# Toynbee Curriculum
## KS4 Knowledge Maps

# SCIENCE

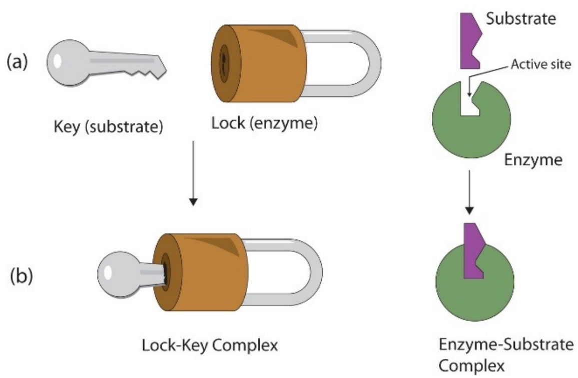
# Toynbee School

Personal Best

# Organisation

## The human digestive system

- The body needs a balanced diet with carbohydrates, lipids, proteins, vitamins, minerals, dietary fibre and water, for its cells' energy, growth and maintenance.
- The digestive system is an example of an organ system in which organs work together to digest and absorb food.
- Organs of the digestive systems are adapted to break large food molecules into smaller ones which can travel in the blood to cells and are used for life processes.
- The **stomach** contains glandular tissue that produces **enzymes** and **hydrochloric acid,** muscle tissue that contracts to churn food and epithelial tissue that protects your stomach against the hydrochloric acid.
- The **pancreas** is a gland that secretes enzymes.
- The **liver** is an organ that produces **bile**. Bile is stored in the **gallbladder** and released by the bile duct after the chyme (partially digested food) leaves the stomach. Bile is an **alkaline emulsifier**. The alkaline pH of bile provides the optimum conditions for lipase to digest **lipids**. Bile also emulsifies lipids allowing smaller droplets to be suspended in the watery chyme rather than large droplets. Smaller droplets increase the surface area of the lipids increasing the rate of digestion.
- Most of our food is absorbed into our blood in the **small intestine**. The inside of the small intestine is covered in small structures called **villi** that increase its surface area and contain blood vessels. Each villus is covered with epithelial cells that have microvilli that increase the surface area even more. The increase in surface area and proximity to our circulatory system speeds up the rate of **diffusion** of food molecules.
- The digestive system is also made up of the large intestine, rectum and anus.
- The products of digestion are used to build new carbohydrates, lipids and proteins. Some glucose is used in respiration.




## Enzymes

- Enzymes are **biological catalysts** that control the rate of biological process and the digestion of food molecules.
- Enzymes are structures made of **protein**. Enzymes have specific shapes and attach to food molecules using an active site. Scientists use the idea of a **lock and key** to show that an enzymes shape is important and that enzymes digest specific food molecules.
- Enzymes are affected by **temperature**. If an enzymes conditions do not match its requirements it will not work properly. All enzymes found in the body prefer body temperature (37 °C). If an enzyme's conditions are too cold, they will move slowly and sluggishly slowing down digestion. If an enzymes conditions are too hot then their shape will be affected. When an enzyme's shape changes the shape of the active site changes and the enzyme can no longer attach to and digest food molecules. When the active site changes shape the enzyme is **denatured**.
- Enzymes are affected by **pH**. If an enzyme's conditions do not match its requirements it will not work properly. In extreme cases the enzyme will lose its structure and the shape of the active site will change. When the active site changes shape the enzyme is denatured.
- **Amylase** is an enzyme that digests starch. It is secreted from the salivary glands, pancreas and small intestine. Amylase breaks down large molecules of starch into smaller sugars such as maltose and glucose. This process begins in the mouth.
- Amylase works best in acidic to neutral condition.
- **Proteases** are enzymes that digest proteins. They are secreted from the stomach, pancreas and small intestine. Protease breaks down large molecules of protein into smaller amino acids. This process begins in the stomach.
- Protease works best in acidic conditions (provided by the hydrochloric acid secreted by the stomach.
- **Lipases** are enzymes that digest lipids. They are secreted from the pancreas. Lipase breaks down large lipid molecules into fatty acids and glycerol. This process begins in the small intestine
- Lipase works best in alkaline conditions (provided by the bile secreted by the bile duct).

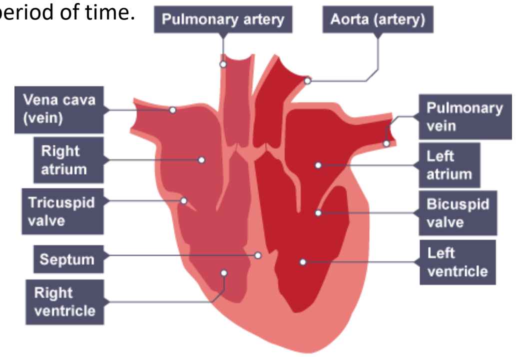
## Food tests

- Food tests can be carried out on foods to test for a range of carbohydrates, lipids and proteins.
- **Benedict's** test is used to detect sugars. Sugars classed as reducing sugars (e.g. glucose) will react with Benedict's solution on heating for a few minutes. A positive result will be red or brown colour. If there's not much present then the final colour may be green, yellow or orange.
- **Iodine** is used to test for starch. Adding a few drops of iodine to a food containing starch will change the colour of the iodine from orange/brown to blue/black.
- The **Biuret** test is used to detect protein. Adding Biuret reagent to a food containing protein will change the colour of the reagent from blue to purple.
- The **Sudan III** test us used to detect lipids. Drops of Sudan III carefully added to solution containing lipids will form a red stained layer.

# Organisation

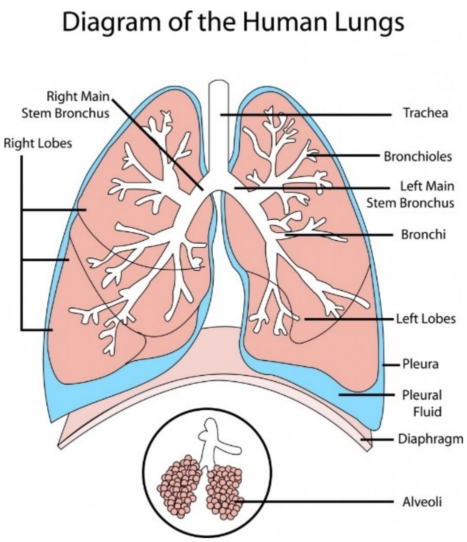
## The Heart

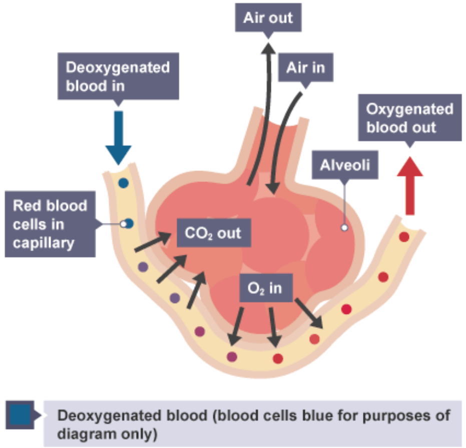
- The **heart** is an organ that pumps blood around the body in a **double circulatory** system.
- **Deoxygenated** blood enters the heart through the **vena cava** and proceeds into the right atrium, through a valve (that prevents backflow) into the right ventricle. Blood is then pumped to the lungs, where it is oxygenated, through the **pulmonary artery**.
- Blood is **oxygenated** in the lungs before it returns to the heart through the **pulmonary vein**. The blood travels through the left atrium and into the left ventricle. It is then pumped out through the **aorta** to the rest of the body.
- Coronary arteries surround the heart, providing the heart with blood containing oxygen and glucose. Muscle tissue that makes up the majority of the heart needs oxygen and glucose for **respiration**. The energy released by respiration is used by the muscles cells to contract.
- The natural resting heart rate is controlled by a group of cells located in the right atrium that act as a pacemaker. Artificial pacemakers can be used if this is not working properly.
- We can measure our pulse to monitor our heart rate. The lower a person's resting pulse rate the fitter they may be. Pulse can be measured by counting the beats over a set period of time.




## The Lungs

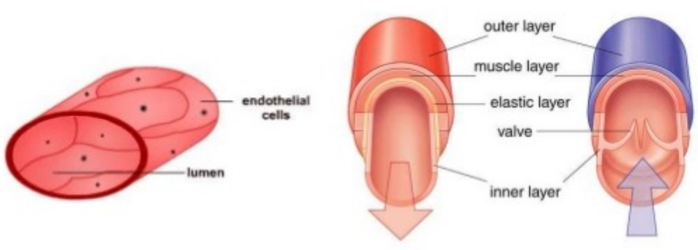
- The lungs are part of the **respiratory system**.
- Air travels to the lungs via the **trachea**. The trachea splits in to two **bronchi** (singular - bronchus) which carry the air to each of the lungs. When the bronchi reach the lungs, they split into many smaller tubes called **bronchioles**. These bronchioles spread though out the lungs with each ending in a small air sac called an alveolus (plural - **alveoli**).
- The lungs and airways have many adaptations. **Goblet cells** lining the trachea produce a sticky mucus that traps dust and microorganisms, preventing them from getting to the lungs. Ciliated cells, covered in small hair like projections called **cilia**, also trap dust and microorganisms.
- The lungs themselves have a **massive surface area**, are incredibly **moist** and contain many **capillaries** carrying blood close to the alveoli, which are the site of gas exchange. These factors increase the rate that oxygen is diffused into the blood and the rate that carbon dioxide is diffused into the lungs.




## Blood vessels

- Arteries are blood vessels that carry blood away from the heart. The blood is under very **high pressure**, so the walls of the arteries are extremely thick. The lumen, that blood travels through, is smaller to maintain blood pressure.
- **Veins** are blood vessels that carry blood to the heart. The blood is under very **low pressure**, so the walls of the veins are thinner, and the lumen is much wider. Veins contain **valves** that prevent blood from flowing the wrong way.
- **Capillaries** are small blood vessels that carry blood to our tissues. Capillaries have walls that are one cell thick. This allows substances found in our blood, such as oxygen and glucose, to move through the wall and into the tissue.

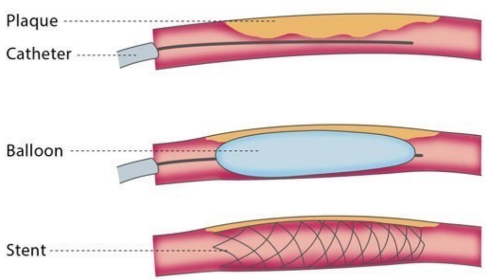


# Organisation

## Coronary heart disease

- In coronary heart disease layers of fatty material build up inside the coronary arteries, narrowing them.
- This reduces the flow of blood through the coronary arteries, resulting in a lack of oxygen for the heart muscle.
- **Stents** can be used to keep the coronary arteries open. Stents can be used as a long-term solution and do not lead to an immune response in the patient. Stents are safe but there are small risks associated with age, general health and whether they have had a heart attack. In some cases, further treatment is needed.

**Angioplasty and stenting**




- **Statins** are drugs that decrease a person's bad cholesterol and increase their good cholesterol. This reduces fatty material in arteries. These drugs must be taken for life to maintain the effect. They are not suitable for people who have liver disease or those that are pregnant or breastfeeding.
- In extreme circumstances a **heart transplant** may be required. Once complete a new heart will improve the quality of life for the patient. Few donor hearts are available and there is a very long recovery time. There is also a chance that the patient's immune system will attack the organ and cause rejection. Immunosuppressant drugs are taken to prevent this which leads to a higher chance of infection.
- **Artificial hearts** can be used to help patients waiting for heart transplants. These devices act as a pump outside of the body and often require a patient to remain in hospital.
- **Mechanical valves** can be used to replace faulty valves in a patient's heart. Faulty valves may not close, allowing the blood to leak backwards. The heart then has to pump harder to pump the required volume of blood. The valve may also not open fully. In this case the heart pumps harder to force the blood through the valve.
- Replacement valves can restore blood flow through the heart but may wear out or promote the formation of blood clots around the new valves. Anti-blood clotting drugs can be taken to prevent this.

## Blood

- The blood contains plasma, in which the red bloods cells, white blood cells and platelets are suspended.
- **Plasma** is the liquid part of the blood. It contains carbon dioxide, digested food, urea, and hormones.
- **Red blood cells** are responsible for transporting oxygen.
- **White blood cells** ingest pathogens and produce antibodies.
- **Platelets** are involved in the clotting of blood.

## Lifestyle

- Non-communicable diseases can have massive human and financial costs to an individual, a local community, a nation and globally.
- Lifestyle factors such as diet, alcohol and smoking have an effect on the incidence of non-communicable disease at a local, national and global level.
- **Risk factors** are linked to an increased rate of a disease.
- Risk factors can be an aspect of a person's lifestyle or substances in a person's body or environment.
- A **causal mechanism** has been proven for some risk factors, but not in others. A causal relationship is when one factor effects another, examples are:
    - The effects of diet, smoking and exercise on cardiovascular disease
    - Obesity as a risk factor for type 2 diabetes
    - The effect of alcohol on the liver and brain function
    - The effect of smoking on lung disease and lung cancer
    - The effect of smoking and alcohol on unborn babies
    - Carcinogens, including ionising radiation, as risk factors in cancer.

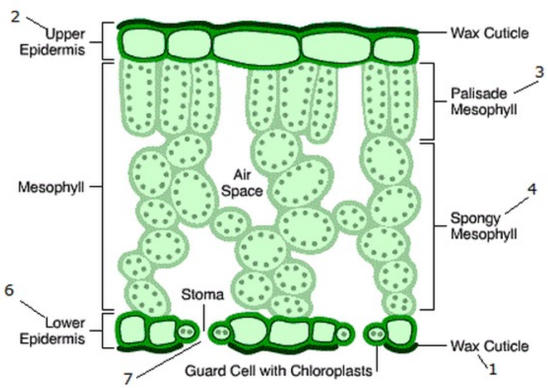
## Health issues

- Health is the state of physical and mental well-being.
- Diseases, both communicable and non-communicable, are major causes of ill health.
- Other factors including diet, stress and life situations may have a profound effect on both physical and mental health.
- Different types of disease may interact:
    - *Defects in the immune system mean an individual is more like to suffer from infectious diseases*
    - *Viruses living in cells can be a trigger for cancers*
    - *Immune reactions initially caused by a pathogen can trigger allergies such as skin rashes and asthma*
    - *Severe physical ill health can lead to depression and other mental illness.*

# Organisation

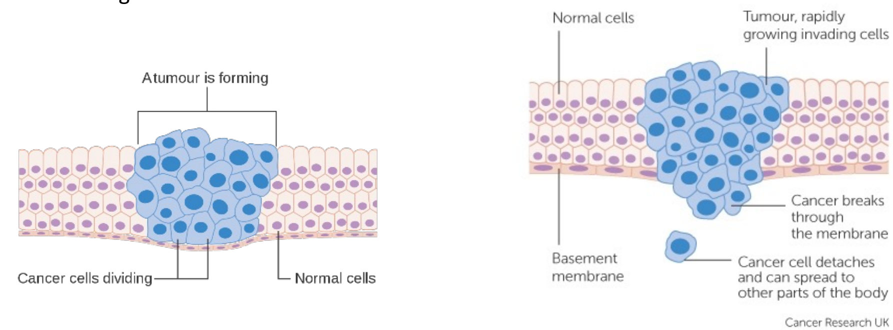
## Plant tissues

- Plants organs include the leaves, roots, and stem.
- These organs are made of tissues that contribute to the organ's function.
- **Epidermal** tissue covers the leaves, stem and the roots.
- Epidermal tissue forms a boundary between the plant and the external environment.
- Epidermal tissue protects against water loss and regulates gas exchange and water loss through holes called **stomata.**
- **Palisade mesophyll** tissue is the layer of the leaf that is adapted to absorb light efficiently.
- Palisade cells that make up the tissue contain many chloroplasts that absorb light needed for photosynthesis.
- Palisade cells are column shaped, packed closely together and are situated towards the upper surface of the leaf to increase the amount of light they can absorb.
- **Spongy mesophyll** tissue is packed loosely for efficient gas exchange.
- Gases dissolve in a thin layer of water that covers the cell which then allows the gases to move into and out of the cell.
- Carbon dioxide **diffuses** into spongy mesophyll cells and oxygen diffuses out.



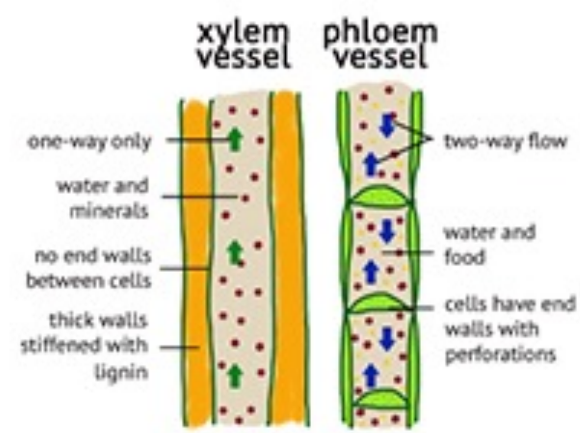

## Cancer

- Changes in cells can lead to uncontrolled growth and division.
- **Benign tumours** are growths of abnormal cells contained in one area, usually within a membrane. They do not invade other parts of the body.
- **Malignant tumour** cells are cancers. They invade neighbouring tissue and spread to different parts of the body in the blood, where they form secondary tumours.
- Scientists have identified lifestyle risk factors for various types of cancer.
- There are also genetic risk factors for some cancers.




## Xylem & Phloem

- **Xylem** transport **water and minerals** from the roots of the plant up the stem and into the leaves.
- Water is used to photosynthesise, cool down leaves (by evaporation) and keep the cells turgid to support the plant.
- The elongated cells that make up the xylem are strengthened with a chemical called lignin.
- The dead cells, which contain no cytoplasm, form continuous hollow tubes that are impermeable to water.

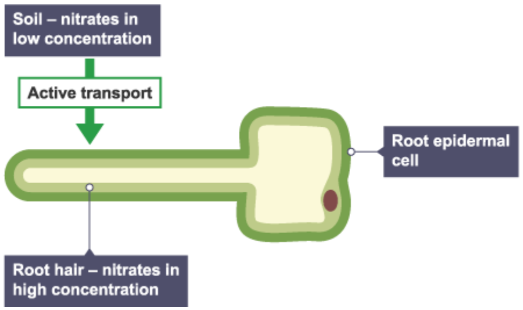



- **Phloem** transport **sugars and amino acids** around the plant.
- The process of moving sugars and amino acid throughout the plant is called translocation.
- Phloem consist of living cells that contain cytoplasm. This can move from one cell to the next through perforated cells called sieve plates. These cells contain no nucleus.
- Companion cells attach to each sieve tube to provide the energy needed for translocation.

# Organisation

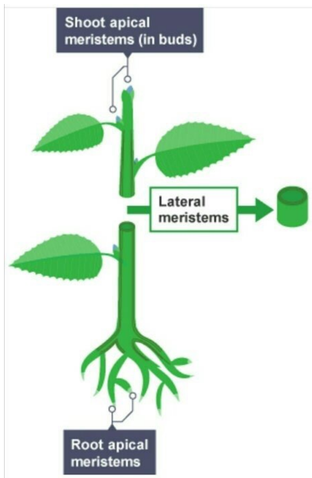
## Root hair cells

- Root hair cells are long and thin so that they can penetrate between soil particles.
- Root hair cells have a large surface area for absorption of water through osmosis.
- Root hair cells have a large vacuole for storing water.
- Root hair cells contain many mitochondria that release energy from glucose for the active transport of minerals.




## Meristems

- Meristem tissue contains cells that can differentiate to produce all types of plant cell.
- Meristem cells are found close to the tip of shoots and roots.
- Meristem cells allow a plant to grow.




## Potometer

- We can measure water uptake using a potometer.
- A potometer is a piece of capillary tubing that is connected to a plant.
- A bubble in the tube moves as water is drawn up the plant.
- We can measure water uptake by recording the time taken for the bubble in the tube to move a set distance.

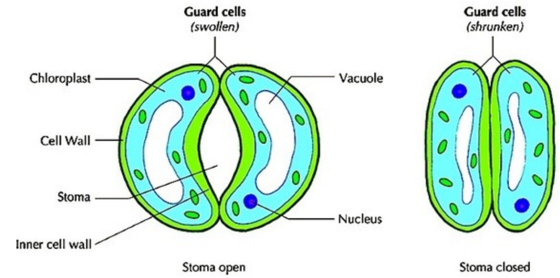
## Transpiration

- The movement of water throughout a plant is caused by the transpiration stream.
- Water covering the spongy mesophyll cells evaporates and exits the leaf through tiny holes called stomata. This is called transpiration.
- Water molecules are attracted to each other, so they are cohesive or "sticky".
- Transpiration produces a tension or "pull" on the water in the xylem vessels, moving the water and other minerals up the plant.
- Changing temperature, humidity, air movement and light intensity all have an affect of the rate of transpiration.

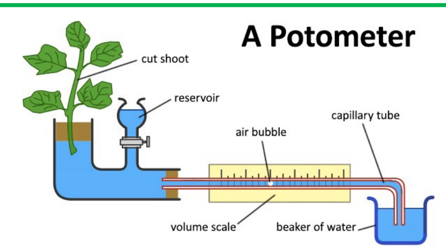
| Factor | Effect on transpiration |
|---|---|
| **Increasing temperature** | Increases |
| **Increasing humidity** | Decreases |
| **Increasing air movement** | Increases |
| **Light intensity** | Increases |

## Guard cells

- Each stoma is surrounded by guard cells that can regulate the amount of water that exits the plant.
- When the vacuoles of the guard cells are full of water, they become turgid opening the stoma.
- In the light, the guard cells absorb water by osmosis, become turgid and the stoma opens.
- When the vacuoles of the guard cells lose water, they become flaccid and the stoma closes.
- In the dark, the guard cells lose water, become flaccid and the stoma closes.



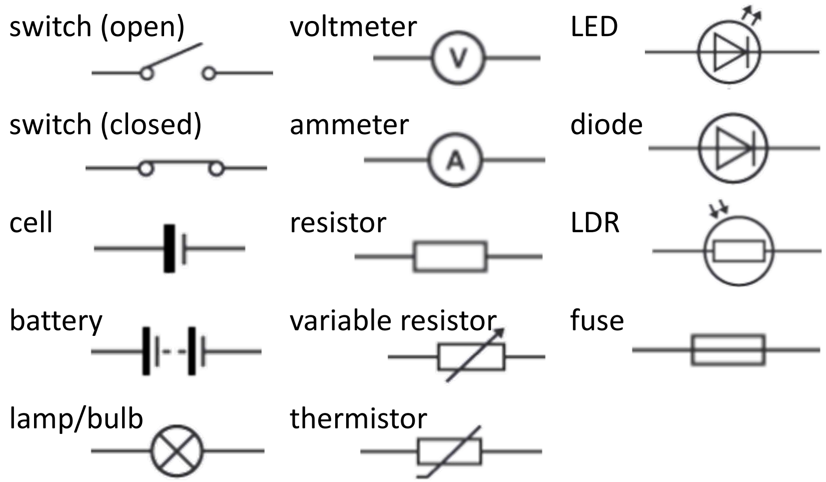

## A Potometer



# Circuit Electricity 1

## 1. Circuit symbols

You must be able to remember the circuit symbols for these components, and use them when drawing a circuit:



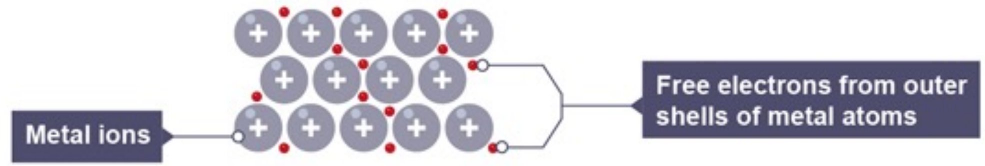

**Remember**: when you draw a circuit diagram, the lines (wires) must be straight and the circuit must be complete!

## 2. Charge

- **Metals are conductors** of electricity
- Non-metals are insulators (poor conductors)
- This is due to their bonding:

Metallic bonding creates a '**sea of delocalised electrons**' that can carry energy around a circuit.

- The unit of charge flow is the **coulomb (C)**. This represents a specific large number of electrons. 1 coulomb is equal to $6 \times 10^{19}$ electrons.




## 3. Current

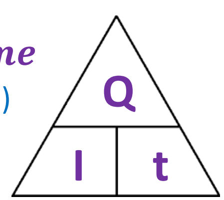
- Current is the **flow of electrical charge** around a circuit.
- It's measured in **amps (A)** using an **ammeter connected in series with the component.**
- A circuit must include a **source of potential difference** (a power source) in order for current to flow.

We can calculate the charge flow using:

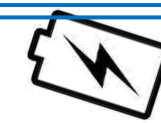
$$charge\ flow = current \times time$$

Learn (C) (A) (s)

You can use the equation triangle to re-arrange this:



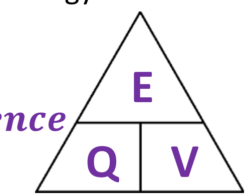

## 4. Potential difference



- Potential difference (or voltage) is the driving force that **pushes** the charge around a circuit. It is the difference in energy between two points on a circuit.
- Potential difference is the energy per unit of charge:

$$energy = charge\ flow \times potential\ difference$$

(J) Learn (C) (V)




- It's measured in **volts (V)** using a **voltmeter connected in parallel over the component.**
- Potential difference can be supplied using a **power source** (e.g. a battery)

## 5. Resistance

- Resistance is something that **slows down** the current.
- It's measured in **ohms (Ω).**
- The **bigger the resistance** of a component, the **less current gets through.**

You can calculate the total resistance in a series circuit using:

total resistance — add together the individual resistances

$$R_{total} = R_1 + R_2 + \ldots$$

Learn

- In parallel the total resistance of two resistors is less than the resistance of the smallest individual resistor.

# Circuit Electricity 2

## 6. Ohm's Law

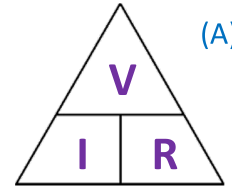
- The current through a circuit depends on the **potential difference** and **resistance**.
- If the potential difference is constant, then the **current will decrease** as **resistance is increased**.
- **Ohm's Law** states that current is **directly proportional** to potential difference for an ohmic conductor (if the temperature remains constant)

The following equation is used to link potential difference, current and resistance:

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

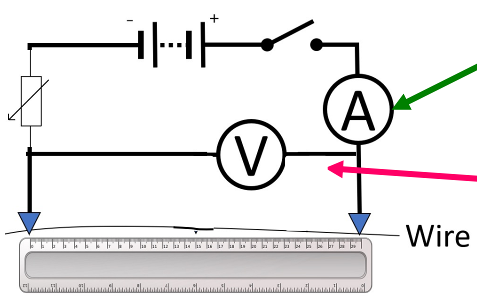
(V) (A) (Ω)

**Learn**




## 7. Required Practical: How does the length of a wire affect its resistance?

- You can calculate the resistance of a wire if you **measure the current and potential difference**.
- **Changing the length** of the wire and taking measurements will allow you to see if the resistance changes.




The **ammeter** measures the current through the circuit.

The **voltmeter** measures the potential difference across the wire.

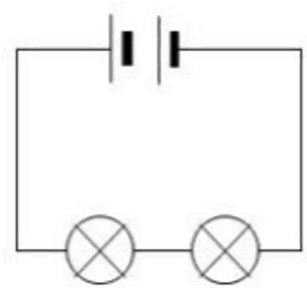
As the current increases, the wire **heats up** which causes its resistance to **increase**. This reduces the **accuracy** of the experiment.

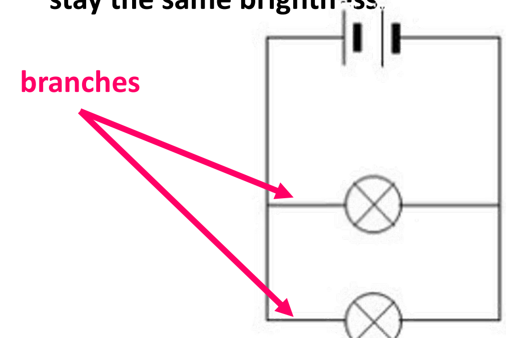
- You can increase the **accuracy** by:
    1. **stopping the current between readings** to let the wire cool
    2. using a **low current** to stop the wire heating up.
- You can increase the **precision** by using **pointed contacts** to connect to the wire so the uncertainty of the measurement is reduced.

## 8. Series and parallel circuits

There are two types of circuit: series and parallel.

| Series Circuits | Parallel Circuits |
|---|---|
| All the components are connected in **one loop.** | The components are connected in **more than one loop.** |
| If one bulb breaks, the **whole circuit stops working.** | If one bulb breaks, the **other branches will continue to work.** |
| The current is **the same everywhere.** | The current is **shared between each branch.** |
| The potential difference is **shared between components.** | The potential difference is **the same across each component.** |
| The total resistance is the **sum** of all the individual resistances. | The total resistance is **less than** the smallest individual resistance. |
| If you add more bulbs, they all **get dimmer.** | If you add more bulbs, they all **stay the same brightness.** |





# Circuit electricity 3

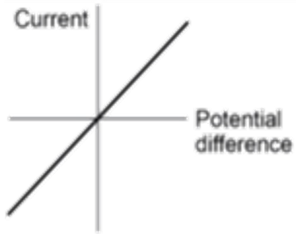
## 9. Required Practical: I-V characteristics of different components

There are two types of conductor:

### Ohmic

- The resistance remains **constant** when you change the current
- The current is **directly proportional** to the potential difference
- If you drew a graph of I against V, it would be a **straight line through (0,0)**

**Example: a resistor at constant temp.**

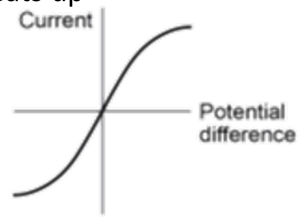



### Non-Ohmic

- The resistance **does** change with current

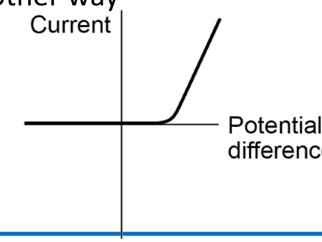
**Example 1: a filament lamp**

The resistance increases as it heats up

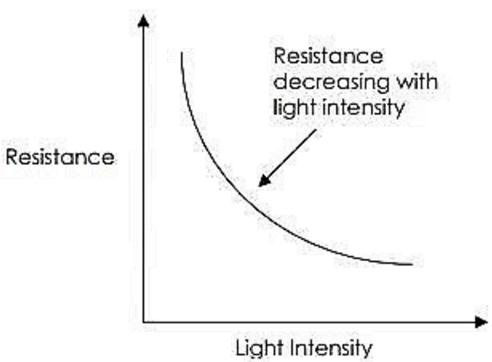



**Example 2: a diode**

Current can only flow in one direction, so resistance is very high the other way




## 10. Thermistors and LDRs




**Light Dependent Resistor**

As light intensity increases the resistance decreases.
They are **not** inversely proportional, it is an inverse square relationship.

$$light\ intensity = \frac{1}{distance^2}$$

### Light Dependent Resistor (LDR)

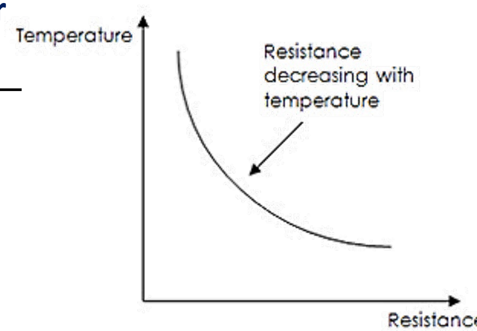
The resistance **decreases** as the light gets **brighter**.

