Health & Immunity Revision

Nutrients

A mixture of different types of food in the correct amounts is needed to maintain health.

The main food groups are carbohydrates, fats and proteins. Mineral ions and vitamins are also important in a healthy diet. They are needed in small amounts for healthy functioning of the body.

Imbalanced diets

An imbalanced diet causes a person to become malnourished. For example:

- too little food may lead to a person being underweight
- too much food may lead to a person being overweight.

A poor diet may also lead to deficiency diseases. For example, too little vitamin D in the diet can lead to rickets, which affects the proper growth of the skeleton. Type 2 diabetes is also a problem related to poor diet.

Metabolic rate

Respiration is a chemical reaction that allows cells to release energy from food. The metabolic rate is the speed at which such chemical reactions take place in the body and varies because of several factors, including age, gender and inherited factors.

Metabolic rate is also affected by the:

•proportion of muscle to fat in the body

•amount of exercise and other physical activity..

Viruses

Viruses are many times smaller than bacteria. They are among the smallest organisms known and consist of a fragment of genetic material inside a protective protein coat. Viruses can only reproduce inside host cells and they damage the cell when they do this.

Bacteria

Bacteria are microscopic organisms. They come in many shapes and sizes, but even the largest are only 10 micrometres long - 10 millionths of a metre. Bacteria are living cells and, in favourable conditions, can multiply rapidly. Once inside the body, they release poisons or toxins that make us feel ill.

Fungi

Larger fungi include moulds and mushrooms. Microscopic fungi can cause diseases such as athlete's foot.

White blood cells

White blood cells can:

- engulf pathogens and destroy them
- produce antibodies to destroy pathogens
- produce antitoxins that neutralise the toxins released by pathogens

Immunisation

People can be immunised against a pathogen through vaccination. Different vaccines are needed for different *pathogens*.

Vaccination involves putting a small amount of an inactive form of a pathogen, or dead pathogen, into the body. Vaccines can contain:

•live pathogens treated to make them harmless

•harmless fragments of the pathogen

•*toxins* produced by pathogens

•dead pathogens

Antibodies combine chemically with substances which the body recognizes as alien, such as bacteria, viruses, and foreign substances in the blood.

The Heart & Blood

The circulatory system consists of:

- a system of tubes (arteries, capillaries and veins)
- a pump (the heart)
- valves to ensure a one-way flow of blood

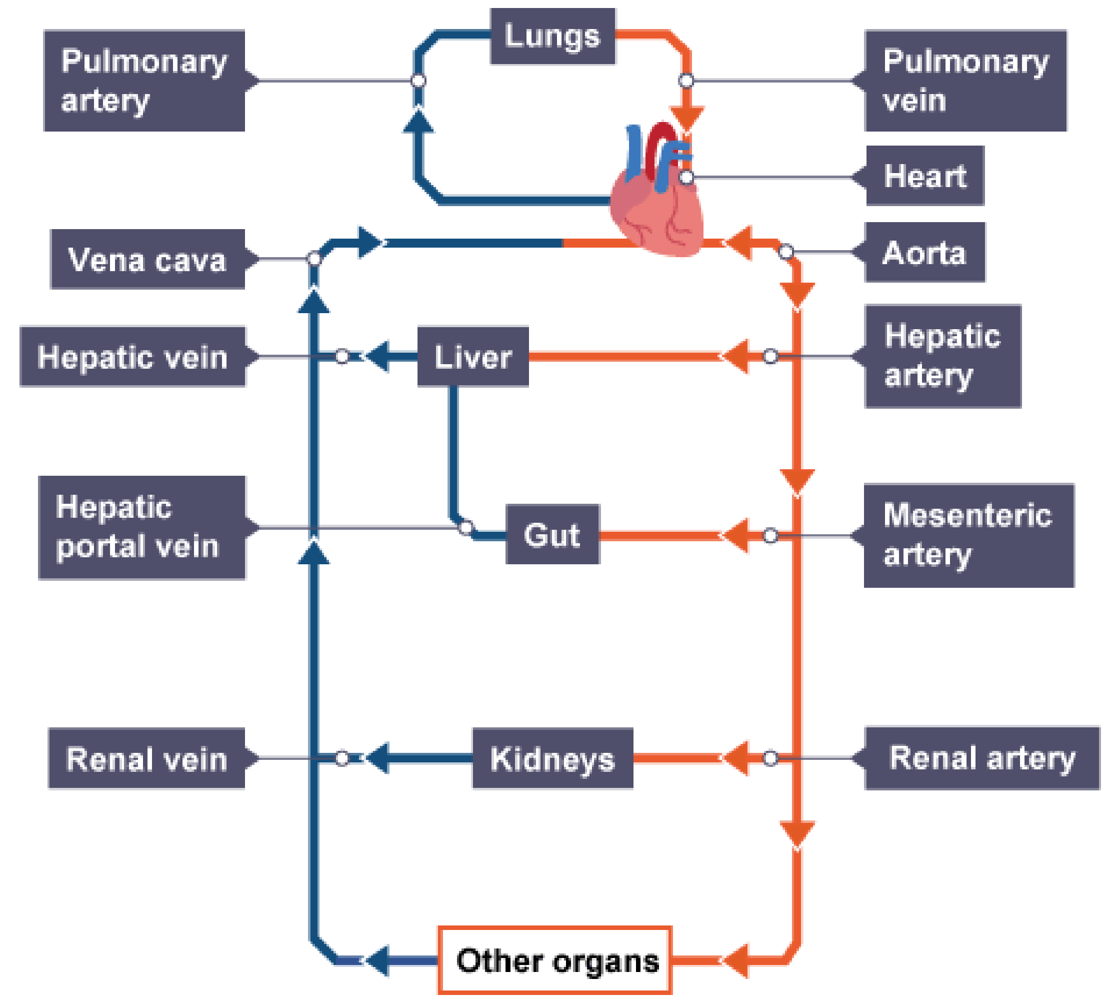
Arteries and veins

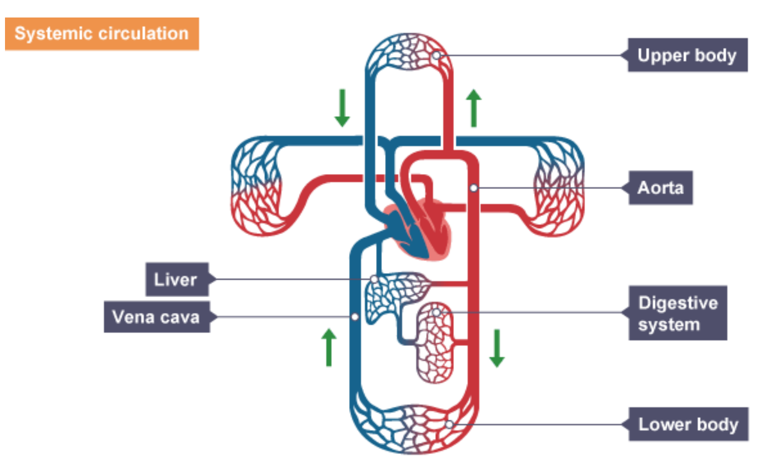
Arteries carry blood away from the heart towards an organ, while veins carry blood from an organ towards the heart.

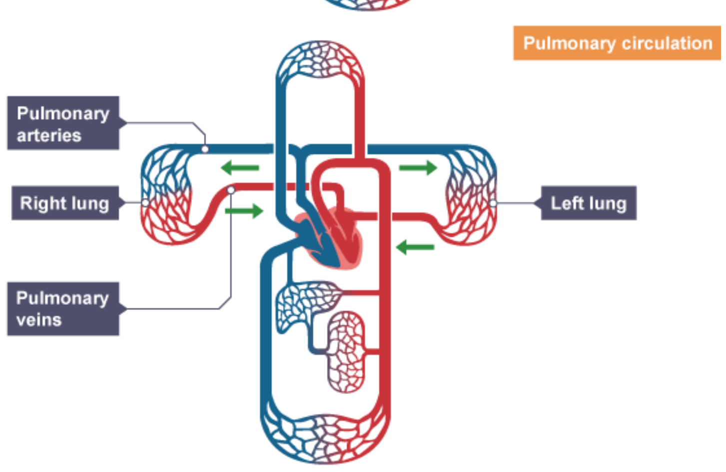
The human circulatory system is a **double circulatory system**. It has two separate circuits and blood passes through the heart twice:

•the **pulmonary circuit** is between the heart and lungs

•the **systemic circuit** is between the heart and the other organs







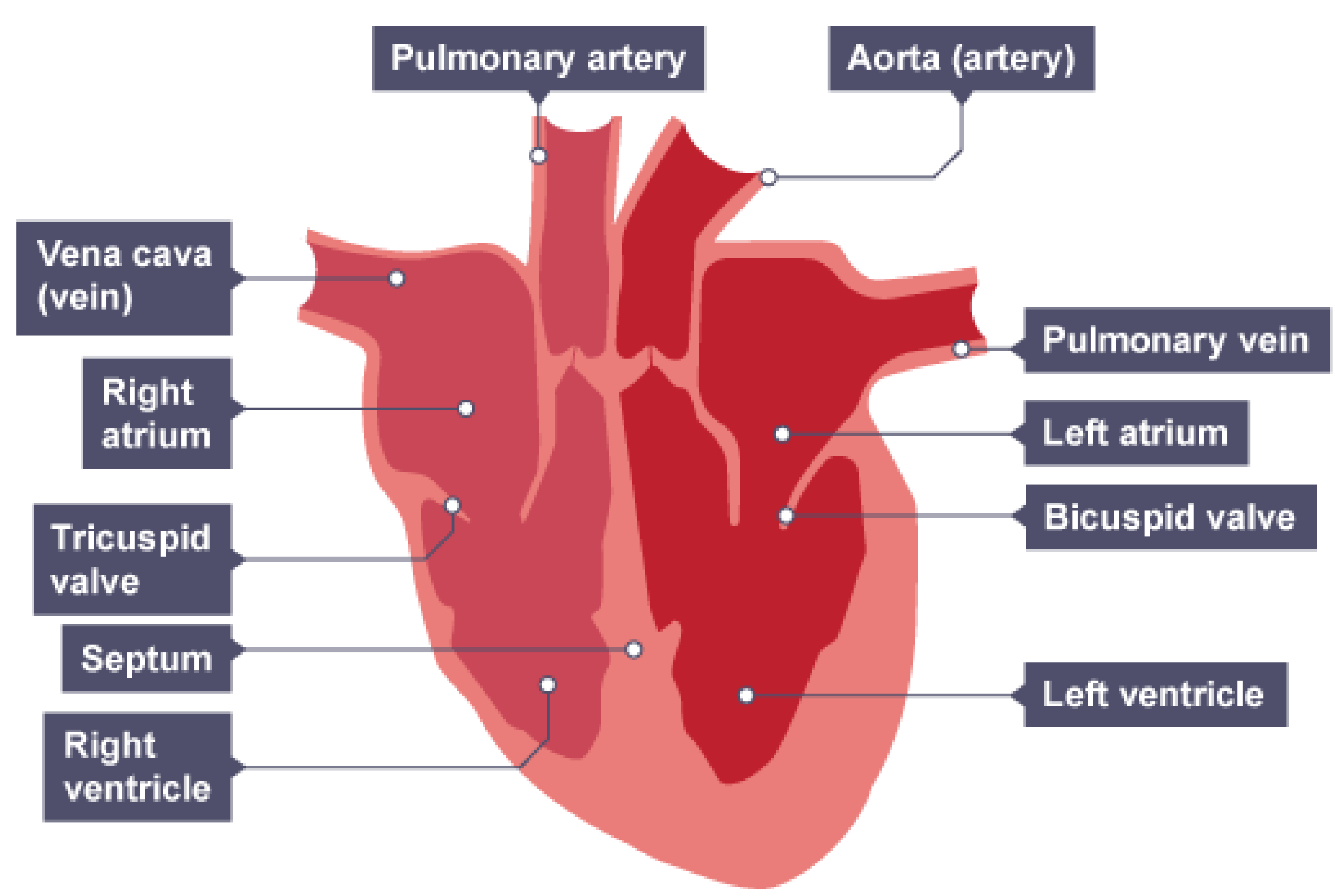
Pulmonary circuit

The pulmonary circuit transports blood to the lungs. The blood is oxygenated there and then carried back to the heart. Gaseous exchange happens in the lungs:

- carbon dioxide diffuses from the blood into the air in the alveoli
- oxygen diffuses from the air in the alveoli into the blood, and is absorbed by haemoglobin in the red blood cells

Systemic circuit

The systemic circuit transports blood around the body. It transports oxygen and nutrients to the body tissues, and carries away deoxygenated blood containing carbon dioxide and other waste materials.



Arteries

- Carry blood away from the heart (always oxygenated apart from the pulmonary artery which goes from the heart to the lungs).
- Have thick muscular walls.
- Have small passageways for blood (internal lumen).
- Contain blood under high pressure.

Veins

- Carry blood to the heart Have thin walls.
- Have larger passageways for blood (internal lumen).
- Contain blood under low pressure.
- Have valves to prevent blood flowing backwards.

Capillaries

- Found in the muscles and lungs.
- Microscopic – one cell thick.
- Very low blood pressure.

The heart is a muscular organ. Its function is to pump blood. The right side pumps blood through the pulmonary circuit, while the left side pumps blood through the systemic circuit.

A septum separates the right and left sides. The left side has thicker walls because it needs to put the blood under higher pressure than the right side.

The Periodic Table

Newlands' octaves

- An English scientist called John Newlands put forward his Law of Octaves in 1864. He arranged all the elements known at the time into a table in order of relative atomic mass.
- When he did this, he found a pattern among the early elements. The pattern showed that each element was similar to the element eight places ahead of it.
- For example, starting at Li (lithium), Be (beryllium) is the second element, B (boron) is the third and Na (sodium) is the eighth element. He then put the similar elements into vertical columns, known as groups.

Mendeleev's periodic table

In 1869, just five years after John Newlands put forward his Law of Octaves, a Russian chemist called Dmitri Mendeleev published a periodic table.
Mendeleev also arranged the elements known at the time in order of relative atomic mass, but he did some other things that made his table much more successful.
He realised that the physical and chemical properties of elements were related to their atomic mass in a repeating or 'periodic' way, and arranged them so that groups of elements with similar properties fell into vertical columns in his table.

Gaps and predictions

Sometimes this method of arranging elements meant there were gaps in his horizontal rows or 'periods'. But instead of seeing this as a problem, Mendeleev thought it simply meant that the elements which belonged in the gaps had not yet been discovered.
He was also able to work out the atomic mass of the missing elements, and so predict their properties. And when they were discovered, Mendeleev turned out to be right.

Newlands	Mendeleev
Ordered elements by atomic weight	Ordered elements by atomic weight
Included only the elements known at the time	Left gaps for elements he predicted would be discovered later
Maintained a strict order of atomic weights	Swapped the order of some elements if that fitted their properties better
Every eighth element had similar properties (Newlands' Law Of Octaves)	Elements in groups had similar properties
Was criticised by other scientists for grouping some elements with others when they were obviously very different to each other	Was seen as a curiosity to begin with, but then as a useful tool when the predicted elements were discovered later

H	Li	Be	B	C	N	O
F	Na	Mg	Al	Si	P	S
Cl	K	Ca	Cr	Ti	Mn	Fe

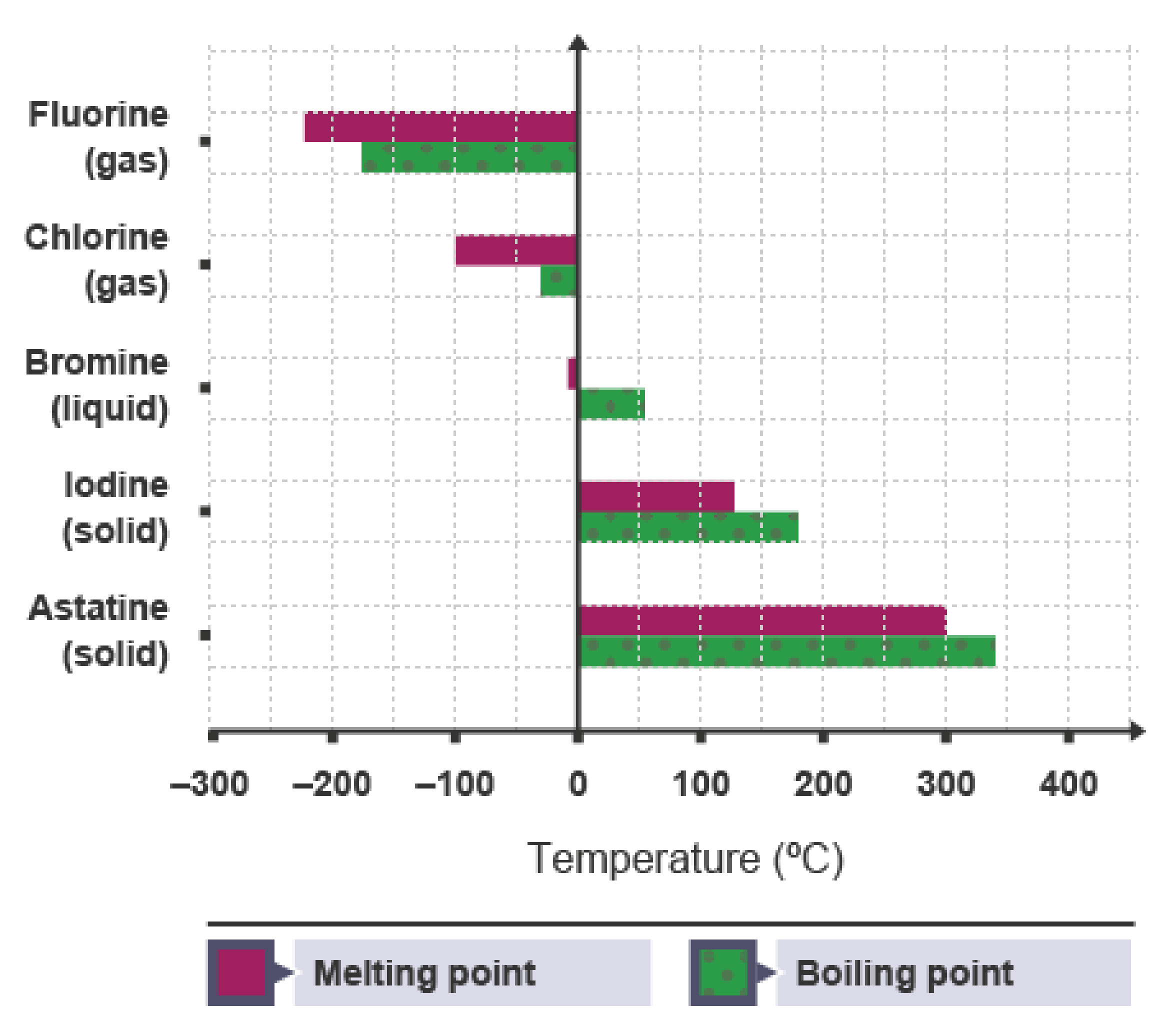
Regular repeats

Newlands' table showed a repeating or periodic pattern of properties, but this pattern eventually broke down.
By ordering strictly according to atomic mass, Newlands was forced to put some elements into groups which did not match their chemical properties. For example, he put iron (Fe), which is a metal, in the same group as oxygen (O) and sulfur (S), which are two non-metals.

The reactivity of Group 1 elements increases as you go down the group because:

- the atoms get larger as you go down the group
- the outer electron gets further from the nucleus as you go down the group
- the attraction between the nucleus and outer electron gets weaker as you go down the group - so the electron is more easily lost

Element	Properties	Typical use
Chlorine	Green gas	Sterilising water
Bromine	Orange liquid	Making pesticides and plastics
Iodine	Grey solid	Sterilising wounds



Making Salts

A salt is any compound formed by the neutralisation of an acid by a base.

The name of a salt has two parts. The first part comes from the metal, metal oxide or metal carbonate. The second part comes from the acid.

You can always work out the name of the salt by looking at the reactants:

- nitric acid always produces salts that end in nitrate and contain the nitrate ion, NO_3^-
- hydrochloric acid always produces salts that end in chloride and contain the chloride ion, Cl^-
- sulfuric acid always produces salts that end in sulfate and contain the sulfate ion, SO_4^{2-}

Metal	Acid	Salt
Sodium hydroxide	Hydro**chloric** acid	**Sodium chloride**
Copper oxide	Hydro**chloric** acid	**Copper chloride**
Sodium hydroxide	**Sulf**uric acid	**Sodium sulfate**
Zinc oxide	**Sulf**uric acid	**Zinc sulfate**

Making a salt from an alkali

If you are using an alkali - which is a soluble base - then you need to add just enough acid to make a neutral solution (check a small sample with universal indicator paper).

Warm the salt solution to evaporate the water. You get larger crystals if you evaporate the water slowly.

Making a salt from an insoluble metal oxide or carbonate

Copper oxide and other transition metal oxides or hydroxides do not dissolve in water. If the base is insoluble, then an extra step is needed to form a salt.

You add the base to the warm acid until no more will dissolve and you have some base left over – this is called an 'excess'. You filter the mixture to remove the excess base, and then evaporate the water in the filtrate to leave the salt behind.

Making insoluble salts

To make an insoluble salt, two soluble salts need to react together in a precipitation reaction.

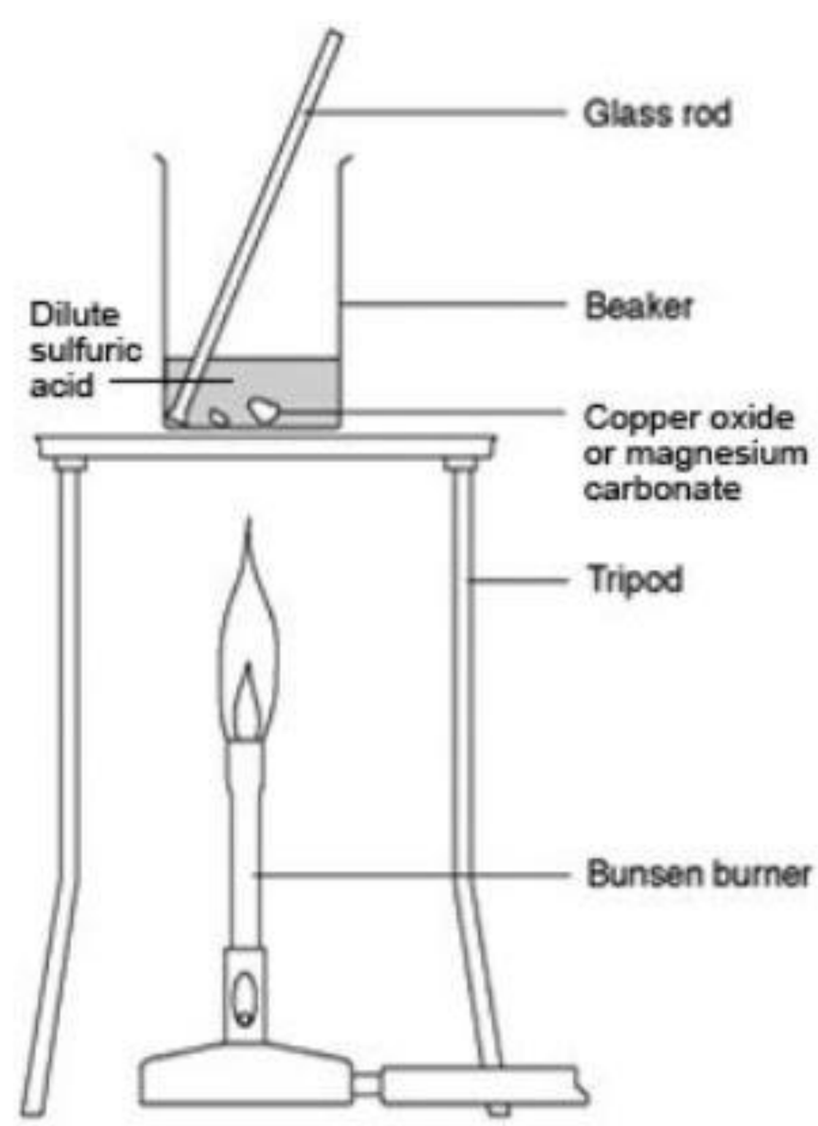
Soluble	Insoluble
All nitrates	None
All common sodium, potassium and ammonium salts	None
Most common sulfates	Calcium sulfate and barium sulfate
Most common chlorides	Silver chloride
Sodium, potassium and ammonium	Most common carbonates

Silver nitrate and sodium chloride are both soluble. When their solutions are mixed together, soluble sodium nitrate and insoluble silver chloride are made:

silver nitrate + sodium chloride → sodium nitrate + silver chloride

$$AgNO_3(aq) + NaCl(aq) \rightarrow NaNO_3(aq) + AgCl(s)$$

The silver chloride appears as tiny particles suspended in the reaction mixture - this is the precipitate. The precipitate can be filtered, washed with water on the filter paper, and then dried in an oven.



