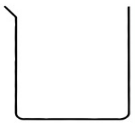
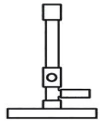
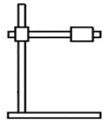
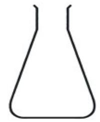
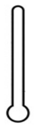
Toynbee Curriculum
KS3 Knowledge Maps

SCIENCE

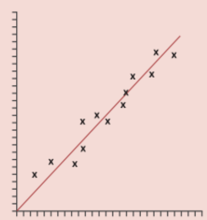
Toynbee School

Personal Best

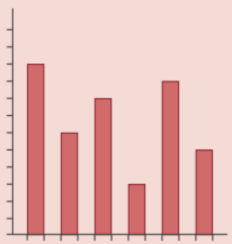
Introduction to Science

beaker	Bunsen burner	tripod	evaporating basin	clamp stand, boss and clamp	conical flask
					
test tube	**funnel**	**measuring cylinder**	**thermometer**	**heatproof mat**	**gauze**
					

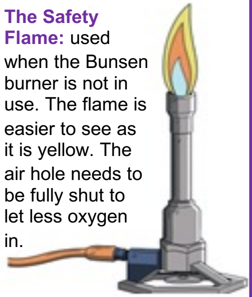
Scatter graph: used to display data when both the independent and the dependent variables are continuous.



Bar chart: used to display data when at least one variable is discrete or categoric.



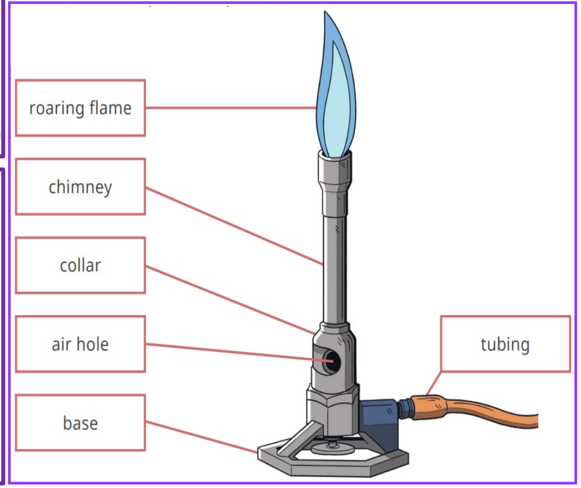
The Safety Flame: used when the Bunsen burner is not in use. The flame is easier to see as it is yellow. The air hole needs to be fully shut to let less oxygen in.



The Roaring Flame: used to heat things quickly. The air hole must be fully open to allow oxygen in.

Lab safety rules:

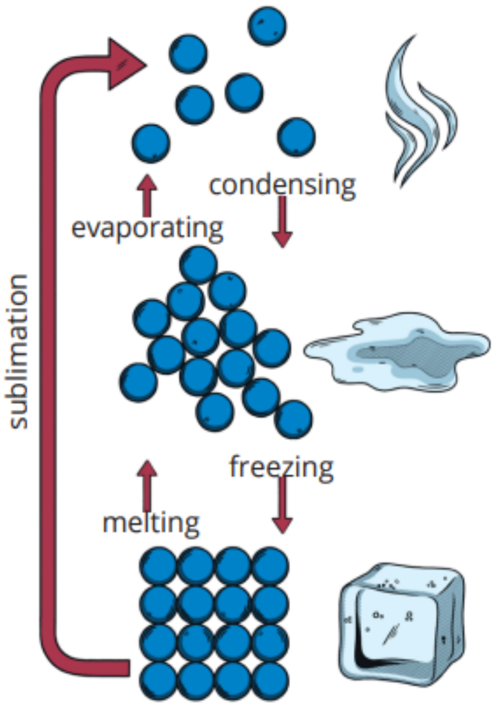
- Always wear eye protection during a practical.
- Carry out a practical while standing up.
- Do not eat or drink in the laboratory.
- Tie long hair back and tuck loose clothing in during practicals.
- If something is spilled or broken, tell the teacher.
- Ensure that the floor and work space is clear of obstacles



Accuracy: How close your measurement is to the true value. We improve it by using equipment correctly.
Precision: Precise measurements are ones that have little spread around the mean value. We improve it by using measuring equipment with a smaller scale resolution.
Independent variable: The thing you change in an investigation.
Dependent variable: The thing you measure in an investigation.
Control variable: The things you keep the same in an investigation.
Continuous data is represented on **line graph**, this means that the data can have any value such as height, age or temperature.
Categoric data is represented on **bar charts**, this means that the data can only fall into a set category, such as sex, hair colour or eye colour.
Anomaly: A result that doesn't fit the pattern.
Prediction: What you think will happen and why.
Risk assessment: Identify hazards, the harms they can do and how you will minimise any risks.
Method: Step-by-step instructions for how to carry out a practical investigation.
Results table: As the practical is carried out, write the results in a table.
Conclusion: An explanation of what you found out in your investigation.
Evaluation: Where you consider the quality of your method and the data you collected.

Moderate hazard	Explosive	Flammable	Toxic	Environmental hazard	Corrosive	Oxidising	Health hazard
May irritate the skin and eyes. Wear goggles.	May explode with heat, friction or shock. Keep away from heat.	Flammable when exposed to heat, fire or sparks. Keep away from ignition sources	Life-threatening. Avoid all contact.	Toxic to aquatic life. May cause environmental effects. Dispose of responsibly.	May cause burns to skin and damage to eyes. May corrode metals. Avoid skin and eye contact.	Burns even in the absence of air. Can intensify fires. Keep away from ignition sources.	Can cause serious long term health effects. Avoid ingestion and contact.
							

Particles & Separation Techniques



- When an object gets heated up the particles take in energy from the surroundings.
- This causes the particles to move faster with more energy.
- When an object cools down the particles transfer energy to the surroundings.
- This causes the particles to move slower.

Dissolving is the process of mixing a **soluble solute** into a **solvent** to make a **solution**.

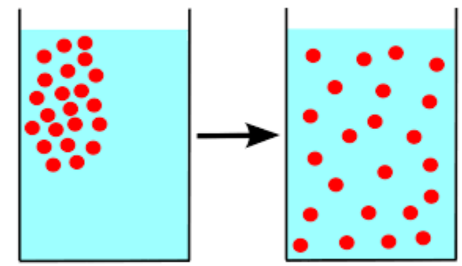
Solutes dissolve faster at higher temperatures and with stirring.

Solute: the substance that is dissolved.
Soluble: able to be dissolved.
Solvent: the liquid that something dissolved in.
Solution: a liquid containing a dissolved solid.

Diffusion

When a liquid or gas is mixed with another, the particles will flow and move about until they are evenly spread. The particles move **from an area of high to low concentration**. This is called **diffusion**.

Diffusion happens faster at higher temperatures and concentrations.

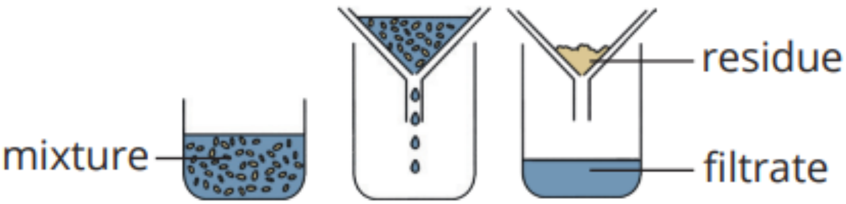


	Solid	Liquid	Gas
Particle Model			
Particle arrangement	Regular structure. No space between particles	Irregular structure. Very little space between particles	Irregular structure. Large space between particles
Volume and shape	Fixed volumed and shape	Fixed volume, shape fills bottom of container	Volume and shape fills container
Able to flow	No	Yes	Yes
Density	High	High	Low
Particle energy	Low	Moderate	High
examples	Wood, plastic, stone	Water, milk, acid	Air, oxygen, carbon dioxide

Filtration

Filtration is used to separate an **insoluble solid** from a liquid. The solution is passed through a filter paper and funnel.

The **residue** remains in the filter paper, and the liquid which passes through is called the **filtrate**. A mixture of sand and water can be separated by filtration.

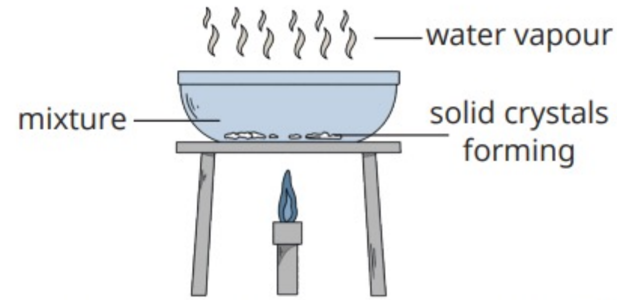


Evaporation

Evaporation separates a **soluble solid** from a **solvent**. The solution is heated, the liquid **evaporates** and the solid **crystallises**.

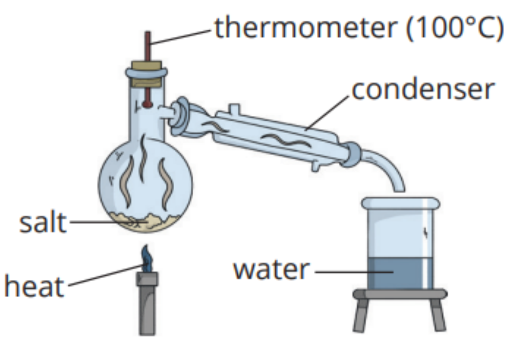
If the evaporation and crystallisation occur quickly, the crystals will be small. If it happens more slowly the crystals have time to grow and become larger.

A solution of salt water can be separated using evaporation.



Distillation

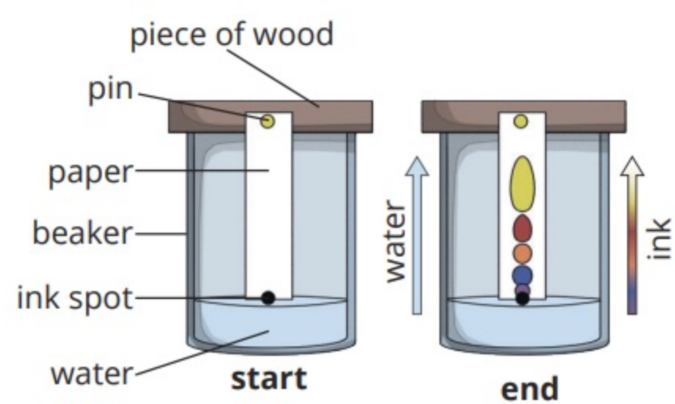
Distillation can separate a **solvent** from a **solution,** e.g. salt water. As the water is heated it **evaporates** from the flask and flows upwards into the **condenser**. The condenser is surrounded by cold water which causes the water vapour to condense back into a liquid. The liquid flows down the tube and into the beaker. The collected water is called **distilled water.**



Chromatography

Chromatography can be used to separate different dyes in ink. The colours are separated because they have different **solubilities**.

The separate inks are carried different distances up the paper by the solvent.



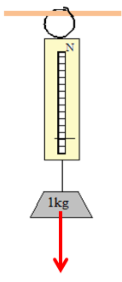
Forces

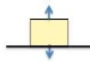
1: Measuring Forces

Force is measured in newtons (N).

A newton meter is used to measure the size of a force.

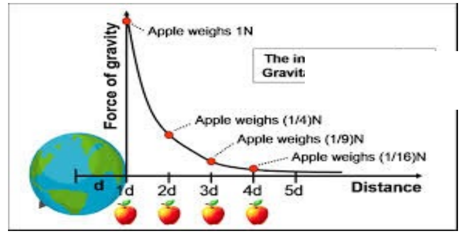
Arrows are added to diagrams to show the size and direction of the force.



Contact forces: interactions between objects that touch		**Non-contact forces:** attract or repel, even from a distance	
	Thrust/Applied		Magnetic
	Tension		Electro-static
	Drag and air resistance		Weight /Gravity
	Friction		
	Normal/reaction		

4. Weight and Gravity

Gravity is an attraction towards the centre of mass. It is caused by any object with mass. The greater the mass the greater the gravity.
As you mover further from an object it's gravity decreases.

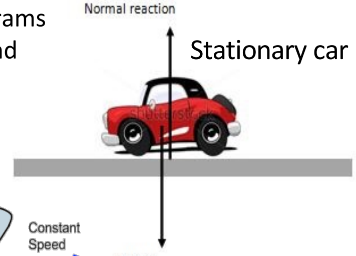


The force called weight is calculated using the following equation:

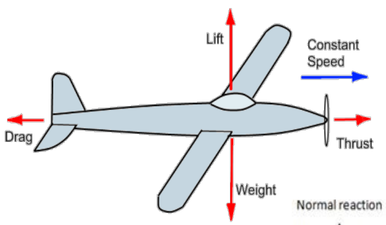
weight = mass x gravity

Mass is the amount of stuff you are made of. If you went to the Moon, your mass would stay the same, but your weight would change.

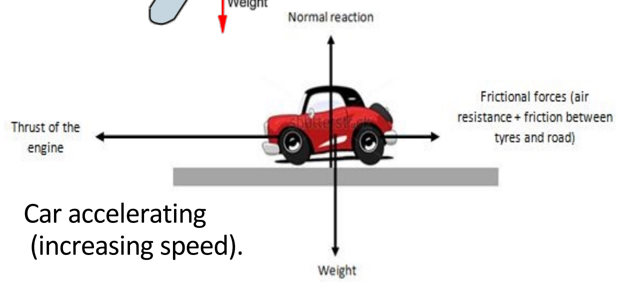
Examples of force diagrams showing balanced and unbalanced forces.



Stationary car



Plane at a constant speed.



Car accelerating (increasing speed).

3. Friction

Whenever an object moves against another object, it feels frictional forces. These forces act in the opposite direction to the movement. Friction makes it more difficult for things to move.

Air resistance

Bikes, cars and other moving objects experience air resistance as they move. Air resistance is caused by the frictional forces of the air against the vehicle. The faster the vehicle moves, the bigger the air resistance becomes. The top speed of a vehicle is reached when the force from the cyclist or engine is balanced by air resistance.

Streamlining

Streamlining reduces air resistance

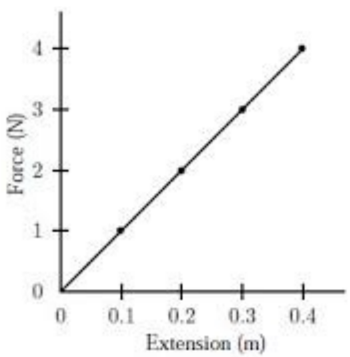
Racing cyclists crouch down low on their bikes to reduce the air resistance on them. This helps them to cycle faster. They also wear streamlined helmets. These have special, smooth shapes that allow the air to flow over the cyclist more easily.

2: Changing shape

When an unbalanced force acts on an object its shape can change. This is like pulling on a spring.

To investigate how adding mass to a spring affects its extension.

Add a 10 g mass holder to a suspended spring and record the spring length.
Add another 10 g mass and record the new spring length.
Take away the previous spring length from the new length to calculate the extension (the difference).
Repeat by adding 10 g masses until 100 g is reached.



Hooke's Law shows that as you double the force the extension of the spring doubles. (Directly proportional).

5. Balanced and unbalanced forces.

Forces interact in pairs. Where there is a push there is also a pull.
e.g. Weight pulls you down but the reaction force from the floor pushes you back up.

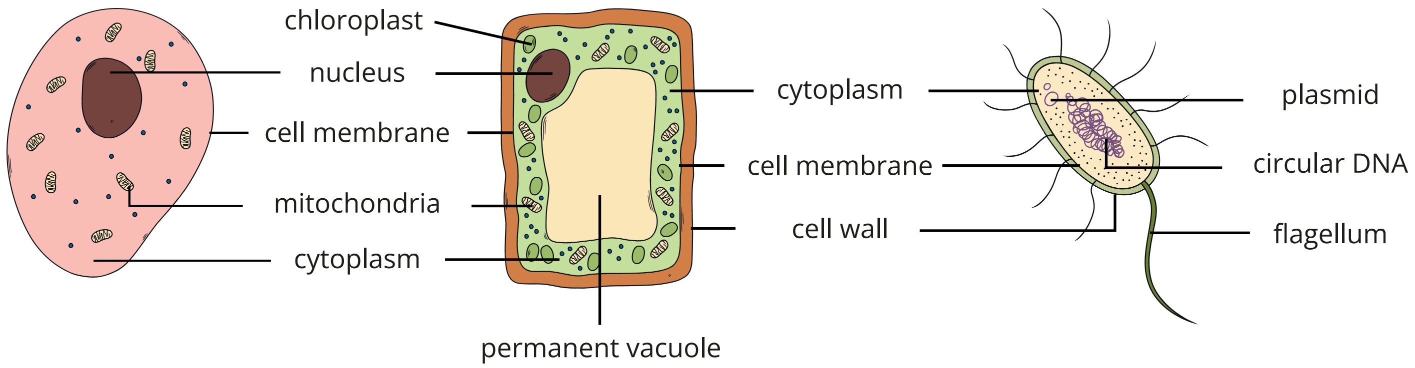
When you apply more thrust to run faster the air resistance increases pulling you back more. Forces can be balanced or unbalanced. When forces are balanced everything stays the same.

However when objects are unbalanced a resultant force is created.
When there is a resultant force three things can happen to an object. It will either:

1) change shape. (like stamping on a can or stretching a spring)
2) change speed (like increasing the thrust in a car engine)
3) change direction (like hitting a tennis ball back over the net).

KS3 Cells and Organisation **Knowledge Organiser**

Animal Cell **Plant Cell** **Bacterial Cell**



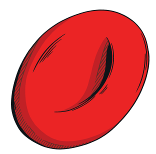
The components of a cell each have different functions.

Sub-Cellular Structure	Function
nucleus	Controls the activities of the cell. It contains genetic material (DNA), which is packaged into structures called chromosomes.
circular DNA	The DNA of bacteria found free in the cytoplasm.
mitochondria	Contain the enzymes needed for aerobic respiration, which releases energy for the cell.
chloroplasts	Contain a pigment called chlorophyll, which absorbs light to provide energy for photosynthesis.
cell wall	Helps to strengthen the cell and provides support for the plant.
cell membrane	Controls the movement of substances into and out of the cell.
cytoplasm	A jelly-like substance that fills the cell, where most chemical reactions occur.
flagellum	A tail-like structure that allows bacteria to move around.
permanent vacuole	Filled with cell sap to keep the cell rigid to support the plant.
plasmids	Plasmids are small rings of DNA that code for specific features, such as antibiotic resistance.

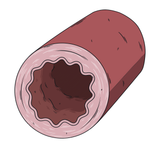
Different cell types contain different sub-cellular structures.

Sub-Cellular Structure	Animal Cell	Plant Cell	Bacterial Cell
nucleus	✓	✓	×
circular DNA	×	×	✓
mitochondria	✓	✓	×
chloroplasts	×	✓	×
cell wall	×	✓	✓
cell membrane	✓	✓	✓
cytoplasm	✓	✓	✓
flagellum	×	×	✓
permanent vacuole	×	✓	×
plasmids	×	×	✓

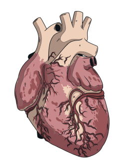
Levels of Organisation



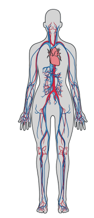
A **cell** is the smallest unit of a living organism. It contains structures needed to carry out life processes.



A **tissue** is a group of cells of the same type.

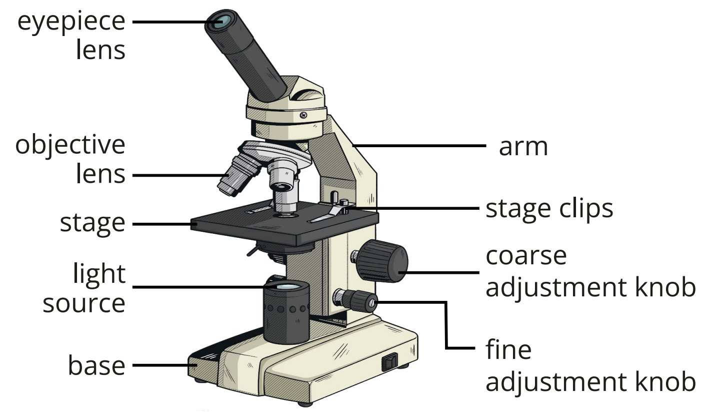


An **organ** is a group of different tissues working together to carry out a job.



An **organ system** is a group of different organs working together to perform a particular function.

Parts of a Light Microscope



Using a Light Microscope

- Plug in the microscope and turn on the light.
- Place the slide on the stage and hold it in place with the stage clips.
- Turn to the objective lens with the lowest magnification.
- Look down the eyepiece lens and use the adjustment knobs to focus the specimen.
- Increase the magnification by turning to a higher power objective lens, then use the fine adjustment knob to bring the cells back into focus.

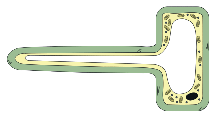
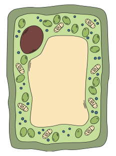
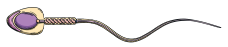
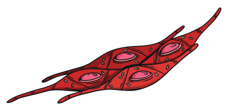
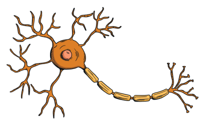
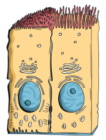
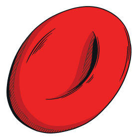
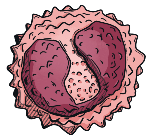
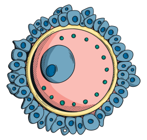
Organ System Functions

Organ System	Function
musculoskeletal system	Muscles and bones working together support and move the body.
reproductive system	Produces sperm (males) and eggs (females). In females, this is where the foetus develops.
respiratory system	Takes in oxygen from the air and removes carbon dioxide from blood.
immune system	Protects the body against infections.
digestive system	Breaks down and absorbs food molecules.
circulatory system	Transports substances around the body.

KS3 Cells and Organisation **Knowledge Organiser**

Specialised Cells

Each function carried out by the organism is performed by different cells. Each type of cell has slightly different features.

Name	Diagram	Functions	Adaptions
root hair cell		To absorb water and minerals from the soil.	Long protrusion fits between grains of soil and provides a large surface area for the absorption of water and minerals into the cell.
palisade cell		To carry out photosynthesis and make food for the plant.	Lots of chloroplasts to absorb light energy for photosynthesis. Its tall, long shape gives the cell a large surface area to maximise the absorption of light.
sperm cell		To travel to and fuse with an egg cell for fertilisation.	Long tail for movement to the egg and lots of mitochondria to release energy to allow the sperm to move.
muscle cell		To help the body to move.	Contains bands of protein that change shape to contract and relax the muscle. Lots of mitochondria to provide energy for muscle contraction.
nerve cell		To carry nerve impulses around the body.	Long fibres carry electrical impulses up and down the body and branching dendrites at each end connect to other nerves or muscles.
ciliated epithelial cell		To move mucus away from the lungs.	Tiny hairs called cilia to help waft mucus along the airways. Lots of mitochondria release energy for the cilia to move.
red blood cell		To transport oxygen around the body.	Biconcave shape increases the surface area for the diffusion of oxygen. No nucleus so that there is more room for haemoglobin, which binds oxygen molecules.
white blood cell		To fight pathogens which cause disease.	Some can change shape to squeeze out of blood vessels and engulf pathogens. Some can produce antibodies or antitoxins.
egg cell		To be fertilised by the sperm cell.	The cytoplasm contains nutrients for the developing embryo. The membrane changes after fertilisation to stop any more sperm getting in.

The Skeleton

The skeleton has several functions:

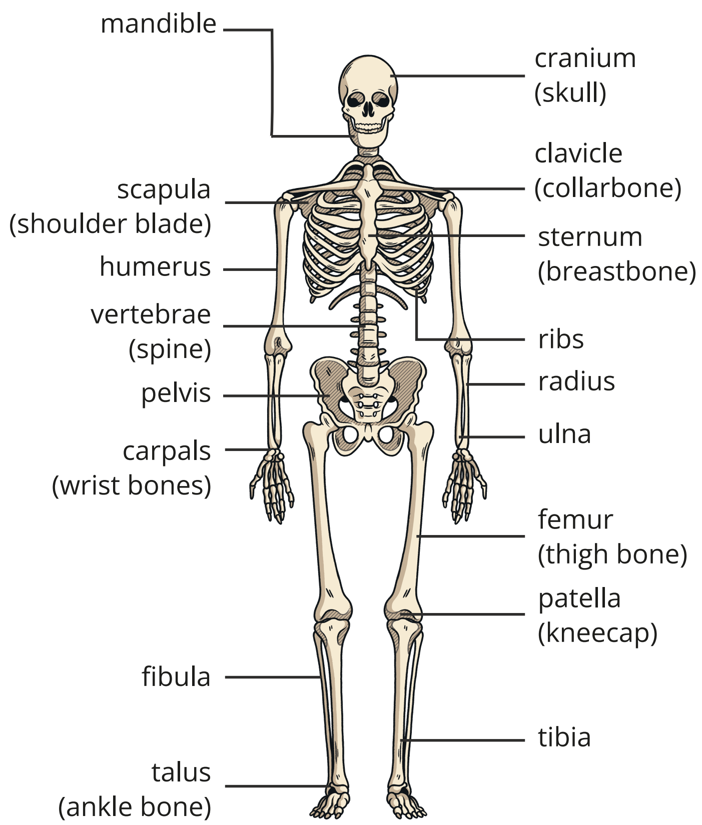
Support – The skeleton provides a frame to hold your body upright and keep your organs in place.

Protection - Bones are hard and strong to protect important organs such as the heart and the brain.

Movement - Your bones and muscles work together to allow your body to move.

Making blood cells – Some bones contain a soft tissue called bone marrow. Red blood cells and white blood cells are made in the bone marrow.

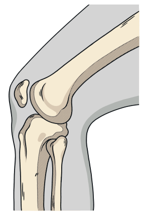
The adult body contains around 206 bones. Some are shown below:



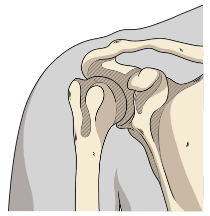
Joints

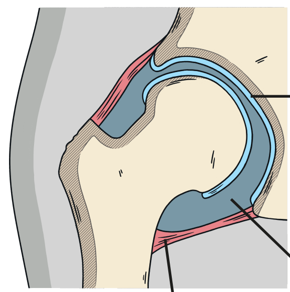
Joints are found where bones meet. Sometimes these joints are fixed but most joints are flexible to allow the body to move.

A **hinge joint** allows backwards and forwards movements. Knees and elbows are hinge joints.



A **ball and socket joint** allows movement in all directions. Shoulders and hips are ball and socket joints.





Cartilage is a strong, smooth tissue that covers the ends of the bones to protect them from damage.

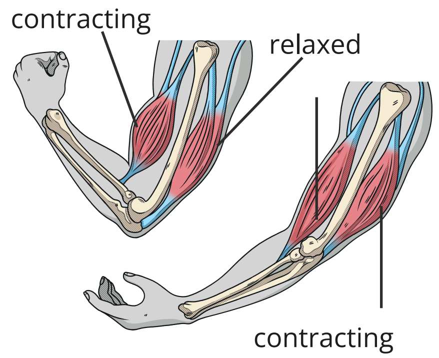
Ligaments hold the bones together.

Fluid in the joints keeps the cartilage slippery to reduce friction.

Muscles

Muscles can't push, they can only pull.

A pair of muscles that work together are called **antagonistic muscles.**

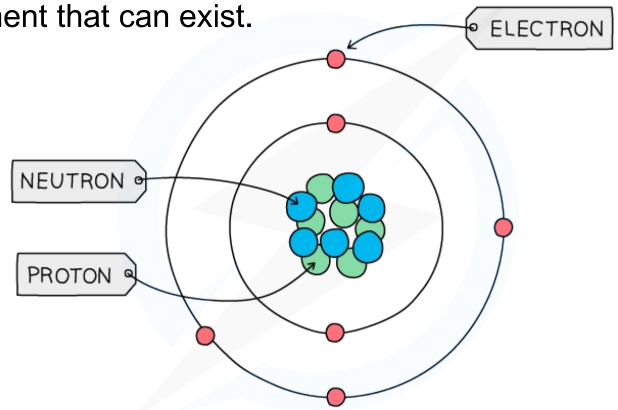


This combination of muscles, bones and joints making our bodies move is called **biomechanics.**

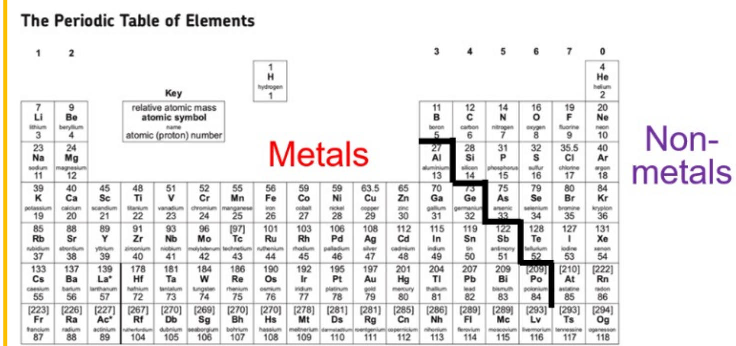
Elements and The Periodic Table

All substances are made up of **atoms**. Atoms include 3 different types of particles – **protons**, **neutrons** and **electrons**. An atom is the smallest part of an element that can exist.

