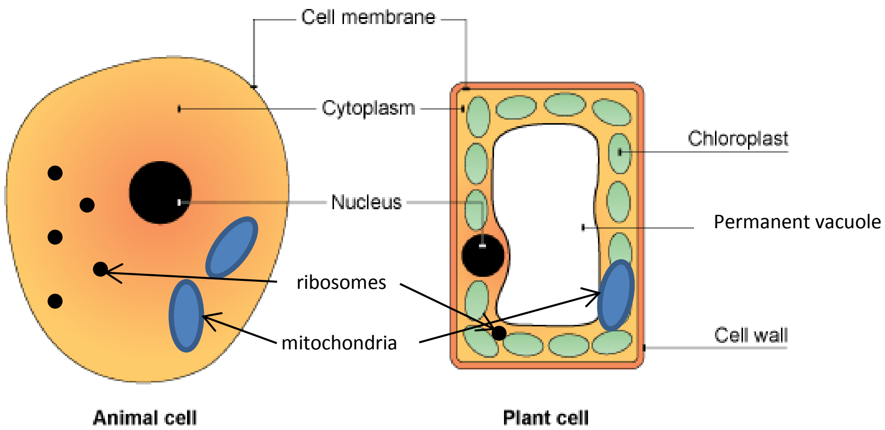
Biology Knowledge Organiser
B1 - Cell structure and transport

Eukaryotic Cells

Eukaryotic cells include all plant and animal cells. Their most important feature is that they have a nucleus, unlike prokaryotic cells.

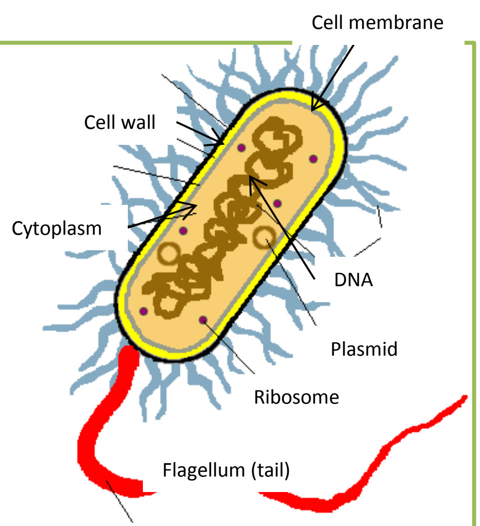


Prokaryotic Cells

Bacteria are prokaryotic cells (all bacteria are single-celled organisms). The most important differences to eukaryotic cells are that they are smaller and their genetic material (DNA) is not enclosed in a nucleus.

Prokaryotic cells have DNA in a loop, and, in addition to the main loop of DNA, they have small loops of DNA called plasmids.

Plasmids allow bacteria to swap genetic information between them.



Key Terms	Definitions
Cell	The basic unit of all forms of life.
Eukaryotic Cells	Cells with a nucleus – e.g. plant and animal cells.
Prokaryotic Cells	Bacterial cells; these don't have a nucleus to enclose their genetic material.
Cell Membrane	The border of all types of cell. The cell membrane separates the inside of the cell from the environment. It controls the movement of substances into and out of the cell.
Sub-cellular structure	A part of a cell. (Sub- means less than – so these are the component parts of cells.)
Nucleus	The enclosure for genetic material found in plant and animal cells.
Cytoplasm	The interior of a cell, where most of the chemical reactions needed for life take place.
Mitochondria	The sub-cellular structure where aerobic respiration takes place.
Ribosome	The sub-cellular structure where proteins are made (synthesised)
Chloroplast	A sub-cellular structure responsible for photosynthesis – only found in plant cells and algal cells.
Permanent Vacuole	A sub-cellular structure only found in plant and algal cells – it is filled with cell sap (a store of nutrients for the cell).
Cell Wall	A sub-cellular structure that is never found in animal cells. It is made of cellulose, it is outside the cell membrane and it strengthens the cell.
DNA	The molecule that holds the genetic information in a cell. In eukaryotic cells, it is one linear strand. In prokaryotic cells, the DNA forms a loop.
Plasmid	A small loop of DNA, only found in prokaryotic cells.

