screen of a tablet computer, you are applying a force to it.

What is energy?

Energy is what makes everything happen. It cannot be created or destroyed, but it can be transferred. For example, kicking a ball transfers energy from the person to the ball. Energy can also be converted from one form to another—as when the chemical energy in gasoline is converted into the kinetic energy in a moving car.



Kinetic energy

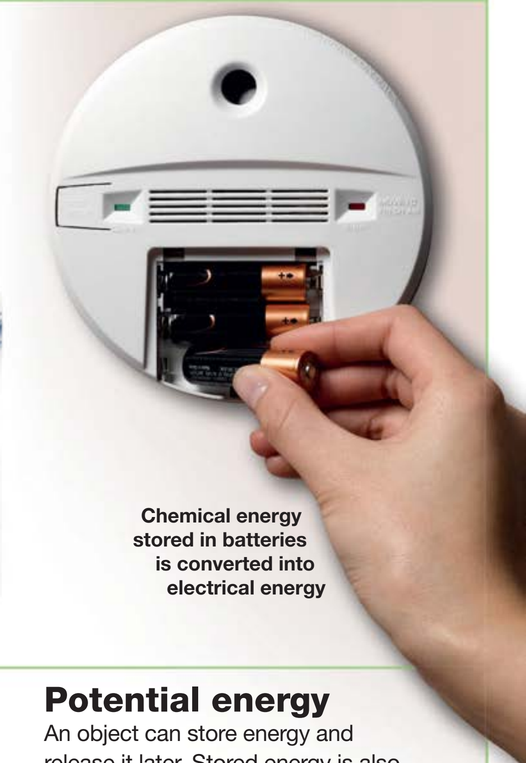
The energy an object has because it is moving is called kinetic energy. A ball thrown into the air or a roller coaster hurtling down a track both have kinetic energy. The greater the mass of an object and the faster it moves, the more kinetic energy it will have.

A ball flying through the air has kinetic energy

Chemical energy

Energy stored in substances is called chemical energy, and it can only be released through a chemical reaction. Chemical energy is stored in food, which must be broken down and its energy released by the body's metabolism.

Food stores chemical energy



Chemical energy stored in batteries is converted into electrical energy

Potential energy is stored in the string of the bow

Potential energy

An object can store energy and release it later. Stored energy is also called potential energy because it has the potential to make things happen. A coiled spring has potential energy, as does an archer's bow when it is drawn and ready to shoot an arrow. When the spring is not coiled and the bow not drawn, they have no potential energy.

Energy chain

Energy can take many different forms, from the heat of the Sun to the chemical energy stored in sugar. This energy chain shows how energy can be converted from one form to another.

Nuclear energy inside the Sun is converted into heat and light energy.

The green leaves of plants convert the **light energy** from the Sun into the **chemical energy** stored in sugar, by a process called photosynthesis (see page 115). Sugar is then stored in fruits.

Energy resources

Humans harness energy from many sources to supply power to their homes and vehicles. These include solar power, wind power, and nuclear power. The vast majority of our power, however, comes from fossil fuels, such as oil, coal, and gas.

Wind mills

When humans eat the fruits, the chemical energy is transferred to their bodies and used for all kinds of things. Winding up an alarm clock, for example, changes this chemical energy to **potential energy** in the spring of the alarm.

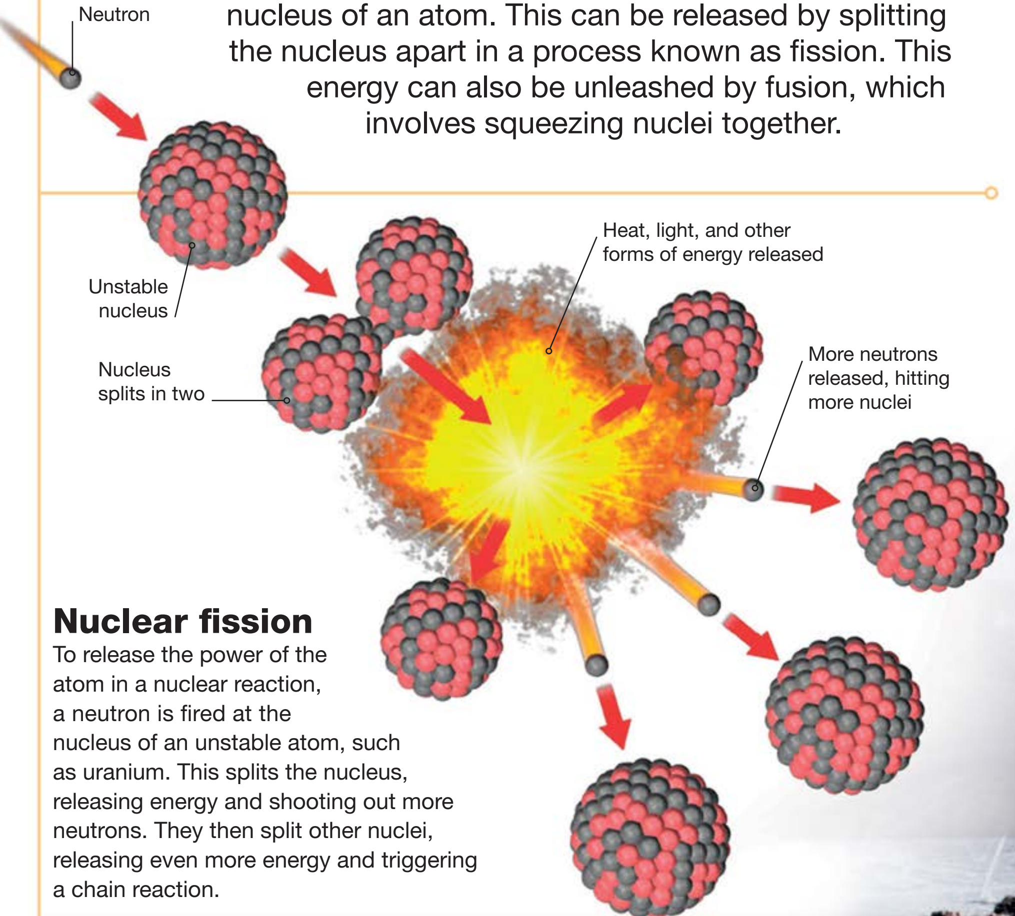
The potential energy of the wound-up spring is converted into the **kinetic energy** of the alarm bell and the **sound energy** of the alarm. The clock keeps working until the spring is unwound and has lost its potential energy.

Saving energy

One day the supply of fossil fuels will run out and we may face energy shortages. It is important to save energy, for example, by using low-energy light bulbs and insulating homes. Many governments have also begun investing in reusable sources of energy, such as solar and wind power.

Atom power

An enormous amount of energy is locked up inside the nucleus of an atom. This can be released by splitting the nucleus apart in a process known as fission. This energy can also be unleashed by fusion, which involves squeezing nuclei together.



Nuclear fission

To release the power of the atom in a nuclear reaction, a neutron is fired at the nucleus of an unstable atom, such as uranium. This splits the nucleus, releasing energy and shooting out more neutrons. They then split other nuclei, releasing even more energy and triggering a chain reaction.

Using fission power

Fission reactions take place in a nuclear power plant. Although only a small amount of fuel, usually uranium or plutonium, is used, huge amounts of energy are released. This superheats water, which is turned into high-pressure steam and drives the blades of a turbine. The spinning turbine drives a generator, which makes electricity.

Nuclear power plant

Atomic explosion

Atomic bombs, or A-bombs, use nuclear fission to release massive amounts of energy with devastating effects. Hydrogen bombs, or H-bombs, use both nuclear fission and nuclear fusion to generate explosions that can be thousands of times more powerful than an atomic bomb explosion.

A test detonation of a US atomic bomb in 1957 throws up a giant mushroom cloud of debris

STAR POWER

The Sun releases a lot of energy

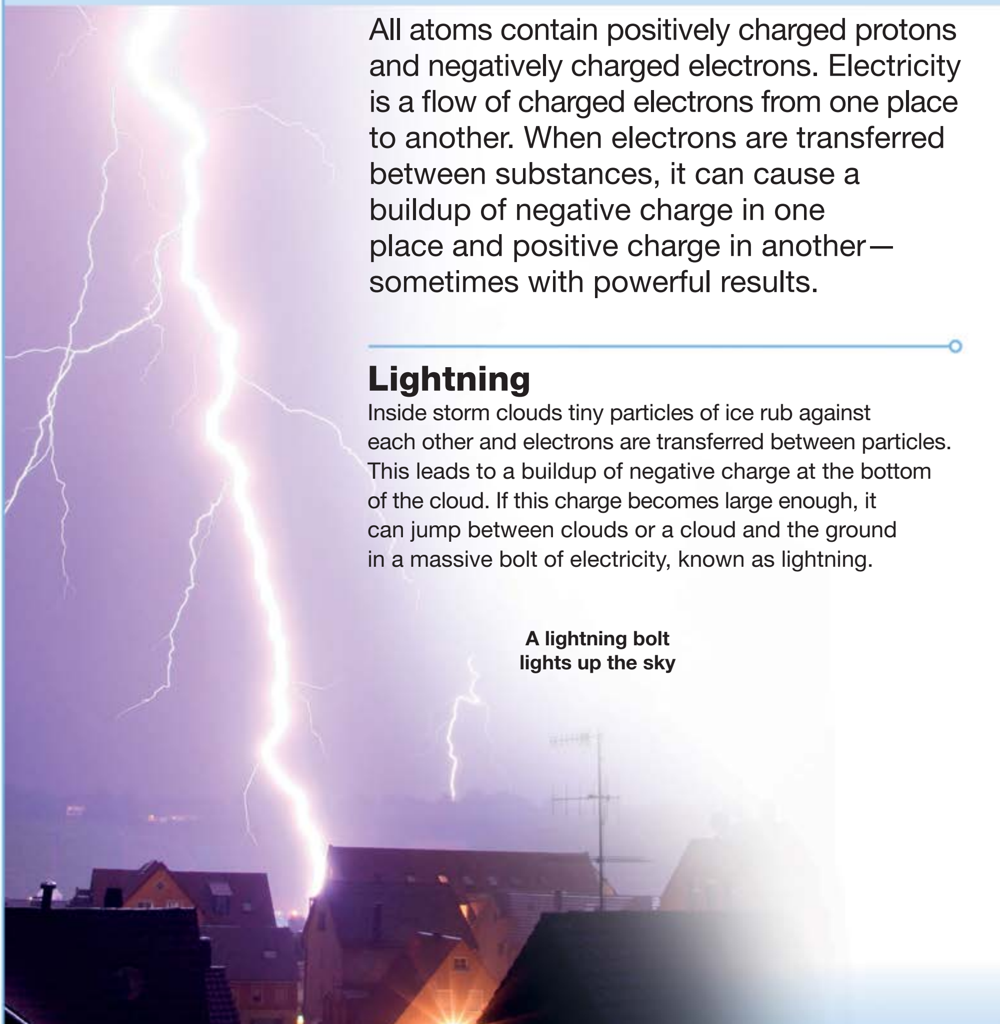
Nuclear fusion releases energy by forcing nuclei together to form new elements. Fusion reactions are the source of the Sun's energy. Every second, deep inside its core, 699 million tons (635 million metric tons) of hydrogen turn into helium.

Electricity

All atoms contain positively charged protons and negatively charged electrons. Electricity is a flow of charged electrons from one place to another. When electrons are transferred between substances, it can cause a buildup of negative charge in one place and positive charge in another—sometimes with powerful results.

Lightning

Inside storm clouds tiny particles of ice rub against each other and electrons are transferred between particles. This leads to a buildup of negative charge at the bottom of the cloud. If this charge becomes large enough, it can jump between clouds or a cloud and the ground in a massive bolt of electricity, known as lightning.



A lightning bolt lights up the sky

Static electricity

When electrical charge builds up in one place it is called static electricity. If you rub your hair on a balloon, electrons are transferred from your hair to the balloon. This gives your hair a positive charge and the balloon a negative charge. Particles with opposite charge are attracted to each other so your hair will stick to the balloon.

Hairs separate because particles with the same kind of charge repel each other

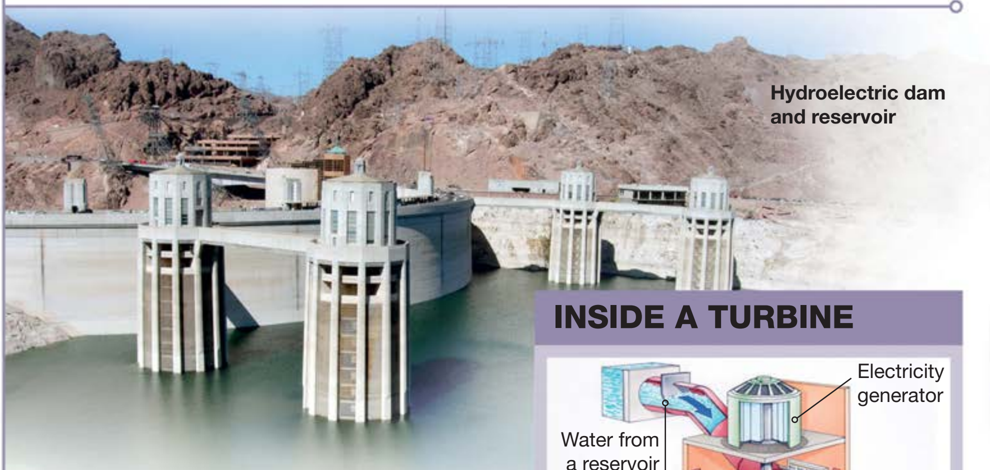
Current electricity

The electricity that powers our homes is known as current electricity. It flows from power plants to our homes and offices along long electric cables that are made from conducting materials (see page 25). These cables are supported by towers that are protected from the current by ceramic insulators.

Towers support electric cables

Using electricity

The electricity we use around our homes and to power our gadgets is produced in several ways. It can be generated in massive power plants located far away. On a smaller scale, items such as flashlights and cell phones can be powered by batteries that provide electricity whenever we want.

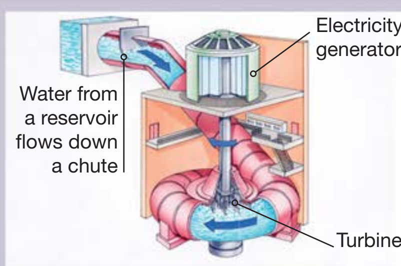


Hydroelectric dam and reservoir

Generating electricity

Electricity is produced, or generated, at power plants. They use massive machines called generators, which contain large coils of wire that spin inside a magnetic field to produce electricity. The coils are connected to turbines—large wheels with blades that are pushed around by steam or water. The steam is produced by heating coal, oil, or gas, or using nuclear power. Water-powered turbines are found at hydroelectric power plants.

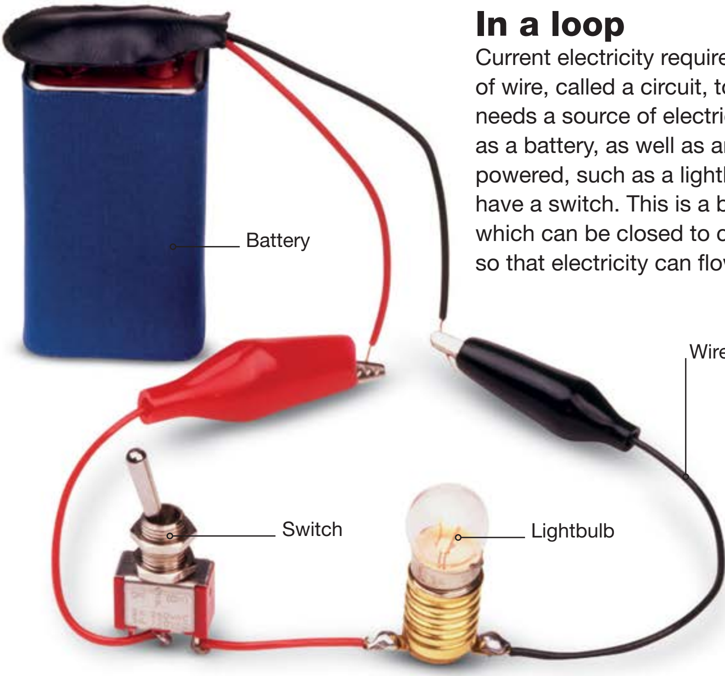
INSIDE A TURBINE



When water is released from a hydroelectric power plant's reservoir it rushes past the turbine's blades, sending them spinning.

In a loop

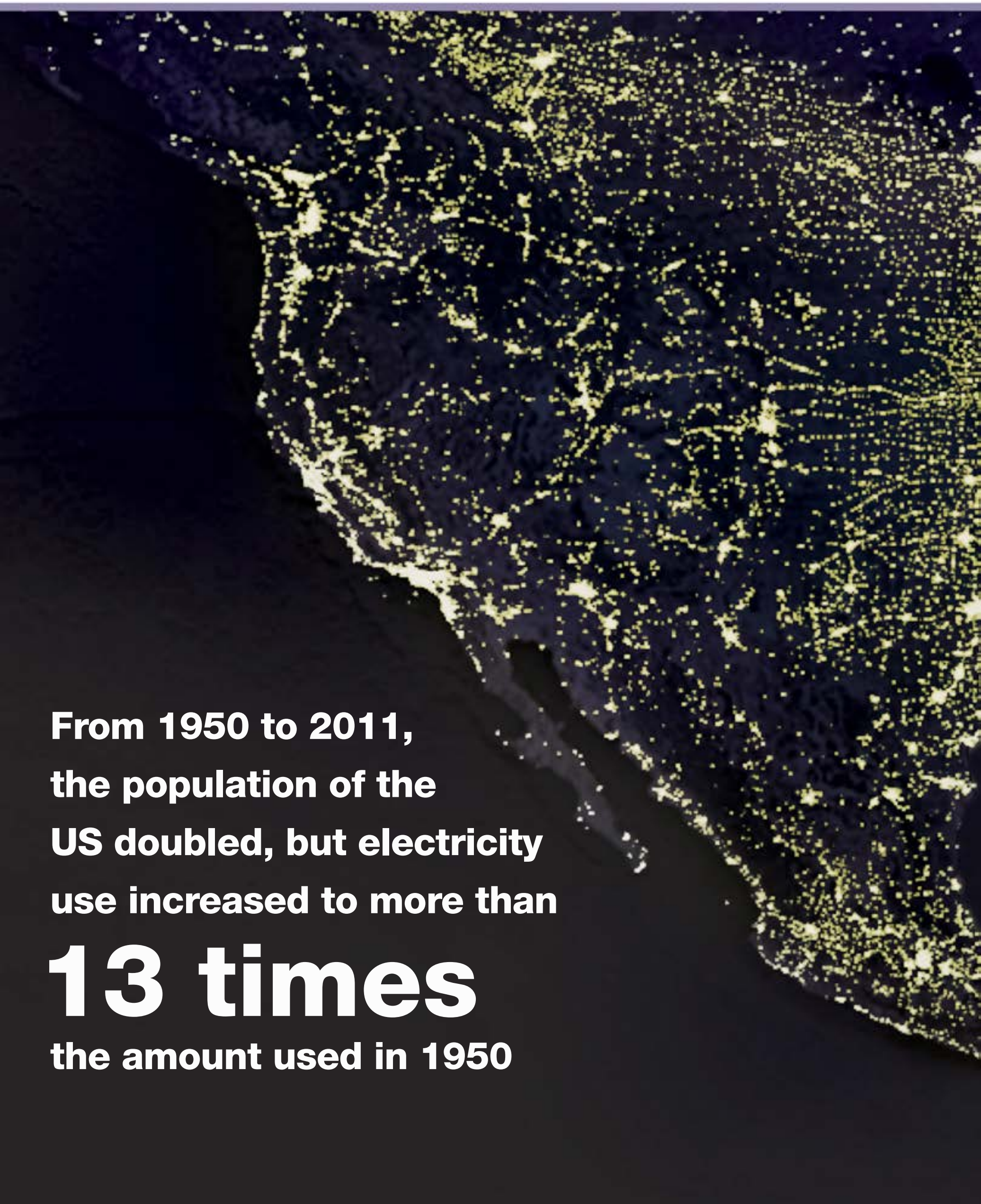
Current electricity requires a complete loop of wire, called a circuit, to flow. A circuit needs a source of electrical energy, such as a battery, as well as an object to be powered, such as a lightbulb. It can also have a switch. This is a break in the circuit, which can be closed to complete the loop so that electricity can flow.



A simple circuit

Storing electricity

Batteries store energy in chemicals. When a battery is put into a circuit it makes a current flow around the circuit. Batteries are very useful for small electrical devices that do not need much power, or for devices that have to be portable.