Example: **street lights** use these so they turn on when it gets dark

### Thermistor

The resistance **decreases** as temperature **increases**.

Example: used in **thermostats** to turn on the heating when it gets cold

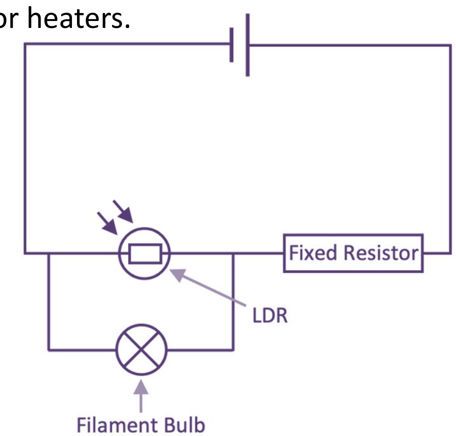



**Thermistor**

Temperature is inversely proportional to resistance.
This can be proved using the table of results.
The product of the IV x DV will be the same for every row of data.

### Applications

As both an LDR and thermistor have low resistance at high temperature or light intensity, a parallel circuit is needed to use them to turn on lights or heaters.



# Chemical Changes

| Metal | Reaction with cold water | Reaction with dilute acids | Reactivity | Extraction method |
|---|---|---|---|---|
| Potassium | Violent | Violent | Most reactive | Electrolysis |
| Sodium | | | | |
| Lithium | | | | |
| Calcium | Fast | Rapid | | |
| Magnesium | Very slow | | | |
| Aluminium | no reaction | Slow | | |
| (Carbon) | | | | |
| Zinc | no reaction | Slow | | Heating with carbon |
| Iron | Rusts slowly | | | |
| (Hydrogen) | | | | |
| Copper | No reaction | No reaction | | Heating with carbon |
| Gold | | | Least reactive | Found pure |

**The Reactivity Series**

- When metals react with other substances the metal atoms form positive ions.
- The reactivity of a metal is related to its tendency to form positive ions.
- Metals can be arranged in order of their reactivity in a reactivity series.
- The metals potassium, sodium, lithium, calcium, magnesium, zinc, iron and copper can be put in order of their reactivity from their reactions with water and dilute acids.
- The non-metals hydrogen and carbon are often included in the reactivity series.
- A more reactive metal can displace a less reactive metal from a compound.

**Extracting iron and copper**

- **Unreactive metals** such as gold are found in the Earth's **crust** as the uncombined **elements**. However, most metals are found combined with other elements to form **compounds**.
- Most metals are extracted from **ore** found in the Earth's crust. An ore is a rock that contains enough of a metal or a metal compound to make extracting the metal worthwhile.

**Extraction methods**

- The **extraction** method used depends upon the metal's position in the **reactivity series**. In principle, any metal could be extracted from its compounds using **electrolysis**. However, large amounts of **electrical energy** are needed to do this, so electrolysis is expensive.
- If a metal is less **reactive** than carbon, it can be extracted from its compounds by heating with carbon. Copper is an example of this.

Copper oxide + carbon → copper + carbon dioxide

$$2CuO_{(s)} + C_{(s)} \rightarrow 2Cu_{(l)} + CO_{2(g)}$$

- Copper oxide is **reduced** as carbon is **oxidised**, so this is an example of a **redox** reaction.

A **base** is any substance that reacts with an **acid** to form a **salt** and water only. This means that metal oxides and metal hydroxides are bases.
Bases that are **soluble** in water are called **alkalis** and they **dissolve** in water to form **alkaline solutions**. For example:

- copper oxide is a base, but it is not an alkali because it is **insoluble** in water
- sodium hydroxide is a base, and it dissolves in water so it is also an alkali

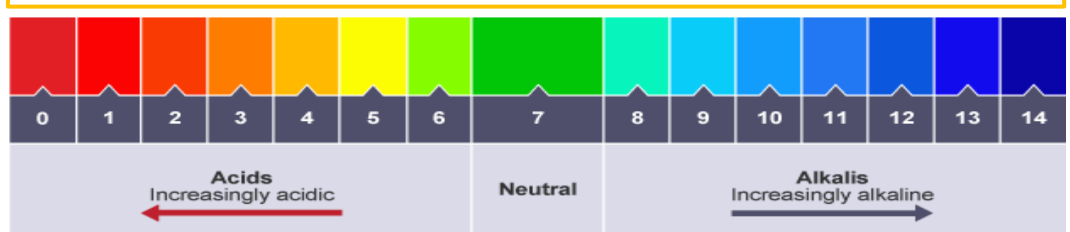
**The pH Scale and Neutralisation**

Acids produce hydrogen ions ($H^+$ ) in aqueous solutions. Aqueous solutions of alkalis contain hydroxide ions ($OH^-$ ). The pH scale, from 0 to 14, is a measure of the acidity or alkalinity of a solution, and can be measured using universal indicator or a pH probe. A solution with pH 7 is neutral. Aqueous solutions of acids have pH values of less than 7 and aqueous solutions of alkalis have pH values greater than 7. In neutralisation reactions between an acid and an alkali, hydrogen ions react with hydroxide ions to produce water. This reaction can be represented by the equation:

$$H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$$

**Strong & Weak Acids –** *[Higher tier]*

A strong acid is completely ionised in aqueous solution. Examples of strong acids are hydrochloric, nitric and sulfuric acids. A weak acid is only partially ionised in aqueous solution. Examples of weak acids are ethanoic, citric and carbonic acids. For a given concentration of aqueous solutions, the stronger an acid, the lower the pH. As the pH decreases by one unit, the hydrogen ion concentration of the solution increases by a factor of 10.



# Chemical Changes

## Reactions with Acid

The general formula for the reaction of an acid and metal is:

**acid + metal → salt + hydrogen**

For example:

hydrochloric acid + magnesium → magnesium chloride + hydrogen

$2HCl_{(aq)} + Mg_{(s)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$

**acid + metal oxide → salt + water**

For example:

sulfuric acid + copper oxide → copper sulphate + water

$H_2SO_{4(aq)} + CuO_{(s)} \rightarrow CuSO_{4(aq)} + H_2O_{(l)}$

Alkalis are soluble bases. A salt and water are produced when acids react with alkalis. In general:

**acid + alkali → salt + water**

For example:

nitric acid + sodium hydroxide → sodium nitrate + water

$HNO_{3(aq)} + NaOH_{(aq)} \rightarrow NaNO_{3(aq)} + H_2O_{(l)}$

The general formula for an acid reacting with a metal carbonate is:

**acid + metal carbonate → salt + carbon dioxide + water**

For example:

hydrochloric acid + calcium carbonate → calcium chloride + carbon dioxide + water

## Redox Reactions – *[Higher tier]*

Oxidation is the loss of electrons and reduction is the gain of electrons.
**Reduction** and **oxidation** happen at the same time, so the reactions are called redox reactions.
The reactions of acids with metals are **redox reactions**. For example, the **ionic equation** for the reaction of magnesium with hydrochloric acid is:

$2H^+_{(aq)} + Mg_{(s)} \rightarrow Mg^{2+}_{(aq)} + H_{2(g)}$

This ionic equation can be split into two **half equations**:

- $Mg_{(s)} \rightarrow Mg^{2+}_{(aq)} + 2e^-$ **(oxidation)**
- $2H^+_{(aq)} + 2e^- \rightarrow H_{2(g)}$ **(reduction)**

Notice that:

- magnesium atoms lose **electrons** - they are **oxidised**
- hydrogen ions gain electrons - they are **reduced.**

## Using Electrolysis to Extract Metals

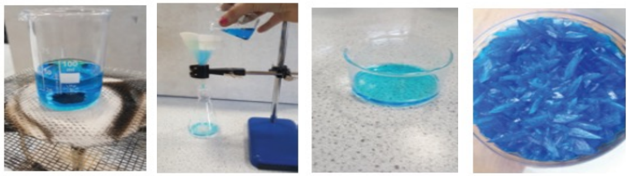
Metals can be extracted from molten compounds using electrolysis. Electrolysis is used if the metal is too reactive to be extracted by reduction with carbon or if the metal reacts with carbon. Large amounts of energy are used in the extraction process to melt the compounds and to produce the electrical current. Aluminium is manufactured by the electrolysis of a molten mixture of aluminium oxide and cryolite using carbon as the positive electrode (anode).

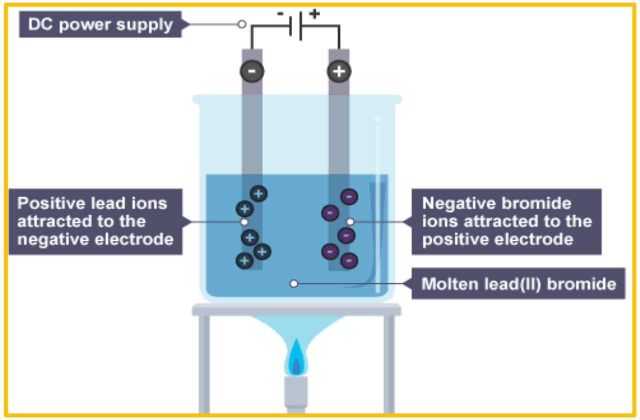
## Naming Salts

Hydrochloric acid makes chloride salts; sulphuric acid makes sulphate salts; nitric acid makes nitrate salts

## Required practical: making soluble salts

1. Make a saturated solution by stirring copper oxide into sulphuric acid until no more will dissolve.
2. Filter the solution to remove excess solid copper oxide.
3. Half fill a beaker with water and heat it over a Bunsen burner. Place an evaporating dish on top of the beaker.
4. Add some of the solution to the evaporating basin and heat until crystals begin to form.
5. Pour the remaining liquid into a crystallising dish and leave to cool for 24 hours.
6. Remove crystals with a spatula and pat dry between paper towels.






## Metal Oxides

- Metals can react with oxygen to make compounds called **oxides**.
- The reactions are **oxidation** reactions because the metal gains oxygen.
- Metal oxides are **bases**. This means they can neutralise an acid.
- Non-metal oxides dissolve in water to make acidic solutions.
- If oxygen is lost from a compound, this is called **reduction.**

## Electrolysis

When an ionic compound is melted or dissolved in water, the ions are free to move about within the liquid or solution. These liquids and solutions are able to conduct electricity and are called electrolytes. Passing an electric current through electrolytes causes the ions to move to the electrodes. Positively charged ions move to the negative electrode (the cathode), and negatively charged ions move to the positive electrode (the anode). Ions are discharged at the electrodes producing elements. This process is called electrolysis.

## Electrolysis of Molten Compounds

When a simple ionic compound (e.g. lead bromide) is electrolysed in the molten state using inert electrodes, the metal (lead) is produced at the cathode and the non-metal (bromine) is produced at the anode.

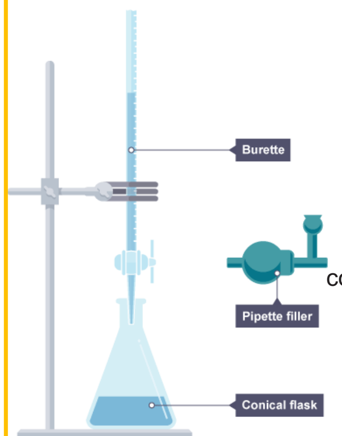
# Chemical Changes

## Electrolysis of Aqueous Solutions

The ions discharged when an aqueous solution is electrolysed, using inert electrodes, depend on the relative reactivity of the elements involved. At the negative electrode (cathode), hydrogen is produced if the metal is more reactive than hydrogen. At the positive electrode (anode), oxygen is produced unless the solution contains halide ions in which case the halogen is produced. This happens because in the aqueous solution water molecules break down producing hydrogen ions and hydroxide ions that are discharged.

## Required Practical Titration *(Separate Chemistry Only)*

1.Use the pipette and pipette filler to add 25 $cm^3$ of alkali to a clean conical flask.
2.Add a few drops of **indicator** and put the conical flask on a white tile.
3.Fill the burette with acid and note the starting volume.
4.Slowly add the acid from the burette to the alkali in the conical flask, swirling to mix.
5.Stop adding the acid when the end-point is reached (the appropriate colour change in the indicator happens). Note the final volume reading.




The difference between the reading at the start and the final reading gives the volume of acid added. This volume is called the titre.

You can calculate the amount of a substance in **moles** in a solution if you know the volume and concentration. You can also work out the concentration of an acid reacting with an alkali, or vice versa.

concentration in mol/$dm^3$ = amount in mol ÷ volume in $dm^3$

**Worked example:**

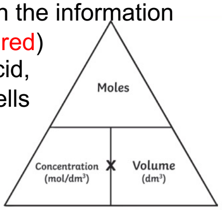
In a titration, $20cm^3$ of 1.0mol/$dm^3$ sulphuric acid reacted with $25cm^3$ of sodium hydroxide. What was the concentration of sodium hydroxide?

| | Acid ($H_2SO_4$) | Alkali (NaOH) |
|---|---|---|
| Moles | 0.02 | 0.04 |
| Concentration mol/$dm^3$ | 1.0 | 1.6 |
| Volume $dm^3$ | 0.02 | 0.025 |

Write out a balanced symbol equation for the reaction:

$$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$$

Draw a table as shown and fill in the information given in the question (shown in red)
Work out number of moles of acid, (shown in blue). The equation tells us there are twice as many moles of alkali (0.04). Finally we can work out the concentration - **moles/volume = 1.6mol/$dm^3$**




## Required practical: Electrolysis of Aqueous Solutions

This required practical involves developing a **hypothesis**.
An investigation starts with a scientific question, for example:

- What are the products of electrolysis of aqueous solutions?
- Is there a pattern in the products of electrolysis of aqueous solutions?

The first step in answering a scientific question is to develop a hypothesis. A hypothesis is an idea to be tested, which is backed up by scientific knowledge.
Suitable hypotheses are:

- a non-metal will be produced at the positive electrode because non-metal ions are negative.
- solutions that include ions of metals that are low in the reactivity series produce the metal at the negative electrode (not hydrogen) because ions of unreactive metals have a greater tendency to gain electrons.

The hypothesis can then be used to make predictions, such as 'In the electrolysis of copper chloride, the product at the positive electrode will be chlorine.'
The set up below is suitable. The positive electrode is connected to the positive terminal of a dc power pack. The negative electrode is connected to the negative terminal of the power pack.

**Test solutions**

It is best to test at least five solutions. Suitable solutions include copper sulphate, copper chloride, sodium chloride, sodium nitrate, sodium bromide. There are many more.

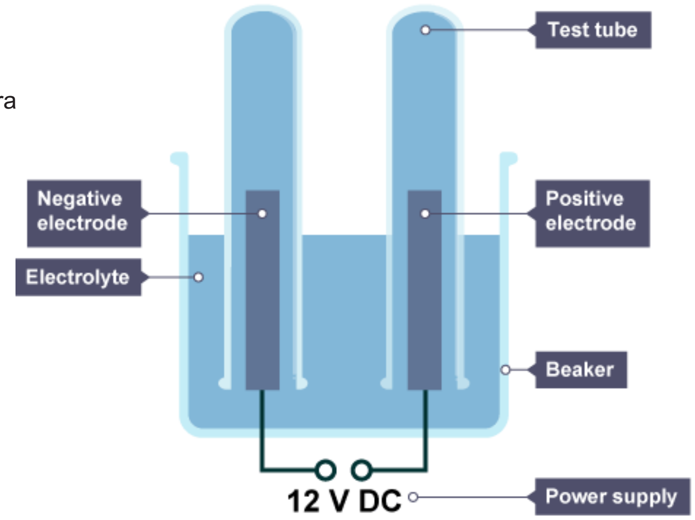
**Identifying the products**

Any gases produced can be collected in the test tubes. They need to be stoppered and tested later. Gas tests include:

1. hydrogen - lighted splint goes out with a squeaky pop
2. oxygen - a glowing splint relights
3. chlorine - damp blue litmus paper turns red and is then bleached white.

The electrodes need to be examined carefully each time, to see if a metal has been deposited on them.

Concentra



# Mains electricity 1

## 1. AC versus DC

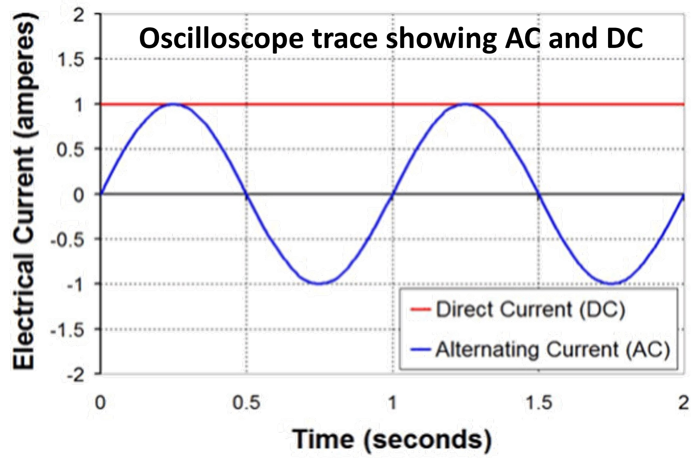
There are two types of current:

1. **Direct current (DC):** the current travels in **one direction only.**
   **Examples:** batteries, cells
2. **Alternating current (AC):** the charge moves **backwards and forwards** at a certain **frequency** (rate).
   **Examples:** mains electricity, generators

The current is produced from two types of potential difference:

1. **Direct potential difference:** the potential difference always stays the same
2. **Alternating potential difference:** the potential of the live wire changes from a positive value to a negative value, while the neutral wire remains at 0 V. This causes a change in the direction of the potential difference.

- Mains electricity in the UK is an **AC** supply.
- It has a frequency of **50 Hz** and a potential difference of **230 V.**




- We can use **transformers** to increase the potential difference and decrease the current.
- Reducing the current reduces any **heat loss** through the wires, making the energy transfer **more efficient.**

## 2. 3-pin plug

- Plugs connect devices to the mains supply.
- The cable contains **3 copper wires coated in plastic**:

### Live Wire

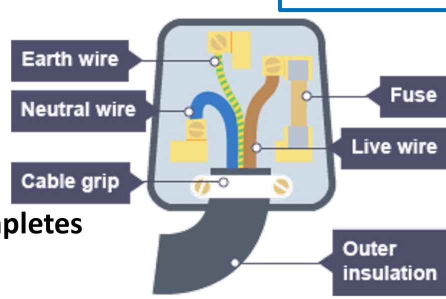
- Copper wire coated with **brown** plastic
- **Carries the AC current** to the device

### Neutral Wire

- Copper wire coated with **blue** plastic
- Connects to the mains supply and **completes the circuit**

### Earth Wire

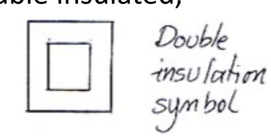
- Copper wire coated with **green/yellow striped** plastic
- **Safety wire** – provides a path to the ground in case of a fault




## 3. Electrical safety

Sometimes a **fault** can cause the current to get **too high**. There are 2 ways in which the circuit can be **disconnected** to stop danger:

1. **Fuse**: appliances and plugs have glass/ceramic containers that have a **thin wire** inside. This melts if the current is too high. The fuse is placed between the live pin and the live wire.
2. **Earthing:** most appliances with **metal cases** are earthed. This means when a fault occurs a large current flows from the live wire to the earth and **melts the fuse**. Some appliances are double insulated, and therefore have no earth connection. A double insulated appliance has a casing made of an insulating material.




**Electric shocks**

The live has a potential of **230 V**, but the ground (earth) has a potential of **0 V**. This creates a **potential difference** and current flows.

The live, neutral and earth pins are made of brass as this is stronger than pure copper, but has good conductivity.

# Mains Electricity 2

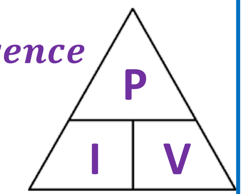
## 4. Power

- Power is the **rate at which energy is transferred** in circuits.
- It's measured in **watts (W)**.
- It can be calculated using:

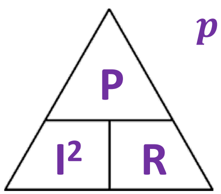
$$power = current \times potential\ difference$$

(W) (A) (V)

**Learn**




If you don't know the potential difference, you can substitute the $V = I \times R$ equation to get $P = I \times I \times R$ . This can be simplified to:




$$power = current^2 \times resistance$$

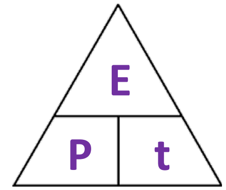
(W) (A) (Ω)

**Learn**

- If you double the current, the **power quadruples**.
- This shows how important it is to **keep current low** in appliances.

## 5. Electrical appliances

- Energy is usually measured in Joules (J), but in the home we can also measure it in **kilowatt hours (kWh)**.
- You can calculate the energy of an appliance using:




$$energy = power \times time$$

(J) **OR** (kWh) (W) **OR** (kW) (s) **OR** (h)

**Learn**

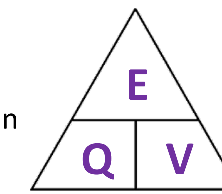
- Appliances' energy rating is usually labelled in **kilowatt hours**.
- The higher the energy rating, the **more powerful** the appliance is.
- Appliances that have a **heating** element (e.g. kettles and ovens) usually use the most energy.

If you are working with **small amounts of energy** (e.g. electrostatics), you can use the following equation:

$$energy = charge\ flow \times potential\ difference$$

(J) (C) (V)

**Learn**




This also helps define potential difference (see section 3(a))

## 6. The National Grid

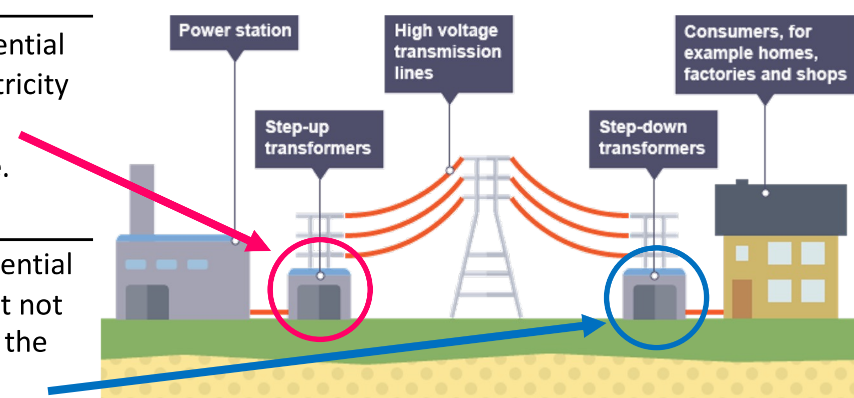
- The electricity generated in power stations is transported to the home through the **National Grid** via the use of **cables** and **transformers**.
- The National Grid is very **efficient**, because it uses **low current** to transport the electricity (remember – high current causes energy to be lost as **heat**!).

### Step-Up Transformers

- These are used to **increase** the potential difference to **275 000 V** as the electricity leaves the power station.
- This causes the current to **decrease**.

### Step-Down Transformers

- These are used to **decrease** the potential difference back down to a saf<u>er</u> (but not safe) **230 V** as the electricity leaves the National Grid and enters the home.
- This causes the current to **increase**.

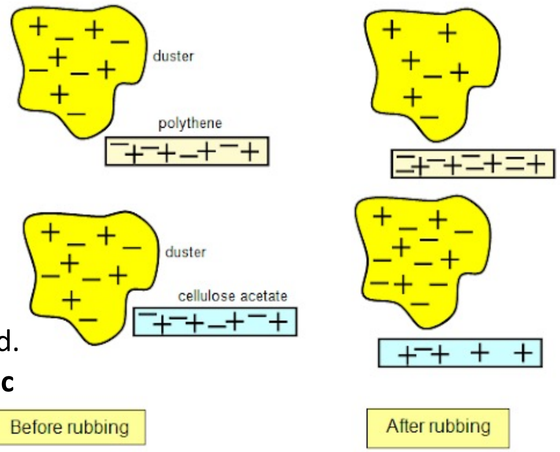


# Static Electricity

*(separate Physics only)*

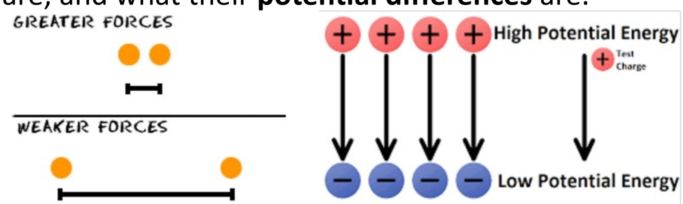
## 7. Static charge

- When certain materials are **rubbed together**, they become **electrically charged**.
- Negatively charged **electrons** are rubbed off one material and onto the other.
- The material that **gains** electrons becomes **negatively** charged.
- The material that **loses** electrons becomes **positively** charged.
- This is called **static electricity.**



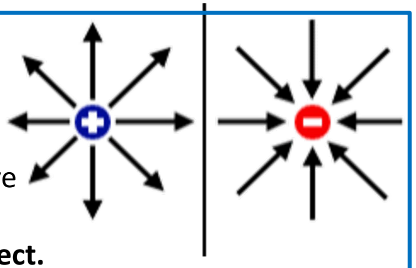

## 8 (b). Static shocks

- When two charged objects get close to each other, **sparking** can occur.
- **Sparking** is the sudden flow of electric current **across the gap between the objects**. This heats the air enough to cause it to **glow**. This can be very dangerous in industry.
- The size of the spark depends on **how far away** the objects are, and what their **potential differences** are.



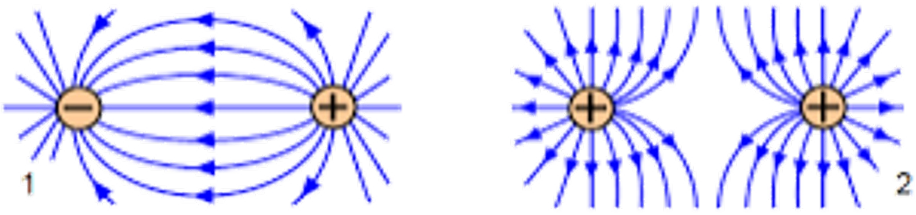

- Too close a distance or too great a potential difference leads to a **static shock**!

## 8 (a). Electric fields



- When an object is electrically charged, it creates an **electric field** around itself.
- The field **direction** goes **away** from a positive charge and **towards** a negative one.
- Electric fields are **strongest close to the object.**

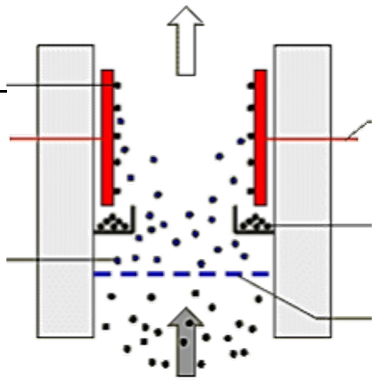
- When two electrically charged objects are brought together, they **exert a force** on each other. This is an example of a **non-contact force.**
- Like charges **repel,** and opposite charges **attract**.
- This is because of the **electric fields** around the objects (see below).




## Static electricity uses

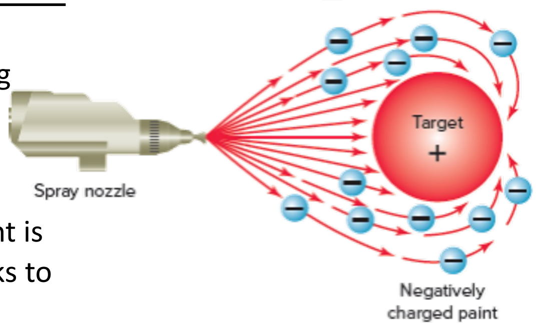
### Factories

- Used to **reduce pollution** (smoke) coming out of factories.
- The smoke particles are given a charge, and sticks to electrodes with the **opposite** charge in the chimneys instead of leaving out the top.



### Spray Paint

- Used to **evenly cover surfaces** without wasting paint or missing spots (e.g. cars).
- The object is given a **positive charge**. The spray paint is **negatively charged**. So, the paint is **attracted** to the object and sticks to it evenly.

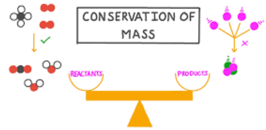


# Quantitative chemistry

## Conservation of mass and balanced equations

The law of **conservation of mass** states that no atoms are lost or made during a chemical reaction, so the mass of the reactants equals the mass of the products.

| ***Reactants*** | | ***Products*** |
|---|---|---|
| *$CaCO_3$* | ➔ | *$CaO + O_2$* |
| *100g* | ➔ | *56g + 44g* |




**Balanced equations** are used to show the number of each type of atom remains the same throughout the reaction.

Numbers are used along with chemical symbols to show the number of each type of atom in a reaction.

A multiplier, represented by a normal script number **in front** of an atom or compound (e.g. 2MgO) multiplies each atom in the compound (2MgO = 2 lots of Mg and 2 lots of O).

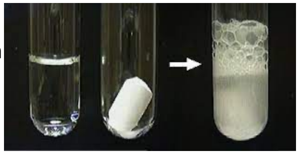
A multiplier, represented by a subscript number **after** an atom ($NH_3$) multiplies the atom in front of the number only ($NH_3$ = 1 lot of N and 3 lots of H).

**Brackets** can be used to show that subscript numbers apply to a section of the formula (e.g. $Ca(OH)_2$ = 1 lot of Ca, 2 lots of O and 2 lots of H).

If no number is present, then there is 1 atom.

## Mass changes when a reactant or product is a gas

Some reactions can appear to show a change in mass.



Some reactions **produce gases** which can escape from unsealed systems. An example of this is the thermal decomposition of calcium carbonate which release carbon dioxide.

Some reactions involve **gases as reactants** which may mean that some products have more mass. An example of this is the reaction of magnesium with oxygen forming magnesium oxide.

## Use of the amount of a substance in relation to volumes of gases *(separate Chemistry only)*

Equal amounts of moles of gases occupy the same volume under the same conditions of temperature and pressure.

The volume of one mole of any gas at room temperature and pressure (20 °C and 1 atmosphere pressure) is **$24dm^3$.**

The volumes of gaseous reactants and products can be calculated from balanced equations.

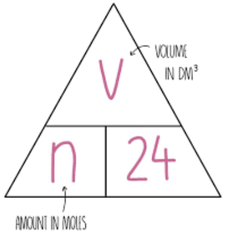
*$Mg + 2HCl$ ➔ $MgCl_2 + H_2$*

*Hydrogen is a gas. We can calculate its volume using this equation:*

*Volume ($dm^3$) = moles (mol) x $24dm^3$*

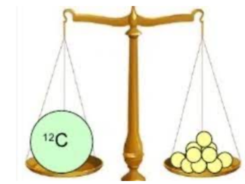
*Volume ($dm^3$) = 1 x 24*

*Volume ($dm^3$) = $24dm^3$*




## Relative formula mass

Relative formula mass (***$M_r$***) is the sum of the relative atomic masses of the elements shown in the formula.




*Mg=24* *O=16*

*MgO = 24 + 16*

The relative atomic mass of an element can be found on the periodic table.

In balanced equations the relative formula mass of the reactants and products should be equal:

*$2Mg + O_2$ ➔ 2MgO*

*24 + 24 + 16 +16 ➔ 24 + 24 + 16 +16*

*80 ➔ 80*

## Percentage by Mass

The percentage and mass of an element can be calculated from a balanced equation:

***Percentage of element*** *= (total relative mass of element ÷ relative formula mass of compound) x 100*

*Percentage of oxygen in MgO = (16 ÷ 40) x 100*

*Percentage of oxygen in MgO = 40%*

We can calculate the mass of an element in a compound using the percentage of an element.