Acids & Alkalis

Indicators

- When an acid is dissolved in water we get an acidic solution. When a base dissolves in water it is an alkali and makes an alkaline solution. If a solution is neither acidic nor alkaline it is neutral. Pure water is neutral, and so is paraffin.
- Indicators are substances that change colour when they are added to acidic or alkaline solutions. Litmus, phenolphthalein, and methyl orange are all indicators that are commonly used in the laboratory.

Acids

When acids dissolve in water they produce hydrogen ions, H+. These are sometimes called protons, because hydrogen ions are the same as a hydrogen nucleus (which is a proton).

For example, take a look at the equation for hydrochloric acid:
$HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$

Acids are often produced from non-metal oxides. For example, sulfur oxides make sulfuric acid.

Alkalis

When alkalis dissolve in water they produce hydroxide ions, OH-.
For example, take a look at the equation for sodium hydroxide:
$NaOH(aq) \rightarrow Na^+(aq) + OH^-(aq)$

Ammonia is slightly different. This is the equation for ammonia in solution:
$NH_3(aq) + H_2O(l) \rightarrow NH_4^+(aq) + OH^-(aq)$

Bases

A base is chemically opposite to an acid. Some bases dissolve in water and are called alkalis. But other bases, including many metal oxides, do not dissolve in water.

Neutralisation reaction

When the H+ ions from an acid react with the OH- ions from an alkali, a neutralisation reaction occurs to form water. This is the equation for the reaction:

$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

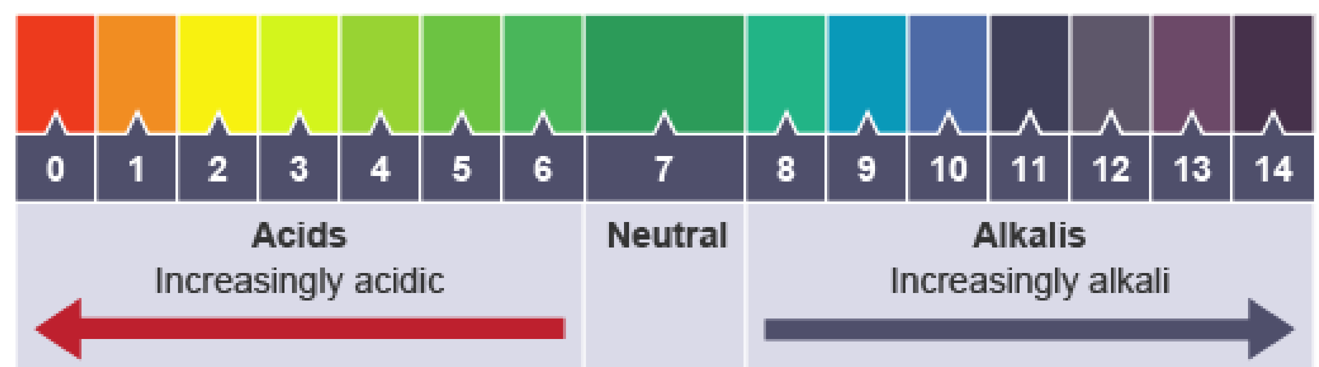
For example, hydrochloric acid and sodium hydroxide solution react together to form water and sodium chloride solution. The acid contains H+ ions and Cl– ions, and the alkali contains Na+ ions and OH– ions. The H+ ions and OH– ions produce the water, and the Na+ ions and Cl– ions produce the sodium chloride, NaCl(aq).

The pH scale

The chemical properties of many solutions enable them to be divided into three categories - acidic, alkaline and neutral solutions.

- The pH scale is used to measure acidity and alkalinity:
- solutions with a pH less than 7 are acidic
- solutions with a pH of 7 are neutral
- solutions with a pH greater than 7 are alkaline

If universal indicator is added to a solution it changes to a colour that shows the pH of the solution. Universal indicator is a mixture of a variety of other indicators and can be used to measure the approximate pH of a solution. A more accurate value can be obtained using a pH probe.



Acid solutions contain hydrogen ions. The higher the concentration of hydrogen ions, the lower the pH. Hydrochloric acid is a strong acid and ethanoic acid is a weak acid. Strong acids are fully ionised but weak acids are only partly ionised in solution. At the same concentration, strong acids have a higher concentration of hydrogen ions than weak acids. The electrolysis of acids produces hydrogen gas at the negative electrode.

Strong and weak acids

Acids ionise in water to produce **hydrogen ions**, H^+.
Strong acids fully ionise. For example:

- hydrochloric acid: $HCl \rightarrow H^+ + Cl^-$
- nitric acid: $HNO_3 \rightarrow H^+ + NO^{3-}$
- sulfuric acid: $H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$

Weak acids **do not** fully ionise. Instead, they form an **equilibrium** mixture.
For example:
ethanoic acid: $CH_3COOH \rightleftharpoons CH_3COO^- + H^+$
At the same concentration, strong acids have lower pH than weak acids.

pH and hydrogen ion concentration

The pH of a solution is related to its concentration of hydrogen ions - the higher the concentration of hydrogen ions H+ the lower the pH.

At the same concentration of acid, the concentration of hydrogen ions will be higher in a strong acid than in a weak acid. This is why the pH of a strong acid like hydrochloric acid will be lower than the pH of a weak acid like ethanoic acid.

Acid strength vs concentration

The strength of an acid is a measure of the degree of its ionisation - strong acids are fully ionised but weak acids are only partly ionised. Remember that the opposite of *strong is weak*.
The concentration of an acid is a measure of the number of *moles* of acid in 1 dm^3 of acid solution. For example, 2 mol/dm^3 hydrochloric acid is twice as concentrated as 1 mol/dm^3 hydrochloric acid or 1 mol/dm^3 ethanoic acid.
Remember: the opposite of *concentrated is dilute*.

Water Treatment

Purifying water

Raw water may contain dissolved salts and minerals, microbes, pollutants and insoluble materials like sand and stones. Water is treated to remove any harmful components before being fed into the public supply. This is done in several ways:

- Filtration - the water is sprayed onto specially-prepared layers of sand and gravel. As it trickles through, different-sized insoluble solids are removed. The filter beds are cleaned periodically by pumping clean water backwards through the filter.
- Sedimentation - a chemical is added which causes tiny solid particles (which would pass through a filter) to clump together into larger particles. These can then be allowed to settle out or may be filtered.
- Chlorination - chlorine gas is injected into the water to sterilise it. The chlorine kills microbes.

Hard and soft water

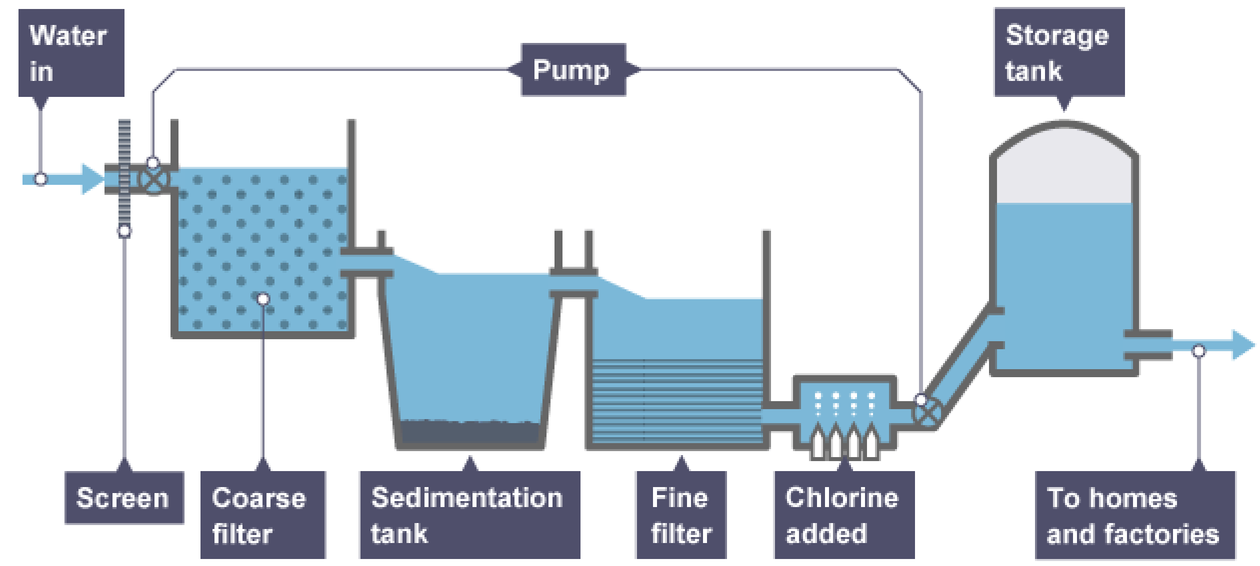
The water in some parts of the country is soft, while the water in other parts of the country is hard.
Hard water contains dissolved magnesium ions and calcium ions, which can get into the water when it comes into contact with limestone and other rocks that contain calcium compounds. This can happen, for example, when rainwater flows over rocks on its way to a reservoir.

Temporary hardness

Temporary hardness is caused by dissolved calcium hydrogencarbonate, $Ca(HCO_3)_2$.
Rainwater is naturally **acidic** because it contains dissolved carbon dioxide from the air. It reacts with calcium carbonate in rocks to form calcium hydrogencarbonate (which is soluble):
calcium carbonate + water + carbon dioxide → calcium hydrogencarbonate
$CaCO_3(s) + H_2O(l) + CO_2(g) \rightarrow Ca(HCO_3)_2(aq)$
Temporary hardness is removed by boiling the water. When this happens, the soluble calcium hydrogencarbonate **decomposes** (breaks down) to form calcium carbonate (which is insoluble), water and carbon dioxide:
calcium hydrogencarbonate → calcium carbonate + water + carbon dioxide
$Ca(HCO_3)_2(aq) \rightarrow CaCO_3(s) + H_2O(l) + CO_2(g)$
The insoluble calcium carbonate forms a layer of **limescale**. This may coat the heating element in kettles and irons, for example, making them less efficient. Limescale is unsightly and it clogs up hot water pipes and boilers.

Permanent hardness

Permanent hardness is caused by dissolved calcium sulfate (CaSO4), which does not decompose (break down) when heated.
Therefore, unlike temporary hardness, permanent hardness is not removed by boiling the water.



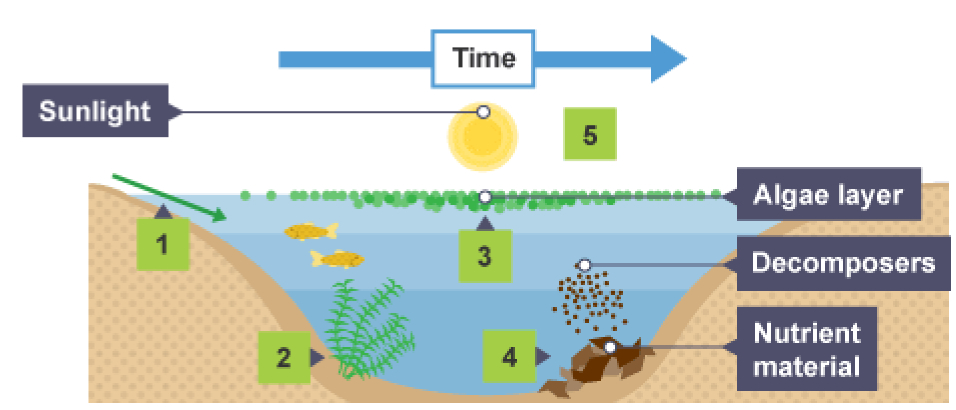
Water pollutants

Water can be polluted in a number of ways. Here are some examples:
Nitrate fertilisers are soluble in water and can be washed off fields (leaching) and into rivers and reservoirs by rainwater. This leads to eutrophication. Because all nitrates are soluble they cannot easily be removed from the water.

- Older houses and water supply systems still rely on lead pipes. Poisonous lead compounds form on the inside of the pipes and slowly dissolve in the water.
- Pesticides used by farmers may be washed or blown into streams and rivers.

Eutrophication

A major problem with the use of fertilisers occurs when they are washed off the land by rainwater into rivers and lakes. This leaching causes an increase in the levels of minerals such as nitrate and phosphate in the water, a process called eutrophication.
Eutrophication encourages the growth of algae. These form a green bloom over the water surface, preventing sunlight reaching other water plants. These plants die because they are unable to carry out photosynthesis.
Bacteria decompose the dead plants, respiring and using up the oxygen in the water as they do this. The low oxygen levels make it difficult for aquatic insects and fish to live, and eventually the lake may be left completely lifeless.



1. Nutrient load up: excessive nutrients from fertilisers are flushed from the land into rivers or lakes by rainwater.
2. Plants flourish: these pollutants cause aquatic plant growth of algae, duckweed and other plants.
3. Algae blooms, oxygen is depleted: algae blooms prevent sunlight reaching other plants. The plants die and oxygen in the water is depleted.
4. Decomposition further depletes oxygen: dead plants are broken down by bacteria decomposers, using up even more oxygen in the water.
5. Death of the ecosystem: oxygen levels reach a point where no life is possible. Fish and other organisms die.

Enzymes & Digestion Revision

Introduction:

Digestion is the breakdown of carbohydrates, proteins and fats into small, soluble substances that can be absorbed into the blood. Lipases and proteases are used in biological detergents, and enzymes are used in the manufacture of food and drink

Peristalsis

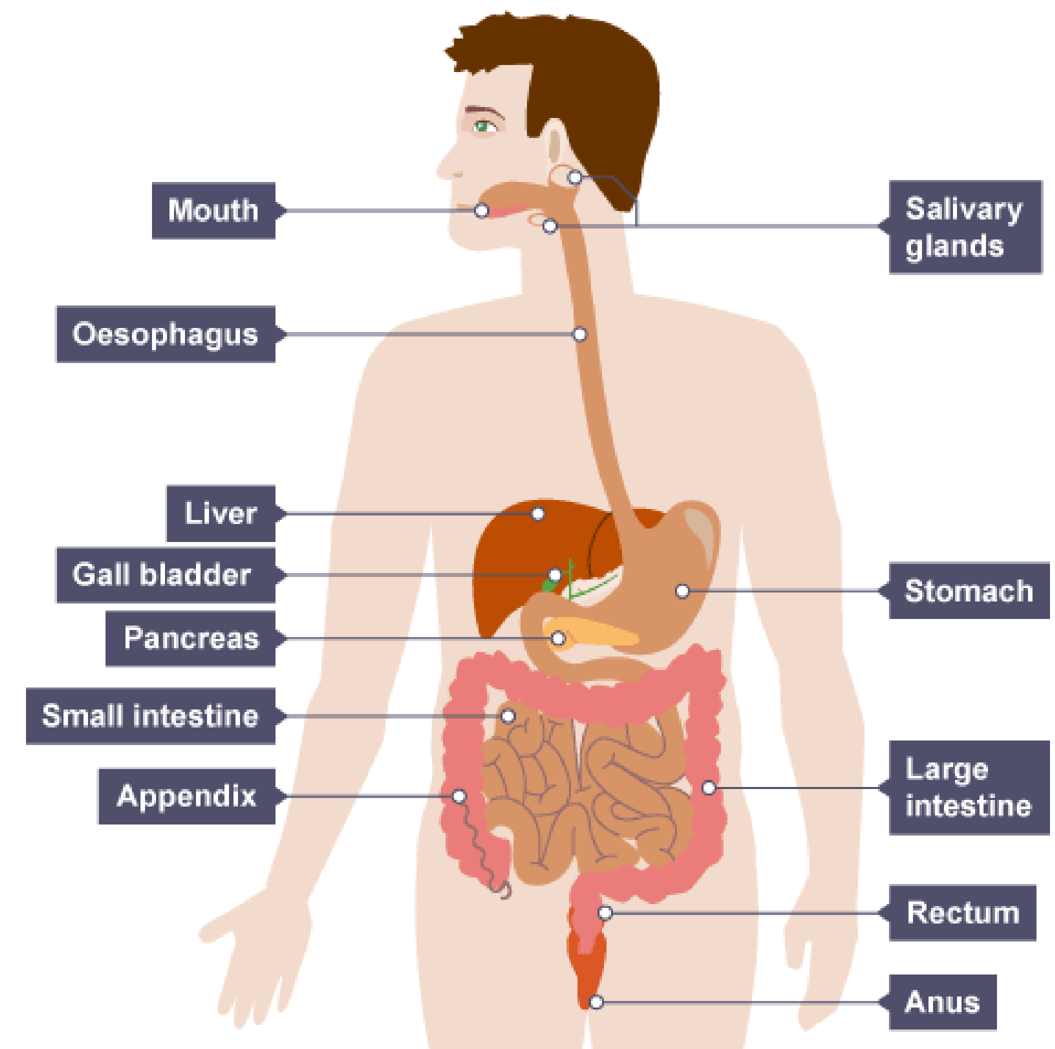
Food is moved the digestive system by a process known as peristalsis. This is the contractions of two sets of muscles in the walls of the gut. One set runs along the gut, while the other set circles it. Their wave-like contractions create a squeezing action, moving down the gut.

Bile

After the stomach, food travels to the small intestine. The enzymes in the small intestine work best in alkaline conditions, but the food is acidic after being in the stomach. Bile is an alkaline substance produced by the liver and stored in the gall bladder. It is secreted into the small intestine, where it emulsifies fats. This is important, because it provides a larger surface area in which the lipases can work.

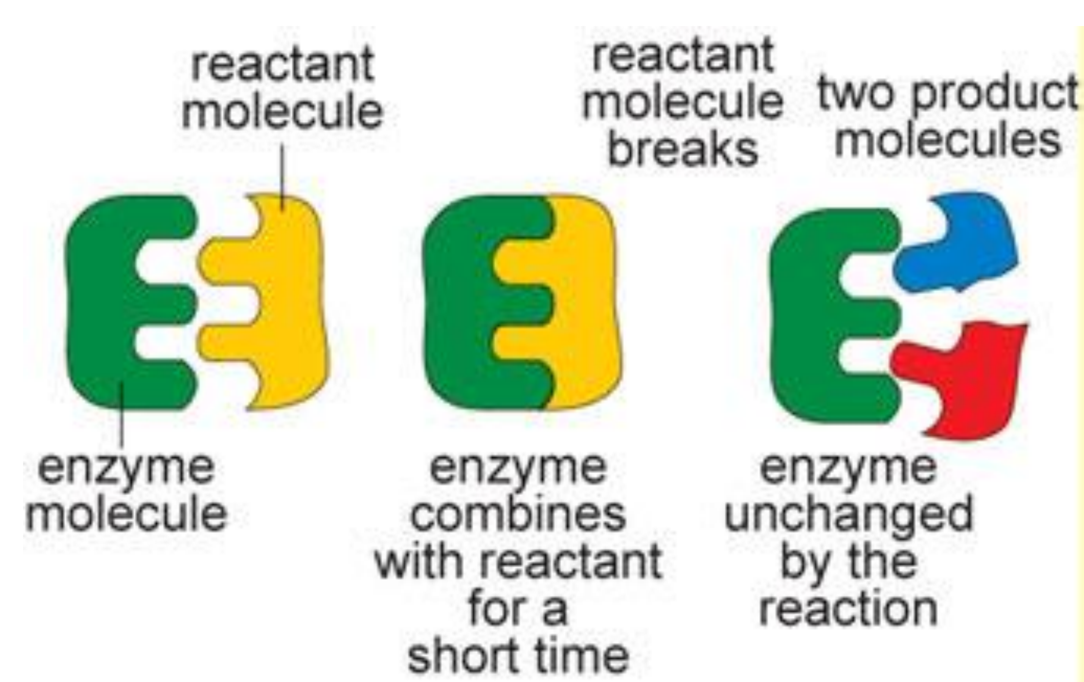
The intestines

Digested food molecules are **absorbed** in the **small intestine**. This means that they pass through the wall of the small intestine and into our bloodstream. The inside wall of the small intestine is **thin**, with a **large surface** area. This allows absorption to happen quickly and efficiently. To get a big surface area, the inside wall of the small intestine is lined with tiny **villi**. These stick out and give a big surface area. They also contain blood capillaries to carry away the absorbed food molecules.



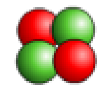
Enzyme	Where produced
Amylase	Salivary glands, pancreas, small intestine
Protease	Stomach, pancreas, small intestine
Lipase	Pancreas, small intestine

- Amylase catalyses the breakdown of starch into sugars in the mouth and small intestine
- Proteases catalyse the breakdown of proteins into amino acids in the stomach and small intestine
- Lipases catalyse the breakdown of fats and oils into fatty acids and glycerol in the small intestine



Radioactivity

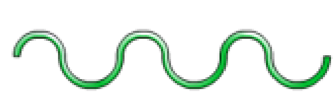
What is alpha (α) radiation?

Description	2 neutrons, 2 protons  Note:– An alpha particle is the same as a helium nucleus
Electric charge	+2
Relative atomic mass	4
Penetrating power	Stopped by paper or a few centimetres of air
Ionizing effect	Strongly ionizing
Effect of magnetic/ electric field	Weakly deflected

What is beta (β) radiation?

Description	High energy electron 
Electric charge	-1
Relative atomic mass	1/1860
Penetrating power	Stopped by a few millimetres of aluminium
Ionizing effect	Weakly ionizing
Effect of magnetic/ electric field	Strongly deflected

Gamma (γ) radiation

Description	High energy electromagnetic radiation 
Electric charge	0
Relative atomic mass	0
Penetrating power	Stopped by several centimetres of lead or several metres of concrete
Ionizing effect	Very weakly ionizing
Effect of magnetic/ electric field	Not deflected

Background radiation: is all around us. We can do little to avoid it. Most background radiation comes from natural sources, while most artificial radiation comes from medical examinations, such as X-ray photographs.

Introduction:

- Radioactive substances give out radiation all the time. There are three types of nuclear radiation - alpha, beta and gamma. Alpha is the least penetrating, while gamma is the most penetrating.
- Radiation can be harmful, but it can also be useful. The uses of radiation include smoke detectors, paper-thickness gauges, treating cancer and sterilising medical equipment.

Dangers of Radiation

- Alpha radiation is the **most dangerous** because it is easily absorbed by cells
- Beta and gamma radiation are not as dangerous because they are less likely to be absorbed by a cell and will usually just pass right through it

If the radioactive source is **outside** the body:

- Alpha radiation is not as dangerous because it is unlikely to reach living cells inside the body
- Beta and gamma radiation are the **most dangerous sources** because they can penetrate the skin and damage the cells inside

Uses of alpha radiation

- Ionisation is useful for smoke detectors. Radioactive americium releases **alpha radiation**, which ionises the air inside the detector. Smoke from a fire absorbs alpha radiation, altering the ionisation and triggering the alarm.

Uses of beta radiation

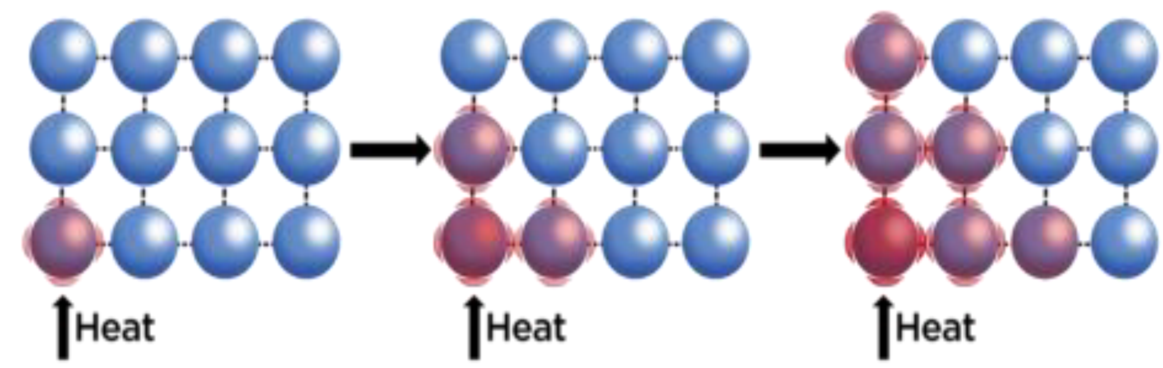
- Beta radiation is used for tracers and monitoring the thickness of materials.
- Radiation is used in industry in detectors that monitor and control the thickness of materials such as paper, plastic and aluminium. The thicker the material, the more radiation is absorbed and the less radiation reaches the detector. It then sends signals to the equipment that adjusts the thickness of the material.