From 1950 to 2011, the population of the US doubled, but electricity use increased to more than

13 times

the amount used in 1950

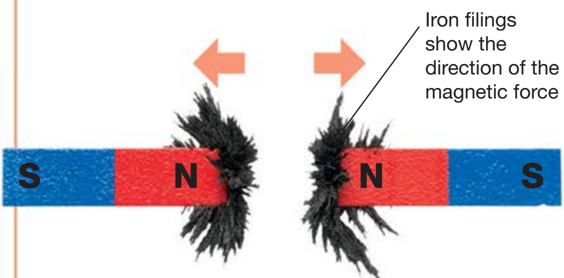
BRIGHT LIGHTS
Twinkling lights show where the towns and cities are on this satellite image of the US at night. The country generates more electricity than any other—more than twice the generating capacity of the second largest producer of electricity, China.

Magnetism

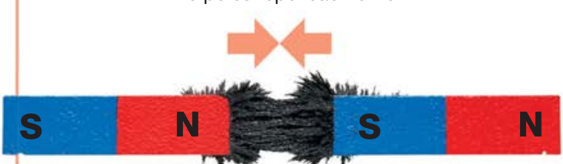
Magnetism is a force that can attract (pull toward) or repel (push away). Materials that are strongly attracted to magnets, such as iron or nickel, are called ferromagnetic materials. Some magnets are permanently charged with magnetism, while others are only magnetic when they are inside a coil of wire with an electrical current flowing in it.

Repel or attract

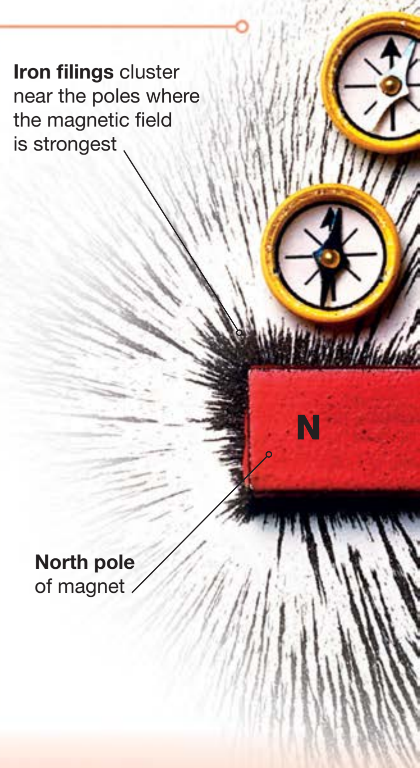
A magnet has two ends, or poles—a north pole and a south pole. When two magnets are placed near each other with like (the same) poles facing, the two poles will push each other away. If a north pole is facing a south pole, they will pull toward each other.



Like poles repel each other

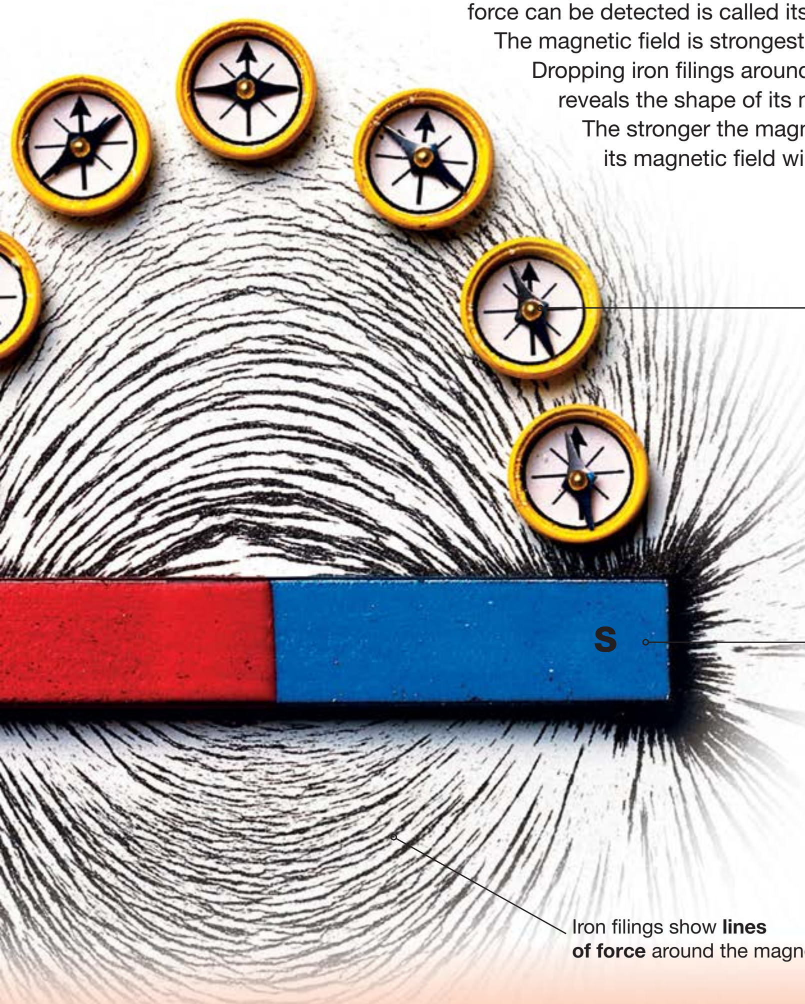


Opposite poles attract each other



Magnetic field

The area around a magnet where a magnetic force can be detected is called its magnetic field. The magnetic field is strongest near the poles. Dropping iron filings around a magnet reveals the shape of its magnetic field. The stronger the magnet, the larger its magnetic field will be.



Compass needles align with the **magnetic field**

South pole of magnet

Iron filings show **lines of force** around the magnet

Magnets in action

We use magnets in many different ways. The motors inside many machines are driven by small magnets, while large magnets can power trains. Compasses use Earth's magnetism to show us the way.

Electric motors

This toy car is powered by an electric motor, which uses magnets to produce a spinning motion. Electric motors are found in many machines. Washing machines and vacuum cleaners contain large motors, while the hands of a wristwatch are moved by tiny motors just a few millimeters wide.

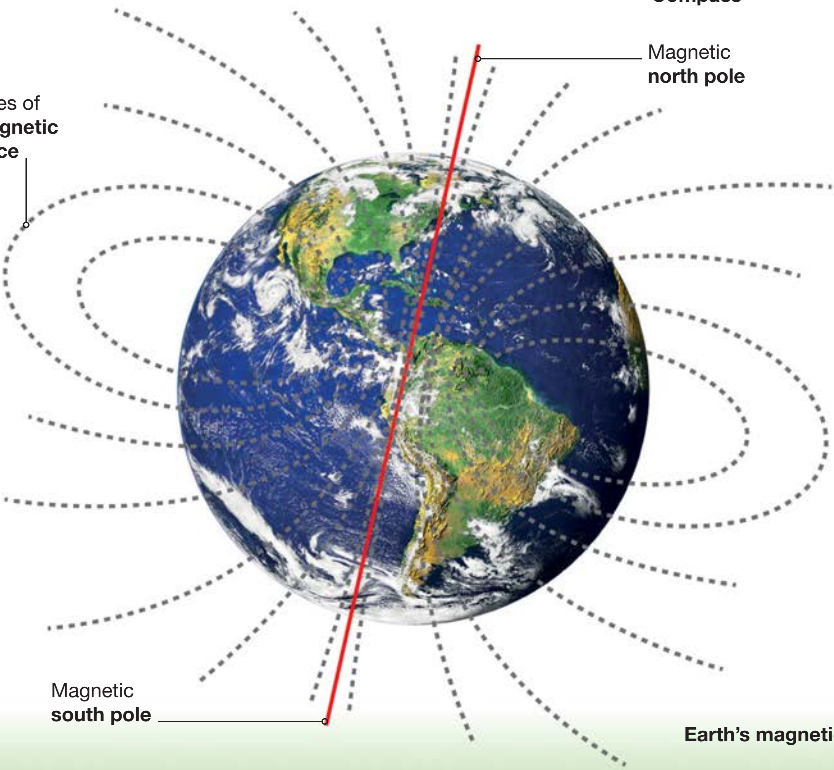
Magnetic trains

A maglev train is moved by magnetism. Magnets under the train and on the track make the train hover up to nearly ½ in (10 mm) above the track. The train does not have an engine, but is pushed forward by another set of magnets, and can reach speeds of up to 360 mph (580 kph).

Magnetic Earth

Earth is a giant magnet. It is surrounded by a magnetic field, which is produced by electric currents deep inside the planet's molten metal core. A compass works by sensing Earth's magnetism. It contains a small magnetic needle, and the south pole of the needle points toward Earth's magnetic north pole.

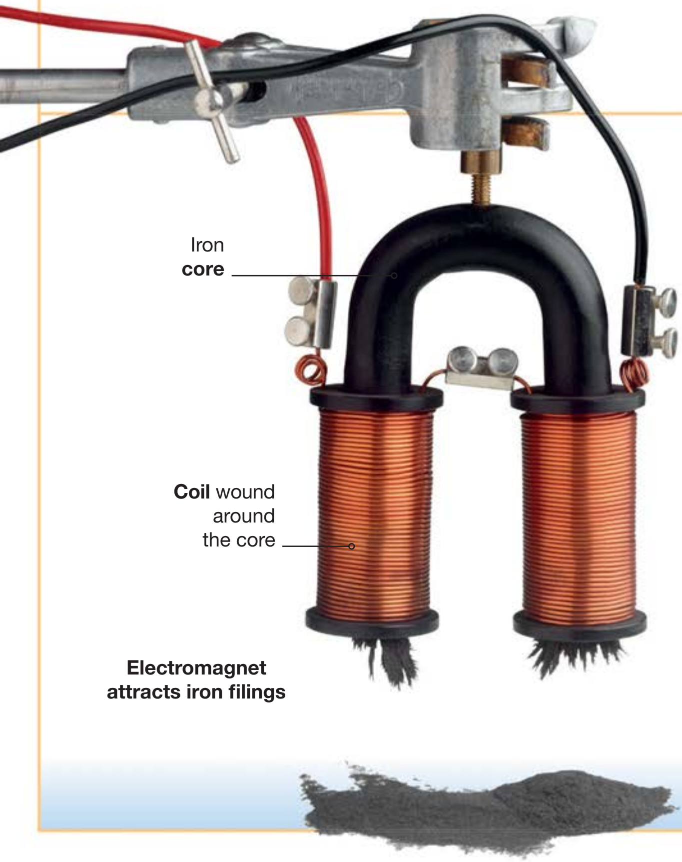
Compass



Earth's magnetic field

Electromagnetism

An electrical current always produces a magnetic field around it. Electromagnets are made by passing electricity through a wire that has been wrapped around a piece of iron. Unlike permanent magnets, an electromagnet loses its magnetism as soon as the electrical current is switched off.

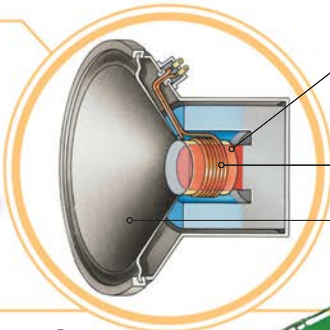


How an electromagnet works

To make an electromagnet, a copper wire is wrapped tightly around an iron core. When electricity passes through the wire, the iron core is turned into a magnet. The stronger the electrical current, and the more times the wire is wrapped around the core, the stronger the magnet will be.

Making sounds

Speakers use electromagnets to make sounds. Electricity flows through a small electromagnet inside the speaker. Changes to its magnetic field causes a cone to vibrate. We hear these vibrations as sounds. Varying the strength of the electrical current changes the volume of the sound produced by the speaker.



Lifting metals

Scrapyards use powerful electromagnets to pick up and move heavy objects. Only magnetic materials such as iron are attracted to the magnet. Electromagnets are also used to separate magnetic metal from non-magnetic materials so that it can be recycled.

The EM spectrum

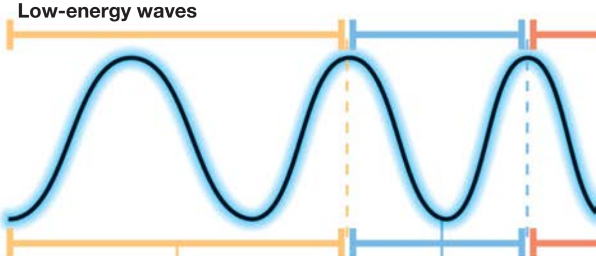
Electromagnetic (EM) radiation is a form of energy that travels in waves at a speed of 186,000 miles (300,000 km) per second, which is the fastest speed in the universe. Different kinds of radiation make up the EM spectrum. All types of radiation except visible light are invisible.

The spectrum

The EM spectrum is made up of seven major types of radiation, which vary in the length of their waves. The shorter the radiation's wavelength, the higher its energy. The longest waves can be many miles long, while the shortest are shorter than a single atom.

Hot objects, including mammals, give off invisible rays of heat called **infrared (IR) waves**.

Low-energy waves

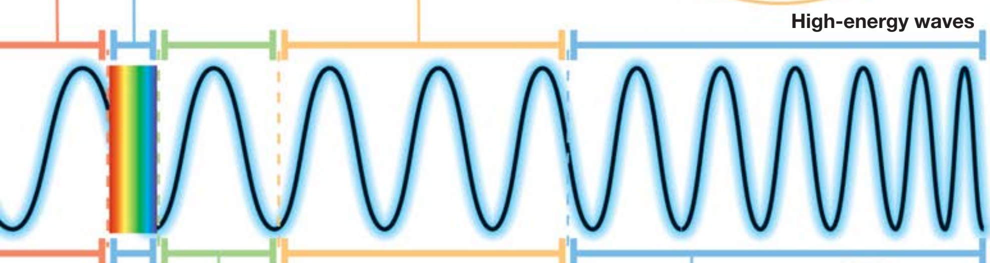


Radio waves have the longest wavelength. Radio and TV broadcasts and Wi-Fi use radio waves.

Microwaves are used to heat food. They are also used by cell phones.

X-rays have enough energy to pass through many materials. They are used to scan the contents of bags at security checks.

Visible light includes all the colors of the rainbow.



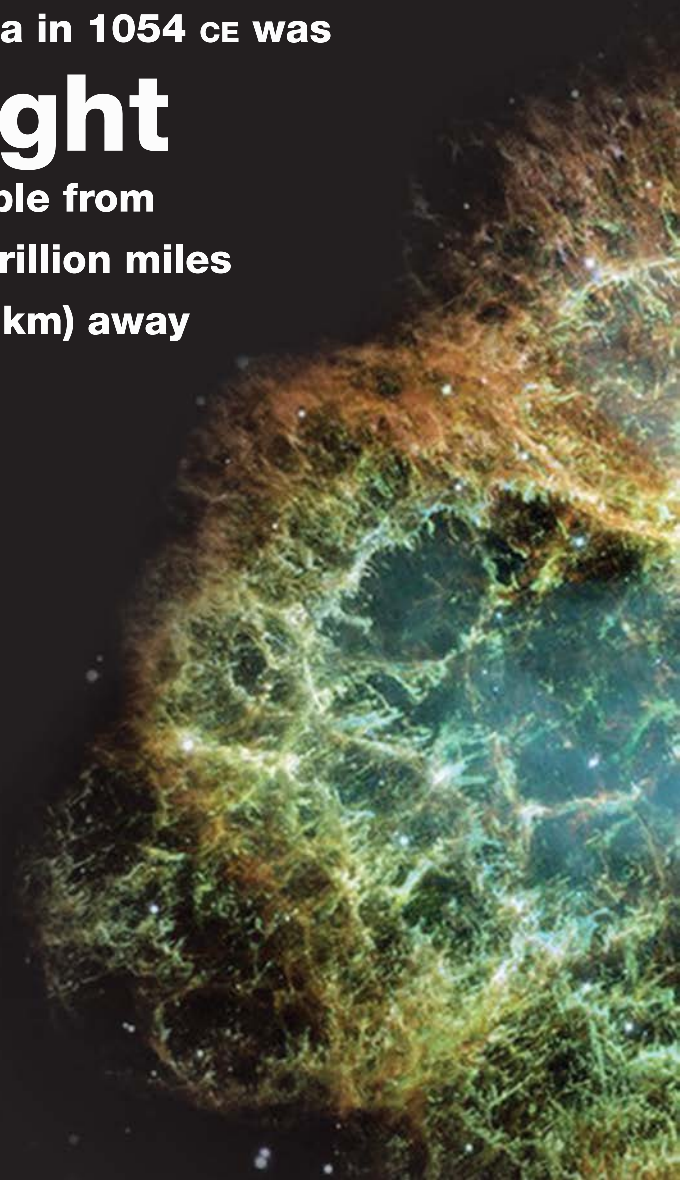
Sunlight contains **ultraviolet (UV) rays**. Goggles, sunglasses, and sun screen protect the eyes and skin from UV rays, which can be harmful.

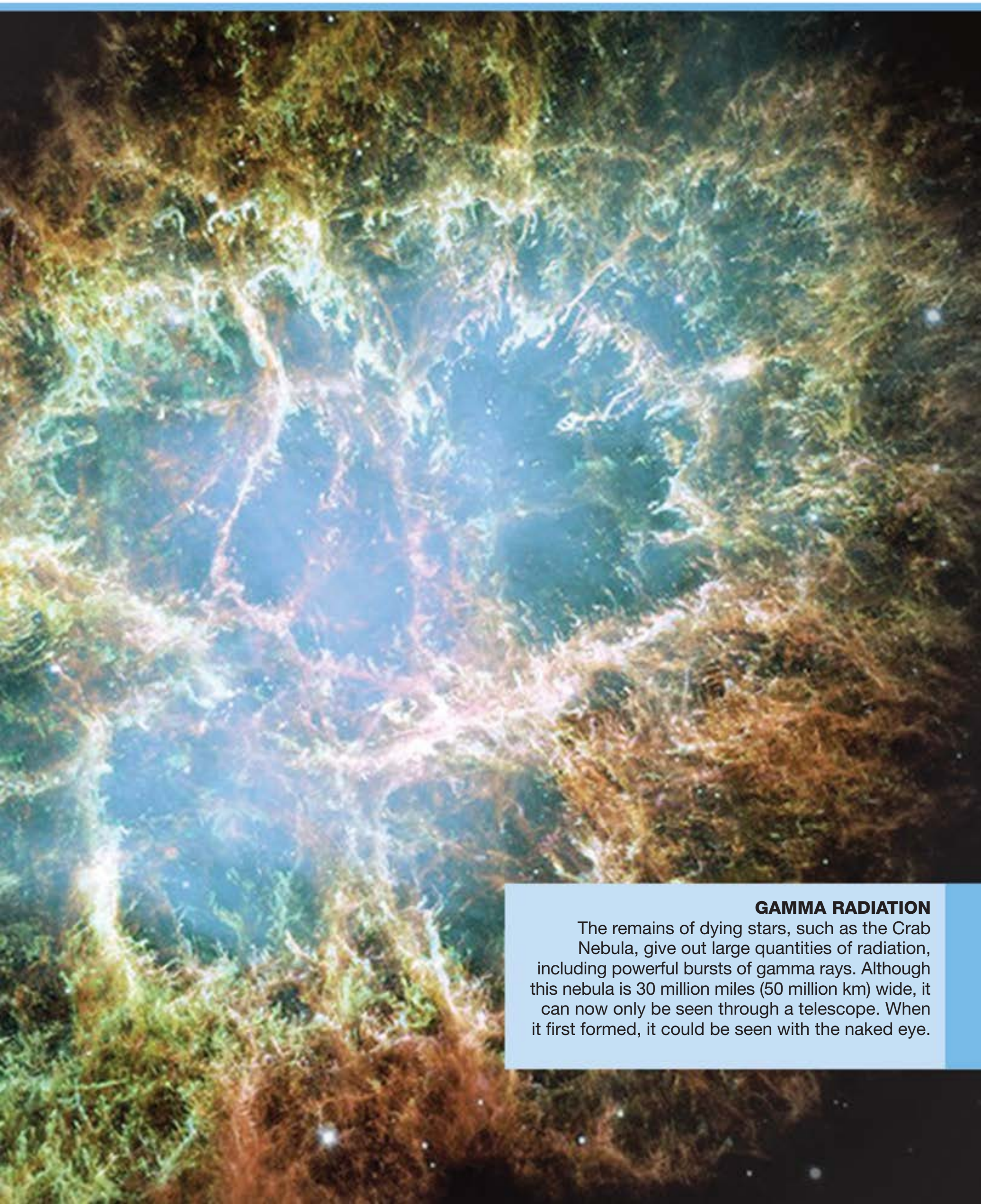
Gamma rays have the highest energy of all. Observatories measure gamma rays emitted by very hot stars and other bodies in space.

The explosion of the star that formed the Crab Nebula in 1054 CE was

so bright

that it was visible from Earth, 39,000 trillion miles (62,000 trillion km) away





GAMMA RADIATION
The remains of dying stars, such as the Crab Nebula, give out large quantities of radiation, including powerful bursts of gamma rays. Although this nebula is 30 million miles (50 million km) wide, it can now only be seen through a telescope. When it first formed, it could be seen with the naked eye.