Protons and neutrons are found in the nucleus of the atom (the centre). Electrons orbit around the nucleus.

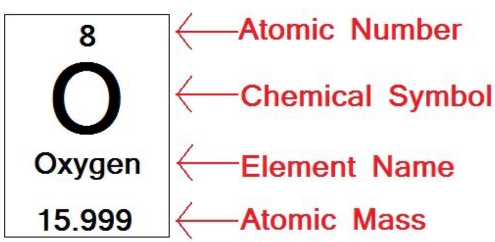


The **periodic table** gives important information about elements. The columns are the '**groups**'. The rows are called '**periods**'.

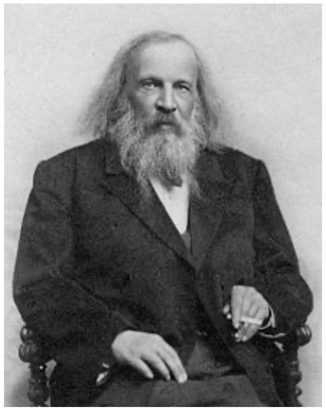


Elements are arranged in the periodic table based on their properties. A property is the characteristics of something.

Each element contains an atomic number (the number of protons), a chemical symbol, an element name and the atomic mass number (the mass of the element).



Mendeleev



Metals

Metals are found on the left-hand side of the periodic table (they are separated by a 'staircase line' as shown above). Properties of metals include:

- Shiny
- High density (feels heavy for its size)
- Strong
- Malleable (they bend without breaking)
- Good conductors of heat
- Good conductors of electricity (current passes through it).
- Some are magnetic (iron, cobalt, nickel)
- Sonorous (they make a ringing sound when they are hit)

<u>Development of the Periodic Table</u>

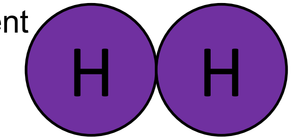
Dobereiner suggested the Law of Triads where he grouped together groups of 3 elements which shared similar properties.
Next, **Newlands** decided the order for the elements based on the element's atomic number. He found that every 8 elements had a repeating pattern. Some, however, did not fit this pattern.
Then **Mendeleev** decided to leave gaps for elements yet to be discovered.

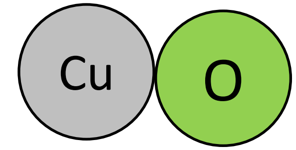
Compound – two or more elements chemically bonded together. This can be written as a <u>chemical formula</u> such as CO_2 or H_2O or CuO. This shows how many of each atom are in a compound.

Mixture – contains different substances that are not chemically joined together, for example, the air.

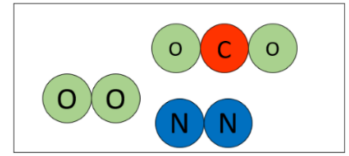
Element – one type of atom only, e.g. H_2

Element

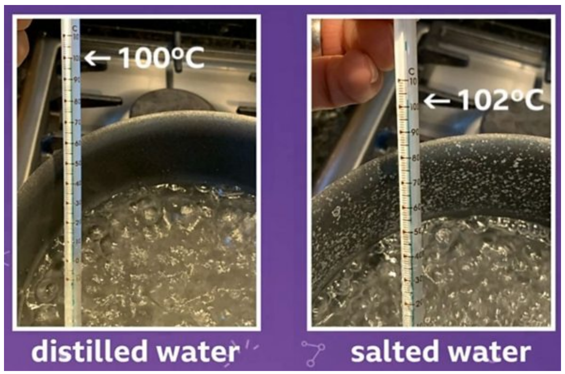




Compound

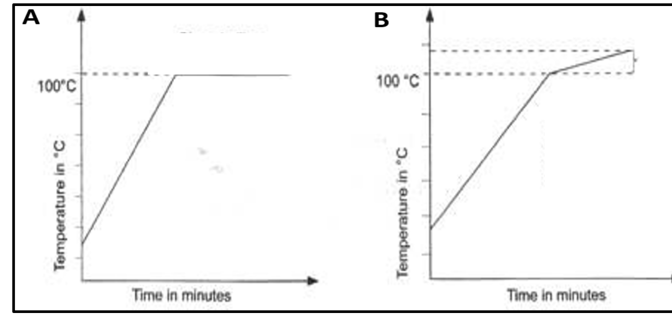


Mixture



A **pure substance** contains only one element or compound.

Pure compounds/elements have a fixed melting and boiling point – when they change state their temperature remains constant.



Impure compounds/ elements have a varying melting and boiling point – their temperature fluctuates as they change states. It is often higher than the pure boiling/ melting point.

Elements in the same group have similar properties. They also have trends/patterns as you go down the group.

Group 1 elements

Known as 'alkali metals'.

As you go down group 1, the metals get more reactive with water and air.

Lithium in water floats on the surface, sodium is a vigorous reaction and potassium burns with a lilac flame.

gp. 1 metal + water → metal hydroxide + hydrogen

lithium + water → lithium hydroxide + hydrogen

Group 1 elements can be used for fertilisers, cleaning products and batteries.

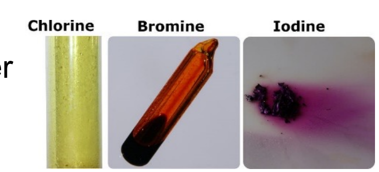
Group 7 elements

Known as 'halogens'.

As you go down group 7, the metals get less reactive with water and air.

As you go down group 7, the melting point and boiling point increase.

Group 7 elements can be used for toothpaste, sterilising water and making plastics.



Group 0 elements

Known as 'noble gases'.

Group 0 elements are not very reactive (inert).

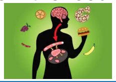
As you go down group0, the melting point and boiling point increase.

Group 7 elements can be used for balloons, fluorescent lights and lightbulbs.

Energy

1. Energy in food

Energy stored in food can be released by combustion (burning) or by respiration in our cells. The labels on packets of food show how much energy is available from the food. In some instances food energy is measured in kilojoules - mostly by the scientific community - though some food packaging also gives kilojoule (kJ) values. 1 kilocalorie = 4.2 kilojoules.



2. Energy stores and transfers

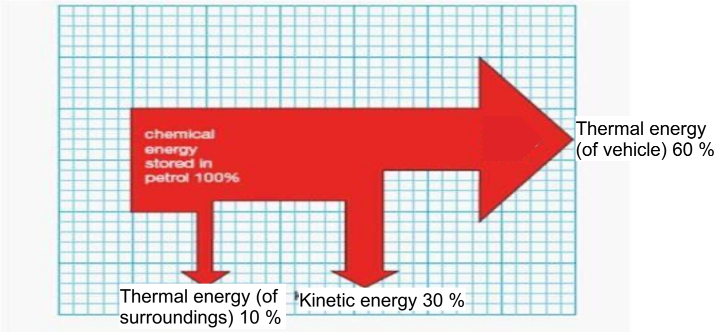
Energy Store	Definition
Kinetic energy	All moving things have kinetic energy. The amount of kinetic energy an object has depends upon: • the mass of the object • the speed of the object. 
Thermal energy	**Thermal energy** is energy possessed by an object or system due to the movement of particles. The faster the movement of the particles the greater the thermal energy and temperature.
Elastic potential energy	Some objects can change shape reversibly, e.g. rubber balls, springs and elastic bands. When a rubber ball is stretched or squashed, it can regain its shape again. Elastic potential energy is stored in stretched or squashed materials.
Gravitational potential energy	When an object is moved higher, it gains gravitational potential energy. The amount depends upon: • the mass of the object • the extra height it gains • the gravitational field strength (on Earth this is 9.81 m/s^2. it is often rounded to 10 m/s^2). 
Electrostatic	Some objects carry electrical charges and create electric fields. These charged objects can exert forces on each other. You get an electric current when charged particles move through a wire.
Magnetic	Some objects can be magnetised and create magnetic fields. They can exert forces on other magnetised objects, or on magnetic materials.
Chemical	The energy contained in a chemical substance, such as food, petrol or a battery.
Atomic	The energy contained in a nuclear substance, such as stars, nuclear weapons and fuel for nuclear power stations.

3. Heat and temperature

A thermometer is used to measure the temperature of an object
The temperature of an object is a measure of the average kinetic energy per particle of the object. It is measured in degrees Celsius. Note that the unit of temperature is written as °C, (not °c or oC).
All objects contain internal energy. Some of this is due to the movement of the particles in the object. When an object is heated, its particles move more vigorously and its internal energy increases. Unless the object changes state (e.g. melts or boils), its temperature will increase.

4. Conservation of energy.

Energy can be stored or transferred, but it cannot be created or destroyed. This means that the total energy of a system stays the same. Sankey diagrams show the conservation of energy and how energy stores empty and fill.



Sankey diagram for a petrol engine

The total amount of energy never changes, it just changes the type of store it is in.

Energy Transfer	Definition
Heating (by particles)	Energy is transferred from a hotter object to a cooler one. This can be done by conduction or convection.
Working Mechanically	Energy can be transferred mechanically through the movement of the parts in machines, and when the motion or position of an object changes. Sound waves and seismic waves (formed during earthquakes) are mechanical waves that transfer energy through materials and from place to place.
Working Electrically	Energy is transferred when an electrical circuit is complete.
Heating (by radiation)	Visible light, infrared light, microwaves and radio waves are forms of radiation. They are carried by waves (although unlike sound, these are not mechanical waves and can travel through empty space).

7. Power

Power is the rate at which energy is transferred.
The unit of power is the watt, which has the symbol W. 1 W is 1 J per second.

$$power\ (W) = \frac{energy\ (J)}{time\ (s)}$$

$$energy\ (kWh) = power\ (kW) \times time\ (h)$$

The cost of the energy used can be calculated: $cost = energy\ (in\ kWh) \times cost\ of\ 1\ kWh$

8. Work Done

By doing "work" you are transferring energy

$$work\ done\ (J) = force\ (N) \times distance\ (m)$$

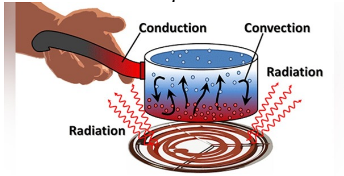
When a force causes a body to move, work is being done on the object by the force. Work is the measure of energy transfer when a force (*F*) moves an object through a distance (*d*).
So when work is done, energy has been transferred from one energy store to another, and so:
energy transferred = work done
Energy transferred and work done are both measured in joules (J).

4 & 5 Thermal equilibrium

If there is a difference in temperature between two objects, energy is transferred from the hotter object to the cooler one. This will continue until both objects are at the same temperature. When they are at the same temperature, we say that they are in thermal equilibrium, and there is no overall transfer of energy any more between the two objects.

Energy can be transferred from a hot object to a cooler one by:

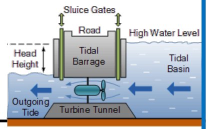
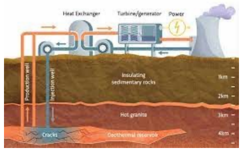
- conduction
- convection
- radiation



Type of heat transfer	Description	Useful information
Conduction (if the particles are in fixed positions)	When a substance is heated, its particles gain internal energy and move more vigorously. The particles bump into nearby particles and make them vibrate more. This passes internal energy through the substance by conduction, from the hot end to the cold end.	A substance that transfers energy easily from the hot part to the cold part is called a conductor. Metals are good conductors. A substance that does not transfer energy easily from the hot part to the cold part is called an insulator. Air and plastics are insulators.
Convection (if the particles are free to move)	The particles in liquids and gases can move from place to place. Convection happens when particles with a lot of thermal energy in a liquid or gas move, and take the place of particles with less thermal energy. Thermal energy is transferred from hot places to cold places by convection.	Convection cannot happen in a solid as the particles cannot move. Lava lamps work via convection; the cold lava with a greater density sinks in the water and the less dense, hotter lava rises.
Radiation	All objects transfer energy to their surroundings by infrared radiation. The hotter an object is, the more infrared radiation it gives off. No particles are involved in radiation, unlike conduction and convection.	Radiation is how we are warmed by the Sun, even though it is millions of kilometres away in space Infrared cameras give images even in the dark, because they are detecting infrared light, not visible light.

Energy is transferred from warm homes to the outside by: conduction through the walls, floor, roof and windows, and radiation from the walls, roof and windows. Insulation such as double glazing, carpets and reflective foil reduce the energy transferred.

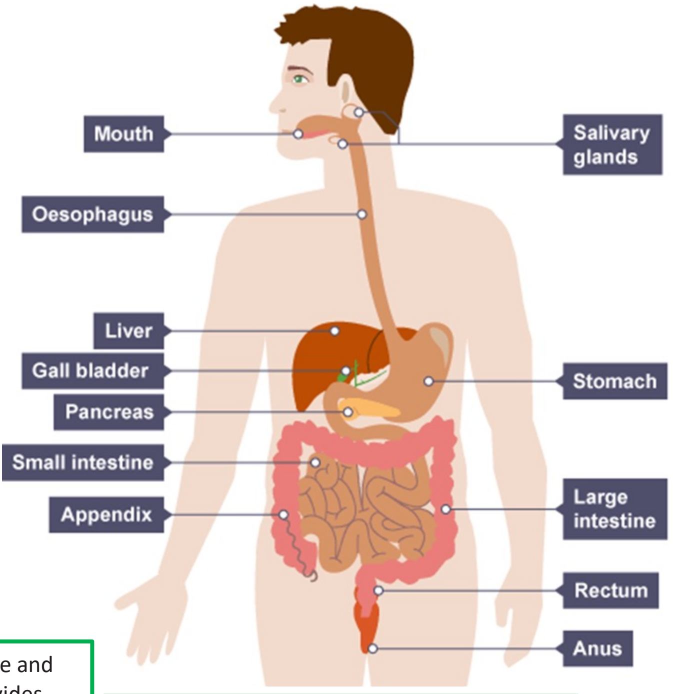
6. Energy resources

Power station	Fossil Fuel	Renewable	How do they generate electricity?	Positives	Negatives
Coal, Oil and Gas	Yes	No	Energy from the burning fuel is used to boil water. The steam turns turbines, and these turn electrical generators.	Relatively cheap Reliable Provide large amounts of energy.	Releases pollution, including: carbon dioxide, which is a greenhouse gas and increases climate change; sulphur dioxide and nitrogen oxides, which cause acid rain.
Nuclear 	No	No	The main nuclear fuels are uranium and plutonium. The energy released is used to boil water. Steam spins turbines, which then drive generators.	Nuclear fuels do not produce carbon dioxide or sulphur dioxide.	Large amounts of radioactive material could be released into the environment. Nuclear waste remains dangerously radioactive for thousands of years. It must be stored safely.
Wind Turbine	No	Yes	As the wind blows, it transfers some of its kinetic energy to the blades (turbine), which turn and drive the generator.	There are no fuel costs and no harmful polluting gases.	Noise pollution and visual pollution They are not reliable. The amount of electricity generated depends on the strength of the wind.
Wave generator	No	Yes	The water in the sea rises and falls because of waves on the surface. Wave machines use the kinetic energy in this movement to drive electricity generators.	There are no fuel costs and no harmful polluting gases are produced.	They are not reliable. The amount of electricity generated depends on the strength of the wind creating the waves. Difficult for wave machines to produce large amounts of electricity.
Tidal barrage	No	Yes	A tidal barrage is a barrier built over a river estuary to make use of the kinetic energy in the moving water. The barrage contains turbines inked to generators, which are turned by the water flowing through the barrage.	Very reliable and can be easily switched on. There are no fuel costs and no harmful polluting gases produced.	Tidal barrages destroy the habitats of estuary species, including wading birds. Only available for about 10 hours per day. 
Hydro-electric power	No	Yes	Hydroelectric power stations use the kinetic energy in moving water. The water high up behind the dam has a lot of gravitational potential energy. This is transferred to kinetic energy as the water rushes down through tubes inside the dam. The moving water rotates turbines which drive electrical generators.	Very reliable and can be easily switched on. There are no fuel costs and no harmful polluting gases are produced.	Dams flood farmland and push people from their homes. The rotting vegetation underwater releases methane, which is a greenhouse gas.
Geo-thermal	No	Yes	Some rocks contain radioactive substances such as uranium. These release energy, which warms up the rocks. Cold water pumped down. The water runs through cracks in the rocks and is heated up. It returns to the surface as hot water and steam. Here the steam can be used to turn turbines to drive generators.	There are no fuel costs and no harmful polluting gases are produced. The hot water and steam can be used to heat buildings directly.	Most parts of the world do not have suitable areas where geothermal energy can be exploited. 
Solar Cells 	No	Yes	Converts light energy directly into electrical energy. Some pocket calculators use solar cells, and you may have seen large panels of solar cells on house roofs.	There are no fuel costs and no harmful polluting gases are produced.	Solar cells are expensive and inefficient, so the cost of their electricity is high. Solar cells are not reliable as they do not work at night and not as well when it is cloudy.

Heath and the Human Body

Nutrient	Use in the body	Good sources
Carbohydrate	Source of chemical energy, (used in respiration).	Cereals, pasta, rice and potatoes
Protein	To provide materials to make new cells and to repair damaged tissues, such as muscles.	Fish, meat, eggs, beans, pulses and dairy products
Lipids (fats and oils)	To provide energy. Also to store energy in the body and insulate it against the cold.	Butter, oil and nuts
Minerals	These include iron, used to transport oxygen in the blood, and calcium, used in making bones and teeth.	Salt, milk (for calcium) and liver (for iron)
Vitamins	Used in many processes, e.g. vitamin K helps blood clot and vitamin C stops illness.	Fruit, vegetables, dairy foods
Dietary fibre	Helps to keep the food moving through the digestive system.	Vegetables and bran
Water	Keeps you hydrated, chemical reactions in cells take place in water and the blood transports substances dissolved in water.	Water, fruit juice, milk

People need a different amount of energy depending on factors such as: biological sex, age and your amount of daily activity (exercise). Food labels show how much energy the food provides.



The Digestive System

Imbalanced diets and deficiency diseases.

- Too little food can cause someone to be underweight and potentially cause starvation. This can eventually lead to death
- Too much food can cause someone to be overweight and potentially cause obesity. This causes an increase risk of other health issues such as heart disease, cancer, stroke.
- A balanced diet contains the right amount of all the nutrients needed for healthy growth. If you have too little of a nutrient, you have a **deficiency** in that nutrient.

Food sample	Name of test (Reagent)	Method	Initial colour	Colour of positive result
Glucose (sugar)	Benedict's	Add Benedict's reagent to the food and heat	Blue	Brick red precipitate
Starch	Iodine	Add iodine reagent to the food.	Yellow/ Brown	Blue-black
Protein	Biuret	Add Biuret reagent to the food.	Blue	Pink/purple
Fat	Ethanol	Add ethanol to the food to dissolve the fat then add water.	Colour-less	White emulsion

Enzymes are the **biological catalysts** needed to make this happen quickly enough to be useful.
Enzymes are not living things. They are special proteins that can break large molecules into small soluble molecules.
Different types of enzymes can break down different nutrients:

Food	Enzyme	Product
Starch	Carbohydrase	Glucose
Protein	Protease	Amino Acids
Fat	Lipase	Fatty Acids & Glycerol

Organ	Function
Mouth	Digestion of food starts in the mouth. Teeth break down the food and mix it with the enzymes in saliva.
Oesophagus	This is a thin tube that connects the mouth to the stomach.
Liver	This releases a chemical called bile into the intestines. Bile breaks down lipids in the food.
Stomach	This is a muscular bag which mixes food and drink with acid.
Pancreas	This releases enzymes into the intestines which break down carbohydrates, protein and lipids in food.
Small intestine	Here, carbohydrates, proteins and lipids digest. The nutrients produced are then absorbed into the blood.
Large intestine	Food which cannot be broken down - mainly fibre - passes into the large intestine. Water is absorbed into the blood.
Rectum	Any undigested food passes into the rectum where it is stored as faeces.
Anus	This is the opening at the very end of the digestive system through which faeces leaves the body.

A **drug** is a substance that has an effect on the body.

Drug	Type of Drug	Legality	Effects on behaviour	Effect on health
Alcohol	Depressant	Legal (for over-18s)	Slows thinking, reduces inhibitions.	Short term effects include hangovers, while long term effects include liver disease.
Caffeine	Stimulant	Legal	Alert, and if too much taken then nervousness and restlessness.	Too much causes lack of sleep.
Paracetamol	Painkiller	Legal	None	Reduces pain without addressing the cause.
Cocaine, MDMA, meth	Stimulant	Illegal	Feel euphoric, energetic, talkative, touch.	Anxiety, panic, seizures, headaches, stomach cramps, aggression and paranoia.
LSD, ketamine	Hallucinogens	Illegal	Change the way people see, hear, taste, smell or feel, and affect mood and thought.	Can cause flashbacks, depression and anxiety.

Smoking

Harmful Substance	Effect
Tar	Tar causes cancer of the lungs, mouth and throat. It coats the inside of the lungs, including the alveoli, causing coughing. It damages the alveoli, making it more difficult for gas exchange to happen.
Smoke	Cells in the lining of the trachea, bronchi and bronchioles produce sticky mucus. This traps dirt and microbes. Cells with tiny hair-like parts, called cilia then move the mucus out of the lungs. However, hot smoke and tar from smoking damages the cilia. As a result of this, smokers cough to move the mucus and are more likely to get bronchitis.
Nicotine	Nicotine is addictive. It causes a smoker to want more cigarettes. Nicotine also increases the heart rate and blood pressure, and makes blood vessels narrower than normal. This can lead to heart disease.
Carbon monoxide	Carbon monoxide is a gas that takes the place of oxygen in red blood cells. This reduces the amount of oxygen that the blood can carry. It means that the circulatory system has to work harder, causing heart disease.

The effects of smoking on an unborn baby.

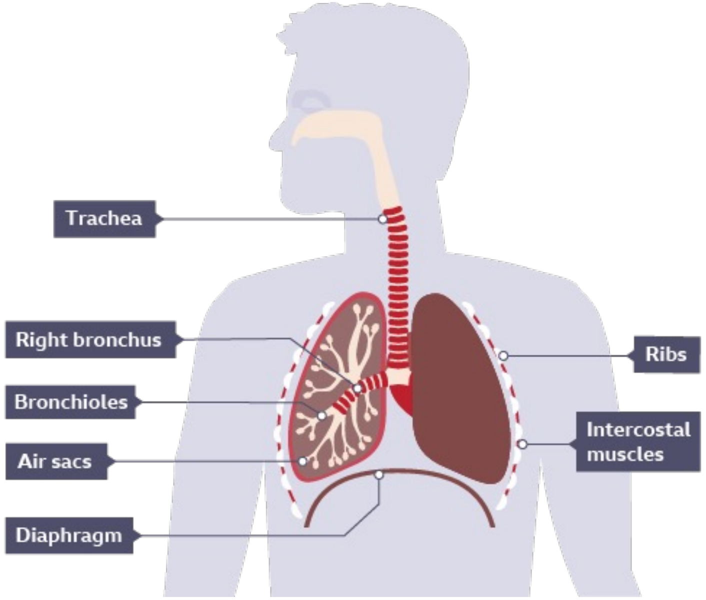
When a pregnant woman smokes, the chemicals diffuse into her bloodstream. That blood flows to the placenta and umbilical cord. The chemicals then diffuse into the foetus' blood. Carbon monoxide restricts the supply of oxygen that's essential for the foetus' healthy growth and development. Babies born to mothers that smoke, often have a lower birth weight, a greater risk of still birth and miscarriage.

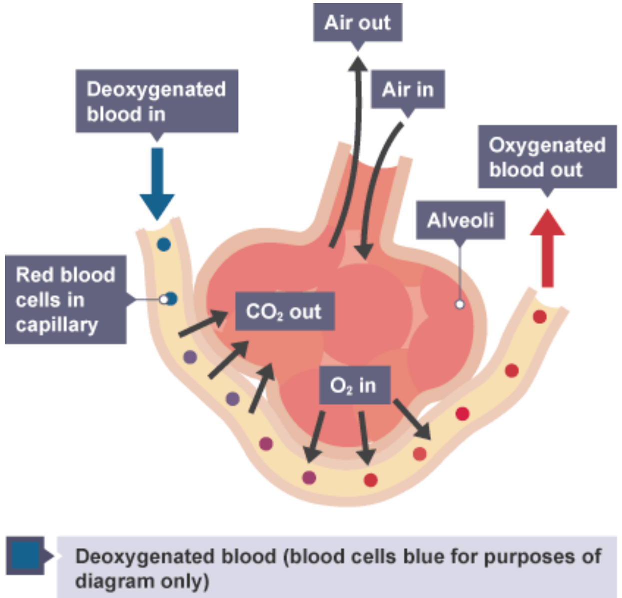
Gas exchange

Part of the gas exchange system	Function
Trachea	This is also called the windpipe. This tube runs from the mouth, down the throat towards the lungs. It is lined with rings of cartilage which keep it open at all times.
Bronchus	The trachea splits into a left and right bronchus (plural: bronchi), each leads to a lung.
Bronchiole	Each bronchus splits again and again into thousands of smaller tubes called bronchioles which take the air deeper into the lungs.
Alveoli	At the ends of bronchioles are tiny air sacs called alveoli. Here oxygen moves into the blood and carbon dioxide moves out.
Intercostal muscles	These muscles run between the ribs and form the chest wall. They contract and relax with the diaphragm when a person breathes.
Diaphragm	The diaphragm is a dome-shaped, flat sheet of muscle under the lungs. It contracts and relaxes with the intercostal muscles during breathing.

How are the alveoli adapted for gas exchange?

- Alveoli have a very **large surface area** to enable more diffusion of oxygen **into** the blood from the alveoli, and more carbon dioxide **out of** the blood into the alveoli.
- They are only one cell thick so that the diffusion distance is small.
- They have lots of blood **capillaries** to ensure a good blood supply to maintain concentration gradients of oxygen and carbon dioxide.
- They have moist surfaces for gases to dissolve in to form a solution to pass through the cell membrane.





Breathing

	Inhaling	Exhaling
Diaphragm	Contracts and moves downwards	Relaxes and moves upwards
Intercostal muscles	Contract, moving the ribs upwards and outwards	Relax, letting the ribs move downwards and inwards
Volume of ribcage	Increases	Decreases
Pressure inside the chest	Decreases below atmospheric pressure	Increases above atmospheric pressure
Movement of air	Moves into the lungs	Moves out of the lungs

Reactions

1. Chemical Reactions

- A chemical reaction results in a chemical change. The atoms of the reactants have either broken up or been combined to form a new product.
- Changes of state are a physical reaction because a new product has not been made.

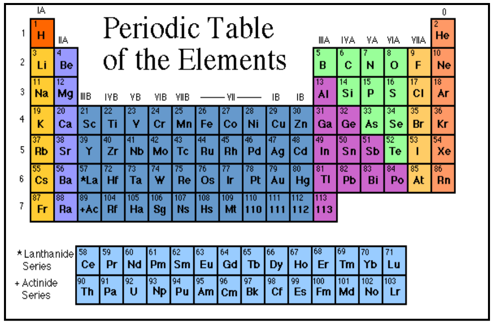
Physical change	Chemical change
No new substance formed	New substance formed
Can be reversed	Hard to reverse
Temporary	Permanent

2. Equations

$$CH_4 + O_2 \rightarrow CO_2 + 2H_2O$$

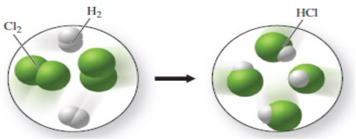
C=1		C=1
H=4	≠	H=4
O=2		O=4

- Elements are found in the periodic table represented by letters.
- Elements chemically combine together to form compounds.
- The name of reactants and products in a reaction are known as a word equation.
- The periodic table letters of the reactants and products are known as a symbol equation.

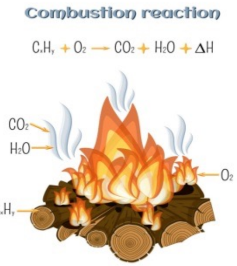


3. Conservation of Mass

- When a reaction takes place the mass stays the same. The mass of the reactants (starting substances) equals the mass of the products (what you end up with).



5-6. Types of Reaction



COMBUSTION

- Combustion is the chemical name for a fuel burning in oxygen.
- The products are carbon dioxide and water.

OXIDATION

- This is the addition of oxygen to a substance.

THERMAL DECOMPOSITION

- This is when a substance breaks down using heat only.

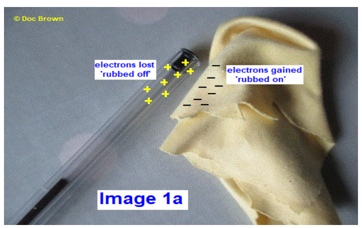
4. Endothermic and Exothermic reactions

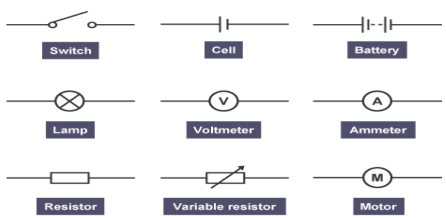
- **Endothermic** reactions transfer energy into the reaction (takes in).
- The reaction decreases in temperature.