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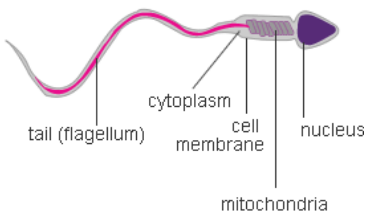
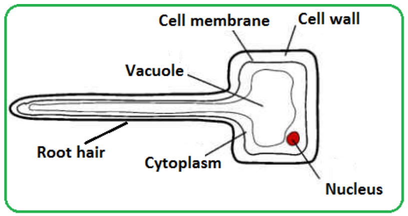
B1 - Cell structure and transport

Multicellular Organisms

You are a multicellular organism, just like all animals, plants and many types of fungus. But, not all your cells are the same. Cells become specialised by **differentiation**, which means they develop new features to help them perform a specific function. E.g. sperm cells and root hair cells.





Tissues are formed when cells with similar structures and functions work together. For example: muscle tissue in animals; phloem tissue in plants.

Organs are formed from multiple tissues working together. For example: the stomach in animals; the leaf in plants.

Organ systems are formed when multiple organs work together. For example: the digestive system in animals; the vascular (transport) system in plants.

Microscopy

Use of a microscope is called microscopy. Microscopes allowed scientists to discover cells and find all the sub-cellular structures.
Because cells and their parts are very small, it is not useful to measure them in metres. Instead, we use small divisions of the metre as follows:

Centimetre = 1/100 metre (10^{-2}). A centimetre is 1 one hundredth of a metre. (cm)
Millimetre = 1/1000 metre (10^{-3}). A millimetre is 1 one thousandth of a metre. (mm)
Micrometre = 1/1 000 000 (10^{-6}). A micrometre is 1 one millionth of a metre. (µm)
Nanometre = 1/1 000 000 000 (10^{-9}) A nanometre is 1 one billionth of a metre. (nm)

Electron microscopes were a vital invention for understanding cells. They have higher magnification and more resolving power than light microscopes, so they let you see smaller structures.

Key Terms	**Definitions**
Organism	Any living thing: can be made of one cell or be multicellular.
Multicellular	This describes an organism that is made of lots of cells – such as animals or plants.
Specialised Cell	Almost all cells in multicellular organisms have a particular job, or function. While they usually have all the parts labelled on your cell diagrams, they change to suit their functions. This may include developing different sub-cellular structures (e.g. the tail of a sperm cell).
Tissue	A group of cells with similar structures and functions – i.e. a group of specialised cells.
Organ	An organ is a collection (or aggregation) of tissues performing a specific function.
Organ System	Organs don't operate alone: they work together to form organ systems.
Organism (again)	An organism has many organ systems, all contributing to its survival.
Light microscope	A usual school microscope is a light microscope. You can see large sub-cellular structures like a nucleus with it, but not a lot more detail than that.
Magnification	This is the measure of how much a microscope can enlarge the object you are viewing through it.
Resolution	This is the measure of the level of detail you can see with a microscope.
Electron microscope	A type of microscope with much high magnification and resolution than a light microscope. Essential for discovering the smaller sub-cellular structures.

Equation	**Meanings of terms in equation**
$magnification = \frac{size\ of\ image}{size\ of\ real\ object}$	*The image Is how it looks through the microscope. The real object is what you are looking at. The image and object must be measured with the same unit, e.g. both in nm.*

Biology Knowledge Organiser
B1 - Cell structure and transport

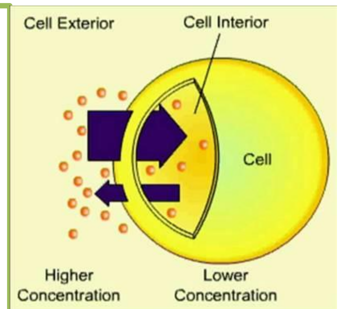
Exchange and Transport

To stay alive, all organisms must exchange substances with their environment. This means they must transport **into** cells the substances they need from the environment and transport **out** waste products to the environment.