Light

Light is the only form of electromagnetic radiation we can see. Most things absorb and reflect light, but few objects give out light. The Sun is the main source of light in the day, while electric lights provide illumination at night.

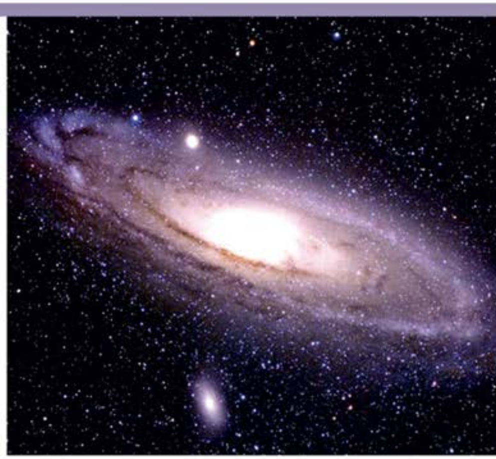
Making shadows

Some materials, such as glass, allow light to pass through them. They are known as transparent. Other materials, such as wood or metals, do not let light pass through. They are known as opaque. If something blocks the path of light, it creates a dark area behind called a shadow.

A snowboarder blocks the straight path of light, creating a shadow

Speed of light

In a vacuum (a space that is empty of all matter), light travels at 186,000 miles (300,000 km) per second. Nothing in the universe can travel faster. The distances of very far-off objects, such as stars and galaxies, are calculated using the distance light can travel in a year. This distance is known as a light-year. One light-year equals about 6 trillion miles (10 trillion km).



The Andromeda Galaxy is 2.5 million light-years away

Bending and reflecting

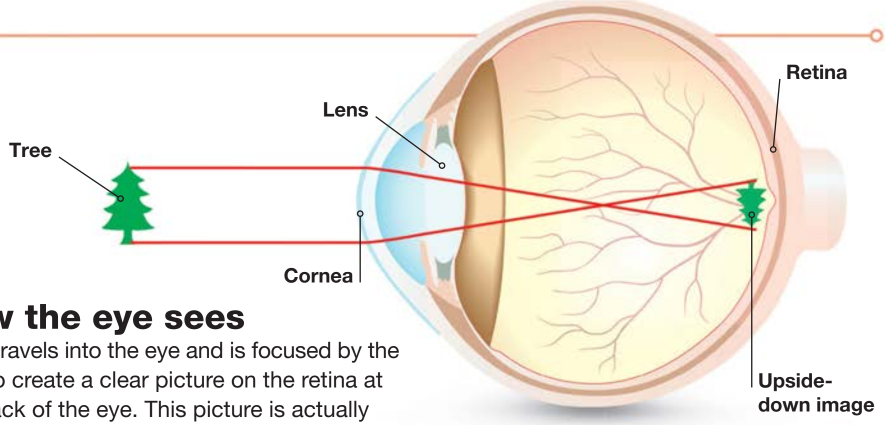
Light normally travels in straight lines. When light travels from one material to another, such as when it passes from air to water, its path is bent, or refracted. This can create a distorted image. Light is also bounced, or reflected, by a shiny surface, which sends light back at the same angle at which it hits the surface.

Reflection in a mirror

Refraction makes the straw appear bent where it meets the water

Using light

We need light to see the world and to find our way around it. In the earliest days of humanity, we just used the natural light produced by the Sun and went to bed when it got dark. Today, we can also use artificial lights to illuminate the world.



Human eye

How the eye sees

Light travels into the eye and is focused by the lens to create a clear picture on the retina at the back of the eye. This picture is actually upside down, but the brain turns the image the right way up so we can understand it.

Telescopes

Telescopes collect light from distant objects, such as planets and stars. Lenses and mirrors within the telescope then bend the light rays to make a clear image of the object, making it seem closer than it really is.

Telescope

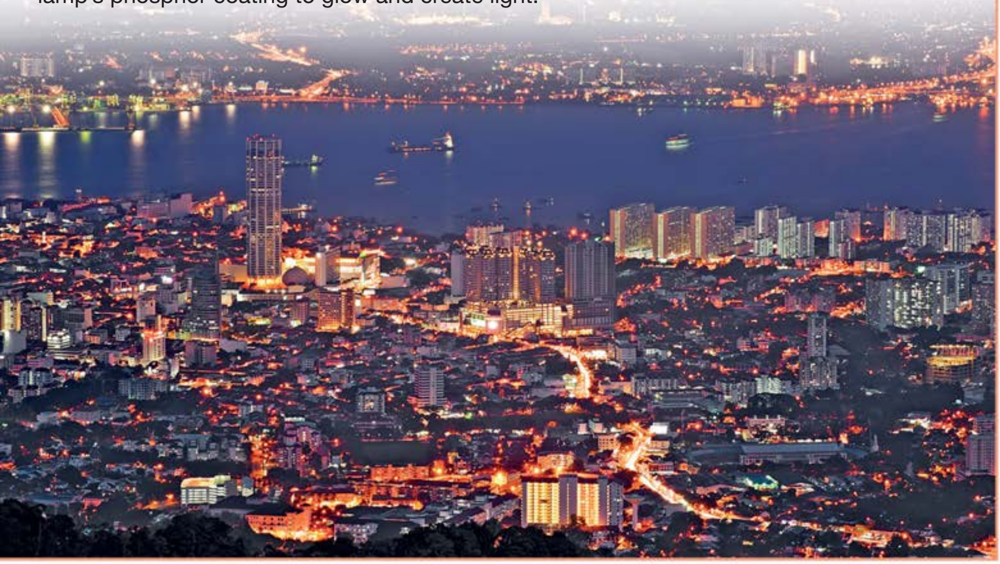
Camera

Like our eyes, cameras collect and bend light to produce a clear picture. The camera lens focuses light into an image, which is recorded on light-sensitive film or a light-sensitive microchip.

Light is focused by a number of glass lenses to form a sharp image

Lighting the dark

Electric lights convert electrical energy into light. In an incandescent light bulb, this is done by heating a thin piece of metal until it glows. In compact fluorescent lights, electricity is passed through a gas, causing the lamp's phosphor coating to glow and create light.



Electric lights illuminate the city of Penang, Malaysia, at night

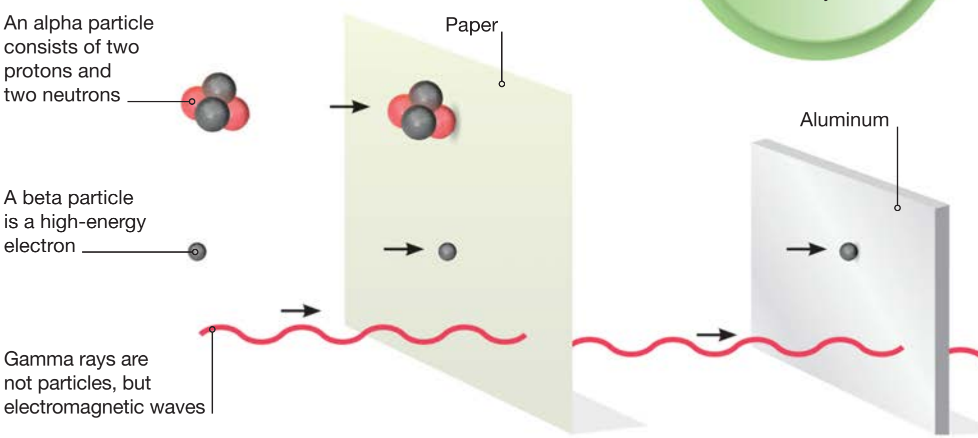
Radioactivity

In some atoms, the nucleus changes over time, releasing particles and energy, known as radiation. This process is called radioactive decay. We encounter low-level radiation all the time—in the soil, in the air, and in the food we eat.

Types of radioactivity

There are three types of radioactivity: positively charged alpha particles, which are slow-moving and cannot pass through materials easily; negatively charged beta particles, which move much faster; and gamma rays—a form of electromagnetic radiation (see pages 68–69)—which carry no charge.

Radioactivity was discovered in 1896 by the French physicist Henri Becquerel when he was investigating X-rays.



Alpha particles cannot pass through paper, but beta particles and gamma rays can

Beta particles are blocked by a thin sheet of metal, but gamma rays pass through

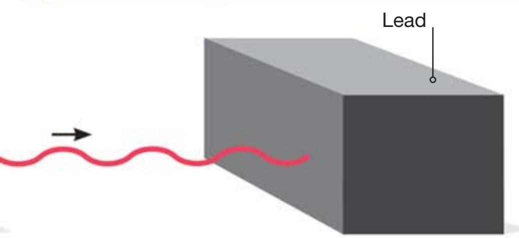
Detecting radiation

Radiation is invisible, but it can be detected using a Geiger counter. This simple handheld device uses a gas-filled tube to measure the presence of alpha particles, beta particles, and gamma rays.

Measuring radiation levels in tomatoes

Using radiation

While high levels of radiation can be harmful, some forms of radioactivity are useful. PET scanners use gamma rays to produce highly detailed images of the inside of the body, which can help doctors to diagnose illnesses.



Gamma rays can be stopped only by a thick layer of dense material, such as lead

Heat

The atoms and molecules that make up matter are always on the move. The more energy they have, the faster they move. We feel this energy as heat. Heat will always move from a warmer area to a colder one until both areas are the same temperature.

Cooling down

The molecules in a hot mug of coffee are moving very fast. The coffee transfers heat energy to the cooler air. This makes the molecules in the coffee slow down, meaning that it gets cooler. After about an hour, the coffee and the air will be the same temperature. The colder the air around the mug, the faster the coffee will cool down.

This infrared image of a person eating an ice pop shows the coldest areas in black and warm areas in red and yellow

Detecting heat

Heat energy escapes objects as infrared radiation. Infrared is invisible to our eyes, but special cameras can detect it. Infrared cameras are used by firefighters to see whether there are people trapped in a building, and by the military to see at night.

The balloon is filled with hot, less dense air

Expanding air

When substances heat up, the molecules in them move faster and take up more space. This means that substances expand as they are warmed and become less dense. To make a hot-air balloon float, a burner heats up the air in the balloon. The air inside the balloon is now less dense than the colder air outside it. This causes the balloon to rise.

Measuring temperature

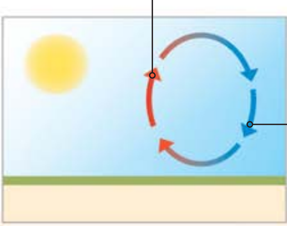
Temperatures are measured using thermometers. Simple thermometers work by measuring the length of a column of liquid. As the temperature increases, the liquid expands and the column becomes longer.

Radiation

Warm objects give off heat in the form of infrared radiation. Earth is warmed by the heat given off by the Sun, which is the hottest object in the solar system. Infrared lamps can be used to produce heat—the lamp shown here keeps the pigs warm at night.

Convection

Heat can be transferred from one place to another through convection, which is the movement of hot liquid or gas, such as air. As air heats up, it becomes less dense and rises. Cooler air sinks and takes its place. This causes convection currents of moving air.



Convection currents

Insulators

Materials that do not allow heat to pass through them easily are called insulators. Plastic, rubber, and wood are all insulators. Air is also a good insulator. Fur keeps animals warm by trapping a layer of air next to the skin. This stops heat from being removed from the body.

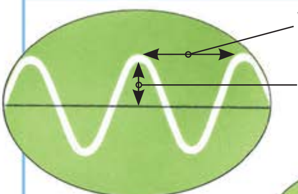
Clothing made from good insulating material keeps this climber warm

Conduction

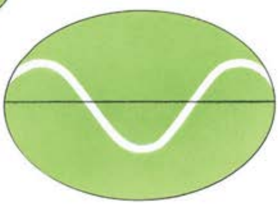
As molecules move, they pass on some of their heat energy to neighboring molecules. This transfer of heat is called conduction. Solids conduct heat more easily than liquids or gases. Metals are good conductors and are used to make saucepans and the base plates of irons.

Sound

Sounds are vibrations that we hear with our ears. The vibrations travel through substances such as air or water in the form of sound waves. When the waves reach our ears, they make our eardrums vibrate. The size and shape of the waves determine the kind of sound we hear.



A high-frequency wave has a short wavelength



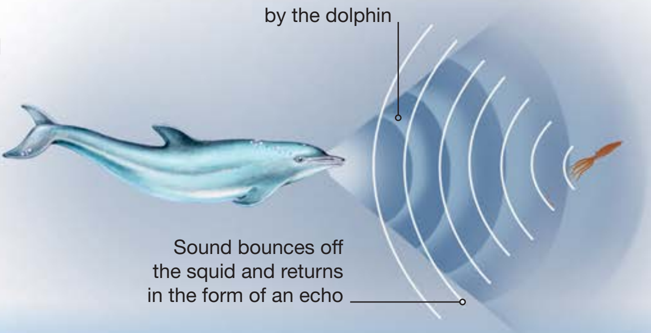
A low-frequency wave has a long wavelength

High and low

The number of vibrations a sound wave makes every second is called its frequency. The higher a sound's frequency, the higher its pitch, or note. Some animals, such as dogs, can hear sounds with a very high pitch that humans cannot hear. Elephants can hear very low-pitched sounds.

Using sounds

Sound waves bounce off hard objects. We hear sound bouncing back at us as an echo. Some animals, such as dolphins and bats, use echoes to detect prey. They emit high-pitched sounds and listen out for any echo bouncing back off objects around them.

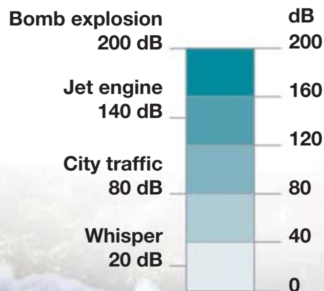


Sound quality

The quality, or timber, of a sound is determined by the shape of its wave. Each instrument in an orchestra has a different timber. Some, such as a flute, produce sound waves with a regular shape, which we hear as a pure note. Others, such as drums, make rougher sounds with irregular waves.

Loud and soft

The more energy a sound wave contains, the larger its amplitude. We hear sounds with lots of energy as loud sounds. A sound's loudness is measured in decibels. Decibels are measured on a special scale called a logarithmic scale. A sound measured at 20 dB is 10 times louder than one measured at 30 dB.



Decibel (dB) scale

The sound of a bomb explosion may hit 200 dB, which is loud enough to damage our ears

Forces

Forces are pushes and pulls that change an object's shape or movement. Every time an object speeds up, slows down, or changes direction, this happens because a force is acting on it. Forces such as gravity can act over huge distances, keeping the planets in orbit around the Sun.

Gravity

The force of gravity pulls all objects toward each other. Objects with just a small mass only pull very weakly, but the gravity of our planet Earth is strong enough to hold us to the ground. Space rockets use powerful engines to push them away from the ground and break free from Earth's gravity.

A black hole is a very dense object in space. It has such strong gravity it pulls everything around it, even light from stars.

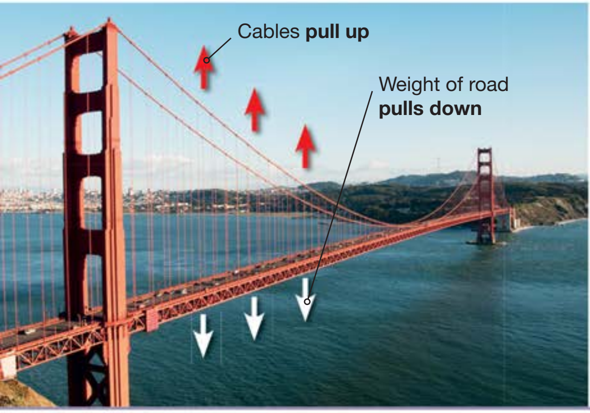
Atlas V rocket launching into space

Wide tracks spread the weight of the tank over a large area, stopping it from sinking in the sand

The force of the person swinging the pick ax is concentrated on the sharp point of the ax, producing enough pressure to split the rock

Under pressure

A force acting on a particular area causes pressure. A force applied over a small area produces more pressure than the same force applied over a larger area. The tracks on a tank's wheels spread its weight over a large area. This reduces the pressure and stops it from sinking in soft ground.



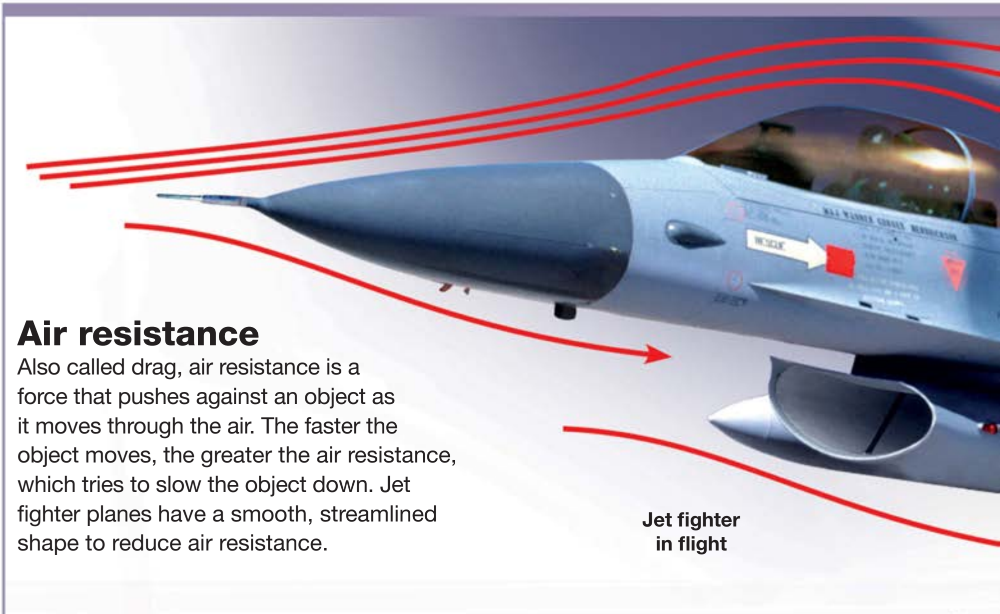
Balanced forces

More than one force can act on an object at the same time. Two forces pulling in opposite directions will stretch an object, but will not move it. The cables holding up a suspension bridge pull against the weight of the bridge to stop it from collapsing.

Golden Gate Bridge, San Francisco, California

Air resistance

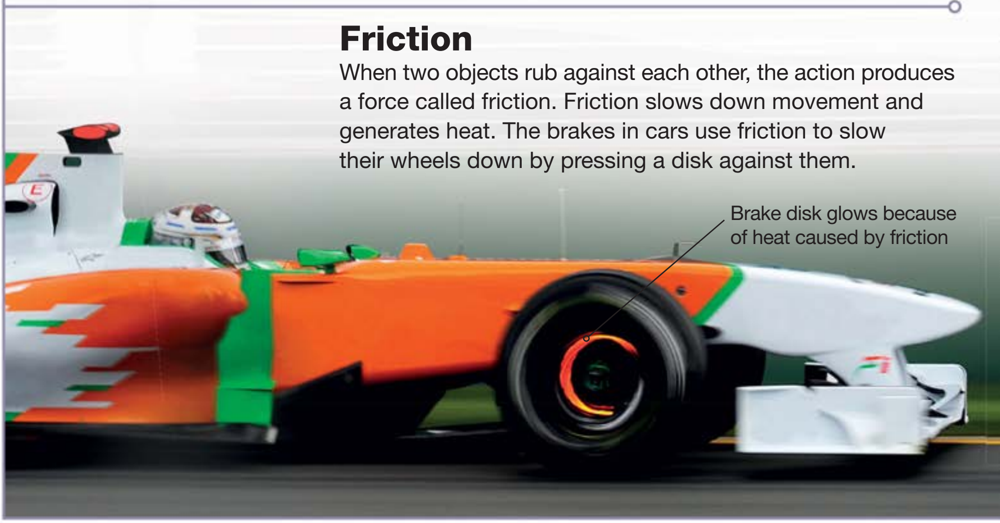
Also called drag, air resistance is a force that pushes against an object as it moves through the air. The faster the object moves, the greater the air resistance, which tries to slow the object down. Jet fighter planes have a smooth, streamlined shape to reduce air resistance.



Jet fighter in flight

Friction

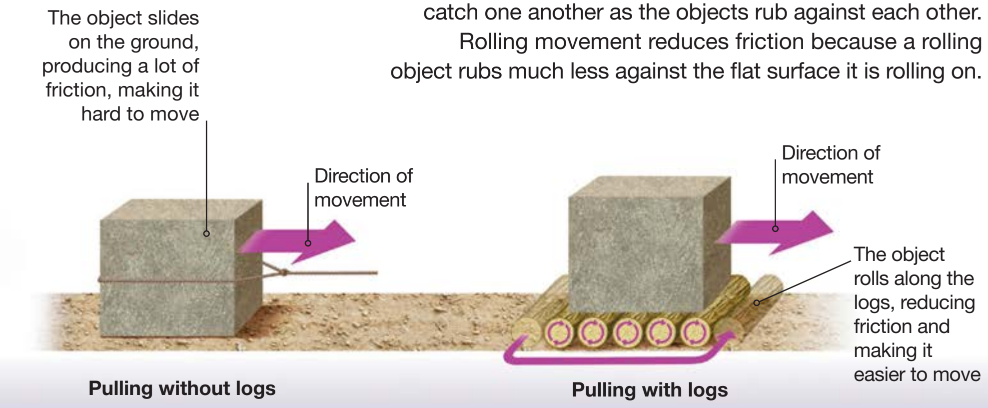
When two objects rub against each other, the action produces a force called friction. Friction slows down movement and generates heat. The brakes in cars use friction to slow their wheels down by pressing a disk against them.