- **Exothermic** reactions transfer energy out of the reaction (gives out).
- The reaction increases in temperature.

Electricity and Magnetism

Static electricity –All substances are made of **atoms**. These are often called particles. An atom is electrically neutral - has no overall electrical **charge**. When two objects are rubbed together, electrons are transferred from one object to the other. One object becomes positive and the other negative. A non-contact force exists between charged objects. Two charged objects will **repel** each other if they have like charges (they are both positive or both negative). Two charged objects will **attract** each other if they have opposite charges (one is positive and the other is negative).





We use **circuit symbols** to draw diagrams of electrical circuits, with straight lines to show the wires. The diagram shows some common circuit symbols.

Conductors and insulators of electricity

Different materials have different resistances:

- an electrical **conductor** has a low resistance
- an electrical **insulator** has a high resistance.

You can easily find out which materials are conductors and which are insulators using a simple circuit. You set up a series circuit with a cell, lamp and wires. Leave a gap in the circuit between two of the wires. Then connect the two wires using pieces of each material and see if the lamp lights up:

- it will light up if the material is a conductor
- it will not light up if the material is an insulator.

Electric current

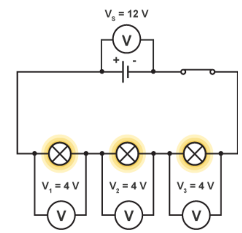
An **electric current** is a flow of charge, and in a wire this will be a flow of electrons. We need two things for an electric current to flow:

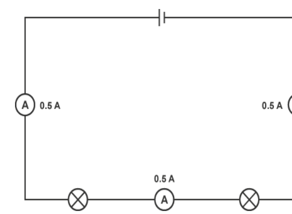
- something to transfer energy to the electrons, such as a cell, battery or power pack
- a complete path for the electrons to flow through (an electric **circuit**).

A simple complete circuit is a light bulb, a cell and two wires. To measure the current we have to add an ammeter to the circuit.

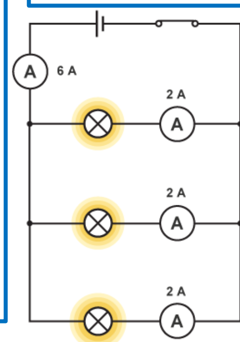
Potential difference is a measure of the difference in energy between two parts of a circuit. The bigger the difference in energy, the bigger the potential difference. Potential difference is measured in **volts**.
Potential difference is measured using a device called a **voltmeter.** However, unlike an ammeter, you must connect the voltmeter **in parallel** to measure the potential difference across a component in a circuit.

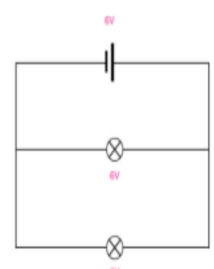
In **series circuits** the electrical components are connected one after the other. The current can take one path only.



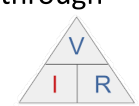


In a **parallel circuit** the components are connected in branches or in parallel so the current can pass through more than one path. Parallel circuits are used in house wiring.





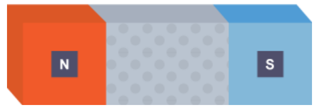
Resistance is a measure of how easy or difficult it is for charges to pass through a component in a circuit. The unit of **resistance** is the **ohm**, or Ω.
The resistance increases when you add more components in series. For example, the resistance of two lamps is greater than the resistance of one lamp, so less current will flow through them.
Resistance can be calculated:



$$potential\ difference = current \times resistance$$

Magnets

A bar magnet is a **permanent magnet**. A bar magnet has two magnetic poles: **north pole** (or north-seeking pole) and **south pole** (or south-seeking pole). Like poles attract, opposite poles repel.

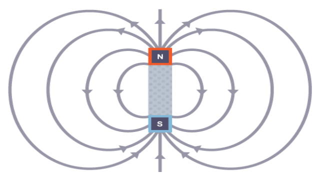


A magnetic material can be magnetised or will be attracted to a magnet.

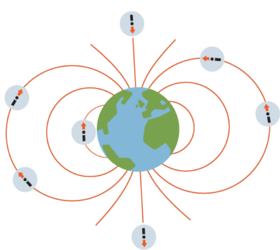
The magnetic elements are iron, cobalt and nickel. Steel is an alloy containing mainly iron, so it is also magnetic.

A magnet creates a **magnetic field** around it. You cannot see a magnetic field, but you can observe its effects. A force is exerted on a magnetic material brought into a magnetic field.

The force is a **non-contact force** because the magnet and the material do not have to touch each other.

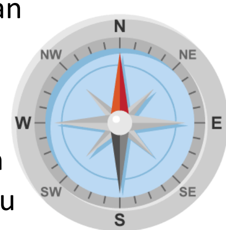


The magnetic field can be drawn around a magnet with the help of a **compass.**



The Earth behaves as if it contains a giant magnet. It produces a magnetic field in which the field lines are most concentrated at the poles. This magnetic field can be detected using magnetic materials or magnets.

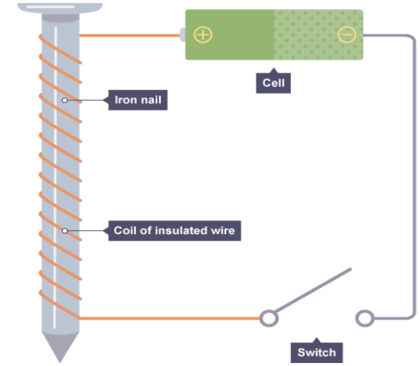
1. A compass is made from:
- a magnetic needle mounted on a pivot (so it can turn freely)
- a dial to show the direction.



2. The north pole (north-seeking pole) of the compass needle points towards the Earth's north pole. If the needle points to the N on the dial, you know that the compass is pointing north. This lets you navigate outdoors using a map.

Electromagnets

When an electric current flows in a wire, it creates a magnetic field around the wire. This effect can be used to make an **electromagnet**. A simple electromagnet comprises a length of wire turned into a coil and connected to a battery or power supply.



You can make an electromagnet stronger by doing these things:
- wrapping the coil around a piece of iron (such as an iron nail)
- adding more turns to the coil
- increasing the current flowing through the coil.

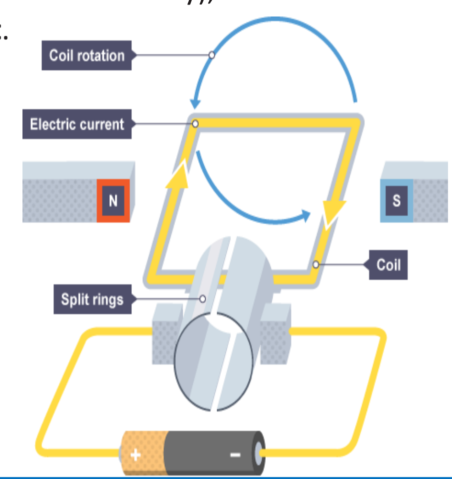
Electromagnets have some advantages over permanent magnets. For example:
- they can be turned on and off
- the strength of the magnetic field can be varied.

These properties make electromagnets useful for picking up scrap iron and steel in scrapyards.

DC motors

Electric motors use the forces produced by magnetic fields to produce a turning motion. If you put a length of wire in a magnetic field and pass a **DC current** through it (such as from a battery), the wire will move. This is called the **motor effect**.

To make a simple **DC motor**, you need:
- two bar magnets
- a coil of wire wrapped around something to support it
- an axle for the coil of wire to spin around
- two half rings ('split rings').



Reproduction

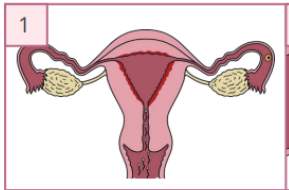
The Menstrual Cycle

Day	Description
1-5	The uterus lining breaks down and passes out of the vagina. This is known as menstruation or 'having a period'.
5-14	The uterus lining starts to build up again. An egg cell starts to mature in the ovary.
14	An egg cell is released from the ovary. This is called ovulation.
14-28	The uterus lining remains thick. During this time, the egg may be fertilised by a sperm cell.
28	If the egg cell is not fertilised by a sperm cell, the uterus lining begins to break down again and the cycle repeats.

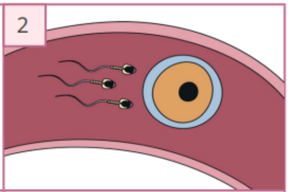
The **placenta** is attached to the foetus by the **umbilical cord. Smoking** cigarettes and drinking **alcohol** during pregnancy can increase the risk of miscarriage, stillbirth or sudden infant death syndrome (SIDS), premature birth, and/or have a low birthweight. They can also cause the baby to have problems with brain development which can result in learning difficulties and behavioural problems.

Puberty is a period of time in a person's life when they become sexually mature. Puberty causes physical and emotional changes that affect males and females differently. These changes happen because of **hormones.** Changes that affect both males and females: • growth of pubic hair • growth of underarm hair • growth spurts • acne or occasional pimples • body odour becomes stronger • mood changes • sexual thoughts and feelings.

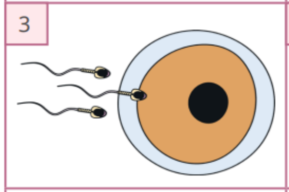
Fertilisation



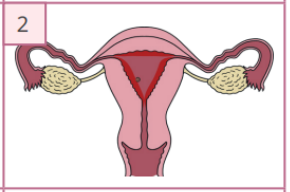
During sexual intercourse, semen containing sperm cells is ejaculated from the penis into the vagina.



Sperm cells travel through the female reproductive system to meet an egg cell in the oviduct.

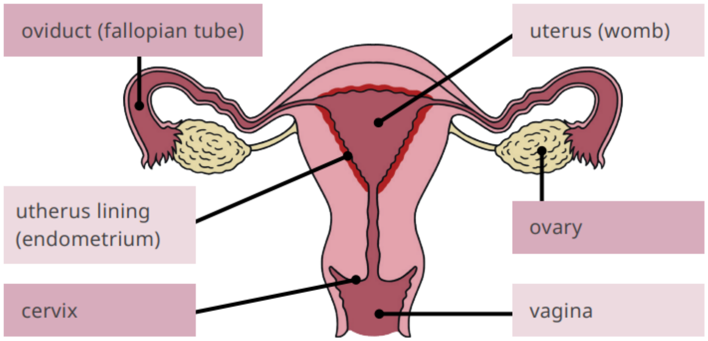


One sperm cell penetrates the egg cell membrane. The nucleus of the sperm cell fuses with the nucleus of the egg cell. This is called fertilisation.

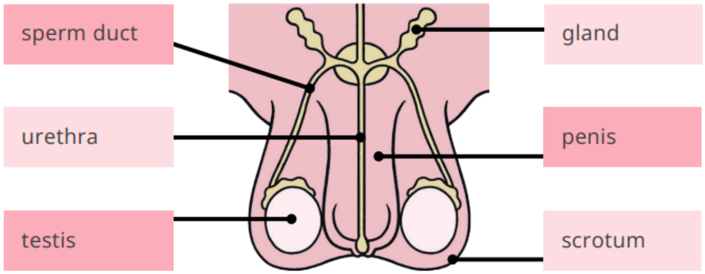


The resultant zygote divides several times to form a ball of cells called an embryo, which implants in the uterus lining.

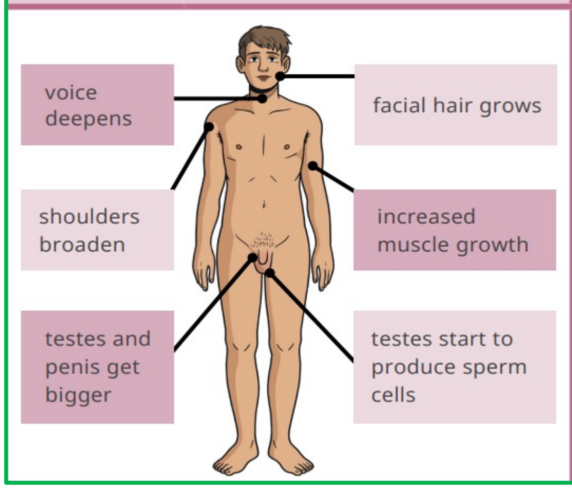
Female Reproductive System



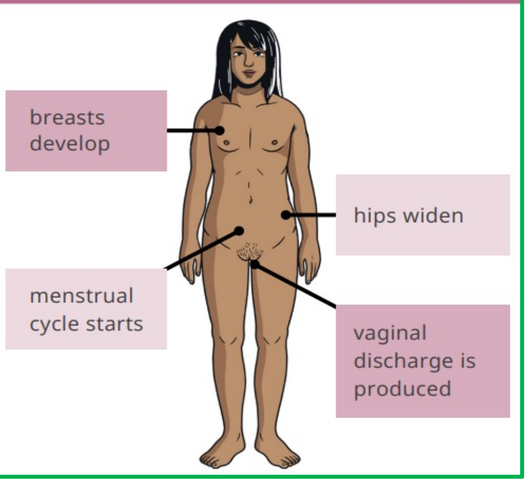
Male Reproductive System



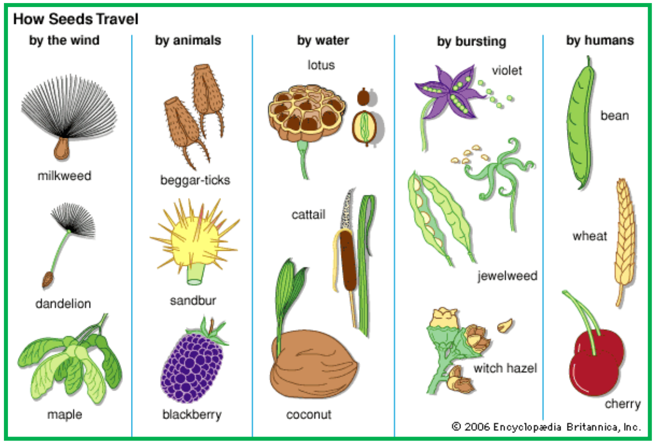
Puberty Changes in Males



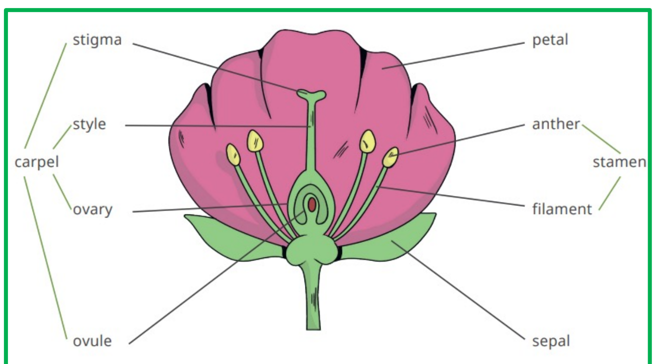
Puberty Changes in Females



Key word	Definition
Anther	Produces male sex cells (pollen).
Carpel	The female reproductive part of the flower, consisting of the ovary, ovule, style and stigma.
Filament	A stalk-like structure that supports the anther.
Ovary	Produces female sex cells (eggs).
Ovule	Develops into a seed after fertilisation.
Stamen	The male part of a flower consisting of an anther held up on a filament.
Stigma	The top of the female part of the flower, which is sticky, so pollen grains stick to it.
Style	The tube connecting the stigma to the ovary which pollen travels down.
Oviduct	Carries egg cells from the ovaries to the uterus.
Uterus	Where the baby develops during pregnancy.
Cervix	A ring of muscle at the lower end of the uterus. This keeps the baby in place during pregnancy.
Vagina	A muscular tube that leads from the cervix to the outside of the body.
Testis	Produces sperm cells and releases the male sex hormone testosterone.
Gland	Produces fluids that mix with sperm cells to make semen.
Urethra	Allows urine and semen to pass out of the male's body.



Pollination is where the pollen from one flower is transferred to the stigma of another. This can be done by wind or animals. The pollen then moves down the style to the ovary and the nucleus of the pollen fuses with the nucleus of the egg. This is **Fertilisation.** The flower then turns into a fruit.
When the fruit dies, the seeds inside it are released into the environment and a new plant will grow (**germinate**). The plant is adapted to **disperse** its seeds as far as possible from the parent plant so that the new plant is not competing for water and light with its parent.



Insect Pollinated Plants	Wind Pollinated Plants
They have bright petals with a sweet smell to attract insects.	No petals or small green/brown petals, as no need to attract insects.
The stigma and anther are inside the flower.	The anther hangs loosely out of the plant to make it easier for wind to blow it from the plant.
The stigma is sticky, so that pollen carried from the insects sticks to it.	The stigma hangs outside of the plant to make it easier to catch pollen on the wind.
Pollen grains are larger and can easily stick to insects, so fewer pollen grains need to be produced.	The stigma may be feathery or sticky to catch pollen blown by the wind.
The anthers are firm and rigid to allow the insects to brush against them.	They produce large amounts of pollen to increase the chances of it reaching another plant.
They often contain nectar, which is sweet and sugary to attract insects. Some bees use nectar to make honey.	Their pollen has a low mass so can be blown far on the wind.

Acids and Alkalis

Acids

- Acids are corrosive/harmful substances that taste sour.
- Common acids include citric acid, vinegar, fizzy drinks and stomach acid.
- Acids can be found at the bottom of the pH scale from the number 1 to 6.
- Strong acids are found at the bottom of the scale (1) and weak acids are found nearer the middle (6).
- Strong acids appear red, medium acids appear orange and weak acids appear yellow when universal indicator is added.

Indicators

- Indicators are chemicals that change colour when they come into contact with acids or alkalis.
- Liquid universal indicator can be used with lightly coloured liquids.
- Universal indicator paper gives slightly more accurate results and is less affected by the colour of the liquid.
- Strong acids appear red, medium acids appear orange and weak acids appear yellow.
- Strong alkalis appear purple, medium alkalis appear blue and weak alkalis appear dark green.

Neutralisation

- Acids and alkalis can neutralise each other when added in the correct quantities to produce water and a salt.
- Acids and alkalis are neutralised when the number of acid particles and the number of alkali particles in solution are equal.
- Neutral substances are neither acid or alkali and are found at pH 7.
- Water and salts are neutral substances.

Diluted means that the substance has been mixed with water.
Dilute acids/alkalis are harmful which could mean they cause irritation of skin or eyes.
Concentrated means that there is less water and more acid or alkali.
Concentrated acids/alkalis are corrosive and very dangerous with some able to destroy skin or even metal.

Harmful

Corrosive

The pH scale

Acids and bases/alkalis form each end of a linear scale called a pH scale which is marked from 0-14.
Neutral substance are found in the middle (7).

Alkalis

- Alkalis are corrosive/harmful substances that appear soapy to touch.
- Common alkalis include washing up liquid, toothpaste, washing powder and soap.
- Alkalis can be found at the top of the pH scale from 8-14.
- Strong alkalis can be found at the top of the scale (14) while weak alkalis are found near the middle (8).
- Strong alkalis appear purple, medium alkalis appear blue and weak alkalis appear dark green when universal indicator is added.

Reactions

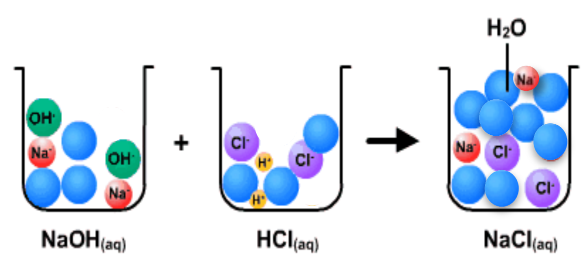
metal + acid → salt + hydrogen

acid + alkali → salt + water

- The name of the salt is created by combining the name of metal with the name of the acid:
  - nitric acid makes nitrate salts
  - hydrochloric acid makes chloride salts
  - sulphuric acid makes sulphate salts.

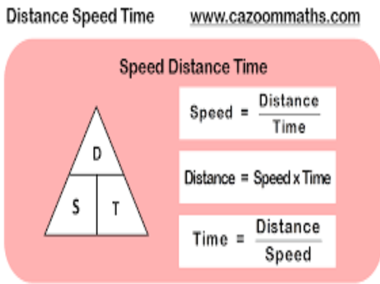
magnesium + nitric acid → magnesium nitrate + hydrogen

copper oxide + hydrochloric acid → copper chloride + water



Motion and Pressure

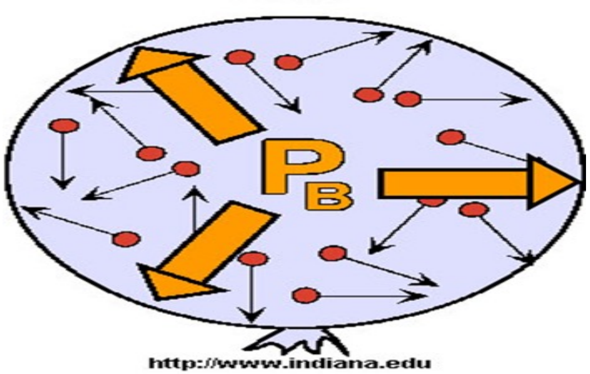
Speed is a measure of how **fast** something or somebody is moving. The units of speed are linked to the units of the **distance** and **time** being used.



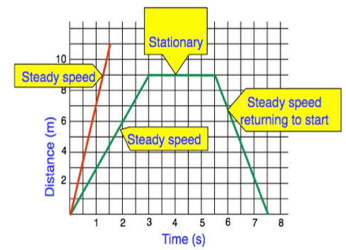
A **formula triangle** is a quick way to calculate the speed, distance or time.
The units are: m/s, km/h, mph (miles per hour).

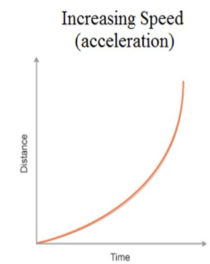
Gas Pressure is **caused by** the collisions between the atoms of **gas** and walls of the container as those atoms travel in the confined space. More molecules mean more collisions. Increasing the temperature of the gas leads to more kinetic energy of the particles and therefore to more pressure.
Also, pressure increases if the volume is decreased.
Pressure decreases with altitude. The higher up above the Earth, the less air particles there are therefore the lower the pressure.

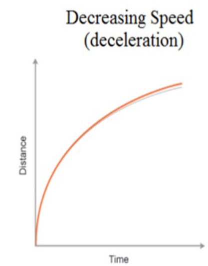
Figure 5.1.1 Internal pressure in a balloon.



Distance-time graphs.
If an object moves along a straight line, the **distance** travelled can be represented by a **distance-time graph**. In a **distance-time graph**, the gradient of the line is equal to the speed of the object. The greater the gradient (and the steeper the line) the faster the object is moving.
A curved distance time graph can show acceleration or deceleration.
To work out the speed of an object from a graph we have to work out the gradient.



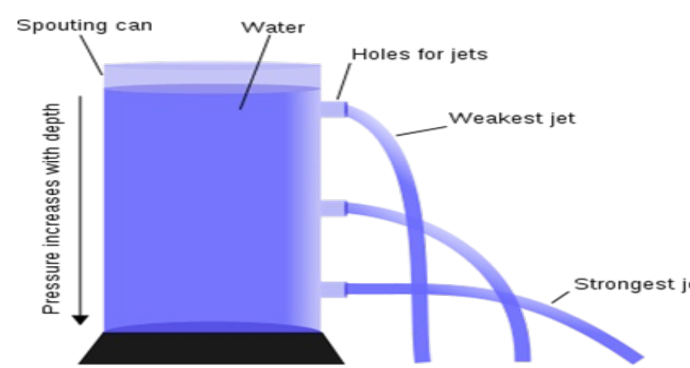




Pressure in liquids
Liquids exert pressure on objects. The pressure in liquids changes with depth. The deeper you go:

- the greater the weight of liquid above it
- the greater the liquid pressure.

Liquid pressure is exerted on the surface of an object in a liquid. This pressure causes **upthrust**. An object placed in a liquid will begin to sink. As it sinks, the liquid pressure on it increases and so the upthrust increases. For a floating object, the upthrust is equal and opposite to the object's weight. An object will continue to sink if its weight is greater than the maximum upthrust.



Pressure in solids

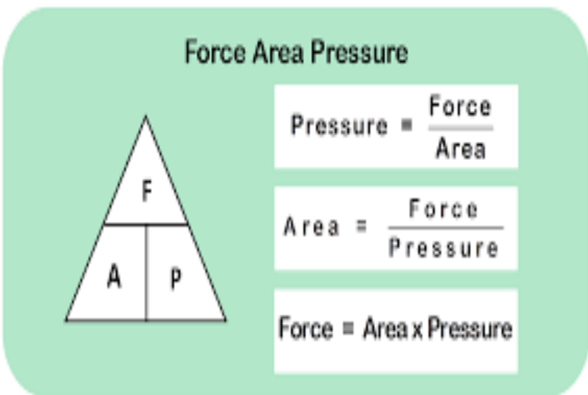
To calculate pressure, you need to know two things:

- the force or weight exerted
- the **surface area** over which the force or weight is spread.

Pressure is calculated using this equation:

$$pressure = \frac{force}{area}$$

Force Area Pressure



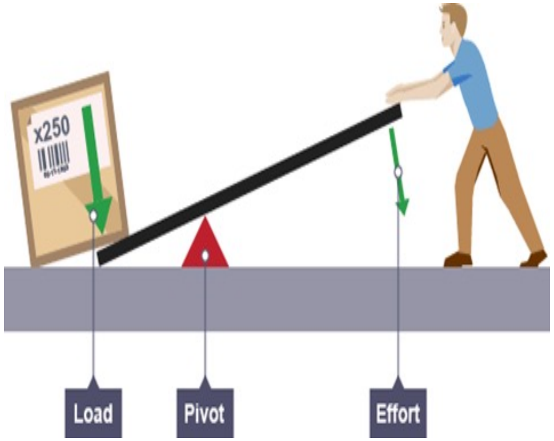
Using pressure

Snow shoes help to decrease the pressure so you don't sink into it. This is because show shoes have a large surface area.

A nail can be hammered easily into wood. This is because a large pressure can be applied over a small surface area.

Moments

A **moment** is a turning effect of a force. Forces can make objects turn if there is a **pivot**.



Calculating moments

To calculate a moment, you need to know two things:

- the distance from the pivot that the force is applied
- the size of the force applied.

$$moment = force \times distance$$

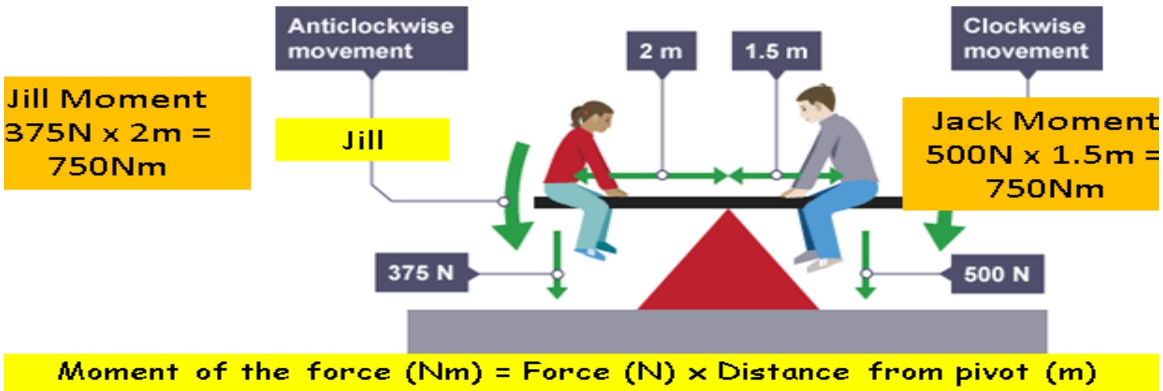
Law of moments.

When an object is balanced (in equilibrium) the sum of the clockwise **moments** is equal to the sum of the anticlockwise **moments**.

$$Force\ 1 \times distance\ from\ pivot = Force\ 2 \times distance\ from\ pivot$$

Is the see-saw balanced?