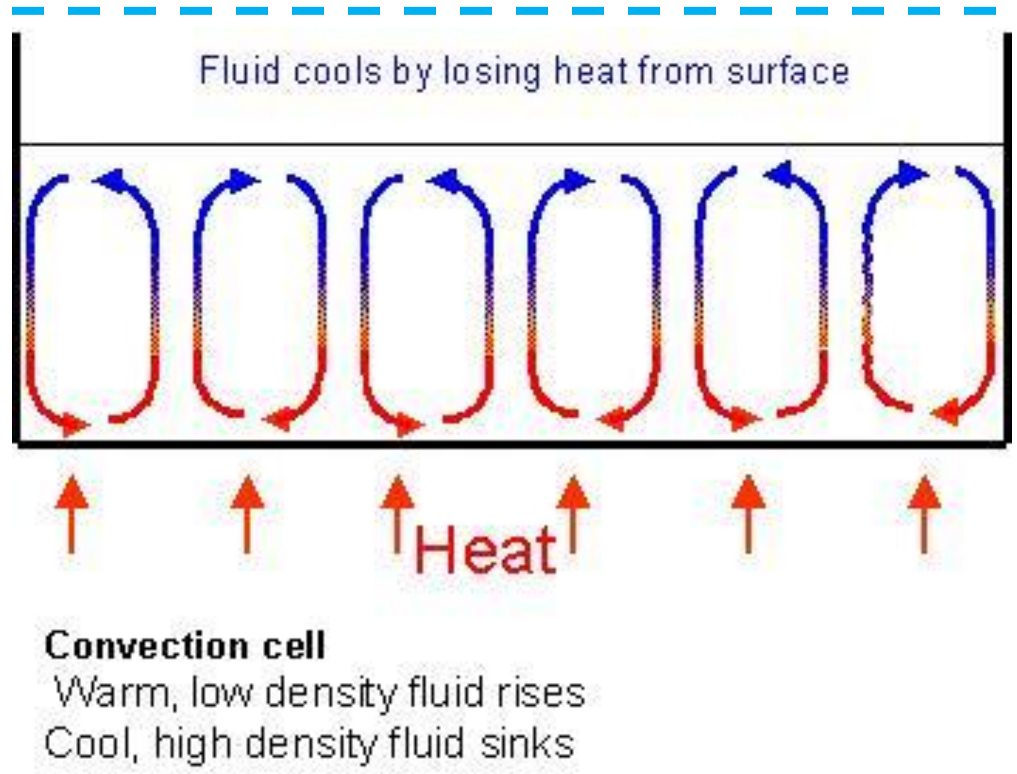
Uses of gamma radiation

- Gamma radiation is used in the treatment of cancer, testing equipment and sterilising medical instruments.

Heat Transfer Revision

Conduction
Heat energy can move through a substance by conduction. Metals are good conductors of heat, but non-metals and gases are usually poor conductors of heat. Poor conductors of heat are called insulators. Heat energy is conducted from the hot end of an object to the cold end.
The electrons in piece of metal can leave their atoms and move about in the metal as free electrons. The parts of the metal atoms left behind are now charged metal ions. The ions are packed closely together and they vibrate continually. The hotter the metal, the more kinetic energy these vibrations have. This kinetic energy is transferred from hot parts of the metal to cooler parts by the free electrons. These move through the structure of the metal, colliding with ions as they go.





Convection
Liquids and gases are fluids. The particles in these fluids can move from place to place. Convection occurs when particles with a lot of heat energy in a liquid or gas move and take the place of particles with less heat energy. Heat energy is transferred from hot places to cooler places by convection.
Liquids and gases expand when they are heated. This is because the particles in liquids and gases move faster when they are heated than they do when they are cold. As a result, the particles take up more volume. This is because the gap between particles widens, while the particles themselves stay the same size.
The liquid or gas in hot areas is less dense than the liquid or gas in cold areas, so it rises into the cold areas. The denser cold liquid or gas falls into the warm areas. In this way, convection currents that transfer heat from place to place are set up.

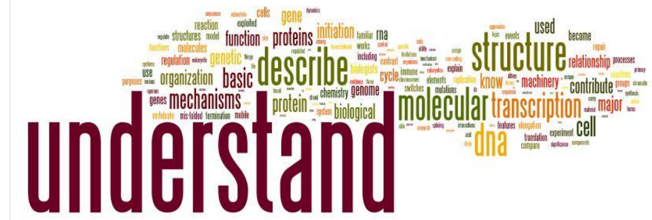
Radiation
All objects give out and take in thermal radiation, which is also called infrared radiation. The hotter an object is, the more infrared radiation it emits.

Infrared radiation is a type of electromagnetic radiation that involves waves. No particles are involved, unlike in the processes of conduction and convection, so radiation can even work through the vacuum of space. This is why we can still feel the heat of the Sun, although it is 150 million km away from the Earth. Some surfaces are better than others at reflecting and absorbing infrared radiation.

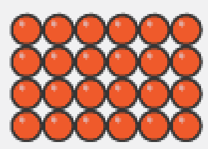
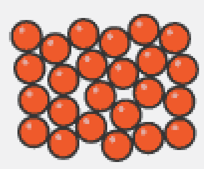
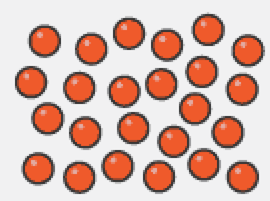
Evaporation
The particles in a liquid have different energies. Some will have enough energy to escape from the liquid and become a gas. The remaining particles in the liquid have a lower average kinetic energy than before, so the liquid cools down as evaporation happens. This is why sweating cools you down. The sweat absorbs energy from your skin so that it can continue to evaporate.

Condensation
The particles in a gas have different energies. Some may not have enough energy to remain as separate particles, particularly if the gas is cooled down. They come close together and bonds form between them. Energy is released when this happens. This is why steam touching your skin can cause scalds: not only is the steam hot, but energy is released into your skin as the steam condenses.

Matter

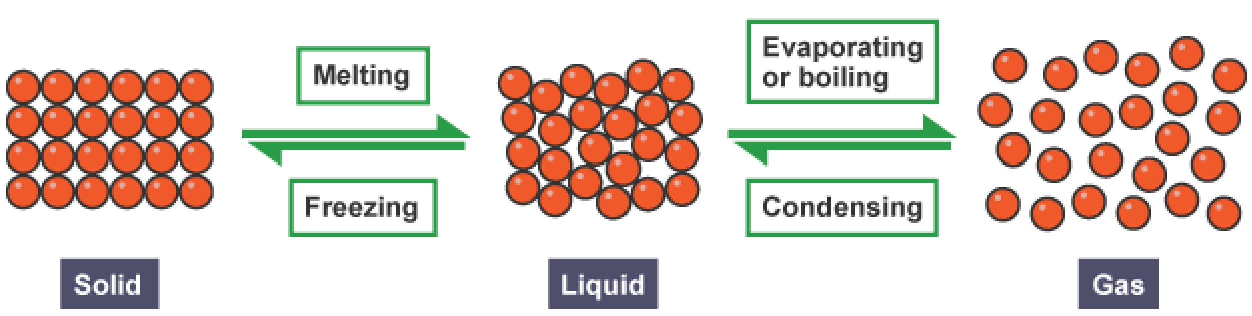


The kinetic particle theory explains the properties of the different states of matter. The particles in solids, liquids and gases have different amounts of energy. They are arranged differently and move in different ways.

	Solid	Liquid	Gas
Arrangement of particles	Close together Regular pattern	Close together Random arrangement	Far apart Random arrangement
Movement of particles	Vibrate on the spot	Move around each other	Move quickly in all directions
Diagram			

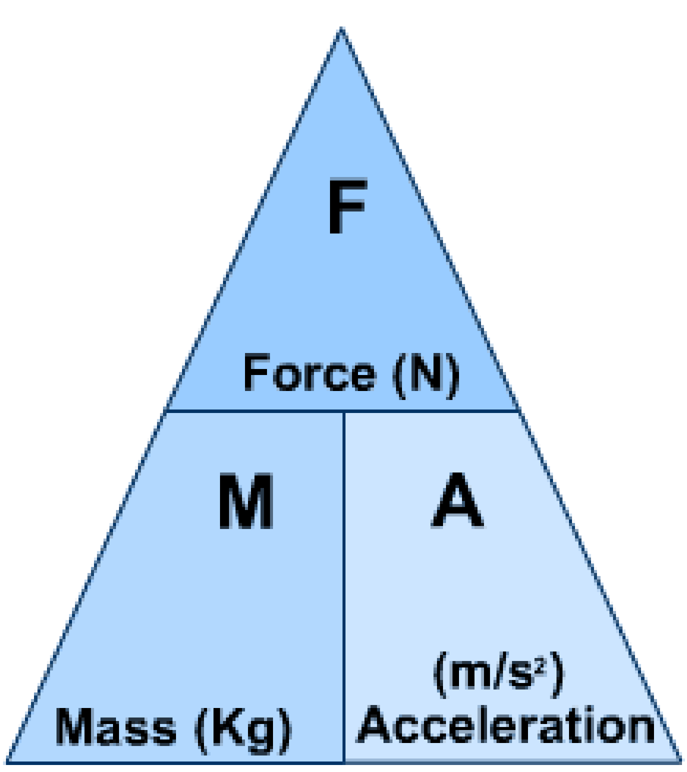
State changes

Substances can exist as a solid, liquid or gas. Converting from one state to another usually involves heating or cooling.



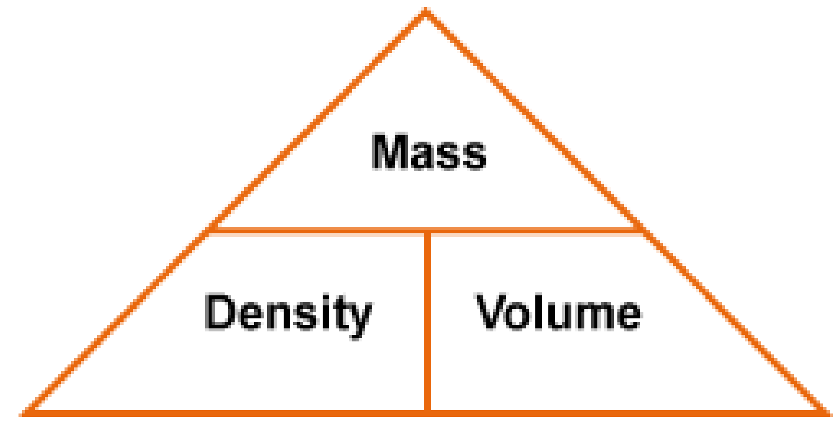
Heat must be supplied to a substance for it to melt, evaporate or boil. For example, you need to heat ice to melt it, and you need to heat water to make steam.
Heat must be removed from a substance to condense or freeze it. In other words, the substance must be cooled down.

Under certain conditions, some solids turn straight into a gas when heated. This process is called sublimation. A good example is solid carbon dioxide, also called 'dry ice'. At atmospheric pressure, it turns straight into gaseous carbon dioxide.
Liquid carbon dioxide can only exist under high pressure, such as in fire extinguishers. Iodine also sublimes - it turns directly from shiny purple-black crystals to a purple vapour when warmed up.



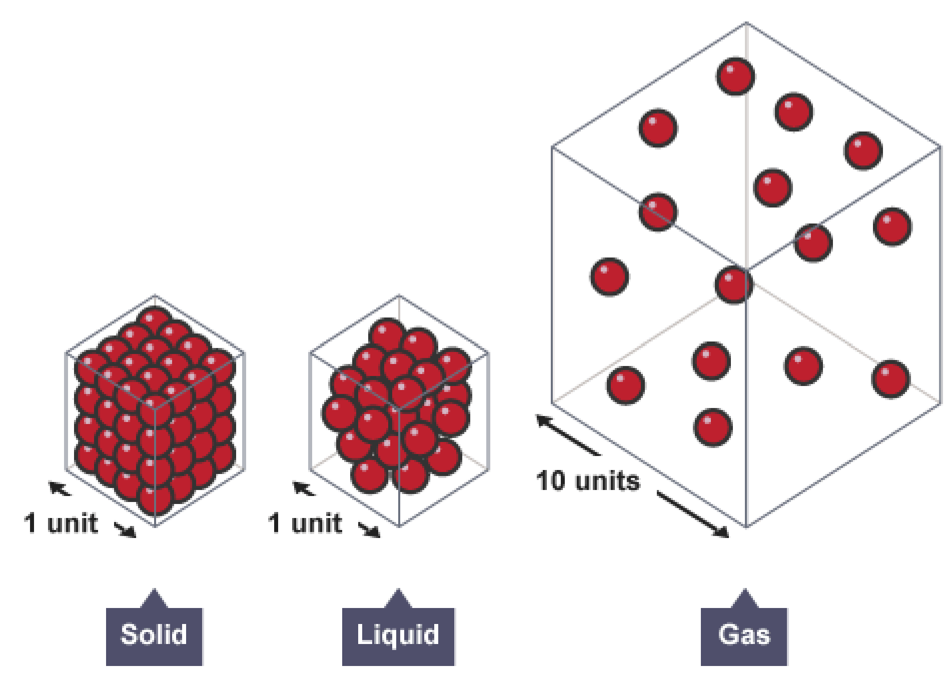
Density

Density is the mass per unit volume. It can be measured in several ways.
The most accurate way to calculate the density of any solid, liquid or gas is to divide its mass in kilograms by its volume (length × width × height) in cubic metres.



Densities of solids, liquids and gases

For most substances, the change from a solid to a liquid state does not mean a big change in volume. This is because the particles stay approximately the same distance apart. This means that the density of a substance, for example iron, does not change by much when it melts.



Pressure

- Pressure is the force per unit area.
- This means that the pressure a solid object exerts on another solid surface is its weight in newtons divided by its area in square metres.

Pressure in fluids

The pressure in a fluid is caused by the particles that make up the fluid. These particles have a disordered motion so the pressure acts equally in all directions.

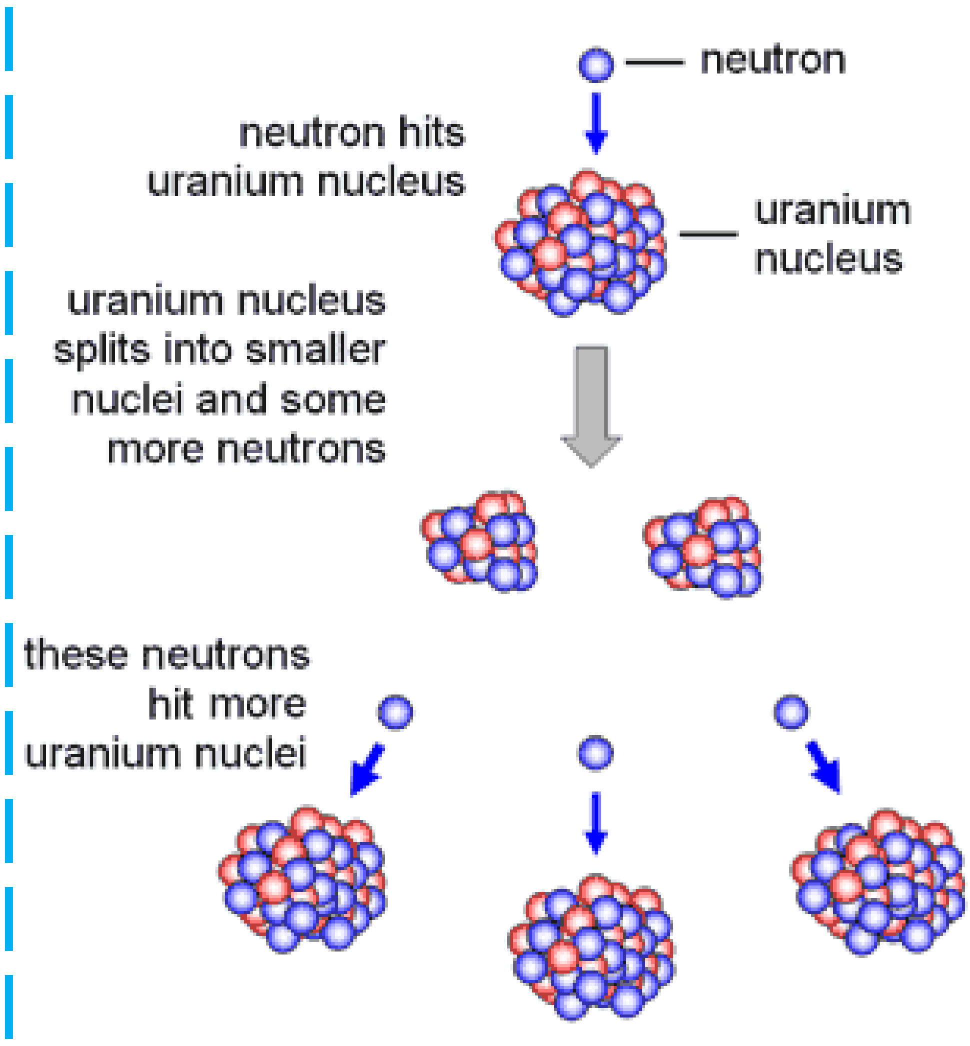
Three factors affect the pressure in a fluid:

- The depth the pressure is measured at
- The density of the fluid
- The gravitational field strength

Fission & Fusion Revision

Fission

- Fission is another word for splitting. The process of splitting a nucleus is called nuclear fission. Uranium or plutonium isotopes are normally used as the fuel in nuclear reactors, because their atoms have relatively large nuclei that are easy to split, especially when hit by neutrons.
- When a uranium-235 or plutonium-239 nucleus is hit by a neutron, the following happens:
- the nucleus splits into two smaller nuclei, which are radioactive
- two or three more neutrons are released
- some energy is released
- The additional neutrons released may also hit other uranium or plutonium nuclei and cause them to split. Even more neutrons are then released, which in turn can split more nuclei. This is called a chain reaction. The chain reaction in nuclear reactors is controlled to stop it going too fast.



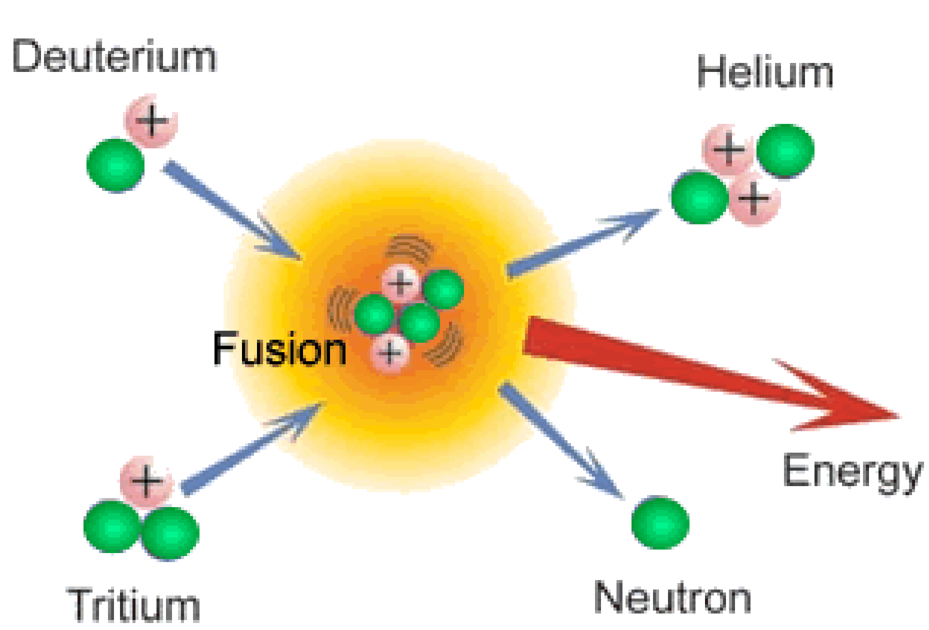
$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{90}_{36}Kr + ^{143}_{56}Ba + ^{1}_{0}n + ^{1}_{0}n + ^{1}_{0}n$$

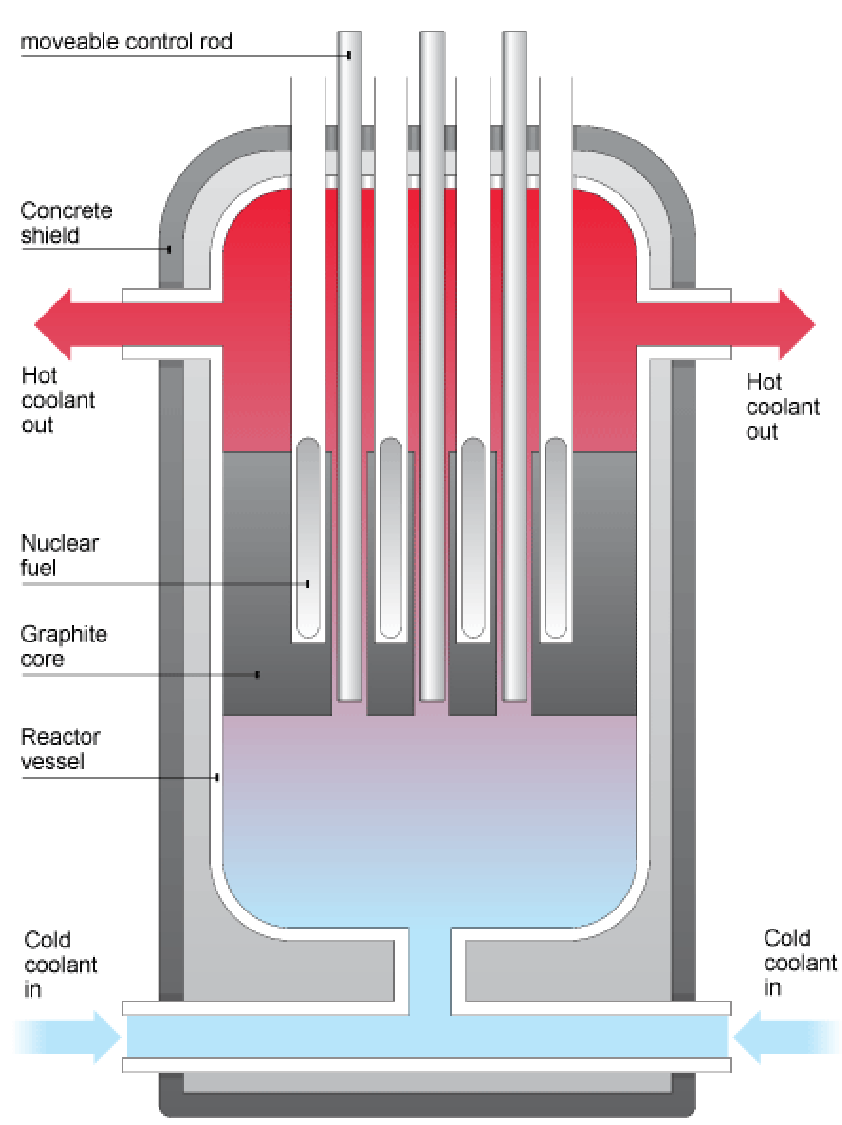
Nuclear Power

A nuclear reactor is designed to allow a controlled chain reaction to take place. Moveable control rods are placed between the rods of nuclear fuel. These control rods absorb some of the neutrons, so fewer neutrons are available to split uranium nuclei. The position of the control rods is adjusted so there are just enough neutrons for the chain reaction to keep going.