***Mass of an element*** *= Total mass of a compound x percentage (decimal)*

*Mass of oxygen in 50g of MgO = 50g x 0.4*

*Mass of oxygen in 50g of MgO = 20g*

## Chemical measurements

Whenever a measurement is made there is always some uncertainty about the result obtained.

Experiments that have been repeated allow us to see uncertainty. We can use the range and mean to measure uncertainty. The greater the spread of data the more uncertainty.

| Test | 1 | 2 | 3 | Mean |
|---|---|---|---|---|
| A | 40 | 41 | 39 | 40 |
| B | 35 | 42 | 44 | 40 |

$$uncertainty = \frac{range}{2}$$

*The range of results for test A is far less than the range for test B. Test A has less uncertainty.*

# Quantitative chemistry

## Moles *[HT only]*

Chemical amounts are measured in moles. The symbol for the unit mole is mol.

The mass of one mole of a substance is grams is equal to its relative formula mass.

*Mg=24 O=16*

*1 mole of magnesium (Mg) is 24 g*

*1 mole of oxygen ($O_2$) is 32 g*

One mole of a substance contains the same number of particles, atoms, molecules or ions as one mole of any other substance.

The number of atoms, molecules or ions in a mole of a given substance is the Avogadro constant. The value of the Avogadro constant is $6.02 \times 10^{23}$ per mole.

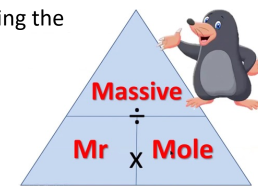
*In 1 mole of carbon (C) the number of atoms is equal to the number of molecules in 1 mole of carbon dioxide ($CO_2$).*

We can calculate the number of moles in a given mass using the following equation:

*moles = mass (g) ÷ relative formula mass*

*moles of Mg in 60 g of magnesium = 60 ÷ 24*

*moles of Mg in 60 g of magnesium = 2.5 mol*




## Amounts of substance in equations *[HT only]*

The masses of reactants and products can be calculated from balanced symbol equations.

Moles can be represented in a formula equation by normal script numbers before the element or compound.

$$Mg + 2HCl \rightarrow MgCl_2 + H_2$$

*This shows that 1 mole of Mg reacts with 2 moles of HCl to produce 1 mole of $MgCl_2$ and 1 mole of $H_2$.*

We can use these equations, along with the atomic mass/relative formula mass to calculate the masses of substances.

*Mg =24, H = 1, Cl = 35.5*

$$Mg + 2HCl \rightarrow MgCl_2 + H_2$$

$$24g + 73g \rightarrow 95g + 2g$$

We can also calculate masses of reactants or products given a known mass of another reactant or product:

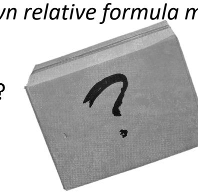
*unknown mass = (known mass ÷ known relative formula mass) x unknown relative formula mass*

$$Mg + 2HCl \rightarrow MgCl_2 + H_2$$

*How much Mg is needed to make 130g of $MgCl_2$?*

*unknown mass = (130 ÷ 95) x 24*

*unknown mass = 32.84g*



## Concentration of solutions

Many chemical reactions take place in solutions.

The concentration of a solution can be measured in mass (of solute) per given volume of solution e.g. $g/dm^3$.

A decimetre cubed or $dm^3$ is 1000ml or 1000 $cm^3$.

Concentration can be calculated using the following equation:

*mass(g) = concentration ($g/dm^3$) x volume ($dm^3$)*

*If 38g of $MgCl_2$ is added to 400ml of water the concentration would be*

*38g = concentration ($g/dm^3$) x $0.4dm^3$*

*concentration ($g/dm^3$) = 38 ÷ 0.4*

*concentration ($g/dm^3$) = $95g/dm^3$*

Don't forget to convert units!

## Using moles to balance equations *[HT only]*

Converting the mass of reactants and products to moles can allow us to balance equations.

$$Mg + O_2 \rightarrow MgO$$

*If we had* - 96g + 64g $\rightarrow$ 160g

*moles = mass (g) ÷ relative formula mass*

*(96÷24) + (64÷32) $\rightarrow$ (160÷40)*

$$4Mg + 2O_2 \rightarrow 4MgO$$

Ratios can be used to calculate simple whole numbers:

$$4Mg + 2O_2 \rightarrow 4MgO$$

4:2:2

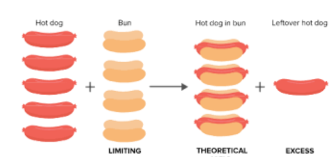
2:1:1

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

## Limiting reactants *[HT only]*

In a chemical reaction involving 2 reactants it is common to use an excess of one of the reactants to ensure all the other reactant is used.

The reactant that is completely used up is called a limiting reactant because it limits the amount of product.



# Quantitative chemistry *(separate Chemistry only)*

## Percentage yield

Even though no atoms are gained or lost in a chemical reaction, it is not always possible to obtain the calculated amount of product for the following reasons.

*The reaction may not go to completion because it is reversible.*

*Some of the product may be lost when it is separated from the reaction mixture.*

*Some of the reactants may react in ways different to the expected reaction .*

The amount of product obtained is known as the yield.

The yield you would expect to get is called the maximum theoretical yield.

The amount of product obtained compared to the maximum theoretical yield is called the percentage yield.

*%yield = (mass of product actually made ÷ maximum theoretical yield) x 100*

$Mg + 2HCl \rightarrow MgCl_2 + H_2$

*24g + 73g ➔ 95g + 2g*

*This equation shows that we should make 95g of $MgCl_2$ if we use 24g of Mg. If we only make 76g the %yield would be:*

*%yield = (76 ÷ 95) x 100*

*%yield = 80%*

$$\text{PERCENTAGE YIELD} = \frac{\text{ACTUAL YIELD}}{\text{THEORETICAL YIELD}} \times 100$$


## Using concentrations of solutions in mol/dm³

If the volumes of two solutions that <u>react completely</u> are known and the concentration of one solution is known, the concentration of the other solution can be calculated.

$2\ NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + 2\ H_2O$

*25cm$^3$ of $H_2SO_4$ reacts completely with 22cm$^3$ NaOH. The concentration of the NaOH is 0.105mol/dm$^3$*

*To calculate the concentration of the $H_2SO_4$ we use the following formula (where mass represents the mass of solute in solution):*

*mass(g) = concentration (g/dm$^3$) x volume (dm$^3$)*

*Calculating 2NaOH*

*mass = 0.105 x 0.022*

*mass = 0.00231g*

*There is twice as many moles of NaOH as there is of $H_2SO_4$ so we divide this figure by 2*

*mass = 0.001155g*

*Calculating $H_2SO_4$*

*mass(g) = concentration (g/dm$^3$) x volume (dm$^3$)*

*0.001155 = concentration (g/dm$^3$) x 0.025*

*concentration (g/dm$^3$) = 0.001155 ÷ 0.025*

*concentration (g/dm$^3$) = 0.0462g/dm$^3$*

4 mol/dm³

## Atom economy

The atom economy is a measure of the amount of starting materials that ended up as useful products.

A high atom economy is desirable for environmental and economic reasons.

Atom economy can be calculated using the formula:

*Atom economy = (Relative formula mass of the desired product ÷ sum of relative formula masses of all reactants) x 100*

*Mg =24, H = 1, Cl = 35.5*

$Mg + 2HCl \rightarrow MgCl_2 + H_2$

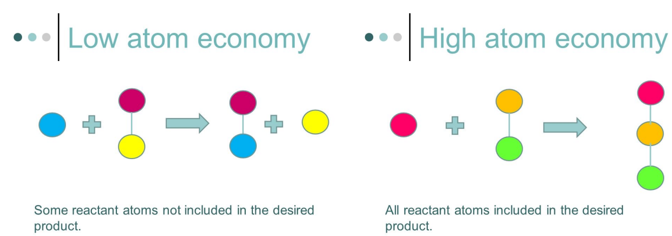
*If $MgCl_2$ is the desired product then*

*Atom economy = (95 ÷ 97) x 100*

*Atom economy = 97.94%*

Particular reaction pathways can be selected because of the atom economy, yield, equilibrium position and usefulness of the by-products.

$$\text{\% ATOM ECONOMY} = \frac{\text{Mr OF DESIRED PRODUCT}}{\text{Mr OF TOTAL PRODUCTS}} \times 100$$



# Using Earth's Resources

## Resources

The human population is increasing rapidly and our use of Earth's resources has increased. Resources can be **finite** (those being used more quickly than they are made, e.g. metals and fossil fuels) or **renewable** (e.g. solar energy, wind power, geothermal energy). We use resources for shelter, food, clothing and construction.

## Potable Water

**Potable** water is water that is safe to drink. It has low levels of dissolved solutes and microbes and a pH of between 6.5 and 8.5. It is not necessarily pure.
**Pure water** would contain $H_2O$ molecules only.

To make  water potable, the method depends on location. In the UK water is collected as surface water (lakes, reservoirs) or groundwater (rocks) and can then be treated.
Step 1. Filtration through mesh
Step 2: Aluminium sulphate is added to clump together particles which fall to the bottom of the tanks as sludge.
Step 3. Filtration through gravel and sand bed to remove fine particles
Step 4. Sterilised to kill microbes using chlorine, UV or ozone.

## Desalination

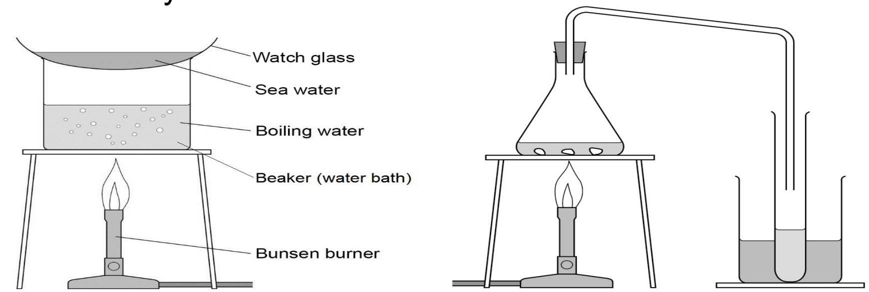
Sea water can undergo a process of desalination to remove the salt to make it potable.
**Distillation**: water is heated until it evaporates. The steam cools and condenses in a condensing tube. The salt is left behind. This is expensive due to the energy requirement of boiling water.
**Reverse osmosis**: salt water is forced through a membrane at high pressure. The membrane has holes so small only water molecules can fit through. These membranes are expensive.

## Required practical - Safe drinking water

In this investigation you will analyse a water sample and purify a water sample using distillation.

**Analysing the water sample:**

1. Use the universal indicator paper to measure the pH of the water sample.
2. Accurately weigh an empty evaporating basin and record to two decimal places.
3. Pour 10 $cm^3$ of water sample 1 into the evaporating basin.
4. Heat the evaporating basin on a tripod and gauze using a Bunsen burner until the solids start to form and the majority of water has evaporated.
5. Weigh the cooled evaporating basin again and calculate the mass of the solids that were dissolved in the water.
6. Record your results in a table




**Purifying the Water Sample:**

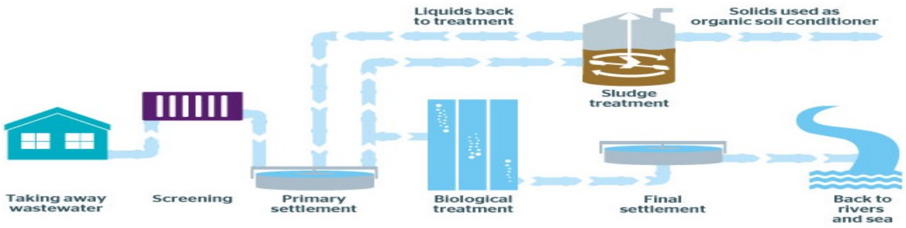
1. Place the water sample in the conical flask. Set up the apparatus for distillation as shown in the diagram above.
2. Heat the water using the Bunsen burner until it boils. Then reduce the heat so that the water boils gently.
3. The distilled water will collect in the cooled test tube. Collect about 1 cm depth of water in this way, then stop heating.
4. Analyse the water you have distilled by determining its boiling point

# Using Earth's Resources

## Treating waste water

1. Water is screened to remove branches, twig, grit etc
2. Sedimentation: water is placed in a settlement tank, the heavier solids sink to the bottom and the lighter effluent floats on top.
3. The effluent is transferred to another tank where microbes are added to digest the organic matter. Oxygen is bubbled into the water for the microbes to use in respiration.
4. The water is now clean enough to be released into rivers.

The sludge can be used as fertilisers on crops, burnt as fuel, or used to produce biogas fuel.




## Alternative ways of extracting metals *[Higher tier]*

In order to conserve the copper ores, copper is extracted from low-grade ores by **phytomining**, and **bioleaching**. These methods avoid digging, moving and disposing of large amounts of rock.

**Bioleaching** uses bacteria to produce leachate solutions that contain metal compounds.

**Phytomining** uses plants to absorb metal compounds. The plants are harvested and then burned to produce ash that contains metal compounds. The metal can be purified either by:

a. displacement reaction extracts copper from solutions of copper compounds by displacement using scrap iron

iron + copper sulfate → iron(II) sulfate + copper

$$Fe(s) + CuSO_4(aq) \rightarrow FeSO_4(aq) + Cu(s)$$

b. Electrolysis uses electricity to split the positive copper ions away from the negative non-metal ions it is bonded to in the ore.

## Life Cycle Assessments

A LCA is used to assess the environmental impact a product has over its whole lifetime. They provide a way of comparing several alternative products to see which one causes the least damage to the environment.

To carry out an LCA, scientists measure the impact of:

- Extracting the raw materials
- Processing raw material
- Manufacturing the product
- How the product is used
- How the product is transported
- How the product is disposes of at the end of its life.

LCAs can be subjective and hard to quantify and can therefore be misused for advertising a product.

## Reduce, Reuse, Recycle

It is important to reduce the amount of finite raw materials used to produce new products. This also reduces pollution and waste products so there is less of an environmental impact.

**Glass bottles** can be reused by crushing and melting to make different glass products.

**Metals** can be recycled by melting and recasting or reforming into different products. The amount of separation required for recycling metal depends on the material and the properties required of the final product.

For example, some scrap steel can be added to iron from a blast furnace to reduce the amount of iron that needs to be extracted from iron ore.

## Using Earth's Resources *(separate Chemistry only)*

**Corrosion**

Corrosion is the destruction of materials by chemical reactions with substances in the environment. An example of corrosion is **rusting**. For iron to rust it needs both water and oxygen. Iron + water + oxygen → hydrated iron ( **III** ) oxide

Corrosion can be prevented by applying a coating that acts as a barrier, such as greasing, painting or electroplating.

Aluminium has an oxide coating that protects the metal from further corrosion.

**Sacrificial protection** is the coating of a metal with a more reactive one. e.g. zinc is used to galvanise iron.

**Alloys**

Most metals in everyday use are alloys. They are made up of two or more chemical elements, of which at least one is a metal.

An **alloy** has properties different from the metals it is made of. In an alloy, there are atoms of different sizes. The smaller or bigger atoms distort the layers of atoms in the pure metal. This means that a greater force is required for the layers to slide over each other. The alloy is harder and stronger than the pure metal.

**Bronze** is an alloy of copper and tin. **Brass** is an alloy of copper and zinc.

Gold used as jewellery is usually an alloy with silver, copper and zinc. The proportion of gold in the alloy is measured in carats. **24 carat being 100% (pure gold)** and 18 carat being 75% gold.

**Steels** are alloys of iron that contain specific amounts of carbon and other metals. **High carbon steel** is strong but brittle. **Low carbon steel** is softer and more easily shaped. Steels containing chromium and nickel (stainless steels) are hard and resistant to corrosion. **Aluminium** alloys are low density.

**Ceramics, Polymers and Composite**

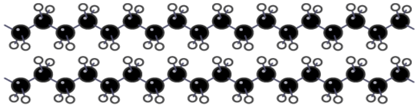
Glass can be made by heating a mixture of sand, sodium carbonate and limestone. This is called **soda-lime glass Borosilicate glass**, is made from sand and boron trioxide. It melts at higher temperatures than soda-lime glass.

**Clay ceramics**, including pottery and bricks, are made by shaping wet clay and then heating in a furnace.

Most **composites** are made of two materials, a matrix or binder surrounding and binding together fibres or fragments of the other material, which is called the reinforcement.

Examples of composites are: carbon fibre composite, reinforced concrete, fibreglass.

**Polymers** are large molecules made from small, repeating molecules called **monomers**.



**Low density and high density poly(ethene)** are both produced from ethene but at different temperatures. LD is made at moderate temperatures and high pressure and is flexible. HD is made at lower temperature and pressure with different catalysts and is more rigid.

**Thermosoftening** polymers melt when they are heated because the polymer chains are entwined between them with weak forces between the chains.

**Thermosetting** polymers do not melt when they are heated because the polymer chains have cross-links between them.

# Using Earth's Resources *(separate Chemistry only)*

The **Haber process** is a way of making ammonia ($NH_3$)
The raw materials are:
- Nitrogen – from the air
- Hydrogen – from natural gas (methane)

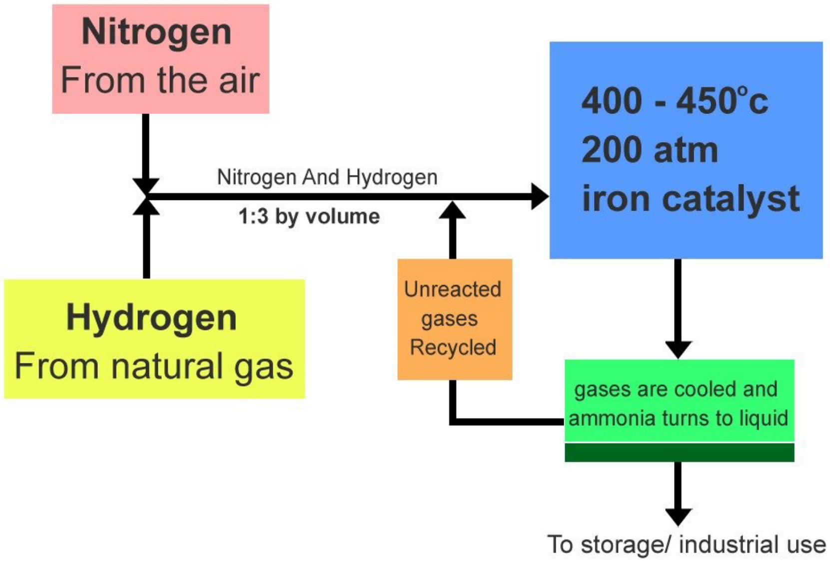
$$N_{2\,(g)} + 3H_{2\,(g)} \rightleftharpoons 2NH_{3\,(g)}$$

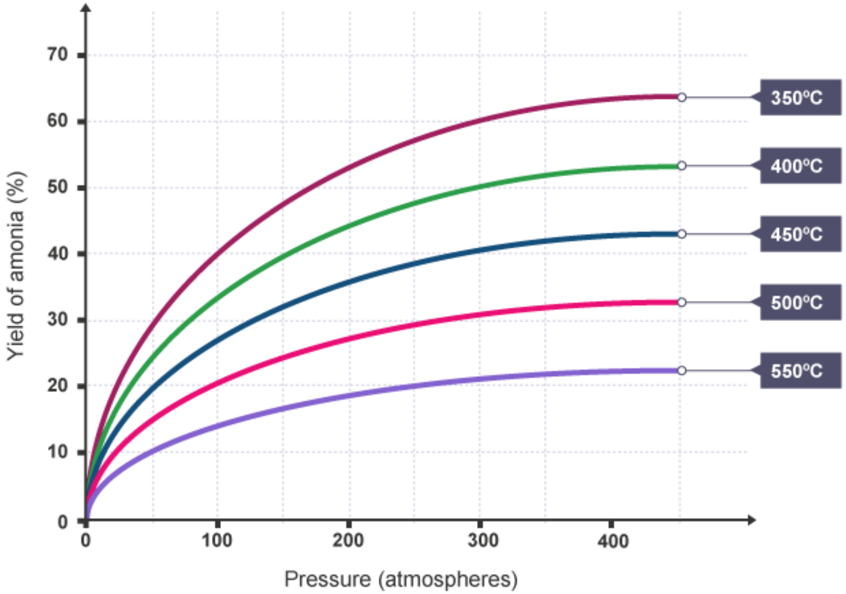
This is a **reversible reaction.**
The conditions for making ammonia are:
- 200atm pressure
- 450°C temperature
- Iron catalyst

The ammonia is cooled and condensed into liquid and removed so that it doesn't break back down into hydrogen and nitrogen. Unreacted hydrogen and nitrogen are recycled.

The forwards reaction is **exothermic**, so if the temperature is increased, the **equilibrium position** moves in the direction of the **endothermic** reaction. This means it moves to the left in the Haber process. The rate of reaction is low at low temperatures. So a compromise temperature of 450 °C is chosen. This is:
•low enough to achieve an acceptable yield
•high enough to do this in an acceptable time

If the **pressure** is increased, the equilibrium position moves in the direction of the fewest **molecules** of gas. This means it moves to the right in the Haber process. It is expensive to achieve very high pressures. Stronger equipment is needed, and more energy is needed to compress the gases. So a compromise pressure of **200 atmospheres** is chosen. This is:
- low enough to keep costs down
- high enough to achieve an acceptable yield.



# Using Earth's Resources *(separate Chemistry only)*

## Fertilisers

Fertilisers are **formulations** which may contain nitrogen, phosphorus and potassium **compounds** to promote plant growth. Fertilisers that supply all three **elements** are often called **NPK fertilisers**, after the chemical symbols for these three elements.

Fertiliser compounds must be **soluble** in water so they can be absorbed by the root hair cells:

- **Ammonium nitrate** - $NH_4NO_3$ - and **ammonium sulphate** - $(NH_4)_2SO_4$ - are examples of fertilisers that contain the essential element nitrogen.
- **Ammonium phosphate** - $(NH_4)_3PO_4$ - contains the elements nitrogen and phosphorus.
- **Potassium nitrate** - $KNO_3$ - contains the elements potassium and nitrogen.

**Potassium salts** can be mined from rock, they are already soluble so don't need treating with acid.

**Phosphate rock** is also obtained by mining, but phosphate rock cannot be used directly as a fertiliser. Phosphate rock is treated with nitric acid or sulfuric acid to produce soluble salts that can be used as fertilisers (see the table).

| Phosphate rock reacts with… | Compound(s) produced |
|---|---|
| Nitric acid | Calcium nitrate and phosphoric acid (which is neutralised with ammonia to make ammonium phosphate) |
| Sulfuric acid | Single superphosphate (a mixture of calcium sulfate and calcium phosphate) |
| Phosphoric acid | Triple superphosphate (calcium phosphate) |

To make the salts, ammonia is reacted with different acids. Ammonia produces the ammonium ion $NH_4^+$ when it is involved in neutralisation reactions. Ammonia is an alkali.

**alkali + acid → salt**

**ammonia + nitric acid → ammonium nitrate**

$$NH_3 + HNO_3 \rightarrow NH_4NO_3$$

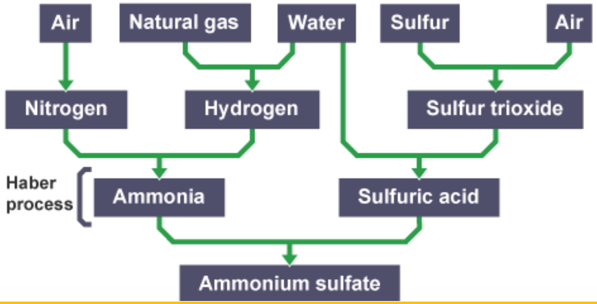
**ammonia + sulfuric acid → ammonium sulphate**

$$2NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$$

**ammonia + phosphoric acid → ammonium phosphate**

$$3NH_3 + H_3PO_4 \rightarrow (NH_4)_3PO_4$$

**Ammonia sulphate** can be made in a lab by reacting ammonia + sulphuric acid, or on an industrially large scale




| Factor | Industrial method | Laboratory method |
|---|---|---|
| Temperature | Between 60°C and 450°C | Room temperature then heating to evaporate the water |
| Equipment and process | Very expensive chemical plant machinery, used in a continuous process | Cheap and versatile laboratory equipment, used in a batch process |
| Starting materials | Reactants are made from raw materials, eg sulfur, air, water | Reactants are purchased from a chemical supplier |
| Scale/yield | Huge quantities can be made quickly. | Small quantities are made slowly |
| Running costs | Automatic control, labour and running costs are low | very labour-intensive, so running costs are high |

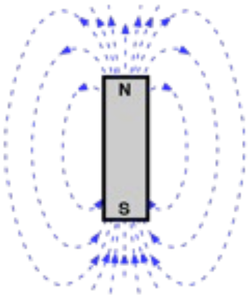
# Magnets and Electromagnets

## 1. Magnets

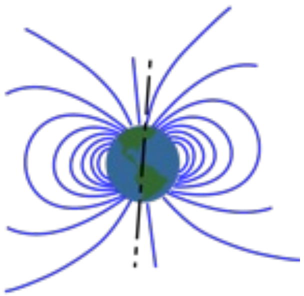
The 2 poles of a bar magnet are called the north (seeking) pole and the south (seeking) pole

Magnetic materials:
Iron
Cobalt
Nickel
Steel (an alloy of iron)

Like poles repel
Unlike poles attract



Bar Magnet


The Earth

**Permanent magnets** have their own magnetic field. Field lines follow the same pattern running from north to south. The strongest field is at the poles.

You can find the invisible lines using iron filings or a plotting compass

**Induced** magnets
A magnetic material will become magnetised when placed in a strong magnetic field.
Induced magnetism always causes a force of attraction.

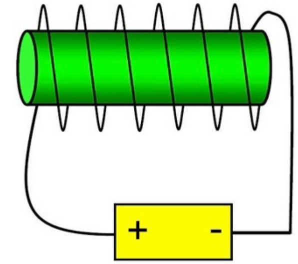
The liquid core of the Earth generates a magnetic field like a bar magnet. It stretches beyond the atmosphere.

## 2. Electromagnets

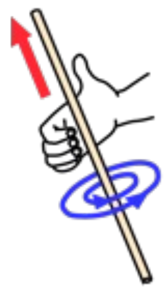
When a current flows through a wire a magnetic field is produced around the wire. It always creates the same pattern and can be predicted using the right hand thumb rule.

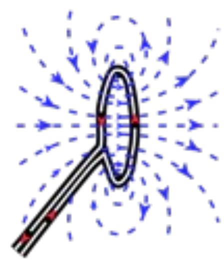
The strength of the magnetic field depends on the current through the wire and the distance from the wire.

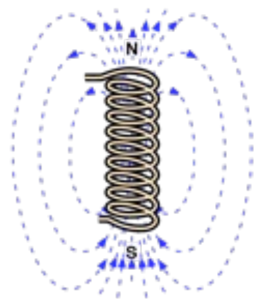
A **solenoid** is a coil of wire; coiling the wire increases the strength of the magnetic field by increasing the length of wire involved in the coil.
The magnetic field created around a solenoid is a similar shape to a bar magnet.




An **electromagnet** is a solenoid with an iron core; adding the core increases the strength of the magnetic field


Current in wire

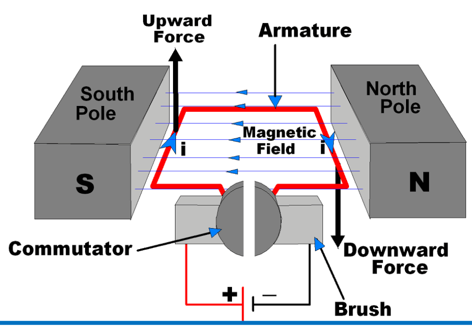

Loop of wire



Solenoid

## 3. The motor effect

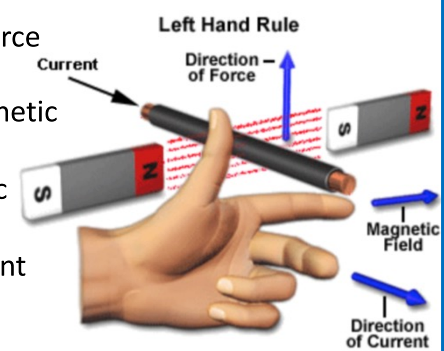
When a current carrying wire is placed in a permanent magnetic field they exert a force on each other; this is the **motor effect.**




The factors that affect the size of the force are:
- the size of the current
- the strength of the permanent magnet (the magnetic flux density)
- the length of the wire

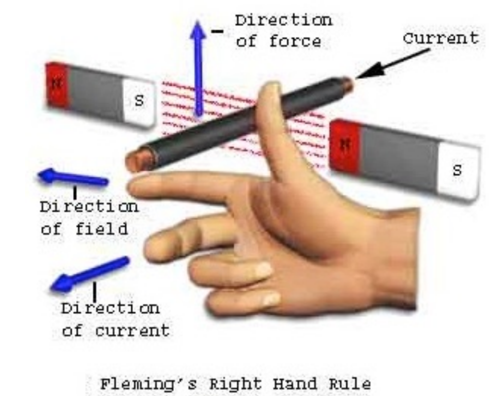
These are linked in the formula ***F=BIl***.

Fleming's left-hand rule allows us to predict the force when the current is perpendicular to the magnetic field:
**F**irst finger is the magnetic **F**ield
se**C**ond finger is the **C**urrent
thu**M**b is the force (**M**ovement)



# Magnets and Electromagnets *(separate Physics only)*

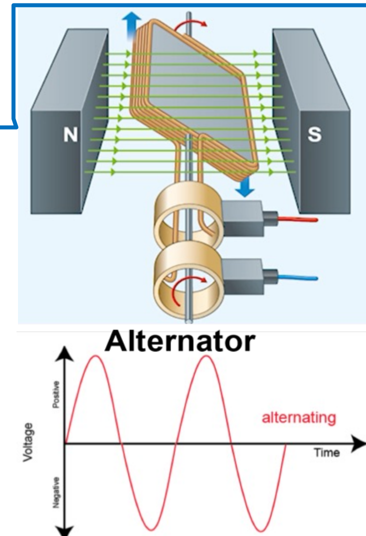
## 4. The generator effect



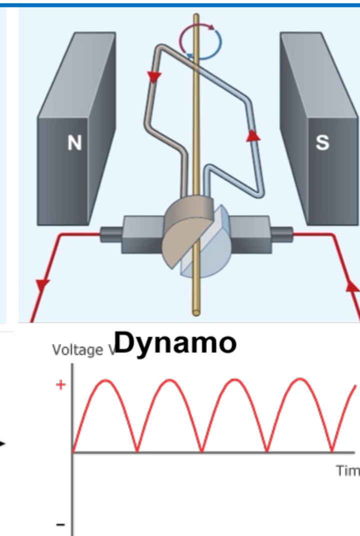

A wire moving in a magnetic field induces a potential difference between the 2 ends of the wire. If the wire is part of a circuit a current will flow; this is called the **generator effect** and current direction can be predicted using Fleming's right-hand rule.

The size of the induced potential difference is affected by
- the strength of the magnetic field
- length of the wire in the solenoid
- force of the movement

The direction of the induced current is affected by the direction of the magnetic field and the direction of the movement.




The generator effect is used in an **alternator** to produce a.c. A rotating magnet spins within a coil of wire inducing an alternating potential difference.




The generator effect is used in a **dynamo** to produce d.c. This works in the same way as an alternator, but uses a split ring commutator to stop the current reversing.