- Calculate the moments of Jack and Jill

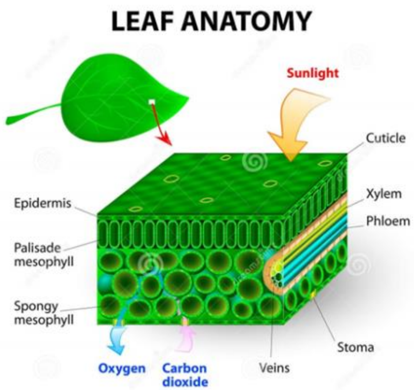


Photosynthesis & Respiration

Photosynthesis

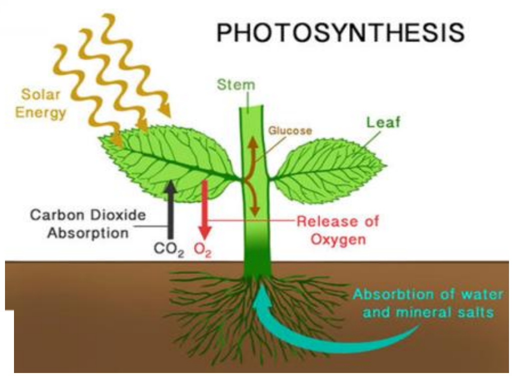
$$\textit{water} + \textit{carbon dioxide} \xrightarrow{\textit{light}} \textit{glucose} + \textit{oxygen}$$

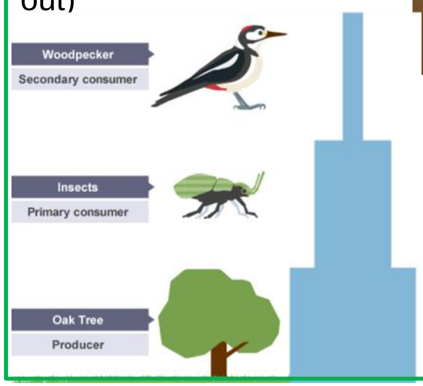
- leaves are wide and flat to create a large surface area to absorb sunlight; leaf cells contain lots of chloroplasts
- leaves are thin to allow gases to reach cells
- leaves have veins to carry water to the cells and glucose away from the cells
- leaves have stomata to allow gas exchange



Plants store their glucose as insoluble starch, fats or oils, sucrose (sugar in fruit) or cellulose (in cell walls); or use it for **respiration** to release energy to make other substances e.g. amino acids to make proteins.

A stoma is a small hole in the underside of the leaf. It allows gases to **diffuse** in and out. (CO_2 diffuses in, H_2O and O_2 diffuse out)





Almost all life on Earth depends on plants and algae to make glucose and other molecules. Plants are the start of all food chains and the source of all **biomass** (the living, or once living, mass of tissue)

Respiration

Aerobic respiration – in the presence of oxygen

$$\textit{oxygen} + \textit{glucose} \rightarrow \textit{water} + \textit{carbon dioxide}$$
$$(+\textit{energy})$$

- Respiration is the process of releasing energy from food (glucose)
- It occurs in mitochondria in cells.
- All species carry out respiration.
- During exercise, our muscles contract more, which requires more energy, so more respiration occurs.
- We breathe faster and deeper during exercise to absorb more oxygen and remove the extra water and carbon dioxide.
- Our heart beats faster during exercise to pump the blood containing oxygen and glucose to our working muscles.

Anaerobic respiration – no oxygen present; it is less efficient at releasing energy than aerobic respiration. In humans this happens during periods of intense, but brief exercise, like sprinting.

In humans

$$\textit{glucose} \rightarrow \textit{lactic acid} + \textit{energy}$$

The lactic acid builds up in our cells causing a burning sensation leaving an oxygen debt. The oxygen debt must be paid back to get rid of the lactic acid.

In micro-organisms (yeast)

$$\textit{glucose} \rightarrow \textit{alcohol} + \textit{carbon dioxide}$$

This is also called **fermentation**. It is used to make alcoholic drinks, and to make bread rise (the CO_2 forms bubbles in the bread to make it rise)

Materials

Metals and Acids

- Metals react with acids to produce a salt plus hydrogen.

Example -

metal + acid ➔ salt + hydrogen

- The name of the salt is created by combining the name of metal with the name of the acid.
- Nitric acid makes nitrate salts, hydrochloric acid makes chloride salts, and sulphuric acid makes sulphate salts.

Example -

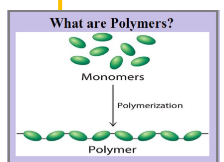
iron + sulphuric acid ➔ iron sulphate + hydrogen

$$Fe + H_2SO_4 \rightarrow FeSO_4 + H_2$$

- Hydrogen is a gas, this creates fizzing.
- Hydrogen creates a squeaky pop when ignited with a lit splint.

Polymers and composites

- Polymers are solids that are made of many small units or “monomers”.
- Common polymers include polyethene (used to make plastic bags), PVC (used to make water pipes), Nylon and Lycra (which can be used to make fabrics that stretch).
- Polymers are chemically unreactive solids at room temperature, can be moulded into shape, are electrical and thermal insulators and are strong and hardwearing.

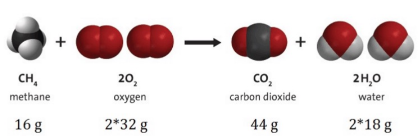


- Composites are materials that are made from two or more different types of material.
- Composites combine the properties of the materials they are made of to make stronger or more functional materials.
- Common composites include steel reinforced concrete, MDF, and fibreglass.

Conservation of Mass

- In a chemical reaction the number and type of element remains the same, but the atoms change positions.
- In a chemical reaction bonds are broken, and new bonds can be formed.
- The mass of the reactants and the mass of the products are always the same.

Example –



Ceramics

- Ceramics are solids made from baking material in a very hot oven
- They are very hard, tough, waterproof, have high melting points, are strong under compression, are unreactive and are electrical and thermal insulators
- Ceramics are often brittle so will break if dropped or bent
- Common ceramics are bricks, pottery, glass, porcelain, tiles and cement

Reactivity series

Potassium	most reactive ↑
Sodium	
Calcium	
Magnesium	
Aluminium	
Carbon	
Zinc	
Iron	
Tin	
Lead	
Hydrogen	
Copper	
Silver	
Gold	
Platinum	↓ least reactive

Metals and Oxygen

- An example of oxidation is when an element gains oxygen.
- Metals are normally found as ores where the metals have reacted with elements or compounds from the environment.
- Common ores are metal oxides where the metals have reacted with oxygen.

Example -

metal + oxygen ➔ metal oxide

magnesium + oxygen ➔ magnesium oxide

$$2Mg + O_2 \rightarrow 2MgO$$

Oxidation and reduction

- Carbon can be used to displace metals from their metal oxide.
- When carbon is used to extract metals from their ores it is called smelting.
- Carbon can only be used to extract metals that are lower on the reactivity series.

Example -

iron oxide + carbon ➔ iron + carbon dioxide

$$2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$$

- Oxidation is when an element gains oxygen.
- Reduction is when an element loses oxygen.
- The more reactive element will gain oxygen.
- The least reactive element will lose oxygen.
- Redox reactions are a type of displacement reaction where both oxidation and reduction occur in the same reaction.

Displacement

- A more reactive element will displace a less reactive element from its compound in a displacement reaction.

Example –

Less reactive

magnesium + copper (II) chloride ➔ magnesium chloride + copper

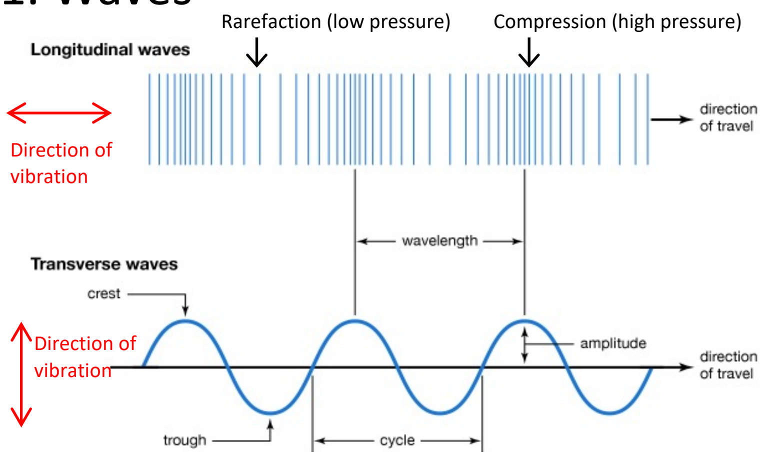
More reactive

$$Mg + CuCl_2 \rightarrow MgCl_2 + Cu$$

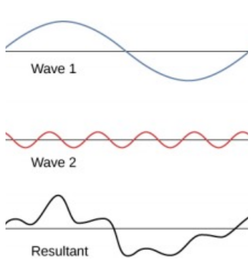
- Metals and non-metals can be arranged in order of reactivity.
- Non-metals; hydrogen and carbon are also part of the reactivity series.

Waves

1. Waves



There are two types of wave, **transverse and longitudinal**. Water and light waves are transverse, sound waves are longitudinal.



Superposition – waves can combine to create a new wave.

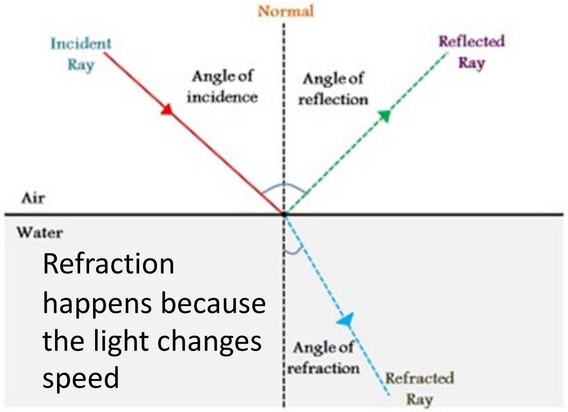
Mechanical waves need particles, e.g. sound.
Electromagnetic waves travel through a vacuum (no particles), e.g. light.

2. Properties of light

The speed of light is 300 000 000m/s.

Transparent materials transmit light through them.
Opaque materials absorb light.
Translucent materials transmit light through, but scatter it on the way, so only a hazy image is seen.

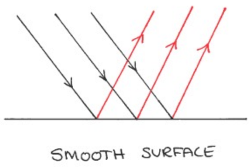
When light reaches a boundary it can be **absorbed, reflected or refracted**.

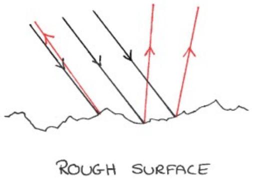


Refraction happens because the light changes speed

The Law of Reflection states that the angle of incidence is equal to the angle of reflection.

Specular reflection occurs at smooth surfaces. If parallel rays hit the surface they are all reflected in the same direction. An image is produced.



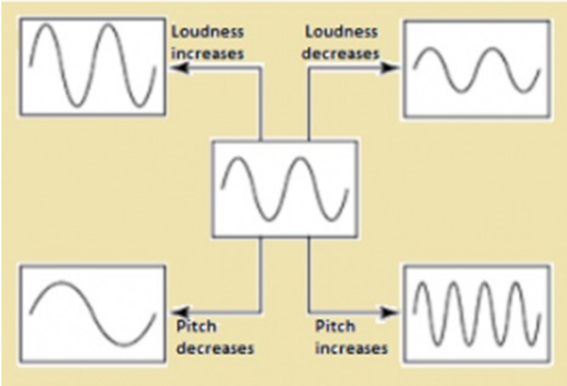


Diffuse reflection occurs at rough surfaces. If parallel rays hit the surface they are scattered in different directions. The Law of Reflection still applies, but the surface is at a different angle each time. No image is produced.

3. Properties of sound

The speed of sound in air is 340m/s.

The louder the sound, the bigger the amplitude of the wave.
The higher the pitch the higher the frequency (and so the shorter the wavelength) of the wave.



Frequency is measured in Hertz (Hz).

State of matter	Relative speed of sound
Solid	Very fast
Liquid	Medium
Gas	Slow
Vacuum	Stopped

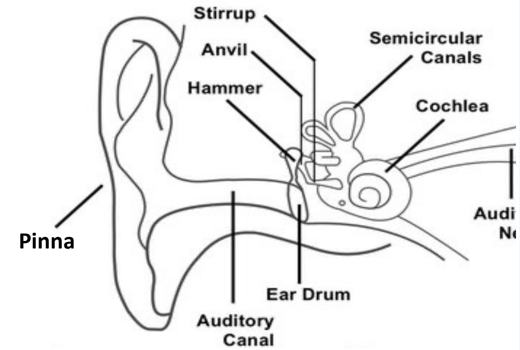
The **density** of a material affects the speed sound passes through it.
In a solid the particles are close-packed so vibrations travel fastest.

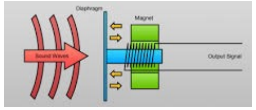
The speed of sound in a vacuum is 0m/s.

Waves

4. Hearing

The **pinna** funnels sound waves down the ear canal to the **ear drum**.
The changes in pressure cause the ear drum to vibrate. The vibrations are transmitted by the 3 small bones to the **cochlea**. This converts the sound to electrical signals to travel to the brain along the auditory nerve.

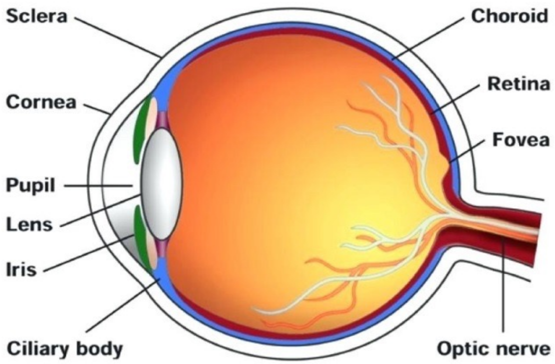


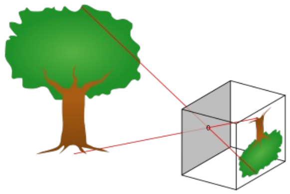


A microphone works in a similar way, with sound (pressure) waves causing the diaphragm to vibrate.

6. Vision

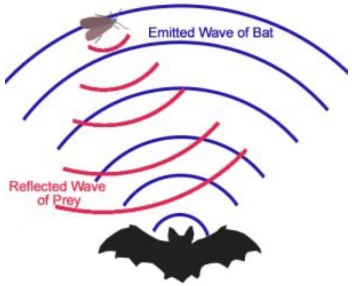
Light rays enter the eye through the **cornea** and then the pupil. The **iris** controls the size of the pupil (and the amount of light).
The cornea and the **lens** refract the light to focus it on the **retina** at the back of the eye.
The retina is a layer of light sensitive cells that convert the rays into electrical signals to travel along the optic nerve to the brain.





A pinhole camera works in a similar way, with rays entering through the pin hole and projecting onto the screen.

5. Ultrasound

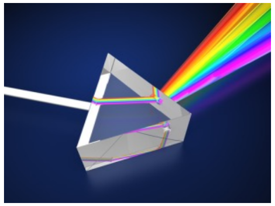


Ultrasound is sound waves of a **very** high frequency, above 20 000Hz.

Ultrasound and echolocation use the same principle.
Sound waves are reflected when the sound reaches a boundary or object. The distance the sound travels can be calculated.

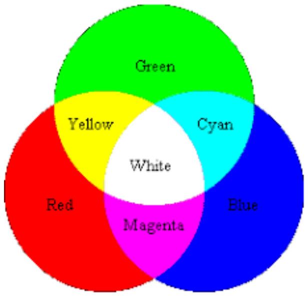
Ultrasound can be used in medical imaging (e.g. pre-natal scans of a foetus), in physiotherapy to treat injuries and in cleaning sensitive objects (e.g. the inside of watches).

7. Colour



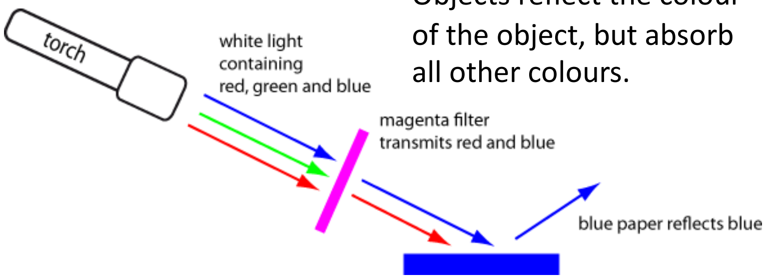
White light is made up of the 7 colours of the spectrum – red, orange, yellow, green, blue, indigo and violet.

There are 3 primary colours of light – red, blue and green.



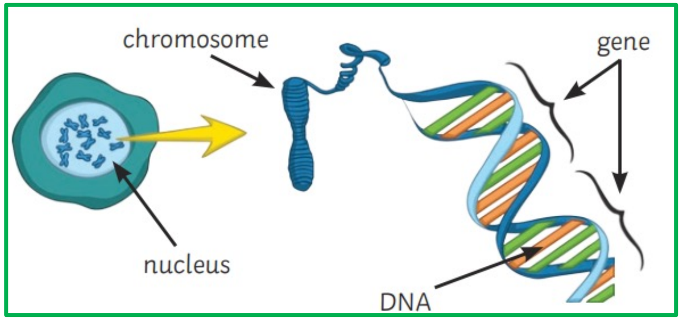
Filters transmit the colour of the filter, but absorb other colours.

Objects reflect the colour of the object, but absorb all other colours.



Inheritance & Evolution Knowledge Map

- **DNA** is the genetic code which makes up **genes**, which are responsible for giving an organism a specific characteristic.
- **Watson** and **Crick**, with help from **Franklin** and **Wilkins**, discovered the **double helix** structure of DNA in 1953.
- The sperm and the ovum (egg cell) each carry half of the **DNA** from the parent. These join together during **fertilisation** to form a new organism, with approximately half of the DNA from each parent. So there are almost always two copies of each gene. Pairs of genes for a characteristic are called **alleles**.



Genetic only	Environmental only	Genetic and environmental
Eye colour	Tattoos	Height
Blood group	Scars	Weight
Attached ear lobes	Language spoken	Human's hair colour - can lighten in summer or can be dyed
Animal's fur colour	Colour of hydrangea flower - blue in acid soil, pink in alkaline	Size of plant

- A **species** is a group of organisms that interbreed to produce fertile offspring.
- We can **classify** species into groups of increasing specificity.

Linnaeus's system of classification

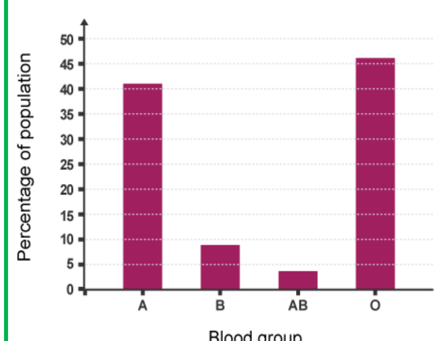
Kingdom → Phylum → Class → Order → Family → Genus → Species

- Scientists things to make it easier to study them. It helps to make sense of the world as well as to understand how different groups of living organisms are related to each other.

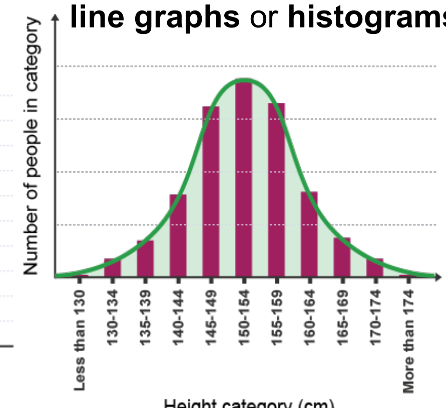
Variation

- The differences in characteristics between individuals of the same is called **variation**.
- Some variation is passed on in DNA from parents. This is **inherited** variation.
- Some variation is the result of differences in the surroundings, or what an individual does. This is called **environmental** variation.
- Surveys into variation give data that are **continuous**, which means to come in a range, or **categoric**, which means to come in groups.

Categoric variation e.g. blood group is displayed in a **bar chart.**



Continuous variation e.g. human height is displayed in **line graphs** or **histograms**



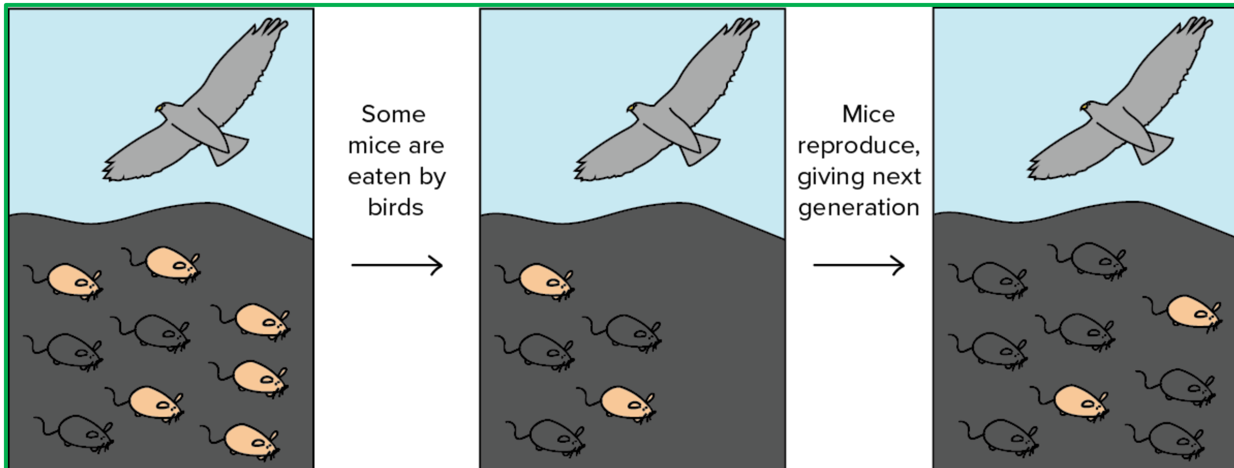
Inheritance & Evolution Knowledge Map

Extinction is where all members of a species have died. Extinction can be caused by different elements including **catastrophic events, disease, predators, climate change, and competition**.

The steps in evolution:

1. In every population there is **variation**, some of which is inherited.
2. Individual organisms with the best **adaptations** are most likely to survive and reproduce. This is **natural selection.**
3. **Inheritance** means these adaptations are likely to be passed to offspring.
4. It also means that less well adapted organisms are less likely to pass on their adaptations.
5. Over **many generations** these small differences add up to the formation of new species by **evolution.**

Variation can be caused by small changes in DNA called **mutations.** Most of these have no effect, some are advantageous and some are disadvantageous.



A population of mice has moved into a new area where the rocks are very dark. Due to natural genetic variation, some mice are black, while others are tan.

Tan mice are more visible to predatory birds than black mice. Thus, tan mice are eaten at higher frequency than black mice. Only the surviving mice reach reproductive age and leave offspring.

Because black mice had a higher chance of leaving offspring than tan mice, the next generation contains a higher fraction of black mice than the previous generation.

Biodiversity is a measure of the range of living organisms within a habitat.

A **gene pool** is the range of DNA in a species.

Biodiversity can be maintained by conservation, preservation and gene banks.

n a seed bank on the remote Svalbard Island off the cost of Norway, seeds from around one million different plants are stored at -18°C.

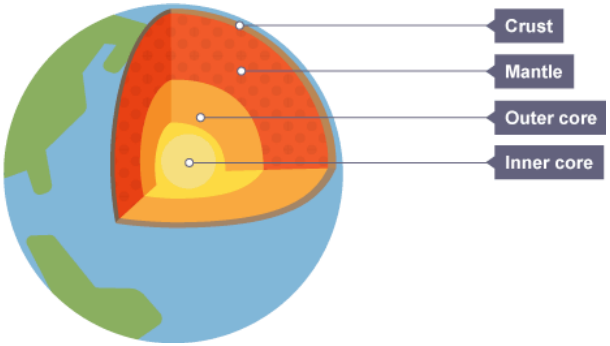
Seed banks are an example of a gene bank. Gene banks are used to preserve genetic material for use in the future.

Some species have become extinct in the wild and now only live in zoos, or their numbers have greatly reduced.

Earth & Atmosphere

Earth's Structure

The Earth is a planet and is roughly the shape of a sphere. There are three layers that make up the Earth's structure.

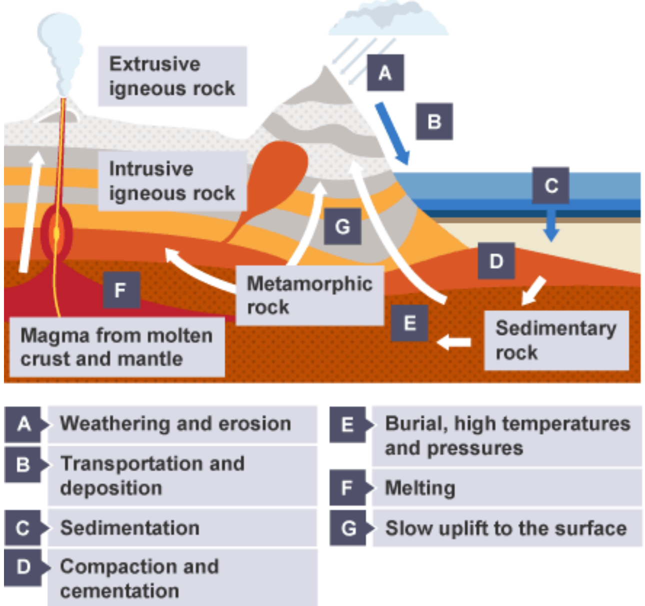


The three layers, starting from the outside, are:

- the **crust** – the rocky outer layer. The crust is made of huge pieces of land called tectonic plates which fit together like a huge jigsaw. These plates move around because they are floating on the mantle below them, and this moves very slowly. The tectonic plates only move a few centimetres each year.

- the **mantle** – the mantle is a semi-solid layer below the crust. The mantle is the thickest layer of the Earth and is made of semi-solid rock that moves very slowly, like a liquid. The tectonic plates float on top of the mantle, meaning the tectonic plates and the mantle move at the same time.

- the **core** - the innermost layer which is divided into an inner core and outer core. The core is made of iron, with a smaller amount of nickel. The inner core is solid and the outer core is liquid. The two metals in the core, iron and nickel, are both magnetic. This is what gives the Earth its **magnetic field**, including the north and south poles.



Weathering & Erosion

Weathering breaks down rocks on the surface of the Earth. There are **three** types of weathering.

1. Biological weathering: this describes rocks being broken up by the roots of plants, or animals burrowing into them.

2. Chemical weathering: this describes rocks being broken up because substances in rainwater, rivers and seawater or the air, react with minerals in the rocks.

3. Physical weathering: this describes rocks being broken up by changes in temperature, freezing and thawing of trapped water or the action of waves and rivers.

Erosion is the process of moving the small pieces of rock formed by weathering. Erosion occurs from the action of water or wind.

Sedimentary rocks are formed by small rock pieces which are transported by rivers and deposited at the bottom of oceans. The grains are arranged in layers. The oldest layers are at the bottom and the youngest layers are at the top.
There are **five** processes that make a sedimentary rock:
transport → deposition → sedimentation → compaction → cementation

Stage	Process	Definition
1	**Sediment transport**	Sediment transport is the first all of the processes by which the sediment is formed. For example, small pebbles of rock are rolled along a river-bed.
2	**Deposition**	In deposition, sediment carried in transport is laid down.
3	**Sedimentation**	Layers of sediment form on top of each other in sedimentation.
4	**Compaction**	As more and more layers build up, the weight of the layers on top compacts the layers below.
5	**Cementation**	In the final process of sedimentary rock formation, some of the minerals in the sediment harden and form a kind of cement which sticks the grains of the rock together.

The Rock Cycle

Rocks are continually changing due to processes such as weathering, erosion and large earth movements. The rocks are gradually recycled over millions of years, changing between the different rock types. The three rock types are:

- **igneous** - formed from the cooling of molten rock
- **sedimentary** - formed by small rock pieces being transported in rivers and laid down in layers
- **metamorphic** - formed from another rock under heat and pressure

This recycling of rocks is a process called **the rock cycle.**

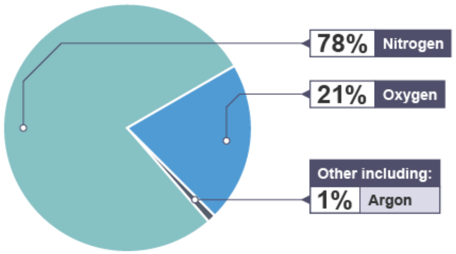
Igneous rocks are formed from molten (liquid) rock that has cooled and solidified. The inside of the Earth is so hot that rocks deep underground are often liquid. **Molten** (liquid) rock underground is called **magma**. Volcanoes can bring molten rock to the surface, which we call **lava**. When the molten rock cools, it turns into a solid and igneous rock forms.
Igneous rocks contain randomly arranged interlocking **crystals**. The size of the crystals depends on how quickly the molten magma solidifies. If the lava cools on the outside of the volcano, it will cool quickly and there won't be time for large crystals to form. This is called **extrusive** igneous rock and it has small crystals. If the lava cools inside the volcano where it is hotter, it will cool slowly and there will be time for larger crystals to form. This is called **intrusive** igneous rock.

Metamorphic rocks are formed from other rocks which change due to **heat** or **pressure**. The original rocks are usually sedimentary rocks or igneous rocks. Sometimes one metamorphic rock can be turned into a different metamorphic rock.
There are three stages involved in the formation of metamorphic rocks:
1. Earth movements cause rocks to be deeply buried or compressed.
2. This causes the rocks to be heated and puts them under great pressure.
3. They do not melt, but the minerals they contain are changed chemically, and form metamorphic rocks.

