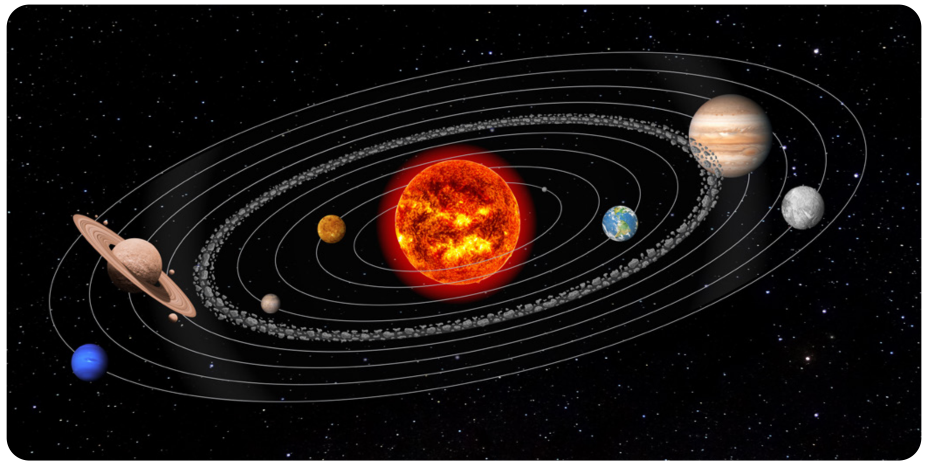
Earth and Space

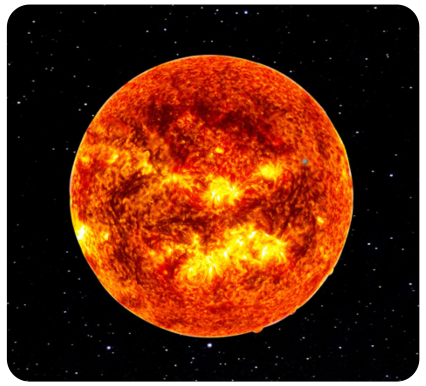
The Solar System

The Solar System consists of eight planets that orbit around the Sun.



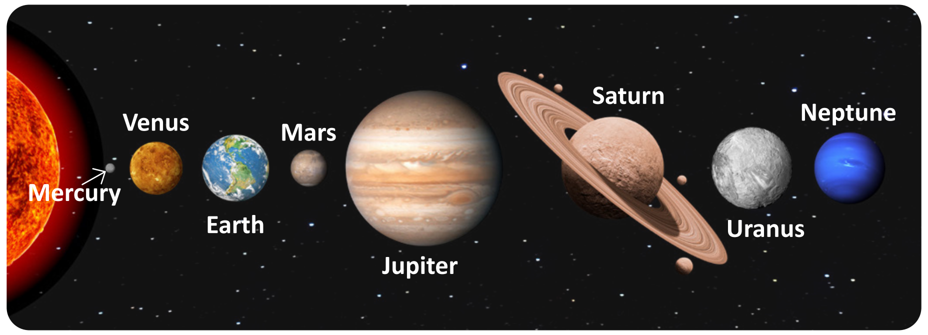
The Sun

The Sun is a 4.5 billion-year-old star. It is a huge, hot ball of gas that rotates on its axis once every 27 Earth days. The Sun is the only source of light and heat in the Solar System. Without it, life as we know it would not exist on Earth.



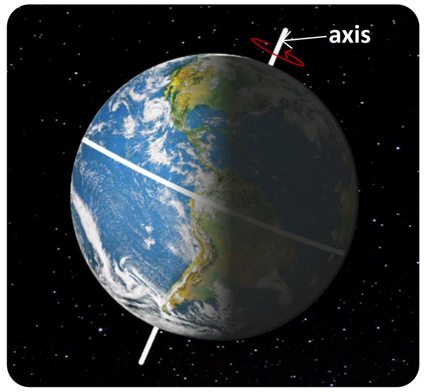
The planets

There are eight planets in the Solar System. The planets closer to the Sun (Mercury, Venus, Earth and Mars) are terrestrial planets because they are made of rock. They are hotter and have a shorter orbit and a shorter year than the planets farther away. Planets that are farther from the Sun (Jupiter, Saturn, Uranus and Neptune) are made of gas and are called gas giants. They are colder and have a larger orbit and a longer year than the closer planets.



The Earth

The Earth is the fourth planet from the Sun in the Solar System and is the only one to support life. The Earth rotates on an axis at a tilt of 23.5°. One rotation takes 24 hours, which is one day. The Earth orbits the Sun once every 365.25 days, which is a year.



The planets and stars are spheres

Each planet and star is spherical because gravity, created by their large mass, pulls all material towards their centre and compresses it into the most compact shape, a sphere.

Models of the Solar System

Geocentric model

In the past, many philosophers and scientists believed the Solar System was geocentric, meaning that the Earth was at the centre, orbited by the Sun and the other planets. The observations and common sense of Aristotle, the mathematics of Ptolemy and the scientific methods of Alhazen supported this theory. The geocentric model was accepted for 1500 years.

Aristotle, c384–c322 BC

Claudius Ptolemy, AD c100–c170

Alhazen, AD c965–c1040

Heliocentric model

In the 16th century, Nicolaus Copernicus suggested the heliocentric model, with the Sun at the centre of the Solar System and the Earth and other planets orbiting around it. Even though this was an unpopular theory at the time, the observations of Galileo Galilei and the scientific laws of Sir Isaac Newton proved that the heliocentric model was correct.

Nicolaus Copernicus, 1473–1543

Galileo Galilei, 1564–1642

Sir Isaac Newton, 1643–1727

Beliefs about the shape of the Earth

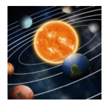
Many ancient civilisations believed the Earth was flat and shaped like a floating disc, a cylinder or even a square.

In ancient Greece, around 500 BC, the philosopher, Pythagoras, thought a sphere was the perfect shape, so the Earth must be a sphere.

Aristotle proved the Earth was a sphere when he observed a ship sailing away to sea. He noticed that the bottom of the ship disappeared first and the sail last. If the Earth were flat, the whole ship would have looked gradually smaller as it sailed away.

Modern technology has provided further evidence that the Earth is spherical. For example, the famous *Earthrise* photograph was taken from the spacecraft *Apollo 8* during the crew's first orbit around the Moon.