Brake disk glows because of heat caused by friction

Reducing friction

Friction is caused when the rough surfaces of objects catch one another as the objects rub against each other. Rolling movement reduces friction because a rolling object rubs much less against the flat surface it is rolling on.



Forces and movement

Whenever an object changes speed or direction, this happens because a force is acting on it. More than 300 years ago, the English scientist Isaac Newton worked out three laws of motion that explain how forces affect movement.

First law of motion

The first law states that an object will continue at the same velocity in a straight line if no force is acting on it. If the object is not moving, it will remain at rest until a force acts on it. The space probe *Voyager 2* is flying through space with almost no forces acting on it to slow it down, so it will continue moving at the same velocity.

Second law of motion

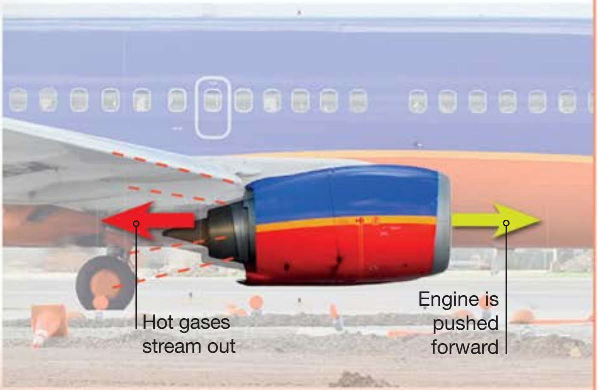
According to Newton's second law, the greater the force applied, the greater the acceleration. Acceleration also depends on the mass of the object—the more mass it has, the more force is needed to accelerate it. Motorcycles have much smaller mass than cars and can accelerate very quickly.

VELOCITY AND ACCELERATION

An object's velocity is the speed at which it is traveling in a particular direction. An increase in velocity is called acceleration, while a decrease is called deceleration. Race cars have powerful engines and can accelerate to high speeds incredibly quickly—from 0 to 100 mph (160 kph) in under 5 seconds.

Third law of motion

Newton's third law of motion states that every action has an equal and opposite reaction. A jet engine attached to an aircraft burns fuel to send out a powerful stream of hot gases behind it. As this jet of gases shoots backward, it pushes the engine forward, and the aircraft with it.



Wind speeds in a tornado can reach more than **300 mph** (480 kph), strong enough to tear down trees and send cars flying through the air

THE FORCES OF WIND

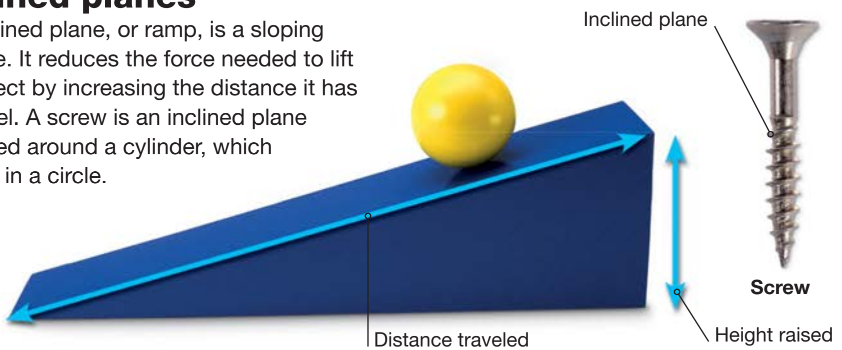
Tornadoes are violently destructive storms that form from rotating blocks of air in thunderclouds. As the hot air rises and the cold air sinks, the two blocks begin to spin, forming a rotating column of superfast winds.

Simple machines

We use simple machines to help us do our work more easily. There are six kinds of simple machine. They change the direction or size of a force, allowing us to use less effort when moving, separating, or keeping heavy objects in place.

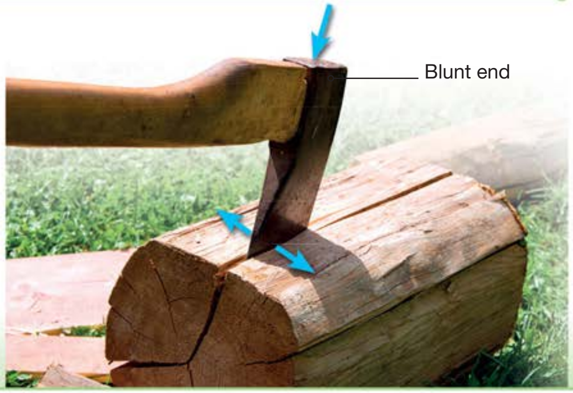
Inclined planes

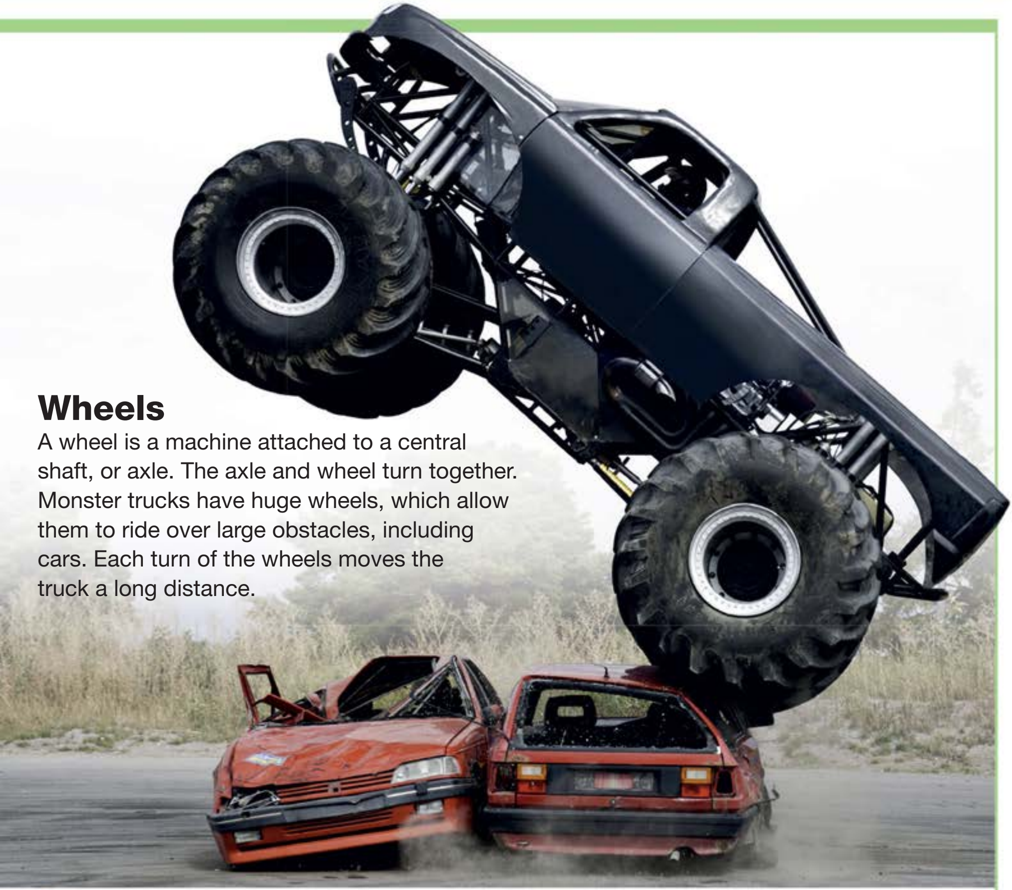
An inclined plane, or ramp, is a sloping surface. It reduces the force needed to lift an object by increasing the distance it has to travel. A screw is an inclined plane wrapped around a cylinder, which moves in a circle.



Wedges

A wedge is a triangular-shaped machine. It changes a force applied to its blunt end into a force that pushes outward. Wedges can be used to cut through objects—as with an ax cutting through wood—or to hold objects in place, like a wedge holding open a door.





Wheels

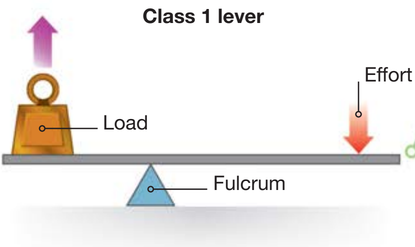
A wheel is a machine attached to a central shaft, or axle. The axle and wheel turn together. Monster trucks have huge wheels, which allow them to ride over large obstacles, including cars. Each turn of the wheels moves the truck a long distance.

Gears

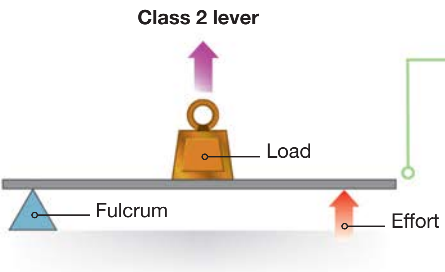
Gears are wheels with teeth. Connected together, gears transfer a force from one place to another and can change the size of the force. Here, the larger yellow gear is twice the size of the smaller blue one. So, for every complete turn of the yellow gear, the blue gear turns twice.

Levers

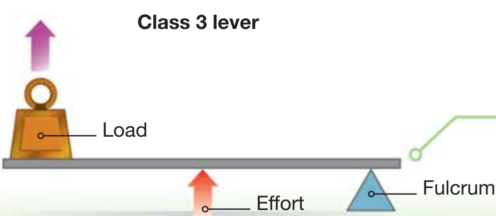
Simple machines called levers make it easier to lift heavy loads. A lever is fixed at one point, called the fulcrum, and rotates around that point. There are three different classes of lever, depending on the position of the fulcrum, the load, and the effort needed to lift the load.



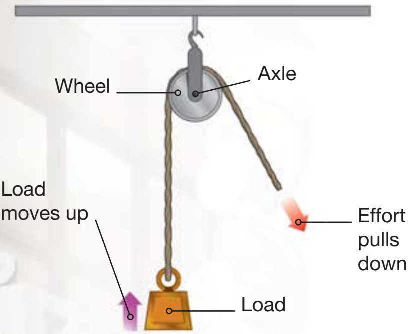
Clawhead hammer



Wheelbarrow



Shovel



Working of a pulley system

Pulleys

A pulley is a wheel on an axle with a rope running around it. A single pulley on its own can change the direction of a force. Two or more pulleys working together reduce the amount of force needed to lift a load by increasing the distance the rope has to travel.

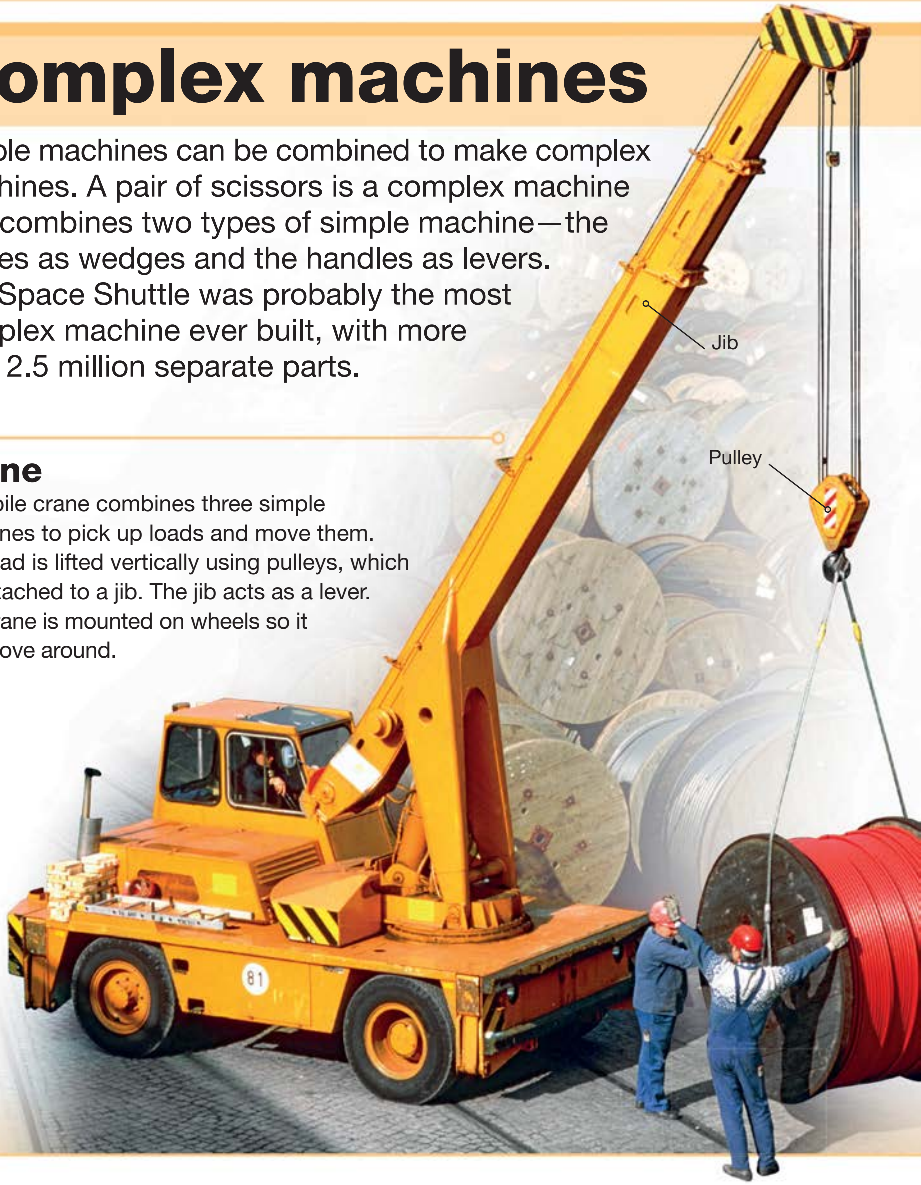
Pulley system being used in a weight-training exercise

Complex machines

Simple machines can be combined to make complex machines. A pair of scissors is a complex machine that combines two types of simple machine—the blades as wedges and the handles as levers. The Space Shuttle was probably the most complex machine ever built, with more than 2.5 million separate parts.

Crane

A mobile crane combines three simple machines to pick up loads and move them. The load is lifted vertically using pulleys, which are attached to a jib. The jib acts as a lever. The crane is mounted on wheels so it can move around.



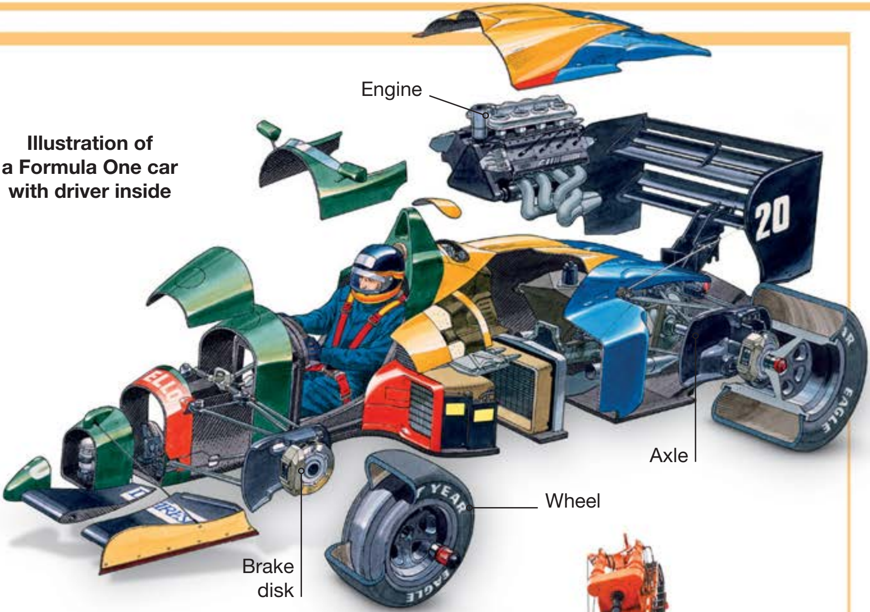


Illustration of a Formula One car with driver inside

Car

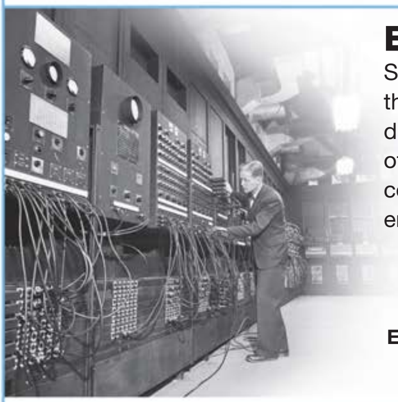
A car contains many simple machines. The wheels are attached to a gearbox, which allows the car to move at different speeds. The driver changes gears by pulling on the gearstick, which is a lever. The engine changes the energy from burning fuel into movements that turn the wheels.

Boring drill

A boring drill is a machine used to make deep holes in the ground. The drill bit is a screw with a sharp wedge on one end. A powerful engine turns the drill bit using a large force so that it can cut through hard ground and rock.

Computers

A computer is a machine that can be programmed to perform a huge range of tasks. Computers work using simple electronic circuits, called transistors, which can only be turned on or off. Millions of transistors can be combined to form microprocessors, which process instructions and tell the computer what to do.



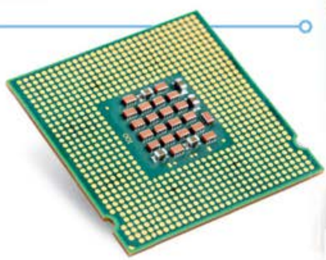
Early computers

Scientists in the UK and the US developed the first programmable electronic computers during World War II. With circuits made up of bulky wire and valves, these early computers were huge, often filling entire rooms.

ENIAC, an early computer

Microchip

Computers began to get smaller and faster following the invention of the microchip in the late 1950s. A microchip is a small piece of semiconducting material, such as silicon (see page 35), on to which millions of tiny circuits have been traced.



Computer chip

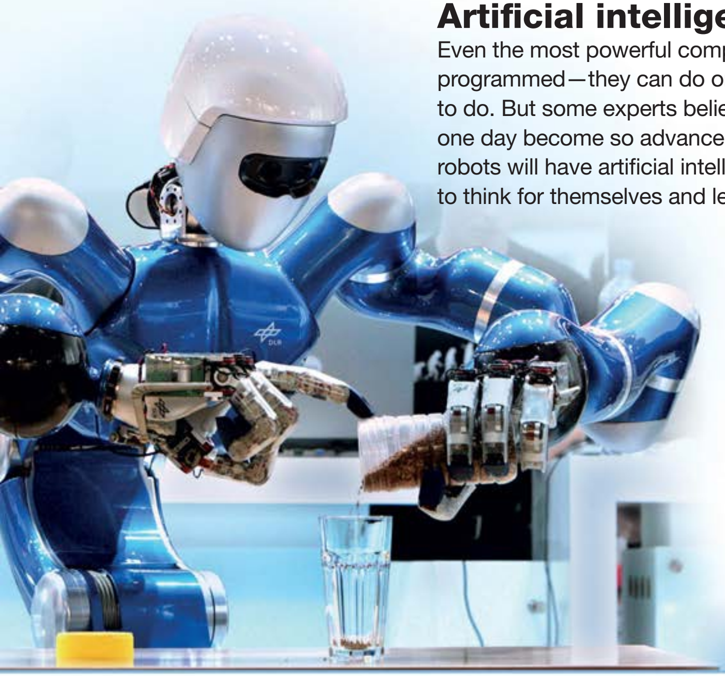
Modern computers

Modern computers are much smaller and millions of times more powerful than the earliest computers. Packed with microchips, they can process millions of instructions in the blink of an eye, allowing them to run applications, take pictures, operate phones, surf the Web, and play games all at the same time.

A tablet computer is operated by touching the screen

Artificial intelligence

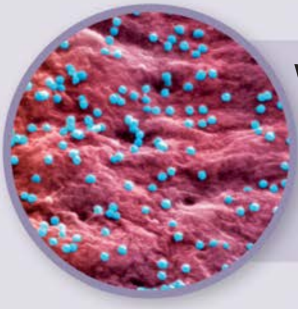
Even the most powerful computers have to be programmed—they can do only what people tell them to do. But some experts believe that computers will one day become so advanced that computers and robots will have artificial intelligence—they will be able to think for themselves and learn from their mistakes.