## 6. Transformers

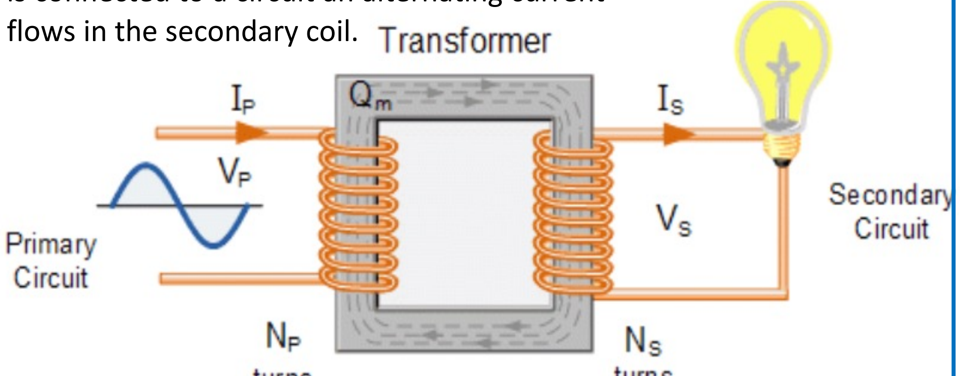
A **transformer** is two separate coils of wire wound around an iron core.

On sheet

An alternating current is supplied to the primary coil. This creates an alternating magnetic field in the iron core. As the alternating field is constantly moving it induces an alternating potential difference in the secondary coil; because the coil is connected to a circuit an alternating current flows in the secondary coil.

$$\frac{V_p}{V_s} = \frac{n_p}{n_s}$$

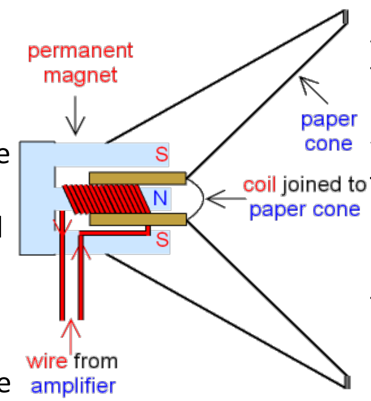
$$V_p \times I_p = V_s \times I_s$$




## 5. Uses of electromagnetism

Two examples needed are the loudspeaker and the microphone.

**Loudspeakers** use the motor effect. The cone of the speaker is attached to a solenoid that is placed in a permanent magnet field. Changes in the current supplied to the solenoid affect the force between the magnet and the solenoid causing it to move backward and forwards; this move the speaker cone in and out creating sound (pressure) waves.




A **microphone** uses the generator effect (works the opposite way to a speaker). The sound waves move a cone in and out. This is attached to a solenoid in a permanent magnetic field; the movement of the solenoid induces a changing p.d., and therefore an a.c..

# Biology Paper 2: Homeostasis & Response

## Homeostasis

**Homeostasis** maintains a constant internal environment in the body to provide the optimal conditions for **enzyme** action, as well as all cell functions.

In the human body, these include the control of:

- **blood glucose** concentration
- body **temperature**
- **water** levels

These automatic control systems may involve nervous responses (**nervous system**) or chemical responses (**endocrine system**).

All control systems include:

- cells called **receptors**, which detect **stimuli** (changes in the environment)
- **coordination centres** (such as the brain, spinal cord and pancreas) that receive and process information from receptors
- **effectors**, muscles or glands, which bring about responses which restore optimum levels.

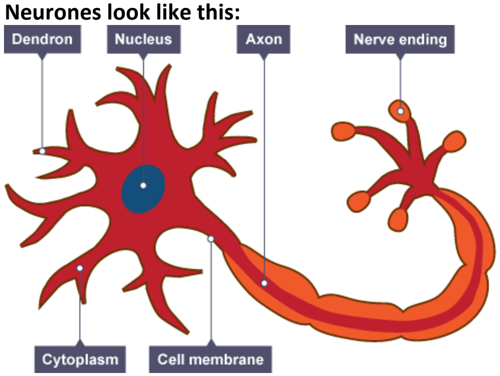
## The Human Nervous System

The nervous system enables humans to react to their surroundings and to coordinate their behaviour**.**

Information from receptors passes along cells (**neurones**) as **electrical impulses** to the central nervous system (**CNS**). The CNS is the brain and spinal cord. The CNS coordinates the response of effectors which may be muscles contracting or glands secreting hormones.

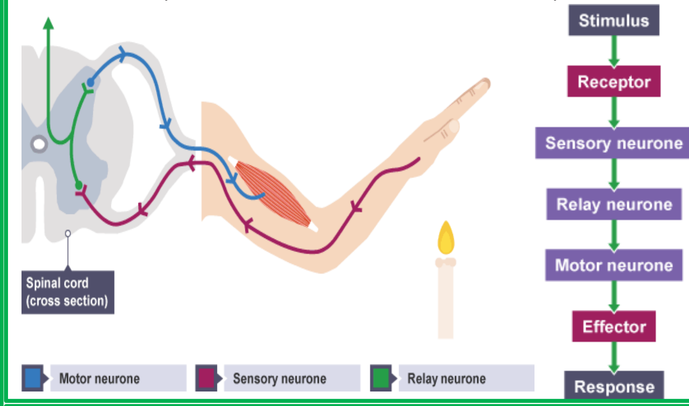
Stimulus → receptor → coordinator → effector → response

**Neurones look like this:**




## Reflexes

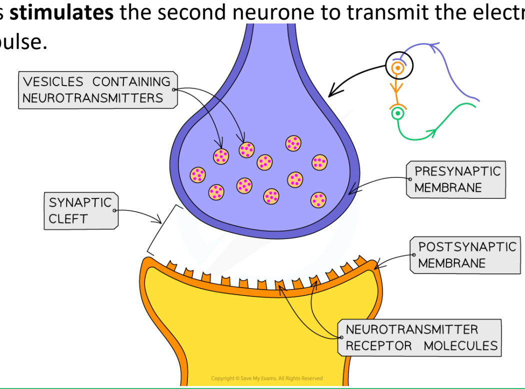
A reflex action follows this general sequence and does not involve the conscious part of the brain, which makes it much quicker.




## Synapses

Where two neurones meet there is a small gap, a **synapse**.

1. An electrical impulse travels along the first axon.
2. This triggers the nerve-ending of a neurone to release **chemical messengers** called **neurotransmitters**.
3. These chemicals **diffuse** across the synapse and bind with receptor molecules on the membrane of the second neurone.
4. The receptor molecules on the second neurone bind only to the **specific neurotransmitters** released from the first neurone. This **stimulates** the second neurone to transmit the electrical impulse.




**Hormones:** The **endocrine system** secretes hormones into the **bloodstream** from **glands** throughout the body. Hormones produce an effect on specific target organs in the body. The pituitary gland is a '**master gland**' which secretes several hormones into the blood in response to body conditions. These hormones in turn act on other glands to stimulate other hormones to be released, the effects are slower but act for longer.

## Required Practical

**Reaction time** is the time taken to respond to a stimulus.

Reaction time can be affected by factors such as **age**, **distractions or use of drugs** (such as caffeine)

**Method:**

1.Work with a partner.

2.Person A holds out their hand with a gap between their thumb and first finger.

3.Person B holds the ruler with the zero at the top of person A's thumb

4.Person B drops the ruler without telling Person A and they must catch it.

5.The number level with the top of person A's thumb is recorded in a suitable table. Repeat this ten times.

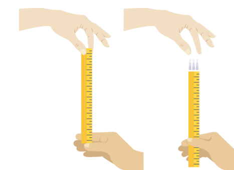
6.Swap places, and record another ten attempts.

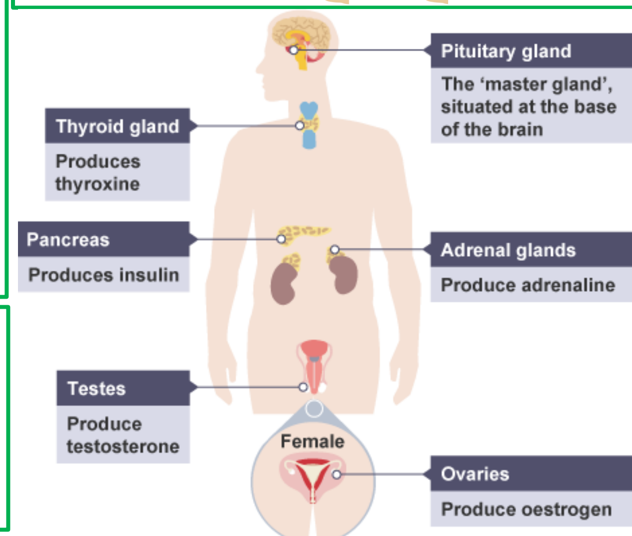
7.You can use a conversion table to help convert your ruler measurements into reaction time or just record the catch distance in cm.

**Control variables:**

The person catching the ruler using their dominant hand each time.

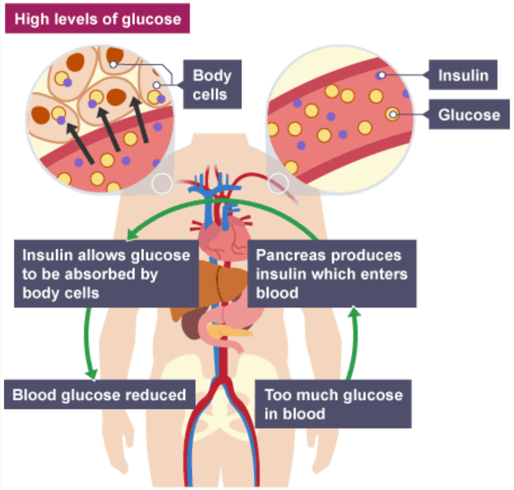
Dropping the same ruler from the same height each time, with the ruler orientated in the same direction (0 cm facing down).





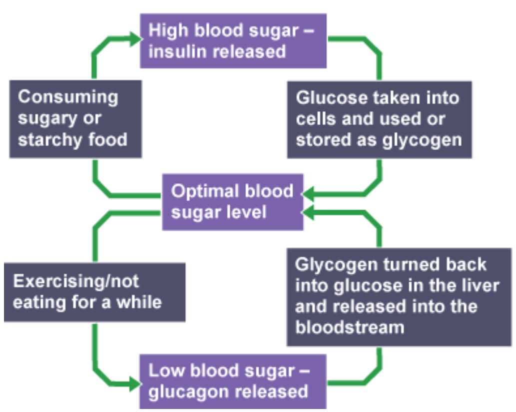
## Control of Blood Glucose Concentration

Blood glucose concentration is monitored and controlled by the **pancreas**. If the blood glucose concentration is too high, the pancreas produces the hormone **insulin** that causes glucose to move from the blood into the cells. In **liver and muscle cells** excess glucose is converted to **glycogen** for storage.




## Low Blood Glucose: *[Higher tier]*

If the blood glucose concentration is too low, the pancreas produces the hormone **glucagon** that causes **glycogen** to be converted into glucose and released into the blood.




## Hormones in Human Reproduction

Changes occur at puberty because of **hormones**:

- **testosterone** - produced by the testes - controls the development of male secondary sexual characteristics
- **oestrogen** - produced by the ovaries - controls the development of female secondary sexual characteristics.

Secondary sexual characteristics appear during puberty and were not present at birth.

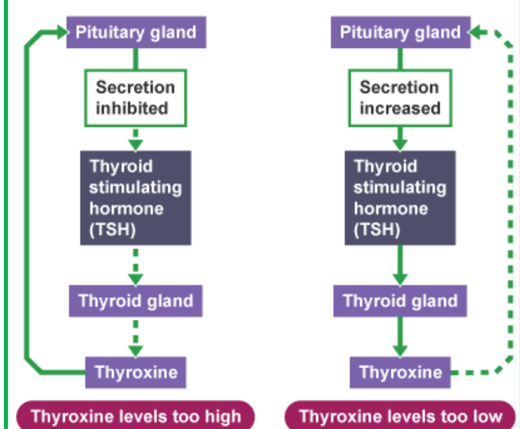
## Hormones in the Menstrual cycle

The **menstrual cycle** is a recurring process which takes around 28 days. During the process, the lining of the **uterus** is prepared for pregnancy. If implantation of the fertilised egg into the uterus lining does not happen, the lining is then shed. This is known as **menstruation**.

| Hormone | Produced | Role |
|---|---|---|
| FSH (follicle stimulating hormone) | Pituitary gland | Causes an egg to mature in an ovary. Stimulates the ovaries to release oestrogen |
| Oestrogen | Ovaries | Stops FSH being produced (so that only one egg matures in a cycle). Repairs, thickens and maintains the uterus lining. Stimulates the pituitary gland to release LH. |
| LH (luteinising hormone) | Pituitary gland | Triggers ovulation (the release of a mature egg) |
| Progesterone | Ovaries | Maintains the lining of the uterus during the middle part of the menstrual cycle and during pregnancy. |

## Diabetes

**Type 1 diabetes** is a disorder in which the pancreas fails to produce sufficient insulin. It is characterised by uncontrolled high blood glucose levels and is normally treated with insulin injections. In **Type 2 diabetes** the body cells no longer respond to insulin produced by the pancreas. A carbohydrate controlled diet and an exercise regime are common treatments. Obesity is a risk factor for Type 2 diabetes.




## Contraception

Fertility can be controlled by a variety of hormonal and non-hormonal methods of contraception. These include:

- **oral contraceptives** that contain hormones to inhibit FSH production so that no eggs mature
- **injection, implant or skin patch** of slow release progesterone to inhibit the maturation and release of eggs for a number of months or years
- barrier methods such as **condoms** and diaphragms which prevent the sperm reaching an egg
- **intrauterine devices** which prevent the implantation of an embryo or release a hormone
- **spermicidal agents** which kill or disable sperm
- **abstaining** from intercourse when an egg may be in the oviduct
- surgical methods of male and female **sterilisation.**

## Hormones to Treat Infertility: *[Higher tier]*

Hormones can be used in modern reproductive technologies to treat infertility. This includes giving FSH and LH in a 'fertility drug' to a woman. She may then become pregnant in the normal way.

**In Vitro Fertilisation (IVF) treatment.**

- IVF involves giving a mother FSH and LH to stimulate the maturation of several eggs.
- The eggs are collected from the mother and fertilised by sperm from the father in the laboratory.
- The fertilised eggs develop into embryos.
- At the stage when they are tiny balls of cells, one or two embryos are inserted into the mother's uterus (womb).

## Negative Feedback: *[Higher tier]*

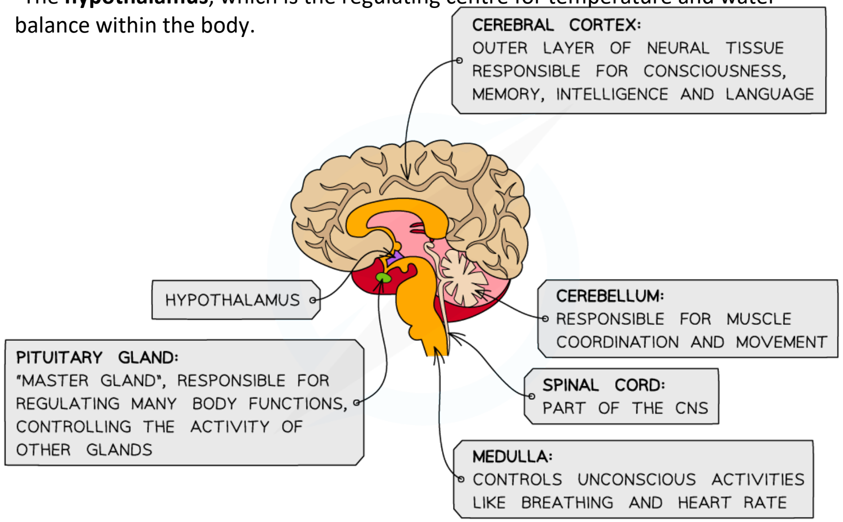
A negative feedback control system responds when conditions change from the ideal and returns conditions to this point. An example is thyroxine. Thyroxine from the thyroid gland stimulates the basal metabolic rate. It plays an important role in growth and development. High thyroxine levels in the bloodstream prevent the release of **TSH** from the pituitary gland, so normal blood levels are restored. Low thyroxine levels in the bloodstream stimulate the pituitary gland to release TSH so the thyroid releases more thyroxine. So, blood levels return to normal. Adrenaline is made by the adrenal glands in times of fear or stress. It increases heart rate and boosts the oxygen and glucose to the brain and muscles, preparing the body for 'flight or fight'.

## The Brain: *(Separate Biology Only)*

The brain controls complex behaviour. It is made of billions of interconnected neurones and has different regions that carry out different functions.

There are four main areas in the brain:

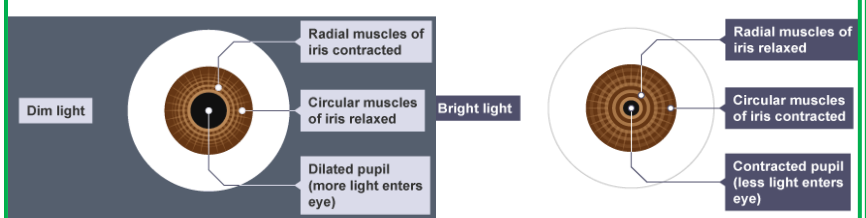
- The **cerebrum** (the outer layer is called the cerebral cortex), which is split into two hemispheres and is highly folded. It controls intelligence, personality, conscious thought and high-level functions, such as language and verbal memory.
- The **cerebellum**, which controls balance, co-ordination of movement and muscular activity.
- The **medulla**, which controls unconscious activities such as heart rate and breathing rate.
- The **hypothalamus**, which is the regulating centre for temperature and water balance within the body.



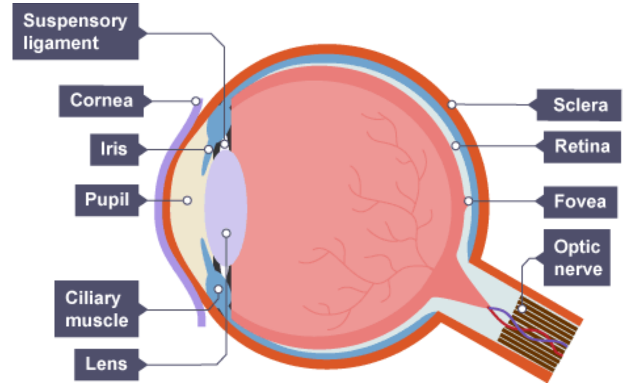

Modern science has allowed scientists to discover how different parts of the brain function. Neuroscientists have been able to map various regions of the brain to particular functions by studying patients with brain damage, electrically stimulating different parts of the brain and using **MRI** scanning techniques.

The complexity and delicacy of the brain makes investigating and treating brain disorders very difficult.

**The pupil reflex** *(Separate Biology Only)* The amount of light entering the eye is controlled by a **reflex action**. The size of the **pupil** changes in response to bright or dim light. This is controlled by the muscles of the iris.



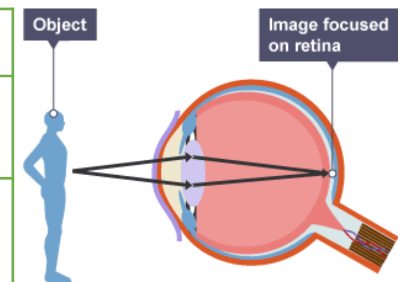

## The Eye: *(Separate Biology Only)*




| Structure | Function |
|---|---|
| Cornea | Refracts light - bends it as it enters the eye |
| Iris | Controls how much light enters the pupil |
| Lens | Further refracts light to focus it onto the retina |
| Retina | Contains the light receptors |
| Optic nerve | Carries impulses between the eye and the brain |
| Sclera | Tough white outer layer of the eye. It helps protect the eye from injury |

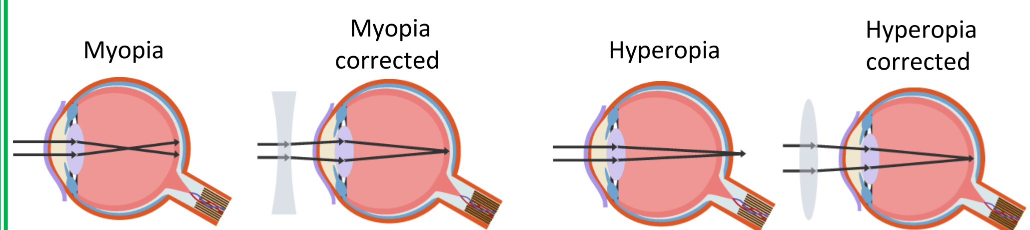
**Accommodation** is the process of changing the shape of the lens to focus on near or distant objects.

| Position of object | Ciliary muscles | Suspensory ligaments | Muscle tension | Lens shape | Refraction |
|---|---|---|---|---|---|
| Near | Contract | Slacken/ loosen | Low | Thicker | Light is refracted strongly |
| Distant | Relax | Stretched/ tighten | High | Thin | Light is only refracted slightly |



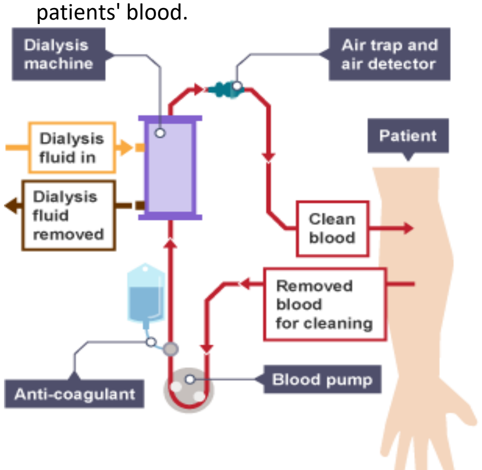

Two common defects of the eyes are **myopia** (short sightedness) and **hyperopia** (long sightedness) in which rays of light do not focus on the retina.

- Generally these defects are treated with spectacle lenses which refract the light rays so that they do focus on the retina.
- New technologies now include hard and soft contact lenses, laser surgery to change the shape of the cornea and a replacement lens in the eye.



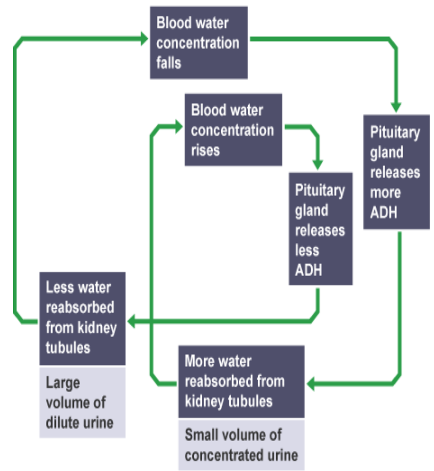
**Dialysis:**
Unfiltered blood that is high in urea is taken from a blood vessel in the arm, mixed with blood thinners or an **anti-coagulant** to prevent clotting, and pumped into the dialysis machine. Inside the machine the blood and dialysis fluid are separated by a **partially permeable membrane** the blood flows in the opposite direction to dialysis fluid, allowing exchange to occur between the two where a concentration gradient exists.
Dialysis fluid contains:

- a **glucose** concentration similar to a normal level in the blood. This prevents the net movement of glucose across the membrane as no concentration gradient exists.
- a concentration of ions similar to that found in normal blood plasma. This means movement of ions across the membrane only occurs where there is an imbalance. If the patient's blood is too **low in ions**, they will diffuse from the dialysis fluid into the blood, restoring the ideal level in the blood. If the patient's blood is **too high in ions**, the excess ions will diffuse from the blood to the dialysis fluid.
- no **urea.** This meanes there is a large concentration gradient - meaning that urea moves across the partially permeable membrane, from the blood to the dialysis fluid, by diffusion. This is very important as it is essential that urea is removed from the patients' blood.




*(Separate Biology Only)*

**The affect of ADH:** Different amounts of ADH are released into the bloodstream according to the concentration of water in the **blood plasma**. ADH is released by the pituitary gland when the blood is too concentrated and it causes the kidney tubules to become more **permeable**. This allows more water to be reabsorbed back into the blood during selective reabsorption. If a person has consumed a large volume of water and has not lost much as sweat, too much water might be detected in the blood plasma. If this occurs, less ADH will be released, which results in less water being reabsorbed and a dilute and larger volume of urine will be produced.

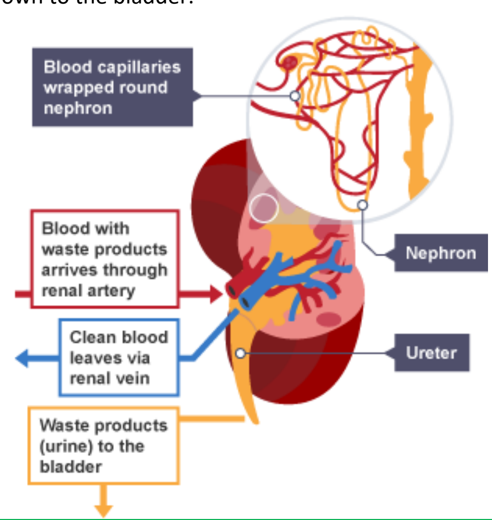



**Maintaining water and nitrogen balance in the body:** Water leaves the body via the lungs during **exhalation**.

- Water, ions and urea are lost from the skin in **sweat**.
- There is no control over water, ion or urea loss by the lungs or skin.
- Excess water, ions and urea are removed via the kidneys in the urine.
- If body cells lose or gain too much water by **osmosis** they do not function efficiently.
- The digestion of **proteins** from the diet results in excess **amino acids** which need to be excreted safely. In the **liver** these amino acids are **deaminated** to form **ammonia**. Ammonia is toxic and so it is immediately converted to **urea** for safe excretion.

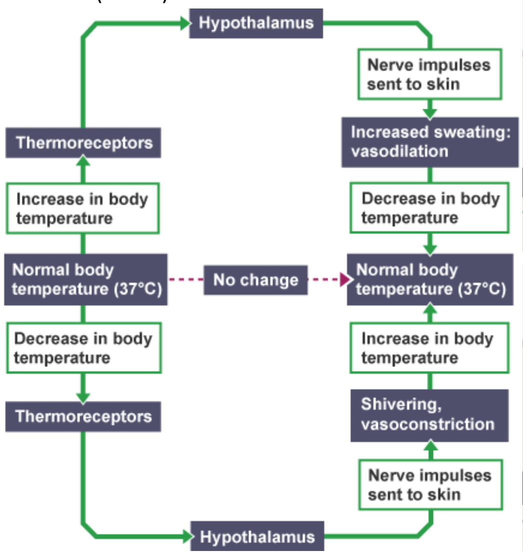
| | Advantages | Disadvantages |
|---|---|---|
| **Transplant** | Patients can lead a more normal life without having to watch what they eat and drink.<br>Cheaper for the NHS overall. | Must take immune-suppressant drugs which increase the risk of infection.<br>Shortage of organ donors.<br>Kidney only lasts 8-9 years on average.<br>Any operation carries risks. |
| **Dialysis** | Available to all kidney patients (no shortage).<br><br>No need for immune-suppressant drugs. | Patient must limit their salt and protein intake between dialysis sessions.<br>Expensive for the NHS.<br>The patient must be connected to this machinery 2-3 times a week for periods (on average) of between 4-6 hours at a time. Impacts on the patient's lifestyle.<br>Dialysis will only work for a limited amount of time before a transplant is needed, and sadly many patients will die before a suitable one is found. |

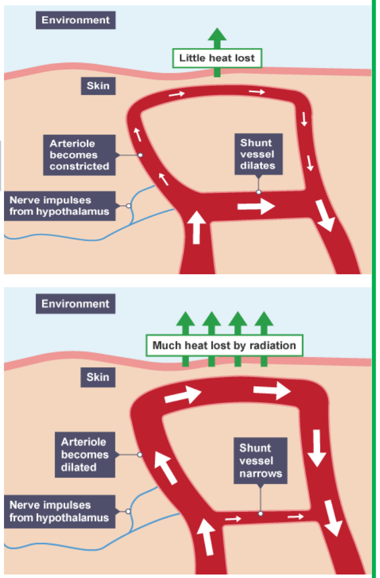
**Kidney Function:**
**Stage 1 - Filtration**
Blood is transported to the kidney through the renal artery. Blood passes through the nephron inside the kidneys, there are many capillaries inside the kidney, and the blood is under high pressure at the start of the nephron, which aids the **ultrafiltration** of the blood. Small molecules are filtered out and pass into the nephron tubule. These small molecules include **urea, water, ions, and glucose**. However, large molecules, such as blood proteins, are too big to fit through the capillary wall and remain in the blood.
**Stage 2 - Selective reabsorption**
Having filtered out small essential molecules from the blood - the kidneys must **reabsorb** the molecules which are needed, while allowing those molecules which are not needed to pass out in the urine. Therefore, the kidneys selectively reabsorb only those molecules which the body needs back in the bloodstream. The reabsorbed molecules include:
• all of the glucose which was originally filtered out
• as much water as the body needs to maintain a constant water level in the blood plasma
• as many ions as the body needs to maintain a constant balance of mineral ions in the blood plasma.
**Stage 3 - The formation of urine**
The molecules which are not selectively reabsorbed (the urea, excess water and ions) continue along the nephron tubule as **urine**. This eventually passes down to the bladder.



**Control of body temperature:**

Body temperature is monitored and controlled by the **thermoregulatory centre** in the brain. The thermoregulatory centre contains receptors sensitive to the temperature of the blood. The **skin** contains temperature receptors and sends nervous impulses to the thermoregulatory centre. If the body temperature is too high, blood vessels dilate (**vasodilation**) and sweat is produced from the sweat glands. Both these mechanisms cause a transfer of energy from the skin to the environment. If the body temperature is too low, blood vessels constrict (**vasoconstriction**), sweating stops and skeletal muscles contract (shiver).




*(Separate Biology Only)*

Ethene controls cell division and ripening of fruits.

Fruit is often picked unripe and then ripened during transport and storage by adding **ethene** and then taken to the shops. **Gibberellins,** which are a group of plant hormones responsible for growth and development, are important for initiating seed **germination**.

Low concentrations can be used to increase the speed of germination, and they stimulate cell **elongation** and cause plants to grow taller.

**Required Practical: Investigate the effect of light or gravity on the growth of newly germinated seedlings.**

Mustard or cress seeds are a good choice for this investigation because they grow fast and their roots and stems are clearly visible.

**Variables**

Independent variable: intensity, direction or colour of light, dark conditions.

Dependent variable: the mean height of seedlings.

Control variables: the number of seeds on each dish, how much they are spread out, the volume of water the seedlings are given, the temperature they are kept at.

**Method**

1. Put cotton wool into three petri dishes, and add the same volume of water to each dish.
2. Add ten seeds to each dish and place them in a warm place where they won't be disturbed.
3. Allow the seeds to germinate, and add more water if the cotton wool dries out.
4. Once the seeds have germinated, ensure the petri dishes each contain the same number of seeds, and remove any extra seeds if necessary.
5. One petri dish will sit in full light on a windowsill, the second will be in a dark cupboard, and the final dish will be placed in partial light.
6. Every day for one week, measure the height of each seedling and record the results in a table. You must record the height of the individual seedlings on each day.
7. Calculate the mean height of seedlings each day, and compare the mean heights in the three different locations.

**Plant Hormones**

Plants produce hormones to coordinate and control growth and responses to light (**phototropism**) and gravity (**gravitropism or geotropism**). Unequal distributions of **auxin hormone** cause unequal growth rates in plant roots and shoots.

There are two main types of tropisms:

- **positive tropisms** – the plant grows towards the stimulus, e.g. In the plant stem, the response to light means the stem grows towards the light.
- **negative tropisms** – the plant grows away from the stimulus. E.g. In the plant root, responses to light means the root grows away from the light.