Earthrise, 1968

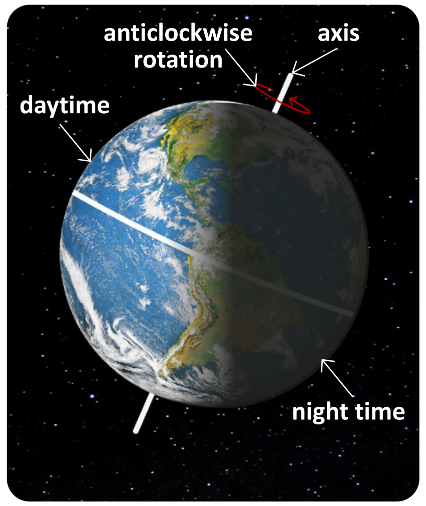


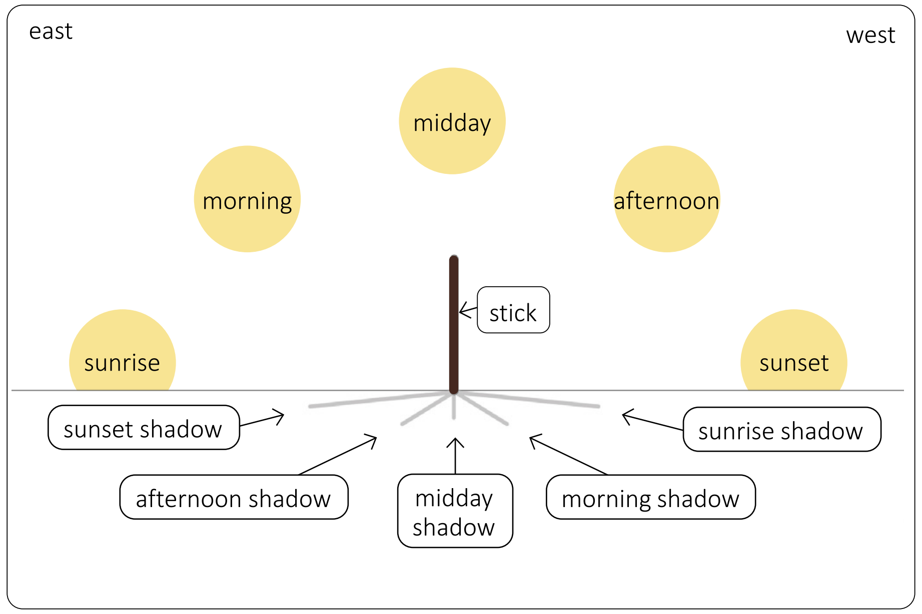
Daytime and night time

As the Earth rotates, it is daytime in the places that face towards the Sun, and night time in the places that face away from the Sun.

During the day, the Sun appears to rise in the east, move across the sky in an arc and set in the west. However, this is due to the Earth rotating and not the Sun moving.

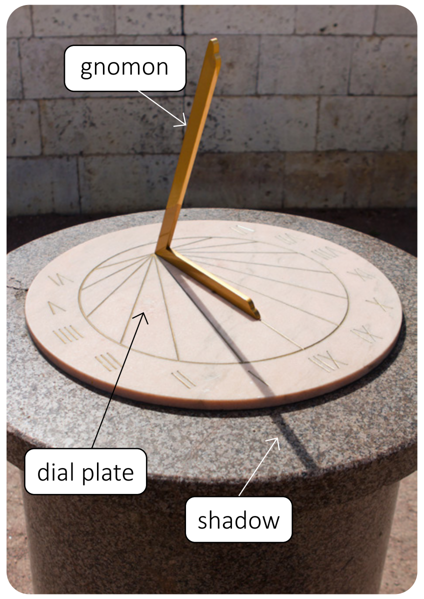
The changing angle of the sunlight during the day changes the direction and length of shadows cast by objects on Earth.





Sundials

Sundials are the earliest form of timekeeping device. They have two parts, a flat **dial plate** marked with Roman numerals or numbers, and a **gnomon** that tilts at the same angle as the Earth's axis and points to true north. Sundials are placed outside and the shadow cast by the gnomon falls on the dial plate and shows the time.

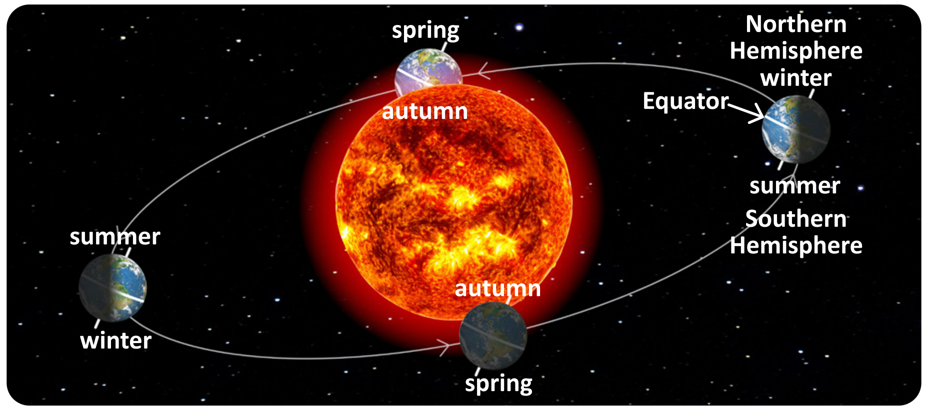


Day length and seasons

The tilt of the Earth on its axis, its daily rotation and its yearly orbit also create different day lengths and seasons.

When the Northern Hemisphere is tilted away from the Sun, it gets little direct sunlight, so daytime is short, night time is long, and the weather is cold. In the Arctic Circle, it never gets light.

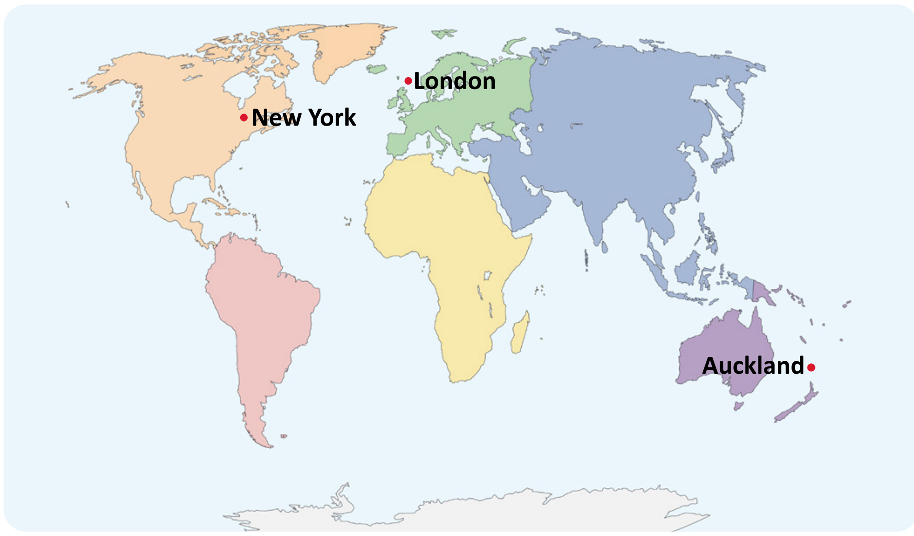
At the same time, when the Southern Hemisphere is tilted towards the Sun, it gets a lot of direct sunlight. Daytime is long, night time is short, and the weather is warm. In Antarctica, it is always light. As the Earth continues its orbit, the seasons change throughout the year.



During Earth's orbit, countries in the tropics that are on or near the equator have the same amount of direct sunlight all year round. This means the length of daytime and night time is similar, and they have warm temperatures all year. They only have two seasons: a rainy season and a dry season.

Times around the world

The Earth's rotation on its axis creates different times around the world. For example, if it is 12:30 on Friday in London, United Kingdom, it is 07:30 in New York, United States of America. At the same moment, it is 00:30 on Saturday in Auckland, New Zealand.