Humanoid (humanlike) robot Rollin' Justin preparing tea

The living world

Earth is the only place in the universe where life is known to exist. Millions of different kinds of life-form are found all over the planet. Some, such as bacteria, are too small to see with the naked eye, while others, such as trees, may be more than 300 ft (100 m) tall. Many habitats are incredibly rich in life—from lush tropical forests teeming with insects, mammals, and frogs to coral reefs on the seafloor that are packed with brightly colored fish, crustaceans, and tiny plankton.



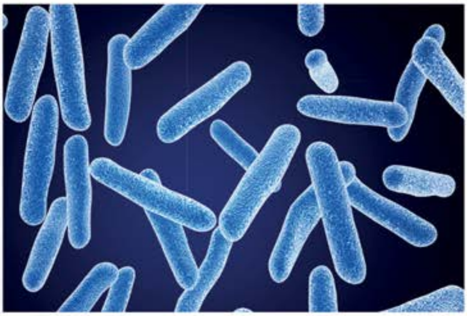
WHAT IS LIFE?
Living things are organized structures that reproduce themselves. Viruses can only reproduce inside other living things, so they are not usually thought of as alive.

Types of living thing

Scientists divide the wide variety of life on Earth into different groups. The smallest group is the "species," which are life-forms that are very similar and are able to breed with each other. The largest group is the "kingdom." There are five kingdoms—fungi, bacteria, protists, plants, and animals.

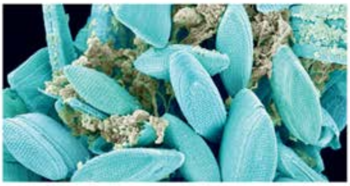
Fungi

A group of living things called fungi feeds on dead or rotting animals and plants. This kingdom includes mushrooms, molds, and yeast.



Bacteria

All living things are made up of microscopic units called cells. Tiny single-celled bacteria are the simplest form of life, and the most common. They are found all over the planet.

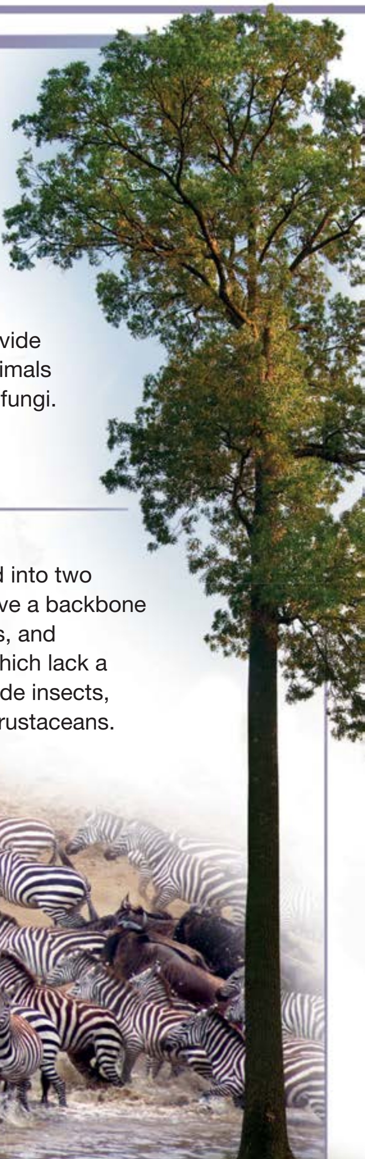


Protists

The protists are also single-celled life-forms. Their cells are more complex than bacteria and contain a nucleus as a control center. Many protists, such as algae, live together in large groups.

Plants

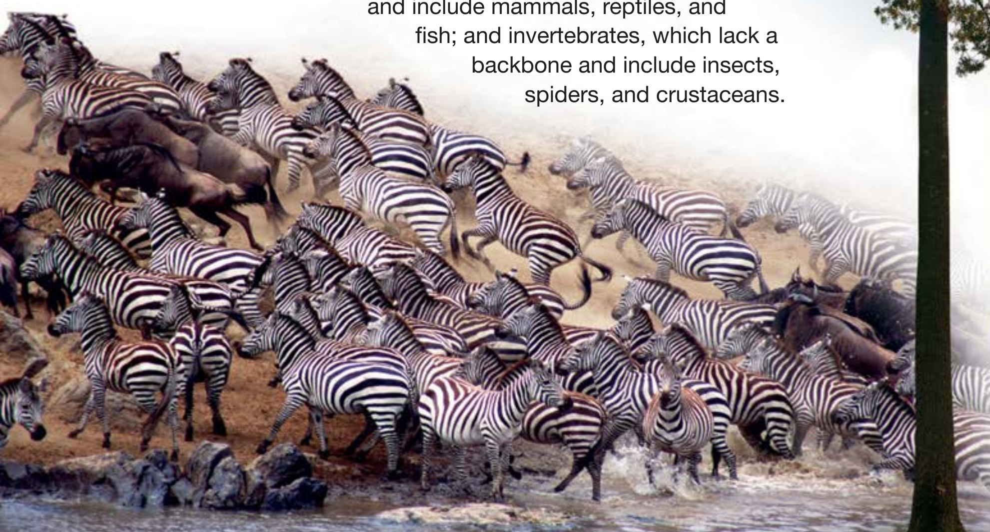
Members of the plant kingdom produce oxygen and are crucial to life on Earth. They make their own food using the energy of the Sun, and also provide food for both animals and fungi.



Animals

The animal kingdom is divided into two groups: vertebrates, which have a backbone and include mammals, reptiles, and fish; and invertebrates, which lack a backbone and include insects, spiders, and crustaceans.

Zebras and wildebeest are mammals, a kind of vertebrate



Classifying life

To study the wide range of life on Earth, scientists group together living things that have similar characteristics. There are different levels of groups, depending on how similar the life-forms are. The broadest level is a kingdom, such as animals. All animals are then divided into smaller and smaller groups until a single species is identified.

What is a species?

A species is a group of very similar living things that usually breed with one other. Each species is identified by a scientific name. The European larch tree has the scientific name *Larix decidua*. It belongs to a family of trees called Pinaceae, which all produce cones.

Class: Mammals
A class is a large group within a phylum. Mammals are warm-blooded vertebrates that feed their young on milk.

Phylum: Chordates
Within the animal kingdom are 35 phyla (plural of phylum). The phylum Chordates contains vertebrates—animals with a backbone.

Start here

Kingdom: Animals
The largest group is a kingdom. The animal kingdom contains all the animals in the world.

Species: *Canis lupis*
The gray wolf is the largest species in the family Canidae. Its scientific name is *Canis lupis*.

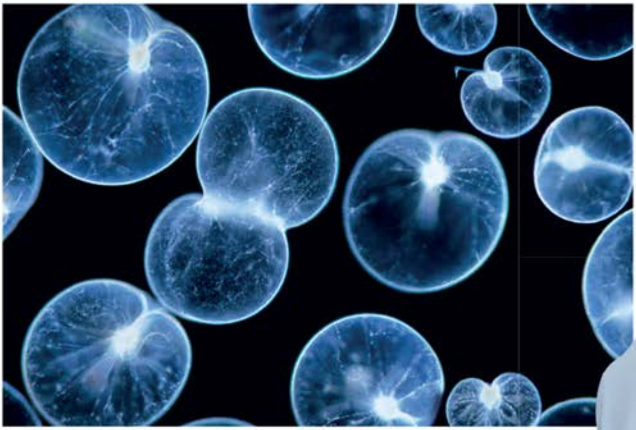
Genus: *Canis*
Families contain different genera (plural of genus). The genus *Canis* contains 10 species, including wolves and domestic dogs.

Family: Canidae
Within the order of carnivores, the family Canidae contains all doglike mammals.

Order: Carnivores
A class is divided into orders. The order of carnivores contains mammals that eat meat.

Microlife

Bacteria and protists are single-celled organisms that can only be seen using a microscope. Bacteria are so small that 10,000 could fit on the head of a pin. Microlife is found all around us, and even inside us—there are 10 times as many bacteria in our bodies as there are cells!



Colony of *Noctiluca scintillans*, a sea-dwelling protist

Protists

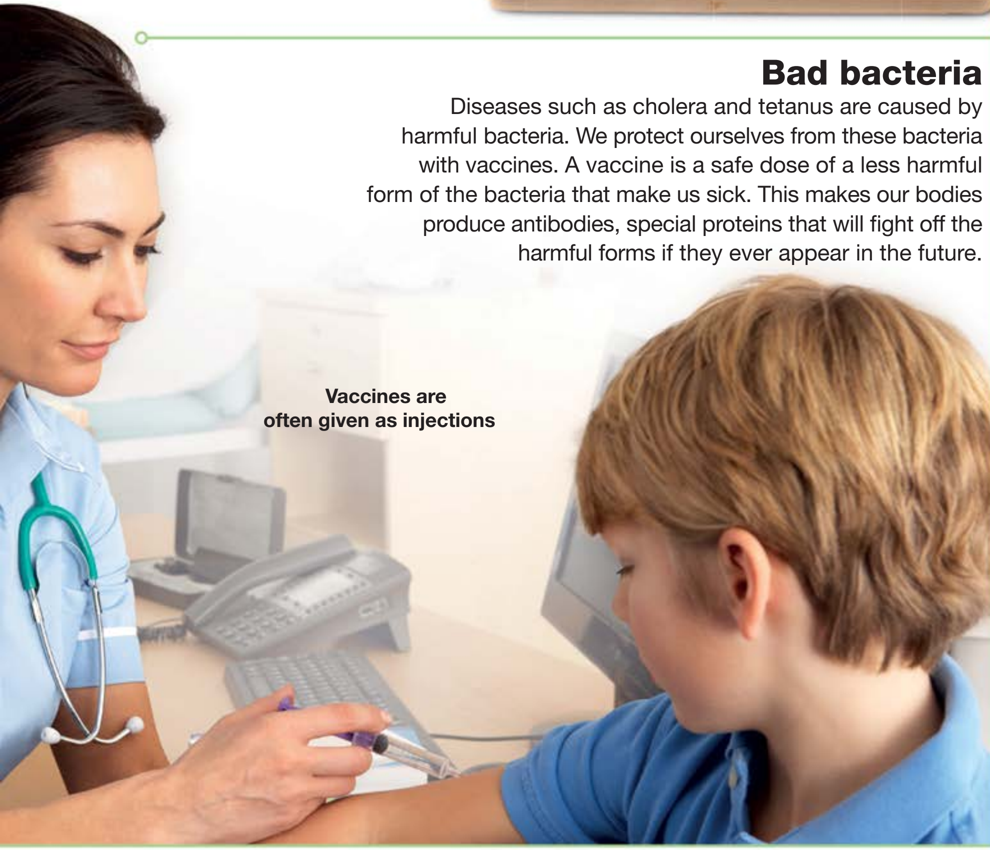
These single-celled organisms are found anywhere there is water. Some, such as protozoa, move around and feed on other protists or on bacteria. Others, such as algae, make their own food using the energy of the Sun, like plants. Sometimes protists come together in huge colonies of billions of individual cells.

Good bacteria

Special bacteria in our stomachs help us to digest food. We can also use bacteria to make our food. The varied flavors of different kinds of cheese are produced with the help of bacteria.

Bad bacteria

Diseases such as cholera and tetanus are caused by harmful bacteria. We protect ourselves from these bacteria with vaccines. A vaccine is a safe dose of a less harmful form of the bacteria that make us sick. This makes our bodies produce antibodies, special proteins that will fight off the harmful forms if they ever appear in the future.



Vaccines are often given as injections

Fungi

Fungi are life-forms such as mushrooms, yeasts, and molds that feed on plants and animals. They break down dead animals and plants, feeding on the nutrients. When the fungi die and are themselves eaten, this recycles the nutrients.

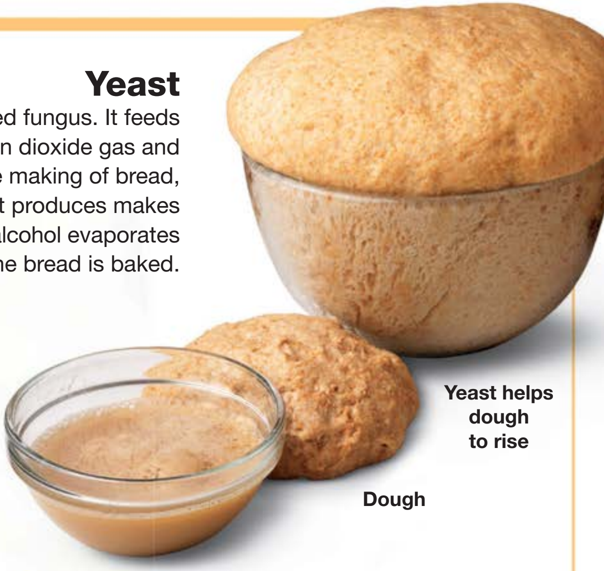
Mushrooms

The familiar mushrooms that grow in fields are just a small part of a fungus that grows underground. The mushrooms are the "fruiting body" of the fungus—they produce and scatter spores, which grow into new fungi. Some mushrooms are edible, but many are poisonous.

After being eaten, mushrooms containing a chemical called psilocybin can cause hallucinations.

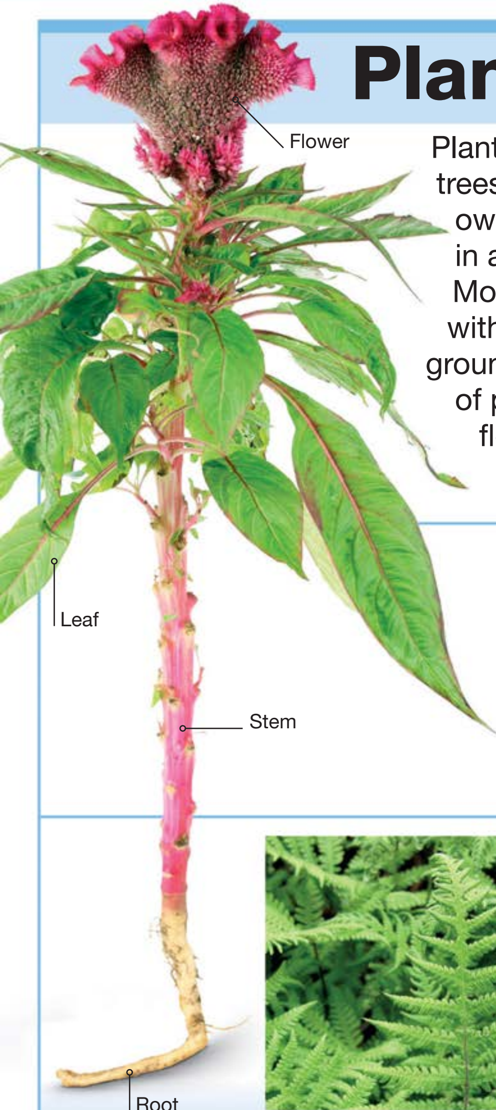
Yeast

Yeast is a tiny single-celled fungus. It feeds on sugars, producing carbon dioxide gas and alcohol. Yeast is used in the making of bread, and the carbon dioxide it produces makes the bread rise. The alcohol evaporates away as the bread is baked.



Molds

Molds are microscopic fungi that grow in thin strands called hyphae. They feed on dead plants and animals, making them rot. In medicine, a mold called *Penicillium* produces penicillin (see page 9), a valuable antibiotic for treating infections.



Plants

Plants range in size from enormous trees to tiny mosses. They make their own food using the energy of the Sun in a process called photosynthesis. Most plants are fixed in one place, with roots that can go deep into the ground. There are many different groups of plant, including ferns, mosses, flowering plants, and conifers.

Plant parts

Every part of a plant has a job to do. The roots hold the plant in place and also take in water and nutrients from the soil. These are transferred to the rest of the plant through the stem, which also supports the leaves and flowers. Flowers produce pollen, seeds, and fruit, which are used for reproduction.

Ferns

Ferns do not make flowers, but reproduce by releasing spores into the air from the surface of special leaves. Ferns are often found in damp, shady woods, but also grow on rock faces, in wetlands, and even on the sides of trees.

Mosses

Mosses are small plants that are ½–4 in (1–10 cm) tall. They grow in clumps in damp, shady areas. Mosses are very simple plants with small leaves attached to wiry stems. They do not have roots or grow flowers.

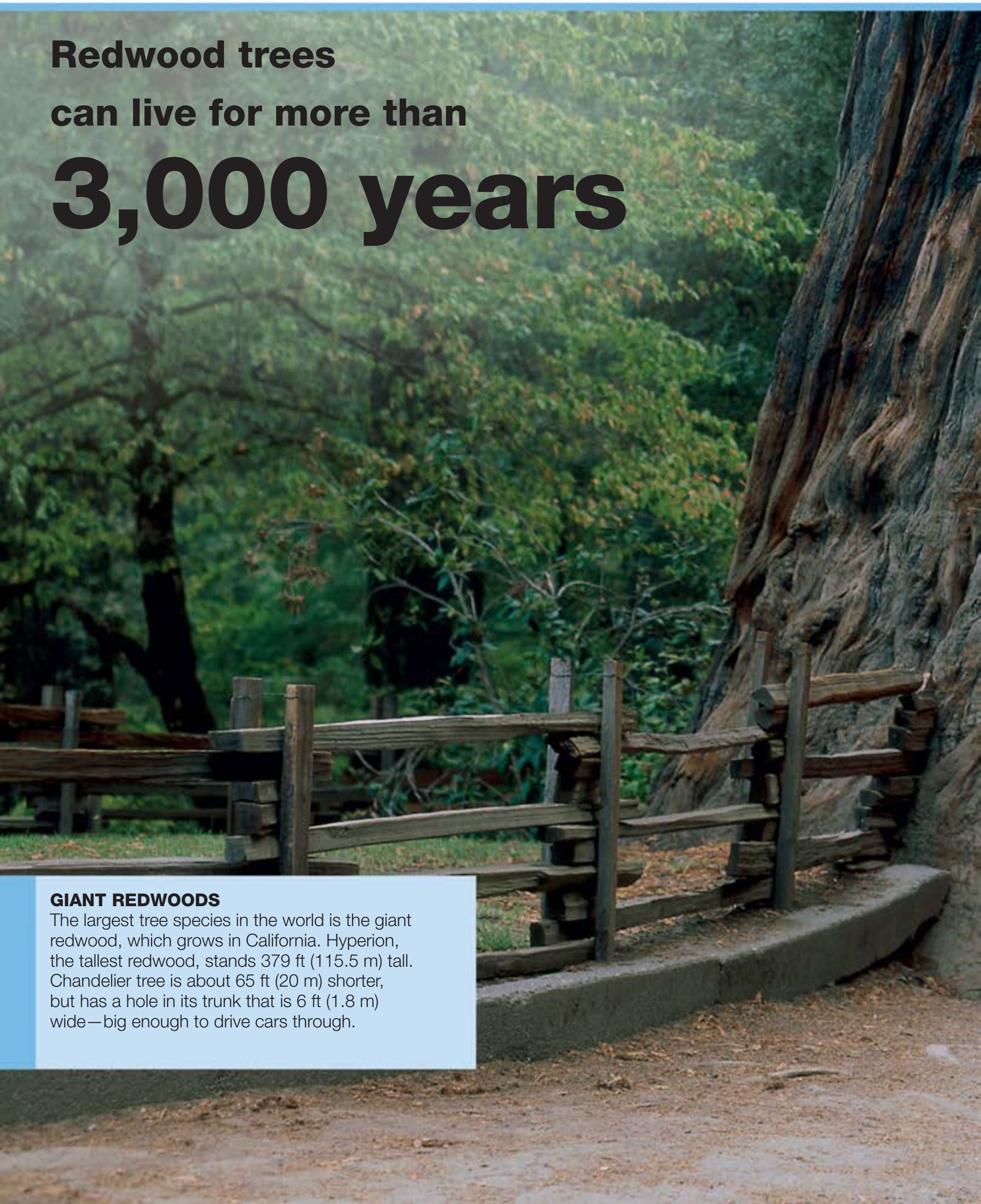
Flowering plants

The biggest group of plants, flowering plants range from mighty oak trees to the tiny duckweed, which is just $^{1}/_{200}$ in (1 mm) long. They produce flowers, fruit, and seeds. The flowers often have brilliant colors and attract insects and birds, which carry pollen from one plant to another, fertilizing them.

Conifers

Many trees are flowering plants. Conifers do not produce flowers, however, but instead grow cones to store their seeds. These trees have needle-shaped leaves and mostly grow in huge forests in cold parts of the world.

Redwood trees can live for more than 3,000 years



GIANT REDWOODS
The largest tree species in the world is the giant redwood, which grows in California. Hyperion, the tallest redwood, stands 379 ft (115.5 m) tall. Chandelier tree is about 65 ft (20 m) shorter, but has a hole in its trunk that is 6 ft (1.8 m) wide—big enough to drive cars through.