Fusion:

- Nuclear fusion involves two atomic nuclei joining to make a large nucleus. Energy is released when this happens.
- The Sun and other stars use nuclear fusion to release energy. The sequence of nuclear fusion reactions in a star is complex, but overall hydrogen nuclei join to form helium nuclei. Here is one nuclear fusion reaction that takes place: hydrogen-1 nuclei fuse with hydrogen-2 nuclei to make helium-3 nuclei



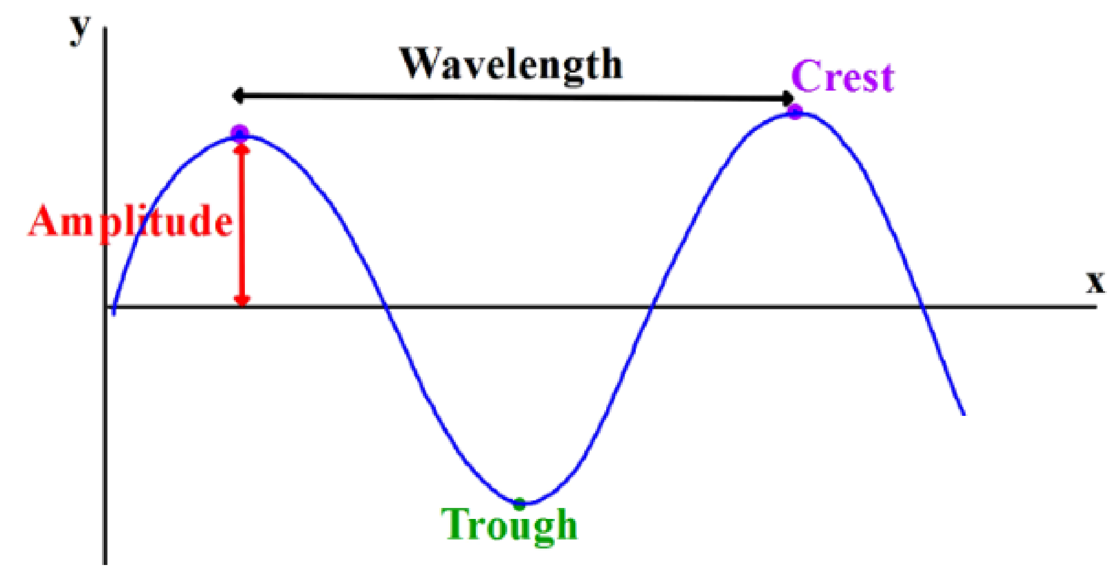


Waves

Transverse waves

In transverse waves, the oscillations (vibrations) are at right angles to the direction of travel and energy transfer

Light and other types of electromagnetic radiation are transverse waves. All types of electromagnetic waves travel at the same speed through a vacuum, such as through space.



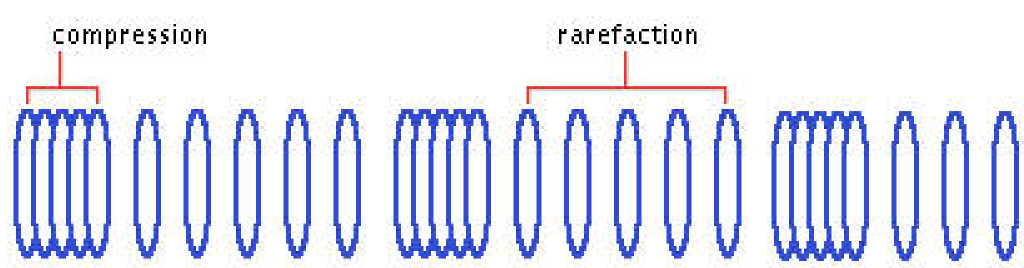


Figure 1: Longitudinal Wave

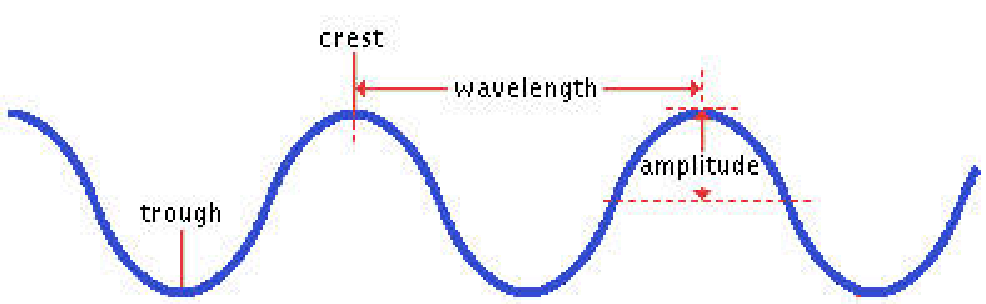


Figure 2: Transverse Wave

Longitudinal waves

In longitudinal waves, the oscillations are along the same direction as the direction of travel and energy transfer.

Sound waves and waves in a stretched spring are longitudinal waves. P waves (relatively fast moving longitudinal seismic waves that travel through liquids and solids) are also longitudinal waves. Longitudinal waves show area of compression and rarefaction.

Wave speed

The speed of a wave is related to its frequency and wavelength, according to this equation:

$v = f \times \lambda$

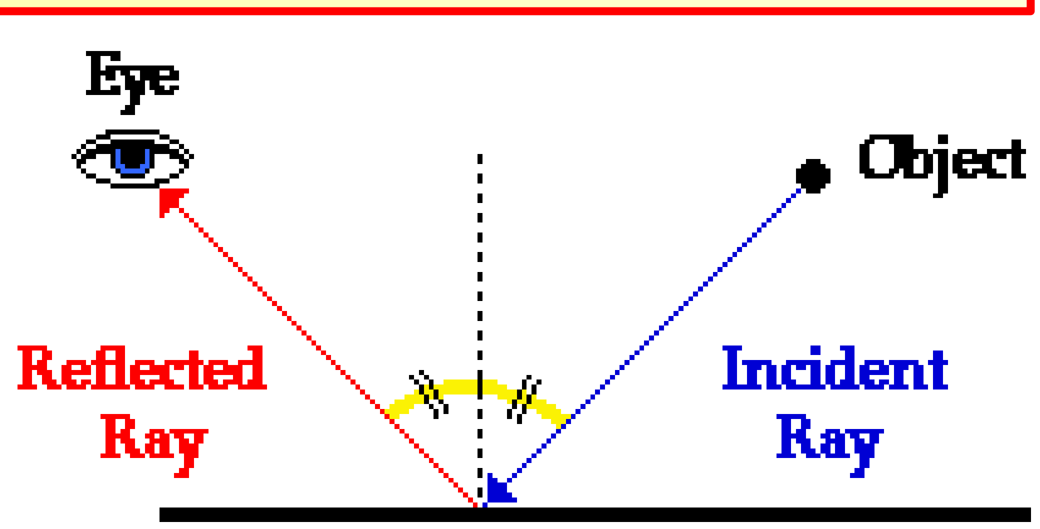
v is the wave speed in metres per second, m/s

f is the frequency in hertz, Hz

λ (lambda) is the wavelength in metres, m.

Refraction

Sound waves and light waves change speed when they pass across the boundary between two substances with different densities, such as air and glass. This causes them to change direction and this effect is called refraction. There is one special case you need to know. Refraction doesn't happen if the waves cross the boundary at an angle of 90° (called the normal) - in that case they carry straight on.



Reflection

Sound waves and light waves reflect from surfaces. When waves reflect, they obey the law of reflection:

the angle of incidence equals the angle of reflection

The normal is a line drawn at right angles to the reflector

The angle of incidence is between the incident (incoming) ray and the normal

The angle of reflection is between the reflected ray and the normal.

Diffraction

When waves meet a gap in a barrier, they carry on through the gap. However, the waves spread out to some extent into the area beyond the gap. This is called diffraction. The extent of the spreading depends on how the width of the gap compares to the wavelength of the waves. Significant diffraction only happens when the wavelength is of the same order of magnitude as the gap. For example:

- a gap similar to the wavelength causes a lot of spreading with no sharp shadow, eg sound through a doorway
- a gap much larger than the wavelength causes little spreading and a sharp shadow, eg light through a doorway.

Photosynthesis Revision

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

Introduction:

Green plants absorb light energy using chlorophyll in their leaves. They use it to react carbon dioxide with water to make a sugar called glucose. The glucose is used in respiration, or converted into starch and stored. Oxygen is produced as a by-product. This process is called photosynthesis. Temperature, carbon dioxide concentration and light intensity are factors that can limit the rate of photosynthesis

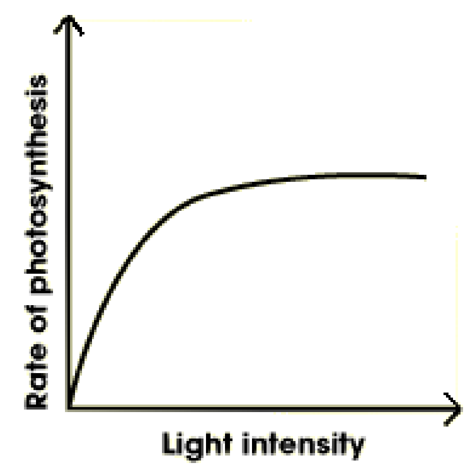
Photosynthesis is the chemical change which happens in the leaves of green plants. It is the first step towards making food - not just for plants but ultimately every animal on the planet.

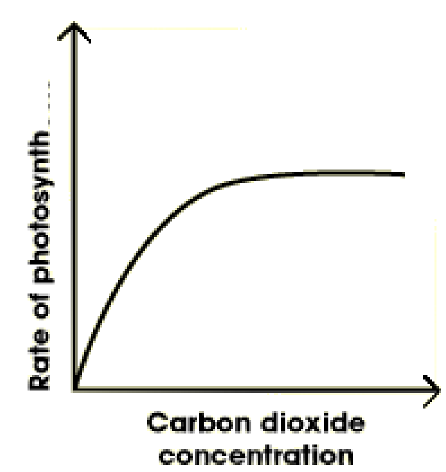
During photosynthesis:

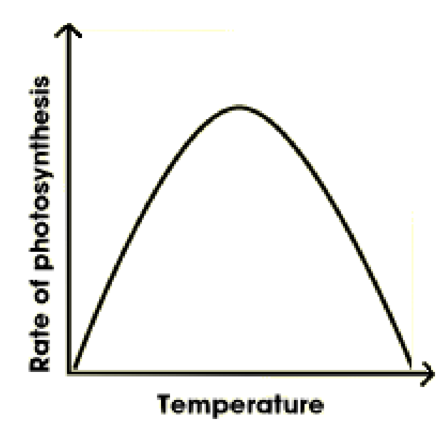
- Light energy is absorbed by chlorophyll, a green substance found in chloroplasts in some plant cells and algae
- Absorbed light energy is used to convert carbon dioxide (from the air) and water (from the soil) into a sugar called glucose
- Oxygen is released as a by-product.

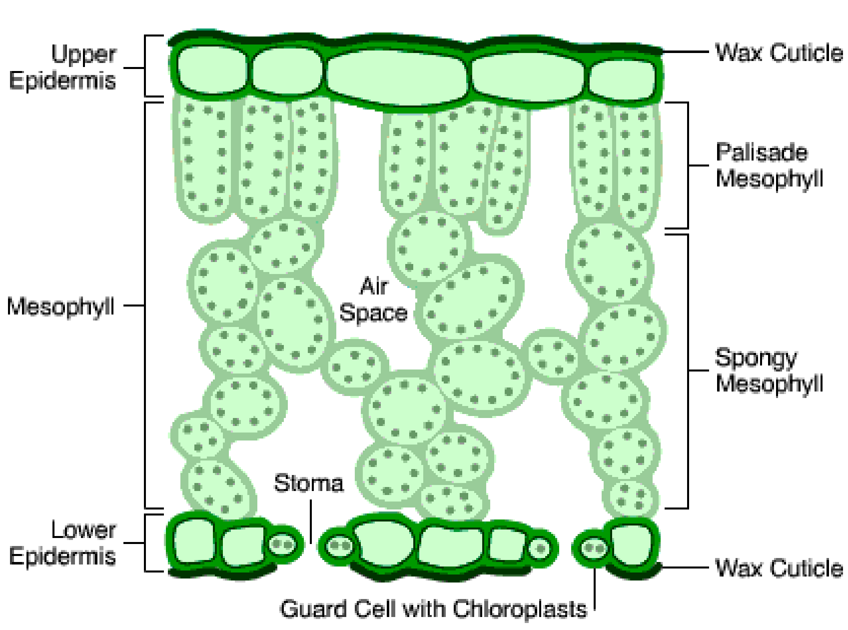
Limiting Factors:

A limiting factor is anything that prevents the rate of photosynthesis from increasing









Structure of the leaf:

Waxy cuticle: See through layer which lets light through and stops the leaf from becoming water logged.

Palisade layer: Cells have lots of chloroplasts so can carry out lots of photosynthesis.

Spongy mesosphere layer: Rounded cells which, creates large air spaces within the leaf.

Guard cells: Open and close the air holes on the underside of the leaf so control the rate of transpiration.

Air spaces: Enable movement of carbon-dioxide into the leaf and oxygen out.

Phloem: Carries away glucose made in photosynthesis.

Xylem: Gives a good supply of water to the leaf so increases the rate of photosynthesis

Storage of glucose

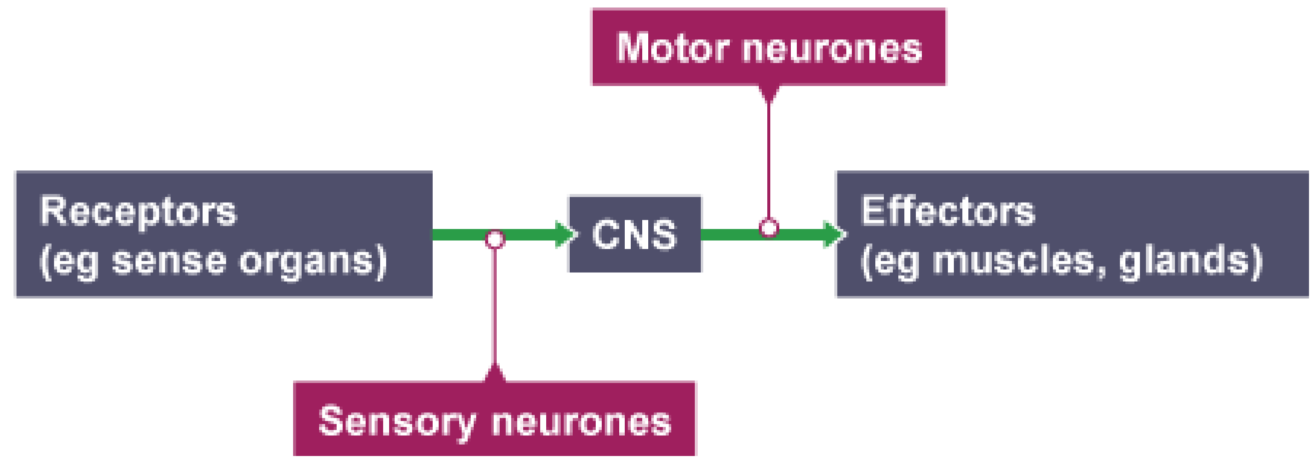
- Glucose is needed by cells for *respiration*. However, it is not produced at night when it is too dark for photosynthesis to happen. Plants and algae store glucose as insoluble products

Use of glucose

- Cellulose - which strengthens the cell wall
- *Proteins* - such as *enzymes* and chlorophyll

Co-ordination & Nerves Revision

Receptors are groups of specialised cells. They can detect a change in the environment (stimulus) and produce electrical impulses in response. Sense organs contain groups of receptors that respond to specific stimuli.



Sense organ	Stimulus
Skin	Touch, temperature
Tongue	Chemicals (in food and drink, for example)
Nose	Chemicals (in the air, for example)
Eye	Light
Ear	Sound

Effectors

Effectors are parts of the body - such as muscles and glands - that produce a response to a detected stimulus. For example:

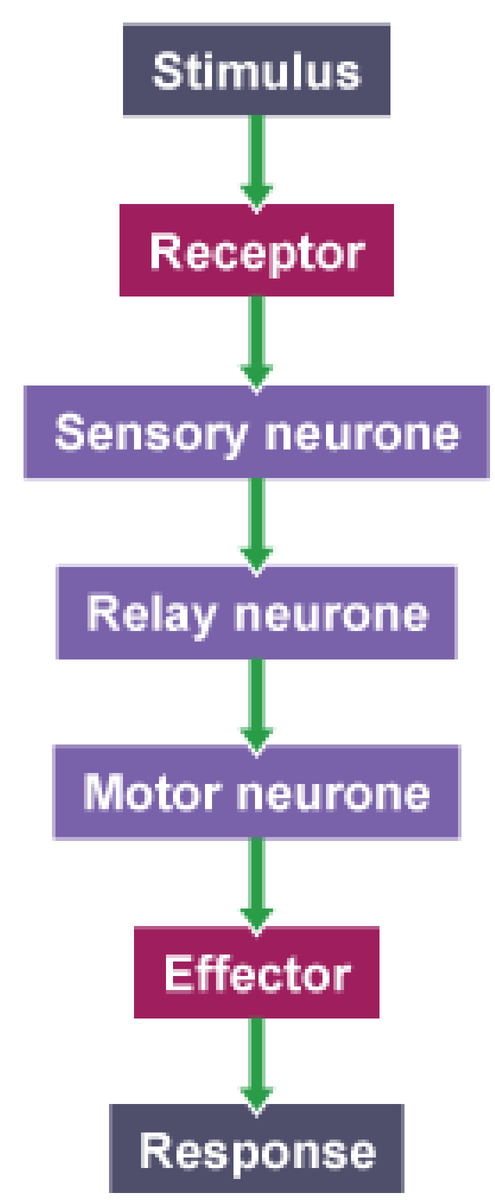
- a muscle contracting to move an arm
- muscle squeezing saliva from the salivary gland
- a gland releasing a hormone into the blood

Reflex actions

A **reflex action** is a way for the body to automatically and rapidly respond to a stimulus to minimise any further damage to the body. It follows this general sequence and does not involve the brain:

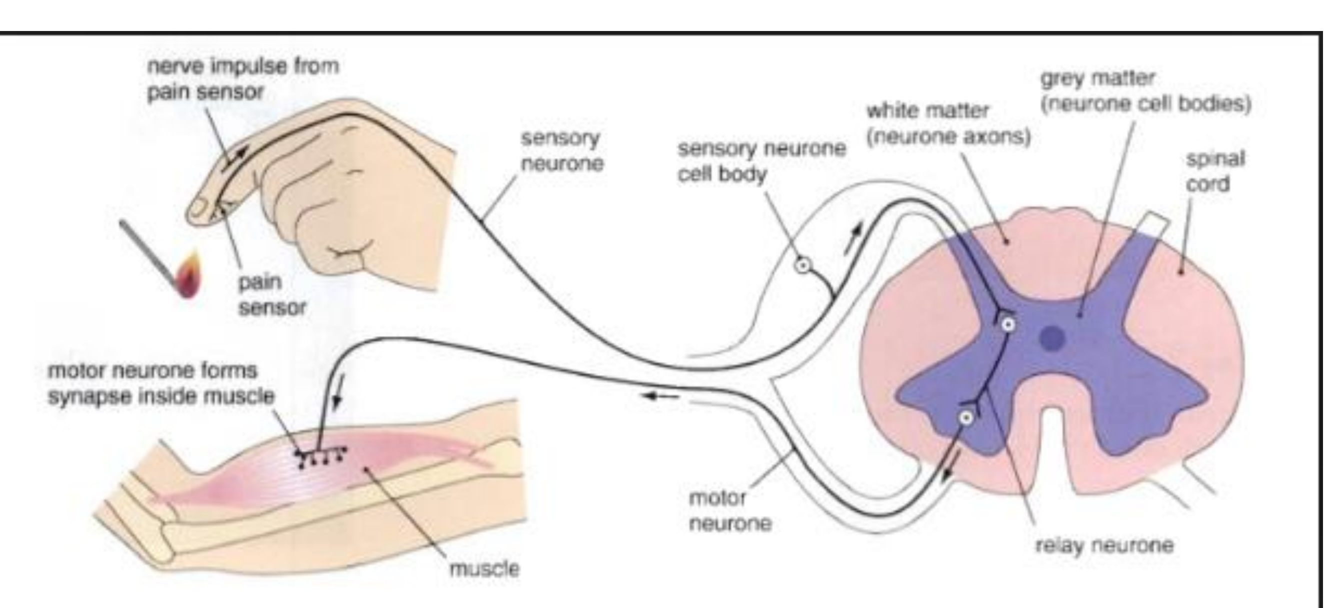
The nerve pathway followed by a reflex action is called a **reflex arc**.

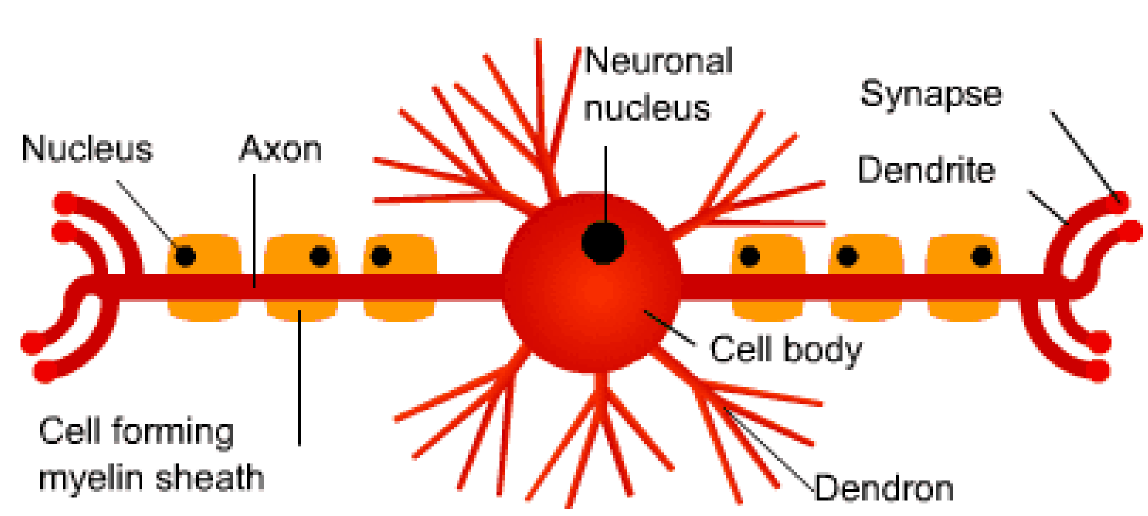
1. Receptor in the skin detects a stimulus (the change in temperature).
2. Sensory neurone sends impulses to relay neurone.
3. Motor neurone sends impulses to effector.
4. Effector produces a response (muscle contracts to move hand away).



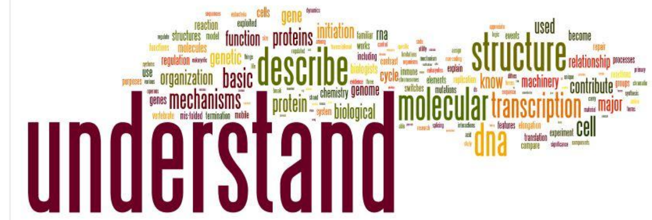
The synapse

Where two neurones meet there is a tiny gap called a synapse. Information crosses this gap using neurotransmitters, rather than using electrical impulses. One neurone releases neurotransmitters into the synapse. These diffuse across the gap and make the other neurone transmit an electrical impulse





Variation & Reproduction Revision



The genetic information passed from parent to offspring is contained in genes carried by chromosomes in the nucleus. Sexual reproduction produces offspring that resemble their parents, but are not identical to them.