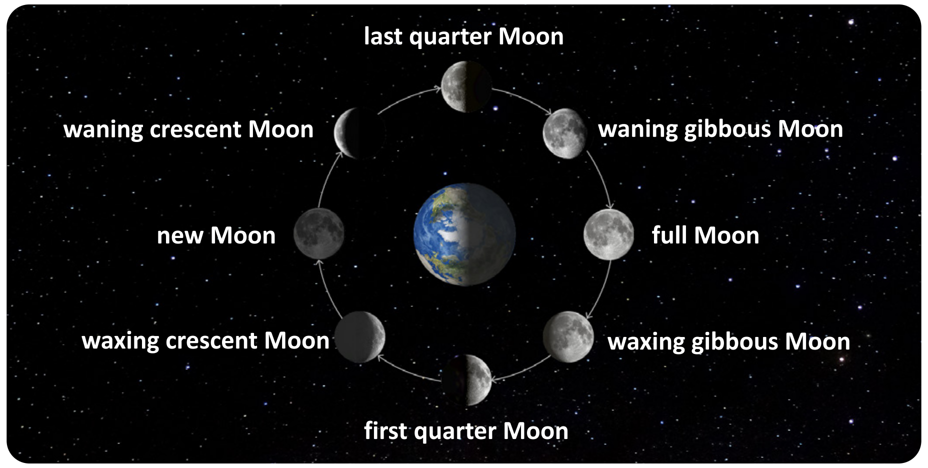


The Moon

The Moon is 385,000km away from Earth and has a diameter of 3500km. It orbits the Earth once every 27.3 days, which is around one month. It also rotates on its axis once every 27.3 days, so we only see one side of the Moon from Earth. The Moon is not a natural light source; it reflects the Sun's light.

Phases of the Moon

As the Moon orbits, we see differing amounts of the Moon's lit side from Earth. These are known as the phases of the Moon.



Solar and lunar eclipse

A **solar eclipse** is when the Moon passes directly between the Earth and the Sun, blocking our view of the Sun and casting a shadow on part of the Earth.

A **lunar eclipse** is when the Earth is in line between the Moon and the Sun and casts a shadow on the Moon.

Glossary

axis	An imaginary line that runs through the centre of an object, such as a planet, about which it rotates.
orbit	The stable, circular path of an object revolving around a central mass with gravitational force, such as the planets revolving around the Sun, or the Moon revolving around the Earth.

Forces and Mechanisms

Forces

A force is a push or a pull that makes something move, change speed or change shape. Forces act in pairs that oppose each other. A force can be either a contact force or a non-contact force.

Contact forces

A contact force is a force that acts between two objects that touch. Contact forces include:

friction	A force between two surfaces as they move across each other that always slows an object down.
air resistance	A frictional force that acts to slow an object's movement when it moves through air.
water resistance	A frictional force that acts to slow an object's movement when it moves through water.

Non-contact forces

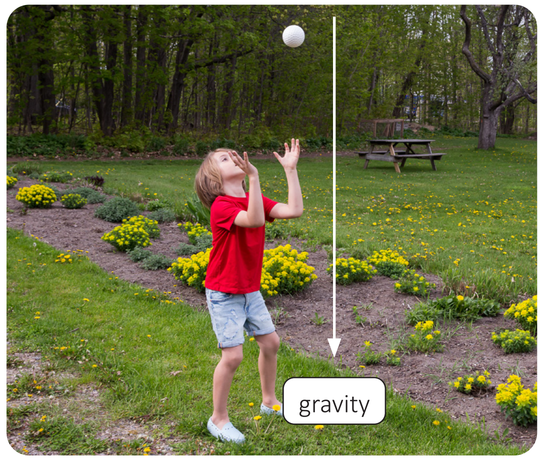
A non-contact force acts between two objects that do not touch. Non-contact forces include:

magnetism	The attraction and repulsion between two magnets or between a magnet and magnetic materials.
gravitational force	A pulling force between objects that have mass.

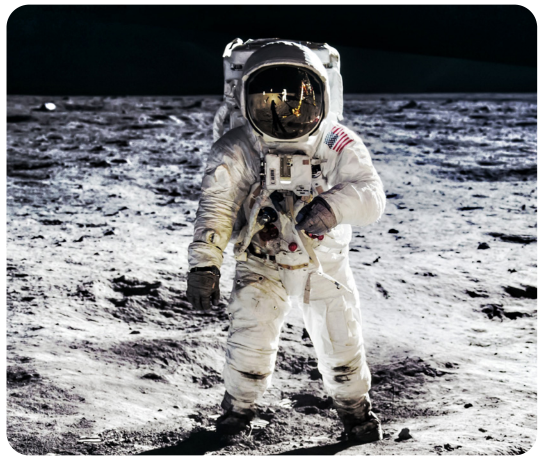
Gravitational force or gravity

All objects have gravity because all objects have mass. Usually, the gravitational force between two objects is very weak because the objects are small. Gravitational force becomes larger as an object's mass increases. Gravity gives an object weight.

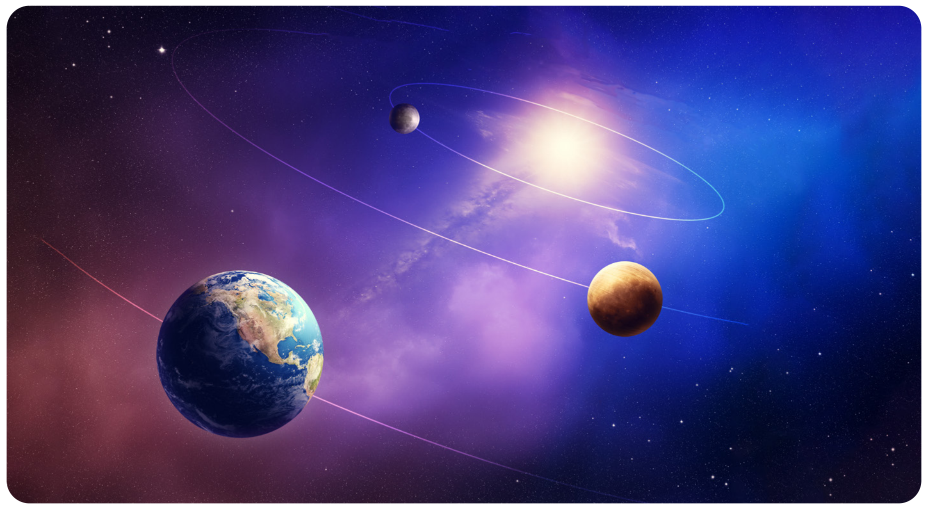
Earth's gravity pulls objects towards its centre. Earth's gravitational force is strong because Earth has a large mass. Gravity keeps objects on the surface of the Earth and pulls all unsupported objects to the ground.



The force of gravity is weaker on the Moon than on the Earth because the Moon has less mass. Gravity on the Moon is about one-sixth of that on Earth.



The Sun has a strong gravitational force because its mass is so large. This force keeps the planets in our solar system travelling in a curved path, called an orbit, around the Sun.



Mass and weight

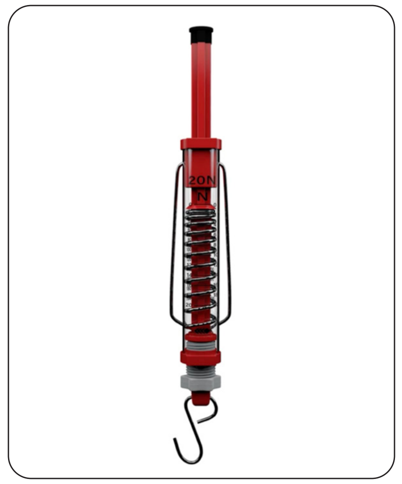
Many people commonly mix up and misuse the words mass and weight, even though they have different meanings and units of measurement.

Mass is the amount of matter that an object or substance contains. It can never be zero and is the same wherever it is, even in space.