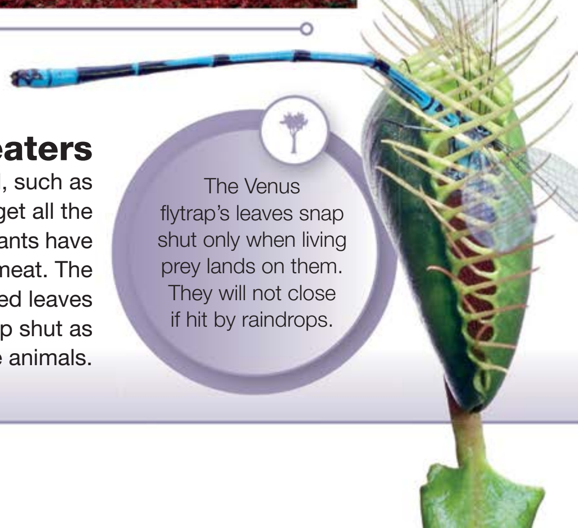

Chandelier Tree
Height 315 ft. Diameter 21 ft.
Maximum Age 2400 yrs.
DRIVE-THRU TREE PARK Leggett CA
California
4FAA050

How plants work

Unlike animals, plants make their own food. They do this during the daytime, when they use sunlight to provide energy for the food-making process, called photosynthesis. This takes place in the plant's leaves, using a green chemical called chlorophyll.

Surviving winter

In cool parts of the world, plants stop growing in the winter. Many trees no longer make their own food and so stop producing chlorophyll. Their leaves turn from green to brown before falling off. This allows them to save energy and stops them from losing water through the leaves.



Dragonfly trapped inside a Venus flytrap

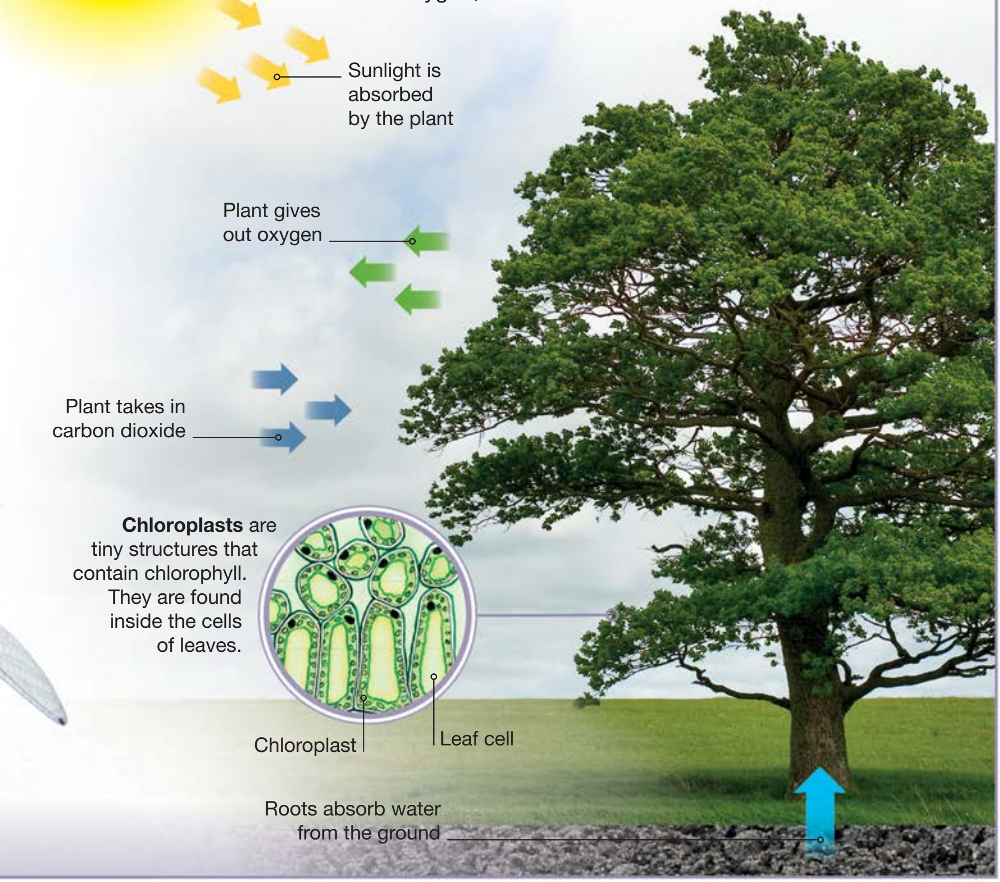
Meat-eaters

In places with poor soil, such as bogs, plants can find it hard to get all the nutrients they need. Carnivorous plants have solved this problem by eating meat. The Venus flytrap has specially adapted leaves that tempt insects in, then snap shut as soon as they land, trapping the animals.

The Venus flytrap's leaves snap shut only when living prey lands on them. They will not close if hit by raindrops.

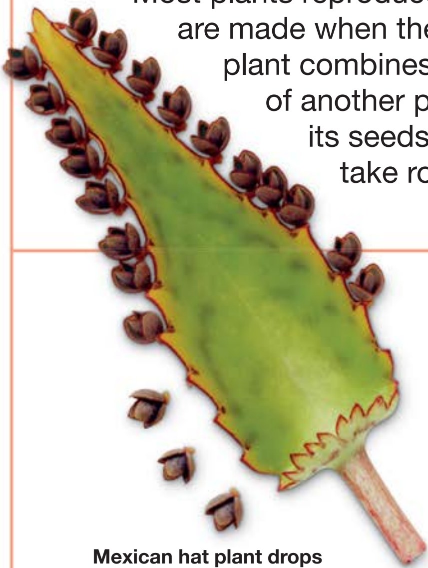
Photosynthesis

Leaves contain a special green chemical called chlorophyll. Chlorophyll is crucial to photosynthesis because it absorbs sunlight and uses the energy to make food from carbon dioxide in the air and water drawn up from the roots. This process produces oxygen, which is released into the air.



Flowers and seeds

Most plants reproduce using seeds. The seeds are made when the male part (pollen) of one plant combines with the female part (ovum) of another plant. The plant then scatters its seeds to new places, where they take root and grow into new plants.



Mexican hat plant drops buds to reproduce

Reproducing alone

Some plants, such as the Mexican hat plant, can reproduce without making seeds. They reproduce by growing buds that drop to the ground to grow into new plants. The new plants are identical to their parent. This process is called asexual reproduction.

Flowers

Most flowers make both pollen and ova (male and female parts) but cannot fertilize themselves (make their own seeds). Instead, the pollen from one flower is carried to other flowers on the bodies of insects and other animals, or by the wind. The pollen fertilizes the ova, which then develop into seeds.

Pollen gets stuck to a bee's body when it visits a flower to collect nectar

SCATTERING SEEDS

Wind can blow away seeds

Animals eat fruits and disperse seeds

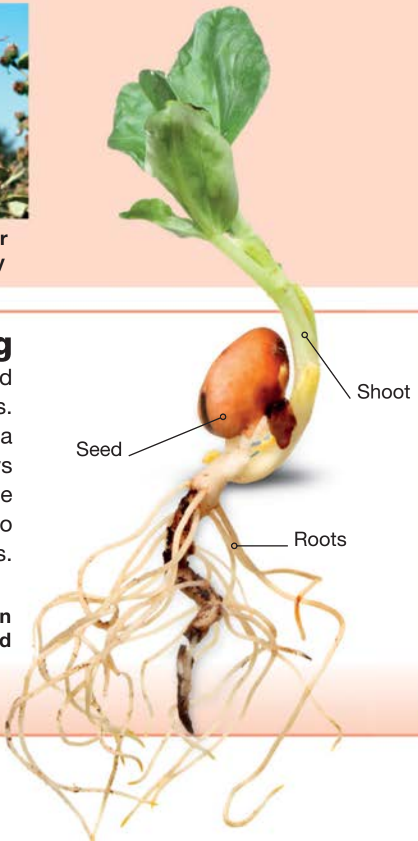
Seeds can be carried away by water

Seeds may stick to fur of animals passing by

Plants spread their seeds in different ways. The flowers may grow into fruit, which are eaten by animals. The seeds then fall to the ground in the animals' droppings. Some plants make sticky seeds called burrs, which stick to animal fur. Others use the wind, rivers, or oceans to carry their seeds away.

Germinating

When a seed lands in the right place and conditions to grow into a new plant, it germinates. A shoot grows out of the seed and develops into a stem that grows upward and a root that grows downward. Food inside the seed gives it the energy to begin germinating, but it soon starts to make its own food in its leaves by photosynthesis.



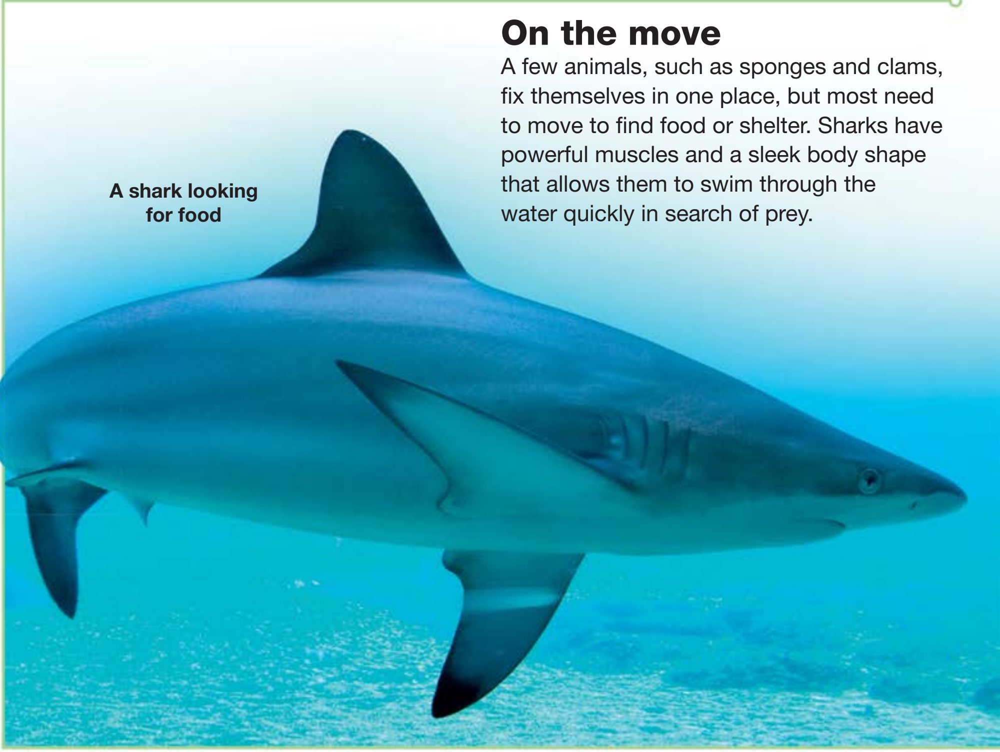
Germination of a bean seed

What is an animal?

Animals are living things that get their energy by feeding on other living things, including plants and other animals. Like plants, animals can respond and react to the world around them and communicate with each other. Most animals can also move around. Animals range from simple, tubelike sponges to complex human beings.

On the move

A few animals, such as sponges and clams, fix themselves in one place, but most need to move to find food or shelter. Sharks have powerful muscles and a sleek body shape that allows them to swim through the water quickly in search of prey.



A shark looking for food

Feeding

All animals obtain energy by eating other living things. Herbivores eat plants, while carnivores eat other animals. Humans are omnivores, which are animals that eat both plants and other animals.

A cow is a herbivore

A crocodile is a carnivore

A bear is an omnivore

Communication

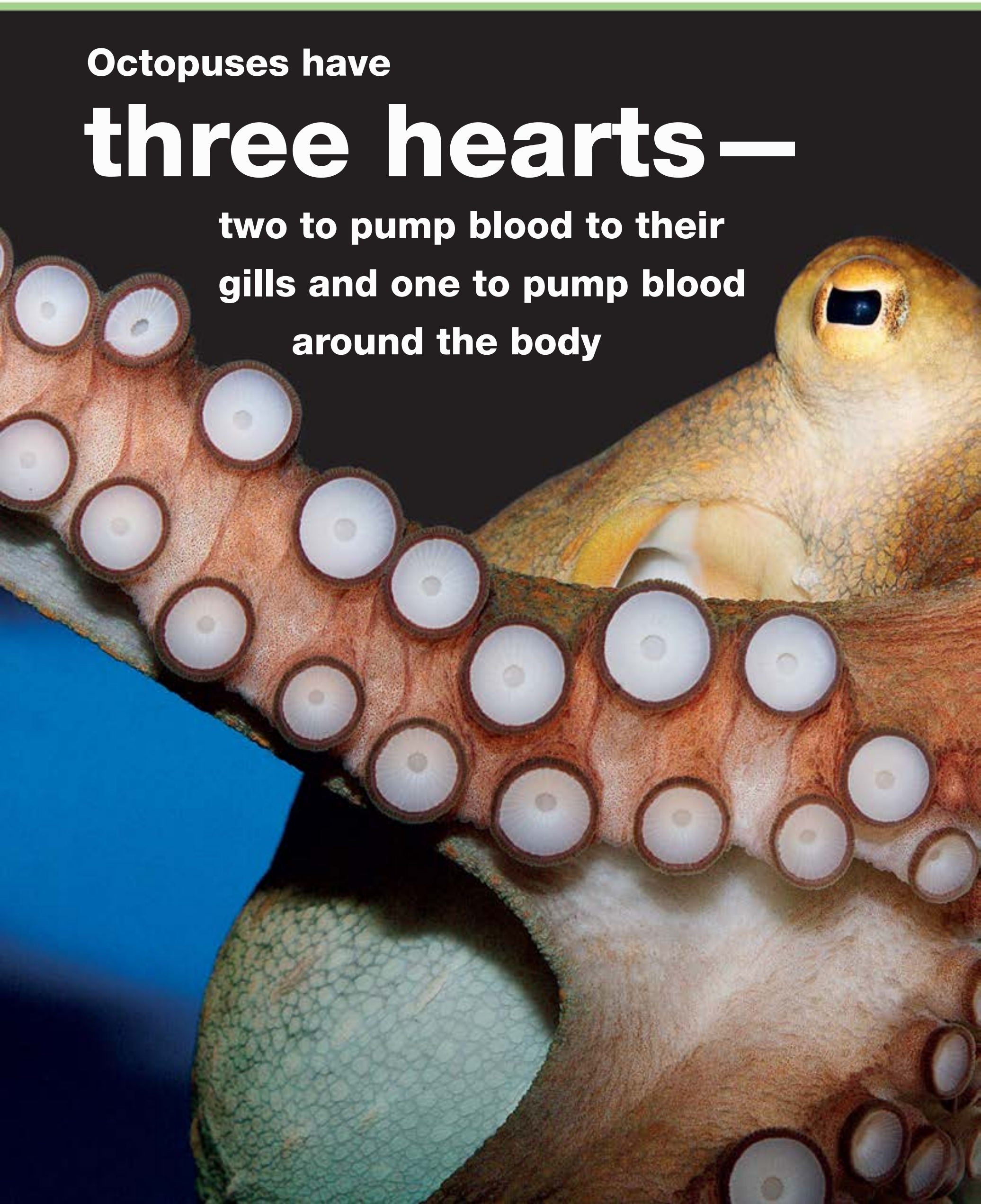
Animals communicate with each other in different ways: using sounds, chemicals, colors, or movements. Bees tell others in their hive where to find food using a special dance that shows which way to fly and how long it will take to get there.

Responding and reacting

Animals have sense organs that tell them what is going on outside their bodies. For example, hairs on a spider's feet sense vibrations when prey gets trapped in its web. The spider then runs over and wraps its prey in silk.

Octopuses have **three hearts—**

two to pump blood to their gills and one to pump blood around the body



ARMED AND DANGEROUS
The octopus lives in holes and crevices on the ocean floor. It has eight arms, lined with suction cups for grabbing hold of its prey, which it then kills with poison from its beak. If it loses an arm, it can grow another one.

Types of animal

There are millions of animal species living on Earth. They are divided into two main groups: vertebrates, such as mammals and fish, which have a backbone; and invertebrates, such as insects and mollusks, which do not have a backbone.

VERTEBRATES

There are five main groups of vertebrates—amphibians, reptiles, fish, birds, and mammals. They all have internal skeletons but come in all shapes and sizes and live in very varied places.

Amphibians, such as frogs, lay their eggs in water and live both in the water and on land.

Reptiles, including alligators, have scaly skin and lay their eggs on land.

Fish, such as goldfish, spend all their lives in water, where they can breathe using gills.

Birds, including eagles, have feathers and many of them can fly.

Mammals are warm-blooded, have hairy skin, and feed their young on milk. They include tigers and humans.

INVERTEBRATES

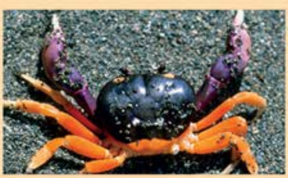
About 97 percent of all known animal species are invertebrates. Insects and crustaceans have hard external skeletons and bodies made from segments. Starfish have simple bodies with bony plates just under the skin, while soft-bodied worms and squid do not have a skeleton at all.

Anthozoa, such as coral, fix themselves in one place and feed on algae or plankton.

Asterozoa, including starfish, are star-shaped, with arms growing out of a central disk.

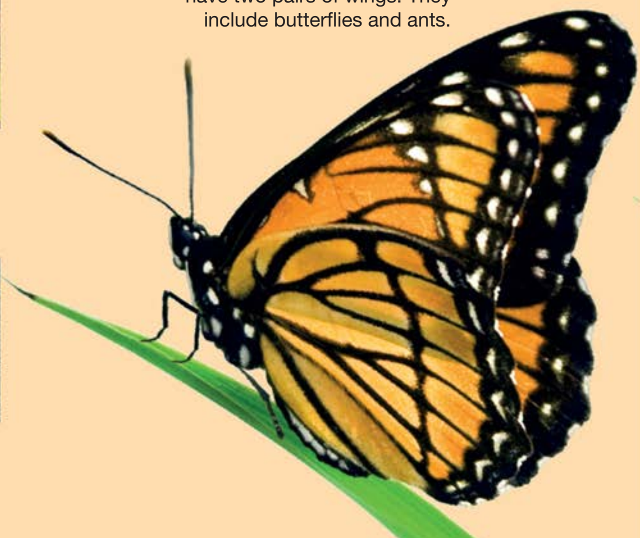
Arachnids have eight legs, which have joints. They include spiders and scorpions.

Gastropods include snails and slugs. They move around using one muscular foot.



Malacostraca, such as crabs, have shells and heads made of five segments.

Insects have six legs, and many have two pairs of wings. They include butterflies and ants.

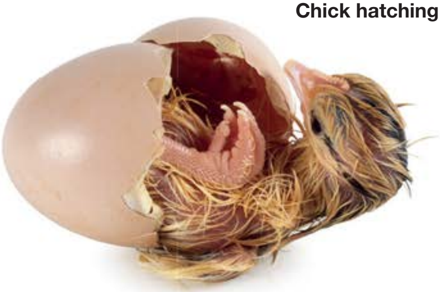


Animal reproduction

Animals use different methods to reproduce (have babies). The young of some species develop inside eggs laid by the mother, while other species give birth to live young. Some have many young, most of which will be eaten by predators, while others produce a few offspring that they look after carefully.

Laying eggs

Many animals lay eggs. Fish and amphibians lay their eggs in water. Their eggs do not have shells and are soft. Reptiles' eggs have leathery shells, while birds' eggs have hard shells. The shells protect the eggs and stop them from drying out. The baby reptiles or birds must break through the shells when they hatch.



Chick hatching

Eggs galore

Some animals, including many amphibians and fish, lay thousands of eggs. They leave the eggs, so the young have to fend for themselves as soon as they hatch. Most of the eggs and young will be eaten before they grow up, but a few of them survive to adulthood.

Mass of frogspawn (frog's eggs)

Live young

Most mammals give birth to live young. The babies develop inside their mothers and receive all the nutrients they need to grow from their mother's blood. After they are born, the young feed on their mother's milk as they continue to grow.

Looking after babies

Some parents look after their young for months or even years after they are born. The parents bring food for the young and teach them the skills they will need to survive. Lions live in groups and help each other care for the young.

Lioness tends to her cubs

Food webs

Energy passes from one living thing to another in the form of food. Food webs show how living things feed on one another. At the bottom of a food web are plants, which make their own food using energy from the Sun. At the top are predators, which feed on other animals.