Substances can be transported into or out of cells by: **diffusion, osmosis** or **active transport**.

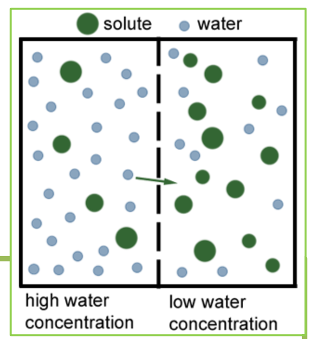
Diffusion

Diffusion allows many substances to move into or out of cells. Thanks to the random motion of particles in liquids and gases, particles will spread out until the concentration is equal throughout. If there is a cell membrane that lets the substance through (is **permeable**) in the way, it doesn't matter. Overall, the **net movement** of the substance will be from higher to lower concentration, as the diagram shows.



Diffusion is the process by which oxygen is transported into the bloodstream, and carbon dioxide is transported out (in the lungs, or gills of fish). It is also how the waste product **urea** moves from cells into the bloodstream, before removal in the urine.

The rate of diffusion is affected by:
1. the steepness of the concentration gradient
2. the temperature (a higher temperature increases the rate of diffusion as particles have more kinetic energy)
3. The surface area of the membrane (a larger surface area of cell membrane increases the rate of diffusion into/out of a cell).



Osmosis

Osmosis is the movement of water from a more dilute solution (more 'watery') to a more concentrated solution (less 'watery') across a partially permeable membrane, such as a cell membrane. Osmosis causes cells to swell up if they are placed in a dilute solution, or shrivel up if they are placed in a concentrated solution (a solution of salt, for instance, or sugar).

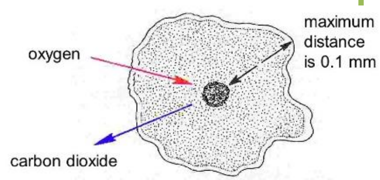
Key Terms	Definitions
Diffusion	The net (overall) movement of particles from a higher concentration to a lower concentration, simply due to the random motion of particles in a liquid or gas. Diffusion happens across cell membranes, from higher to lower concentration. It does not require any energy from the cell.
Concentration gradient	The difference in concentration of a substance between two places. A 'steeper' concentration gradient means there is a bigger difference in concentration.
Surface area to volume ratio	The surface area divided by the volume of an organism, organ or cell. Generally, the smaller something is, the larger the surface area to volume ratio.
Exchange surface	A place, such as the walls of the small intestine, where exchange of substances takes place e.g. by diffusion across it.
Diffusion pathway	The distance over which a substance must diffuse. A thin wall or membrane is a short diffusion pathway.
Osmosis	Osmosis only describes the movement of water. It is the diffusion of water from a dilute solution to a more concentrated solution across a partially permeable membrane.
Partially permeable membrane	A membrane that only allows some substances through – others are prevented from travelling through.
Active transport	The movement of substances **against** the concentration gradient – from lower to higher concentration. This requires energy from respiration.

Active transport

Active transport is so-named because it requires energy. A good example of where it happens is in plant roots. Root hair cells (see specialised cells topic) absorb mineral ions (like magnesium ions and nitrate ions) from the very dilute solution in the soil by active transport. They need ions like these for healthy growth. An example in animals is absorption of sugar from the intestine into the blood – the blood has a higher sugar concentration so active transport is needed. The sugar is needed by all cells in the body for respiration.

Biology Knowledge Organiser
B1 - Cell structure and transport

Adaptations for efficient exchange and transport



Unicellular organisms have a very large surface area to volume ratio compared to multicellular organisms. This means that they simply exchange substances through their cell membrane directly with their environment. They are small enough that diffusion is sufficient to meet their needs (see diagram).