Mass is measured in grams (g) or kilograms (kg) using a scale or the kg scale on a force meter.

Weight is a measure of gravitational force. The weight of an object can vary depending on where it is. For example, gravitational force on the Moon is less than that on Earth, so an object weighs less on the Moon.

Weight is measured in newtons (N) using a force meter.



Frictional forces

Friction is in all places where two surfaces meet. It acts in the opposite direction to movement and always slows an object down. The amount of friction depends on the materials from which the surfaces are made. Friction can be increased by adding tread patterns to tyres and the soles of shoes. Friction can be decreased by smoothing surfaces or using a lubricant, such as oil.

Air resistance

Air resistance is a type of friction that always acts against the direction of movement. It is caused by air particles hitting an object and slowing it down. Objects with a large surface area will hit more particles, and therefore have more air resistance, than objects with a smaller surface area.

Increasing air resistance

Some objects are designed to increase air resistance. Parachute canopies have a large surface area, which increases air resistance and slows down the parachutist's descent.

Decreasing air resistance

Some objects are designed to decrease air resistance. This fighter jet has a small surface area and a streamlined shape which decreases air resistance and allows the plane to move quickly through the air.

Water resistance

Water resistance is another type of friction that always acts against the direction of movement. It is caused by water particles hitting an object and slowing it down. Objects with a large surface area will hit more particles, and therefore have more water resistance, than objects with a smaller surface area.

Increasing water resistance

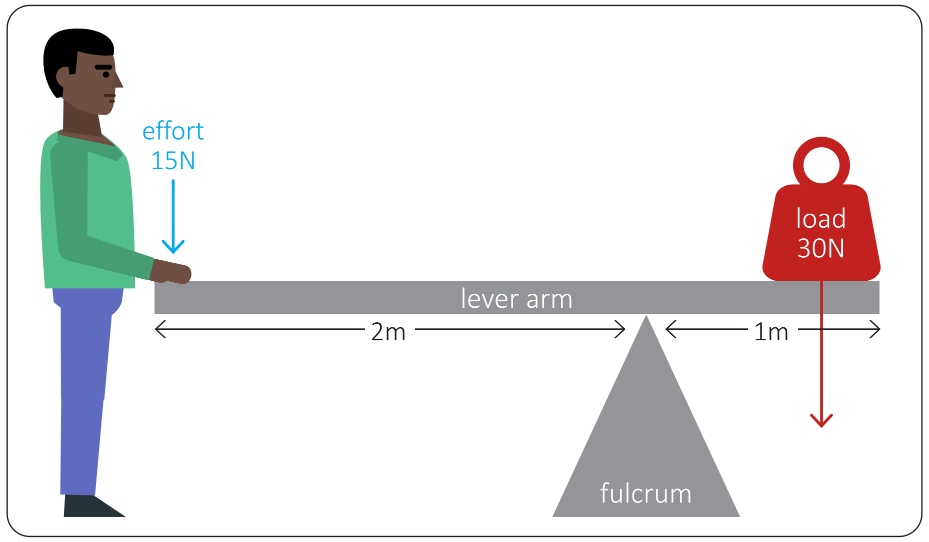
Scuba flippers have a large surface area to increase water resistance as the diver pushes against the water to move forward.

Decreasing water resistance

The front of a submarine has a small surface area and is streamlined to reduce water resistance.

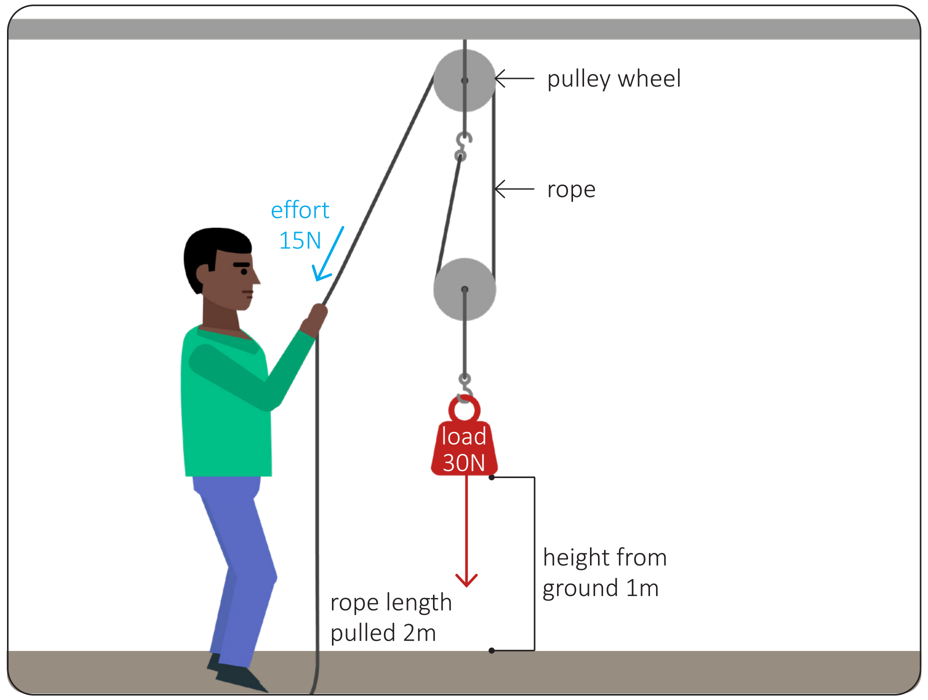
Levers

Levers are simple machines that can be used to provide a mechanical advantage, so a smaller force can have a greater effect. They consist of a lever arm, a fulcrum, a load to lift and an effort force. Levers make it easier to lift a load. For example if the distance between the fulcrum and the effort is double the distance between the fulcrum and the load, the effort needed will be halved.



Pulleys

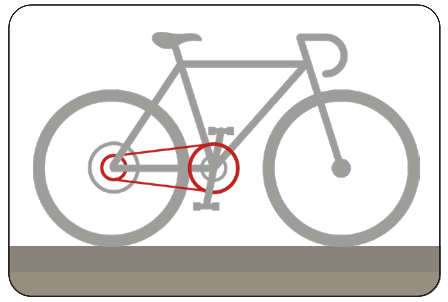
Pulleys are simple machines that can be used to provide a mechanical advantage. They consist of one or more grooved wheels and a rope. Pulleys make it easier to lift a load. For example, when two wheels are used in a pulley, the force needed to lift the load halves. At the same time, the length of rope needed to lift the load 1m off the ground doubles to 2m.



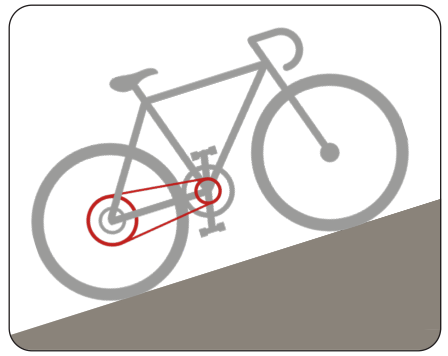
Gears

Gears are wheels with teeth around their edge. They can be connected directly together, so their teeth mesh and they turn in opposite directions. They can also be connected by a chain to turn in the same direction. Gears of different sizes with different numbers of teeth can can create a mechanical advantage. For example, in a mechanism made with a large gear with 12 teeth and a small gear with 6 teeth, the small gear will rotate twice as fast as the large gear but with half the amount of force. Bicycles have different gears. Choosing the right combination of gears can provide a mechanical advantage for the cyclist.