Deer are **primary consumers** that feed on grass

Lions are **secondary consumers** that feed on deer

Decomposers, such as dung beetles, feed on droppings and the bodies of dead animals

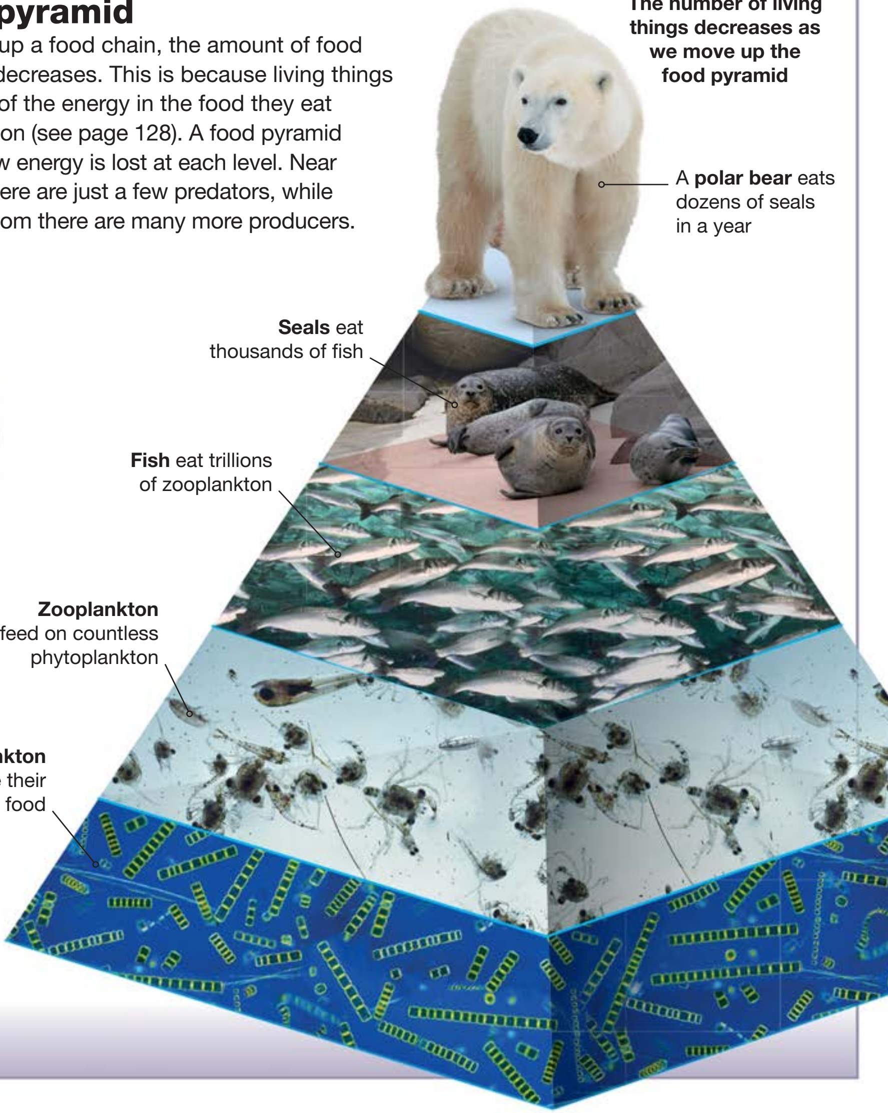
Grasses are **producers** that make their own food by photosynthesis

Food chain

Food webs are made up of many different food chains that have different levels. In a food chain, plants are called producers because they make their own food. Animals that eat plants are called primary consumers. Primary consumers are eaten by other animals called secondary consumers, or predators. When all living things die they become the food of organisms called decomposers.

Food pyramid

As we go up a food chain, the amount of food available decreases. This is because living things use most of the energy in the food they eat in respiration (see page 128). A food pyramid shows how energy is lost at each level. Near the top, there are just a few predators, while at the bottom there are many more producers.

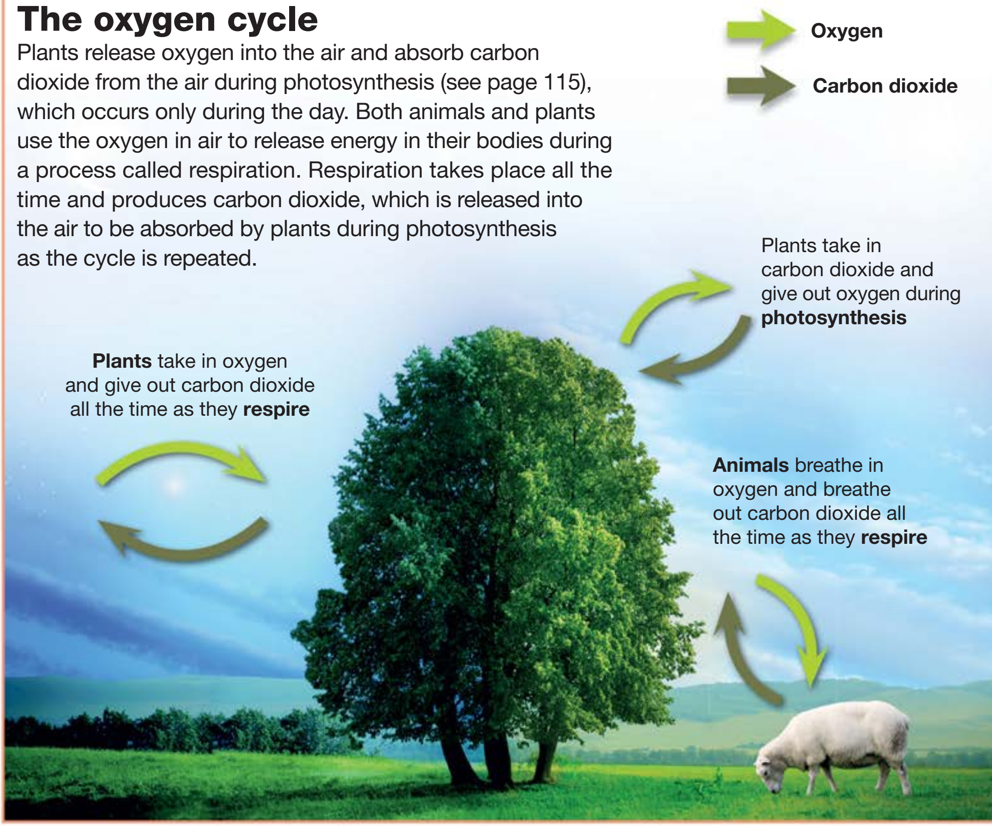


Cycles

Every living thing needs the elements oxygen and carbon to grow and make energy. These elements are constantly passing from the air into living things and back into the air again in cycles that are essential to life.

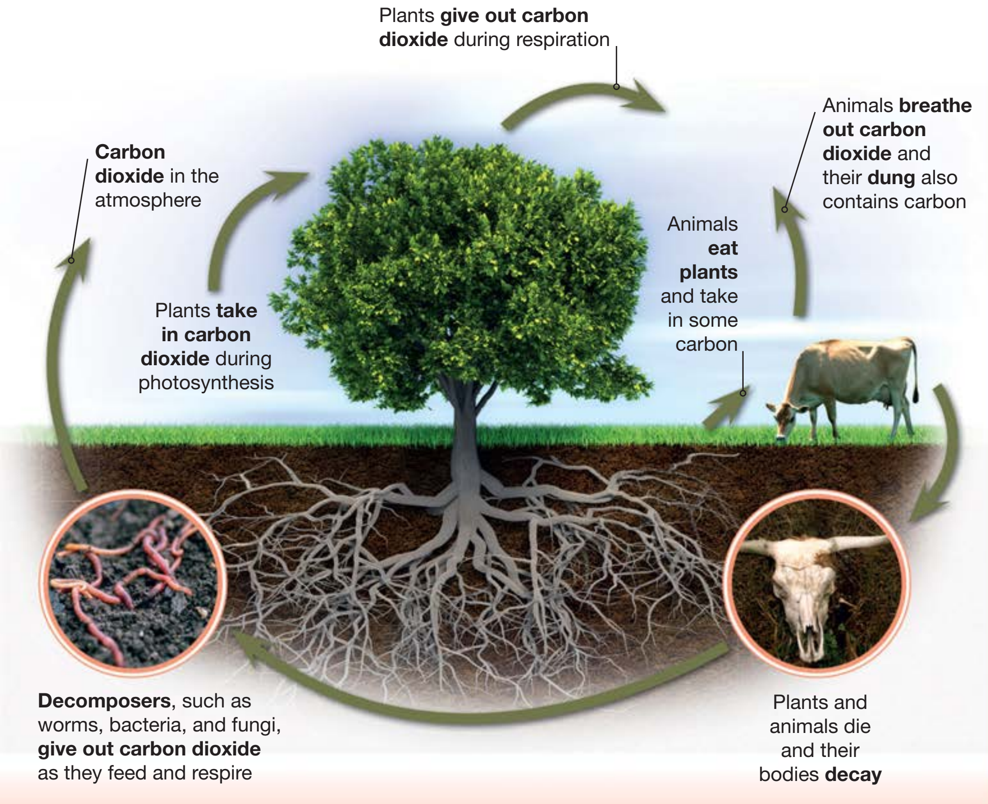
The oxygen cycle

Plants release oxygen into the air and absorb carbon dioxide from the air during photosynthesis (see page 115), which occurs only during the day. Both animals and plants use the oxygen in air to release energy in their bodies during a process called respiration. Respiration takes place all the time and produces carbon dioxide, which is released into the air to be absorbed by plants during photosynthesis as the cycle is repeated.



The carbon cycle

Carbon is taken in by living things in their food. It is released into the atmosphere during respiration and also when plants and animals die and decay. During photosynthesis, plants absorb carbon dioxide from the atmosphere so they can grow; the plants will then become new food for other living things.



Ecosystems

A community of organisms that lives in a particular environment is called an ecosystem. A single ecosystem might be as small as a pond or as large as a desert. Ecosystems vary hugely across the world, depending on conditions such as climate, the soil type, or whether there is salt- or freshwater.

Tundra is found near polar regions and high up on mountains, where it is too cold for trees and so only small flowers and grasses grow. It covers one-fifth of the Earth's land.

Grasslands are wide areas that are baked brown by the Sun in summer and may freeze over in the winter. They are covered with grasses and have few trees.

Rain forests have a thick covering of trees and a rich variety of animal life.

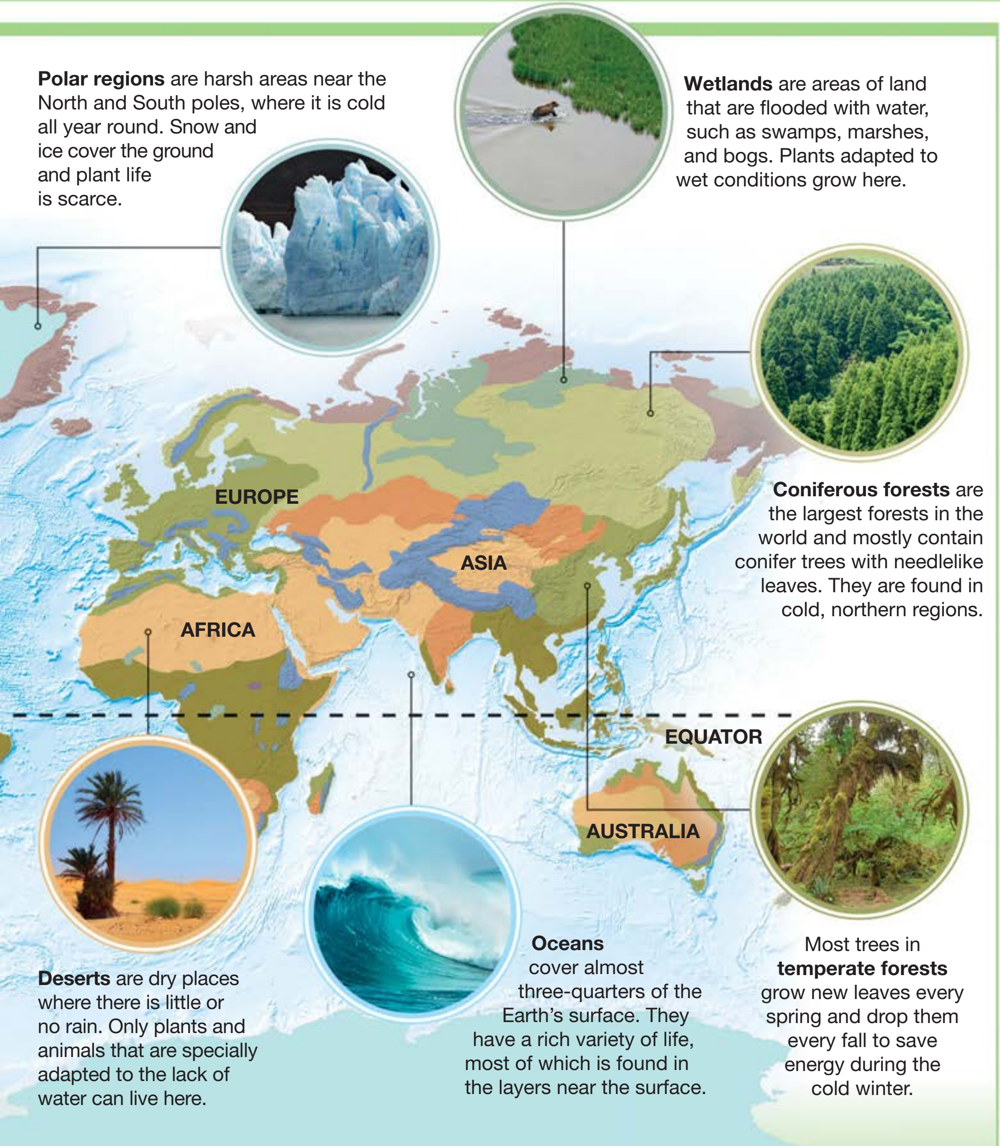
Mountains are high places with a cold, windy climate. Very different groups of plant and animal are found at different heights, as the climate changes rapidly between the peaks and the valleys.

KEY

- Polar regions
- Mountains
- Rain forests
- Coniferous forests
- Temperate forests
- Wetlands
- Grasslands
- Tundra
- Deserts
- Oceans

Polar regions are harsh areas near the North and South poles, where it is cold all year round. Snow and ice cover the ground and plant life is scarce.

Wetlands are areas of land that are flooded with water, such as swamps, marshes, and bogs. Plants adapted to wet conditions grow here.



Coniferous forests are the largest forests in the world and mostly contain conifer trees with needlelike leaves. They are found in cold, northern regions.

Deserts are dry places where there is little or no rain. Only plants and animals that are specially adapted to the lack of water can live here.

Oceans cover almost three-quarters of the Earth's surface. They have a rich variety of life, most of which is found in the layers near the surface.

Most trees in **temperate forests** grow new leaves every spring and drop them every fall to save energy during the cold winter.

The Great Barrier Reef is 1,600 miles (2,600 km) long and is so large that it can be

seen from space

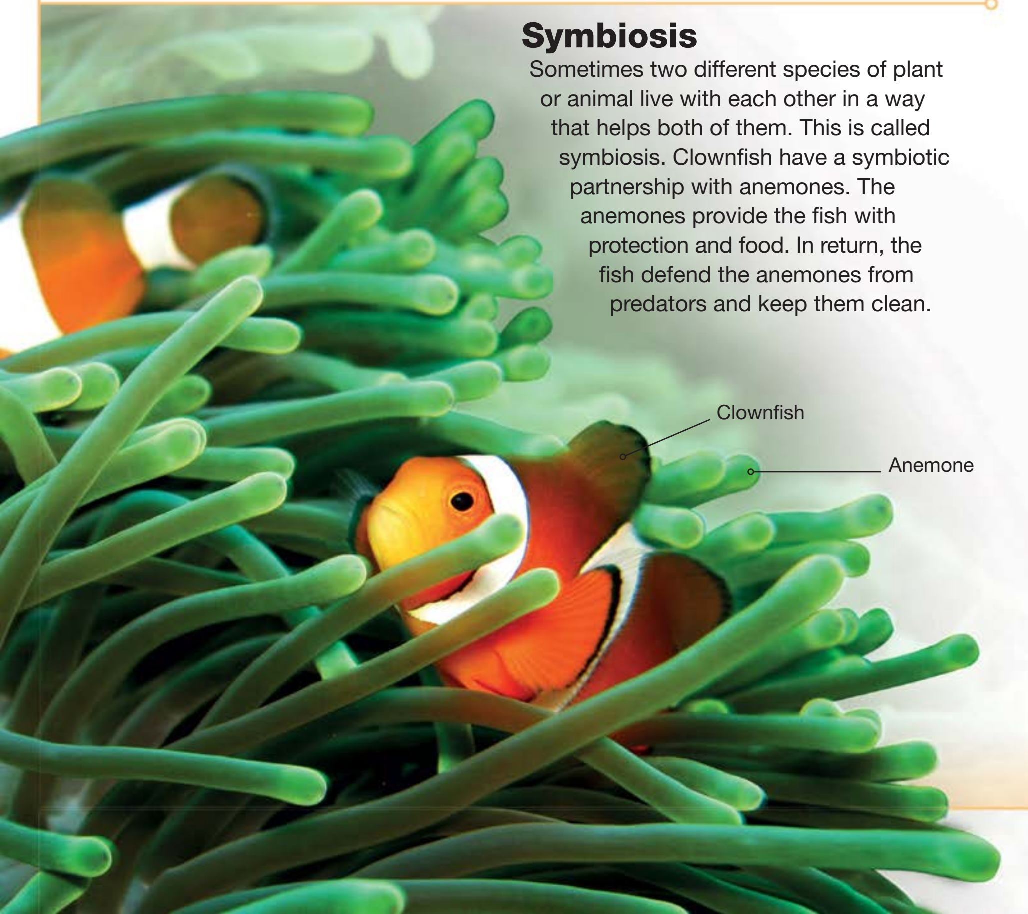
TEEMING WITH LIFE
Coral reefs found in shallow, tropical waters are some of the most diverse habitats on Earth. Although they cover just 0.1 percent of the oceans, they are home to 25 percent of ocean species, including mollusks, sea snakes, crustaceans, and many kinds of colorful fish.

Survival

Living things have a wide range of methods to find food, keep themselves safe from predators, and survive changing conditions. These include living in large groups, moving from place to place, and even feeding off other animals.

Symbiosis

Sometimes two different species of plant or animal live with each other in a way that helps both of them. This is called symbiosis. Clownfish have a symbiotic partnership with anemones. The anemones provide the fish with protection and food. In return, the fish defend the anemones from predators and keep them clean.



Head louse as seen under a scanning electron microscope (SEM)

Parasites

Some living things, called parasites, live off others in a way that harms or even kills them. Head lice live in human hair and feed on our blood. They do not kill us, but they make our scalps very itchy.

Safety in numbers

Some animals travel together in large groups. This makes it harder for predators to catch them and may also help them catch their own food. Fish such as herring form huge groups, called schools, that may number hundreds of millions of individuals.

Migration

Animals may move from one region to another to find food or places to reproduce. This is called migration. Monarch butterflies migrate from Canada to Mexico every fall and back again every spring. Each migration takes three or four generations, so no individual insect survives the whole trip.

Living in water

Creatures that live in oceans or rivers are specially adapted to move, breathe, and feed in water. The oceans contain a wide variety of animal life, from tiny plankton to the gigantic blue whale.

Breathing under water

Fish, such as this stingray, and many other sea creatures breathe the oxygen dissolved in water using organs called gills. Some small creatures absorb oxygen through their skin without using gills.

Hold your breath

Sea-dwelling reptiles, such as turtles, and mammals, such as whales, do not have gills. They have to come to the surface to breathe. Killer whales breathe through blowholes at the top of their heads. They can dive and hold their breath for up to 20 minutes.

Jet-propelled

Some invertebrates, such as an octopus, move through the water using jet propulsion. They suck water into their bodies and force it out behind them in a strong jet that pushes them forward.

Big creatures

Because the weight of their bodies is supported by the water, animals in the oceans can grow to enormous sizes. The biggest of them all, the blue whale, can grow to 100 ft (30 m) long and weigh over 200 tons (180 metric tons).

Flying

Animals that spend much of their time in the air fly using wings. Most flying insects have two pairs of wings attached to their bodies, while birds and bats fly using wings that are specially adapted arms.

Bats' wings are made of skin

Bats flying out of a cave

Insect wings are made of a substance called chitin

Beetle in flight

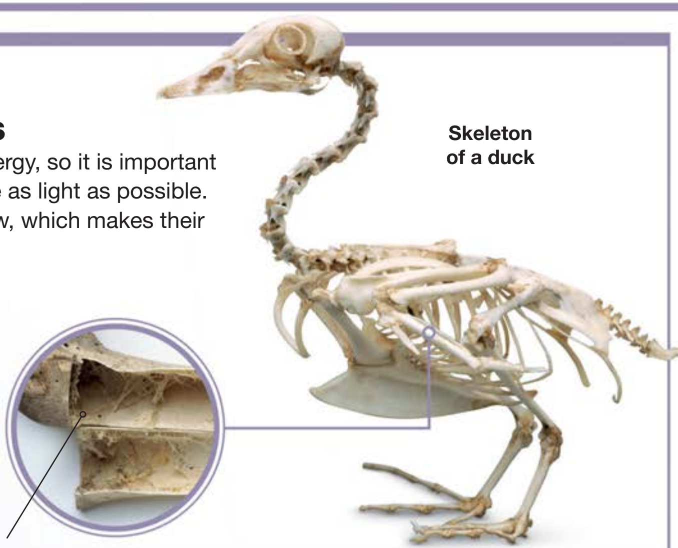
Geese in flight

Wings

For animals to fly, they need to produce an upward force called lift. They do this using their wings, which are a special shape called an aerofoil. They flap their wings to give them more lift, but once in the air, many birds can also fly without flapping.