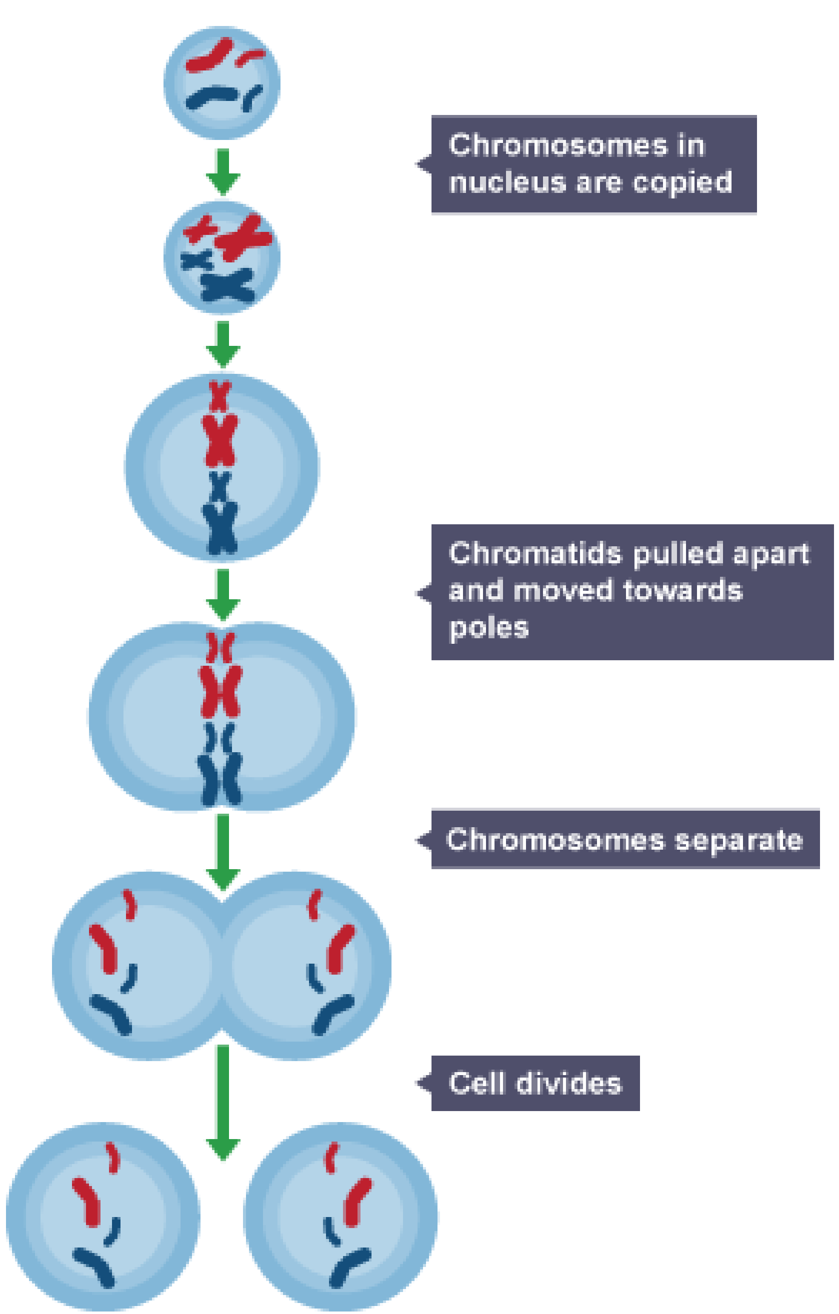
Asexual reproduction

Asexual reproduction only needs **one parent**, unlike sexual reproduction, which needs two parents. Since there is only one parent, there is no fusion of gametes and no mixing of genetic information. As a result, the offspring are **genetically identical to the parent** and to each other: in other words, they are **clones**.

Mitosis

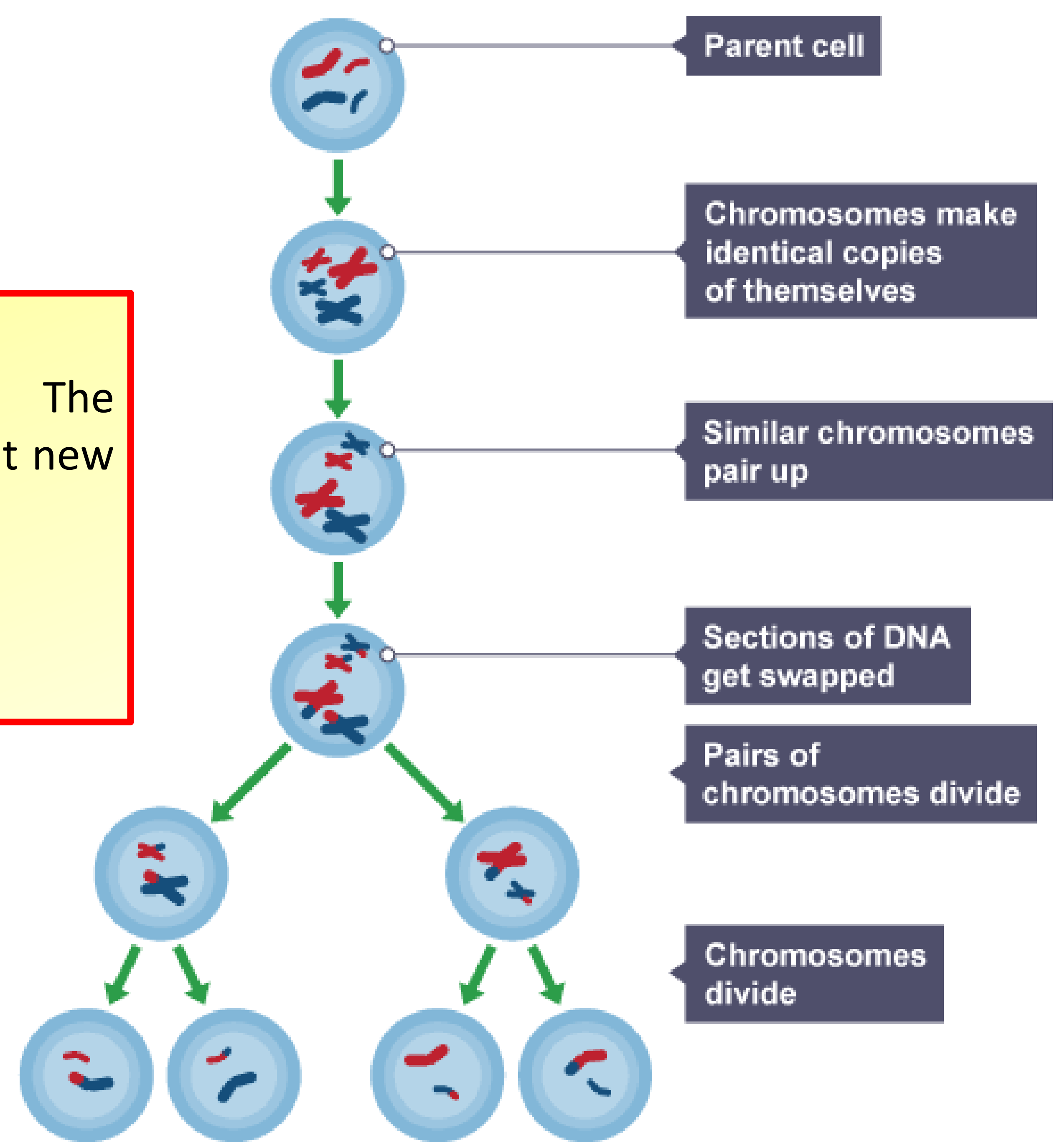
In mammals, body cells are diploid. The chromosomes need to be copied exactly so that new cells can be produced for:

- growth
- repair to damaged tissue
- replacement of worn-out cells



Sexual reproduction

Organisms have sex cells called **gametes**. In human beings, the male sex cells are called **sperm** and the female sex cells are called eggs or **ova**. Sexual reproduction happens when a male gamete and a female gamete join. **This fusion of gametes is called fertilisation**. Sexual reproduction allows some of the genetic information from each parent to mix, producing offspring that resemble their parents but are not identical to them. In this way, sexual reproduction leads to **variety in the offspring**. Animals and plants can reproduce using sexual reproduction.

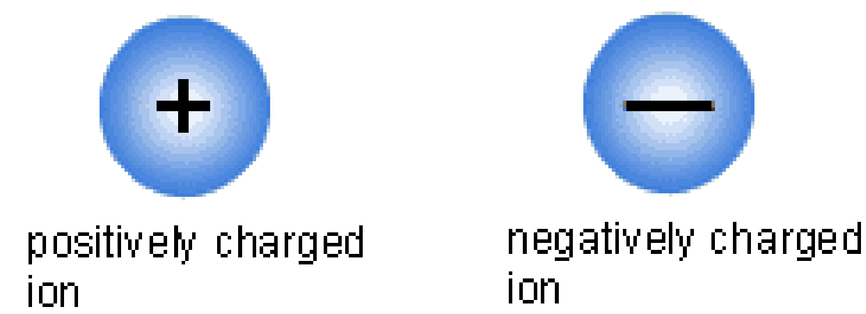


Meiosis is the type of cell division that produces gametes. A human body cell contains 46 chromosomes arranged in 23 pairs. Human gametes are haploid – so their nucleus only contains a single set of 23 unpaired chromosomes.

Alleles

There are pairs of chromosomes in the nucleus of a body cell. The chromosomes in a pair carry the same genes in the same places. But there are different versions of the same gene. Different versions of the same gene are called alleles.

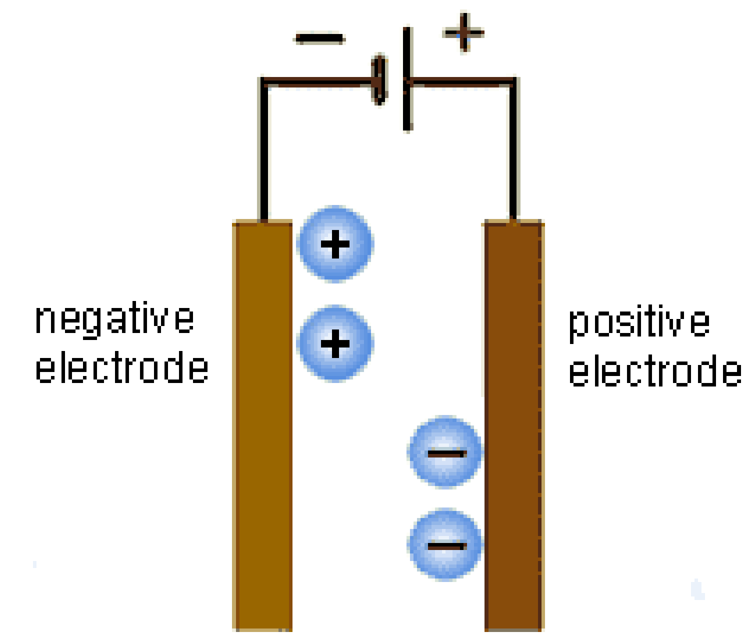
Electrolysis Revision



Introduction

Electrolysis is the process by which ionic substances are broken down into simpler substances using electricity. During electrolysis, metals and gases may form at the electrodes. Ionic substances form when a metal reacts with a non-metal. They contain charged particles called ions. Electrolysis is the process by which ionic substances are decomposed (broken down) into simpler substances when an electric current is passed through them.

- For electrolysis to work, the ions must be free to move. Ions are free to move when an ionic substance is dissolved in water or molten (melted).

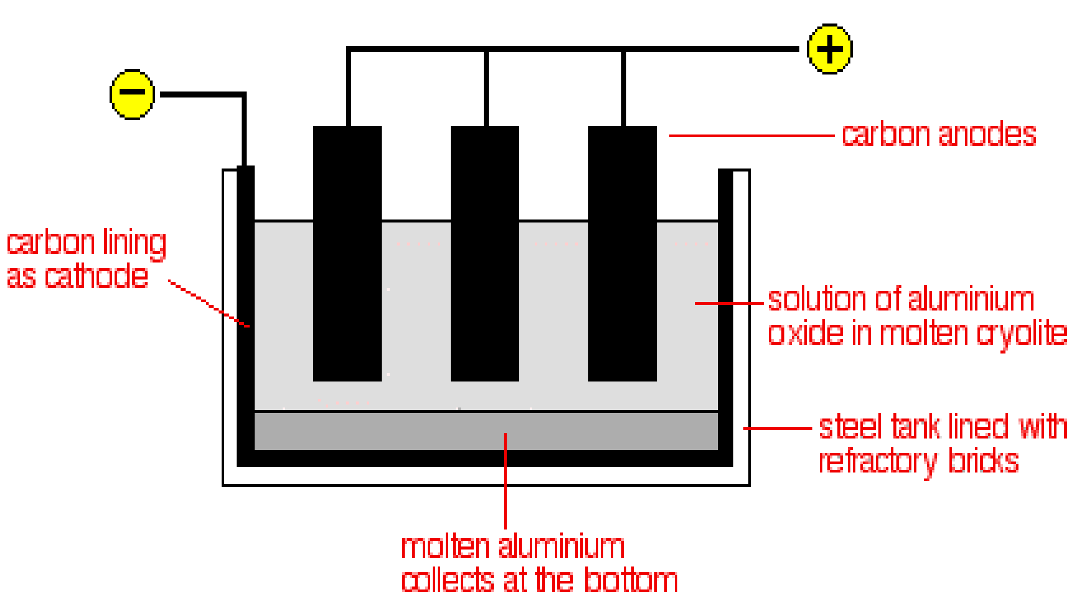


- Positively charged ions move to the negative electrode during electrolysis. They receive electrons and are *reduced*.
- Negatively charged ions move to the positive electrode during electrolysis. They lose electrons and are *oxidised*.

Electrolysis of copper

In this process, the positive electrode (the anode) is made of the impure copper which is to be purified. The negative electrode (the cathode) is a bar of pure copper. The two electrodes are placed in a solution of copper(II) sulfate.

The animation shows what happens when electrolysis begins. Copper ions leave the anode and are attracted to the cathode, where they are deposited as copper atoms. The pure copper cathode increases greatly in size, while the anode dwindles away. The impurities left behind at the anode form a sludge beneath it.



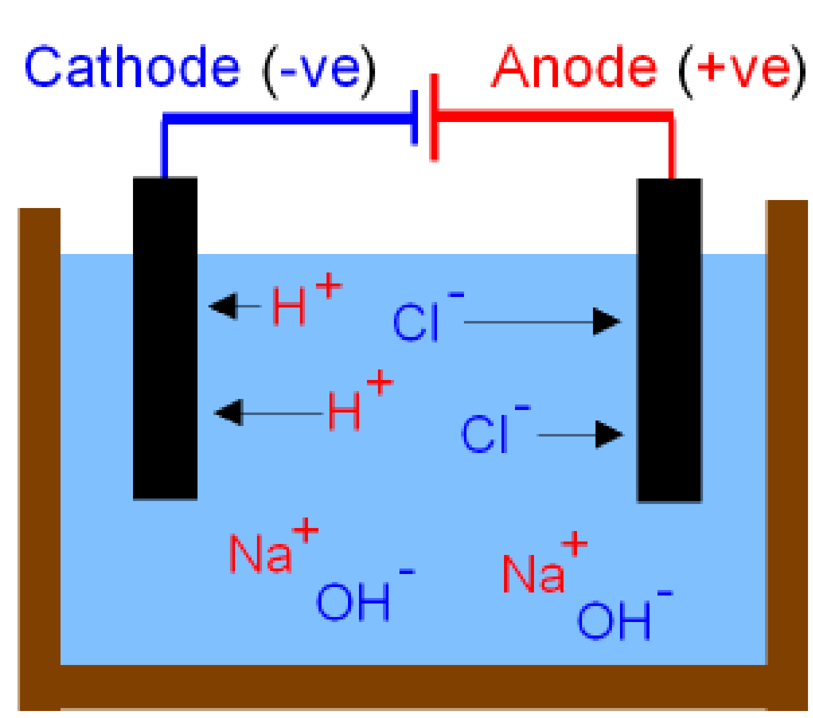
Electrolysis of Aluminium

- Bauxite is purified to produce aluminium oxide
- This is then mixed with cryolite to lower the melting point
- A positive and negative electrode is placed into this mix
- The aluminium gains a positive charge
- The oxygen gains a negative charge
- The aluminium moves towards the negative electrode
- The oxygen moves towards the positive electrode

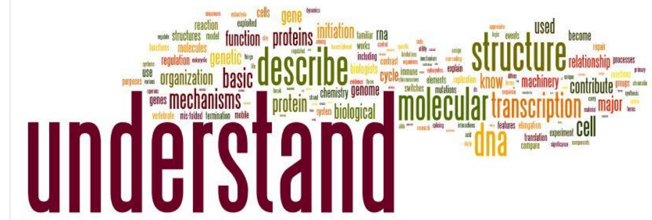
Electrolysis of Brine

Brine is concentrated sodium chloride solution. If an electric current is passed through it, hydrogen gas forms at the negative *electrode* and chlorine gas forms at the positive electrode. A solution of sodium hydroxide forms.

You might have expected sodium metal to be deposited at the negative electrode. But sodium is too reactive for this to happen, so hydrogen is given off instead.

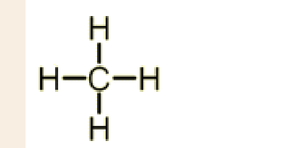
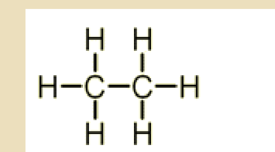
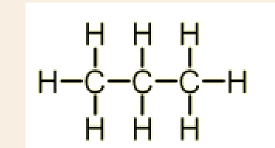
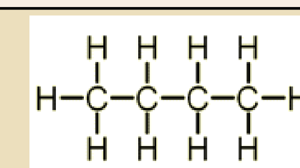


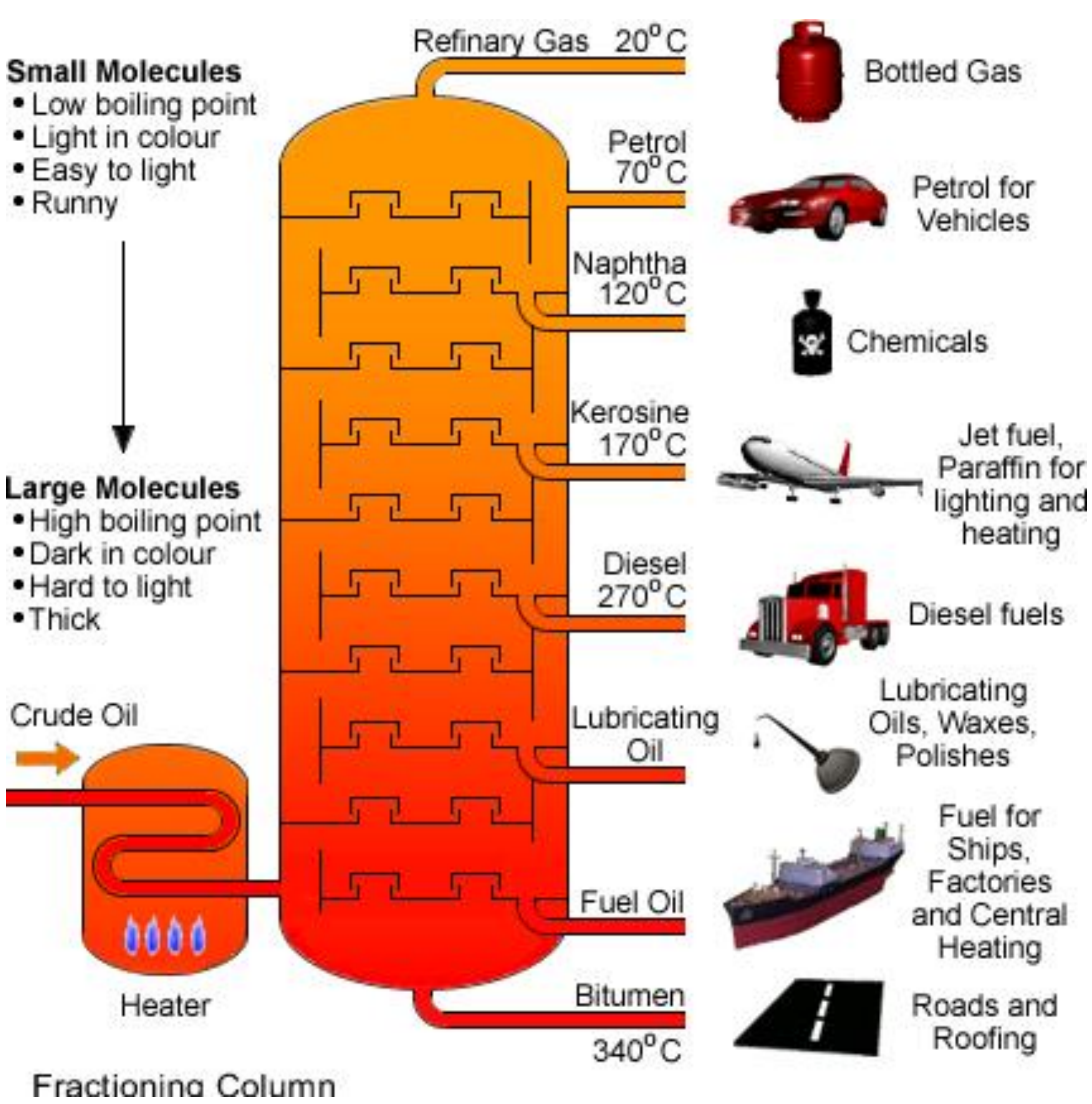
Oil Revision



Alkanes

Crude oil forms naturally over millions of years from the remains of living things. Most of the compounds in crude oil are hydrocarbons. These are compounds that contain hydrogen and carbon atoms only, joined together by chemical bonds called covalent bonds. There are different types of hydrocarbon, but most of the ones in crude oil are alkanes.
The alkanes are a family of hydrocarbons that share the same general formula. This is:
C_nH_{2n+2}

alkane	Molecular formula	Displayed formula
methane	CH_4	
ethane	C_2H_6	
propane	C_3H_8	
butane	C_4H_{10}	

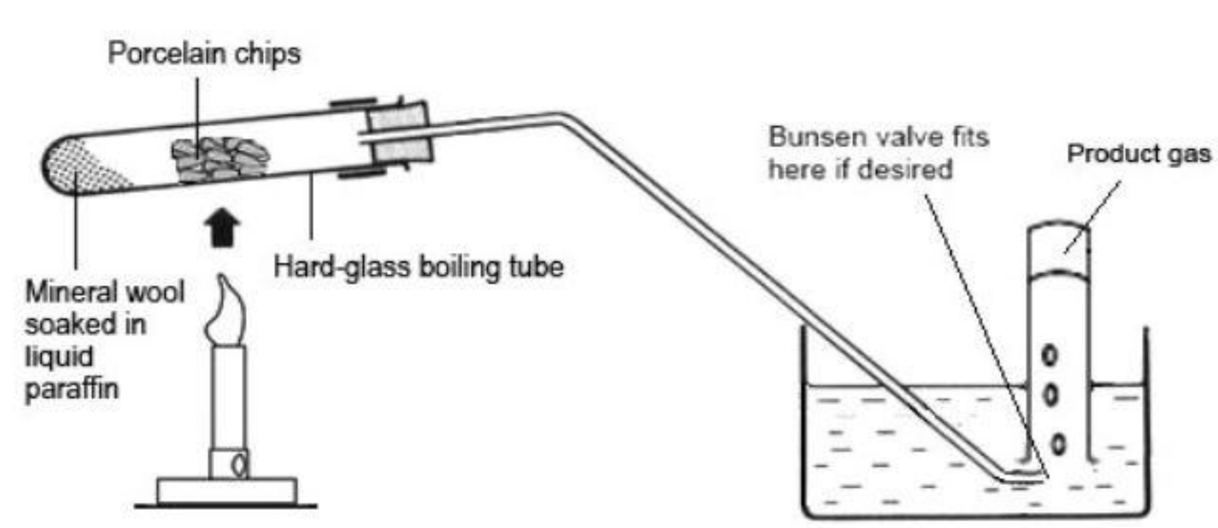


Fractional distillation

Fractional distillation is different from distillation in that it separates a mixture into a number of different parts, called fractions. A tall column is fitted above the mixture, with several condensers coming off at different heights. The column is hot at the bottom and cool at the top. Substances with high boiling points *condense* at the bottom and substances with lower *boiling points* condense on the way to the top.
The crude oil is *evaporated* and its vapours condense at different temperatures in the fractionating column. Each fraction contains hydrocarbon molecules with a similar number of carbon atoms.

Cracking

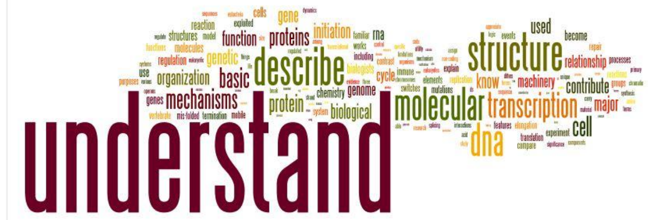
Fuels made from oil mixtures containing large *hydrocarbon* molecules are not efficient. They do not flow easily and are difficult to ignite. Crude oil often contains too many large hydrocarbon molecules and not enough small hydrocarbon molecules to meet demand - this is where **cracking** comes in.
Cracking allows large hydrocarbon molecules to be broken down into smaller, more useful hydrocarbon molecules. Fractions containing large hydrocarbon molecules are vaporised and passed over a hot *catalyst*. This breaks chemical bonds in the molecules, and forms smaller hydrocarbon molecules.