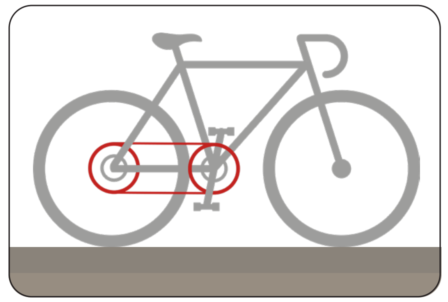
A cyclist can go faster on the flat by using a large gear to pedal slowly attached to a smaller gear at the back, which turns the back wheel quickly.



A cyclist can ride up a hill by using a small gear that is easier to pedal attached to a larger gear, which turns the back wheel slowly but with more force.



Using gears of the same size with the same number of teeth does not give a mechanical advantage because both gears turn with the same force and at the same speed.



Glossary

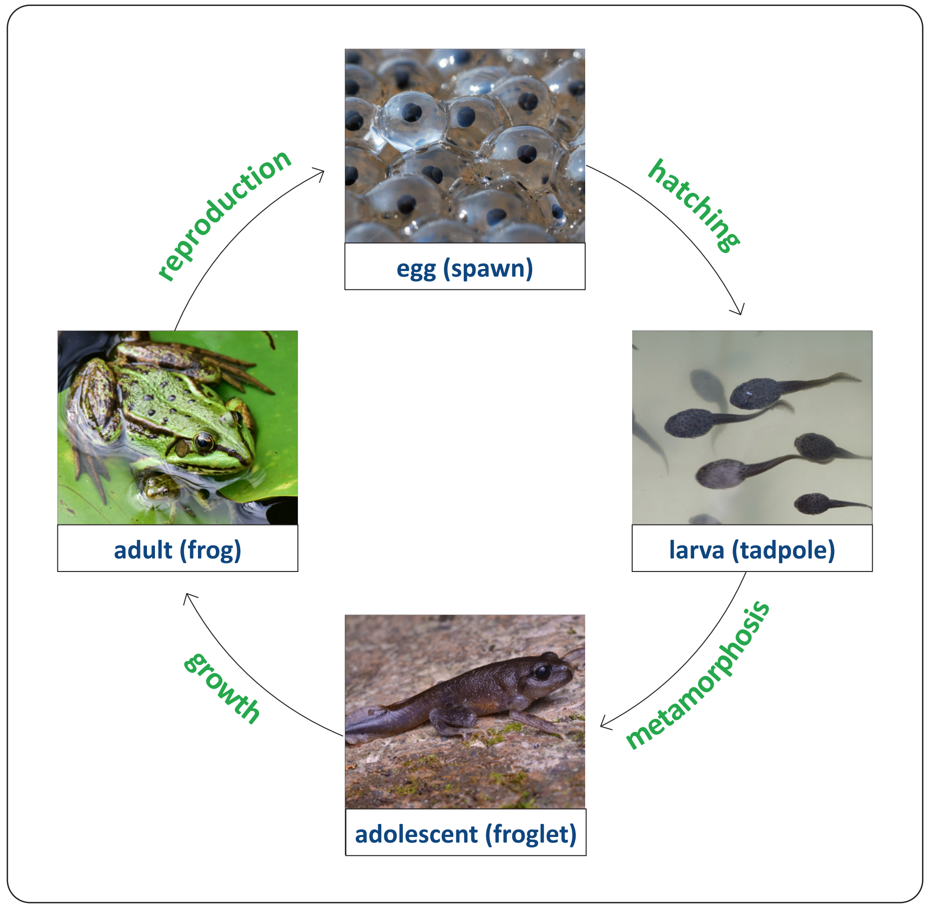
mechanical advantage	A measurement of how much a machine multiplies a force, so a smaller force can have a greater effect.
particle	A single piece of matter that is too small to be seen.
streamline	Having a shape that can move quickly and effectively through a liquid or a gas.

Human Reproduction and Ageing

Reproduction is the process of producing offspring, which is vital for the survival of all plant and animal species. All living things go through a series of changes during their life cycle, where they grow, mature, reproduce and age. As living things age, they gradually decline and then die.

Life cycles

A life cycle is a series of changes that happen to a living thing during its lifespan. The events happen in a set order as the animal or plant grows and develops. A life cycle is presented on a circular diagram to show the main developmental **stages** of a plant or animal's life and the **processes** between these stages. All living things eventually die, but reproduction starts the life cycle again.



Life cycle of the common frog.

Mammals

Mammals are a group of vertebrate animals, which means they have a backbone. Mammals have several characteristics that make them different from other vertebrates. These include:

- producing milk to feed their young
- being warm blooded
- giving birth to live young
- having fur or hair
- breathing air with lungs

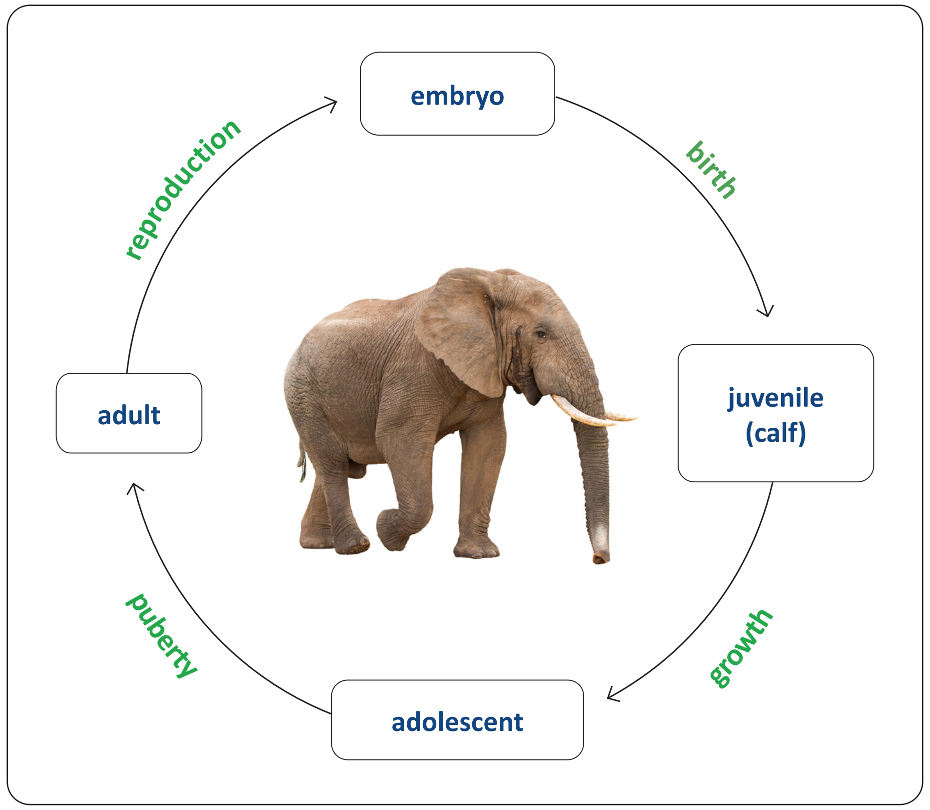
brown bear

Bengal tiger

human

Mammalian life cycle

There are four stages and four processes in the mammalian life cycle.



The length of each stage varies for different animals. For example, the European hamster has a 2–3 week juvenile stage, but the same stage is 10 years for an African elephant.

Human life cycle

The human life cycle has the same stages and processes as other mammalian life cycles.