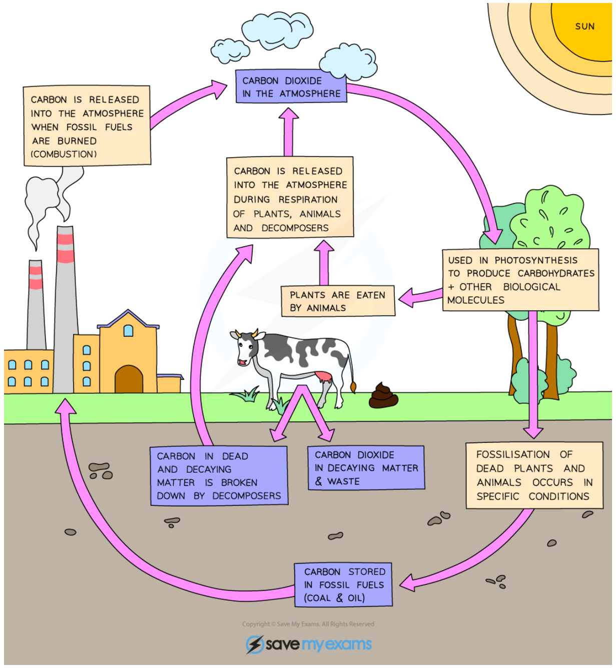
Recycling
Humans extract many resources from the Earth that can then be turned into useful substances or products.
Resources are extracted from the air (atmosphere), water and land. Some resources are **finite** (this means their supply is limited and they will eventually run out).
However, others are **renewable** (which means they can be replaced).
Recycling is one way that we can reduce the amount of finite resources being extracted from the Earth.

The atmosphere
The Earth's atmosphere is the relatively thin layer of gases surrounding the planet. The atmosphere is held close to Earth by gravity, but the higher you go away from the Earth's surface, the thinner the air. Because of this, it's impossible to say how high the atmosphere extends above Earth accurately. However, most scientists use around 100 km when describing where the atmosphere ends and space begins.
The three gases with the highest percentages in the atmosphere are all elements:
- 78% nitrogen, N_2
- 21% oxygen, O_2
- 0.9% argon, Ar.

These three gases make up 99.9% of the atmosphere.
The remaining gases are found in much smaller proportions. These include carbon dioxide and water vapour.



Climate Change
Carbon dioxide makes up less than 1% of the atmosphere; however, it is an important **greenhouse gas.** This means that its molecules in the atmosphere absorb heat radiation, keeping the Earth warmer than it would otherwise be. For the past 100 or so years, carbon dioxide has been added to the atmosphere by human activity more quickly than it is removed. The extra carbon dioxide contributes towards **climate change**, including more frequent droughts and stronger storms.



Carbon Cycle: Carbon is one of the most important elements for life. It is cycled around the environment in a variety of processes as shown in the diagram above and the table below.

Process	What happens to carbon
Combustion	CO_2 is released to the atmosphere when fuel is burned.
Respiration	All organisms release CO_2 as a waste product when energy is released.
Photosynthesis	Plants absorb CO_2 to convert it into glucose in photosynthesis.
Feeding	Carbon in the prey biomass is digested by the predator.
Excretion	Carbon is lost in urine and faeces.
Decomposition	Microbes release CO_2 during respiration when they feed on dead organic matter. They also return mineral ions to the soil.

Space

1: The Earth

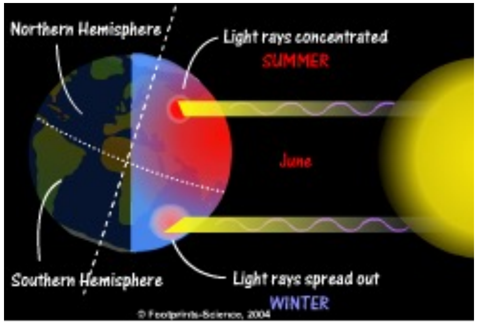
What is a day? A day is **24 hours** long. This is because it takes 24 hours for the Earth to spin once on its axis. The half of the Earth facing the Sun is in daylight. The half facing away from the Sun has no sunlight and so becomes night-time.

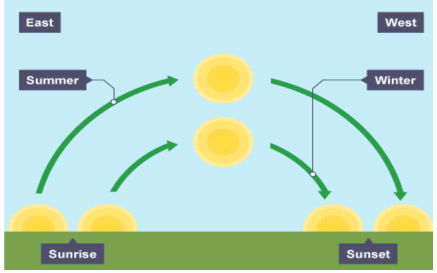
What is a year? A year is how long it takes to travel once around the Sun. This takes 365 days.

What are the seasons?

The Earth's axis is tilted as it travels around the Sun, so some parts of the Earth receive more sunlight each day than others. This changes during the year because the Earth moves about the Sun, which gives rise to the seasons.

The UK is in the top half (**northern hemisphere**) of the Earth. When the northern hemisphere is tilted towards the Sun it is summer and when tilted away it is winter. In Spring, the temperature and day length become longer. In Autumn, they are shorter.





The Sun appears to move from east to west. This is because the Earth turns from west to east.

The Sun appears to rise in the east, set in the west and be due south at midday.

2: The Solar System

The solar system consists of the Sun, with planets and smaller objects such as asteroids and comets in orbit around it.

There are eight planets in the Solar System. Starting with Mercury, which is the closest to the Sun.

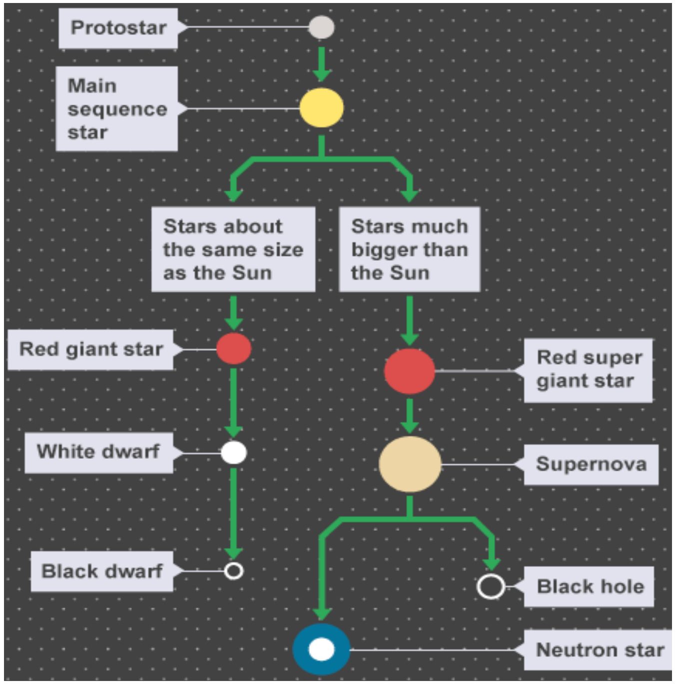
This sentence is a way to remember the correct order: My Very Easy Method Just Speeds Up Naming (Planets).

The distances between objects in space are huge. This means that the numbers used to describe distances in space become very difficult to understand and to write down. To get around this problem, scientists use the **light year** the unit of astronomical distance. It is the distance travelled by light in one year. So, for example: the distance from the Sun to next closest star is about 4.24 light years. It takes light from our Sun about 8 minutes to reach the Earth, so it is 8 light minutes away.

3: The formation and life cycle of stars

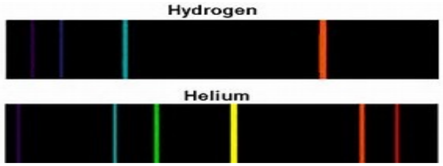
Our Sun is a star, however it is just one of billions. All stars begin the same way, formed from clouds of gas and dust called **nebula,** however how they die depends on their size. The diagram shows the life cycles of stars that are:

- about the same size as the Sun
- far greater than the Sun in size.



How can we tell what stars are made of?

Each element absorbs light at specific wavelengths unique to that atom. When astronomers look at an object's spectrum, they can determine its composition based on these wavelengths. The most common method astronomers use to determine the composition of stars, planets, and other objects is spectroscopy.



The emission spectrums for hydrogen and helium are emitted from main sequence stars.

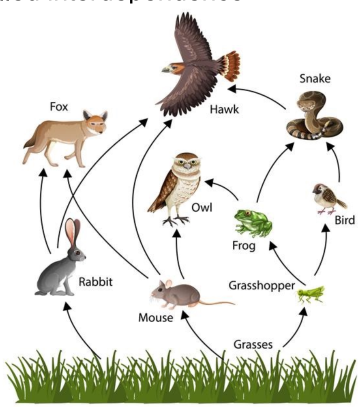
Ecosystems & Interdependence

Food webs

The source of all energy in a food web is the Sun's radiation. It is made useful by plants and algae which make glucose and then other compounds by photosynthesis. This is why plants (producers) are always at the start of a food chain.

The arrow in a food chain/web indicates the direction of the flow of energy.

Species in a food web rely on other species for food. If the number of one species in a food web changes, there will be knock on effects for all other species in the web. This is called interdependence.



Competition

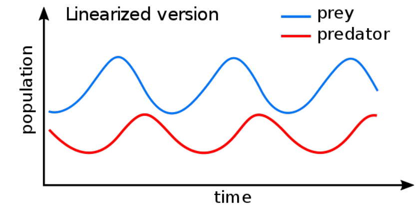
Species will compete with one another (interspecific competition) and also within their own species (intraspecific competition) to survive and reproduce.

Animals compete for resources like food, water, and space/shelter. They may also compete within their species for mates.

Plants compete for light, water, space and minerals. These are needed for photosynthesis.

Predator Prey Cycles

Populations of predators and prey increase and decrease over time in cycles. The size of the predator population depends on the size of the prey population and vice versa.

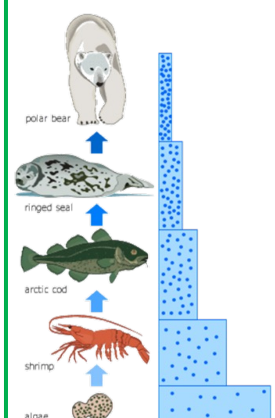


Adaptation

Adaptations are specific features of an organism that help it to survive and reproduce in the conditions of their habitat, e.g.

Animals in a hot climate may have:
- Thin fur
- Produce little urine
- Large surface area : volume
- Active at dawn/dusk when it's cooler

Plants in dry climates may have:
- Deep roots
- Thick waxy cuticle
- Store water
- Spines instead of leaves to reduce surface area



Bioaccumulation

Some toxins (e.g. mercury, or some insecticides like DDT) are **persistent**. This means they do not break down in living tissue.

These toxins can enter a food chain by being absorbed by a plant or eaten by an animal. Low levels of toxins may not kill the organism that ingests it.
Bioaccumulation means that the higher up the food chain the more concentrated the toxins become; it is often the organism at the top of the chain that succumbs to the toxin.

Food Security

Food security is the ability of all people to be able to access nutritious food. A large proportion of the crops humans eat rely on insect pollinators like bees in order to reproduce. Bee populations are under threat from insecticides, loss of habitat and disease. It is important that we protect bees in order to protect our food security.

Sampling

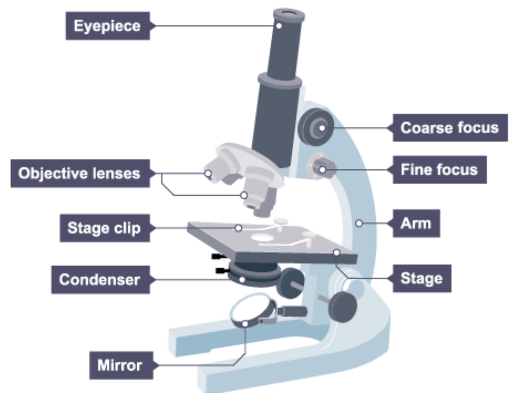
The **distribution** of an organism (where it is found) is affected by living (**biotic**) and non-living (**abiotic**) factors. Quadrats are $1m^2$ square frames that can be used to estimate population sizes. You count the individual organisms in a sample of quadrats, then find the mean by taking the total number organisms you counted and dividing it by the number of samples. Then multiply the mean by the total area being investigated to estimate the number of organisms present. Quadrats must always be placed randomly. If you divide the area to be tested into numbered squares, you could use a random number generator to help you choose where to place the quadrats.

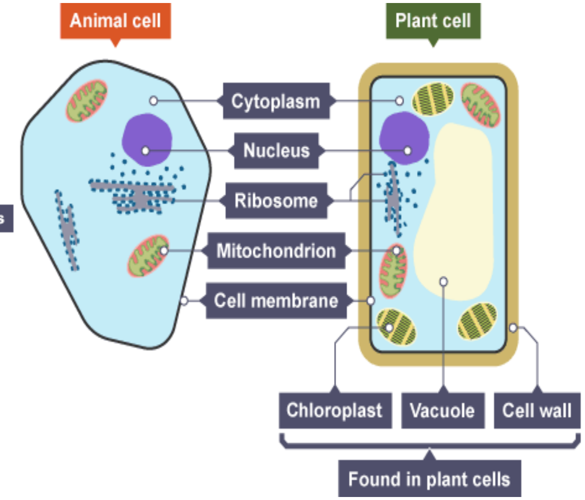
Cell Biology

Eukaryotic & Prokaryotic Cells

A defining feature of **eukaryotic cells** is that their genetic material (DNA) is enclosed within a nucleus. Eukaryotic cells vary in size, usually between 10 and 100 µm and they have subcellular structures, each carrying out a particular function, called organelles. Animal, plant and fungi are eukaryotic.

Bacterial cells are a type of **prokaryotic cell**. A defining feature of prokaryotic cells is that their genetic material is not enclosed within a nucleus, it is found as a single loop of DNA within the cytoplasm. Additional smaller, circular pieces of DNA called plasmids may also be present. The cell membranes of all prokaryotic cells are surrounded by a cell wall. Prokaryotic cells are much smaller in comparison to eukaryotic cells, with many measuring ~ 1 µm in size.





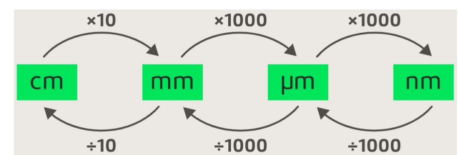
Organelle	Function
Cytoplasm	A jelly-like material that contains dissolved nutrients and salts and structures called organelles. It is where many of the chemical reactions happen.
Nucleus	Contains genetic material, including DNA, which controls the cell's activities.
Cell membrane	Its structure is permeable to some substances but not to others. It therefore controls the movement of substances in and out of the cell.
Mitochondria	Organelles that contain the enzymes for respiration, and where most energy is released in respiration.
Ribosomes	Tiny structures where protein synthesis occurs.
Chloroplast	Organelles that contains the green pigment, chlorophyll, which absorbs light energy for photosynthesis. Contains the enzymes needed for photosynthesis.
Cell wall	Made from cellulose fibres; it strengthens the cell and supports the plant.
Permanent vacuole	Filled with cell sap to help keep the cell turgid.

Required Practical: ***use a light microscope to observe, draw and label a selection of plant and animal cells. A magnification scale must be included.***

Microscopes use lenses to magnify the image of a biological specimen so that it appears larger. **Magnification of the microscope = magnification of eyepiece × magnification of objective.** So, if the magnification of an eyepiece is ×10 and the objective is ×4, the magnification of the microscope is 40.

The formula to calculate magnification of an image is: $magnification = \frac{size\ of\ image}{real\ size\ of\ image}$

It's important to work in the same units when calculating magnification. Sizes of most cells are given in micrometres, µm.



For example: In a book, a photo of the cell measured 100 mm. The real size of the cell shown is 0.05 mm. To calculate the magnification: 100/0.05 = 2000

Method

1. Put the slide on the microscope stage and select the lowest power objective lens (this is usually ×4 objective lens). The end of the objective lens needs to almost touch the slide.
2. Turn the coarse adjustment knob to move the lens towards the slide. Look from the side (not through the eyepiece) when you are adjusting the lens.
3. Look through the eyepiece. Slowly turn the coarse adjustment knob in the direction to increase the distance between the objective lens and the slide. Do this until the cells come into focus.
4. When you have found some cells, switch to a higher power lens (×100 or ×400 magnification).
5. You will have to use the fine adjustment knob to bring the cells back into focus.
6. Make a clear, labelled drawing of some of the cells. Make sure that you draw and label any component parts of the cell. Use a pencil to draw the cells. Write the magnification underneath your drawing.

Cell specialisation
Cells may be have a specialised structure to carry out a particular function.

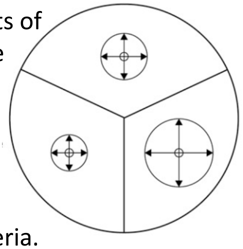
Specialised Cell	Function	Adaptation
Sperm	To get the male DNA to the female DNA.	Streamlined head, long tail, lots of mitochondria to provide energy.
Neuron	To send electrical impulses around the body	Long to cover more distance. Has branched connections to connect in a network.
Muscle	To contract quickly	Long and contain lots of mitochondria for energy.
Root Hair	To absorb water from the soil.	A large surface area to absorb more water.
Phloem	Transports substances around the plant.	Pores to allow cell sap to flow. Cells are long and joined end to end.
Xylem	Transports water through the plant.	Hollow in the centre. Tubes are joined end-to-end

Development of Microscopes
Throughout their development, the **magnification** of **light microscopes** has increased, but very high magnifications are not possible. The maximum magnification with a light microscope is around ×1500.
The ability to see greater detail in an image depends on the **resolution** or resolving power. This is the ability to see two points as two points, rather than merged into one. The resolution of a light microscope is around 0.2 μm, or 200 nm. This means that it cannot distinguish two points closer than 200 nm.
Electron microscopes use a beam of electrons instead of light rays. They have a maximum magnification of around ×1 000 000, but images can be enlarged beyond that photographically. The limit of resolution of the electron microscope is now less than 1 nm.

Cell differentiation
As an organism develops, cells differentiate to form different types of cells. Most types of animal cell differentiate at an early stage. Many types of plant cells retain the ability to differentiate throughout life. In mature animals, cell division is mainly restricted to repair and replacement. As a cell differentiates it acquires different sub-cellular structures to enable it to carry out a certain function. It has become a specialised cell.

Culturing microorganisms *(separate Biology only)*
Bacteria multiply by simple cell division (**binary fission**) as often as once every 20 minutes if they have enough nutrients and a suitable temperature. Bacteria can be grown in a nutrient broth solution or as colonies on an agar gel plate. Uncontaminated cultures of microorganisms are required for investigating the action of disinfectants and antibiotics.
Required practical activity: ***investigate the effect of antiseptics or antibiotics on bacterial growth using agar plates and measuring zones of inhibition***

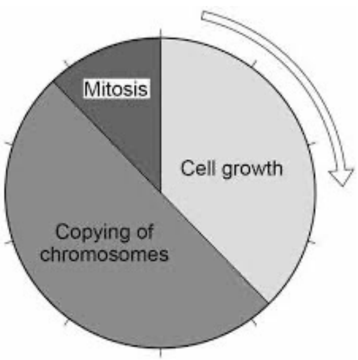
Two measurements of each clear zone



Method
1. Make sure your hands and work space are thoroughly clean before and after the experiment.
2. Use a permanent marker to mark the bottom of the nutrient agar plate (not the lid). Make sure that the lid stays in place to avoid contamination.
3. Divide the plate into three equal sections and number them 1, 2 and 3 around the edge. Add your initials, the date and the name of the bacteria.
4. Put a different antiseptic onto each of three filter paper discs, being careful to shake off excess liquid to avoid splashing.
5. Carefully lift the lid of the agar plate at an angle away from your face. Do not open it fully.
6. Use the forceps to carefully put each disc onto each section. Make a note of which antiseptic is in each section.
7. Secure the lid of the agar plate in place using two small pieces of clear tape. Do not seal the lid all the way around as this creates anaerobic conditions. Anaerobic conditions will prevent the bacteria from growing and can encourage some other very nasty bacteria to grow.
8. Incubate the plate at 25 °C for 48 hours and store upside down to prevent water condensing on the agar and disturbing the bacteria growth.
9. Measure the diameter of the clear zone around each disc. Measure again at 90° to your first measurement, then calculate the mean diameter.

Cell Division

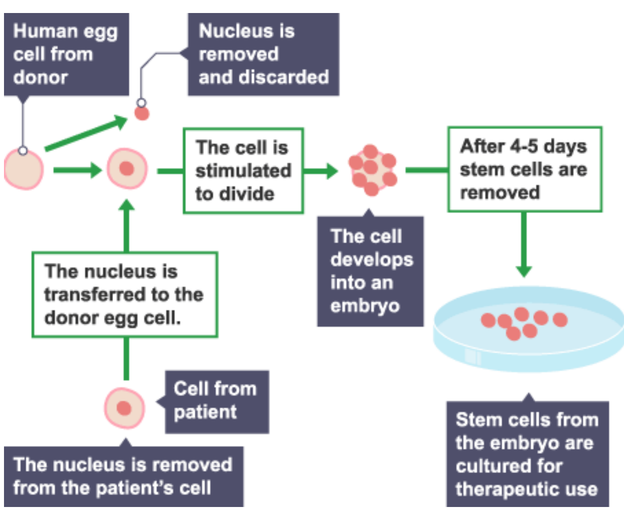
The nucleus of a cell contains chromosomes made of DNA molecules. Each chromosome carries a large number of genes. In body cells the chromosomes are normally found in pairs. Cells divide in a series of stages called the cell cycle.



During the cell cycle the genetic material is **doubled** and then divided into **two identical** cells. There are three stages to the cell cycle:

Cell growth: Before a cell can divide it needs to grow and increase the number of sub-cellular structures such as ribosomes and mitochondria.
Copying of chromosomes: The DNA replicates to form two copies of each chromosome.
Mitosis: one set of chromosomes is pulled to each end of the cell and the nucleus divides. Finally the cytoplasm and cell membranes divide to form two identical cells.

Cell division by mitosis is important in the growth and development of multicellular organisms.



Stem Cell Treatments

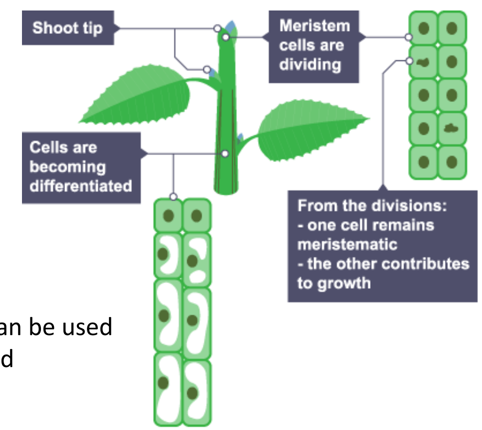
Treatment with stem cells may be able to help conditions such as diabetes and paralysis. In therapeutic cloning an embryo is produced with the same genes as the patient. Stem cells from the embryo are not rejected by the patient's body so they may be used for medical treatment. The use of stem cells has potential risks such as transfer of viral infection, and some people have ethical or religious objections.

Stem Cells

A stem cell is an **undifferentiated** cell of an organism which is capable of giving rise to many more cells of the same type, and from which certain other cells can arise from differentiation.
An **embryo** develops from a fertilised egg. Cells at the early stages in the development of the embryo are called stem cells. If cells are removed from the embryo – called **embryonic stem cells** – they can differentiate into any cell type. Some stem cells remain in the bodies of adults – **adult stem cells**. Adult stem cells are found in limited numbers at certain locations in the body.
Adult stem cells can only differentiate into related cell types; for example, **bone marrow** cells can differentiate into blood cells and cells of the **immune system** but not other cell types.

Stem Cells in Plants

Cell division in plants occurs in regions called **meristems**.
Cells of the meristem can differentiate to produce all types of plant cells at any time during the life of the plant.
The main meristems are close to the tip of the shoot, and the tip of the root.



Stem cells from meristems in plants can be used to produce clones of plants quickly and economically.

- Rare species can be cloned to protect from extinction.
- Crop plants with special features such as disease resistance can be cloned to produce large numbers of identical plants for farmers

Stem Cell Ethical issues

- A source of embryonic stem cells is unused embryos produced by *in vitro* fertilisation (IVF)
- For therapeutic cloning is it right to create embryos for therapy, and destroy them in the process?
- At what stage of its development should an embryo be regarded as, and treated as a person?

Stem Cell Social issues

- Educating the public about what stem cells can, and can't do, is important.
- Whether the benefits of stem cell use outweigh the objections.

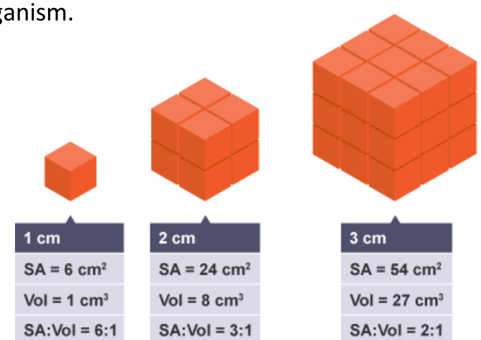
Diffusion

Substances may move into and out of cells across the cell membranes via diffusion. **Diffusion** is the spreading out of the particles of any substance in solution, or particles of a gas, resulting in a net movement from an area of higher concentration to an area of lower concentration. Some of the substances transported in and out of cells by diffusion are oxygen and carbon dioxide in gas exchange, and of the waste product urea from cells into the blood plasma for excretion in the kidney.

Factors which affect the rate of diffusion are:

- the difference in concentrations (concentration gradient)
- the temperature
- the surface area of the membrane.

A single-celled organism has a relatively large **surface area to volume ratio**. This allows sufficient transport of molecules into and out of the cell to meet the needs of the organism.



In multicellular organisms, surfaces and organ systems are specialised for exchanging materials. This is to allow sufficient molecules to be transported into and out of cells for the organism's needs. For example, the small intestine and lungs in mammals, gills in fish, and the roots and leaves in plants, are adapted for exchanging materials

The effectiveness of an exchange surface is increased by:

- having a large surface area
- a membrane that is thin, to provide a short diffusion path
- (in animals) having an efficient blood supply
- (in animals, for gaseous exchange) being ventilated.

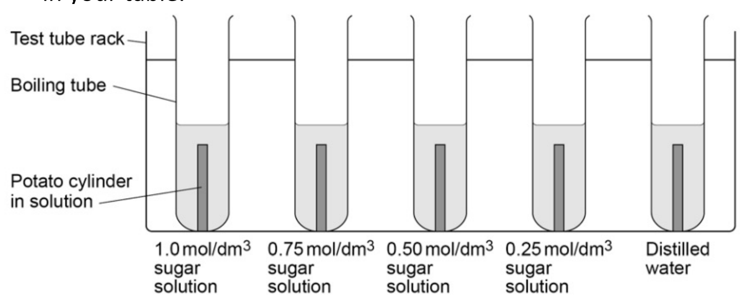
Osmosis

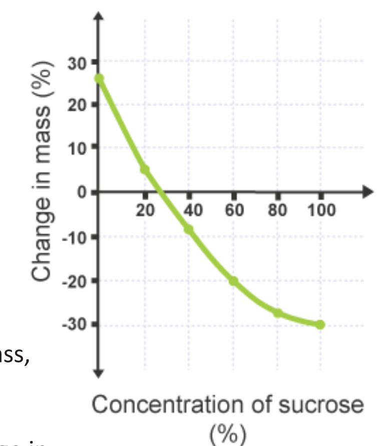
Water may move across cell membranes via osmosis. Osmosis is the diffusion of water from a dilute solution to a concentrated solution through a partially permeable membrane.

Required Practical: I*nvestigate the effect of a range of concentrations of salt or sugar solutions on the mass of plant tissue.*

Method

1. Use a cork borer to cut five potato cylinders of the same diameter. Use the knife to trim off any potato skin on each potato cylinder. Then trim each potato cylinder so that they are all the same length.
2. Accurately measure the mass and length of each potato cylinder. Record your measurements in a table
3. Measure 10 cm^3 of each concentration of sugar or salt solution and put into boiling tubes. Label each boiling tube clearly.
4. Add one potato cylinder to each boiling tube and leave for 24 hrs
5. Remove the potato cylinders from the boiling tubes and carefully blot them dry with the paper towels.
6. Measure the new mass and length of each potato cylinder again. Record your measurements for each concentration in your table.
7. Calculate the percentage change in mass and length of each potato cylinder and record your results in your table.





Where the plotted line crosses the horizontal axis at 0% change in mass, the sucrose concentration is equal to the concentration of dissolved substances in the potato cells.

This can be identified on the graph as the point which shows no change in mass, and therefore represents no **net** movement of water by osmosis.

Active Transport

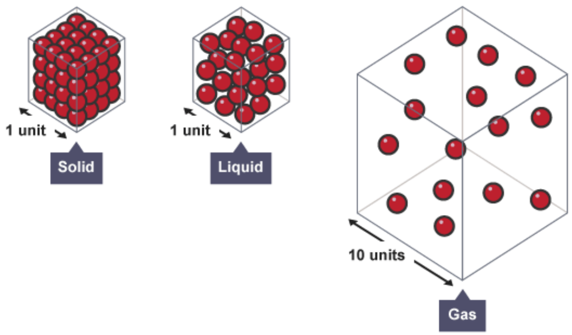
Active transport moves substances from a more dilute solution to a more concentrated solution (against a concentration gradient). This requires energy from respiration. Active transport allows mineral ions to be absorbed into plant root hairs from very dilute solutions in the soil. Plants require ions for healthy growth. It also allows sugar molecules to be absorbed from lower concentrations in the gut into the blood which has a higher sugar concentration. Sugar molecules are used for cell respiration.