**Auxins**

**Auxins** are a family of plant hormones. They are mostly made in the tips of the growing stems and roots, which are known as apical meristems, and can **diffuse** to other parts of the stems or roots.

Auxins control the growth of plants by promoting **cell division** and causing **elongation** in plant cells (the cells get longer).

Stems and roots respond differently to high concentrations of auxins:

- **In a stem**, the shaded side contains more auxin and **grows longer**, which causes the stem to grow towards the light. It is vital to note that the plant does **NOT** bend towards the light.
- **In a root**, the shaded side contains more auxin and **grows less** - causing the root to grow away from the light.

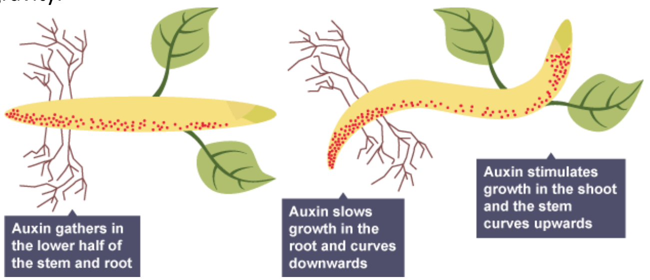
**Geotropism**

- When the stem grows against the force of gravity, this is known as a negative geotropism.
- When a root grows in the direction of the force of gravity, this is known as a positive geotropism.

Just like phototropism, geotropism is also caused by an unequal distribution of auxin.

In a **root placed horizontally**, the bottom side contains more auxin and **grows less** - causing the root to grow in the direction of the force of gravity.

The opposite happens in a stem. When a **stem is placed horizontally**, the bottom side contains more auxin and **grows more** - causing the stem to grow upwards against the force of gravity.



# Energy Changes

## Exothermic & Endothermic Reactions

**Exothermic reactions transfer energy to the surroundings** and the temperature of the surroundings **increases**. **Endothermic reactions take in energy** and the temperature of the surroundings **decreases**.

Examples of exothermic reactions include:
- **combustion** reactions
- many **oxidation** reactions
- most **neutralisation** reactions.

Everyday uses of exothermic reactions include self-heating cans and hand warmers.

Examples of endothermic reactions include:
- **thermal decomposition** reactions
- the reaction of citric acid and sodium hydrogen carbonate.

Everyday uses of endothermic reactions include instant ice packs which can be used to treat sports injuries.

## Bond Energy *[Higher tier]*

During a chemical reaction the difference between the energy needed to break bonds and the energy released when new bonds are made determines the type of reaction.
A reaction is **exothermic** if more heat energy is released in making bonds in the products than is taken in when breaking bonds in the reactants. It is **endothermic** if less heat energy is released in making bonds in the products than is taken in when breaking bonds in the reactants.

To calculate an energy change for a reaction:
- add together the bond energies for all the bonds in the **reactants** - this is the 'energy in'
- add together the bond energies for all the bonds in the **products** - this is the 'energy out'
- energy change = energy in - energy out.

| Bond | Bond energy |
|---|---|
| H–H | 436 kJ/mol |
| Cl–Cl | 243 kJ/mol |
| H–Cl | 432 kJ/mol |

**Example**

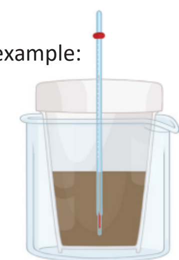
hydrogen + chlorine → hydrogen chloride:

H–H + Cl–Cl → 2 × (H–Cl)

Energy in = 436 + 243 = 679 kJ/mol
Energy out = (2 × 432) = 864 kJ/mol
Energy change = 679 - 864 = -185 kJ/mol
The energy change is **negative.** This shows that the reaction is **exothermic.**

## Required Practical: Temperature Change

**Aim:** To investigate the variables that affect temperature changes in reacting solutions.
**Context:** You could investigate one or more chemical reactions, for example:
- acids reacting with metals, metal carbonates or with alkalis
- displacement reactions of metals.



**Method:** Reacting two solutions, e.g. acid and alkali
1. Place the polystyrene cup inside the glass beaker for stability.
2. Measure an appropriate volume of each liquid, e.g. 25 $cm^3$.
3. Place one of the liquids in a polystyrene cup.
4. Record the temperature of the solution.
5. Add the second solution and record the highest or lowest temperature obtained.
6. Change your **independent variable** and repeat the experiment. Your independent variable could be the concentration of one of the reactants, or the type of acid/alkali being used, or the type of metal/metal carbonate being used.

**Analysis:** The bigger the temperature change in the reaction, the more energy is absorbed or released.
**Evaluation:** The biggest source of error in this experiment is unwanted heat transfer. Using a lid can help to reduce this.
**Hazards, risks and precautions**

| Hazard | Possible harm | Possible precaution |
|---|---|---|
| Dilute acids and alkalis | May irritate the skin or eyes | Avoid contact with skin, rinse off skin if necessary, wear eye protection |
| Solutions of metal salts (used in displacement reactions) | Dangerous to the environment | Dispose of metal salt solutions as advised by teacher. |

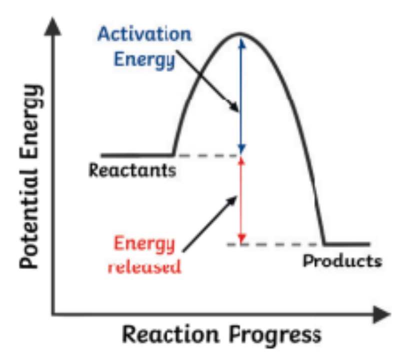
## Reaction Profiles

A reaction profile shows whether a reaction is **exothermic** or **endothermic**. It shows the energy in the **reactants** and **products**, and the difference in energy between them. It also includes the **activation energy**, which is the minimum energy needed by particles when they collide for a reaction to occur. The activation energy is shown as a 'hump' in the line, which:
- starts at the energy of the reactants
- is equal to the difference in energy between the top of the 'hump' and the reactant.

The overall change in energy in a reaction is the difference between the energy of the reactants and products.

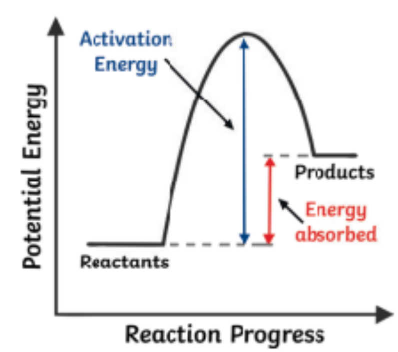
**Exothermic reaction**

The energy level decreases in an exothermic reaction. This is because energy is given out to the surroundings.




**Endothermic reaction**

The energy level increases in an endothermic reaction. This is because energy is taken in from the surroundings.



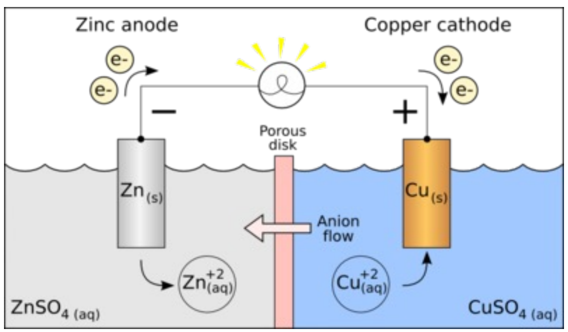
## Chemical Cells *(Separate Chemistry Only)*

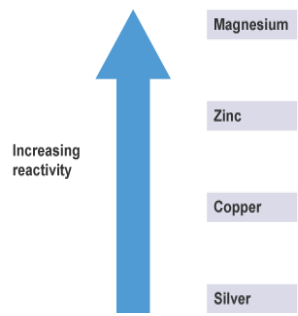
**Chemical cells** use chemical reactions to transfer energy by **electricity**. The **voltage** of a cell depends upon a number of factors, including what the **electrodes** are made from, and the substance used as the **electrolyte**.

A simple cell can be made by connecting two different metals in contact with an electrolyte. A number of cells can be connected in series to make a **battery**, which has a higher voltage than a single cell.

In non-rechargeable cells, e.g. alkaline cells, a **voltage** is produced until one of the **reactants** is used up. When this happens, we say the battery 'goes flat'.
In rechargeable cells and batteries, like the one used to power your mobile phone, the chemical reactions can be reversed when an **current** is supplied.

If we connect different combinations of these metals to make a cell, we find that the voltage changes.
Swapping the two electrodes means that the recorded voltage becomes negative. The biggest voltage occurs when the difference in the reactivity of the two metals is the largest. A cell made from magnesium and copper has a higher voltage than magnesium and zinc, for example.




## Evaluating Cells *(Separate Chemistry Only)*

**Fuel cells** have different strengths and weaknesses, depending on the intended use. For example, fuel cells are used in spacecraft and vehicles.

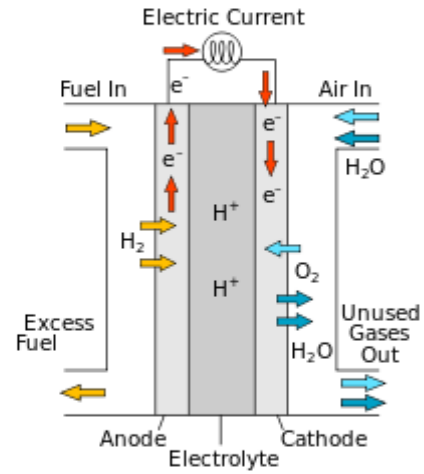
**Fuel cells in spacecraft**
Hydrogen-oxygen fuel cells are used in spacecraft. In addition to the strengths in the table to the right, the water they produce is useful as drinking water for astronauts.
Hydrogen-oxygen fuel cells must be supplied with hydrogen **fuel** and oxygen. This could be a problem once a spacecraft leaves the Earth. However, spacecraft in orbit, such as the **International Space Station**, have **solar cells**. These convert light into **electricity**, so the hydrogen and oxygen can be replaced by the **electrolysis** of water.
Solar cells only work when they are in the light, so the fuel cells allow electricity to be produced even when the spacecraft is in the dark.

## Fuel Cells *(Separate Chemistry Only)*

**Fuel cells** work in a different way than chemical cells. Fuel cells produce **voltage** continuously, as long as they are supplied with:
- a constant supply of a suitable **fuel**
- oxygen, e.g. from the air

The fuel is **oxidised** electrochemically, rather than being burned, so the reaction takes place at a lower temperature than if it was to be burned. Energy is released as electrical energy, not **thermal energy** (heat).

**Hydrogen-oxygen fuel cells**
Hydrogen-oxygen fuel cells are an alternative to rechargeable cells and batteries.
In a hydrogen-oxygen fuel cell, hydrogen and oxygen are used to produce a voltage.
Water is the only product.
The overall reaction in a hydrogen-oxygen fue cell is:
hydrogen + oxygen → water
$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$




**Electrode half equations**
At the negative electrode:
$2H_2 + 4OH^- \rightarrow 4H_2O + 4e^-$
At the positive electrode:
$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$
When you add these two half equations together, you get the following overall equation:

$$2H_2 + 4OH^- + O_2 + 2H_2O + 4e^- \rightarrow 4H_2O + 4e^- + 4OH^-$$

The hydroxide ions, electrons and two $H_2O$ molecules will now cancel because they are on both sides, leaving the overall equation:

$$2H_2 + O_2 \rightarrow 2H_2O$$

| Type of cell | Pros | Cons |
|---|---|---|
| Alkaline cell | Cheaper to manufacture | May end up in landfill sites once fully discharged; recyclable though it is expensive |
| Rechargeable cell | Can be recharged many times before being recycled, reducing the use of resources | Costs more to manufacture |
| Hydrogen fuel cell | Easy to maintain as there are no moving parts; small size; water is the only chemical product | Very expensive to manufacture; need a constant supply of hydrogen fuel, which is a flammable gas |

# Ecology Knowledge Map

| | |
|---|---|
| **Producer** | Producers are plants and algae, which photosynthesise to produce glucose. |
| **Primary consumer** | Primary consumers are herbivores, which eat producers. |
| **Secondary consumer** | Secondary consumers are carnivores, which eat primary consumers. |
| **Tertiary consumer** | Tertiary consumers are also carnivores. They eat secondary consumers. |
| **Population** | All the organisms of the same or closely-related **species** in an area. |
| **Community** | Two or more **populations** of organisms. |
| **Ecosystem** | The interaction of a community of living organisms (**biotic**) with the non-living (**abiotic**) parts of their environment. |
| **Interdependence** | Within a community each species depends on other species for food, shelter, pollination, seed dispersal etc. If one species is removed it can affect the whole community. |
| **Stable community** | One where all the species and environmental factors are in balance so that population sizes remain fairly constant. |
| **Adaptations** | Features of an organism that enable them to survive in their habitat They may be structural (e.g. camouflage), behavioural (e.g. migration) or functional (e.g. low metabolism for hibernation). |
| **Extremophile** | Some organisms live in environments that are very extreme, such as at high temperature, pressure, or salt concentration. Bacteria living in deep sea vents are extremophiles. |
| **Predator** | Consumers that kill and eat other animals. |
| **Prey** | Animals that are eaten by other animals. |
| **Carbon cycle** | Returns carbon from organisms to the atmosphere as carbon dioxide to be used by plants in photosynthesis. |
| **Water cycle** | Provides fresh water for plants and animals on land before draining into the seas. Water is continuously evaporated and precipitated. |
| **Biodiversity** | The variety of all the different species of organisms on Earth, or within an ecosystem. |
| **Deforestation** | Large-scale removal of trees in tropical areas has occurred to provide land for cattle and rice fields and grow crops for biofuels. |
| **Peat bog** | An area of wet muddy ground that is too soft to support a heavy body. It is a good store of carbon. |
| **Climate Change** | Levels of carbon dioxide and methane in the atmosphere are increasing, and contribute to ‘global warming’ and climate change. |
| **Fertilisers** | Chemicals sprayed on crop plants to help their growth. These chemicals cause water pollution when they flow into rivers. |

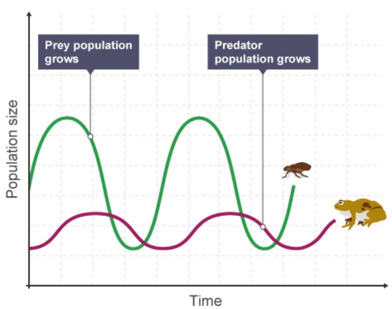
## Competition

To survive and reproduce, organisms require a supply of materials from their surroundings and from the other living organisms there. Plants in a community or habitat often compete with each other for light, space, and for water and mineral ions from the soil. Animals often compete with each other for food, mates and territory.

## Predator-Prey Cycles

The graph shows that there is almost always more prey than predators. It also shows the following patterns:

1. the number of predators increases because there is more prey
2. the number of prey reduces because there are more predators
3. the number of predators reduces because there is less prey.




## Biotic & Abiotic Factors

**Abiotic** (non-living) factors which can affect a community are:
- light intensity
- temperature
- moisture levels
- soil pH and mineral content
- wind intensity and direction
- carbon dioxide levels for plants
- oxygen levels for aquatic animals.

**Biotic** (living) factors which can affect a community are:
- availability of food
- new predators arriving
- new pathogens
- one species outcompeting another so the numbers are no longer sufficient to breed.

## Food Chains

Food chains are diagrams that show the direction of energy transfer in an ecosystem. The producer always starts the food chain, and the arrows point in the direction of energy transfer (so point towards the predator)

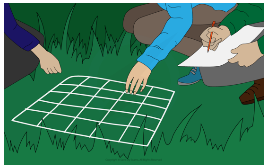
A simple food chain is:

grass → rabbit → fox

If the foxes in the food chain above were killed, the population of rabbits would increase because they are no longer prey to the foxes. As a result the amount of grass would decrease because the increased population of rabbits would be eating it.

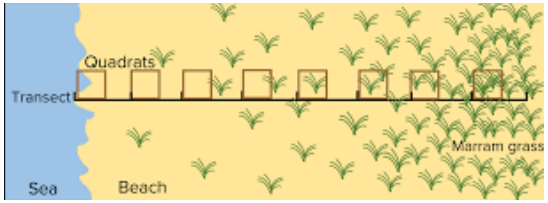
**Required Practical:** ***measure the population size of a common species in a habitat. Use sampling techniques to investigate the effect of a factor on the distribution of this species.***

It is almost always impossible to count all of the organisms in a population. So we look at a small section of a population to draw conclusions about the rest. This process is called **sampling** .



**Quadrats** are square frames of wire usually 0.25 $m^2$. These are placed on the ground to look at the plants or slow-moving animals within them.

A quadrat could be placed at regular distances, for example every five metres, along an imaginary line called a **transect**, which would run from one habitat to another. Systematic sampling would be used along the transect to link changes in **species** to abiotic factors, such as immersion by water, temperature fluctuations, and light intensity, all of which are influenced by the tide in this example.

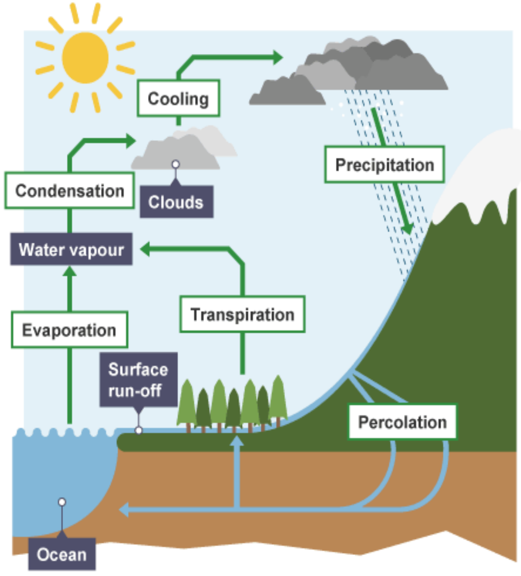


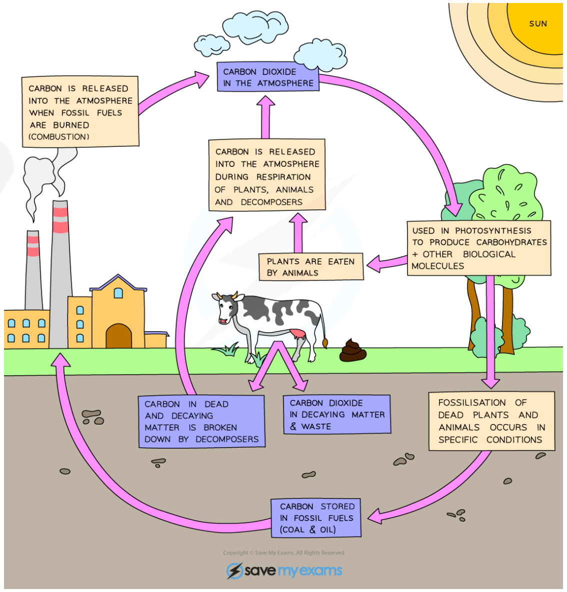

**Aim:** To measure the species richness on the school field in areas in which the grass is regularly and irregularly cut.

**Method:**

1. Choose a starting point on the school field in an area where the grass is often cut.
2. Use **random** numbers to generate a set of coordinates to place your first **quadrat.**
3. Count the number of different plant **species** within this quadrat.
4. Return to your starting position and repeat steps two and three a further 14 times using different random numbers.
5. Repeat steps one to four for a part of the school field which the grass is infrequently cut.
6. Compare your results by calculating a **mean** for each location.
7. To estimate the total population of plants:

$$\frac{\text{Total area}}{\text{Area sampled}} \times \text{number of plants counted}$$




| Process | What happens to water |
|---|---|
| **Evaporation** | Water turns from a liquid to a gas. Energy from the Sun can evaporate water. |
| **Condensation** | Water can cool and convert from gas to liquid, often forming clouds. |
| **Transport** | Water within clouds can be blown many miles by strong winds and so transported to other areas. |
| **Precipitation** | Precipitation occurs when rain, snow, hail and sleet fall from the sky. |
| **Surface runoff** | Some water can run along the surface of the ground. |
| **Infiltration** | Water is absorbed into the ground. This can then be stored within underground rocks called aquifers. |
| **Transpiration** | Plants allow some water to evaporate as water vapour from their leaves to mean that more is continually ‘pulled’ to their leaves from the soil. |

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

## Biodiversity

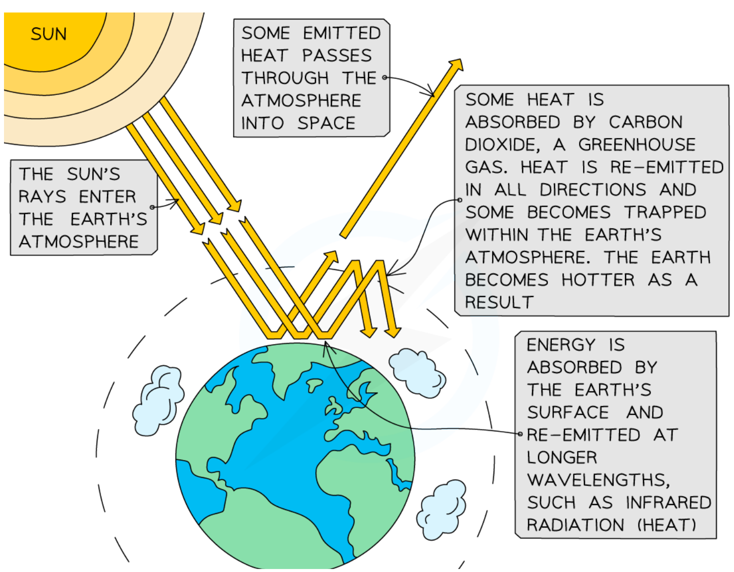
A great biodiversity ensures the stability of ecosystems by reducing the dependence of one species on another for food, shelter and the maintenance of the physical environment. The future of the human species on Earth relies on us maintaining a good level of biodiversity. Many human activities are reducing biodiversity and only recently have measures been taken to try to stop this reduction.

Scientists and concerned citizens have put in place programmes to reduce the negative effects of humans on ecosystems and biodiversity. These include:

- breeding programmes for endangered species
- protection and regeneration of rare habitats
- reintroduction of field margins and hedgerows in agricultural areas where farmers grow only one type of crop
- reduction of deforestation and carbon dioxide emissions by some governments
- recycling resources rather than dumping waste in landfill.

## Land Pollution

Humans reduce the amount of land available for other animals and plants by building, quarrying, farming and dumping waste (landfills). The destruction of peat bogs, and other areas of peat, to produce garden compost reduces the area of this habitat and thus the variety of different plant, animal and microorganism species that live there (biodiversity). The decay or burning of the peat releases carbon dioxide into the atmosphere.




## Air pollution

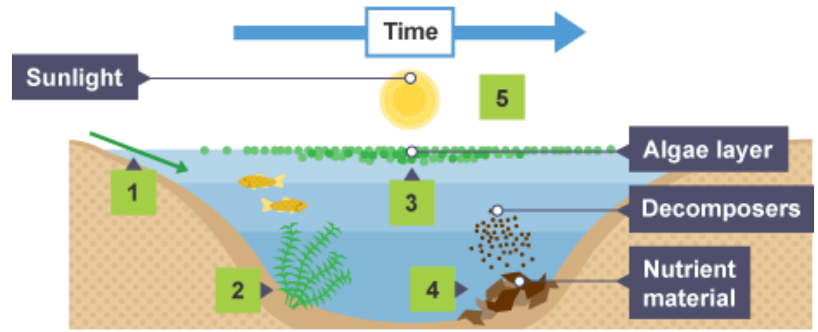
**Combustion** of fossil fuels and other fuels releases carbon dioxide. This contributes to the **greenhouse effect** and leads to **climate change**. It also releases sulphur dioxide and nitrogen oxides which can cause **acid rain**. Air pollution can also be caused by tiny particulates from smoke which can cause **smog**.

## Waste management

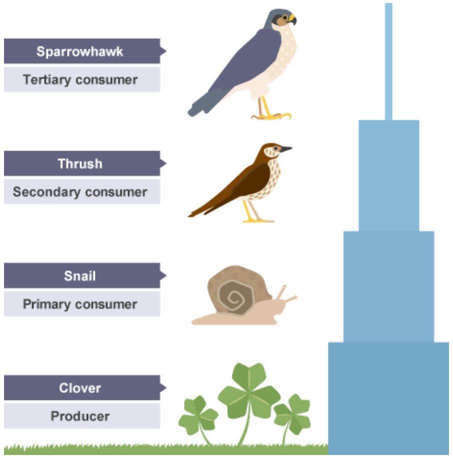
Rapid growth in the human population and an increase in the standard of living mean that increasingly more resources are used and more waste is produced. Unless waste and chemical materials are properly handled, more pollution will be caused.
Pollution kills plants and animals which can reduce biodiversity.

## Water pollution

In some parts of the world, open sewers can lead into water courses, such as streams and rivers, which can cause serious illness in humans that may drink the contaminated water.
Some farmers use too many **fertilisers**, which can run off fields during heavy rain. This can pollute nearby streams and rivers leading to **eutrophication** (shown in diagram below). Some water pollution even comes from **toxic** chemicals released illegally by factories.




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.**




# Separate Biology Only

| | |
|---|---|
| **Decomposer** | Microbes such as bacteria and fungi break down dead plant and animal matter by secreting enzymes into the environment. Small soluble food molecules then diffuse into the microorganism. |
| **Apex predator** | Carnivores with no predators. |
| **Trophic level** | The stages in a food chain. Trophic levels can be represented by numbers, starting at level 1 with plants and algae. |
| **Pyramids of biomass** | Represent the relative amount of biomass in each level of a food chain. Trophic level 1 is at the bottom of the pyramid. |
| **Biomass** | Dry mass of living or recently dead tissues |

## Decomposition

Decomposition, or decay, is the breakdown of dead matter by **decomposers**. The rate at which this happens depends upon the number of decomposing microorganisms and the following:
**Temperature:** At colder temperatures decomposing organisms will be less active, thus the rate of decomposition remains low. This is why we keep food in a fridge. As the temperature increases, decomposers become more active and the rate increases. At extremely high temperatures decomposers will be killed and decomposition will stop.
**Water:** With little or no water there is less decomposition because decomposers cannot survive. As the volume of available water increases, the rate of decomposition also increases.
**Oxygen:** Oxygen is needed for many decomposers to respire, to enable them to grow and multiply. This is why we often seal food in bags or cling film before putting it in the fridge. As the volume of available oxygen increases, the rate of decomposition also increases. Some decomposers can survive without oxygen.

Gardeners and farmers try to provide optimum conditions for rapid decay of waste biological material. The compost produced is used as a natural fertiliser for growing garden plants or crops. Anaerobic decay produces methane gas. Biogas generators can be used to produce methane gas as a fuel.

**Required practical activity 10: *investigate the effect of temperature on the rate of decay of fresh milk by measuring pH change.***
**Method**
1. Place 20 $cm^3$ of fresh milk into three beakers
2. Decide the three temperatures you will investigate. Write these onto the sides of the beakers. They may be 5, 20 and 35°C.
3. Use universal indicator paper or solution to determine the pH of the milk in the three beakers
4. Cover each beaker in cling film and incubate at the appropriate temperature
5. Use universal indicator paper or solution to determine the pH of the milk in the three beakers after 24, 48 and 72 hours.

## Pyramids of Biomass

Pyramids of biomass must be drawn with the:
1.bars equally spaced around the midpoint
2.bars touching
3.bar for the **producer** at the bottom
4.length of each bar is proportional to the amount of biomass available at each trophic level.

Producers are mostly plants and algae which transfer about 1% of the incident energy from light for photosynthesis.
Only about ten per cent of the biomass is transferred from each **trophic level** to the next. The remaining 90 per cent is used by the trophic level to complete **life processes**. Biomass can be lost between stages because not all of the matter eaten by an organism is digested. Some of it is excreted as waste such as solid **faeces**, carbon dioxide and water in **respiration** and water and **urea** in urine. Because only around 10% of the biomass at each trophic level is passed to the next, the total amount becomes very small after only a few levels. So food chains are rarely longer than six trophic levels.

The efficiency of **biomass** transfer is a measure of the proportion of biomass transferred from a lower **trophic level** to a higher one.

To complete this calculation, we divide the amount from the higher trophic level by the amount from the lower trophic level and multiply by one hundred. That is, we divide the smaller number by the bigger one (and multiply by one hundred).

$$\text{Percentage efficiency transfer} = \frac{\text{biomass in higher trophic level}}{\text{biomass in lower trophic level}} \times 100$$

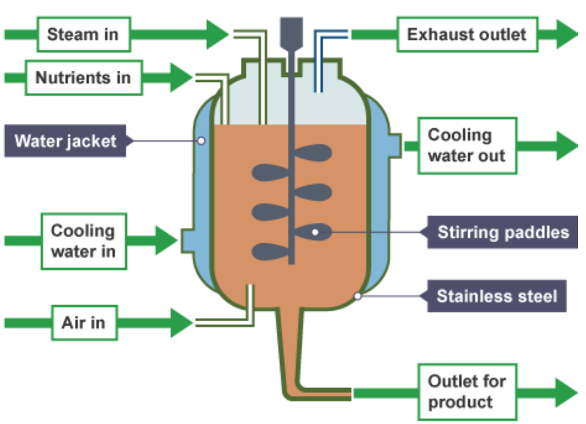
## Separate Biology Only

**Role of biotechnology: Biotechnology** is the alteration of living organisms to develop or make products that help us.

**Genetic modification:** A genetically modified bacterium produces human insulin. When harvested and purified this is used to treat people with diabetes. Golden rice is a variety of rice that has been genetically modified to contain **beta-carotene** which helps people who do not get enough vitamin A in their diet. Other crops have been genetically modified to be resistant to insects or to pesticides. This means that farmers can spray whole fields with **pesticides** and kill the pests, not the crops.

Modern biotechnology techniques enable large quantities of microorganisms to be cultured for food. The fungus *Fusarium* is useful for producing mycoprotein, a protein-rich food suitable for vegetarians. The fungus is grown in large containers called **fermenters**. The conditions inside are maintained to promote maximum growth:

1. the pH and temperature are maintained at the **optimum**
2. the temperature is controlled by a water jacket that surrounds the whole fermenter
3. sterile oxygen is added to make sure that aerobic **respiration** occurs
4. a food source like **glucose syrup** is added
5. the mixture inside is stirred to make sure all the oxygen and nutrients are equally distributed
6. the biomass is harvested and purified.




**Distribution of species can be affected by:**

• temperature: As you climb up a mountain the temperature reduces. This reduction, together with other **abiotic** and **biotic** factors, determines what **species** of plant are found at different elevations.
• availability of water: All life on Earth needs water. Too much and some species will drown or rot. Too little and all species die.
• composition of atmospheric gases: Gases dissolve in liquids, thus oxygen in the air dissolves in water. It is this dissolved oxygen, together with that produced by plants and algae, that support aquatic life. When levels of pollution increase the levels of dissolved oxygen reduce.

These changes may be seasonal, geographic or caused by human interaction.

**Sustainable fisheries**

Fish stocks in the oceans are declining. It is important to maintain fish stocks at a level where breeding continues or certain species may disappear altogether in some areas.

**Sustainable** fisheries do not reduce the overall number of fish, because the number of fish that are caught and killed does not ever exceed the birth of new fish.

Many countries have introduced fishing quotas which limit the amount of fish that can be caught and killed from specific species. The size of the gaps in fishing nets has also been increased to ensure that juvenile fish can reach reproductive maturity and have offspring before being killed.

**Farming techniques**

The efficiency of food production can be improved by restricting energy transfer from food animals to the environment. This can be done by limiting their movement and by controlling the temperature of their surroundings. Some animals are fed high protein foods to increase growth.

| Advantage | Disadvantage |
|---|---|
| Higher yields | Costly additives needed |
| More efficient use of food | Risk of antibiotic resistance |
| Quality control easier | Considered unethical by some people |

**Factors affecting food security**

Food security is a measure of the availability of food required to support a population. It is a measure of how much food there is, if it is of suitable quality and whether people can access it.