However in multicellular organisms, cells that are not at the surface wouldn't be able to directly exchange substances with the environment. This is why organs with specialised exchange surfaces have evolved. Without lungs, gills, or leaves, for example, multicellular organisms wouldn't be able to obtain all the substances they need to survive, or be able to get rid of waste products efficiently.

Specialised exchange surfaces

To be effective at exchanging substances with the environment, any exchange surface must have a **large surface area**, and a thin wall/membrane for a **short diffusion pathway**. In animals, a constant blood supply also increases effectiveness, and in the lungs, ventilation (breathing in and out) increases effectiveness by refreshing the concentration gradient with each breath.

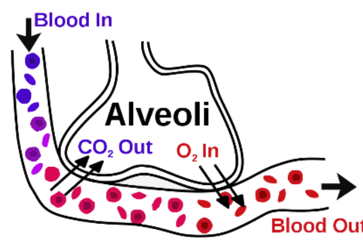
Exchange in animals and plants

Gas exchange in many animals, including us, happens in the lungs. The structures in the lungs where it happens are the **alveoli**. There are millions of these tiny air sacs, so in total their surface area is gigantic. They also have a short diffusion pathway, a good blood supply and air supply due to **ventilation**. (look at the diagram of one alveolus)

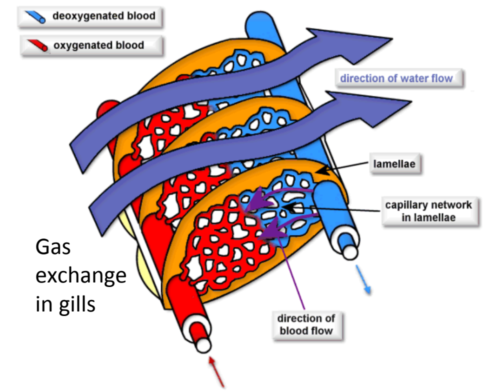
In fish, gills are where gas exchange takes place (see diagram). Again, a huge surface area increases the efficiency of gas exchange, along with a short diffusion pathway and good blood supply. The huge surface area comes from the division of gills into very thin plates of tissue called lamellae. This also creates the short diffusion pathway.

In plants, the roots absorb water and mineral ions. The root hair cells have **long projections** that increase the surface area of this exchange surface, and shorten the diffusion pathway. The leaves are responsible for gas exchange, including oxygen out and water vapour out, and carbon dioxide in. Being flat and broad increases the effectiveness of the leaves as exchange surfaces, by increasing the surface area and shortening the diffusion pathway. In leaves, exchange happens through microscopic holes called **stomata**.

Key Terms	Definitions
Small intestine	The organ in the digestive system where products of digestion are absorbed into the bloodstream.
Lungs	The organs were gas exchange takes place. The air sacs where gases are actually exchanged are called **alveoli**.
Gills	The organs in fish where gas exchange takes place. Oxygen is absorbed from the water into the blood, and carbon dioxide is transferred to the water.
Leaves	The plant organs responsible for gas exchange.
Ventilation	Technical term for breathing in and out. Breathing in brings fresh air, with a relatively high oxygen concentration, into the lungs, and breathing out removes the air with a relatively high concentration of carbon dioxide (and low concentration of oxygen).