The Particle Model of Matter

Solids, liquids and gases

All **matter** contains particles. The difference between the different states of matter is how the particles are arranged:

- in a **solid** - particles are tightly packed in a regular structure
- in a **liquid** - particles are tightly packed but free to move past each other
- in a **gas** - particles are spread out and move randomly



There is little difference between the density of a liquid and its corresponding solid (e.g. water and ice). This is because the particles are tightly packed in both states. The same number of particles in a gas spread further apart than in the liquid or solid states. The same mass takes up a bigger volume - this means the gas is less dense.

Density

Density describes how closely packed the particles are in a solid, liquid or gas. The density of a material is defined by the equation:

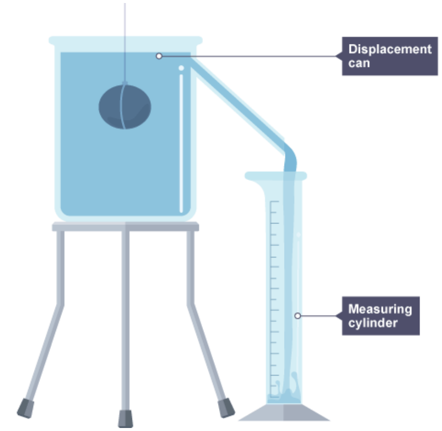
$$density = mass \div volume$$

- density (ρ) is measured in kilograms per metre cubed (kg/m^3)
- mass (m) is measured in kilograms (kg)
- volume (V) is measured in metres cubed (m^3)

Density Required Practical

Method 1: Regular solids

1. Use a ruler or **vernier callipers** to measure the length (l), width (w) and height (h) of a cube.
2. Place the cube on the top pan balance and measure its mass.
3. Calculate the volume of the cube using (l × w × h).
4. Use the measurements to calculate the density of the material using the formula $\rho = \frac{m}{V}$.



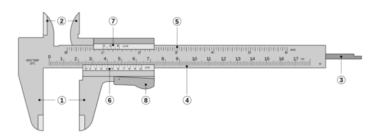
Method 2: Stone or other irregular shaped object

1. Place the stone on the top pan balance and measure its mass.
2. Fill the displacement can (**eureka can**) until the water is level with the bottom of the spout.
3. Place a measuring cylinder under the spout ready to collect the displaced water.
4. Carefully drop the stone into the can and wait until no more water runs into the cylinder.
5. Measure the volume of the displaced water.
6. Use the measurements to calculate the density of the stone using the formula $\rho = \frac{m}{V}$.

Method 3: Water (or any liquid)

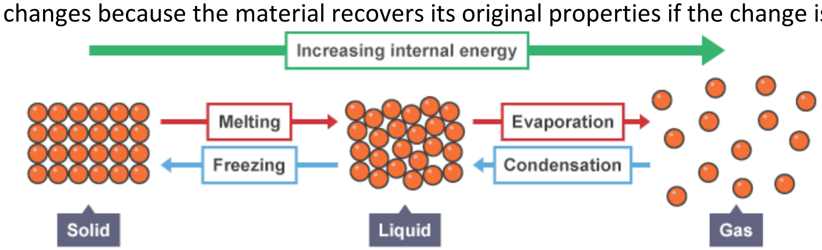
1. Place the measuring cylinder on the top pan balance and measure its mass.
2. Pour 50 cm^3 of water into the measuring cylinder and measure its new mass.
3. Subtract the mass in step 1 from the mass in step 2. This is the mass of 50 cm^3 of water.
4. Use the measurements to calculate the density of the water.

Vernier callipers are a measuring instrument used to find internal or external dimensions accurately, e.g. to the nearest 0.05 mm.



Changes of state

When substances change state mass is conserved. Changes of state are physical changes which differ from chemical changes because the material recovers its original properties if the change is reversed.



Internal energy

Energy is stored inside a system by the particles (atoms and molecules) that make up the system. This is called **internal energy.** Internal energy is the total **kinetic energy** and **potential energy** of all the particles that make up a system.

When a material is heated or cooled, two changes may happen to the particles within the material:

- **intermolecular forces** between the **particles** may strengthen or weaken. This changes the **potential energy** in the material. This happens during a **change of state.**
- the material **changes temperature** as the particles within it gain or lose **kinetic energy**. There is a change in the thermal store of energy within the material.

Whether the energy breaks bonds or just increases the speed of the particles depends on the temperature and **state** of the material.

Particle motion in gases

The molecules of a gas are in constant random motion. The higher the temperature, the more kinetic energy they have. If the volume is kept constant, by increasing the temperature the number of collisions with the sides of the container increase, therefore the pressure exerted by the gas increases.

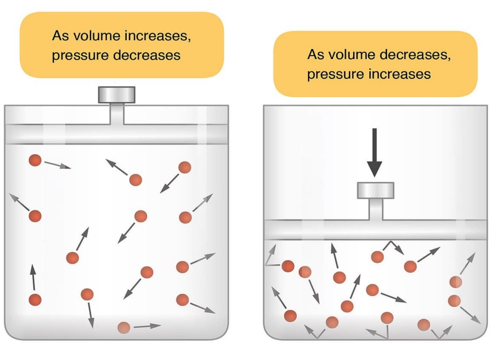
For a fixed mass of gas held at a constant temperature:

pressure × volume = constant

(p V = constant)

- Pressure, p, in pascals, Pa
- Volume, V, in metres cubed, m^3

Work is the transfer of energy by a force. Doing work on a gas increases the internal energy of the gas and can cause an increase in the temperature of the gas. e.g. a bicycle pump, doing work on an enclosed gas leads to an increase in the temperature of the gas.



Specific Heat Capacity

The specific heat capacity of a substance is the amount of energy required to raise the temperature of one kilogram of the substance by one degree Celsius.

Change in energy = mass x specific heat capacity x temperature change

$$\Delta E = m\,c\,\Delta\theta$$

- Change in thermal energy, ΔE, in joules, J
- Mass, m, in kilograms, kg
- Specific heat capacity, c, in joules per kilogram per degree Celsius, J/kg °C
- Temperature change, Δθ, in degrees Celsius, °C.

Specific Latent Heat

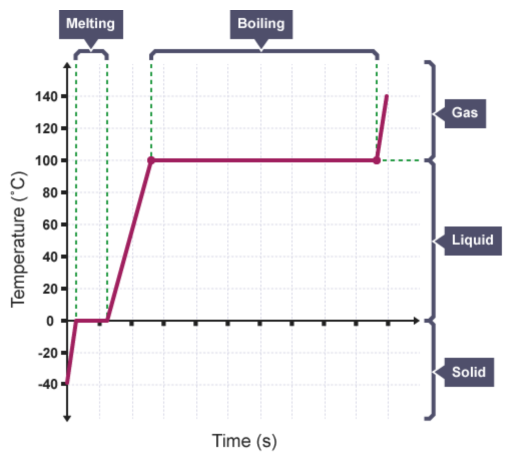
If a change of state happens: The energy needed for a substance to change state is called **latent heat.** When a change of state occurs, the energy supplied changes the energy stored (internal energy) but **not the temperature**. The specific latent heat of a substance is the amount of energy required to change the state of one kilogram of the substance with no change in temperature.

energy for a change of state = mass × specific latent heat

(E = m L)

- Energy, E, in joules, J
- Mass, m, in kilograms, kg
- Specific latent heat, L, in joules per kilogram J/kg

- **Specific latent heat of fusion** – change of state from solid to liquid .
- **Specific latent heat of vaporisation** – change of state from liquid to vapour.



The graph is **horizontal** at two places. These are the places where the energy is not being used to increase the speed of the particles, increasing temperature, but is being used to weaken the forces between the particles to change the state.

The longer the horizontal line, the more energy has been used to cause the change of state. The amount of energy represented by these horizontal lines is equal to the latent heat.

Infection & Response

Communicable (infectious) disease

Pathogens are microorganisms that cause infectious disease. Pathogens may be **viruses, bacteria, protists or fungi**. They may infect plants or animals. Transmission is the spread of disease and can occur in the ways shown in the table below.

Type	Examples
Direct contact	This can be sexual contact during intercourse or non-sexual contact, like shaking hands.
Water	Dirty water can transmit many diseases, such as the cholera bacterium.
Air	When a person who is infected by the common cold sneezes, they can spray thousands of tiny droplets containing virus particles to infect others.
Food	Undercooked or reheated food can cause bacterial diseases like Escherichia coli which is a cause of food poisoning.
Vector	Any organism that can spread a disease is called a vector. Many farmers think tuberculosis in their cattle can be spread by badgers.

Bacteria and viruses may reproduce rapidly inside the body. Bacteria may produce poisons (**toxins**) that damage tissues and make us feel ill. Viruses live and reproduce inside cells, causing cell damage.

The Immune System

If a pathogen enters the body the immune system (**white blood cells**) tries to destroy the pathogen.

One type of white blood cell are called **phagocytes**. They surround any pathogens in the blood and engulf them. The phagocyte’s membrane surrounds the pathogen and enzymes found inside the cell break down the pathogen in order to destroy it.

Lymphocytes are another type of white blood cell. They recognise proteins on the surface of pathogens called **antigens**. Lymphocytes detect that these are foreign (not naturally occurring within your body) and produce **antibodies**. This can take a few days, during which time you may feel ill. The antibodies cause pathogens to stick together and make it easier for phagocytes to engulf them.

Some pathogens produce **toxins** which make you feel ill. Lymphocytes can also produce **antitoxins** to neutralise these toxins. Both the antibodies and antitoxins are highly specific to the antigen on the pathogen.

Preventing the Spread of Disease

Transmission can be prevent in the following ways:

Method	Example	How it works
Sterilising water	Cholera	Chemicals or UV light kill pathogens in unclean water.
Unsuitable hygiene - food	Salmonella	Cooking foods thoroughly and preparing them in hygienic conditions kills pathogens.
Unsuitable hygiene - personal	Athlete's foot	Washing surfaces with disinfectants kills pathogens. Treating existing cases of infection kills pathogens.
Vaccination	Measles	Vaccinations introduce a small or weakened version of a pathogen into your body, and the immune system learns how to defend itself.
Contraception	HIV/AIDs	Using barrier contraception, like condoms, stops the transfer of bodily fluids and sexually transmitted diseases.

Human Defence Systems

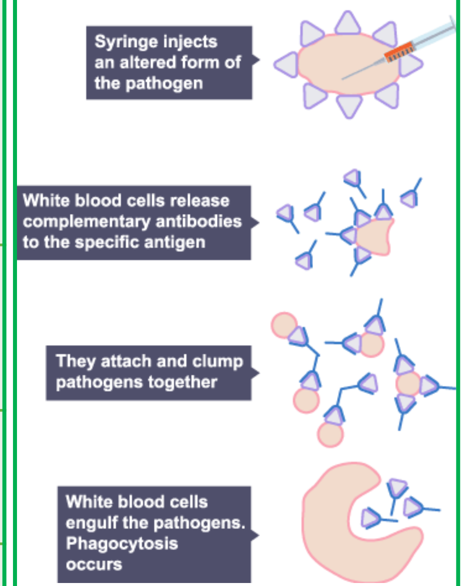
The first line of defence against infection stops the pathogens from entering your body. These are general defences, they are **not specifically** to fight against certain types of pathogen.

- **Skin:** The skin covers almost all parts of your body to prevent infection from pathogens. If it is cut or grazed it immediately begins to heal itself, often by forming a scab, which prevents infection as the skin acts as a physical barrier.
- The eyes produce tears, which contain **enzymes**, which destroy pathogens.
- **Nose:** The nose has internal hairs, which act as a physical barrier to infection. Cells in the nose produce **mucus**. This traps pathogens before they can enter the lungs
- **Trachea & bronchi:** The cells that line the trachea also have hairs called **cilia**, which are much smaller than those in the nose. The **ciliated cells** waft their hairs and move mucus and pathogens upwards towards the throat where it is swallowed into your **stomach**. Other cells called **goblet cells** create the mucus in order to trap pathogens.
- **Stomach:** Stomach acid does not break down food. It is **hydrochloric acid** and kills any pathogens that have been caught in mucus in the airways or consumed in food or water.

Disease	Microbe	Organisms affected	Transmission	Symptoms	Treatment/prevention
Measles	Virus	Humans	Inhalation of droplets from sneezes and coughs.	Fever and a red skin rash. Measles is a serious illness that can be fatal if complications arise.	Vaccination
Tobacco mosaic virus	Virus	Many species of plants including tomatoes	Contact	It gives a distinctive 'mosaic' pattern of discolouration on the leaves which affects the growth of the plant due to lack of photosynthesis.	There's no cure therefore farmers must try to reduce the infection to their crops or attempt to reduce the spread of the virus.
HIV	Virus	Humans	Sexual contact or exchange of body fluids such as blood which occurs when drug users share needles.	Initially causes a flu-like illness. Unless successfully controlled with antiretroviral drugs the virus attacks the body's immune cells. Late stage HIV infection, or AIDS, occurs when the body's immune system becomes so badly damaged it can no longer deal with other infections or cancers.	Use condoms during sex, don't share needles. Treated with antiretroviral drugs
Salmonella	Bacteria	Humans	Bacteria ingested in food, or on food prepared in unhygienic conditions	Fever, abdominal cramps, vomiting and diarrhoea are caused by the bacteria and the toxins they secrete.	In the UK, poultry are vaccinated against Salmonella to control the spread.
Gonorrhoea	Bacteria	Humans	Sexually transmitted disease (STD)	A thick yellow or green discharge from the vagina or penis and pain on urinating. If untreated it can result in infertility.	It was easily treated with the antibiotic penicillin until many resistant strains appeared. Prevented by using condoms.
Malaria	Protist	Humans	The malarial protist has a life cycle that includes the mosquito. It is spread when a mosquito bites a human.	Malaria causes recurrent episodes of fever and can be fatal.	The spread of malaria is controlled by preventing the vectors, mosquitos, from breeding and by using mosquito nets to avoid being bitten.
Rose black spot	Fungus	Roses	Spread in the environment by water or wind.	Purple or black spots develop on leaves, which often turn yellow and drop early. It affects the growth of the plant as photosynthesis is reduced.	Rose black spot can be treated by using fungicides and/or removing and destroying the affected leaves.

Vaccines

Vaccination involves introducing small quantities of dead or inactive forms of a pathogen into the body to stimulate the white blood cells to produce antibodies. If the same pathogen re-enters the body the white blood cells respond quickly to produce the correct antibodies, preventing infection.



During the **primary infection** the antibodies slowly increase, peak at around ten days and then gradually decrease. A **second** exposure to the same pathogen causes the white blood cells to respond quickly in order to produce lots of the relevant antibodies, which prevents infection.

Herd immunity

The majority of the population must be vaccinated against serious diseases to provide **herd immunity**. If the number of people vaccinated against a specific disease drops in a population, it leaves the rest of the population at risk of mass infection, as they are more likely to come across people who are infected and contagious. This increases the number of infections, as well as the number of people who could die from a specific infectious disease.

Antibiotics and painkillers

Antibiotics, such as penicillin, are medicines that help to cure bacterial disease by killing infective bacteria inside the body. It is important that specific bacteria should be treated by specific antibiotics. The use of antibiotics has greatly reduced deaths from infectious bacterial diseases. However, the emergence of strains resistant to antibiotics is of great concern. Antibiotics cannot kill viral pathogens. Painkillers and other medicines are used to treat the symptoms of disease but do not kill pathogens. It is difficult to develop drugs that kill viruses without also damaging the body's tissues.

Discovery and development of drugs

Traditionally drugs were extracted from plants and microorganisms.

- The heart drug **digitalis** originates from **foxgloves.**
- The painkiller **aspirin** originates from **willow**.
- **Penicillin** was discovered by **Alexander Fleming** from the Penicillium mould.

Most new drugs are synthesised by chemists in the pharmaceutical industry. However, the starting point may still be a chemical extracted from a plant.

New medical drugs have to be tested and trialled before being used to check that they are safe and effective. New drugs are extensively tested for:

- **Toxicity:** This is important as some drugs are **toxic**, and have other side effects that might be harmful to people
- **Efficacy:** This checks how well the drug cures the disease, or improves symptoms.
- **Dose:** This varies, and has to be closely controlled, as too high a concentration might be toxic.

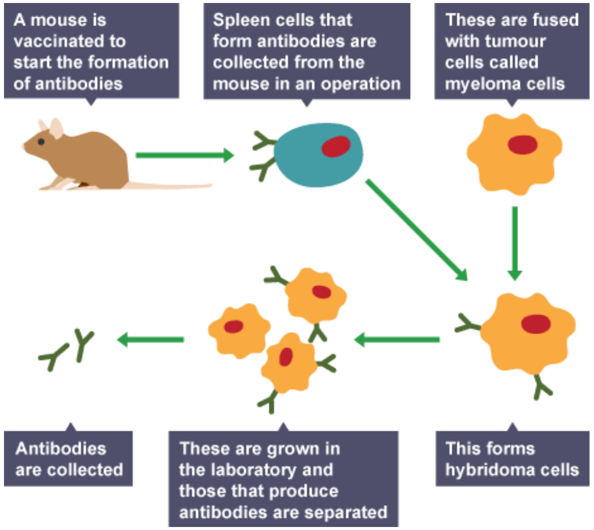
Three stages of testing drugs

1. The drugs are tested using **computer models** and **human cells grown in the laboratory**. This allows the efficacy and possible side effects to be tested. Many substances fail this first test of a **preclinical drug trial** because they damage cells or do not seem to work.
2. Drugs that pass the first stage are **tested on animals in the second part of a preclinical drug trial**. In the UK, new medicines have to undergo these tests. But it is illegal to test cosmetics and tobacco products on animals. A typical test involves giving a known amount of the substance to the animals, then monitoring them carefully for any side-effects.
3. Drugs that have passed animal tests are used in **human clinical trials**. They are tested on healthy volunteers to check that they are safe. The substances are then tested on people with the illness to ensure that they are safe and that they work. Low doses of the drug are used initially, and if this is safe the dosage increases until the optimum dosage is identified.

The **placebo** effect occurs when someone feels they are better when they have been given a dummy form of the drug, not the drug itself.
To reduce the placebo effect in drug testing **double blind trials** are carried out. This is where neither the doctor nor the patient knows who has been given the drug or placebo. Only the researchers know so they can compare the results of the new drug against the placebo effect.

Monoclonal antibodies *(Separate Biology Only)*

Monoclonal antibodies are produced from a single clone of cells. The antibodies are specific to one binding site on one protein antigen and so are able to target a specific chemical or specific cells in the body. They are produced by stimulating mouse lymphocytes to make a particular antibody. The lymphocytes are combined with a particular kind of tumour cell to make a cell called a hybridoma cell. The hybridoma cell can both divide and make the antibody. Single hybridoma cells are cloned to produce many identical cells that all produce the same antibody. A large amount of the antibody can be collected and purified.

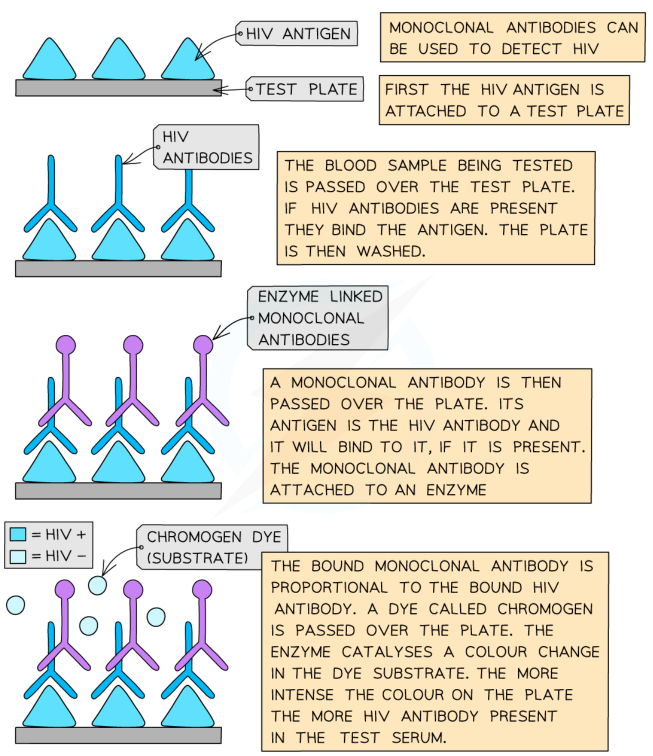


Uses of Monoclonal Antibodies *(Separate Biology Only)*

Some examples of the uses of monoclonal antibodies include:

- for diagnosis such as in **pregnancy tests:** These have been designed to bind with a **hormone** called HCG which is found only in the urine of pregnant women. Monoclonal antibodies are attached to the end of a pregnancy test stick onto which a woman urinates. If she is pregnant, HCG will be present in her urine and will bind to the monoclonal antibodies on the test stick. This will cause a change in colour or pattern which will indicate pregnancy. These specific monoclonal antibodies in the **pregnancy test** will only bind with HCG.
- in laboratories to measure the levels of hormones and other chemicals in blood, or to detect pathogens
- in research to locate or identify specific molecules in a cell or tissue by binding to them with a fluorescent dye
- to treat some diseases: for cancer the monoclonal antibody can be bound to a radioactive substance, a toxic drug or a chemical which stops cells growing and dividing. It delivers the substance to the cancer cells without harming other cells in the body.

Monoclonal antibodies create more side effects than expected. They are not yet as widely used as everyone hoped when they were first developed



Plant defence responses
(Separate Biology Only)

Plants have a range of physical and chemical defence mechanisms to protect them from disease.

Physical defence responses to resist invasion of microorganisms.

- Cellulose cell walls.
- Tough waxy cuticle on leaves.
- Layers of dead cells around stems (bark on trees) which fall off.

Chemical plant defence responses.

- Antibacterial chemicals.
- Poisons to deter herbivores.

Mechanical adaptations.

- Thorns and hairs deter animals.
- Leaves which droop or curl when touched.
- Mimicry to trick animals.

Plant disease
(Separate Biology Only)

Plants can be infected by a range of viral, bacterial and fungal pathogens as well as by insects.

Plant diseases can be detected by:

- Stunted growth
- Spots on leaves
- Areas of decay (rot)
- Growths
- Malformed stems or leaves
- Discolouration
- The presence of pests.

Identification of the disease can be made by:

- Reference to a gardening manual or website
- Taking infected plants to a laboratory to identify the pathogen
- Using testing kits that contain monoclonal antibodies.

Plants can be damaged by a range of ion deficiency conditions:

- Stunted growth caused by **nitrate** deficiency. This is because nitrate ions are needed for protein synthesis and therefore growth.

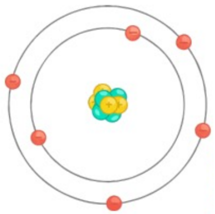
- **Chlorosis** (yellow leaves) caused by **magnesium** deficiency. Magnesium ions are needed to make chlorophyll (the green pigment in chloroplast which absorbs light energy). The absence of this leads to yellowed leaves.

Atomic Structure & the Periodic Table

1. Atoms, elements & compounds (common content with Physics)

Elements are made of atoms with the same atomic number. Atoms can be represented as symbols. **N** = nitrogen **F** = fluorine **Zn** = zinc **Ca** = calcium

Isotopes – an isotope is an element with the **same number of protons** and a **different number of neutrons**. They have the same atomic number, but a different mass number.



Isotope	Protons	Electrons	Neutrons
$^{1}_{1}H$	1	1	1 - 1 = 0
$^{2}_{1}H$	1	1	2 - 1 = 1
$^{3}_{1}H$	1	1	3 - 1 = 2

Compounds – a compound is when two or more elements are chemically joined in fixed proportions, e.g. carbon dioxide and magnesium oxide. The atoms are held together by chemical bonds. Compounds can only be made or separated by chemical reactions.

2. Chemical equations

Chemical reactions can be represented by **word equations** e.g.

magnesium + oxygen → magnesium oxide

On the left are the reactants, on the right are the products. Chemical reactions can also be represented by **symbol equations** e.g.

$$2Mg + O_2 \rightarrow 2MgO$$

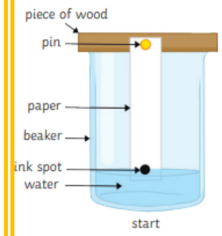
Mass is conserved in a reaction; equations need to be **balanced** so that there are the same number of atoms on each side. To do this, numbers are put in front of the compounds – you can't change the small numbers to the right of the compound.

3. Mixtures

In a mixture there are no chemical bonds, so the molecules are easier to separate. Examples of mixtures are air and sea water.

Mixtures can be separated by physical processes such as **filtration, crystallisation, simple distillation, fractional distillation** and **chromatography**. These physical processes do not involve chemical reactions and no new substances are made.

Chromatography – to separate out mixtures.



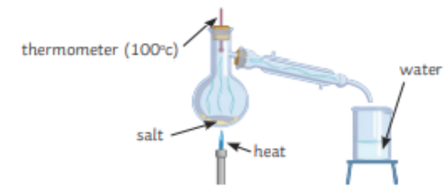
Filtration – to separate solids from liquids.

Evaporation – to separate a soluble salt from a solution; a quick way of separating out the salt.

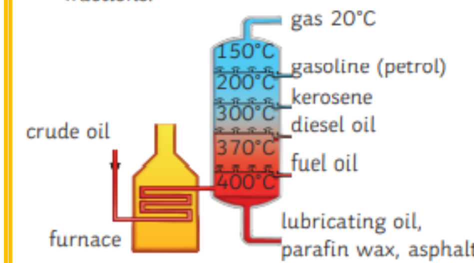
Crystallisation - to separate a soluble salt from a solution; a slower method of separating out salt.

To separate out mixtures of liquids.

1. **Simple distillation** – separating a liquid from a solution.



2. **Fractional distillation** – separating out a mixture of liquids. Fractional distillation can be used to separate out crude oil into fractions.



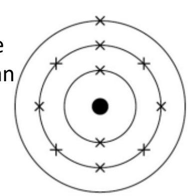
4. Development of the model of the atom (common content with Physics)

Note: you only need to know the names of Bohr and Chadwick (in bold).

Scientist	Discovery
1800's and before	Atoms were thought to be tiny spheres that could not be divided.
JJ Thomson, 1897	The discovery of the **electron** led to the **plum pudding model** of the atom. The plum pudding model suggested that the atom is a ball of positive charge with negative electrons embedded in it.
Ernest Rutherford, 1909	The results from the alpha particle scattering experiment led to the conclusion that the mass of an atom was concentrated at the centre (**nucleus**) and that the nucleus was charged. This nuclear model replaced the plum pudding model.
Niels Bohr, 1911	Niels Bohr adapted the nuclear model by suggesting that **electrons orbit the nucleus** at specific distances. The theoretical calculations of Bohr agreed with experimental observations.
Ernest Rutherford, 1920	Later experiments led to the idea that the positive charge of any nucleus could be subdivided into a whole number of smaller particles. The name **proton** was given to these particles.
James Chadwick, 1940	Provided the evidence to show the existence of **neutrons** within the nucleus. This was about 20 years after the nucleus became an accepted scientific idea.

5. Electronic Structure

The electrons in an atom occupy the lowest available energy levels (innermost available shells). The first energy level can take up to **2** electrons. The subsequent levels can take up to **8** electrons. This rule is applied for the first 20 elements only. The electronic structure of an atom can be represented by numbers or by a diagram. For example, the electronic structure of sodium is 2,8,1 or:



6. Relative Charges of Sub Atomic Particles (common content with Physics)

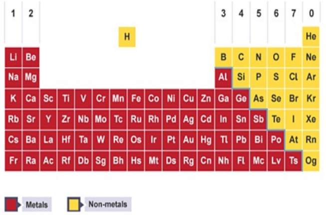
In an atom, the number of electrons is equal to the number of protons in the nucleus. Atoms have no overall electrical charge.

Particle	Relative Mass	Relative Charge
Proton	1	+1
Neutron	1	0
Electron	Very small	- 1

The number of protons, **A_r**, in an atom of an element is its atomic number. All atoms of a particular element have the same number of protons. Atoms of different elements have different numbers of protons.

Atoms are very small, having a radius of about 0.1 nm (1×10^{-10} m). The radius of a nucleus is less than 1/10 000 of that of the atom (about 1×10^{-14} m). Almost all of the mass of an atom is in the nucleus.

8. The Periodic Table



The elements in the periodic table are arranged in order of atomic (proton) number and so that elements with similar properties are in columns, known as **groups**. The table is called a periodic table because similar properties occur at regular intervals. Elements in the same group in the periodic table have the same number of electrons in their outer shell (outer electrons) and this gives them similar chemical properties. A horizontal row is called a **period**. Elements in the same period have the same number of electron shells.

9. Metals & Non-metals

Elements that react to form positive ions are metals. Elements that do not form positive ions are non-metals. The majority of elements are metals. Metals are found to the left and towards the bottom of the periodic table. Non-metals are found towards the right and top of the periodic table.

13. Group 7

Group 7, the Halogens, are very reactive non-metals with 7 electrons on their outer shell. They are molecules made of pairs of atoms (they are diatomic). Reactivity decreases down the group and melting and boiling point increases down the group. They react strongly with group 1 metals. A more reactive halogen can displace a less reactive halogen from an aqueous solution of its salt.