Embryo

The embryo stage takes around 40 weeks. This is called the gestation period.

Juvenile

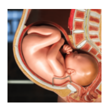
During the juvenile stage, the child grows and develops rapidly until around 12 years old.

Adolescent

The adolescent stage ends at around 19 years old. The process of puberty enables an adolescent to develop into an adult and be able to reproduce.

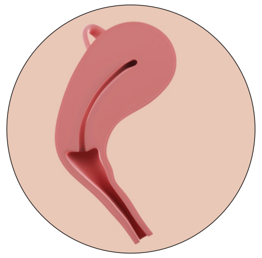
Adult

A person is a fully developed adult at around 20 years old and may choose to reproduce, which starts a new human life cycle.



Human gestation timeline

4 weeks
At four weeks after fertilisation, the embryo has developed into the size of a poppy seed.



16 weeks
At 16 weeks, the embryo has developed into a foetus the size of an avocado. Its nervous system and skeleton have become stronger.

32 weeks
At 32 weeks, the foetus is about the size of a coconut. It moves and sucks its thumb.

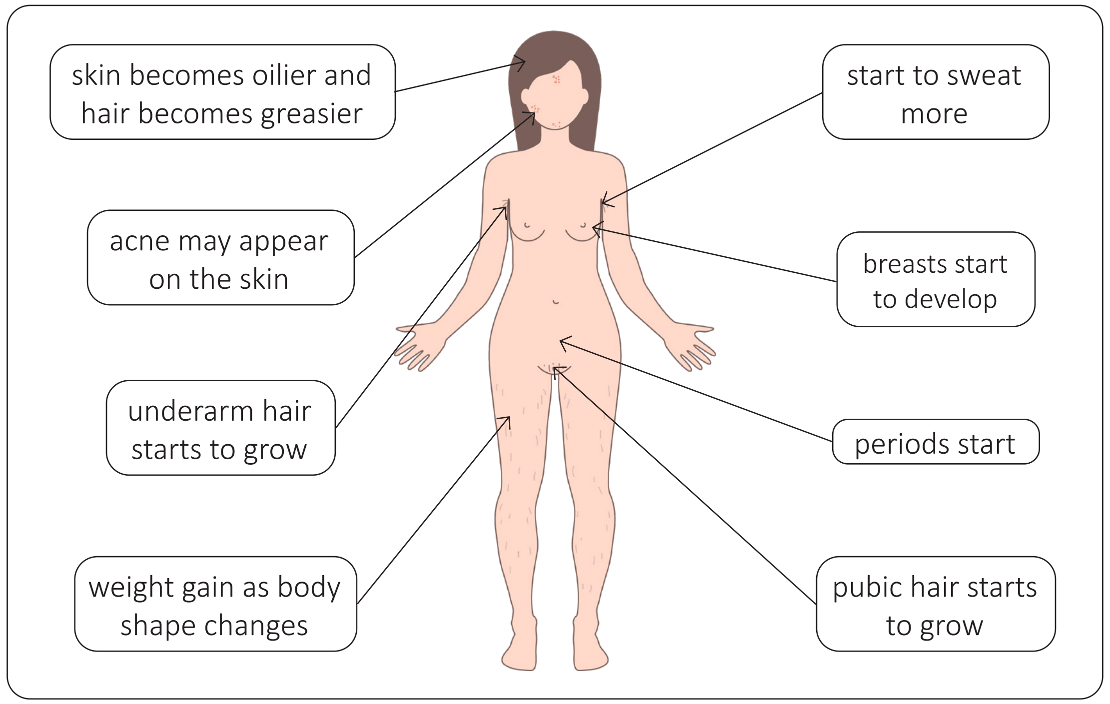
39 weeks
At 39 weeks, the foetus is the size of a small pumpkin. Its lungs are fully formed, ready for birth.

Birth
When the baby is born, it cries, takes its first breath and its umbilical cord is cut.

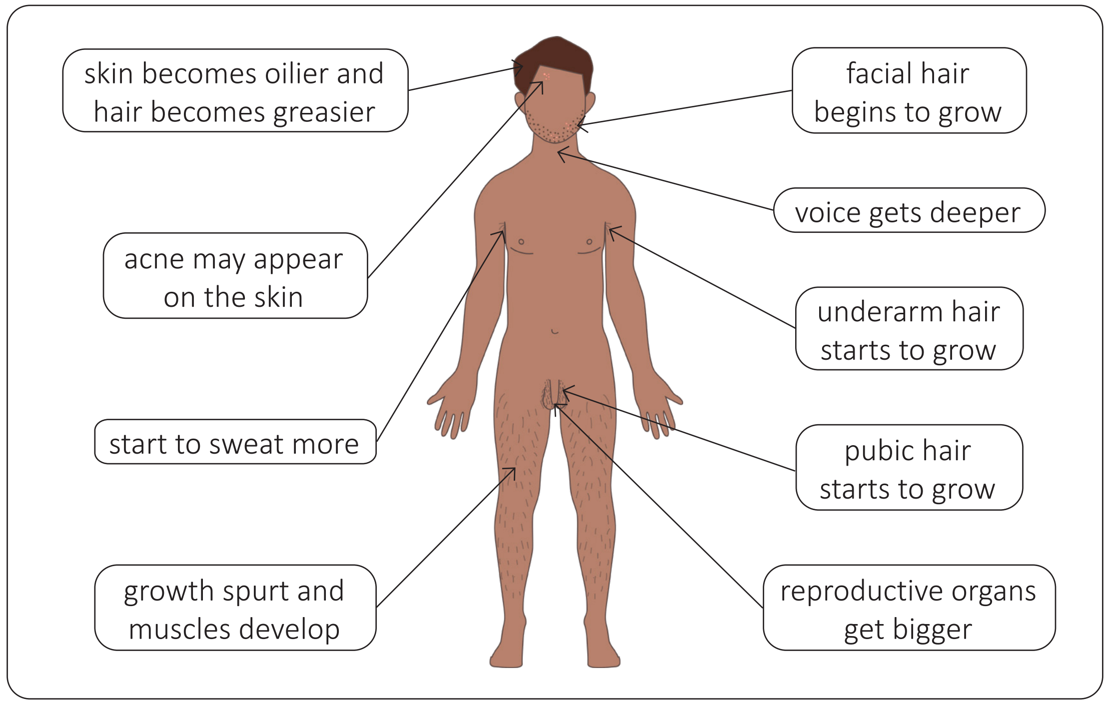
Puberty

Puberty is when a child's body changes as they develop into an adult and become able to reproduce. Puberty can start at any time between the ages of 8 and 14 and takes around four years. Chemicals called hormones cause puberty to begin and create physical changes, such as developing acne, sweating more and growing underarm and pubic hair. Puberty also creates emotional changes, including mood swings, low self-esteem, aggression and depression.