Hollow bones

Flying uses a lot of energy, so it is important for flying animals to be as light as possible. Birds' bones are hollow, which makes their skeletons very light.



GLIDING

Some animals do not truly fly, but can glide long distances through the air. They use flat parts of their bodies like a parachute to slow their fall. Flying squirrels stretch out flaps of skin attached to their front and back legs to glide from one tree to another.

Evolution

Over millions of years, living things change in response to differences in their environment. This is called evolution and it happens through a process called natural selection. Changes that are more likely to help a plant or animal survive are passed to future generations, but living things with changes that are not suited to survival die out.

Cactus stores water to survive in dry conditions

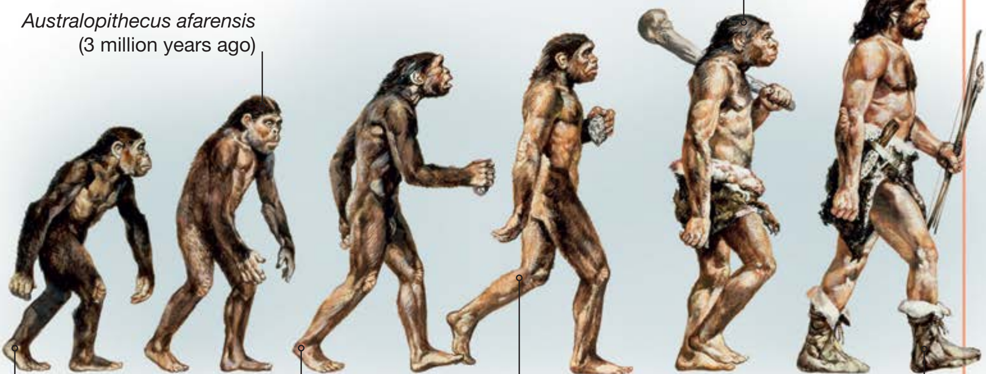
Adaptation

Natural selection has produced living things that are superbly adapted to life in the places where they live. Species that have adaptations better suited to an environment are more likely to survive than those that do not. Plants in deserts need to be able to save water, while animals in the Arctic need to survive the cold.

Polar bear has thick fur that helps in surviving the cold temperatures

Human evolution

Humans evolved from apelike ancestors over millions of years. In that time, different species evolved and were replaced until modern humans first appeared about 200,000 years ago.



Extinction

Changes to the environment, such as climate change, can lead to the disappearance of a whole species in a process called extinction. Extinction is an important part of the evolution process because it gives other species the chance to replace extinct ones.

The dinosaur *Corythosaurus* became extinct about 75 million years ago

Human influence

Human activity is changing environments across the world. We are damaging many natural habitats to meet our growing demands for food, energy, land, and other resources. We are also adding carbon dioxide to the atmosphere by burning fossil fuels such as oil, and this is changing our atmosphere and may be causing global warming.

Habitat destruction

Many forests have been cut down to make use of the wood and to clear land for agriculture. This destroys the forest habitats and also reduces the number of trees in the world. Trees take carbon dioxide from the air, so cutting them down increases the level of this gas in the atmosphere, contributing to dangerous climate change.

Deforestation in Peru

Reducing the impact

There are many ways in which we can reduce the impact of human activity. By planting trees, we replace the ones that have been cut down. We can also reduce our impact by recycling (using again) anything we might normally throw away.

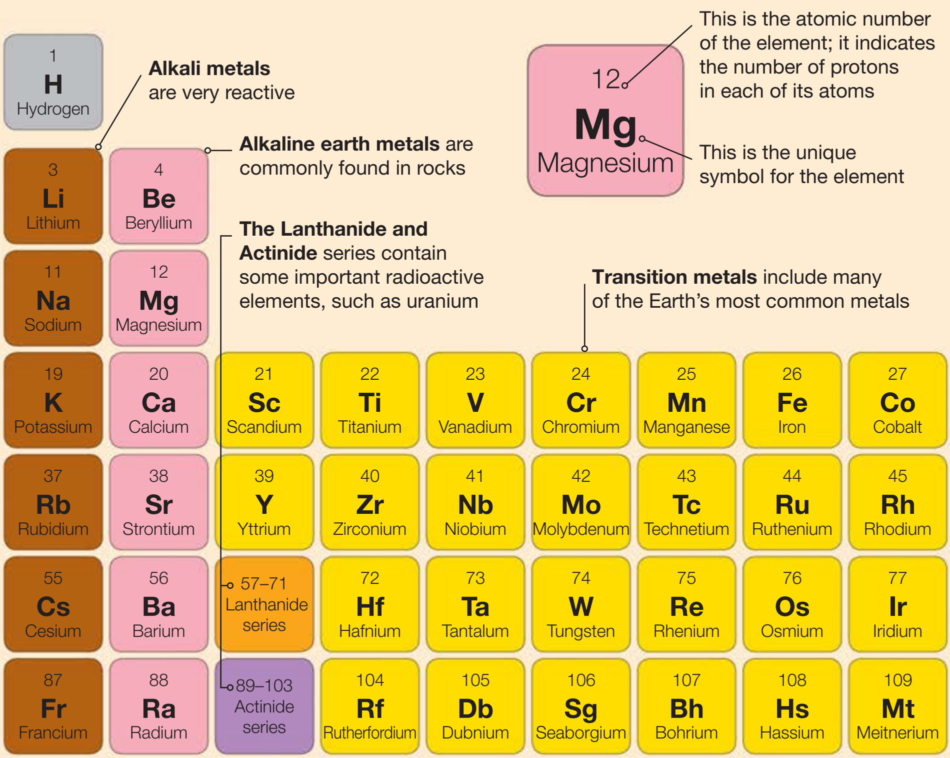
Conservation

The destruction of habitats has left many species of plant and animal endangered. This means that they are close to becoming extinct. Scientists and conservationists study how these species live and grow to see how they can be saved from extinction.

Scientists check on the health of a loggerhead turtle, an endangered species

The periodic table

Elements are pure chemicals that cannot be broken down further (see page 32). The atoms in different elements contain varied amounts of protons, neutrons, and electrons that affect their chemistry. Elements are arranged in a system called the periodic table according to their chemical and physical properties.



KEY

Elements with similar properties are grouped together on the periodic table. Scientists can tell what an element is like from its position in the table.

- Alkali metals
- Alkaline earth metals
- Transition metals
- Lanthanide series
- Actinide series
- Poor metals
- Semimetals
- Nonmetals
- Noble gases
- Hydrogen
- Unknown chemistry

Nonmetals are generally dull and break easily

Noble gases almost never react with other elements

Semimetals sit between the metals and nonmetals

Poor metals include many important elements, such as aluminum and lead

								2 **He** Helium
			5 **B** Boron	6 **C** Carbon	7 **N** Nitrogen	8 **O** Oxygen	9 **F** Fluorine	10 **Ne** Neon
			13 **Al** Aluminum	14 **Si** Silicon	15 **P** Phosphorus	16 **S** Sulfur	17 **Cl** Chlorine	18 **Ar** Argon
28 **Ni** Nickel	29 **Cu** Copper	30 **Zn** Zinc	31 **Ga** Gallium	32 **Ge** Germanium	33 **As** Arsenic	34 **Se** Selenium	35 **Br** Bromine	36 **Kr** Krypton
46 **Pd** Palladium	47 **Ag** Silver	48 **Cd** Cadmium	49 **In** Indium	50 **Sn** Tin	51 **Sb** Antimony	52 **Te** Tellurium	53 **I** Iodine	54 **Xe** Xenon
78 **Pt** Platinum	79 **Au** Gold	80 **Hg** Mercury	81 **Tl** Thallium	82 **Pb** Lead	83 **Bi** Bismuth	84 **Po** Polonium	85 **At** Astatine	86 **Rn** Radon
110 **Ds** Darmstadtium	111 **Rg** Roentgenium	112 **Cn** Copernicium	113 **Uut** Ununtrium	114 **Fl** Flerovium	115 **Uup** Ununpentium	116 **Lv** Livermorium	117 **Uus** Ununseptium	118 **Uuo** Ununoctium

Amazing science facts

MOST COMMON ELEMENTS

- **In the universe:**
Hydrogen—75%
Helium—23%
Other elements—2%

- **In the Earth's crust:**
Oxygen—47%
Silicon—28%
Aluminum—8%
Iron—5%
Calcium—4%
Sodium—3%
Potassium—3%
Magnesium—2%

- **In the human body:**
Oxygen—61%
Carbon—23%
Hydrogen—10%
Other elements—6%

RAREST ELEMENT

- **The rarest element** naturally occurring on Earth is francium. Only about 1 oz (25 g) of francium exists on the Earth at any one time. It is highly radioactive and turns into other elements just minutes after it has formed.

Of the 118 elements known to scientists, only 94 are found naturally on Earth.

MASSIVE MOLECULES

- **The largest man-made molecule**, PG5, is made up of thousands of carbon, hydrogen, and oxygen atoms bonded together. One molecule of PG5 has the same mass as 200 million hydrogen atoms.

- **The largest molecules found in space** are made of 60 carbon atoms joined together in patterns of hexagons and pentagons, like a soccer ball.

- **One strand of DNA**, the molecule that contains the code for life, can contain as many as 220 million pairs of instructions.

SPEED RECORDS

- **The fastest-moving stuff** in the universe is light. A particle of light, called a photon, travels 983,571,056 ft (299,792,458 m) every second.

- **The fastest animal** is the peregrine falcon, which reaches speeds of 200 mph (325 kph) when it dives on its prey.

- **The fastest land animal** is the cheetah, which can run at 71 mph (114 kph).

- **The fastest fish** is the sailfish, which can swim at 68 mph (110 kph).

- **The fastest unpowered human** was skydiver Felix Baumgartner who, on October 14, 2012, reached a top speed of 834 mph (1,342 kph) when he jumped from a high-altitude balloon. He was the first human to travel faster than the speed of sound without a powered vehicle.

- **The fastest manned aircraft** was the Lockheed SR-71 Blackbird, which was clocked at 2,193 mph (3,530 kph). Spacecraft are even faster—the Space Shuttles have traveled at 17,400 mph (28,000 kph) when orbiting the Earth.

- **The fastest passenger train** is the JR-Maglev, an experimental Japanese train that has reached a top speed of 361 mph (581 kph) on test runs.

- **The fastest unmanned train** is a rocket sled. Powered by rockets, these can slide along rails at more than 6,200 mph (10,000 kph).

- **The water speed record** is 317 mph (511 kph). The record was set in 1978 by Ken Warby in a specially designed boat called *Spirit of Australia*.

ENERGY MATTERS

- **The largest power plant** in the world is the hydroelectric power plant at Three Gorges Dam in China. It produces enough electricity to power an area the size of the Netherlands.

- **The largest solar power plant** is Nevada Solar One in the Mojave Desert. It covers an area of more than 400 acres (162 hectares).

- **A single bolt of lightning** contains 5 billion joules of energy. If you could find a way to harness that energy, it would power a house for more than a month.

- **Just 5 percent of the energy** used by an incandescent lightbulb is used to make light. The other 95 percent produces heat. Energy-saving lightbulbs are four times more efficient.

- **The world's strongest magnet** is an electromagnet made by the Florida State University. It is 500,000 times stronger than the Earth's magnetic field.

Natural history facts

OLDEST LIFE

• **The oldest living thing** on Earth is the giant seagrass that grows in the Mediterranean Sea. Some of it may be 200,000 years old.

• **The longest-lived animal** is the clam, which can live for more than 400 years. Of animals that move around, the bowhead whale may live the longest—one whale was recorded to have lived for 211 years.

• **The oldest trees** on Earth are bristlecone pines, some of which are more than 5,000 years old.

• **The oldest group** of living things still around today are archaea (bacterialike single-celled life-forms). They evolved more than 3 billion years ago, soon after the very first life-forms appeared on Earth.

• **The earliest animals** on Earth were sponges that lived in the oceans more than 700 million years ago. The first land plants appeared 425 million years ago. Dinosaurs appeared 230 million years ago.

• Spores of **rod-shaped bacteria that are 250 million years old** have been brought back to life by scientists.

• **Humans** first evolved in Africa about 200,000 years ago. They left Africa to spread across the world about 90,000 years ago.

• **Dinosaurs** were once thought to have died out 66 million years ago. But scientists now think that birds are their direct descendants and should be thought of as living dinosaurs, so the dinosaurs really did not die out at all.

Scientists think there are about 8.7 million species of living thing on Earth. About 90 percent of them have yet to be discovered!

BIG AND SMALL

• The **biggest animal** that has ever lived on Earth is the blue whale, a mammal that can grow up to 100 ft (30 m) and weigh 200 tons (180 metric tons). Possibly the **smallest animal** is the tardigrade, or water bear. This invertebrate can be just $^{1}/_{200}$ in (0.1 mm) long.

• The **biggest fish** is the whale shark, which can grow to 60 ft (18 m). The **smallest fish** is *Paedocypris progenetica*, which is just $^{3}/_{10}$ in (7.9 mm) long.

• The **heaviest bird** is the ostrich, weighing up to 345 lb (156 kg), which is too heavy to fly. The **heaviest flying bird** is the great bustard, which weighs 46 lb (21 kg). The **lightest bird** is the bee hummingbird, which weighs just 1/10 oz (2 g).

• The **largest insect** in the world is the giant weta, which weighs 2 1/2 oz (71 g). The **smallest insect** is the parasitic wasp *Dicopomorpha echmepterygis*, which is less than 1/100 in (0.2 mm) long.

• The **largest spider** is the goliath birdeater tarantula, with a leg span of 12 in (30 cm). The **smallest spider** is *Patu marplesi*, measuring 17/1000 in (0.43 mm)—the size of the period at the end of this sentence.

• The **largest reptile**, the Nile crocodile, grows up to 20 ft (6 m) long. The **smallest reptile**, a dwarf chameleon, is about 1 in (28 mm) long.

• The **biggest amphibian** is the Chinese giant salamander; it can grow up to 6 ft (1.8 m) long. The **smallest amphibian** is *Paedophryne amauensis*, a tiny frog from Papua, New Guinea. At ¼ in (7 mm) long, it is also the world's smallest vertebrate.

• The **smallest mammal** is the hog-nosed bat, also called the bumblebee bat, which weighs just 1/10 oz (2 g).

EXTINCT GIANTS

• The **giant moa** was the tallest bird ever, standing 12 ft (3.6 m) tall. It lived in New Zealand and became extinct about 500 years ago due to hunting by humans.

• The **South American short-faced bear**, which lived about 1 million years ago, weighed 1.7 tons (1.5 metric tons) and stood more than 11 ft (3.4 m) tall when standing on its hind legs. It was twice the size of a polar bear.

• The **steppe mammoth** stood 13 ft (4 m) tall. Its tusks could grow to more than 16 ft (5 m) long. It lived in Siberia 500,000 years ago.

• ***Josephoartigasia monesi*** was a giant rodent that lived in South America 2 million years ago. It was the size of a small car, measuring 10 ft (3 m) long and weighing about 1 ton.

• ***Argentinosaurus*** was one of the largest dinosaurs, measuring 100 ft (30 m) from head to tail and weighing more than 77 tons (70 metric tons). It laid eggs the size of soccer balls.

• ***Meganeura*** was a giant dragonflylike insect that lived 300 million years ago. It had a wingspan of more than 100 ft (60 cm).

Glossary

Acceleration A change in an object's velocity, caused by a force acting upon it.

Amplitude A measure of the height of an energy wave. Loud sounds are made of sound waves with a large amplitude.

Atmosphere A layer of gases that surrounds a planet such as the Earth.

Atom The smallest particle of a chemical element.

Bacteria Tiny single-celled organisms found all over the Earth.

Carnivore An animal, such as a shark, lion, or crocodile, that eats only meat.

Cell The smallest unit of a life-form. Organisms can be single-celled or multicelled.

Circuit A continuous loop around which an electrical current can flow.

Compound A substance made from two or more elements.

Condense To change state from a gas into a liquid.

Conductor A substance that allows electricity to flow through it easily.

Current A flow of electricity.

Decomposition A change that takes place in dead bodies in which complex substances break down into simpler chemicals.

DNA A special substance found in the cells of all living things. The DNA contains instructions that tell the cells how to behave.

Ecosystem A distinct region, such as a forest or an ocean, that contains living organisms.

Electromagnet A powerful magnet made using electricity.

Electron A particle that makes up part of an atom. An electron has a negative charge.

Element A pure substance, such as gold, hydrogen, or oxygen, that is made up of only one kind of atom. There are 118 different elements.

Environment The surroundings in which an organism lives, including other organisms, together with conditions such as temperature and light.

Evaporation The change in state of a substance from a liquid to a gas.

Evolution The process by which species change into other species over very long periods. Evolution is the way life developed on Earth.

Fertilization The process by which male and female parts of an animal or plant come together to reproduce.

Force A push or a pull that changes an object's shape or velocity.

Fossil fuel Fuel such as coal and oil that is made from the remains of living things.

Friction A force caused by rubbing one thing against another. Friction slows down movement and produces heat.

Fulcrum The point around which a lever rotates.

Fungus A kind of organism that feeds on the bodies of living or dead plants and animals.

Gas A state of matter in which molecules are spread out and moving rapidly. Most gases are invisible.

Gear A simple machine that moves a force from one place to another and changes the size of the force.

Germination The process by which a seed begins to grow into a new plant.

Gills Parts of a fish that absorb oxygen dissolved in the water.

Gravity A force that pulls all objects with mass towards each other.

Herbivore An animal, such as a cow, elephant, or deer, that eats only plants.

Hypothesis A theory about how things work. Scientists test their hypotheses by conducting experiments.

Inclined plane A simple machine used to lift or lower heavy objects using less effort.

Infrared A form of invisible radiation given off as heat by objects.

Insulator A substance that does not allow electrical current or heat to pass through it easily.

Invertebrate An animal that does not have a backbone.

Ion An atom or molecule that contains an uneven number of protons and electrons. An ion either has positive or negative charge.

Lever A simple machine that makes a force or a movement larger. Levers can be used to move heavy objects.

Liquid A state of matter in which a substance has a fixed volume but no fixed shape.

Mass The amount of matter within an object.

Matter Any physical substance.

Metabolism The chemical process by which living things make the substances they need to grow and stay healthy.

Migration A journey made by animals from one place to another in search of food or in order to reproduce.

Molecule A group of atoms that have bonded together to make a new substance. Water is made of molecules containing hydrogen and oxygen.

Neutron A particle found in the nucleus of an atom. It does not have a charge.

Nucleus The center of an atom, made of neutrons and protons. Also used to mean a part of a cell that contains most of the cell's DNA.

Nutrient A chemical that a plant or animal needs to stay healthy.

Omnivore An animal that eats both meat and plants.

Orbit The path of an object that follows another object. The Moon makes an orbit around the Earth.

Organism An individual living thing, such as a plant or animal.

Parasite An organism that lives on another organism and harms it.

Particle A very small bit of matter, such as an atom, a molecule, or an electron.

Photosynthesis A process that takes place in the leaves of plants in which the energy of the Sun is used to make sugars they need for food.

Plasma A state of matter similar to a gas and containing charged ions.

Precipitation Water that falls to the Earth's surface from the atmosphere. It can be in the form of rain, hail, or snow.

Predator An animal that hunts other animals for food.

Prey An animal that is hunted by other animals for food.

Protist A simple form of single-celled life.

Proton A particle found in an atom's nucleus. A proton has a positive charge.

Pulley A simple machine used to increase pulling forces.

Radiation A form of energy that travels in the form of electromagnetic waves, such as light and X-rays.

Respiration A chemical process in which food is broken down to release its energy.

Satellite An object that orbits another object. The Moon is the Earth's only natural satellite.

Seed The fertilized egg of a plant, usually surrounded by a store of food to help it grow.

Solid A state of matter in which the molecules are tightly packed together and cannot move freely.

Solution A liquid with another substance dissolved in it.

Species A group of organisms that are very similar and able to breed with one another.

Spore A fertilized cell made by fungi that grows into a new organism.

Static electricity A form of electricity in which electric charge builds up in one place.

Temperature A measure of how hot a substance is.

Ultraviolet A form of radiation found in sunlight. Humans cannot see ultraviolet, but some insects and birds can.

Velocity The speed and direction of movement of an object.

Vertebrate An animal that has a backbone.

Wedge A simple machine that is used to separate objects or to hold them in place.

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