Biological factors which are threatening food security include:
• the increasing birth rate has threatened food security in some countries
• changing diets in developed countries means scarce food resources are transported around the world
• new pests and pathogens that affect farming
• environmental changes that affect food production, such as widespread famine occurring in some countries if rains fail
• the cost of agricultural inputs
• conflicts that have arisen in some parts of the world which affect the availability of water or food.

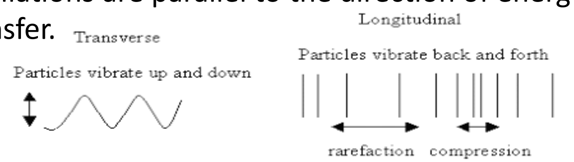
Sustainable methods must be found to feed all people on Earth.

# Waves

## 1 How can you describe a wave?

All waves transfer energy from one place to another. The particles that make up a wave oscillate about a fixed point, passing the energy onto the next particles. Energy moves along but the matter remains around the fixed point. In a transverse wave, e.g. water wave, the oscillations are perpendicular to the direction of energy transfer.

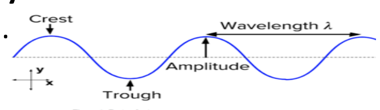
In a **longitudinal** wave, e.g. sound wave, the oscillations are parallel to the direction of energy transfer.




## 2 The wave equation

The **amplitude** - the maximum displacement any particle achieves from its undisturbed position (in metres)

The **wavelength** of a wave is the distance from two equivalent points on the wave. The **frequency** of a wave is the number of waves passing a point per second.




The **period** of a wave is how long it takes for one complete oscillation (in seconds)

$$Period\ [T] = \frac{1}{f}$$

(s) (Hz)

The **wave speed** is the speed at which the energy is transferred (or the wave moves) through the medium.

All waves obey the wave equation:

$$wave\ speed = frequency \times wavelength$$

(m/s) (Hz) (m)

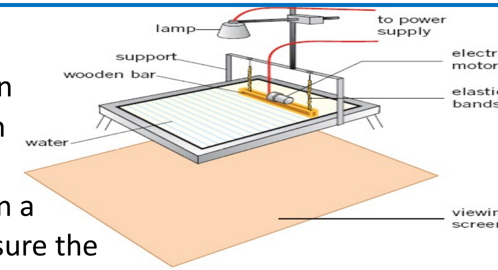
$$v = f\lambda$$

The speed of sound is measured with an oscilloscope.

## 3 Measuring a wave

**Required practical 1**. Measuring the speed of waves in a fluid. Using a ripple tank to measure the wavelength and frequency, so calculate the wave speed.

**Required practical 2**. Measuring the speed of waves in a solid. Using a vibration generator and a string to measure the wavelength and frequency, so calculate the wave speed.

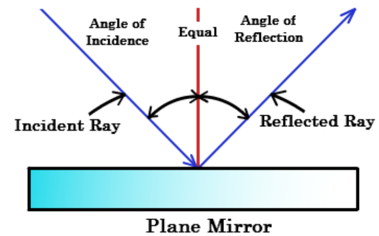


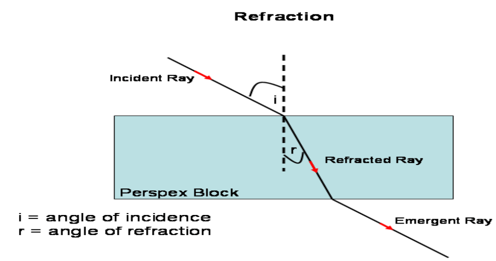

## 4 Properties of waves

Waves travel out from a point in all directions. A ray diagram shows a number of rays travelling in a straight line between the wave source and an object or surface. When a wave meets the boundary between two materials, some of its energy is reflected, some is absorbed, and some is transmitted.

When a wave is **reflected** off a surface, the angle of incidence is equal to the angle of reflection.

When a wave enters a glass block it is **refracted**. The light slows down and bends towards the normal line.



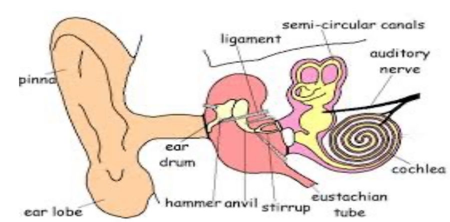

## 5. Sound waves *(separate Physics only)*

Sound waves are **longitudinal** waves which can travel through solids, liquids and gases. Sound in a medium is due to vibration of the particles that make up the medium.

Sounds waves have frequencies, amplitude and wavelength.

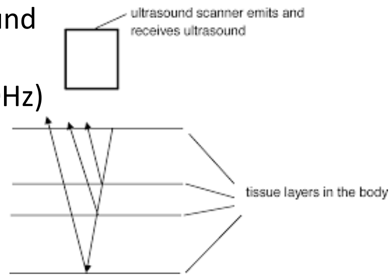
The amplitude of sound is linked to its loudness. The frequency and wavelength of a sound are linked with pitch.

The normal range of human hearing is **20Hz to 20kHz**. Within the ear sound waves cause the ear drum and other structures to vibrate.



## 6 Uses of waves *(separate Physics only)*

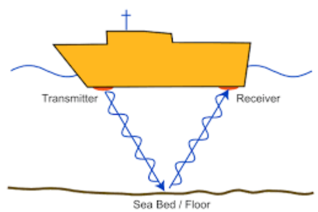
**Ultrasound** waves are sound waves of a very high frequency – above 20,000Hz)

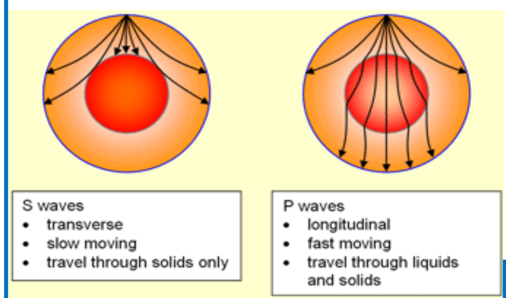



**Ultrasound** waves are used in *pre-natal scanning*, detection of kidney stones, tumours, and producing images of damaged ligaments and muscles.

Ultrasonic waves are partially reflected when they meet a boundary between different materials. The distance of a boundary is calculated by measuring the time taken for the wave to return to the detector and knowing the speed of sound in the medium.

**Echo sounding**, or sonar, uses ultrasonic waves to detect objects in deep water and measuring the depth of water. The time taken between a pulse being sent and the reflection being detected is used to calculate the distance travelled by the sound wave. They use high frequency sound waves.

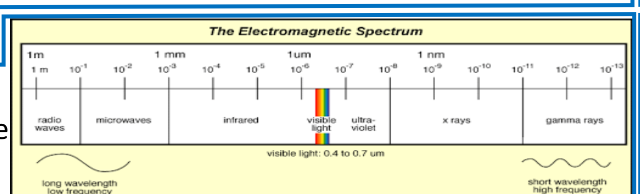



**Seismic waves** are produced by earthquakes and measured with a SEISMOMETER. P-waves are longitudinal waves and travel through solids and liquids but travel twice as fast as S-waves. S-waves are transverse waves and don't travel through liquids. P-waves and S-waves provide evidence for the structure and size of the Earth's core.

## 7. Electromagnetic spectrum

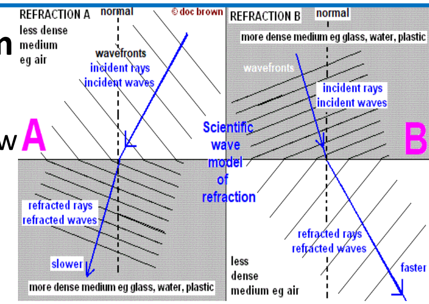
Electromagnetic waves (EM waves) are transverse waves that transfer energy from the source of the waves to an absorber. They all travel with the speed of light in air or a vacuum. They form a continuous spectrum of wavelengths and are grouped in order of their wavelength and their frequency.




Going from long to short wavelength (or from low to high frequency) the groups are: - radio, microwave, infra-red, visible light (red to violet), ultra-violet, X-rays and gamma-rays.

## 8 Properties of EM spectrum

Different wavelengths of electromagnetic waves affect how the wave is reflected, refracted, absorbed or transmitted by different substances *[HT only]*




Wave fronts makes it easier to visualise loads of waves moving together. If we show movement of light from air into glass, when the first wave fronts start to move into glass, they slow down; they move closer together and the wavelength decreases. So, the speed slows down because the frequency stays the same.

The amount of infrared radiation absorbed or radiated by a surface depends on the nature of that surface, e.g. colour.

## 9 EM and electrical circuits

Radio waves can be caused by oscillations in electrical circuits. A transmitter will emit radio waves if a.c. is used. (HT only.)

When radio waves are absorbed by a conductor they create an alternating current with the same frequency as the radio wave itself, this is how the signal is received by an aerial. When the oscillation is induced in an electrical circuit it creates an electrical signal that matches the wave. (HT only.)


## 10 Hazards of EM waves

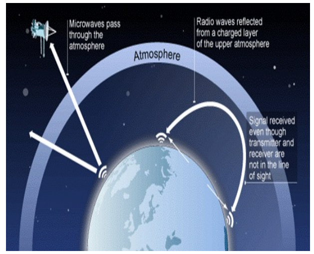
If an unstable nucleus of an atom changes, it can give out excess energy as gamma rays.

The effect on our body depends on the type of radiation and the size of the dose. Radiation dose (in Sieverts, Sv) is a measure of the damage caused by the radiation in the body.

UV waves can cause skin to age prematurely and increase the risk of skin cancer.

X-rays and gamma rays are ionising radiation that can cause mutation of genes and cancer.

## 11 Uses of EM spectrum

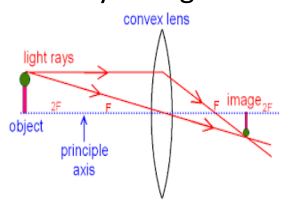


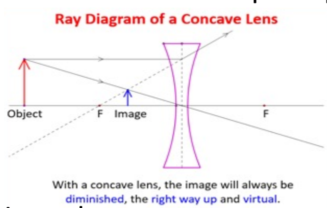

Microwaves can be transmitted by satellites because they can penetrate the ionosphere. Radio waves have lower frequency and are reflected by the ionosphere.

Radio waves – television and radio.
Microwaves – mobile phones, cooking food.
Infrared – electrical heaters, cooking food, IR cameras.
Visible light – fibre optic communications, photography.
Ultraviolet – energy efficient lamps, sun tanning.
X-rays – medical imaging and treatments.
Gamma rays – sterilisation, medical imaging.

## 12 Ray diagrams for lenses *(separate Physics only)*

A lens forms an image by refracting light. In a **convex** lens, parallel rays of light are brought to a focus at the principal focus.



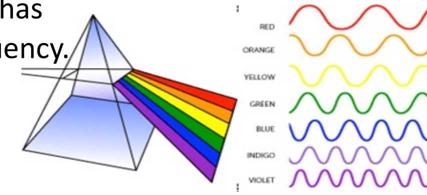




A **virtual** image cannot be projected onto a screen.
The image produced by a convex lens can be either real or virtual. The image produced by a **concave** lens is always virtual. The magnification of a lens can be calculated using the equation:

$$magnification = \frac{image\ height}{object\ height}$$

## 13. Visible light and coloured light *(separate Physics only)*

Each colour within the **visible light** spectrum has its own narrow band of wavelength and frequency.



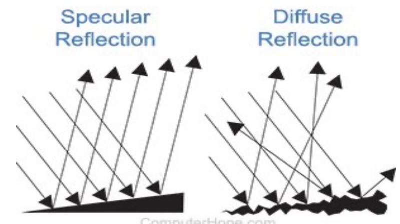

The colour of an object is related to the reflection, absorption and transmission of different wavelengths of light by the object.

Wavelengths not reflected are **absorbed**. If all wavelengths are reflected equally the object appears white.

If all wavelengths are absorbed the objects appears black. Objects that transmit light are either transparent or translucent.

Reflection from a smooth surface in a single direction is called **specular reflection.**

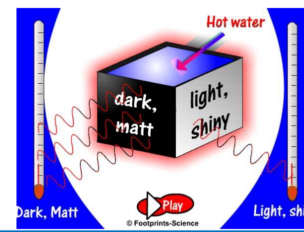
Reflection from a rough surface causes scattering this is called **diffuse reflection**.




The colour of an opaque object is determined by which wavelengths of light are more strongly **reflected**.

## 14. Infra Red radiation

All objects, regardless of temperature, emit and absorb IR radiation. The rate at which an object emits radiation depends on the nature of the surface and on its temperature - the hotter an object is the faster it emits IR radiation.

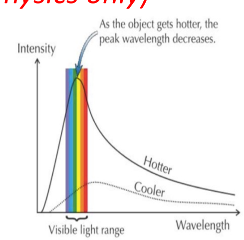



## 15. Black bodies *(separate Physics only)*

A perfect black body is an object that **absorbs all** of the radiation incident on it and it does not reflect or transmit any. Since a good absorber is also a good emitter a perfect black body would be the best possible emitter.

## 16. Thermal equilibrium *(separate Physics only)*

The temperature of a body determines the rate at which it emits radiation and the wavelength of radiation it emits.
As temperature increases the amount of radiation an object emits increases, but the intensity of shorter wavelengths increases faster.
As an object is heated it first glows red hot. As it gets hotter, it emits even shorter wavelengths and it glows white as it emits all visible spectra.




An object at constant temperature is absorbing radiation at the same rate as it is emitting radiation. The temperature of an object increases when the object absorbs radiation faster than it emits radiation.

The temperature of the Earth depends on many factors including; how much energy it receives from the Sun, how much energy is reflected back into space and how much energy is emitted into space. The Earth's atmosphere also affects how much of the radiation emitted from the surface escapes into space.

# Forces (and interactions)

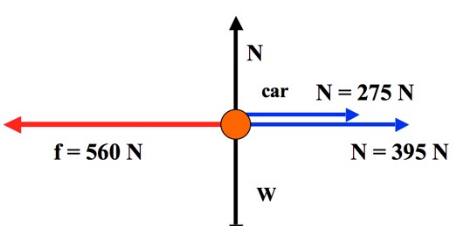
## 1. Describing forces

**Scalar** quantities have size only; **vector** quantities have size and direction.

| Scalar | Vector |
|---|---|
| time | force |
| distance | displacement |
| speed | velocity |

**Contact** forces are where the 2 objects are physically touching; **non-contact** forces occur where the objects are physically separated. Gravity, magnetic and electrostatic attraction are the only non-contact forces.

As force is vector it is represented by an arrow with size and direction.
A **free body diagram** simplifies an object to single shape (circle or rectangle) so that the force arrows are more obvious.

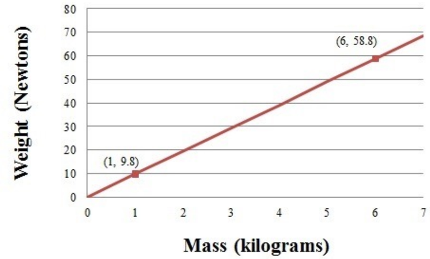



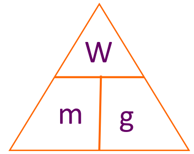

## 3. Gravity

Gravitational force is a weak force.

**Weight** is the force acting on an object due to gravitational field strength. Weight and mass are directly proportional (α) and will produce a straight-line graph through the origin.

This symbol means directly proportional. $\propto$

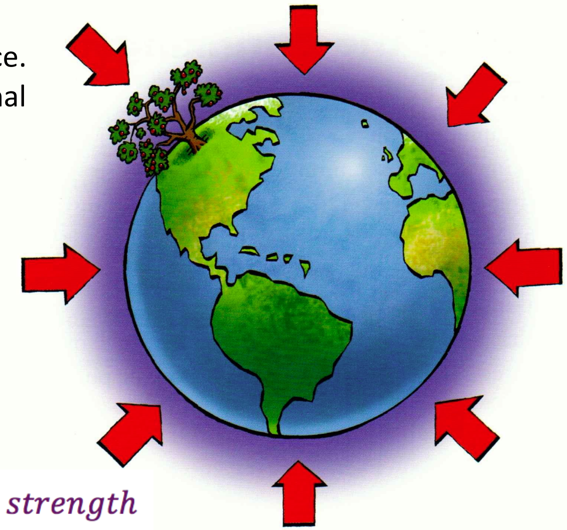



Learn

$$weight = mass \times gravitational\ field\ strength$$

(N) (kg) (9.8 N/kg)



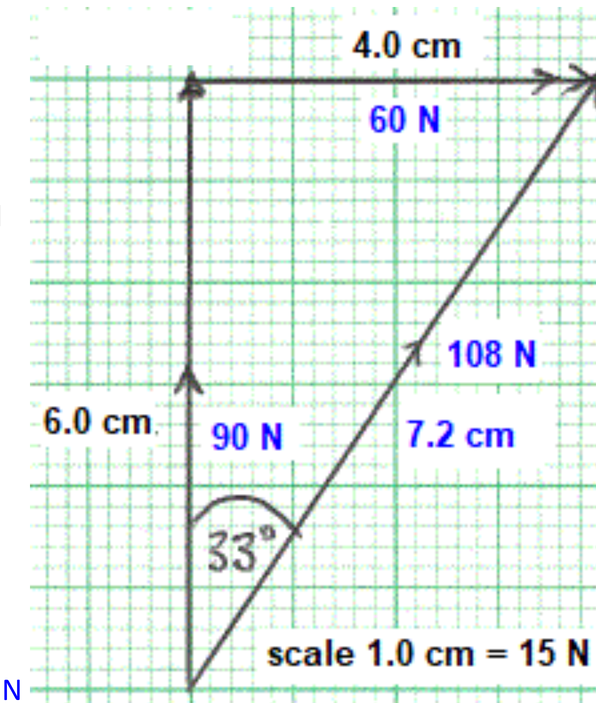
## 2. Resultant force

A **resultant force** is a single force that has the same effect as a system of forces on an object

Forces can be resolved into two perpendicular components or combined into a single resultant force.
In the graph paper example the vertical and horizontal forces were given. The answer needed to have both a size and a direction, e.g. 108N 33° clockwise from the vertical.

**Vector diagrams** use scale drawings to illustrate how forces resolve and determine the resultant force. If the resultant force is zero the object will be in equilibrium , having balanced forces.

The resultant force of two forces acting in a straight line will either be the sum (arrows in the same direction) or the difference (arrows in opposite directions) of the two forces.
For example the forward force of the car is 275 + 395 = 670 N



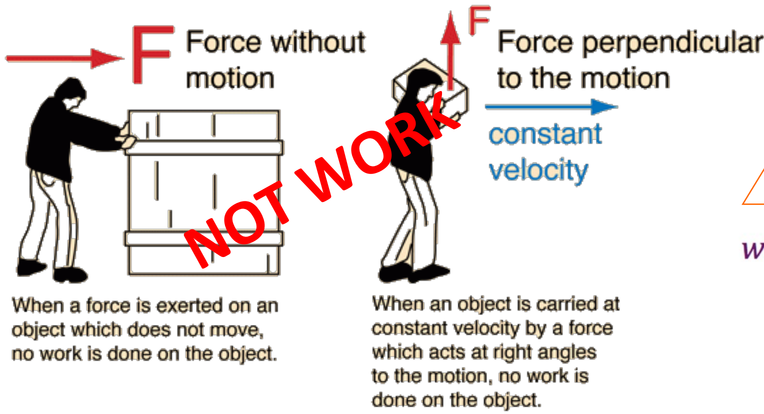
# Forces (and energy)

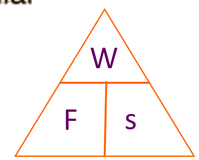
## 4. Work

**Work** is done when a force causes an object to move in the direction of the force.

Energy is transferred when work is done.

One joule of work is done when a force of one newton moves and object a distance of one metre, therefore, 1 joule = 1 newton metre (1 J = 1 Nm)



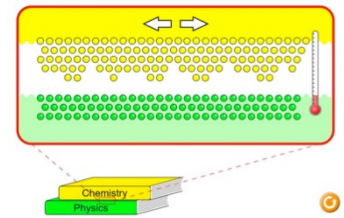




$$work\ done = force \times distance$$

(J) (N) (m)

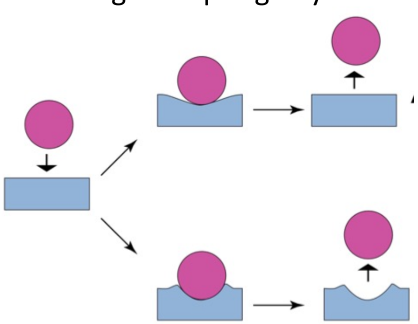
Learn

Work done against **friction** causes an increase in the object's thermal store and the thermal store of the surroundings. This increases the kinetic energy of the particles in the object/surroundings and therefore increases the temperature. **Temperature** is a measure of the average kinetic energy per particle




## 5. Deformation

**Elastic deformation** causes a temporary change of shape; the object will return to its original shape when the force is removed. An example is the stretching of a spring beyond its **elastic limit**.



Elastic

Inelastic

**Inelastic** (or plastic) **deformation** causes an object to permanently change shape.

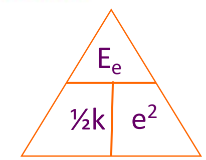
To change the shape of an object **more than one** force needs to be applied.

## 6. Hooke's Law

On sheet

$$elastic\ potential\ energy = \frac{1}{2} \times spring\ constant \times extension^2$$

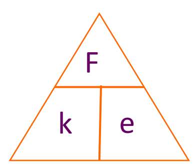
(J) (N/m) (m)




Work is done when a force stretches a spring and all the energy is transferred to the elastic potential store of the spring as long as the elastic limit is not reached.

$$force = spring\ constant \times extension$$

(N) (N/m) (m)



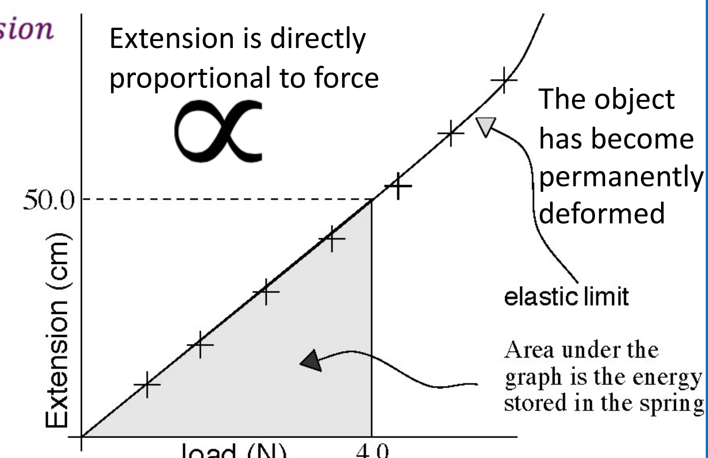

Learn

This also applies in compression, where **e** becomes the amount the spring has been compressed by

Hooke's Law is a **required practical**

Extension is directly proportional to force

$\propto$

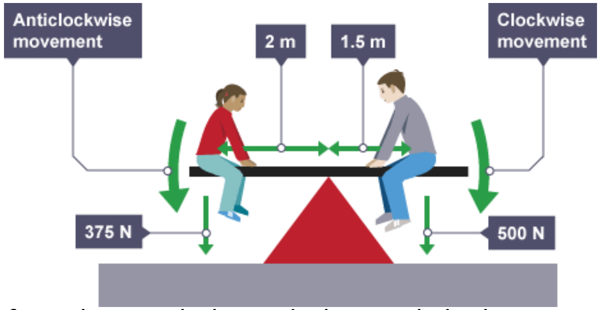


# Forces (and pressure)

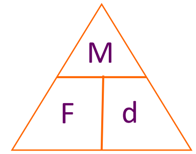
(Separate Physics only)

## 7. Moments

A **moment** is the turning effect of a force.




If an object is balanced, the total clockwise moments must equal the total anticlockwise moments.

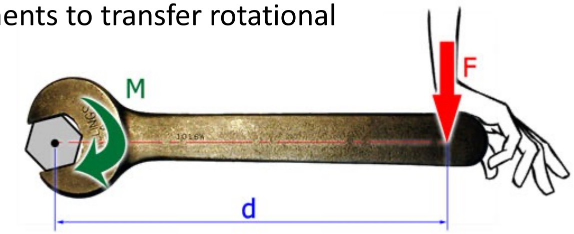



$$moment = force \times distance$$

(Nm) (N) (m)

Learn

Gears and levers are examples of the use of moments to transfer rotational forces.

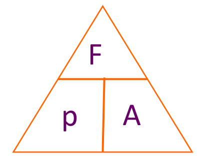



The distance is measured as the perpendicular distance between the force arrow and the pivot.

## 8. Pressure

A **fluid** is a liquid or a gas

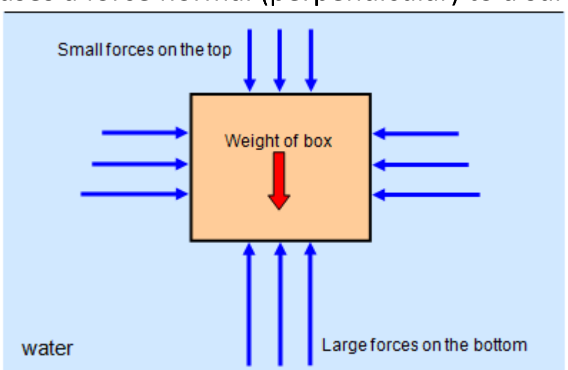
Pressure is caused when the particles in the fluid collide with the surface of the container. Pressure in fluids causes a force normal (perpendicular) to a surface.




Learn

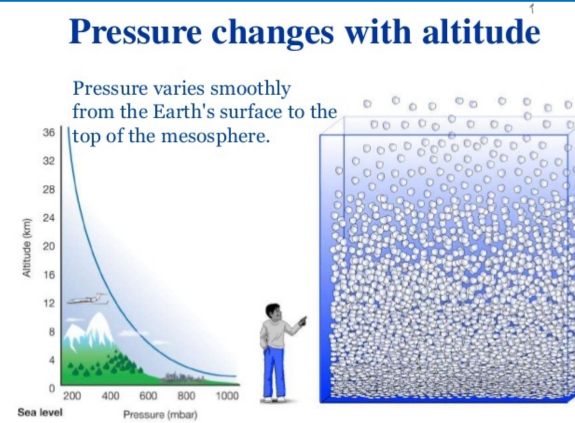
$$pressure = \frac{force}{area}$$

(N/m$^2$) or (Pa) force (N), area (m$^2$)



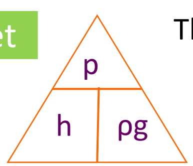

A submerged object experiences a greater pressure on the bottom surface than the top, creating a resultant force upwards. This is called **upthrust**.

An object will float because the force of gravity acting on the mass (weight) is equal to the upthrust, i.e. balanced forces.




As you get further from the surface of the Earth the density of the air in the atmosphere gets less. This is due to less air in the column above you having less weight (fewer particles) to compress the particles together.

On sheet




The pressure due to a column of liquid can be calculated using:

$$pressure = height\ of\ column \times density\ of\ liquid \times gravitational\ field\ strength$$

(Pa) or (N/m$^2$) (m) (kg/m$^3$) (9.8 N/kg)

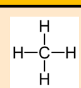
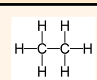
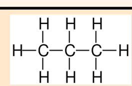
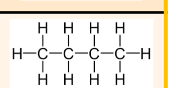
# Organic Chemistry

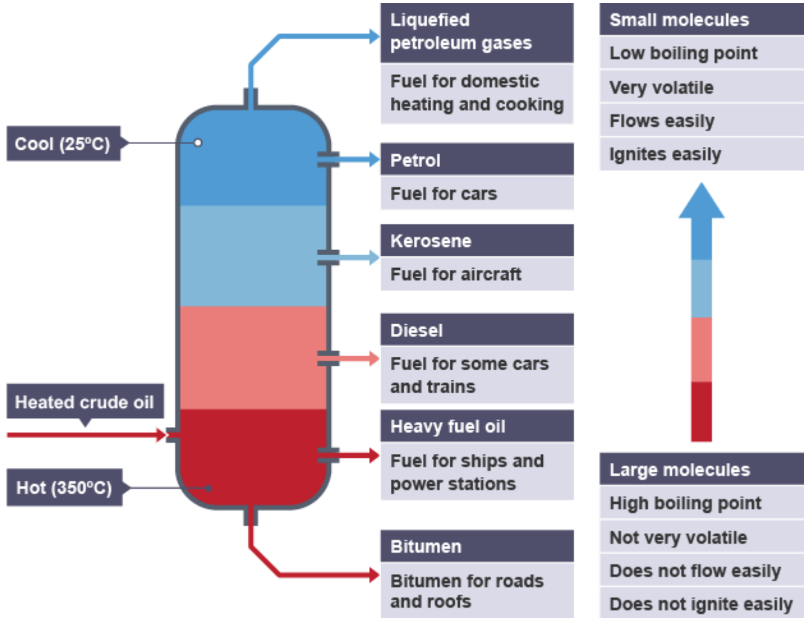
## 1. Hydrocarbons

Crude oil is a **finite** resource found in rocks. Crude oil is the remains of an ancient biomass consisting mainly of **plankton** that was buried in mud. Crude oil is a mixture of a very large number of compounds. Most of the compounds in crude oil are **hydrocarbons**, which are molecules made up of hydrogen and carbon atoms only.

Most of the hydrocarbons in crude oil are hydrocarbons called **alkanes**. Alkanes are hydrocarbons that contain **no double bonds** between the carbon atoms. We say they are **saturated.**

An **homologous series** is a family of molecules that all have the same **general formula** and have chemical properties that are similar.
The general formula for the homologous series of alkanes is **$C_nH_{2n+2}$.** Each alkane differs from the one before as it has an extra $CH_2$ added to it. The lines in the structural formula diagrams represent **covalent bonds.**

| Alkane | Molecular formula | Structural formula |
|---|---|---|
| Methane | $CH_4$ |  |
| Ethane | $C_2H_6$ |  |
| Propane | $C_3H_8$ |  |
| Butane | $C_4H_{10}$ |  |




## 4 Cracking of Hydrocarbons

Hydrocarbons can be broken down (**cracked**) to produce smaller, more useful molecules. Cracking can be done in two ways:

- **Catalytic cracking** needs a temperature of 550°C and a **catalyst** of aluminium oxide.
- **Steam cracking** uses a higher temperature of over 800°C and no catalyst

The products of cracking include alkanes and another type of hydrocarbon called **alkenes**. Alkenes are **unsaturated** and are more reactive than alkanes. They react with orange **bromine water** to turn it colourless. This is the test for alkenes.
For example, hexane can be cracked to form butane and ethene:

$$\text{hexane} \rightarrow \text{butane} + \text{ethene}$$

$$C_6H_{14} \rightarrow C_4H_{10} + C_2H_4$$

Cracking is important for two main reasons:
1.It helps to match the supply of small fractions with the demand for them as fuels.
2. Alkenes are used to produce polymers and as starting materials for the production of many other chemicals.

## 2. Fractional Distillation

Fractional distillation separates the **fractions** (parts of the mixture) of crude oil based on their chain lengths. The fractions can be processed to produce **fuels** and **feedstock** (raw materials for an industrial process) for the petrochemical industry.

During the fractional distillation of crude oil:
• Crude oil is heated until it vaporises and then enters a tall **fractionating column**, which is hot at the bottom and gets cooler towards the top
• **Vapours** from the oil rise through the column
• Vapours **condense** when they become cool enough
• Liquids are led out of the column at different heights.