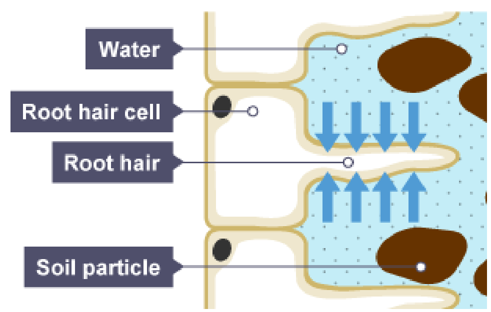


Gas exchange in lungs

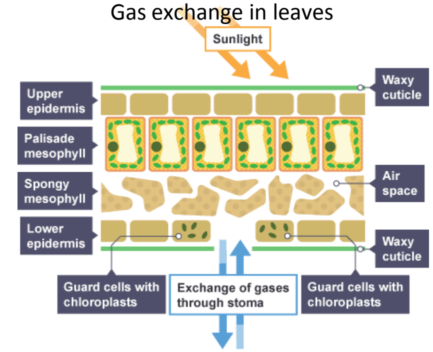


Gas exchange in gills

Substance exchange in roots



Gas exchange in leaves

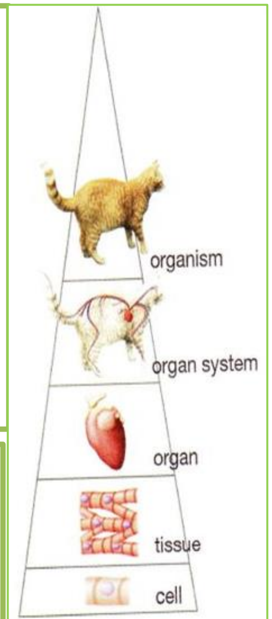


Biology Knowledge Organiser
B2 - Cell division

Unicellular vs. multicellular organisms

Unicellular organisms' bodies are simply one cell. All bacteria and other prokaryotic organisms are unicellular. **Multicellular** organisms are made of many cells and are much more complex. In multicellular organisms, cells **differentiate** to become **specialised cells**, carrying out specific roles in the organism.

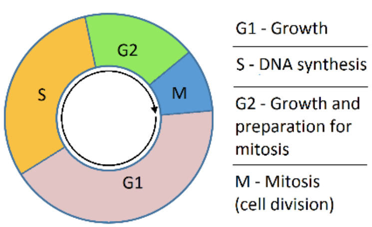
The levels of organisation in multicellular organisms form a **hierarchy**. In biology, hierarchies get simpler as you go down; or more complex as you go up because the upper things are made up of the things below them. The organisational hierarchy in multicellular organisms is shown here.

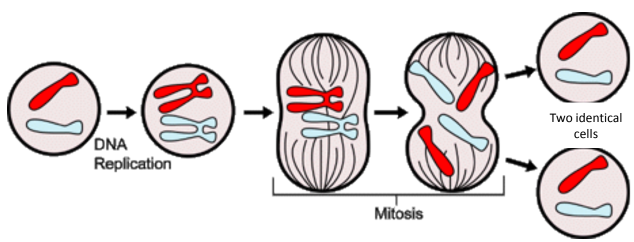


Stem cells

Once cells are specialised, they can't go back to being an unspecialised cell. This is why we all start life as a mass of unspecialised cells, called **stem cells** – this is what an embryo is. Stem cells can divide to make new cells and can differentiate to become specialised cells.

In an young embryo, all the cells are stem cells, so they can be taken, cloned and used to produce any human cells by differentiation.
In adults, there are not many stem cells left – most have differentiated. But there are some, for repair and replacement of specialised cells. For instance, there are stem cells in the bone marrow. These can be collected, cloned and made to differentiate into any type of blood cell. Using stem cells in this way is an active area of medical research, to treat conditions like diabetes and paralysis.





Key Terms	Definitions
Unicellular	Describes organisms formed of only one cell: like all prokaryotic organisms
Multicellular	Describes organisms made of many cells.
Differentiation	The process of becoming a specialised cell. Specialised cells are the result of differentiation of **stem cells**.
Stem cells	Cells that are undifferentiated. Stem cells are capable of forming many more cells of the same type (by cell division), and forming certain types of specialised cell by cell division.
Embryo	A very young multicellular organism, formed by fertilisation. Embryos are made of stem cells.
Cell cycle	The series of stages during which cells divide to make new cells. In the cell cycle, the DNA is replicated (copied exactly) and the cell splits by mitosis into two cells with one set of DNA each.
Mitosis	The specific part of the cell cycle where the cell divides to make two new cells, which are identical.
Chromosome	A structure containing one molecule of DNA. One chromosome contains many genes. In body cells, chromosomes are found in **pairs** (since you inherit one copy of each chromosome from your mother and one copy from your father).