14. Group 0

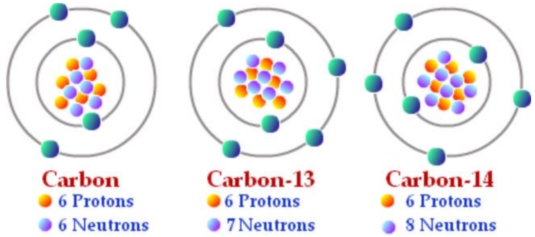
The elements in group 0 of the periodic table are called the noble gases. They are unreactive and do not easily form molecules because their atoms have stable arrangements of electrons. The noble gases have eight electrons in their outer shell, except for helium, which has only two electrons. The boiling points of the noble gases increase with increasing relative atomic mass (going down the group)

7. Mass number (common content with Physics)

The sum of the protons and neutrons in an atom is its mass number. Atoms can be represented as shown in this example:

Mass number, M_r → 23
Atomic number, A_r → 11
Na
Sodium

Atoms of the same element have the same number of protons but a different numbers of neutrons; these atoms are called **isotopes** of that element, e.g.



The relative atomic mass of an element is an average value that takes account of the abundance of the isotopes of the element. To calculate relative atomic mass, use this formula:

$$\frac{\text{sum of (isotope abundance} \times \text{isotope mass number)}}{\text{sum of abundances of all isotopes}}$$

10. Development of the Periodic Table

Before the discovery of protons, neutrons and electrons, scientists attempted to classify the elements by arranging them in order of their **atomic weights**. The early periodic tables were incomplete and some elements were placed in inappropriate groups if the strict order of atomic weights was followed. **Mendeleev** overcame some of the problems by **leaving gaps** for elements that he thought had not been discovered and in some places changed the order based on properties rather than atomic weights. Elements with properties predicted by Mendeleev were discovered and filled the gaps. Knowledge of isotopes made it possible to explain why the order based on atomic weights was not always correct.

11. Transition Metals – (*Separate Chemistry Only*)

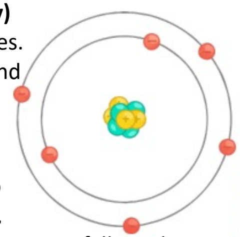
The transition elements are metals with similar properties which are different from those of the elements in group 1. Many transition elements have ions with different charges, form coloured compounds and are useful as catalysts. Example transition metals are Cr, Mn, Fe, Co, Ni, Cu. They tend to be harder, denser, stronger and have higher melting and boiling points than group 1 & 2 metals.

12. Group 1

The elements in Group 1 of the periodic table are known as the alkali metals and have characteristic properties because of the single electron in their outer shell.
They are very reactive with oxygen, water and group 7. Reactivity increases as you down the group and they have low melting and boiling points which decrease as you go down the group.

Atomic Structure: Physics

1. The Structure of the Atom (common content with Chemistry)



- Atoms are very small, they have a radius of about 1×10^{-10} metres.
- Atoms have a positively charged nucleus made from protons and neutrons surrounded by negatively charged electrons.
- The radius of the nucleus is less than 1/10,000 of the radius of the atom, so most of the atom is empty space.
- The electrons are arranged in energy levels. If electrons absorb electromagnetic radiation they may move to a higher energy level, further from the nucleus. If they emit electromagnetic radiation, they may fall to a lower energy level closer to the nucleus.

2. Mass number, Atomic Number and Isotopes (common content with Chemistry)

- In an atom, the number of electrons is equal to the number of protons in the nucleus. Atoms have no overall electrical charge.
- All atoms of a particular element have the same number of protons (called the atomic number).
- The sum of the protons and neutrons in an atom is its mass number

Mass number, M_r → 23
Atomic number, A_r → 11
Na
Sodium

- Atoms of the same element have the same number of protons but can have a different number of neutrons; these atoms are called **isotopes** of that element.
- Atoms turn into positive ions if they lose electrons.

3. Development of the model of the atom (common content with Chemistry)

Note: you only need to know the names of **Bohr and Chadwick (in bold).**

Scientist	Discovery
1800's and before	Atoms were thought to be tiny spheres that could not be divided.
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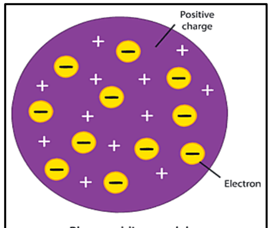
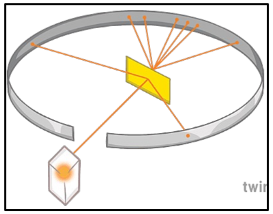
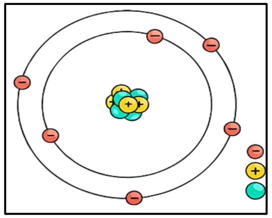


Plum pudding model





4. Atoms & Nuclear Radiation

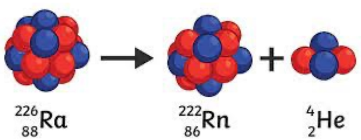
- Some atomic nuclei are **unstable**. This means they give out radiation as it changes to become more stable. This **random** process is called **radioactive decay**.
- Activity is the rate at which a source of unstable nuclei decays it is measured in **becquerel (Bq).**
- **Count-rate** is the number of decays recorded per second by a detector (e.g. a Geiger-Muller tube).

Radiation	Symbol	Made from	Penetrating Power	Ionising power	Range in air
Alpha	**α**	2 protons & 2 neutrons (same as a He nucleus)	Stopped by paper/skin	High	<5cm
Beta	**β**	A high speed electron ejected from the nucleus as a neutron turns into a proton	Stopped by 3mm aluminium foil	Low	Approx. 1 m
Gamma	**γ**	Electromagnetic radiation from the nucleus	Stopped by lead/concrete	Very low	> 1km

5. Nuclear Equations

- Nuclear equations can be used to represent radioactive decay.
- The emission of the different types of radiation may cause a change in the mass and/or charge of the nucleus, for example:

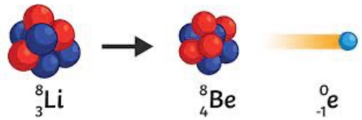
$$^{226}_{88}\text{radium} \rightarrow {}^{222}_{86}\text{radon} + {}^{4}_{2}\alpha$$



An alpha particle may be represented as: $^{4}_{2}He$

- So alpha decay causes both the mass and the charge of the nucleus to decrease.

$$^{8}_{3}\text{lithium} \rightarrow {}^{8}_{4}\text{beryllium} + {}^{0}_{-1}\beta$$



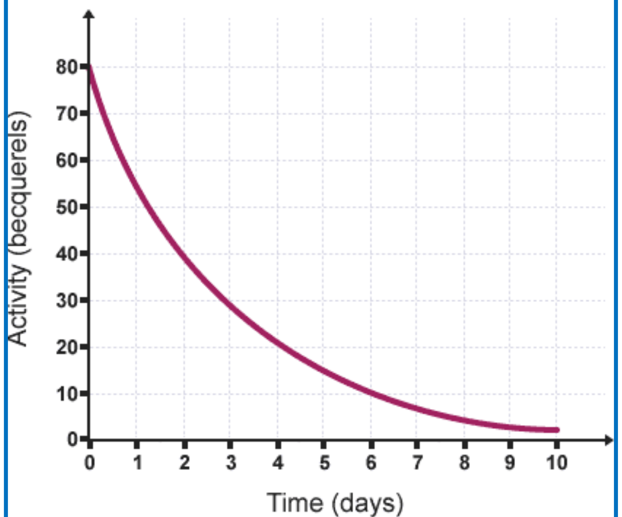
A beta particle may be represented as: $^{0}_{-1}e$

- So beta decay not cause the mass of the nucleus to change, but does cause the charge of the nucleus to increase.
- The emission of a gamma ray does not cause the nucleus to change.

Atomic Structure: Physics

6. Half-lives

- Radioactive decay is random.
- The half-life of a radioactive isotope is the time it takes for the number of nuclei of the isotope in a sample to halve, or the time it takes for the count rate to fall to half of its initial level.



You can calculate half lives from graphs such as the one here. Read off how long it takes the activity to half,
e.g. to go from 80 to 40 Bq takes 2 days.

7. Radioactive Contamination and Irradiation

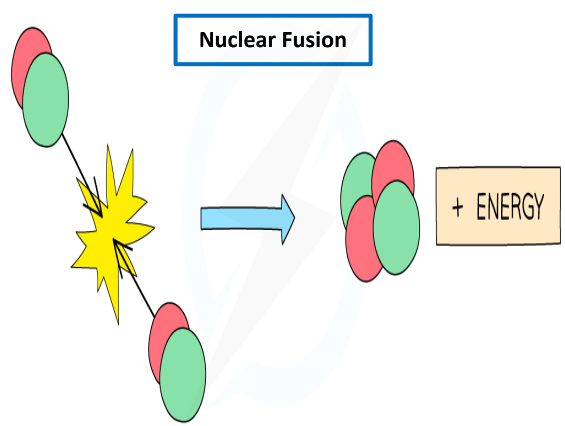
- Radioactive contamination is the unwanted presence of materials containing radioactive atoms on other materials.
- The hazard from contamination is due to the decay of the contaminating atoms. The type of radiation emitted affects the level of hazard.
- Irradiation is the process of exposing an object to nuclear radiation. The irradiated object does not become radioactive.
- Suitable precautions must be taken to protect against any hazard that the radioactive source used in the process of irradiation may present.

8. Background Radiation: *(Separate Physics Only)*

- Background radiation is around us all the time, it comes from:
  - ➢ Natural sources e.g. rocks, cosmic rays
  - ➢ Artificial sources e.g. medical uses, nuclear weapons fallout and nuclear accidents.
- The level of background radiation dose may be affected by occupation and location.
- Radiation dose is measured in sieverts (Sv). 1,000 millisieverts (mSv) = 1 sievert (Sv)
- Radioactive isotopes have a very wide range of half-lives. The use of them depends on the half-life, e.g. a short half-life would be used for a medical tracer so it is not in the body for long.

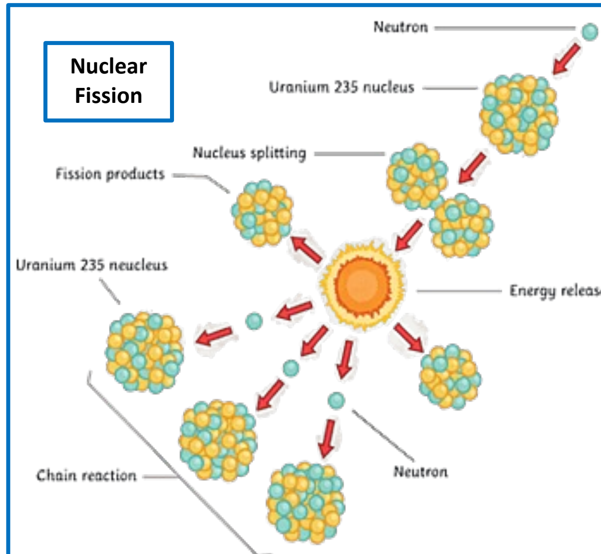
9. Uses of Nuclear Radiation: *(Separate Physics Only)*

- Medicinal uses:
  - ➢ Exploration of internal organs, e.g. tracers
  - ➢ Control and destruction of unwanted tissue (e.g. cancer). Gamma rays can be used in radiotherapy to kill cancer cells when they are targeted directly at the unwanted cells.



10. Nuclear Fission: *(Separate Physics Only)*

- Nuclear fission is the splitting of a large and unstable nucleus (e.g. uranium or plutonium).
- Spontaneous fission is rare.
- For fission to occur the unstable nuclei must absorb a neutron.
- The nuclei undergoing fission splits into two smaller, equal sized nuclei and emits neutrons, gamma rays and energy.
- All the fission products have kinetic energy.
- The neutrons may go on to start a chain reaction.
- The chain reaction is controlled in a nuclear reactor to control the energy released. The explosion caused by a nuclear weapon is caused by an uncontrolled chain reaction.



11. Nuclear Fusion: *(Separate Physics Only)*

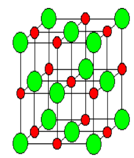
- Nuclear fusion is the joining of two light nuclei to form a heavier nucleus. In this process some of the mass may be converted into the energy of radiation.

Bonding and Structure 1

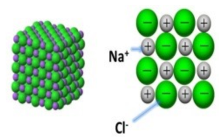
Ions

Ions are charged particles – they can be single atoms (e.g. Cl^-) or group of atoms (e.g. NO_3^-).
When atoms lose or gain electrons to form ions, all they are trying to do is get a full outer shell like a Nobel gas.
Atoms with full outer shells are very stable.
The number of electrons lost or gained is the same as the charge on the ion, e.g. if 2 electrons are lost the charge is 2+ (Mg^{2+}).

Ionic Compounds



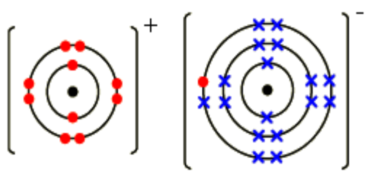
An ionic compound is a giant structure of ions.
Ionic compounds are held together by strong electrostatic forces of attraction between oppositely charged ions.
These forces act in all directions in the lattice – and this is known as ionic bonding.



Ionic Bonding

When a metal atom reacts with a non-metal atom, electrons in the outer shell of the metal atom are transferred.
Metal atoms lose electrons to become positively charged ions.
Non-metals atoms gain electrons to become negatively charged ions.

The ions produced by metals in groups 1 and 2 and by non-metals in groups 6 and 7 have the electronic structure of a noble gas (group 0)



sodium ion, Na^+ [2,8]$^+$ chloride ion, Cl^- [2,8,8]$^-$

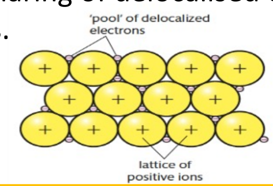
The electron transfer during the formation of an ionic compound can be represented by a dot and cross diagram.

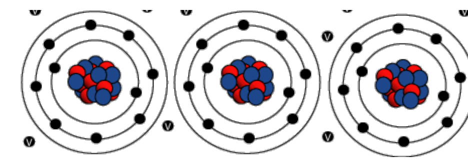
Properties of Ionic Compounds

- Regular structure (giant ionic lattice) in which there are strong electrostatic forces of attraction in all directions between oppositely charged ions.
- High melting and boiling points because of the large amount of energy needed to break the many strong bonds.
- When melted or dissolved in water, ionic compounds conduct electricity because the ions are free to move and so charge can flow.

Metallic Bonding

Metals consist of giant structures of atoms arranged in a regular pattern.
The electrons in the outer shell of metal atoms are delocalised and are free to move through the whole structure.
The sharing of delocalised electrons gives rise to strong metallic bonds.

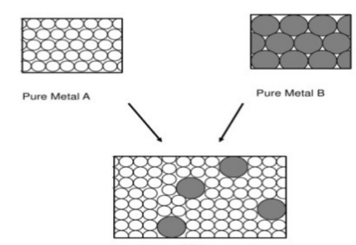




Properties of Metallic Bonding

- Metals have a giant structure of atoms with strong metallic bonding.
- High melting and boiling points.
- Metals are good conductors of electricity because the delocalised electrons in the metal are free to move and can carry electrical charge.
- Metals are good thermal conductors because the energy is transferred by the delocalised electrons.

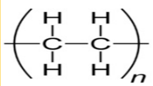
Pure Metals – atoms are arranged in layers, which allow metals to be bent and shaped. They are too soft for many uses
Alloys – metals mixed to make the structure less regular and therefore stronger

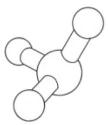
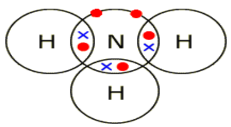


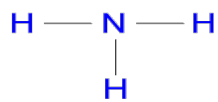
Bonding and Structure 2

Covalent Bonding

When atoms share pairs of electrons, they form covalent bonds
These bonds between the atoms are strong **(intramolecular)**
Covalently bonded substances may consist of **small molecules** (liquids, e.g. water, and gases, e.g. oxygen).
Some covalently bonded substances have **very large molecules**, such as polymers.
Some covalently bonded substances have giant covalent structures, such as diamond and graphite.



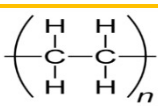





Properties of Small Covalent Molecules

- Usually gases or liquids with relatively low melting and boiling points.
- These substances have weak forces between the molecules (**intermolecular forces**). It is these forces which are overcome (not the covalent bonds) when the substance melts or boils.
- The intermolecular forces increase with the size of the molecules, so larger molecules have higher melting points.
- They do not conduct electricity because the molecules do not have an overall charge.

Properties of Polymers

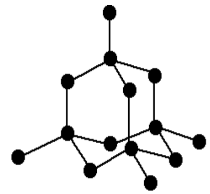


- Polymers have very large molecules.
- The atoms are linked to other atoms by strong covalent bonds.
- The intermolecular forces between the polymer molecules are relatively strong and so they are solid at room temperature.

Giant Covalent Structures

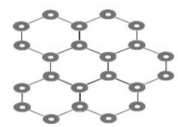
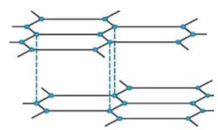
Giant covalent structures are solids with very high melting points
All the atoms in the structure are linked to other atoms by strong covalent bonds.
These bonds must be overcome for the substance to melt or boil.
Diamond, graphite and silicon dioxide are examples.

Diamond



- Each carbon atom forms **four** covalent bonds with other carbon atoms.
- Diamond is very hard.
- Very high melting point.
- Does not conduct electricity.

Graphite

- Each carbon atom forms **three** covalent bonds with three other carbon atoms.
- Forms layers with hexagonal rings which have no covalent bonds between the layers so they can slide over each other.
- One electron from each carbon atom is delocalised and is free to move and carry charge so graphite can conduct electricity.

Graphene and Fullerenes

Graphene is a single layer of graphite and has properties which make it useful in electronics and composites.
Fullerenes are molecules of carbon atoms with hollow shapes. The structure is based on hexagonal rings of carbon atoms but they may also contain rings with 5 or 7 carbon atoms.
The first fullerene to be discovered was Buckminsterfullerene (C_{60}) which has a spherical shape.
Carbon Nanotubes are cylindrical fullerenes with very high length to diameter ratios. Their properties make them useful for nanotechnology, electronics and materials.

Bonding and Structure 3

(Separate Chemistry Only)

Sizes of Particles and their Properties

1 nm is 0.000000001 m or 1×10^{-9} m.

Nanoscience refers to structures 1-100nm in size (few hundred atoms).

Nanoparticles are smaller than fine particles (100-2500nm), coarse particles are 1×10^{-5} to 2.5×10^{-6}m in size (dust).

As the size of cube decreases by a factor of 10 the surface area to volume ratio increases by a factor of 10.

Nanoparticles may have different properties to the bulk atom because of their high surface area to volume ratio.

It also means less nanoparticles are needed to be effective than materials with normal particle size.

Uses of Nanoparticles

Advantages:
Medicine (cancer drug transporters in the body), electronics, cosmetics, deodorants (silver nanoparticles have antibacterial properties), sun creams and catalysts.

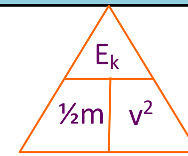
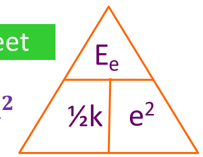
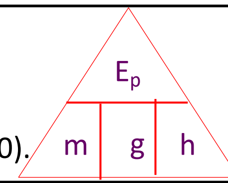
Disadvantages:
The way they affect the body is not fully understood (must be tested thoroughly), long term impacts on health are unknown, products should be clearly labelled so people are aware of nanoparticles.

Energy Stores

There are 8 stores we look at in this topic:

1. Types of energy store

Energy is a means of working out if it is possible for something to happen.
This means each store is linked to a calculation

Energy Store	Definition	Examples
kinetic	The energy of any **moving object**. This can be calculated using: Learn $kinetic\ energy = \frac{1}{2} \times mass \times speed^2$ (J) (kg) (m/s)  	• A person running • Particles in a solid vibrating
thermal	**All** objects have internal energy (the sum of the kinetic and potential energy of the particles. This can be calculated using: On Sheet $Thermal\ energy = mass \times specific\ heat\ capacity \times change\ in\ temperature$ (J) (kg) (J/kg°C) (°C)	• Hot tea or coffee • The human body
elastic potential	The energy stored when an object is **stretched/squashed**. This can be calculated using: On Sheet $Elastic\ potential\ energy = \frac{1}{2} \times spring\ constant \times extension^2$ (J) (N/m) (m)  	• Stretched elastic bands • Compressed springs
gravitational potential (g.p.e)	When an object is moved **higher**, it gains g.p.e. This can be calculated using: Learn $g.p.e = mass \times gravitational\ field\ strength \times height$ (J) (kg) (N/kg) (m) Gravitational field strength on Earth is always 9.8 m/s^2 (can be rounded to 10).  	• Aeroplanes • Skydivers • A mug on a table
electrostatic	The energy stored when two objects carrying **electrical charge** interact. These charged objects can exert forces on each other. You get an electric current when charged particles move through a wire.	• Thunderclouds • Van Der Graaf generators
magnetic	Some objects can be **magnetised** and create magnetic fields. They can exert forces on other magnetised objects, or on magnetic materials.	• Fridge magnets • Navigational compass
chemical	The energy stored in **chemical bonds** (e.g. between molecules). This is how energy is stored in food, and how animals store energy in their muscles.	• Food • Cells in muscles
atomic	The energy stored in the **nucleus of an atom**. It is described by Einstein's famous equation $E=mc^2$ where c is the speed of light.	• Radioactive materials • Stars

Energy Pathways

2. Types of energy transfer

There are 4 ways that energy can be transferred from one type of store to another. These are called pathways:

Heating by particles

Energy is transferred from a **hotter** object to a **cooler** one.

This can be done by **conduction**, **convection** or **radiation**.

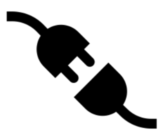
Mechanically working

Energy is transferred when something is **moved**.

Example: a person running

Electrically working

Energy is transferred when an **electrical circuit is complete**.



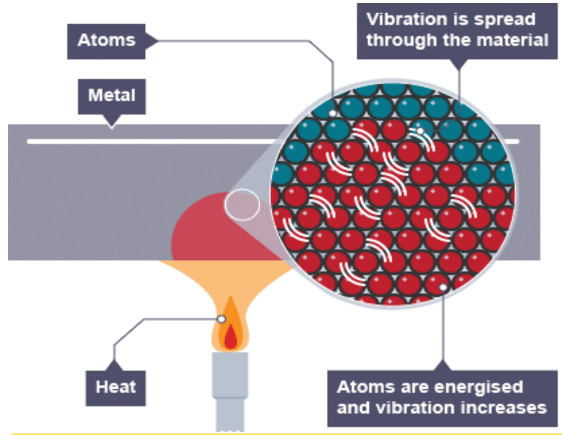
Heating by radiation

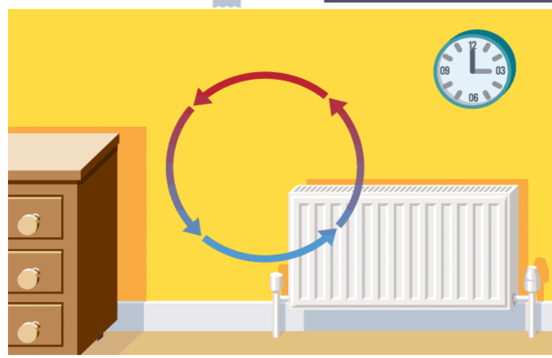
Energy is transferred as an **electromagnetic wave.**

Example: the Sun warms the Earth

3. Energy transfer in houses

Energy can be lost from your home through **conduction**, **convection** or **radiation**:





Conduction

- Happens in **solids**.
- When the internal energy store is filled up, the particles move more vigorously. They **bump into particles around them** and pass internal energy through the solid. If the material has **delocalised electrons** this process is faster.
- A material that lets heat pass through it **easily** has good thermal conductivity. Therefore it is called a **conductor** (e.g. metal). A material that **doesn't** is called an **insulator** (e.g. plastic).

Example: if a metal pan is heated from underneath; the handle will eventually become hot.

Convection

- Happens in **liquids/gases** (fluids).
- These particles can move around, so the particles that have more internal energy **take the place** of the less energetic particles.
- In a liquid, the energetic particles rise to the **top** and the less energetic particles sink to the **bottom**.

Examples: radiators, hot air balloons

Radiation

- Energy is transferred as an **electromagnetic wave**.
- There are **no particles** involved.

Examples: radiators giving out heat.

Heat energy is lost through roofs, windows, walls, floors and through gaps around windows and doors. However, there are ways that these losses can be reduced. Ways to reduce heat transfer:

- **Fitting carpets** (conduction), **curtains**, **draught excluders** (convection) and **reflective foil** in the walls or on them (radiation).
- **double glazing** has a **vacuum** to reduce heat transfer (conduction and convection).
- **cavity wall insulation** (conduction and convection).
- **loft insulation** (conduction and convection).

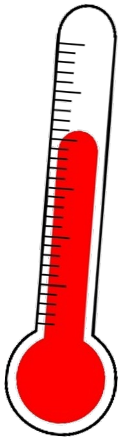
4. Thermal equilibrium

If there is a difference in temperature between 2 objects, **energy is transferred** from the hotter object to the cooler one.

When they are both the same temperature, they are in **thermal equilibrium**.

Energy Calculations

5. Heat and temperature



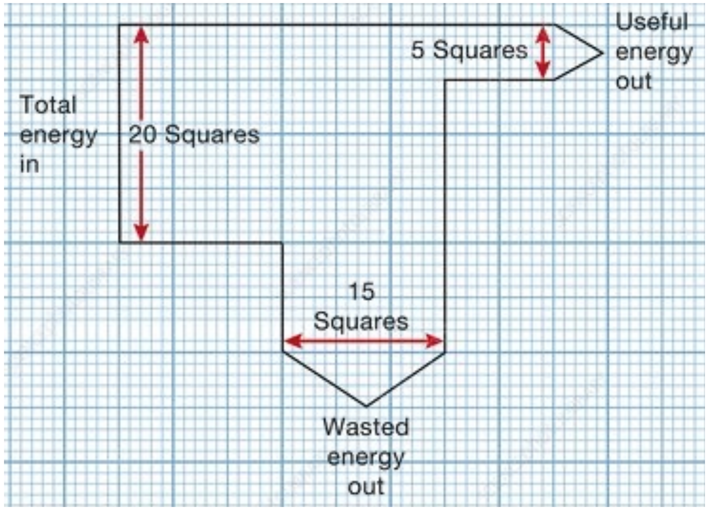
- Temperature is a measure of the **average kinetic energy per particle in a substance.**
- We use a **thermometer** to measure temperature in degrees Celsius (**ºC**).
- When the **kinetic energy** of a substance increases, the temperature does as well.
- As a material changes state the potential energy per particle increases, not the kinetic energy, so the temperature remains constant.

6. Conservation of energy

Conservation of energy rule: energy cannot be created or destroyed, only stored or transferred.

This means that the **total energy of a closed system is always the same**. The energy can be in a different form, but there is always the **same amount**.

We can draw **Sankey diagrams** to demonstrate the conservation of energy:



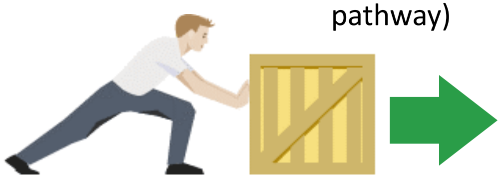
We can use these diagrams to calculate the **efficiency** of something:

$$efficiency = \frac{useful\ energy\ output}{total\ energy\ input} \times 100$$

Learn

7. Work Done

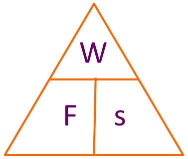
(Mechanically working pathway)



- When a force causes something to move, we say that **work is being done** on the object.
- Work is the measure of **how much energy has been transferred, in Joules (J).**
- We can calculate work done using:

$$work\ done = force \times displacement$$

Learn (J) (N) (m)



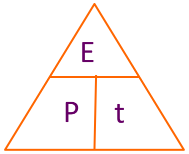
- Work done is **the same** as the energy transferred to the moving object.
- The direction of the force and the displacement must be parallel, or no work is done.

8. Power

- Power is the **rate at which energy is transferred, or the energy per unit of time**
- Power is measured in **Watts (W).** **1 Watt = 1 Joule per second**
- Energy used in the home is measured in **kilowatt hours (kWh),** and can be calculated using:

$$energy\ used = power \times time$$

Learn (kWh) (kW) (h)



- You can calculate the **cost of energy** using:

$$cost = energy\ used\ (in\ kWh) \times cost\ per\ kWh$$

Energy Resources

Humans can generate energy in lots of different ways.
An energy resource has high energy density.
All energy resources are **renewable**, except for **fossil fuels and nuclear power**.
A renewable resource is one that can be replenished as it is used.