Physical changes during puberty in females

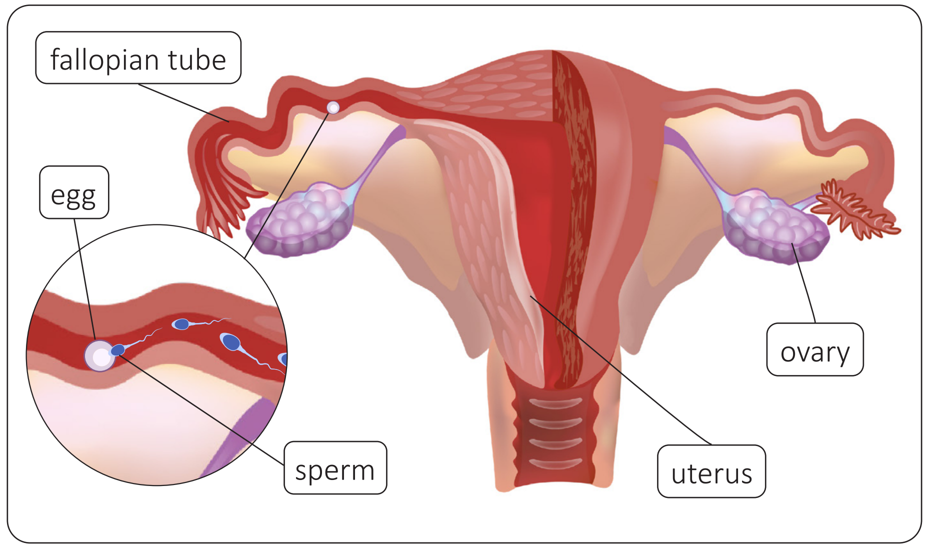


Physical changes during puberty in males



Human sexual reproduction

Sexual reproduction is the process of reproduction that involves one female and one male. When humans reproduce, a male sperm fertilises a female egg that has been released from the ovary into the fallopian tube. The fertilised egg divides as it travels down the fallopian tube and becomes a ball of cells called a blastocyst. The blastocyst implants in the wall of the uterus and develops into an embryo.



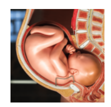
A sperm fertilises an egg in the female reproductive system.

Human ageing

Humans reach the peak of their physical fitness during the first decade of adulthood. After this, the cells that make up the human body begin to decay. They lose the ability to function correctly, causing various ageing effects, including cataracts, loss of hearing, greying hair, deterioration of organs and muscles, age spots and wrinkles.

Glossary

cataract	A condition in which the lens of the eye becomes cloudy, resulting in loss of vision.
foetus	A stage in the mammalian life cycle when a mammal in the uterus has begun to develop limbs and organs.
gestation	The length of time the young of a mammal develops inside the female's body until birth.
process	A series of changes that happen naturally.
stage	One part of a life cycle or period of development.



Properties and Changes of Materials

Properties of materials

All objects are made from materials. Different materials have different properties. For example:

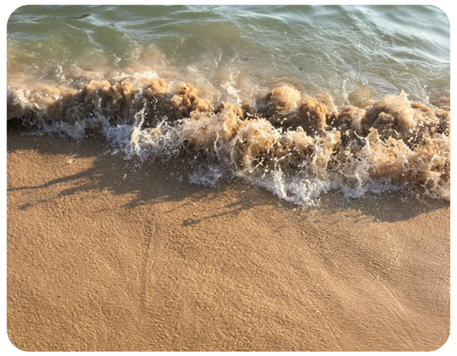
- hard or soft
- stretchy or not stretchy
- rough or smooth
- bendy or not bendy
- opaque or transparent
- waterproof or not waterproof
- absorbent or not absorbent
- strong or not strong
- magnetic or not magnetic
- reflective or non-reflective
- electrically conductive or electrically non-conductive
- thermally conductive or thermally non-conductive
- soluble or insoluble

Various tests can be carried out to investigate which properties materials have. A material's properties make it suitable for specific purposes. For example, oil cloth is a waterproof fabric, which makes it suitable to be used as a wipe clean tablecloth.

Solubility

Solubility is a measure of a material's ability to dissolve. When a material dissolves it disappears and becomes incorporated into another material. The material that dissolves is called the solute. The material it dissolves into is called the solvent. When the solute has dissolved in the solvent, it is known as a solution. A material that can dissolve is described as soluble. A material that cannot dissolve is described as insoluble.

sugar is soluble in water



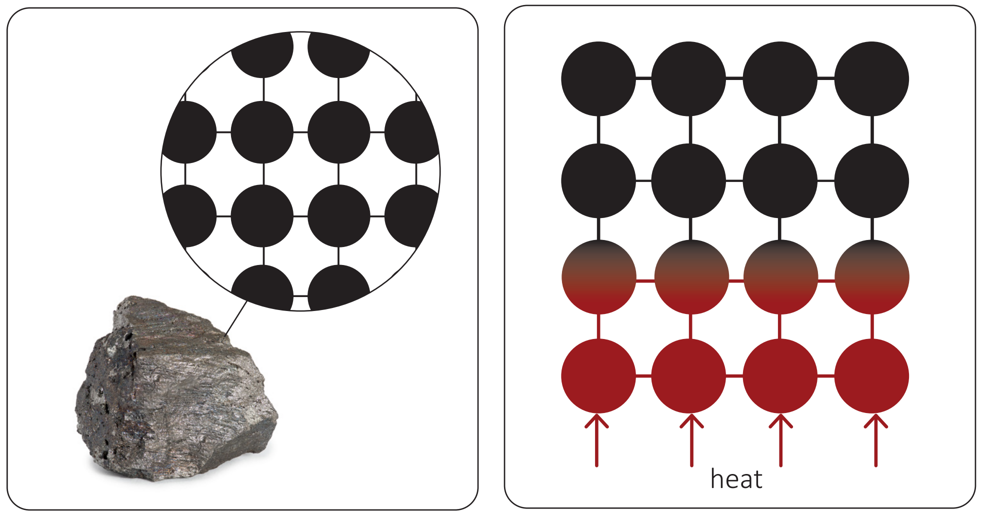
sand is insoluble in water

Dissolving can also happen with other states of matter. Air is a mixture of dissolved gases. Carbon dioxide gas is dissolved into liquids to make drinks fizzy.

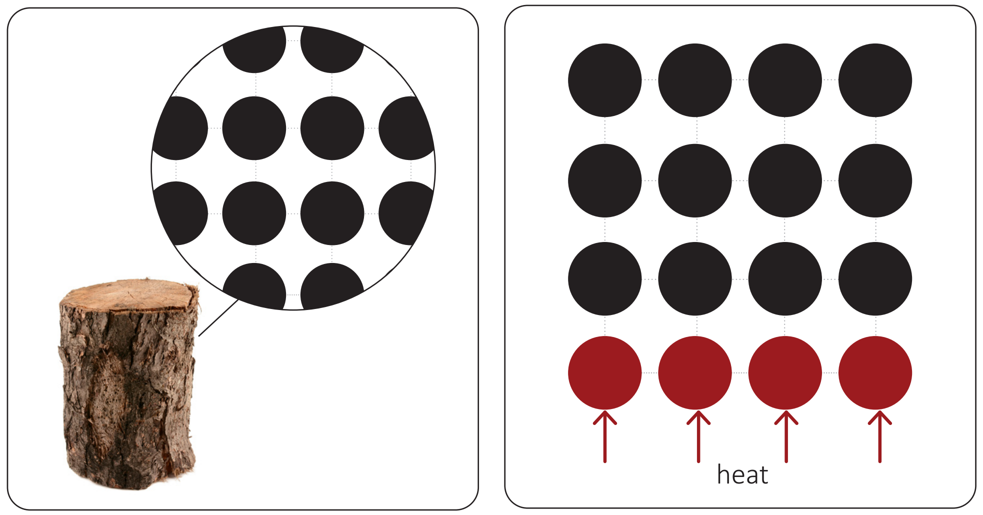
Thermal conductors

Thermal conductivity is a measure of a material's ability to conduct heat. Materials can be thermally conductive or thermally non-conductive. Thermally conductive materials allow heat to pass through them. Thermally non-conductive materials do not allow heat to pass through them. Whether a material is thermally conductive or thermally non-conductive depends on its state of matter and how its particles are arranged.