The cell cycle – diagram bottom left

Cells divide to make new cells, for growth and repair, in the **cell cycle**. It isn't as simple as the cell splitting in two: it must prepare before doing that.

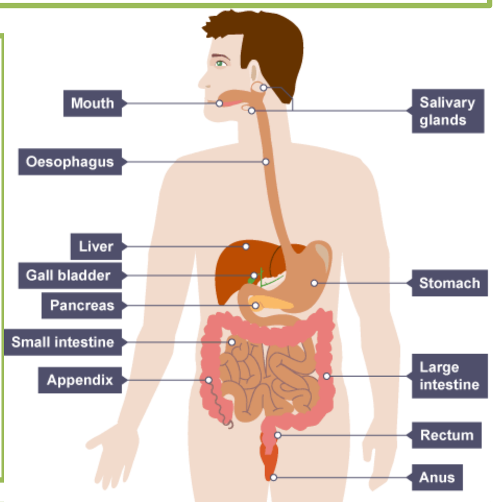
1. The cell grows larger and makes more sub-cellular structures, such as ribosomes and mitochondria. (It makes enough for two cells!)
2. The genetic material (**DNA**) is doubled by making an exact replica of the chromosomes. So, there are two copies of every chromosome at this point (labelled S on the cell cycle diagram).
3. Tiny fibres in the cell pull the copies of each chromosome to opposite ends of the cell, breaking the replica chromosomes apart. This means the nucleus can divide into two, each with the full set of chromosomes.
4. The cytoplasm and cell membranes divide to form two genetically identical cells. This is summarised in the diagram left.

Biology Knowledge Organiser
B3 - Organisation and the digestive system

The human digestive system

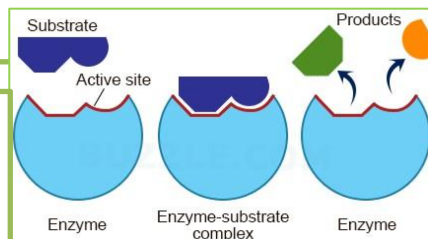
The digestive system breaks down food molecules into molecules our cells can actually use, and absorbs the simpler molecules resulting from digestion. The products of digestion are used to make new molecules we need, and the glucose is used in respiration. It is an **organ system**; the organs of the digestive system are shown on the diagram.

Mechanical digestion occurs in the mouth and stomach especially, where food is physically broken up into smaller pieces. This does not, however, break down the large molecules that our food is made from (carbohydrates, lipids and proteins). That is the role of chemical digestion, which is what enzymes do.



Enzymes and digestion

Enzymes are large proteins; there are many different types. All organisms use enzymes to control chemical reactions (**metabolism**). Enzymes are **catalysts**, so they speed up chemical reactions. They work by having an **active site** with a specific shape. A specific molecule slots into the active site (like a key into a lock) and the reaction takes place. So, the shape of the active site is vitally important, and only one sort of enzyme will work on each substrate. The diagram shows this 'lock and key' model of enzyme action.



Bile

Bile is a vital substance for digestion. It is made in the **liver** and stored in the **gall bladder** before being released into the small intestine just after the stomach. It is **alkaline**, to neutralise the stomach acid and to make the partly digested food pH 8 – the optimum pH for enzymes in the small intestine. It also **emulsifies** fats, meaning it breaks them up into small droplets. This increases the fat droplets' surface area, increasing the rate of digestion by lipase.