Energy Resource	Positives	Negatives
Fossil Fuels (Coal, Oil and Gas)	✓ Relatively cheap fuel ✓ Infrastructure already exists	✗ Releases carbon dioxide (greenhouse gas) ✗ Releases sulphur dioxide, which causes acid rain ✗ Finite resource
Nuclear	✓ Doesn't produce greenhouse gases ✓ Very high energy density	✗ Radioactive material could be released into the environment ✗ Expensive to store safely (nuclear waste remains dangerous for a long time) ✗ Finite resource
Wind	✓ No fuel costs ✓ Doesn't produce any harmful chemicals ✓ Wind energy is available all over the world	✗ Noise pollution ✗ Visual pollution ✗ Unreliable (depends on the wind)
Wave	✓ No fuel costs ✓ Doesn't produce any harmful chemicals ✓ Low-lying, so little visual pollution	✗ Unreliable (depends on the waves) ✗ Difficult for wave machines to produce large amounts of electricity ✗ Limited suitable sites
Tidal	✓ Very reliable (tides are predictable) ✓ No fuel costs ✓ Doesn't produce any harmful chemicals	✗ Can destroy the habitats of estuary species (e.g. wading birds) ✗ Only produces energy for about 10 hours a day ✗ Affects shipping trying to navigate estuaries
Hydroelectric	✓ Very reliable and quick to start ✓ No fuel costs ✓ Doesn't produce any harmful chemicals	✗ Dams create reservoirs, which can force people/local wildlife to relocate ✗ The vegetation underwater releases methane (a greenhouse gas) ✗ Fast flowing rivers are needed, so limited sties available
Geothermal	✓ Hot water/steam can be used to directly heat buildings ✓ No fuel costs ✓ Doesn't produce any harmful chemicals	✗ Most parts of the world do not have suitable areas where geothermal energy can be exploited ✗ Hazardous gases and minerals may be release (difficult to dispose of safely)
Solar	✓ No fuel costs ✓ Doesn't produce any harmful chemicals ✓ Solar energy is available all over the world	✗ Very expensive ✗ Not very efficient ✗ Unreliable (depends on amount of sunlight)
Bioenergy	✓ Carbon neutral ✓ Can be stored for when it is needed ✓ Available all over the world	✗ Burning fuels (e.g. rubbish) causes some air pollution/greenhouse gases ✗ Growing biofuels uses land that could be used for food crops ✗ Materials for fuels are bulky, so have high transport costs

Bioenergetics

Photosynthesis

- Photosynthesis is a chemical reaction which takes place in plants. It converts **carbon dioxide** and **water** into **glucose** and **oxygen.** It uses light energy to power the reaction which is absorbed by green **chlorophyll.** Because it absorbs energy, it is an **endothermic** reaction.
- The whole reaction occurs inside **chloroplasts** in plant cells.
- Photosynthesis can be represented by the following word and balanced symbol equations

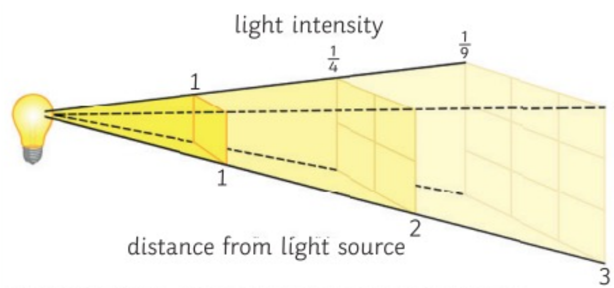
$$\text{carbon dioxide} + \text{water} \xrightarrow{\text{light}} \text{glucose} + \text{oxygen}$$

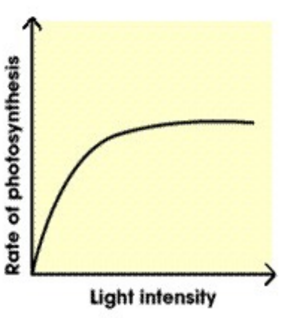
$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

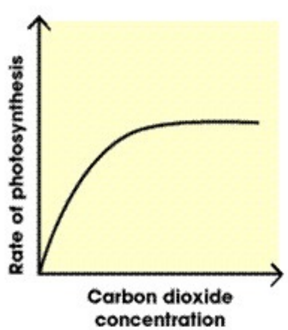
The inverse square law – *[Higher tier]*

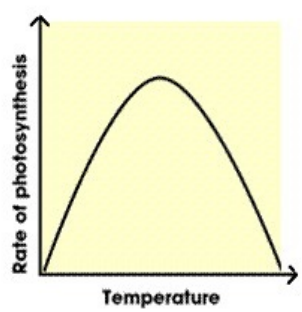
- The inverse square law is used to describe light intensity at different distances from the source. It states that: **the intensity of the light is inversely proportional to the square of the distance from the source.**
- Light intensity is proportional to $1/\text{distance}^2$
- E.g. if the light source is 0.25m away, the light intensity will be $1/\text{distance}^2$

So 1/0.0625 = 16 arbitrary units



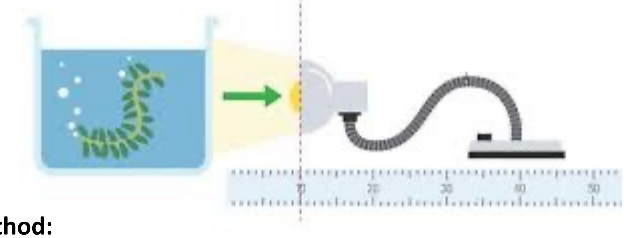






The Rate of Photosynthesis Required Practical

- The rate of photosynthesis can be measured by monitoring the rate that oxygen is produced by plants. To do this we can count bubbles produced by water plants or measure the volume of oxygen produced



Method:

1.Set up a boiling tube containing 45 cm^3 of sodium hydrogencarbonate solution (1%). Allow the tube to stand for a few minutes and shake to disperse any air bubbles that might form.

2.Cut a piece of the pondweed, *Cabomba*. The pondweed should be 8 cm long.

3.Use forceps to place the pondweed in the boiling tube carefully. Make sure that you don't damage the pondweed, or cause the liquid to overflow.

4.Position the boiling tube so that the pondweed is 10 cm away from the light source. Allow the boiling tube to stand for five minutes. Count the number of bubbles emerging from the cut end of the stems in one minute. Repeat the count five times and record your results.

5.Calculate the mean number of bubbles produced per minute. Repeat the experiment at different distances away from the light source.

- Independent variable – distance from the light source/light intensity.
- Dependent variable – the number of bubbles produced per minute.
- Control variables – concentration of sodium hydrogencarbonate solution, temperature, using the same piece of *Cabomba* pondweed each time.

Limiting Factors

- The rate of photosynthesis is affected by water, temperature, light intensity, carbon dioxide concentration and the amount of chlorophyll. These are referred to as **limiting factors** as if one is in short supply, it will limit the rate of reaction.
- Increasing the light intensity or carbon dioxide concentration increases the rate of photosynthesis but does not do so indefinitely. The rate of photosynthesis will stop increasing as another limiting factor is in short supply.
- Increasing the temperature increases the rate of photosynthesis until an optimum temperature is reached. Before the optimum temperature is reached the rate of photosynthesis is slowed by the particles involved in the chemical reaction, moving slowly. Above the optimum temperature the rate of photosynthesis decreases due to the denaturing of enzymes that act as catalyst for the reaction.

Bioenergetics

Aerobic Respiration
- Cellular respiration is a chemical reaction that takes place in the **mitochondria** of cells of all living organisms in order to release energy from glucose.
- The energy released is used for movement, warmth and building larger molecules for growth and repair.
- Respiration releases energy so it is **exothermic.**
- Respiration can be either aerobic (using oxygen) or anaerobic (without oxygen)
- Aerobic respiration can be represented by the following word and balanced symbol equations :

glucose + oxygen ➔ carbon dioxide + water (+ energy)

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

Anaerobic Respiration
- Anaerobic respiration in animal cells can be represented by the following word equation:

glucose ➔ lactic acid (+ energy)

- Anaerobic respiration is far less efficient than aerobic respiration, because of the incomplete oxidation of glucose, and so releases much less energy.
- Anaerobic respiration in plant and yeast cells can be represented by the following word equation:

glucose ➔ ethanol + carbon dioxide (+ energy)

- The products of anaerobic respiration in plant and yeast cells can be used for baking (carbon dioxide cause bread dough to rise) and producing alcohol (used in alcoholic drinks and biofuels).
- Anaerobic respiration occurs in the cytoplasm of cells, rather than in mitochondria.

Oxygen Debt
- When a period of exercise is over, lactic acid must be removed. The body's tolerance of lactic acid is limited.
- Lactic acid is taken to the liver by the blood, and either:
  - ➢ oxidised to carbon dioxide and water, or
  - ➢ converted to glucose, then glycogen - glycogen levels in the liver and muscles can then be restored.
- These processes require oxygen. This is why, when the period of activity is over, a person's breathing rate and heart rate do not return to normal straightaway.
- The amount of oxygen required to remove the lactic acid, and replace the body's reserves of oxygen, is called the **oxygen debt**.

Response to Exercise
- When we exercise there is an increased demand for energy. To release this energy there is an increase rate of cellular respiration
- The increased rate of cellular respiration requires an increase in oxygen and glucose to be delivered to cells.
- To increase the oxygen in the body available for cellular respiration the body increases heart rate (to increase blood flow in order to transport oxygen and glucose), breathing rate and breath volume (to increase the intake of oxygen)
- If insufficient oxygen is supplied anaerobic respiration will take place
- Incomplete oxidation of glucose causes a build-up of lactic acid and creates an oxygen debt

Metabolism
- Metabolism is the sum of all the chemical reactions in a cell or in the body.
- The energy transferred by cellular respiration in cells is to make new molecules.
- Important factors contributing to an organism's metabolism include reactions such as:
  - ➢ Starch, glycogen and cellulose produced by converting glucose
  - ➢ Lipid molecules produced from fatty acids and glycerol
  - ➢ Proteins synthesised from glucose and nitrate ions
  - ➢ Respiration
  - ➢ The breakdown of proteins to form urea.

Uses of Glucose in Plants
The glucose produced by photosynthesis can be used for:
- Respiration (a chemical reaction that releases the energy stored in glucose)
- Converted to insoluble starch for storage
- To produce fats and oils for energy storage (especially in seeds)
- To produce cellulose that strengthens cell walls
- To combine with nitrate ions (NO_3^-) that are absorbed from the soil to produce amino acids for protein synthesis.

Greenhouse Economics – *[Higher tier]*
- A greenhouse creates the most suitable conditions for growing plants.
- Artificial lighting can provide light in darker winter days
- A paraffin heater provides extra warmth and carbon dioxide is given off in combustion.
- These additions can be expensive, but the cost is often outweighed by the additional yield of the crop.

The rate and extent of chemical change

Calculating rates of reaction

- Chemicals used in a reaction are called reactants.
- Chemicals formed in a reaction are called products.
- The quantity of reactant or product can be measured by mass in grams, volume in cm^3 or moles (mol) *[HT only].*
- How fast a chemical reaction proceeds is referred as a reaction's rate
- The equations for calculating rate are:

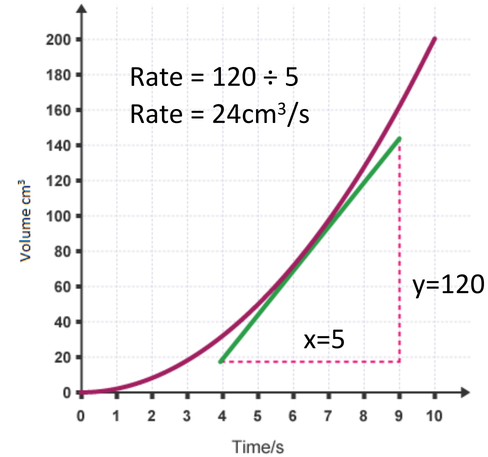
  mean rate of reaction = quantity of reactant used ÷ time taken

  mean rate of reaction = quantity product formed ÷ time taken
- The units for mean rate of reaction can be g/s or cm^3/s.
- To calculate the mean rate of reaction in an experiment where a colour change is timed the following equation is used:

  mean rate of reaction = 1 ÷ time taken

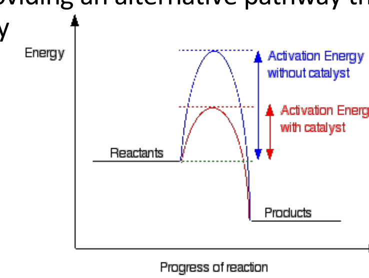
Calculating the rate of reaction from a graph

- Draw a tangent – this is a straight line that touches a curved surface at a single point but does not cross the curve at any point
- Complete a triangle using your tangent
- Use you scale to calculate the width and height of your graph (x & y)
- Calculate the rate of reaction by diving the height by the width of the triangle.
- The rate of the reaction is the same as the gradient of the graph (or tangent).



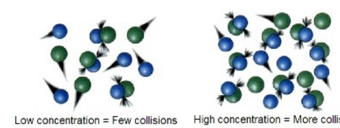
Catalysts

- Catalysts can be added to a reaction to change the rate of reaction
- Catalysts are not used up by the reaction and do not change the products of the reaction
- Different reactions need different catalysts
- Enzymes act as catalyst in biological systems
- Catalysts increase the rate of reaction by providing an alternative pathway that requires a lower amount of activation energy

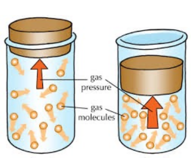


Collision theory and activation energy

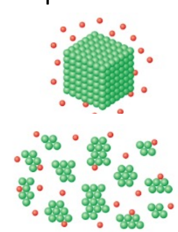
- Chemical reactions occur when particles of the reactants collide with sufficient energy
- The energy needed for a chemical reaction to occur is called the activation energy
- Increasing the concentration of a reactant increases the number of particles present. If more particles are present, then there will be more collisions. If there are more collisions, then the rate of reaction will be greater.



- Increasing the pressure of gases can be achieved in different ways Firstly, increasing the amount of a gas in a container, secondly, decreasing the size of the container and thirdly, by heating up the particles. All of these methods will increase the pressure by increasing the number of collisions with the container. The particles themselves will also collide more often. This will lead to a greater rate of reaction.



- Cutting solid reactants into smaller pieces increase the surface area to volume ratio. Increasing the surface area of solids by cutting solids into smaller pieces reveals more particles of the solid. This increases the number of particles colliding. The greater the number particles colliding the greater the rate of reaction.



- Increasing the temperature increases the particles kinetic energy. If particles have more energy they move faster. If particles are moving faster, they are more likely to collide and will also collide more energetically. This increases the rate of reaction.

Calculating surface area to volume ratio

Calculate the surface area of the reactant (area of 1 side x number of sides).
Calculate the volume of the reactant (length x width x height).
Calculating a ratio using the surface area and volume, e.g.
Surface area = $10cm^2$:Volume= $2cm^3$
Ratio= 5:1

The rate and extent of chemical change

Reversible reactions

- In some reactions the products of the reaction can react to form the original reactants.
- We show reversible reactions by using the ⇌ symbol.
- We can change the direction of a reversible reaction by changing the conditions of the reaction.

$$A + B \rightleftharpoons C + D$$

This shows that the reactants A and B react to form products C and D. The example also shows that the products C and D react together to form the reactants A and B.

Equilibrium

- If a reversible reaction takes place in a sealed container (one that prevents the escape of reactants or products) it will reach equilibrium when the rate of the forward and reverse reaction is equal.

The effect of changing conditions on equilibrium

- Changing the conditions of a reaction that has reached equilibrium will cause the reaction to respond and counteract the change.
- The conditions that can be changed are temperature, pressure, and concentration.

Changing concentration

- If the concentration of one of the reactants or products is changed then the reaction will no longer be at equilibrium.
- If a reaction is no longer at equilibrium the concentrations of all the substances involved in the reaction will change until a new equilibrium is found.
- If the concentration of a reactant is increased more products will be formed until a new equilibrium is reached.
- If the concentration of a product is increased more reactants will be formed until a new equilibrium is reached.

Energy changes and reversible reactions

- If a reversible reaction is exothermic in one direction it is endothermic in the opposite direction. The same amount of energy is transferred in each case.

$$A + B \underset{\textit{Endo}}{\overset{\textit{Exothermic}}{\rightleftharpoons}} C + D$$

- In this example the reaction is exothermic (releases heat energy/gets hotter) when A and B react to form C and D. The reaction is endothermic (takes in heat energy/gets colder) when C and D react to form A and B.

Changing temperature

- If we increase the temperature the reaction will move in the endothermic direction.
- If we decrease the temperature the reaction will move in the exothermic direction.

$$A + B \underset{\textit{Endo}}{\overset{\textit{Exothermic}}{\rightleftharpoons}} C + D$$

- In this example we will make more of A and B if we increase the temperature. We can say that the reaction moves in the endothermic direction.
- We will make more of C and D if we decrease the temperature. We can say that the reaction moves in the endothermic direction.
- If we decrease the temperature too much the rate of reaction will be very slow (see collision theory & activation energy). To prevent this from happening scientists often have to <u>compromise</u> by reducing the temperature to a point where the rate of reaction is still suitable.

Changing pressure

$$N_{2\,(g)} + 3H_{2\,(g)} \rightarrow 2NH_{3\,(g)}$$

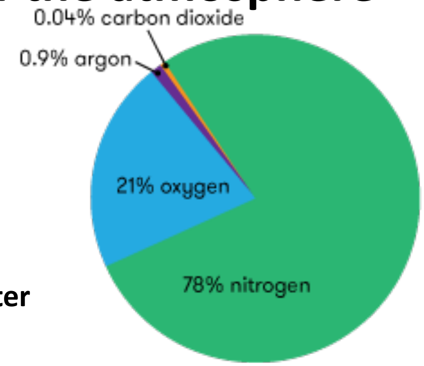
- If we increase the pressure in a reaction involving gases the reaction will move to the side with the fewest molecules of gas. In this example there are only two molecules of NH_3 so the reaction will move to the right.
- If we decrease the pressure in a reaction involving gases the reaction will move to the side with the most molecules of gas. In this example there is one molecule of N_2 and three molecules of H_2 (four in total) so the reaction would move to the left.

Chemistry of the Atmosphere – Composition and Evolution

1 (a). Composition of the atmosphere

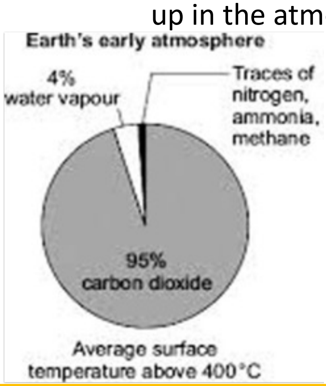
For the last **200 million years**, the composition of the atmosphere has been **much the same**:

- 78% **nitrogen**
- 21% **oxygen**
- Small amounts of other gases (including **carbon dioxide, water vapour and noble gases**)



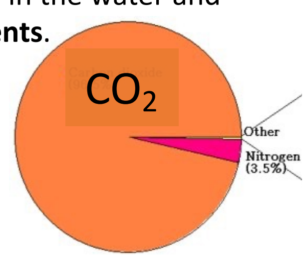
1 (b). The early atmosphere

- When the Earth first formed **4.6 billion** years ago, the atmosphere was very different.
- We **cannot be certain** what the early atmosphere was like as it happened a very long time ago, but scientists have a **theory** that is widely accepted:
    1. During the first **billion years**, there was lots of **volcanic activity**, which released gases that formed the atmosphere.
    2. These gases consisted mainly of **carbon dioxide** and **water vapour** (which condensed to become the **oceans**).
    3. The volcanoes also produced **nitrogen** which gradually built up in the atmosphere.



4. When the oceans formed, the carbon dioxide **dissolved** in the water and produced **sediments**.

The early atmosphere was very similar to that of **Mars and Venus today**.



2. Evolution of the atmosphere

As the Earth evolved, the atmosphere changed. The amount of **oxygen increased** and **carbon dioxide decreased:**

How oxygen increased

- Plants make their own food through **photosynthesis**:

$$6CO_2 + 6H_2O \xrightarrow{\text{light}} C_6H_{12}O_6 + 6O_2$$

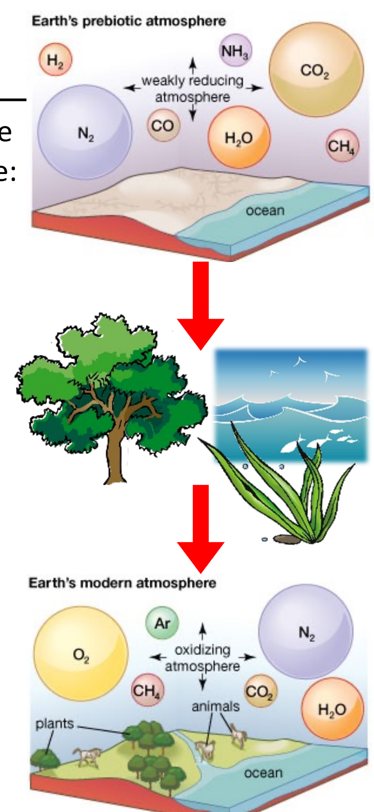
carbon dioxide + water → (light) glucose + oxygen

- Algae first produced oxygen about **2.7 billion years ago**.
- Over the next billion years, plants **evolved** and the percentage of oxygen in the atmosphere **increased** to a level that allowed animals to **evolve**.

How carbon dioxide decreased

There are 3 ways in which carbon dioxide was removed from the early atmosphere:

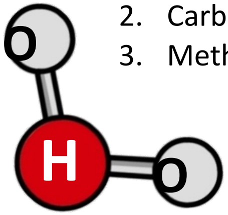
1. When the oceans formed, carbon dioxide **dissolved** into the water and formed **soluble carbonates.** These were then **precipitated** as **sedimentary rocks** (e.g. limestone).
2. Carbon dioxide dissolved in the oceans was also **absorbed by algae** for photosynthesis.
3. Carbon dioxide was **absorbed by plants**, which then **died**. Some of these became **fossil fuels** (coal, oil and gas) which contain carbon. Compression and heating over millions of years formed **trees into coal**, and **plants/small organisms into oil/natural gas.**

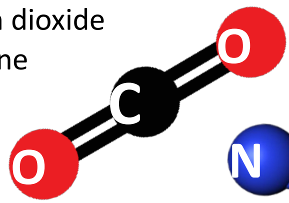


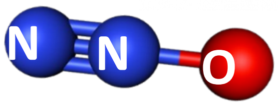
Chemistry of the Atmosphere – Greenhouse Gases

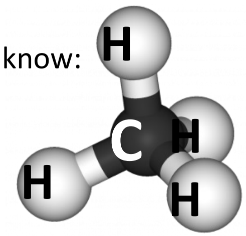
3 (a). Greenhouse gases

- Greenhouse gases are gases in the atmosphere that **increase the temperature of the Earth**. They make the Earth warm enough to **support life**.
- There are 3 greenhouse gases you need to know:
    1. Water vapour
    2. Carbon dioxide
    3. Methane









3 (b). The greenhouse effect

The greenhouse effect is how the Earth is warmed by greenhouse gases. **How it works:**

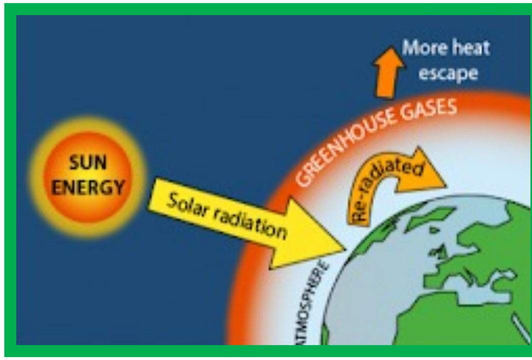
1. Electromagnetic radiation passes through the Earth's atmosphere.
2. The Earth **absorbs** most of the radiation and **heats up**.
3. The Earth **emits infrared radiation**.
4. Some of the infrared radiation is transmitted into **space**.
5. Greenhouse gases **absorb** the infrared and **release energy** in all directions. This warms up the Earth's **lower atmosphere**.

- The **carbon footprint** of something is the **total amount of greenhouse gases it produces** during its lifetime.
- To calculate the carbon footprint of an **object** (e.g. a car), you have to consider the greenhouse gases released when:
    1. **mining and transporting the parts.**
    2. **generating electricity to power it.**
    3. **using** the object.
    4. the object is **disposed of/recycled**.
- To calculate the carbon footprint of a **person**, you have to consider the greenhouse gases released when:
    1. they use **electricity/boilers at home**.
    2. they **use transport** (e.g. cars, planes).
    3. they eat **beef or rice** (releases methane).

It can be **difficult** to reduce your carbon footprint (e.g. if you are too far away from work to cycle/walk).

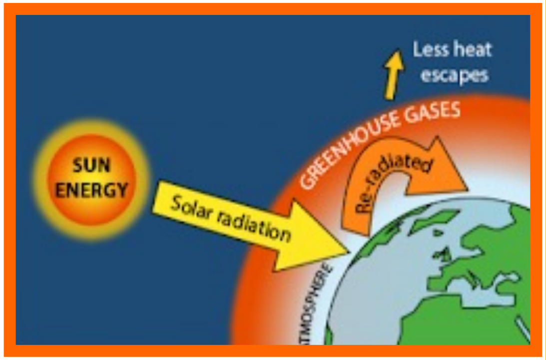
Natural Greenhouse Effect

- This is the emission of greenhouse gases through **natural causes.**
- **Carbon dioxide** is produced through **respiration** of animals and **volcanic activity**.
- **Methane** is produced through the **formation of coal** and **decomposition** (usually in wetlands).



Enhanced Greenhouse Effect

- This is **overproduction** of greenhouse gases due to **human activities**.
- **Carbon dioxide** is released through **deforestation** and the **burning of fossil fuels** (coal, oil, and gas).
- **Methane** is released through the **decomposition of landfills**, **burning biomass** and **digestive emissions** from cattle.
- **Nitrous oxides** are released through **car exhaust fumes** and **fertilisers** used on farms.

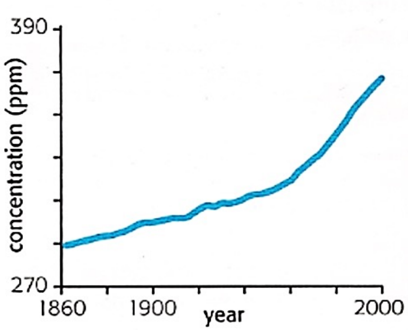


Chemistry of the Atmosphere – Climate Change and Pollution

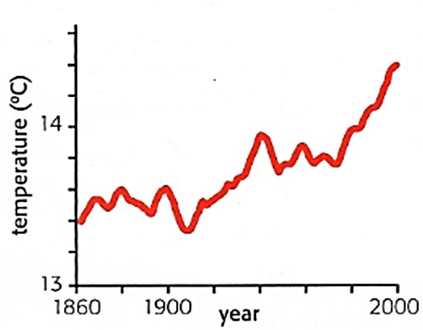
4. Climate change

- **Global warming** describes how the Earth's temperature has risen in the past 200 years.
- **Climate change** is the long-term alteration of the Earth's climate.
- Based on **peer-reviewed evidence**, most scientists believe that human activities will result in **global climate change** due to the Earth getting warmer.
- However, this is **difficult to model**, which leads to lots of speculation and opinion in the media that may be **biased**.
- The main evidence that humans are causing climate change is the **strong correlation** between the **rise of CO_2 levels** due to human activities and the **rise in global temperature:**

Carbon dioxide in the atmosphere



Average global temperature



When evaluating the **quality of evidence** on an issue like climate change, you should consider:

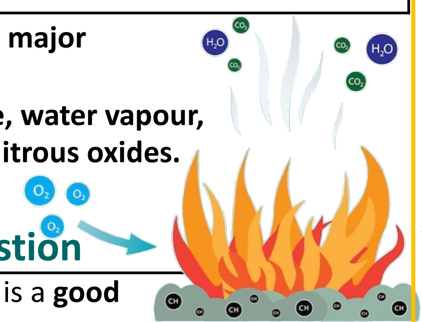
- Who **did** the research.
- Who **funded** the research.
- What **methods were used** to collect and analyse the data.
- Which **organisation** is reporting/publishing the evidence.

5. Pollutants and their sources

Pollutant	Source	Effect
carbon dioxide (CO_2)	Complete combustion	Greenhouse gas
carbon monoxide (CO)	Incomplete combustion	Poisonous, odourless and colourless gas
soot (C)	Incomplete combustion	Irritates lining of the lungs, can cause cancer, global dimming
unburned hydrocarbons	Hydrocarbon fuel molecules which have not been oxidised	Reacts with other pollutants to create ozone (in smog), global dimming
sulphur dioxide (SO_2)	Combustion of fuel that contains sulphur	Causes acid rain, which harms the environment
nitrogen oxides (NO_x)	Inside vehicle engines	Causes acid rain and smog (harmful to health)

- **Combustion** is the burning of fuels. It is a **major contribution** to atmospheric **pollutants**.
- Burning fuels may release **carbon dioxide, water vapour, carbon monoxide, sulphur dioxide** and **nitrous oxides.**

There are 2 types of combustion:



Incomplete Combustion

- Happens when there is a **poor supply of oxygen.**
- Releases **less** energy.
- Can produce **carbon monoxide** and/or **soot** (carbon particles) instead of carbon dioxide.

Example:

$$2C_2H_6 + 5O_2 \rightarrow 4CO + 6H_2O$$

ethane + oxygen → carbon monoxide + water

Complete Combustion

- Happens when there is a **good supply of oxygen.**
- Releases the **maximum** amount of energy.
- Produces **carbon dioxide** and **water**.

Example:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

methane + oxygen → carbon dioxide + water