Small hydrocarbon molecules have weak **intermolecular forces**, so they have low boiling points. They do not condense, but leave the column as gases. Long hydrocarbon molecules have stronger intermolecular forces, so they have high boiling points. They leave the column as hot liquid bitumen.

## 3 Properties of Hydrocarbons

The boiling point, viscosity and flammability of hydrocarbons depends on their chain length, as shown in the diagram above. These properties influence how hydrocarbons are used as fuels.
The combustion of hydrocarbon fuels releases energy. During combustion, the carbon and hydrogen in the fuels are oxidised.

**hydrocarbon + oxygen → carbon dioxide + water**

For example, the complete combustion of propane:

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$$

# Organic Chemistry

## 5. Alkenes

Alkenes are hydrocarbons with a double carbon-carbon bond, C=C , this is the their **functional group**. A functional group is the atoms that determine the reactions of organic compounds. The general formula for the homologous series of alkenes is $\mathbf{C_nH_{2n}}$ Alkene molecules are unsaturated because they contain two fewer hydrogen atoms than the alkane with the same number of carbon atoms.

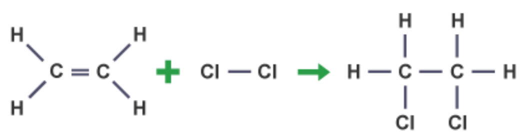
Alkenes react with **oxygen** in combustion reactions in the same way as other hydrocarbons, but they tend to burn in air with smoky flames because of **incomplete combustion.**

The functional group, C=C, allows alkenes to undergo **addition reactions** with halogens, hydrogen or water.

**alkene + halogen → halogenoalkane**

Chlorine, bromine or iodine can be added to an alkene. These reactions are usually spontaneous e.g.

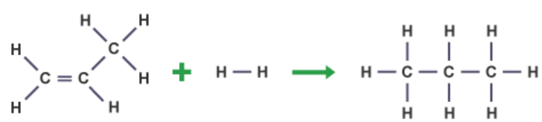
ethene + chlorine → dichloroethane




**alkene + hydrogen → alkane**

This is called **hydrogenation**, and it needs a **catalyst** e.g.

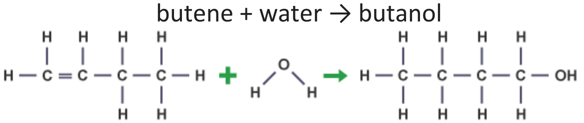
propene + hydrogen → propane

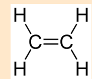
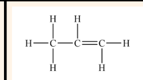
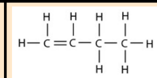
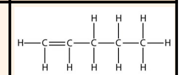


**alkene + water (steam) → alcohol**

This is called **hydration**. It needs a temperature of approximately 300°C and a catalyst. e.g.

butene + water → butanol



| Alkene | Molecular formula | Structural formula |
|---|---|---|
| Ethene | $C_2H_4$ |  |
| Propene | $C_3H_6$ |  |
| Butene | $C_4H_8$ |  |
| Pentene | $C_5H_{10}$ |  |

**Alcohols continued…**

**Solubility in water**

When the alcohols with the shortest hydrocarbon chains are added to water, they mix easily to produce a solution. However, the solubility decreases as the length of the alcohol molecule gets longer, so butanol is less soluble than propanol. It may not mix easily, and two distinct layers might be left in the container.

**Oxidation of alcohols**

Alcohols can be oxidised without **combustion** to produce **carboxylic acids**. E.g. ethanol can be oxidised to ethanoic acid using an **oxidising agent**.

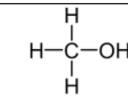
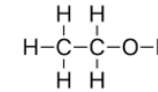
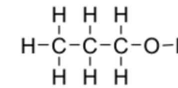
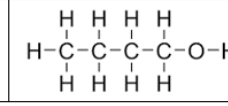
ethanol + oxidising agent → ethanoic acid + water

$CH_3CH_2OH + 2[O] \rightarrow CH_3COOH + H_2O$

Each of the two oxygen atoms provided by the oxidising agent are shown as [O]. Notice that the left-hand side of the ethanol molecule is unchanged. The reaction involves the -OH group on the right-hand side.

## 6. Alcohols

Alcohols contain the functional group –OH.

| Name | Formula | Structural formula |
|---|---|---|
| Methanol | $CH_3OH$ |  |
| Ethanol | $CH_3CH_2OH$ ($C_2H_5OH$) |  |
| Propanol | $CH_3CH_2CH_2OH$ ($C_3H_7OH$) |  |
| Butanol | $CH_3CH_2CH_2CH_2OH$ ($C_4H_9OH$) |  |

Ethanol can be produced by **fermentation** which is an **anaerobic** process in **yeast**:

glucose → ethanol + carbon dioxide

The typical conditions needed for fermentation include:

- sugars **dissolved** in water, and mixed with yeast
- an air lock to allow carbon dioxide out, while stopping air getting in
- warm **temperature**, 25-35°C

**Uses of alcohols:**

Methanol is used as a chemical **feedstock**. It's **toxic**, so it's added to industrial ethanol (methylated spirits) to prevent people from drinking it. Ethanol is the alcohol present in alcoholic drinks. It is also used as a **fuel** and a **solvent**. Propanol and butanol are also used as solvents and fuels.

**Combustion**

ethanol + oxygen → carbon dioxide + water

$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$

When less oxygen is present, **incomplete combustion** will occur, producing $H_2O$ and either $CO_2$ or CO.

**Reactions with sodium**

sodium + ethanol → sodium ethoxide + hydrogen

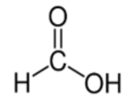
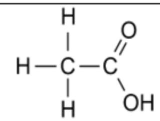
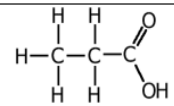
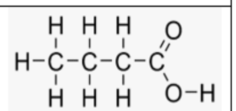
$2Na + 2C_2H_5OH \rightarrow 2C_2H_5ONa + H_2$

Methanol, propanol and butanol undergo similar reactions.

# Organic Chemistry *(separate Chemistry only)*

## 7. Carboxylic Acids

Carboxylic acids have the functional group –COOH.

| Carboxylic acid | Formula | Structural formula |
|---|---|---|
| Methanoic acid | HCOOH |  |
| Ethanoic acid | $CH_3COOH$ |  |
| Propanoic acid | $CH_3CH_2COOH$ ($C_2H_5COOH$) |  |
| Butanoic acid | $CH_3CH_2CH_2COOH$ ($C_3H_7COOH$) |  |

The carboxylic acids have the **typical properties of acids** due to the –COOH functional group. For example, they:

- **dissolve** in water to form **acidic solutions** with **pH** values less than 7
- react with **metals** to form a **salt** and hydrogen
- react with **bases** to form a salt and water
- react with **carbonates** to form a salt, water and carbon dioxide.

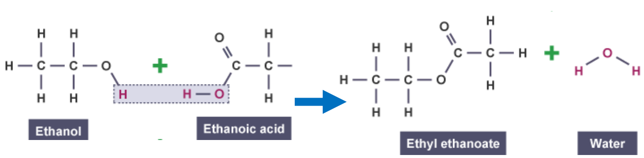
Carboxylic acids can react with alcohols to make **esters**. Esters are **organic compounds** which all contain the **functional group** -COO-. Esters have fruity smells and can be used as **solvents**.

The general equation for the formation of an ester is:

alcohol + carboxylic acid → ester + water

For example:

ethanol + ethanoic acid → ethyl ethanoate + water

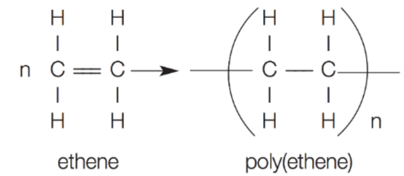



### Carboxylic Acids continued…

Carboxylic acids are weak acids. This means that their solutions do not contain many hydrogen ions compared with a solution of a strong acid with the same **concentration**. The pH of a weak acid will be higher than the pH of a strong acid, with the same concentrations. In a solution of a strong acid, the molecules are fully ionised, but in a weak acid, very few of the molecules are **ionised**.

## 8. Addition Polymerisation

Alkenes can be used to make **polymers** such as poly(ethene) and poly(propene) by addition polymerisation. In addition polymerisation reactions, many small molecules (**monomers**) join together to form very large molecules (**polymers**). For example:




In addition polymers the repeating unit has the same atoms as the monomer because no other molecule is formed in the reaction.

## 9. Condensation Polymerisation

Condensation polymerisation involves monomers with two functional groups (OH, COOH, COO). When these types of monomers react they join together, usually losing small molecules such as water, and so the reactions are called condensation reactions. The simplest polymers are produced from two different monomers with two of the same functional groups on each monomer.

Example (notice the repeating units) –

*ethanediol (2-alochol functional groups -OH)*
*$HO-CH_2-CH_2-OH$*
*(HO-☐-OH)*

and

*hexanedoic acid (2-carboxylic acid function groups -COOH)*
*$HOOC-CH_2-CH_2-CH_2-CH_2-COOH$*
*(HOOC-☐-COOH)*

polymerise to produce a polyester:

*n HO-☐-OH + HOOC-☐-COOH → -(O-☐-O-CO-☐-CO)-$_n$ + $2nH_2O$*

## 10. Amino Acids

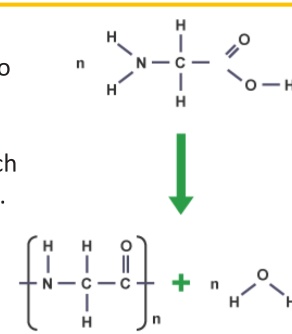
**Amino acids** are **molecules** which have at least two functional groups. All amino acids contain the $-NH_2$ group and also the carboxylic acid group -COOH. Amino acids are polymerised in cells to make **polypeptides** and **proteins**.

Amino acids react by **condensation polymerisation** so for every monomer which is added to the growing polymer chain, one molecule of water is also produced.

For example, glycine is the simplest amino acid. An equation for the formation of a polypeptide which is made only from glycine is:

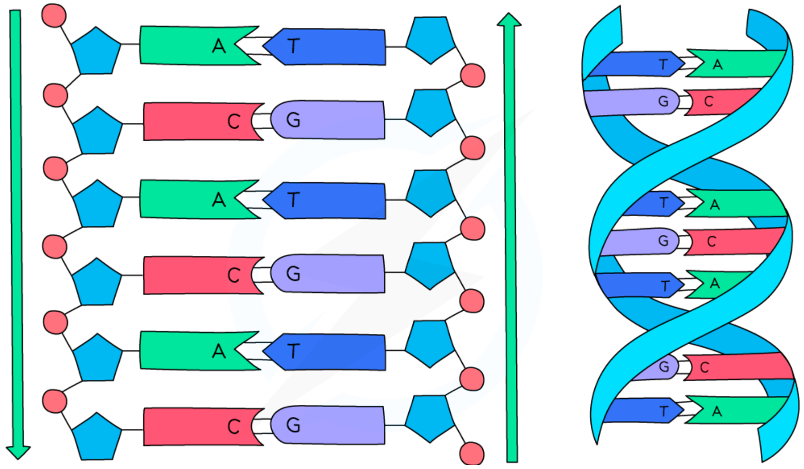
n glycine → poly(glycine) + water

$n\ H_2NCH_2COOH \rightarrow (-HNCH_2CO-)_n + n\ H_2O$

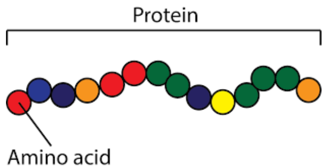


## 11. DNA and other Naturally Occurring Polymers *(separate Chemistry only)*

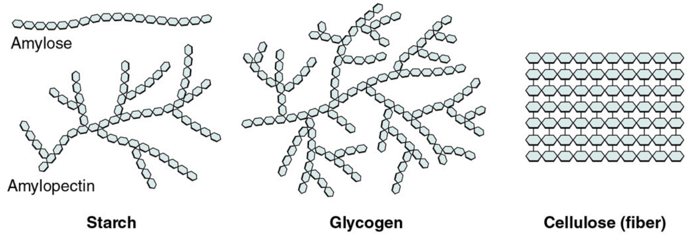
DNA (**deoxyribonucleic acid**) is a large molecule essential for life. DNA encodes genetic instructions for the development and functioning of living organisms and viruses. Most DNA molecules are two polymer chains, made from four different monomers called **nucleotides**, in the form of a **double helix**.




**Proteins** are biological polymers made inside cells. They are made from amino acid monomers and have a huge range of roles inside living things. For example, all **enzymes** are made from proteins.




**Starch and cellulose** are biological polymers which are made by plants. The monomers for both starch and cellulose are sugar molecules. Starch is used by plants as a way of storing energy as a complex **carbohydrate**. Cellulose is used to make the strong cell wall which gives plant cells (and therefore plants) strength.



# Inheritance

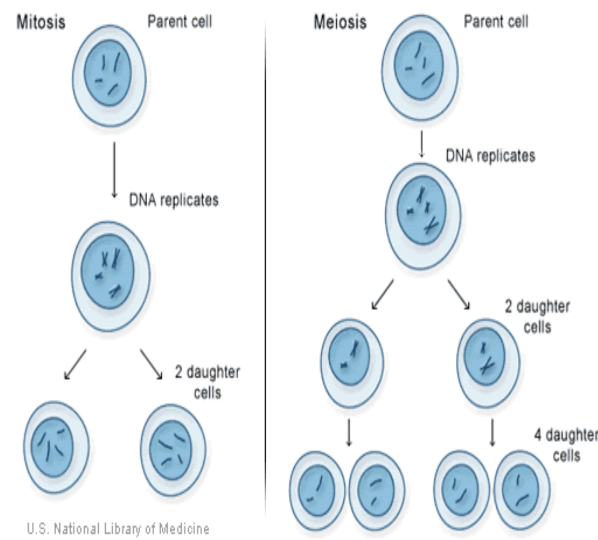
## Sexual and Asexual Reproduction

1. Mitosis leads to identical cells being formed.
Asexual reproduction involves only one parent.
There is no mixing of genetic information or fusion of gametes.
Offspring are identical (clones).
2. Meiosis leads to non-identical cells being formed.
Gametes (sperm and egg in animals and pollen and egg in flowering plants) are formed using meiosis in the reproductive organs.
When a cell divides to form gametes:

- copies of the genetic information are made (mitosis with a slight mixing of DNA)
- the cell divides **twice** to form **four** gametes, each with a single set of chromosomes
- all gametes are genetically different from each other.

Sexual reproduction involves the joining (fusion) of male and female gametes to form a cell with a complete set of genetic information.
The new cell divides by mitosis. The number of cells increases. As the embryo develops cells differentiate and become specialised.
Genetic information is mixed which leads to variety in offspring.

| Advantages of Sexual Reproduction | Advantages of Asexual reproduction |
|---|---|
| Produces variation in the offspring | Only one parent needed |
| If the environment changes variation gives a survival advantage by natural selection | More time and energy efficient as do not need to find a mate |
| Natural selection can be speeded up by humans in selective breeding to increase food production *Separate Biology only* | Faster than sexual reproduction<br>Many identical offspring can be produced when conditions are right |




- Malarial parasites reproduce asexually in the human host but sexually in the mosquito.
- Many fungi reproduce asexually by spores but also reproduce sexually to give variation.
- Many plants produce seeds sexually but also reproduce asexually by runners such as strawberries or bulb division such as daffodils.

*Separate Biology only*

## Sex Determination

Ordinary human body cells contain 23 pairs of chromosomes.
22 pairs control characteristics only, but one pair carriers the genes that determine sex.
Females the sex chromosomes are XX.
Males the sex chromosomes are XY.

## Inherited Disorders

**Polydactyl** (extra digits) is caused by a dominant allele. If a parent has Polydactyl (Pp) there is a 50% chance of the offspring inheriting it.
**Cystic Fibrosis** (disorder of the cell membrane where too much mucus is produced and the cilia can't move it away from the airways) is caused by a recessive allele. Both parents must be carriers (Nn) in order for there to be a 25% chance of a child inheriting the disorder.

## Genetic Inheritance

Some characteristics are controlled by a single gene, such as fur colour in mice and red-green colour blindness in humans.
Each gene may have different forms called alleles
The alleles present are called the genotype and the characteristic that is expressed is called the phenotype.
A dominant allele is always expressed even if only one copy of the allele is present. And is written using a capital letter.
A recessive allele is only expressed if both alleles are present. And is written using a lower case letter.
If the two alleles present are the same the organism is homozygous for that trait, but if the alleles are different they are heterozygous.
Punnett squares are used to express the probable outcome of a genetic cross.

| | R | r |
|---|---|---|
| r | Rr | rr |
| r | Rr | rr |

# Inheritance

## DNA and the genome

The genetic material in the nucleus of a cell is composed of a chemical called DNA.

DNA is a polymer made up of two strands forming a double helix.

The DNA is contained in structures called chromosomes.

A gene is a small section of DNA on a chromosome. Each gene codes for a particular sequence of amino acids, to make a specific protein.

The genome of an organism is the entire genetic material of that organism.

The whole human genome has now been studied and this will help medicine in the future:

- search for genes linked to different types of disease
- understanding and treatment of inherited disorders
- use in tracing human migration patterns from the past.

## Protein Synthesis

*Separate Biology only*

Proteins are synthesised on ribosomes according to a template.

Carrier molecules bring specific amino acids to add to the growing protein chain in the correct order.

When the protein chain is complete it folds up to form a unique shape.

This unique shape enables the proteins to do their job as enzymes, hormones or forming structures in the body such as collagen.

## Mutations *Separate Biology only*

Mutations occur continuously. Most do not alter the protein or only alter it slightly so that its appearance or function is not changed.

A few mutations code for an altered protein with a different shape. An enzyme may no longer fit the substrate biding site or a structural protein may lose its strength.

Not all parts of DNA code for proteins. Non coding parts of DNA can switch genes on and off, so variations in these areas of DNA may affect how genes are expressed.

## DNA Structure *Separate Biology only*

DNA is a polymer made from four different nucleotides.

Each nucleotide consists of a common sugar and phosphate group with one of four different bases attached to the sugar

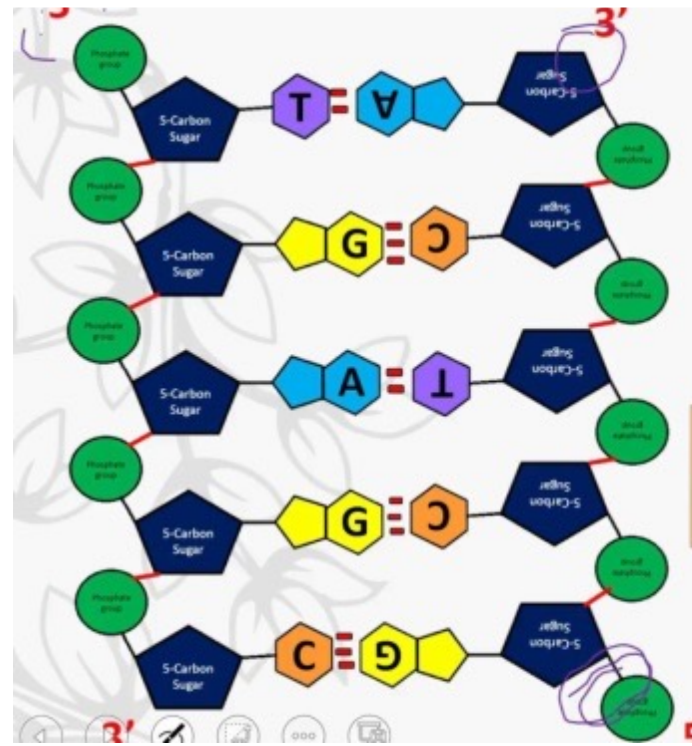
DNA contains four bases, A, C, G and T.

In the complementary strands a C is always linked to a G on the opposite strand and a T is always linked to an A.

A sequence of three bases is the code for a particular amino acid.

The order of bases controls the order of amino acids to produce a particular protein.

A change in DNA will produce a different sequence of bases and this results in a change in the protein synthesised by a gene.



# Variation

## Variation

Differences in the characteristics of individuals in a population is called variation and may be due to differences in:

- the genes they have inherited (genetic causes)
- the conditions in which they have developed (environmental causes)
- a combination of both.

There is usually extensive genetic variation within a population of a species.
All variations arise from mutations and most have no effect on the phenotype.

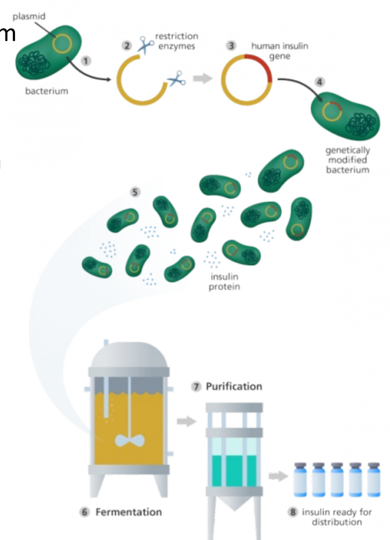
## Evolution

This is a change in the inherited characteristics of a population over time through a process of natural selection which may result in the formation of a new species.
The **theory of evolution** by **natural selection** states that all species of living things evolved from simple life forms that first developed more than three billion years ago.
**Natural Selection** results in phenotypes (characteristics) that are best suited to their environment.
If two populations of one species become so different in phenotype that they can no longer breed to produce fertile offspring they have formed two new species.

## Genetic Engineering

Modifying the genome of an organism by introducing a gene from another organism to give a desired characteristic.
Plant crops have been genetically engineered to be resistant to diseases or to produce bigger fruits.
Bacterial cells have been genetically engineered to produce useful substances such as human insulin to treat diabetes.

1. Genes from the chromosome of humans and other organisms can be 'cut out' and transferred to cells of other organisms.
2. Enzymes are used to isolate the required gene; this gene is inserted into a vector, usually a bacterial plasmid or a virus.
3. The vector is used to insert the gene into the required cells.
4. Genes are transferred to the cells of animals, plants or microbes at an early stage in their development so that they develop with desired characteristics.
5. Crops that have had their genes modified in this way are called genetically modified (GM) crops. GM crops include ones that are resistant to insect attack or to herbicides. GM crops generally show increased yields.

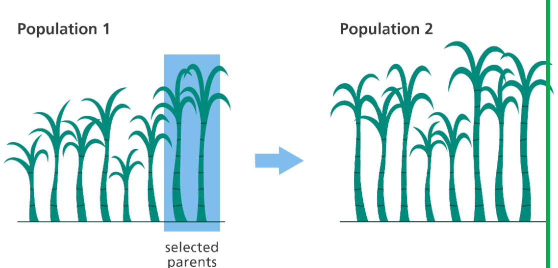



Concerns about GM crops include the effect on populations of wild flowers and insects. Some people feel the effects of eating GM crops on human health have not been fully explored.
Modern medical research is exploring the possibility of genetic modification to overcome some inherited disorders.

## Selective Breeding

- Selective Breeding (artificial selection) is the process by which humans breed plants and animals for particular genetic characteristic.
- Humans have been doing this for thousands of years since they first bred food crops from wild plants and domesticated animals.

1. Parents with desired characteristics are chosen from a mixed population.
2. They breed together.
3. From the offspring those with the desired characteristics are bred together.
4. This continues over many generations until all the offspring show the desired characteristics:
   - diseases resistance in food crops
   - animals which produce more meat or milk
   - domestic dogs with a gentle nature
   - large or unusual flowers.




Selective Breeding can lead to "inbreeding" where some breeds are particularly prone to disease or inherited defects.

# Variation *Separate Biology only*

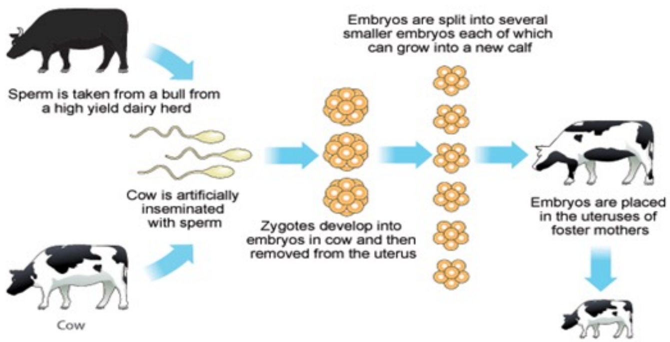
## Cloning

### Tissue culture:

Using small groups of cells from part of a plant to grow identical new plants. This is important for preserving rare plant species or commercially in nurseries.

### Cuttings:

An older, but simple method used by gardeners to produce many identical new plants from a parent plant.

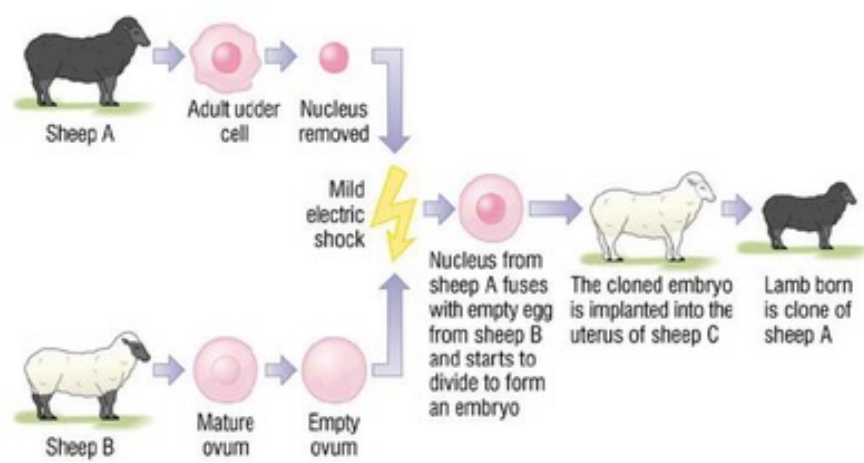



### Embryo transplants:

Splitting apart cells from a developing animal embryo before they become specialised, then transplanting the identical embryos into host mothers.

### Adult cell cloning:

The nucleus is removed from an unfertilised egg cell.
The nucleus from an adult body cell, such as skin cell, is inserted into the egg cell.
An electric shock stimulates the egg cell to divide to form an embryo.
These embryo cells contain the same genetic information as the adult skin cell.
When the embryo has developed into a ball of cells, it is inserted into the womb of an adult female to continue its development.



# Evolution

## Evidence for Evolution

The theory for evolution by natural selection is now widely accepted.
Evidence for Darwin's theory is now available as it has been shown that characteristics are passed on to offspring in genes. There is further evidence in the fossil record and the knowledge of how antibiotic resistance evolves in bacteria.

## Extinction

This occurs when there are no remaining individuals of a species still alive. It can be caused by:

- natural disaster
- disease
- habitat destroyed
- competition for food
- new predator.

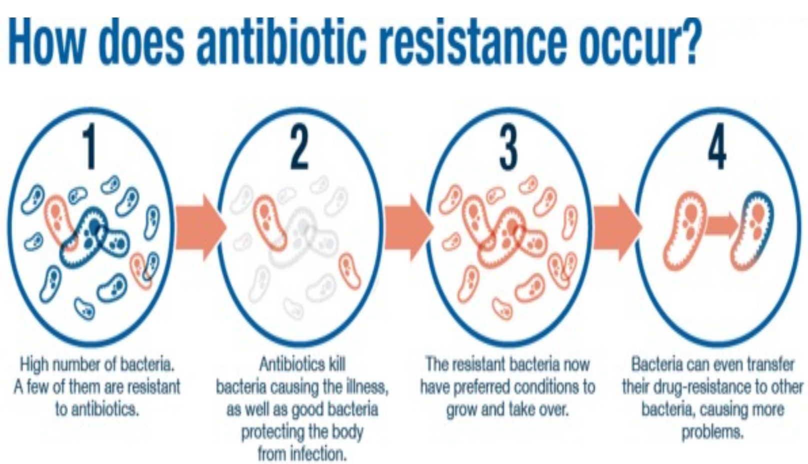
## Fossils

Fossils are the 'remains' of organisms from millions of years ago, which are found in rocks.
Fossils may be formed:

- from parts of organisms that have not decayed because one or more of the conditions needed for decay are absent
- when parts of the organism are replaced by minerals as they decay
- as preserved traces of organisms, such as footprints, burrows and rootlet traces.

Many early forms of life were soft-bodied, which means that they have left few traces behind. What traces there were have been mainly destroyed by geological activity. This is why scientists cannot be certain as to how life began on Earth.
We can learn from fossils how much or how little different organisms have changed as life developed on Earth.

## Resistant Bacteria




Bacteria can evolve rapidly because they reproduce at a fast rate.
Mutations of bacterial pathogens produce new strains. Some strains might be resistant to antibiotics, and so are not killed. They survive and reproduce, so the population of the resistant strain rises. The resistant strain will then spread because people are not immune to it and there is no effective treatment.
MRSA is resistant to antibiotics.
To reduce the rate of antibiotic resistant strains:

- doctors should not incorrectly or over prescribe antibiotics
- you should complete the course of antibiotics to ensure they are all killed
- the agricultural use of antibiotics should be restricted.

# Evolution *Separate Biology only*

## The Theory of Evolution

**Charles Darwin**, as a result of observations on a round the world expedition, backed by years of experimentation and discussion and linked to developing knowledge of geology and fossils, proposed the theory of evolution by natural selection.

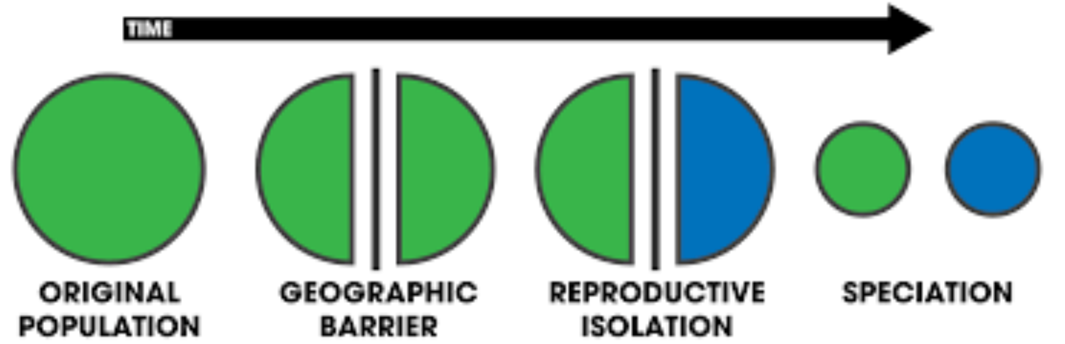
1. Individual organisms within a particular species show a wide range of variation for a characteristic.
2. Individuals with characteristics most suited to the environment are more likely to survive to breed successfully.
3. The characteristics that have enabled these individuals to survive are then passed on the next generation.

Darwin published his ideas in *On the Origin of Species* – the theory of evolution by natural selection was only gradually accepted because:

- the theory challenged the idea that God made all the animals and plants that live on Earth
- there was insufficient evidence at the time the theory was published to convince many scientists
- the mechanism of inheritance and variation was not known until 50 years after the theory was published.

Other theories – including **Jean-Baptiste Lamarck's** are based mainly on the idea that changes that occur in an organism during its lifetime can be inherited. We now know that in the vast majority of cases this type of inheritance cannot occur.

## Speciation




- **Alfred Russell Wallace** independently proposed the theory of evolution by natural selection.
- He published joint writings with Darwin which prompted Darwin to publish 'On the Origin of Species' the following year.
- Wallace worked worldwide gathering evidence for evolutionary theory. He is best known for his work on warning colourations in animals and his theory of speciation.
- Wallace did much pioneering work on speciation but more evidence over time has led to our current understanding of the theory of speciation.