Alkenes

Alkenes are hydrocarbons that contain a carbon-carbon double bond. The number of hydrogen atoms in an alkene is double the number of carbon atoms. For example, the molecular formula of ethene is C_2H_4, while for propene it is C_3H_6.

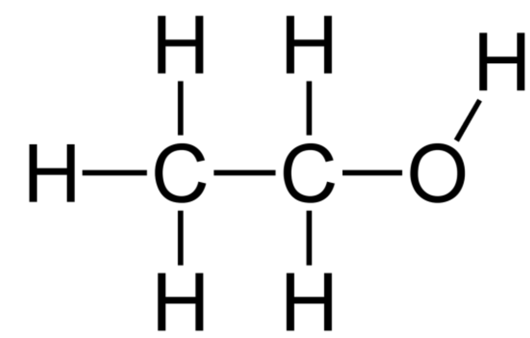
Organic Chemistry



Alcohols

The alcohols are a homologous series of organic compounds. They all contain the functional group –OH, which is responsible for the properties of alcohols.

- The names of alcohols end with 'ol', eg ethanol.
- The first three alcohols in the homologous series are methanol, ethanol and propanol. They are highly flammable, making them useful as fuels. They are also used as solvents in marker pens, medicines, and cosmetics (such as deodorants and perfumes).
- Ethanol is the alcohol found in alcoholic drinks such as wine and beer. Ethanol is mixed with petrol for use as a fuel.



Ethanol from ethene and steam

Ethanol can be manufactured by the hydration of ethene. In this reaction, ethene (which comes from cracking crude oil fractions) is heated with steam in the presence of a catalyst of phosphoric acid (to speed up the reaction):

$$ethene + steam \xrightarrow[high\ pressure]{high\ temperature} ethanol$$

$$C_2H_4 + H_2O \xrightarrow[high\ pressure]{high\ temperature} C_2H_5OH$$

This reaction typically uses a temperature of around 300°C and a pressure of around 60–70 atmospheres.
Notice that ethanol is the only product. The process is continuous – as long as ethene and steam are fed into one end of the reaction vessel, ethanol will be produced. These features make it an efficient process. However, ethene is made from crude oil, which is a non-renewable resource.

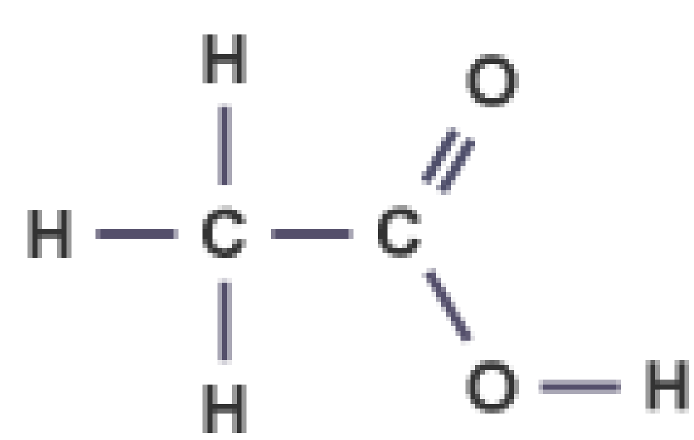
Fermentation

During fermentation, sugar (glucose) from plant material is converted into ethanol and carbon dioxide. This typically takes place at temperatures of around 30°C. The enzymes found in single-celled fungi (yeast) are the natural catalysts that can make this process happen:

$$C_6H_{12}O_6 \xrightarrow{enzymes\ in\ yeast} 2C_2H_5OH + 2CO_2$$

Carboxylic acids

- The carboxylic acids are a homologous series of organic compounds.
- Carboxylic acids contain the carboxyl functional group (-COOH). Carboxylic acids end in '-oic acid'.
- The carboxyl group will never have a position number in a carboxylic acid, as it is always on the end of the carbon chain.
- The basic rules of naming apply. Carboxylic acids take their names from their 'parent' alkanes. For example, ethane is the 'parent' alkane of ethanoic acid. Ethanoic acid has the formula CH3COOH and this structure:



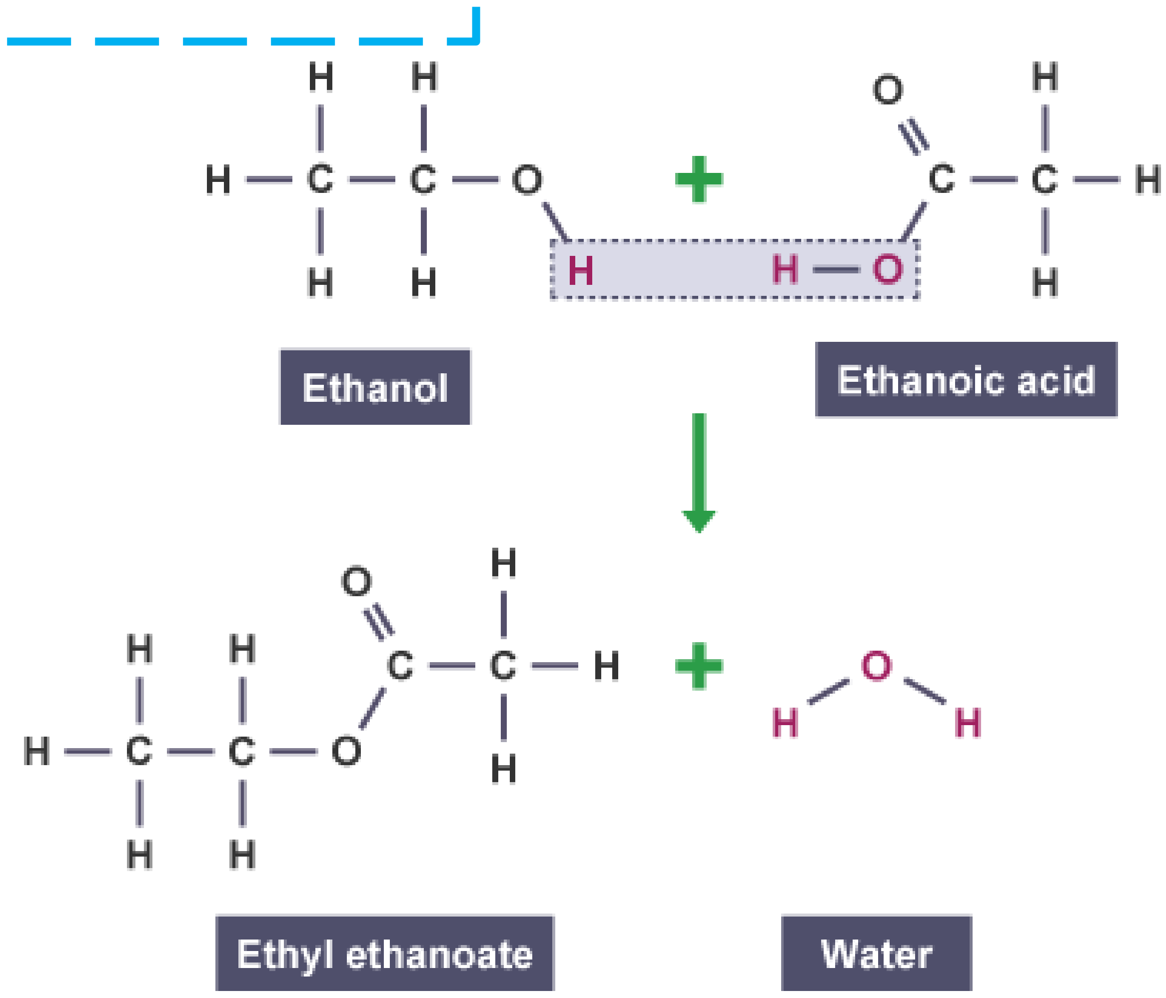
Properties of carboxylic acids

Short carboxylic acids are liquids and are soluble in water. Longer carboxylic acids are solids and are less soluble in water.
The boiling point of a carboxylic acid is higher than that of the alkane with the same number of carbon atoms because the intermolecular forces are much stronger.
Carboxylic acids are weak acids, so they can donate a hydrogen ion (H+) in acid-base reactions.

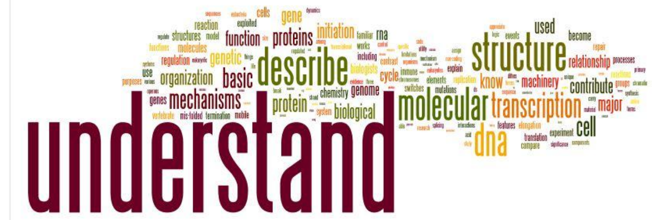
Esters

Esters occur naturally - often as fats and oils - but they can be made in the laboratory by reacting an alcohol with an organic acid. A little sulfuric acid is needed as a catalyst.

The general word equation for the reaction is:
alcohol + organic acid → ester + water



Motion Revision



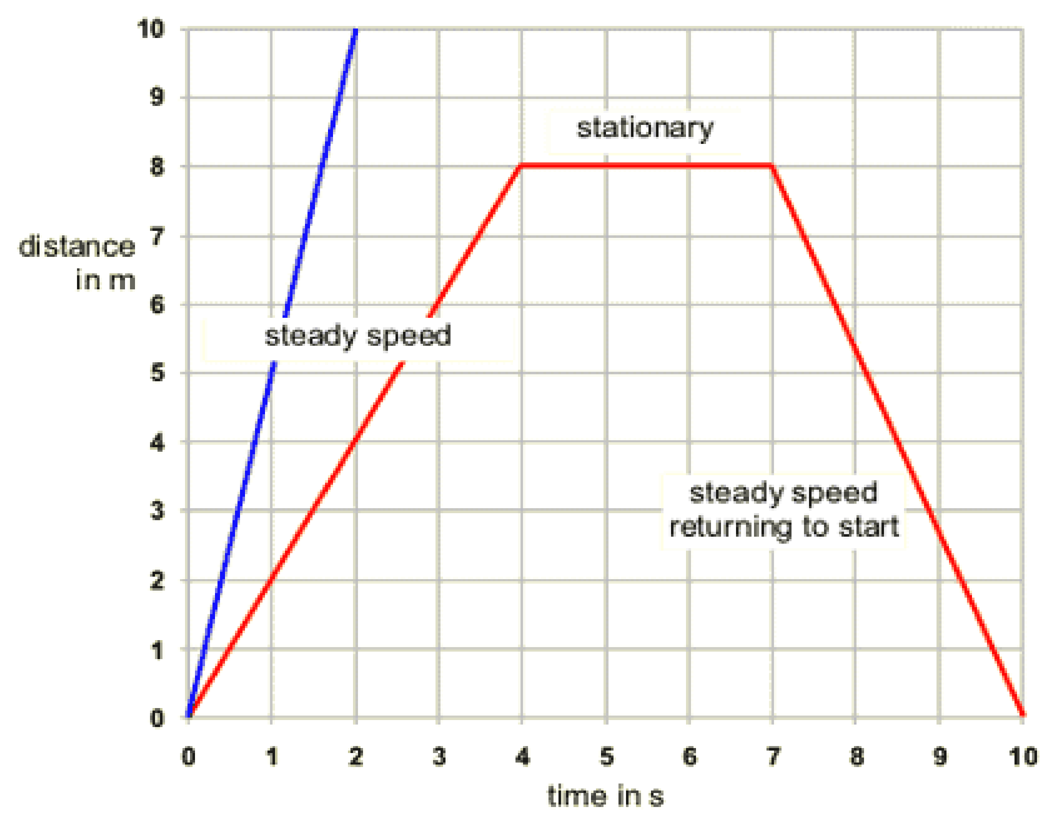
Speed, distance & time

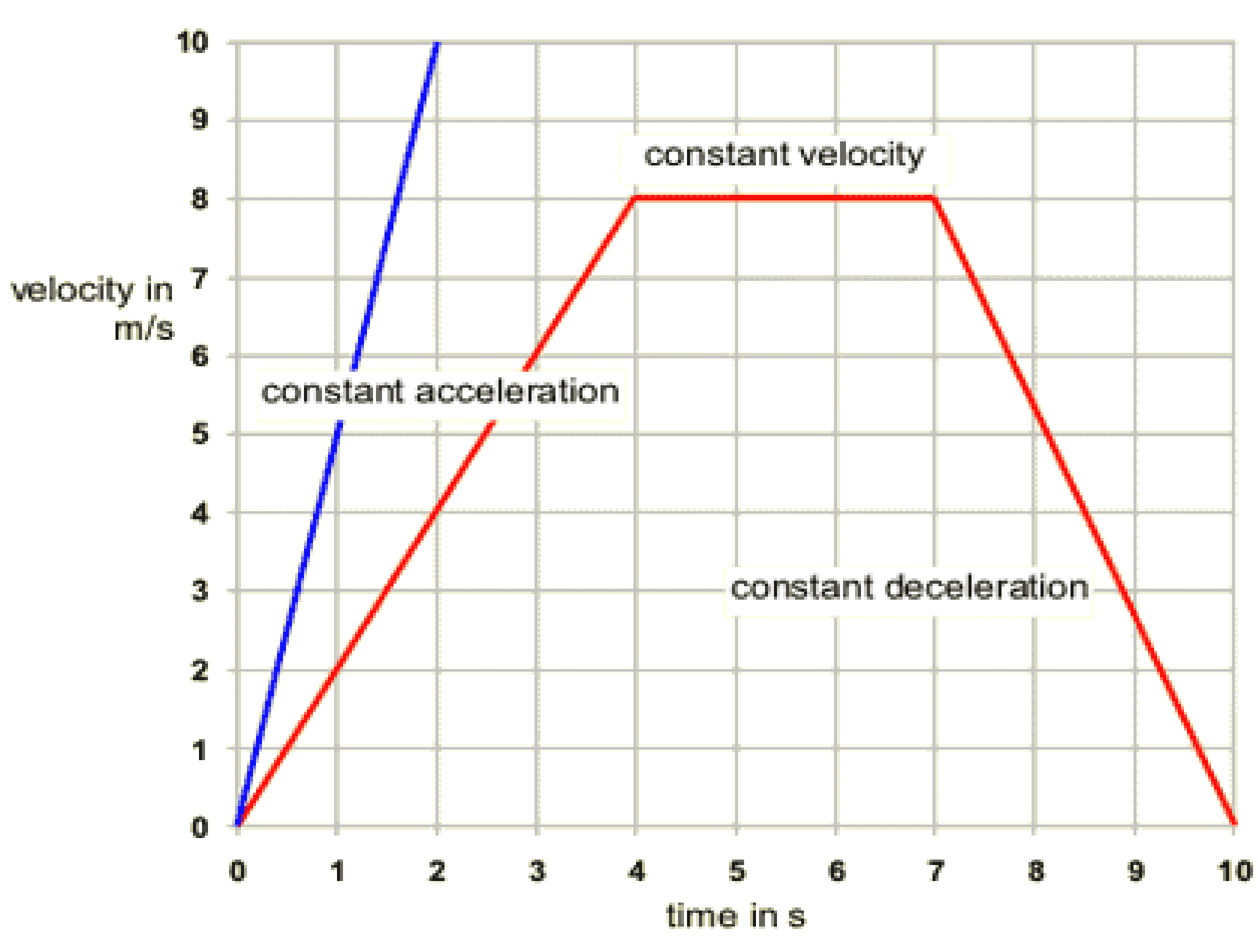
When an object moves in a straight line at a steady speed, you can calculate its speed if you know how far it travels and how long it takes. This equation shows the relationship between speed, distance travelled and time taken:

$$\text{speed (metre per second, m/s)} = \frac{\text{distance travelled (metre, m)}}{\text{time taken (second, s)}}$$

Distance / time graphs

- You should be able to draw and explain distance-time graphs for objects moving at steady speeds or standing still.
- The vertical axis of a distance-time graph is the distance travelled from the start. The horizontal axis is the time from the start.
- When an object is stationary, the line on the graph is horizontal. When an object is moving at a steady speed, the line on the graph is straight, but sloped.





Velocity-time graphs

- You should be able to explain velocity-time graphs for objects moving with a constant velocity or constant *acceleration*.
- The velocity of an object is its speed in a particular direction. This means that two cars travelling at the same speed, but in opposite directions, have different velocities.
- The vertical axis of a velocity-time graph is the velocity of the object. The horizontal axis is the time from the start.
- When an object is moving with a constant velocity, the line on the graph is horizontal. When an object is moving with a constant acceleration, the line on the graph is straight, but sloped. The diagram shows some typical lines on a velocity-time graph.

Acceleration

When an object moves in a straight line with a constant acceleration, you can calculate its acceleration if you know how much its velocity changes and how long this takes. This equation shows the relationship between acceleration, change in velocity and time taken:

$$\text{acceleration (metre per second squared)} = \frac{\text{change in velocity (metre per second)}}{\text{time taken (second, s)}}$$

Life Cycle of a Star Revision

Introduction:

- Stars form when enough dust and gas clump together because of gravitational forces. Nuclear reactions release energy to keep the star hot. Planets form when smaller amounts of dust and gas clump together because of gravitational forces.
- Stable stars like the Sun change during their lifetime to form other types of stars, such as red giants, white dwarfs, neutron stars and black holes. The fate of a star depends upon how much matter it contains.

Nebula:

The space between the stars is not empty. It is filled with gases and dust particles referred to as interstellar medium or interstellar matter. Gases make up most of the interstellar medium with the dust accounting for a very small amount of the total mass. The gas is mostly hydrogen and the dust contains tiny grains of silicates, graphite and iron. Interstellar matter clump together to form clouds called **nebulae**. It is in these clouds or nebula that stars are formed.

Protostar:

As the dust and gas clouds become denser and acquire more mass, the gravitational interactions between the particles can overcome the outward pressures due to kinetic energy. This creates a gravitational instability and the causes a gravitational collapse of the cloud. This is when the clouds collapse into small bodies under the action of their own gravity. During the collapsing or contraction of the cloud the material at the centre of the cloud heats up due to the transfer of gravitational potential energy into thermal energy. This hot core at the centre of the collapsing cloud is called a **Protostar**.

Main Sequence Star:

If the mass of the protostar exceeds about 0.08 of the sun's mass then the gravitational contraction provides sufficient transfer of gravitational potential energy to kinetic energy for nuclear fusion. The star produces energy which makes it shine. Equilibrium is achieved between the inward gravitational force from the tremendous mass of outer layers and the outward forces from the internal pressures. The star is now on a stage of its life called the main sequences phase and is thus called a **main sequence star**

Red Giant:

Towards the end of the main sequence stage all the hydrogen in the core of the star is exhausted and transformed to inert helium. Without the hydrogen the thermonuclear reactions in the core stop and gravity compresses the core to a smaller size. Surrounding the core is a layer of hydrogen; gravitational contraction provides enough energy for nuclear fusion of the hydrogen in this layer. The outward pressure from the nuclear reaction prevents the star from collapsing and makes it expand to several hundred times its former size. Due to the expansion of the outer layers the energy from the hydrogen layer is spread over a larger surface area resulting in a lower surface temperature and a shift in the stars light output to a red wavelength. The star has now become a **Red Giant**.

End of a Star:

- A small star ends as a white dwarf
- A massive star goes super nova then turns into a neutron star
- A super massive star goes super nova then turns into a black hole

Adaptation & Competition Revision

Introduction:

Organisms are adapted to survive in different conditions. Over many generations, these adaptations have come about through variation. Variation involves small changes between organisms which may allow that organism to compete better for survival. Variation can have environmental or genetic causes.

Cold climates

Every organism has certain features or characteristics that allow it to live successfully in its habitat. These features are called adaptations, and we say that the organism is adapted to its habitat. Organisms living in different habitats need different adaptations.

The polar bear

- Polar bears are well adapted for survival in the Arctic. They have:
- a white appearance, as camouflage from prey on the snow and ice
- thick layers of fat and fur, for insulation against the cold
- a small surface area to volume ratio, to minimise heat loss
- a greasy coat, which sheds water after swimming.

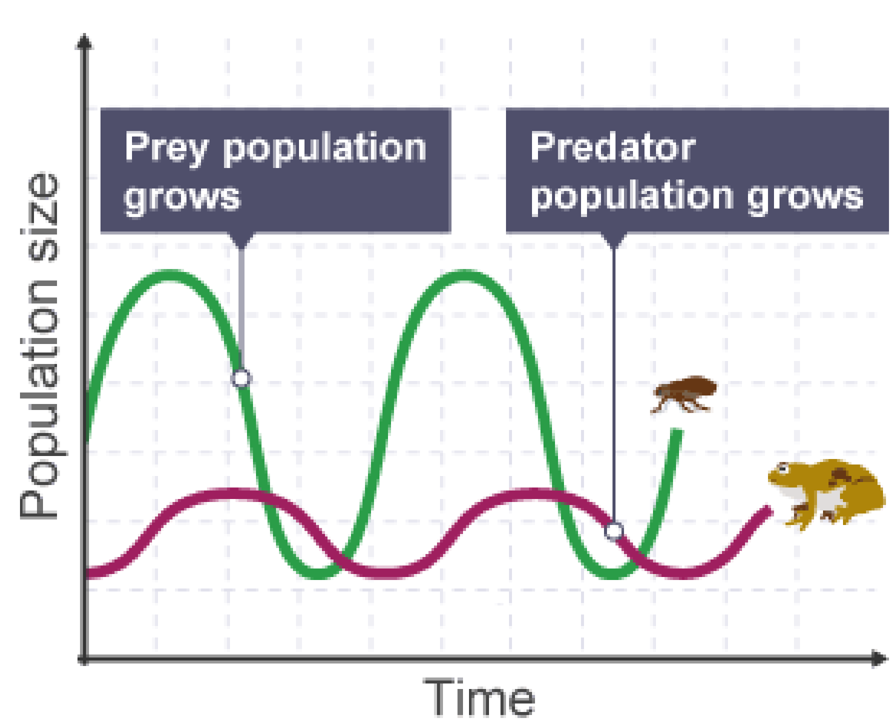
Hot climates

Camels live in deserts that are hot and dry during the day, but cold at night. They are well adapted for survival in the desert. Camels have:

- Large, flat feet to spread their weight on the sand.
- Thick fur on the top of the body for shade, and thin fur elsewhere to allow easy heat loss.
- A large surface area to volume ratio to maximise heat loss.
- The ability to go for a long time without water (they don't store water in their humps, but they lose very little through urination and sweating).
- The ability to tolerate body temperatures up to 42°C.
- Slit-like nostrils and two rows of eyelashes to help keep the sand out.

Competition

Habitats have limited amounts of the resources needed by living organisms and organisms can only survive if they can get enough of these resources, so they must compete for resources with other organisms. If they are unsuccessful and cannot move to another habitat, they will die.



Animals

The resources that animals compete for include:

- food
- water
- space.
- Animals may also compete for mates so that they can reproduce.

Plants

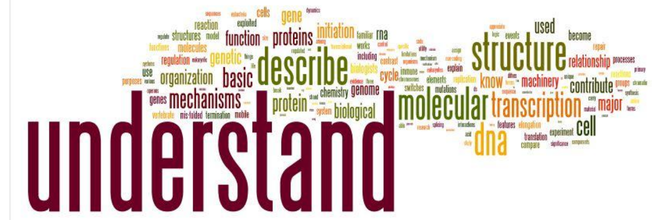
Remember that plants make their own food using photosynthesis, so they do not compete for food. The resources that plants compete for include:

- water
- space
- mineral salts.

Extremophiles are organisms that live in very extreme environments and can survive conditions that would kill most other organisms. The extreme conditions can include:

- high temperatures
- high concentrations of salt in water
- high pressures.

Evolution Revision



Darwin's theory

Key points of evolution by natural selection:

- individuals in a species show a wide range of variation
- this variation is because of differences in their genes
- individuals with characteristics most suited to the environment are more likely to survive and reproduce
- the genes that allow these individuals to be successful are passed to their offspring.