Solid metals are good thermal conductors because their particles are closely packed and they have strong, lattice metallic bonds. When heat is applied to a metal, the particles vibrate and the bonds transfer heat energy to adjacent particles. Other solids, such as plastic, wood and glass, do not have these strong metallic bonds so they do not conduct heat. They are thermal insulators. Liquids and gases are thermally non-conductive because their particles are far apart.



Solid metals are thermal conductors because their strong, metallic lattice bonds transfer heat.



Other solids do not have strong, metallic lattice bonds so they do not conduct heat.

Mixtures

A mixture is a combination of two or more substances that aren't chemically joined and can be separated into their individual substances. There are two types of mixtures: heterogeneous and homogeneous.

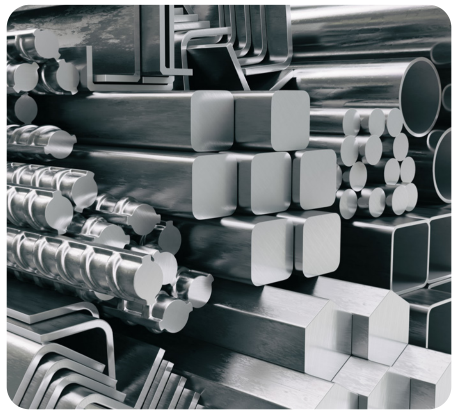
mixture of soil and water

Heterogeneous mixtures

Heterogeneous mixtures consist of distinctly different substances. This means you can easily see the different parts and they are easy to separate. Soil is an example. It is a mixture of solid, decayed organic matter and eroded rock. Salad is an example. It is a mixture of different solid fruits and vegetables.

Homogeneous mixtures

Substances in homogeneous mixtures are evenly distributed and you cannot see the different parts. Homogeneous mixtures are difficult to separate. Coffee is an example. It is a mixture of solid coffee granules dissolved in liquid water. Steel is an example. It is a mixture of iron and carbon.

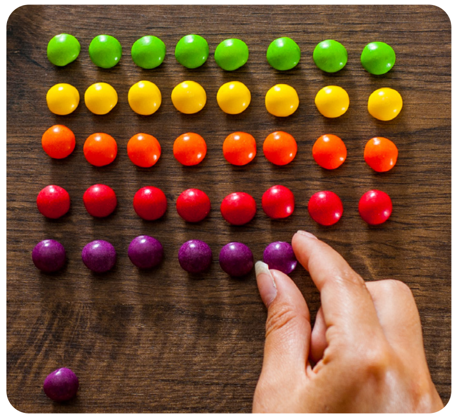


Separating heterogeneous mixtures

Heterogenous mixtures can be separated in different ways, including:

Classifying and grouping

When classifying and grouping, the substances in a mixture are observed and the individual parts are then put into groups by hand. A mixture of sweets can be separated by classifying and grouping.



Sieving

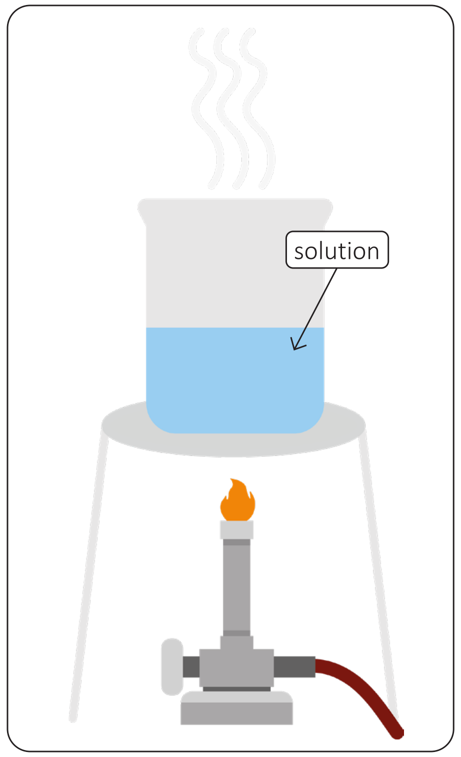
A sieve is a mesh that separates solids from liquids or large solid particles from smaller solid particles. This mixture of oats and milk can be separated by sieving.

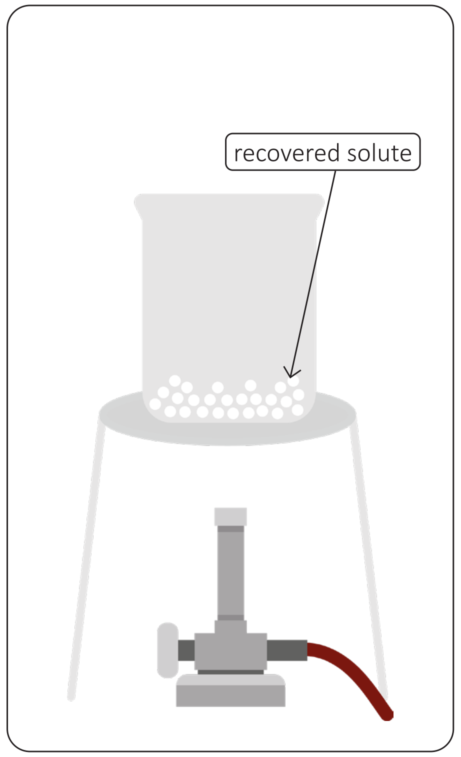
Filtration

Filtration is a way of separating very small solid particles mixed with liquids or gases using a filter. Filters can be made from thin materials, such as filter paper, which contain tiny holes, or from layers of solid materials, such as sand, gravel or charcoal. This mixture of ground coffee beans and water can be separated by filtering.

Separating homogeneous mixtures

Some homogeneous mixtures, such as seawater, can be separated into their different parts by evaporating. Evaporating involves heating a solution until the solvent changes states from a liquid to a gas. When all the solvent has evaporated, the solute is left behind. The solvent is usually lost during evaporation.





Other techniques are used to separate homogeneous mixtures, such as air, metals and oil in water. For example different gases in air can be separated using cooling. The separated gases can then be used in industries, such as hospitals and manufacturing.

Reversible and irreversible changes

There are two types of changes, reversible and irreversible changes.

Reversible changes

Reversible changes can be reversed or changed back to recover the original materials. They are physical changes, which means no new materials are formed, and recovered materials are the same, even if they look or feel different. Reversible changes happen between the three main states of matter: solids, liquids and gases. Melting, freezing, evaporation, condensation and dissolving are all reversible changes.

Irreversible changes

Irreversible changes cannot be reversed or changed back to recover the original materials. They are chemical changes that form new materials. Several processes cause irreversible changes, including cooking, burning, rusting, decaying and chemical reactions. Signs of irreversible changes include the production of a gas, a sound, a smell or light. The temperature, colour and smell can also change.

burning

rusting

decaying

chemical reaction

Glossary

absorbent	To be able to take in or soak up another material.
chemical reaction	A process when two or more materials react together to make new materials.
conduct	Able to let heat or electricity pass through.
filter	A device that removes small solid particles from a liquid or gas, by not permitting the solid particles to pass through.
solute	A dissolved substance, such as salt.
solution	A mixture in which the solute and solvent particles are evenly spread out, such as seawater.
solvent	A substance that dissolves a solute, such as water.