## The understanding of genetics

In the mid 19th century, **Gregor Mendel** carried out breeding experiments on plants. One of his observations is determined by 'units' that are passed on to descendants unchanged.

His work was not accepted until after his death because:

- in the late 19th century the behaviour of chromosomes during cell division was observed
- in the early 20th century it was observed that chromosomes and Mendel's 'units' behaved in similar ways. This led to the idea that the 'units' now called genes were located on chromosomes
- in the mid 20th century the structure of DNA was determined and the mechanism of gene function worked out.

This scientific work by many scientists led to the gene theory being developed.

# Classification

## Classification of living organisms

Traditionally living things have been classified into groups, depending on their structure and characteristics, in a system developed by **Carl Linnaeus.**

Linnaeus classified living things into **kingdom, phylum, class, order, family, genus and species.**

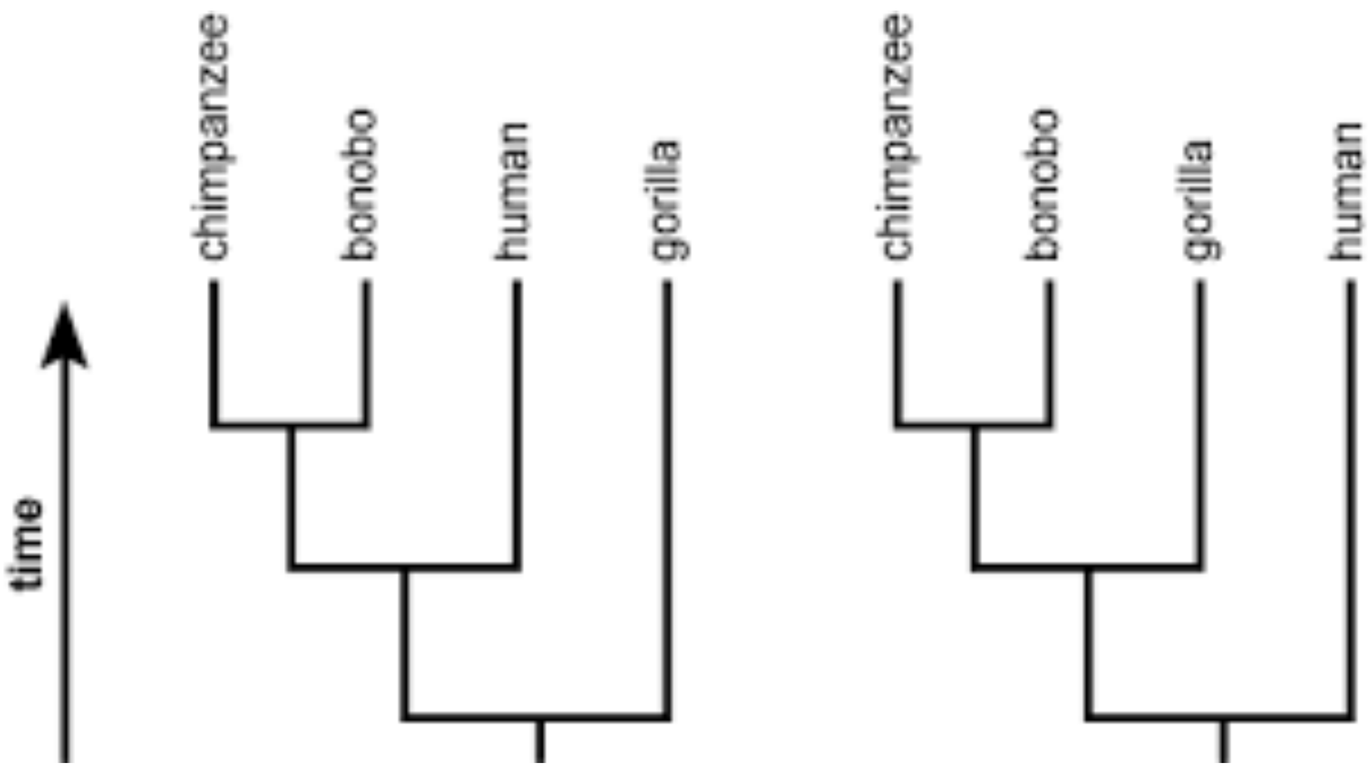
Organisms are named by the binomial system of genus and species.

As evidence of internal structures became more developed due to improvements in microscopes, and the understanding of biochemical processes progressed, new models of classification were proposed.

Due to evidence available from chemical analysis there is now a 'three-domain system' developed by Carl Woese:

- archaea (primitive bacteria usually in extreme environments)
- bacteria (true bacteria)
- eukaryota (which includes protists, fungi, plants and animals).

Evolutionary trees are a method used by Scientists to show how organisms are related.



# Forces (and motion 1)

## 1. Scalar and vector

**Distance** is a scalar quantity (magnitude only) and measures how far something moves. **Displacement** is a vector quantity (magnitude and direction) and measures how far something is from its starting point.

**Speed** is a scalar quantity, the speed of a moving object is rarely constant and an average speed is often calculated.

**Velocity** is a vector quantity. It is a measure of the displacement divided by the time taken to move.

## 5. Terminal velocity

Initial acceleration due to weight.

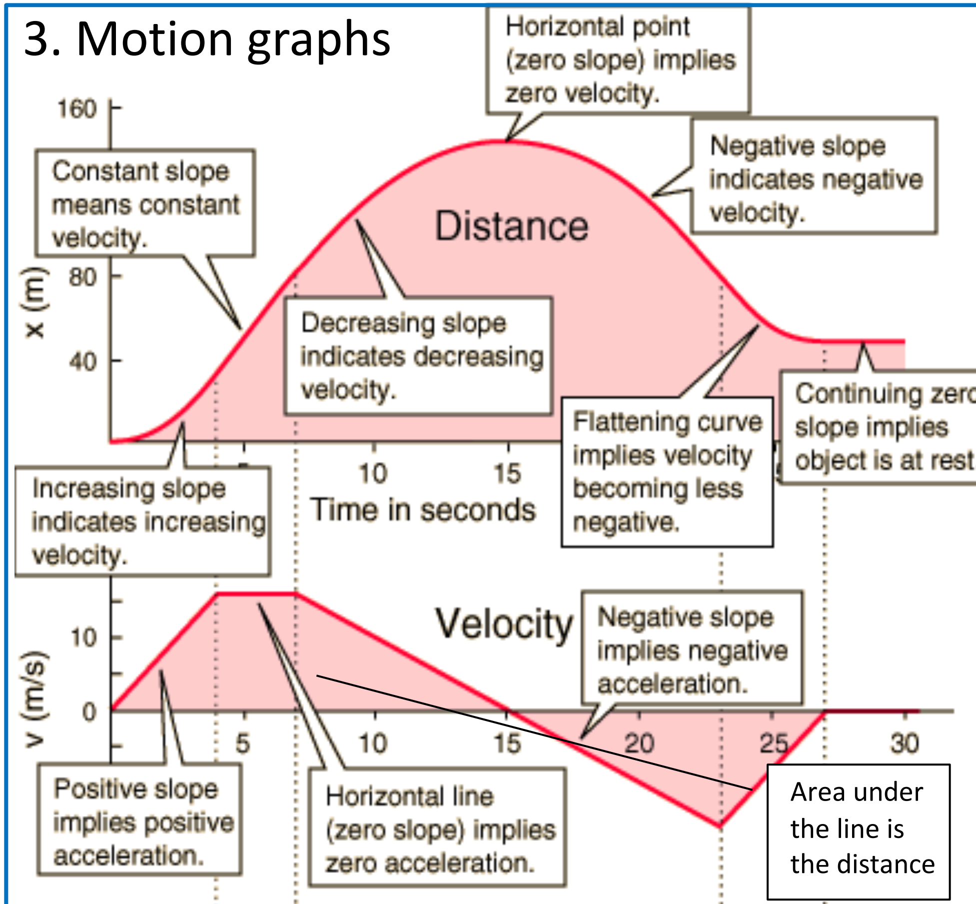
Drag forces increasing, but still accelerating.

Drag balances weight and terminal velocity reached.

Larger surface area means the drag force increases causing deceleration.

Lower terminal velocity reached

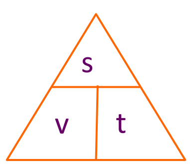
## 3. Motion graphs




## 4. Velocity and acceleration

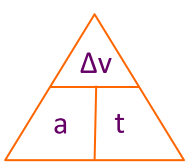
$$distance\ travelled = velocity \times time$$

(m) (m/s) (s)




Learn

Learn




$$acceleration = \frac{change\ in\ velocity}{time}$$

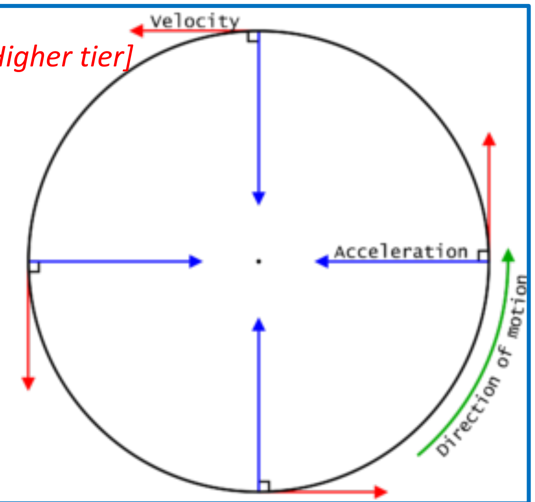
(m/s²) (m/s) (s)

## 2. Circular motion *[Higher tier]*

Circular motion involves constant speed, but a changing velocity due to the change in direction.

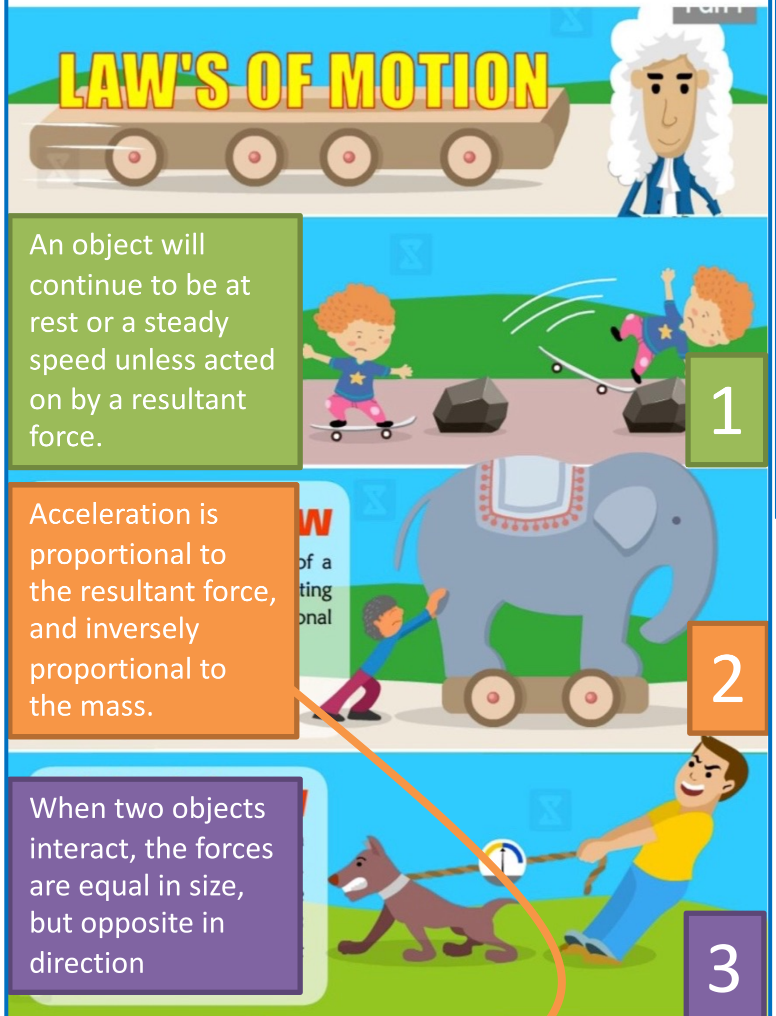
A **change in velocity** over time is the definition of acceleration.

This means that an object travelling in a circle will be accelerating due to a resultant force acting towards the centre of the circle.



# Forces (and motion 2)

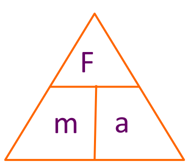
## 6. Newton's laws of motion




An object will continue to be at rest or a steady speed unless acted on by a resultant force.

Acceleration is proportional to the resultant force, and inversely proportional to the mass.

When two objects interact, the forces are equal in size, but opposite in direction




$force = mass \times acceleration$

(N) (kg) $(m/s^2)$

Learn

## 7. Stopping distances

**Thinking distance** is the distance travelled while a driver reacts to a situation.

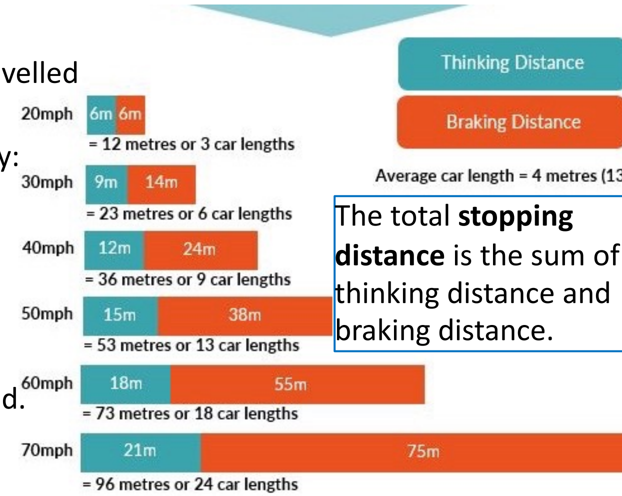
Thinking distance may be affected by:

- tiredness
- drugs
- alcohol
- distractions e.g. mobile phone.

**Braking distance** is the distance travelled while the brakes are applied.

A vehicle's braking distance may be affected by:

- the condition of the road
- the weather
- the condition of the car
- the mass of the vehicle.




The total **stopping distance** is the sum of thinking distance and braking distance.

When a force is applied to the brakes, work is done by friction. This decreases the kinetic energy store of the car, but increases the thermal store of the brakes and surroundings, increasing the temperature.

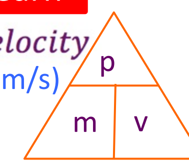
## 8. Momentum [Higher tier]

Learn

In a closed system, **momentum** is conserved; the total momentum before a collision is equal to the total momentum after a collision.

$momentum = mass \times velocity$

(kgm/s) (kg) (m/s)

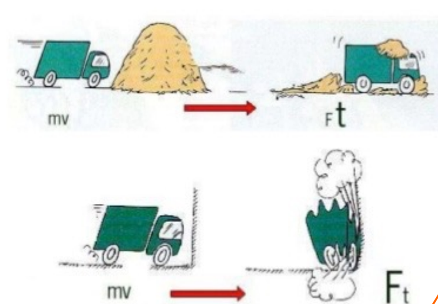


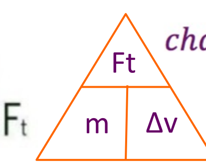

## 9. Change in Momentum

*(Separate Physics only)*

For a **change in momentum**, force and time are inversely proportional; if you can increase the time of a collision you can decrease the force involved.

Seat belts, air bags, crash mats, cycle helmets and cushioned surfaces for playgrounds all use this idea.




$change\ in\ momentum = force \times time$

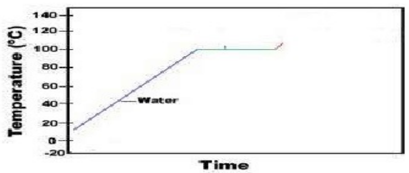
(kgm/s) (N) (s)

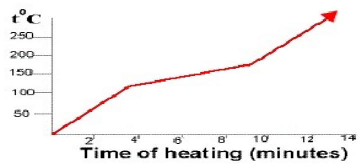
On sheet

# Chemical Analysis

## Pure Substances

In chemistry a pure substance is a single element or compound, not mixed with any other substance.
Pure elements and compounds melt and boil at specific temperatures.
Melting point and boiling point data can be used to distinguish pure substances from mixtures.
In advertising a pure substance can mean a substance that has had nothing added to it (in its natural state).




Pure substance:
Fixed boiling point

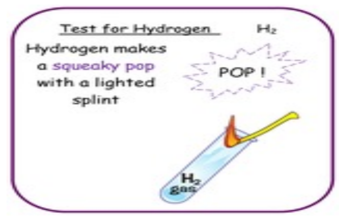
Mixture:
Unclear boiling point

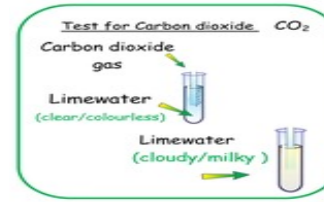
## Formulations

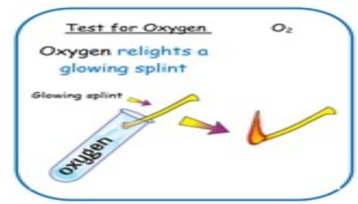
A formulation is a mixture that has been designed as a useful product.
Many products are complex mixtures in which each chemical has a particular purpose.
Formulations are made by mixing the components in carefully measured quantities to make sure the product has the required properties.

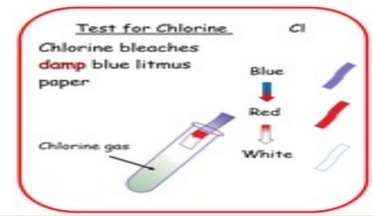
**Fuels** **Cleaning agents** **Paints** **Medicines** **Alloys** **Fertilisers** **Foods**

## Testing Gases



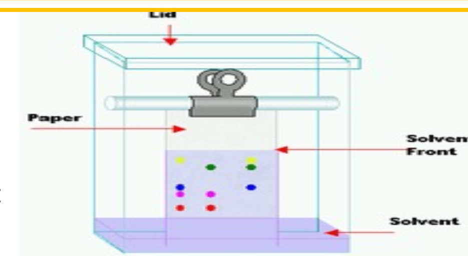



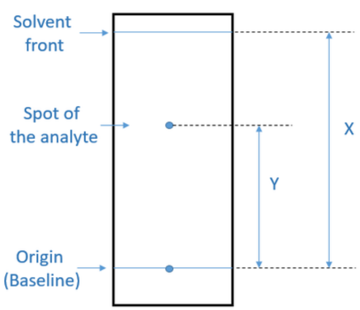




## Chromatography

Chromatography can be used to separate mixtures and can give information to help identify substances.
Chromatography involves a stationary phase (where the molecules can't move – the paper) and a mobile phase (where the molecules can move – the liquid called the solvent)
Separation depends on the distribution of substances between the phases. The chemicals in a mixture spend different amounts of time dissolved in the mobile phase and stuck to the stationary phase.




$R_f = Y \div X$

The $R_f$ value of a chemical is the ratio between the distance travelled by the dissolved substance (the solute) and the distance travelled by the solvent

$$R_f = \frac{distance\ moved\ by\ substance}{distance\ moved\ by\ solvent}$$

Different compounds have different $R_f$ values in different solvents which can be used to help identify the compounds.
The compounds in a mixture may separate into different spots depending on the solvent but a pure substance will produce a single spot in all solvents.

**Required practical:** Investigate how paper chromatography can be used to separate and tell the difference between coloured substances. Place spot of mixture on chromatography paper and place in solvent. When the solvent moves up the paper the mixture will separate into spots. Calculate the $R_f$ value of each spot.

# Chemical Analysis *(separate Chemistry only)*

**REQUIRED PRACTICAL: Use chemical tests to identify the ions in unknown single ionic compounds (the cation and the anion).**

## Testing Cations (positive ions)

### Flame tests

Flame tests can be used to identify some metal ions (cations)
If a sample contains a mixture of ions then some flame colours can be masked.

| Metal Ion | Flame Colour |
|---|---|
| **Lithium** | Crimson |
| **Sodium** | Yellow |
| **Potassium** | Lilac |
| **Calcium** | Orange-red |
| **Copper** | Green |

### Metal Hydroxides

Sodium hydroxide can be used to identify some metal ions (cations).
They form metal hydroxide precipitates.

| Metal Ion | Colour of Precipitate | Ionic equation for precipitate |
|---|---|---|
| **Calcium $Ca^{2+}$** | White | $Ca^{2+}{}_{(aq)} + 2OH^-{}_{(aq)} \rightarrow Ca(OH)_{2\,(s)}$ |
| **Copper (II) $Cu^{2+}$** | Blue | $Cu^{2+}{}_{(aq)} + 2OH^-{}_{(aq)} \rightarrow Cu(OH)_{2\,(s)}$ |
| **Iron (II) $Fe^{2+}$** | Green | $Fe^{2+}{}_{(aq)} + 2OH^-{}_{(aq)} \rightarrow Fe(OH)_{2\,(s)}$ |
| **Iron (III) $Fe^{3+}$** | Brown | $Fe^{3+}{}_{(aq)} + 3OH^-{}_{(aq)} \rightarrow Fe(OH)_{3\,(s)}$ |
| **Aluminium $Al^{3+}$** | White but then re dissolves to form a colourless solution | $Al^{3+}{}_{(aq)} + 3OH^-{}_{(aq)} \rightarrow Al(OH)_{3\,(s)}$ |
| **Magnesium $Mg^{2+}$** | White | $Mg^{2+}{}_{(aq)} + 2OH^-{}_{(aq)} \rightarrow Mg(OH)_{2\,(s)}$ |

## Testing Anions (negative ions)

### Carbonates

Carbonates react with dilute acids to form carbon dioxide gas.
Carbon dioxide can then be tested for using limewater.

$Na_2CO_{3\,(aq)} + 2HCl_{(aq)} \rightarrow CO_{2\,(g)} + 2NaCl_{(aq)} + H_2O_{(l)}$

### Sulphates

Sulphate ions in solution produce a white precipitate with barium chloride solution (in the presence of dilute HCl).
The precipitate is **barium sulphate**.

$Ba^{2+}{}_{(aq)} + SO_4{}^{2-}{}_{(aq)} \rightarrow BaSO_{4\,(s)}$

### Halides

Adding halides to silver nitrate solution (with nitric acid).
produce precipitates of silver halides.

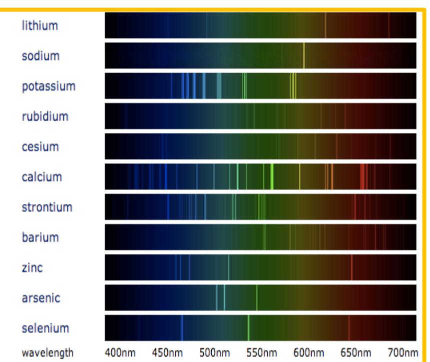
| Halide | Colour of Precipitate in acidified silver nitrate | Ionic equation for precipitate |
|---|---|---|
| **Chloride $Cl^-$** | White | $Ag^+{}_{(aq)} + Cl^-{}_{(aq)} \rightarrow AgCl_{(s)}$ |
| **Bromide $Br^-$** | Cream | $Ag^+{}_{(aq)} + Br^-{}_{(aq)} \rightarrow AgBr_{(s)}$ |
| **Iodide $I^-$** | Yellow | $Ag^+{}_{(aq)} + I^-{}_{(aq)} \rightarrow AgI_{(s)}$ |

## Instrumental Analysis

**Advantages** over chemical testing: They produce **fast**, **sensitive** and **accurate** means of analysing chemicals and are particularly useful when the amount of chemical being **analysed is small**.

### Flame emission spectroscopy

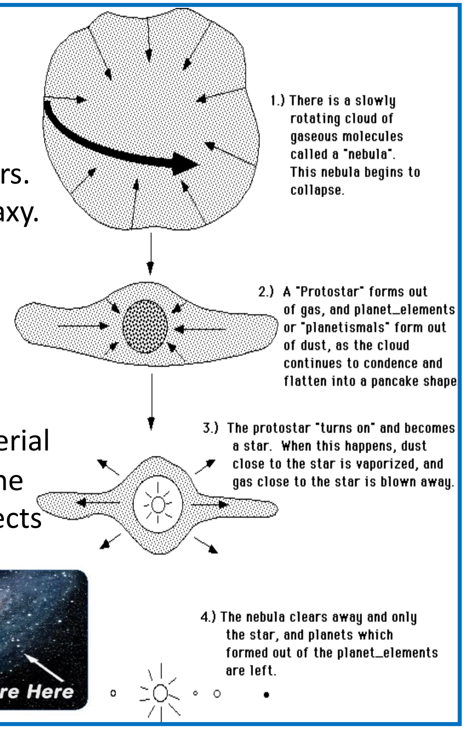
- Used to analyse **metal ions** in solution.
- The sample is put into a flame and the light given out is passed through a spectroscope.
- The output is a line spectrum that can be analysed to identify the metal ions in the solution and measure their concentrations.
- The line spectrum is unique for every ion – so you compare the pattern you get with known samples to identify the correct ion.

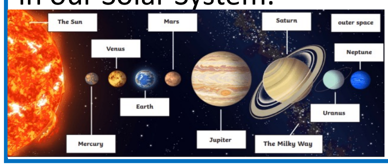


# SPACE *(Separate Physics only)*

## 1 Stars and the Solar system

The Universe is made from billions of galaxies.
Each galaxy contains hundreds of millions of stars.
The Solar System is a tiny part of Milky Way galaxy.
Galaxies are made from; stars, planets, dwarf planets, asteroids and comets. Planets, dwarf planets and comets orbit a star, moons orbit planets.
The Sun was formed from a nebula which was pulled together by the force of gravity. The material not drawn into the Sun stayed in orbit around the new star and formed the planets and other objects in our Solar System.

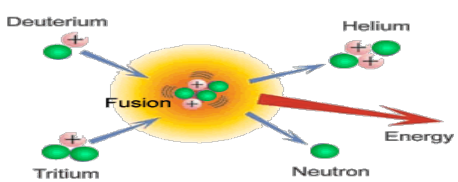




## 2 Nuclear fusion

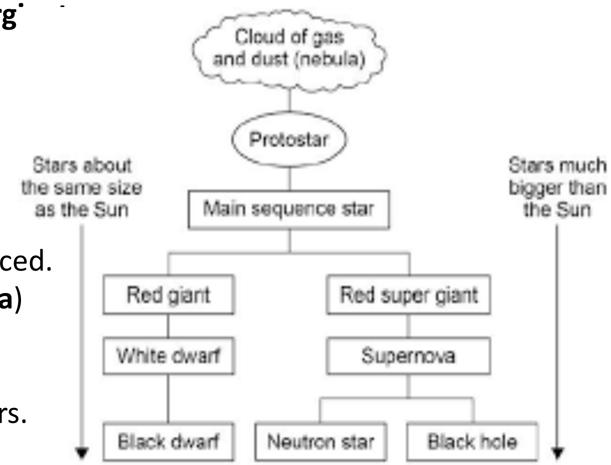
During nuclear fusion two smaller nuclei join together to form a heavier nucleus.




Some of the mass is converted into energy and some of this energy is emitted as radiation.
Nuclear fusion needs very high temperature and pressure to overcome the electrostatic repulsion of the small nuclei and to bring the positive nuclei close together enough for fusion to take place.
To work out the amount of energy release we need to apply the formula :
$E = mc^2$
E is energy, m is mass and c is the speed of light (300,000,000 m/s).

## 3 Life cycle of a STAR

The lifecycle of a star depends on the size of the star.
They begin the same way as the Sun did - clouds of dust and gas are drawn together by gravity to form a **protostar** and eventually a **main sequence star**. This is when fusion begins where hydrogen atoms fuse together to create helium. In this stage the star is stable for a long time because the force of gravity is balanced by the outward radiation pressure cause by nuclear fusion.
As the star ages, more and more mass is converted into energy by nuclear fusion. As the mass decreases, the outward forces become larger than the force from gravity. The star expands and cools becoming a **red giant** or **red superg**




As the star cools and the hydrogen is used up, the outward forces are reduced.
The star collapses inwards (**supernova**) due to the gravity and it causes the temperature to increase once more.
Small stars end up as **black dwarf** stars.
Larger stars become **neutron stars**.
The largest stars become **black holes**.

## 4 Formation of elements

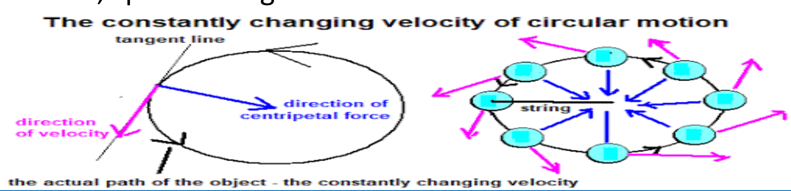
$${}^{4}_{2}He + {}^{8}_{4}Be \rightarrow {}^{12}_{6}C$$

Before stars, the only element in the Universe was hydrogen.
All the other elements up to uranium in the periodic table were cause by the fusion process.
All stars fuse hydrogen into helium.
Bigger stars fuse helium into lithium and other lightweight elements up to and including iron.
During a supernova, the amount of energy released is so great that temperature and pressure is high enough to force nuclei together to create elements heavier than iron up to uranium.
The formation of new elements is called **nucleosynthesis**.

# SPACE *(Separate Physics only)*

## 5 Orbits of planets, moons, satellites

Planets go around the Sun in orbits. The more distant a planet is the longer it takes to orbit the Sun.
Artificial satellites are man-made satellites that orbit the Earth. They are used for: communications, GPS, weather forecasting, surveys of the Earth's surface, map making , spying and space explorations.
If an object moves in circular motion, the speed of the object does not change, but the direction of travel changes. The instantaneous velocity is perpendicular to the centripetal force; the velocity changes. The change in velocity is acceleration. The force of gravity pulls the object in a curved path. These two quantities create a resultant force called centripetal force which acts towards the centre of the circle.
Some objects move in elliptical orbits. For them, distance is not constant, speed changes. Therefore acceleration is not constant



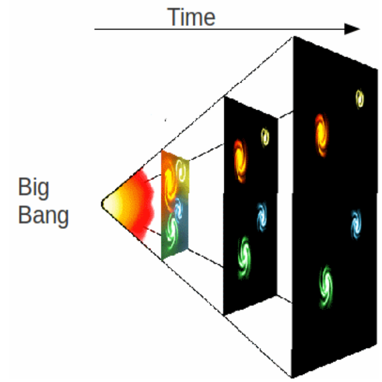

## 6 Gravity


**The** force of gravity is important to Earth.

*Weight = mass x gravitational field strength*
(N) (kg) (9.81 N/kg)

learn

On Earth, gravitational field strength is 9.81 N/kg (often rounded to 10 N/kg).
Gravitational field strength is different on other planets and stars.
The more distant a planet is, the weaker the force of gravity, the slower the planet moves.
Gravity is an inverse square law. If you triple the distance the force of gravity is 1/9$^{th}$.




It is thought that **dark matter** hold the galaxies together by gravitational attraction. Also it is thought that **dark energy** is responsible for the increased rate of expansion of the Universe.

## 7 Big Bang theory, Red Shift, Doppler Effect

The Big Bang theory states that the Universe began from a very small region that was extremely hot and dense. When the Big Bang happened, matter and high energy radiation were released. Since then, space started expanding and the expansion is still happening. The evidence is that the distant galaxies are moving faster and further away from us.

There is an observed increase in the wavelength of light from distant galaxies – the further the galaxy, the greater the apparent change in wavelength, the bigger the Red Shift


The same effect can be detected with sound. The Doppler Effect states when a car moves away from the observer, the pitch of the engine decreases, and the wavelength increases. When the car moves towards the observer the pitch increases so the wavelength decreases. This is called the Doppler Effect