Individuals that are poorly adapted to their environment are less likely to survive and reproduce. This means that their genes are less likely to be passed to the next generation. Given enough time, a species will gradually evolve.

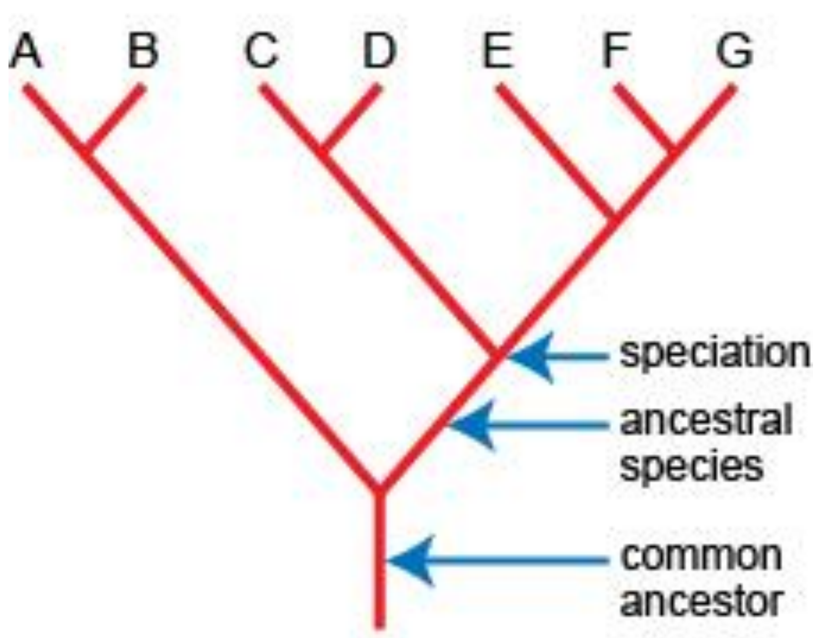
Lamarck's theory

Jean-Baptiste Lamarck was a French scientist who developed an alternative theory at the beginning of the 19th century. His theory involved two ideas, which are:

1. a characteristic that is used more and more by an organism becomes bigger and stronger, and one that is not used eventually disappears
2. any feature of an organism that is improved through use is passed to its offspring.

However, we now know that in most cases this type of inheritance cannot happen.

Lamarck's theory cannot account for all the observations made about life on Earth. For instance, his theory implies that all organisms would gradually become complex, and simple organisms disappear. On the other hand, Darwin's theory can account for the continued presence of simple organisms.



Evolutionary trees

Evolutionary trees are used to represent the relationships between organisms. The diagram shows an evolutionary tree.

In this evolutionary tree, species A and B share a common ancestor. Species F and G share a common ancestor, which itself shared a common ancestor with species E. All seven species share a common ancestor, probably from the distant past.

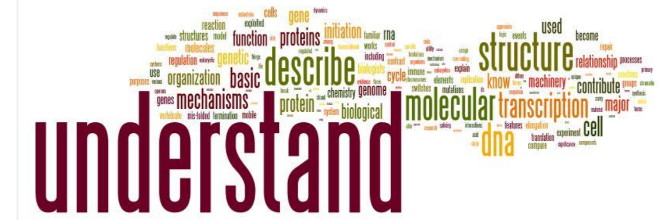
Mutations cause changes in genes. When new forms of a gene appear because of mutation, a rapid change in a species may happen if the environment changes. Such rapid changes support the theory of evolution by natural selection.

Extinction

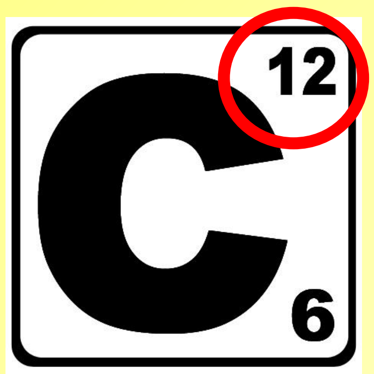
Individuals that are poorly adapted to their environment are less likely to survive and reproduce than those that are well adapted. Similarly, it is possible that a species that is poorly adapted to its environment will not survive and will become extinct. Here are some of the factors that can cause a species to become extinct:

- changes to the environment, such as a change in climate
- new diseases
- new predators
- new competitors

Chemistry Calculations Revision



The mass of atoms



The mass of an atom is made up by adding together it's protons and neutrons

- Protons have a mass of 1
- Neutrons have a mass of 1

Moles

Because saying 'relative formula (or atomic!) mass in grams' is a bit clumsy, we simply say 'moles' instead. This means that 1 mole of Carbon Dioxide is 44 grams, or 44g.

To calculate how many moles of a substance there is divide the amount of it by the mass of 1 mole of the substance

1. NaOH
   23 + 16 + 1 = 40g is one mole of NaOH

2. We have 100g in our reaction so…
   $\frac{100}{40}$ = 2.5 moles

Empirical Formula

1. Divide the mass of each element by its relative atomic mass to find out the number of moles reacted
2. Create a ratio and simplify if necessary
3. Write a formula based on the ratio

The mass of compounds

Relative formula mass can be found by adding up the relative atomic masses of each element in a compound.

E.g. Carbon Dioxide (CO_2)

- Carbon has a relative atomic mass of 12
- Oxygen has a relative atomic mass of 16
- The relative formula mass of Carbon Dioxide is therefore:
  12 + (16 x 2) = 44

Percentage Mass

We can use the relative atomic mass (A_r) of elements and the relative formula mass (M_r) of compounds to find out the percentage composition of different elements.

1. Work out the formula mass of the compound
2. Convert this into grams
3. Work out the percentage by using this equation:

$$\frac{\text{Mass of element}}{\text{Total mass of compound}} \times 100\%$$

Yield

Rather than talk about the yield of a chemical reaction in terms of mass (grams, tonnes etc.) we can talk about the percentage yield. This gives us an idea of the amount of product that the reaction really makes, compared to what it could possibly make under perfect conditions.

1. Work out the maximum mass of a product that could be made using it's chemical formula
2. Divide the actual mass of the product made by it's maximum mass
3. Multiply by 100

Chemical Analysis Revision

Testing for ions - flame tests

- The Group 1 elements in the periodic table are known as the alkali metals. They include lithium, sodium and potassium, which all react vigorously with air and water.
- It is possible to use a flame test to detect the presence of an alkali metal ion.
- A cleaned, moistened flame test wire is dipped into a solid sample of the compound. It is then put into the edge of a blue Bunsen flame. The flame colour produced indicates which alkali metal ion is present in the compound.

Flame colour	Ion present
Red	Lithium, Li^+
Orange	Sodium, Na^+
Lilac	Potassium , K^+
Brick red	Calcium, Ca^{2+}

Identifying transition metal ions

Transition metals form coloured **compounds** with other **elements**. Many of these are soluble in water, forming coloured solutions.
If sodium hydroxide solution is then added, a transition metal hydroxide is formed. Transition metal hydroxides are **insoluble** so they form solid **precipitates**. These precipitates often appear as small particles suspended in a solution.
Here are the equations for copper sulfate solution reacting with sodium hydroxide solution:

- copper(II) sulfate + sodium hydroxide → copper(II) hydroxide + sodium sulfate

- $CuSO_4(aq) + 2NaOH(aq) \rightarrow Cu(OH)_2(s) + Na_2SO_4(aq)$

Detecting ammonium ions

Ammonium ions (NH_4^+) are present in dilute ammonia solution and any ammonium salt, such as ammonium chloride.
Ammonium ions can be identified in a solution by adding dilute sodium hydroxide solution and gently heating. If ammonium ions are present, they will be converted to ammonia gas. Ammonia has a characteristic choking smell. It also turns damp red litmus paper or damp universal indicator paper blue.

Metal ion	Colour
Iron(II), Fe^{2+}	Green - turns orange-brown when left standing
Iron(III), Fe^{3+}	Orange-brown
Copper(II), Cu^{2+}	Blue

Testing for sulfate ions

Sulfate ions in solution, SO_4^{2-}, are detected using barium chloride solution. The test solution is acidified using a few drops of dilute hydrochloric acid, and then a few drops of barium chloride solution are added. A white **precipitate** of barium sulfate forms if sulfate ions are present.

For example:
barium chloride + sodium sulfate → sodium chloride + barium sulfate
$BaCl_2(aq) + Na_2SO_4(aq) \rightarrow 2NaCl(aq) + BaSO_4(s)$

Testing for halide ions
The halogens are the **elements** in Group 7 of the **periodic table**. Chlorine, bromine and iodine are halogens. Their ions are called **halide ions**, eg chloride, Cl^-.

Halide ions in solutions are detected using silver nitrate solutions. The test solution is acidified using a few drops of dilute nitric acid, and then a few drops of silver nitrate solution are added. Different coloured silver halide precipitates form, depending on the halide ions present:

- chloride ions give a **white precipitate** of silver chloride
- bromide ions give a **cream precipitate** of silver bromide
- iodide ions give a **yellow precipitate** of silver iodide

For example:
silver nitrate + sodium bromide → sodium nitrate + silver bromide
$AgNO_3(aq) + NaBr(aq) \rightarrow NaNO_3(aq) + AgBr(s)$

One way to remember the colours is to think of 'milk, cream, butter' (white, cream, yellow).

The nitric acid is added first to remove any carbonate ions that might be present - they would produce a white precipitate of silver carbonate, giving a false positive result for chloride ions.

Testing for nitrate ions

Nitrate ions (NO_3^-) can be detected by **reducing** them to ammonia. This is done by:

- adding sodium hydroxide solution, then aluminium powder or foil
- heating strongly

If nitrate ions are present, ammonia gas is given off. This has a characteristic choking smell. It also turns damp red **litmus paper** or damp **universal indicator paper** blue.

Tests for gases

- Hydrogen, oxygen, carbon dioxide, ammonia and chlorine can be identified using different tests.
- Hydrogen
- A lighted wooden splint makes a popping sound in a test tube of hydrogen.
- Oxygen
- A glowing wooden splint relights in a test tube of oxygen.
- Carbon dioxide
- Carbon dioxide turns limewater milky. A lighted wooden splint goes out in a test tube of carbon dioxide but this happens with other gases, too. So the limewater test is a better choice.
- Chlorine has a characteristic sharp, choking smell. It also makes damp blue litmus paper turn red, and then bleaches it white. Chlorine makes damp starch-iodide paper turn blue-black.

Testing for carbonate ions

Carbonate **ions**, CO_3^{2-} can be detected whether in a solid **compound** or in solution. An **acid**, such as dilute hydrochloric acid, is added to the test compound.

Carbon dioxide gas bubbles if carbonate ions are present. **Limewater** is used to confirm that the gas is carbon dioxide. It turns from clear to milky when carbon dioxide is bubbled through.

Chemical Analysis

Testing for ions - flame tests

The Group 1 elements in the periodic table are known as the alkali metals. They include lithium, sodium and potassium, which all react vigorously with air and water.
It is possible to use a flame test to detect the presence of an alkali metal ion.

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Hydroxide precipitates

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Here are the equations for copper sulfate solution reacting with sodium hydroxide solution:
copper(II) sulfate + sodium hydroxide → copper(II) hydroxide + sodium sulfate
$CuSO_4(aq) + 2NaOH(aq) \rightarrow Cu(OH)_2(s) + Na_2SO_4(aq)$
(blue solution + colourless solution → blue precipitate + colourless solution)

Metal ion	Colour
Iron(II), Fe^{2+}	Green - turns orange-brown when left standing
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Copper(II), Cu^{2+}	Blue

Investigating transition metal ions

To tell whether an unknown substance contains iron(II) nitrate or iron(III) nitrate, add a few drops of sodium hydroxide solution:

- if you get a green precipitate, the unknown substance is iron(II) nitrate
- if you get an orange-brown precipitate, the unknown substance is iron(III) nitrate
- Note that it is the metal that determines the colour. So you would get the same result whether you used copper(II) chloride or copper(II) nitrate - a blue precipitate in this example.

Testing for carbonate ions

Carbonate ions, CO_3^{2-} can be detected whether in a solid compound or in solution. An acid, such as dilute hydrochloric acid, is added to the test compound.
Carbon dioxide gas bubbles if carbonate ions are present. Limewater is used to confirm that the gas is carbon dioxide. It turns from clear to milky when carbon dioxide is bubbled through.

Tests for metal ions - white precipitates

Many metal ions produce white precipitates with sodium hydroxide. These are the two tests you would carry out to identify a metal ion:
add dilute sodium hydroxide to a solution of the metal ion
add dilute ammonia solution
The second test is necessary because the result of the first test can be the same for some metals. For instance, zinc and aluminium ions have the same reaction with sodium hydroxide as shown in these tables:

Ion	A few drops	Excess
Zn^{2+}	White precipitate forms	Precipitate redissolves
Ca^{2+}	White precipitate forms	No change
Al^{3+}	White precipitate forms	Precipitate redissolves

Testing for sulfate ions

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Tests for gases

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- Oxygen: A glowing wooden splint relights in a test tube of oxygen.
- Carbon dioxide: Carbon dioxide turns limewater milky. A lighted wooden splint goes out in a test tube of carbon dioxide but this happens with other gases, too. So the limewater test is a better choice.
- Ammonia: Ammonia has a characteristic sharp, choking smell. It also makes damp red litmus paper turn blue. Ammonia forms a white smoke of ammonium chloride when hydrogen chloride gas, from concentrated hydrochloric acid, is held near it.
- Chlorine: Chlorine has a characteristic sharp, choking smell. It also makes damp blue litmus paper turn red, and then bleaches it white. Chlorine makes damp starch-iodide paper turn blue-black.

The Atmosphere

Gases in air

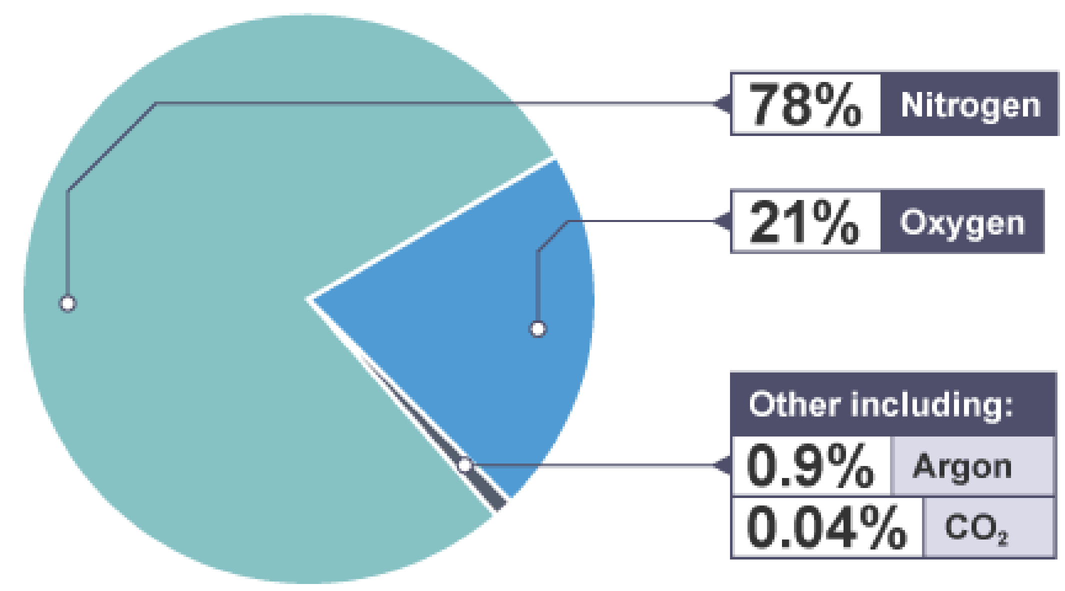
The air is a mixture of gases. The amount of water vapour in the air varies from place to place, and day to day. For this reason, the proportions of the gases in the air are usually given for dry air.

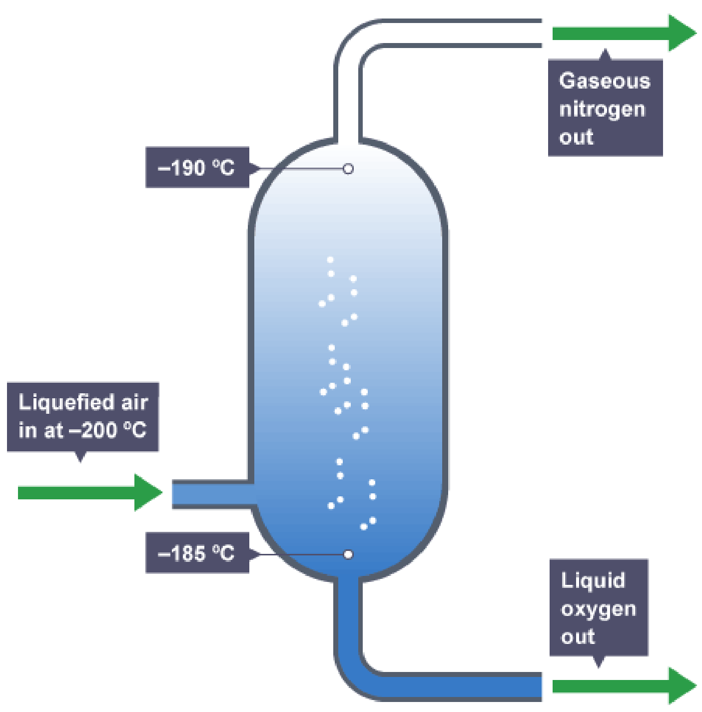
Some of the gases in the air are **elements**:

- nitrogen, N_2
- oxygen, O_2
- argon, Ar

Some are **compounds**, including:

- carbon dioxide, CO_2
- water vapour, H_2O





Fractional distillation of air

About 78 per cent of the air is nitrogen and 21 per cent is oxygen. These two gases can be separated by **fractional distillation of liquid air**.

Liquefying the air

Air is filtered to remove dust, and then cooled in stages until it reaches –200°C. At this temperature it is a liquid. The air has been **liquefied**.

Here's what happens as the air liquefies:

- water vapour **condenses**, and is removed using absorbent filters
- carbon dioxide freezes at -79°C, and is removed
- oxygen liquefies at -183°C
- nitrogen liquefies at -196°C

The liquid nitrogen and oxygen are then separated by **fractional distillation**.

The liquefied air is passed into the bottom of a fractionating column. Just as in the columns used to separate oil **fractions**, the column is warmer at the bottom than it is at the top.

The early atmosphere

Scientists believe that the Earth was formed about 4.5 billion years ago. Its early atmosphere was probably formed from the gases given out by volcanoes. It is believed that there was intense volcanic activity for the first billion years of the Earth's existence.

The early atmosphere was probably mostly carbon dioxide, with little or no oxygen. There were smaller proportions of water vapour, ammonia and methane. As the Earth cooled down, most of the water vapour condensed and formed the oceans.

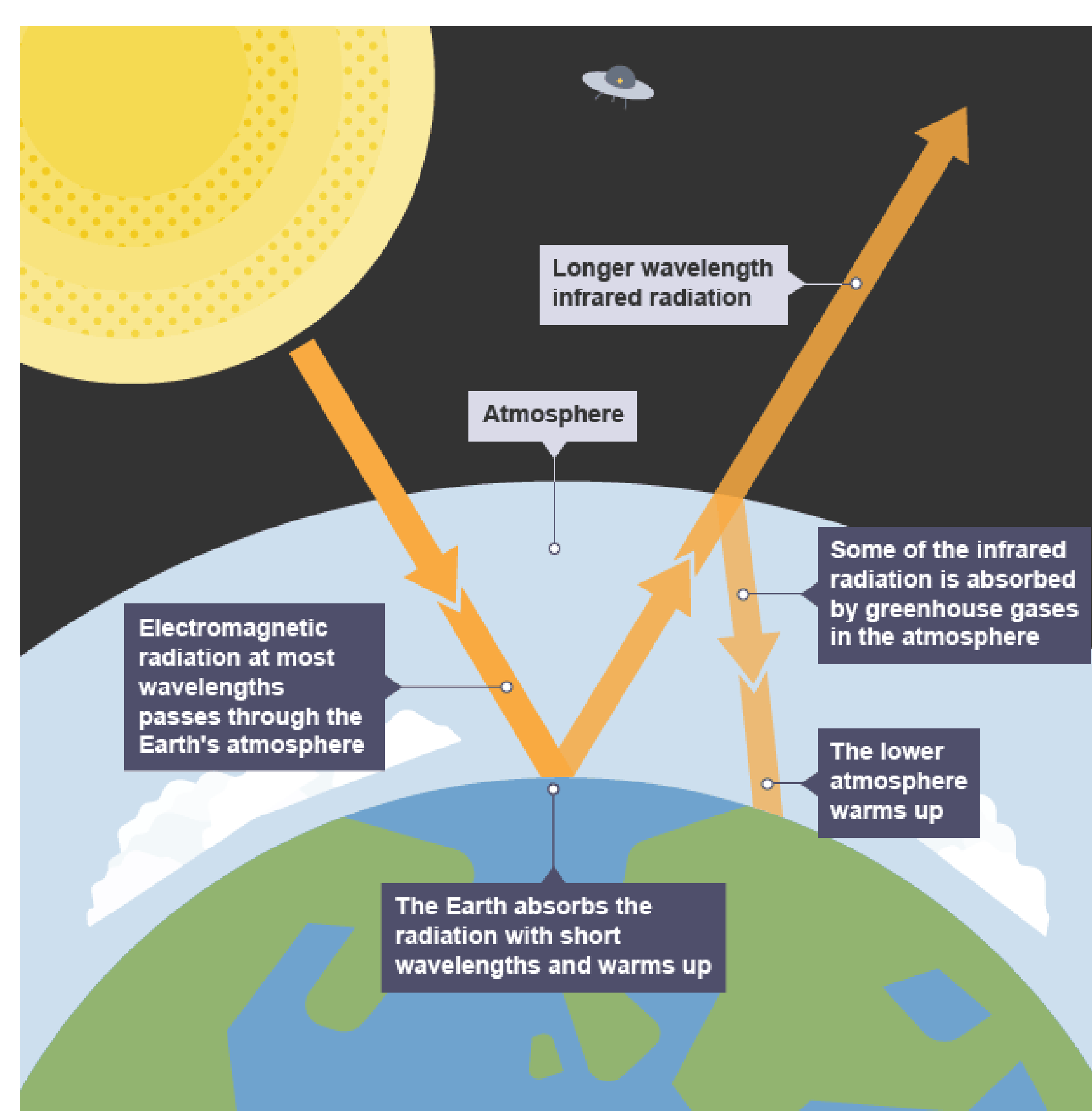
It is thought that the atmospheres of Mars and Venus today, which contain mostly carbon dioxide, are similar to the early atmosphere of the Earth.

Scientists can't be sure about the early atmosphere and can only draw evidence from other sources. For example, volcanoes release high quantities of carbon dioxide. Iron-based compounds are present in very old rocks that could only have formed if there was little or no oxygen at the time.

Greenhouse gases in the atmosphere absorb heat energy and prevent it escaping into space. This keeps the Earth warmer than it would be without these gases. Greenhouse gases are not a bad thing in themselves, but too much of them in the atmosphere leads to an increase in the greenhouse effect and global warming.

There are many greenhouse gases but these are some of the most important:

- water vapour, H_2O
- carbon dioxide, CO_2
- methane, CH_4
- nitrous oxide, N_2O
- CFCs (chlorofluorocarbons)



Changes in the atmosphere

So how did the proportion of carbon dioxide in the atmosphere go down, and the proportion of oxygen go up?

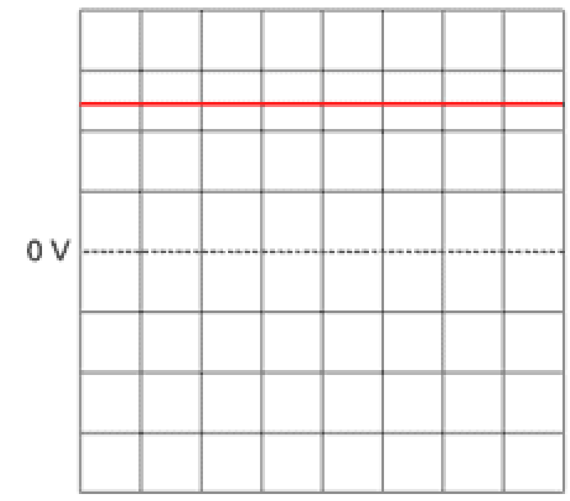
The proportion of oxygen went up because of photosynthesis by plants.

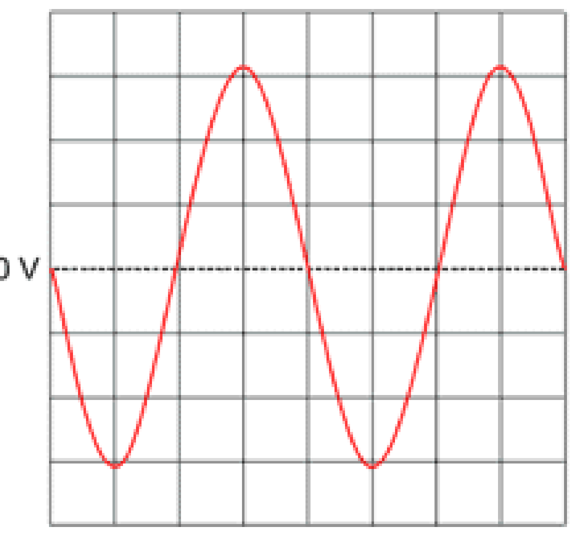
The proportion of carbon dioxide went down because:

- it was locked up in sedimentary rocks (such as limestone) and in fossil fuels
- it was absorbed by plants for photosynthesis
- it dissolved in the oceans
- The burning of fossil fuels is adding carbon dioxide to the atmosphere faster than it can be removed. This means that the level of carbon dioxide in the atmosphere is increasing.

Electricity at Home Revision

Direct current
If the current flows in only one direction it is called direct current (DC). Batteries and cells supply DC electricity, with a typical battery supplying around 1.5 V. The diagram shows an oscilloscope screen displaying the signal from a DC supply.

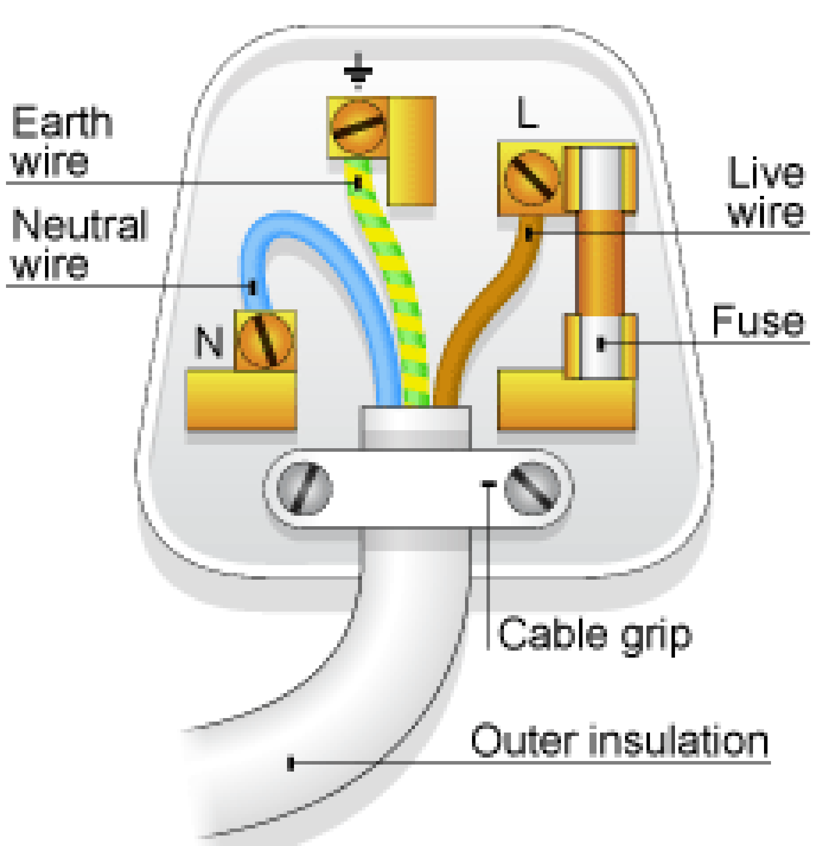




Alternating current
If the current constantly changes direction, it is called alternating current (AC). Mains electricity is an AC supply, with the UK mains supply being about 230 V. It has a frequency of 50 Hz (50 hertz), which means it changes direction, and back again, 50 times a second. The diagram shows an oscilloscope screen displaying the signal from an AC supply.

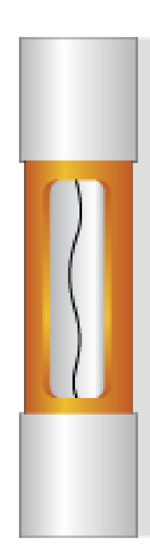
The cable
A mains electricity cable contains two or three inner wires. Each has a core of copper, because copper is a good conductor of electricity. The outer layers are flexible plastic, because plastic is a good electrical insulator. The inner wires are colour coded:

Colour	Wire
blue	neutral
brown	live
green and yellow stripes	earth



The plug
The features of a plug are:
- The case is made from tough plastic or rubber, because these materials are good electrical insulators.
- The three pins are made from brass, which is a good conductor of electricity.
- There is a fuse between the live terminal and the live pin.
- The fuse breaks the circuit if too much current flows.
- The cable is secured in the plug by a cable grip. This should grip the cable itself, and not the individual wires inside it.

The fuse breaks the circuit if a fault in an appliance causes too much current flow. This protects the wiring and the appliance if something goes wrong. The fuse contains a piece of wire which melts easily. If the current going through the fuse is too great, the wire heats up until it melts and breaks the circuit.



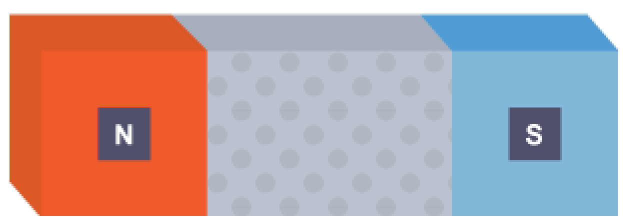
Residual current circuit breakers, RCCBs, protect some circuits. They detect a difference in the current between the live and neutral wires. RCCBs work much faster than fuses do.

Magnetic Fields

Properties of magnets

Bar magnets are permanent magnets. This means that their magnetism is there all the time and cannot be turned on or off as it can with electromagnets.
Bar magnets have two poles:

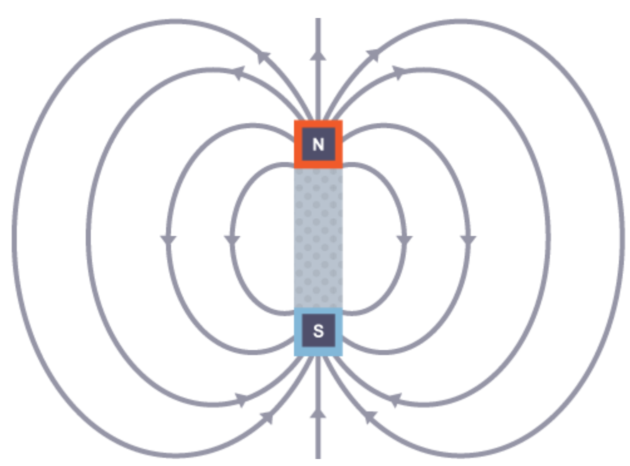
- north pole – normally shown as N
- south pole – normally shown as S
- Opposite (unlike) poles attract, and like poles repel.



- If permanent magnets are repeatedly knocked, the strength of their magnetic field is reduced. Converting a magnet to a non-magnet is called demagnetisation.
- Magnets are made from magnetic metals – iron, nickel and cobalt. These are the only pure metals that can be turned into a permanent magnet. Steel is an alloy of iron and so can also be made into a magnet.
- If these metals have not been turned into a permanent magnet they will still be attracted to a magnet if placed within a magnetic field. In this situation they act as a magnet - but only whilst in the magnetic field. This is called induced magnetism.
- Substances that can be permanently magnetised are described as magnetically hard. These are often alloys of iron, nickel and cobalt.
- Substances that can only be temporarily magnetised are described as magnetically soft. Alloys with less iron, nickel or cobalt will be magnetically soft and have a weaker magnetic field. Alloys of iron are called ferrous and those without iron are called non-ferrous.

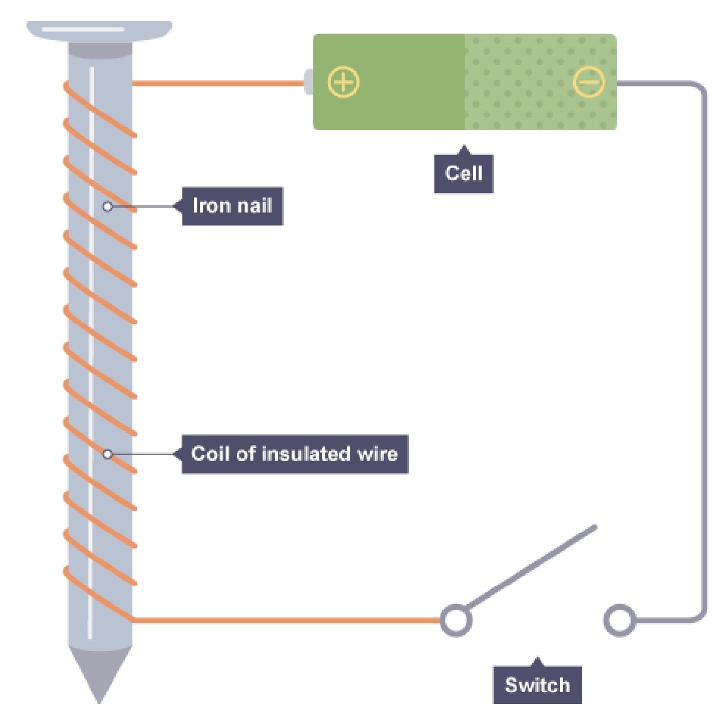
Magnetic field lines

Magnets create magnetic fields. These magnetic fields cannot be seen. They fill the space around a magnet where the magnetic forces work, and where they can attract or repel magnetic materials.



In the diagram, note that:

- the field lines have arrows on them
- the field lines come out of N (north pole) and go into S (south pole)
- the field lines are more concentrated at the poles
- The magnetic field is strongest at the poles, where the field lines are most concentrated.



Electromagnets

When an electric current flows in a wire it creates a magnetic field around the wire. By winding the wire into a coil we can strengthen the magnetic field. Electromagnets are made from coils like this.
We can make an electromagnet stronger by:

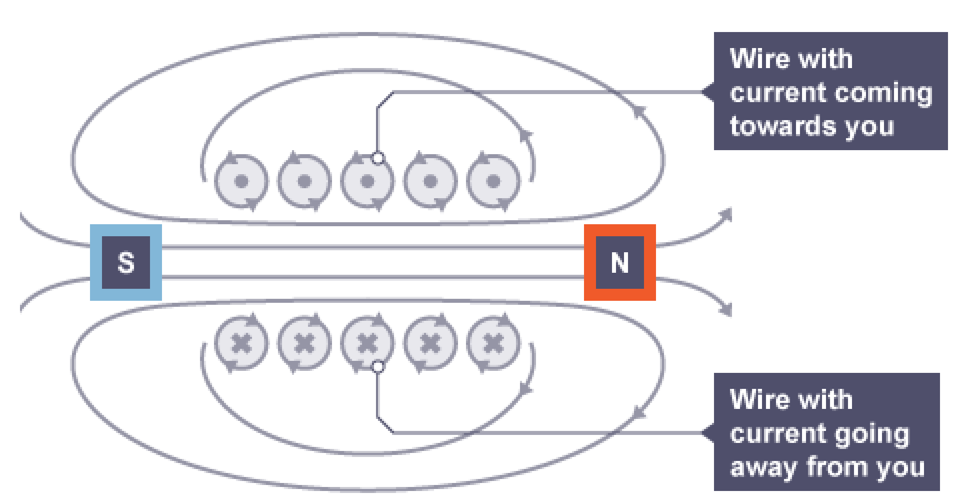
- wrapping the coil around an iron core
- adding more turns to the coil
- increasing the current flowing through the coil

Electromagnetic induction

A magnet and a coil of wire can be used to produce an electric current. A voltage is produced when a magnet moves into a coil of wire. This process is called electromagnetic induction. The direction of the induced voltage is reversed when the magnet is moved out of the coil again. It can also be reversed if the other pole of the magnet is moved into the coil.
If the coil is part of a complete circuit then a current will be induced in the circuit.
Notice that no voltage is induced when the magnet is still, even if it is inside the coil.

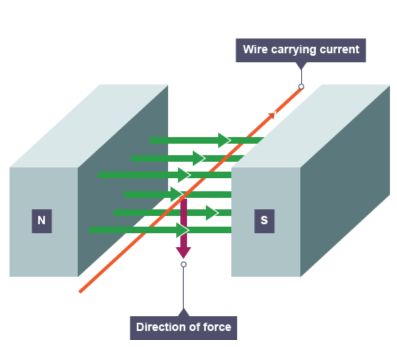
- To increase the induced voltage:
- move the magnet faster
- add more turns to the coil
- increase the strength of the magnet

The magnetic field around an electromagnet is just the same as the one around a bar magnet. It can, however, be reversed by turning the battery around. Unlike bar magnets, which are permanent magnets, the magnetism of electromagnets can be turned on and off just by closing or opening the switch.



Field line patterns

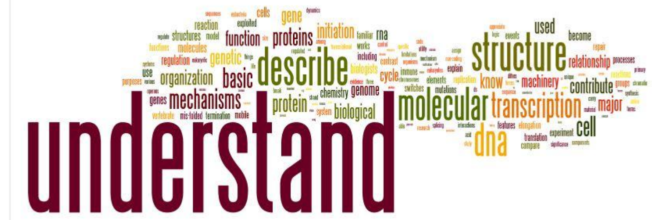
Magnets have a north pole and a south pole. Field line patterns show the direction and shape of a magnetic field. These diagrams are made using a plotting compass. In diagrams of a magnetic field the arrows on the lines show the direction from the north to the south poles.
A magnetic field is also created when an electric current moves through a coil of wire.
Plotting compasses can be used to show the shape and direction of the magnetic field created by a coil of wire.



The motor effect

A current-carrying wire or coil can exert a force on a permanent magnet. This is called the motor effect. The wire could also exert a force on another nearby current-carrying wire or coil.
If the current-carrying wire is placed in a magnetic field (whose lines of force are at right angles to the wire) then it will experience a force at right angles to both the current direction and the magnetic field lines.

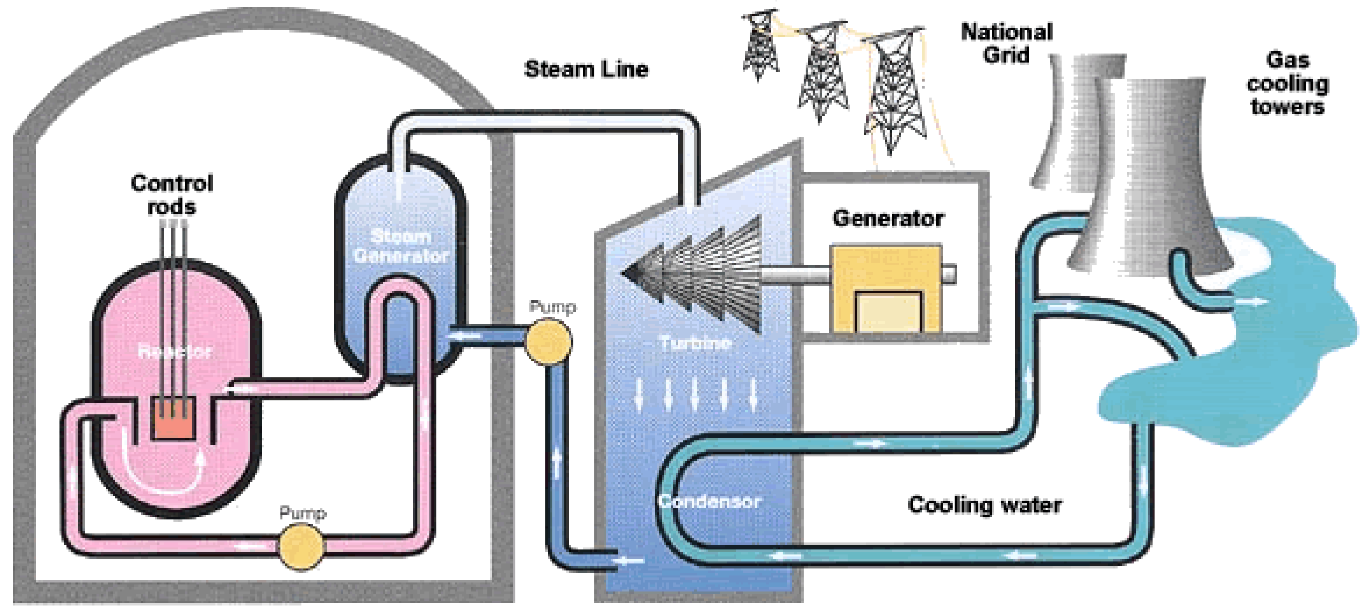
Generating Electricity Revision



Generators can be turned indirectly using fossil or nuclear fuels. The heat from the fuel boils water to make steam, which expands and pushes against the blades of a turbine. The spinning turbine then turns the generator.

These are the steps by which electricity is generated from fossil fuels:

1. Heat is released from fuel and boils the water to make steam.
2. The steam turns the turbine.
3. The turbine turns a generator and electricity is produced.
4. The electricity goes to the transformers to produce the correct voltage.



Nuclear Energy → **Heat Energy** → **Kinetic Energy** → **Electrical Energy**

- **Nuclear Energy**: stored in the nucleus of an atom and released as nuclei are split
- **Heat Energy**: produced from the fission as kinetic energy of the fragments of the fission and the KE of free neutrons
- used to heat water and produce steam that under pressure causes turbine blades to turn
- **Kinetic Energy**: The turning of the turbine makes the coil of wire turn in a magnetic field
- **Electrical Energy**: Produced by electromagnetic induction and then tranmitted to the National Grid to be transported around the country.

Wind power. **Wind** is produced as a result of giant convection currents in the Earth's atmosphere, which are driven by heat energy from the Sun. This **means** the kinetic energy in **wind** is a renewable energy resource - so long as the Sun exists, **wind** will too.

Nuclear power stations

The main nuclear fuels are uranium and plutonium, both of which are radioactive metals. Nuclear fuels are not burned to release energy. Instead, heat is released from changes in the nucleus.

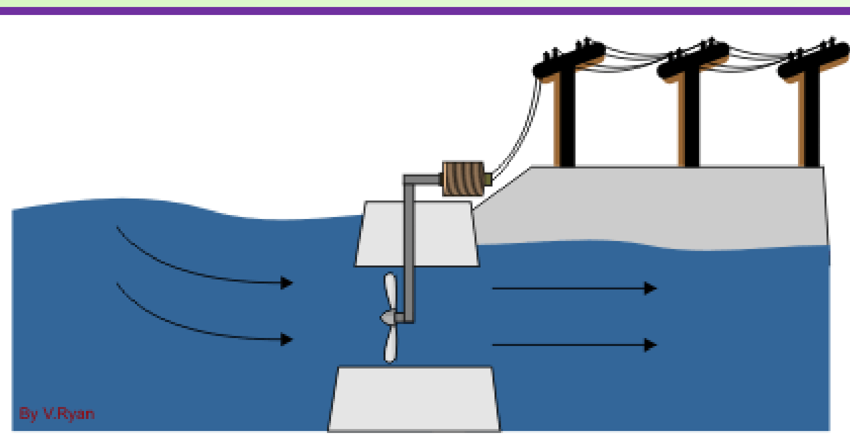
Just as with power stations burning fossil fuels, the heat energy is used to boil water. The kinetic energy in the expanding steam spins turbines, which drive generators to produce electricity

Advantages

Unlike fossil fuels, nuclear fuels do not produce carbon dioxide.

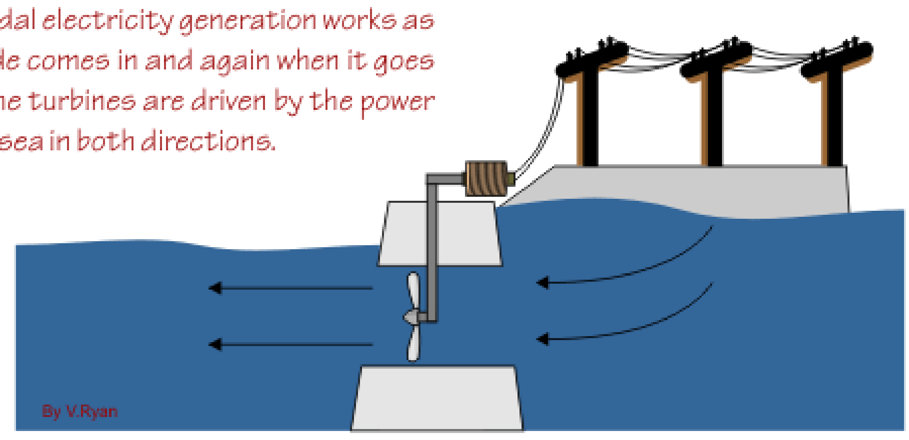
Disadvantages

Like fossil fuels, nuclear fuels are non-renewable energy resources. And if there is an accident, large amounts of radioactive material could be released into the environment. In addition, nuclear waste remains radioactive and is hazardous to health for thousands of years. It must be stored safely.

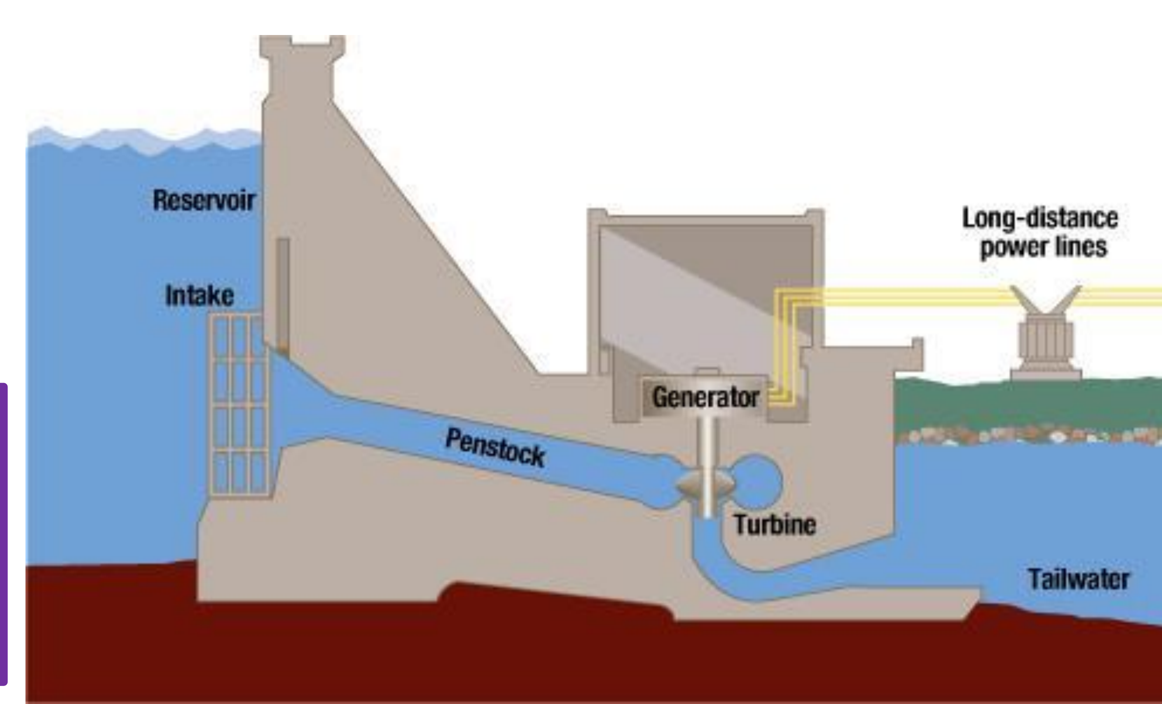


TIDE COMING IN

This tidal electricity generation works as the tide comes in and again when it goes out. The turbines are driven by the power of the sea in both directions.



TIDE GOING OUT



Hydroelectricity is the term referring to electricity generated by hydropower; the production of electrical power through the use of the gravitational force of falling or flowing water.