Key Terms	Definitions
Enzyme	A biological catalyst that speeds up chemical reactions in living organisms. Enzymes are large proteins.
Digestive enzyme	Enzyme that works in the digestive system, breaking down large food molecules into simpler, smaller molecules for absorption into the blood.
Active site	The part of an enzyme where the reaction takes place. They are very specific in shape, so that a specific substrate fits into the active site.
Denature	To disrupt the shape of the active site of an enzyme. Denaturation happens when the enzyme is at too high a temperature or at the wrong pH for that enzyme.
Substrate	The molecule that fits into an enzyme's active site and reacts to make a product or products.
Carbohydrate	A type of molecule found in all living things. Made of carbon, hydrogen and oxygen. Simple sugars like glucose are carbohydrates, and so are complex sugars like starch – in fact, starch is made of many glucose molecules joined up.
Lipid	Scientific name for fat. Lipids are made up of **glycerol** and **fatty acids**. Made mainly of carbon and hydrogen (+ oxygen).
Protein	Type of molecule made from **amino acids**. Proteins in the body can be **structural** (e.g. muscle is made mainly of proteins) or **metabolic** (control chemical reactions – e.g. enzymes). Made mainly of carbon, hydrogen, oxygen and nitrogen.
Optimum	The ideal temperature or pH for enzymes to work.

Digestive enzyme	Site of production	Site of action	Substrate	Product
Carbohydrase - e.g. amylase	Salivary glands, pancreas and small intestine wall	Mouth, small intestine	Complex carbohydrates - e.g. starch	Simple sugars - e.g. glucose
Protease	Stomach, pancreas, small intestine wall	Stomach, small intestine	Proteins	Amino acids
Lipase	Pancreas, small intestine wall	Small intestine	Lipids	Glycerol and fatty acids

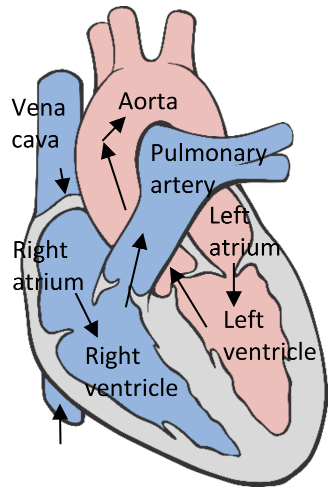
Biology Knowledge Organiser
B4 - Organising animals and plants

The heart

The heart is an organ whose role is to pump blood around the body. In humans and other mammals, the heart is part of a **double circulatory system**. This means the blood goes through the heart twice on its route around the body. It goes: right side of heart → lungs → left side of heart → body (and back to the heart again).

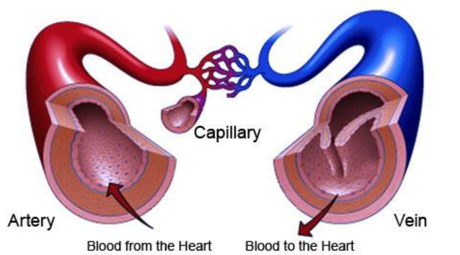
Learn the labelled parts of the heart. The arrows show the direction of blood flow. The heart walls are made mainly of muscle – when the heart 'beats', the muscle contracts to pump the blood.

The natural resting heart rate is controlled by a group of cells in the right atrium that act as a **pacemaker**. These cells set off the impulses that make the heart muscle contract. If there is a fault in the heart and the heart rate is irregular, an **artificial pacemaker** can be fitted to correct these irregularities.



Blood vessels

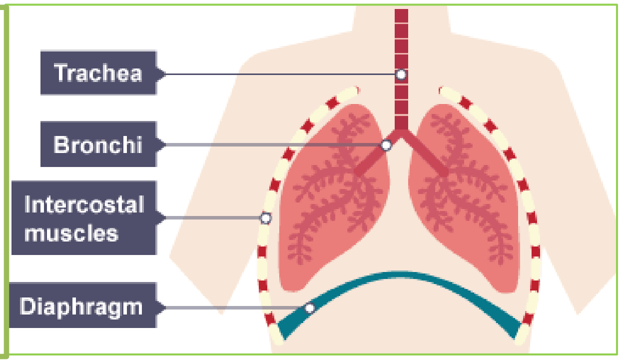
Blood is restricted to blood vessels in the body (unless you cut yourself!). There are three types: **arteries**, **capillaries** and **veins**. Blood being pumped by the heart always travels in the order arteries → capillaries → veins and veins return the blood to the heart. Arteries carry the blood at high pressure, so they have **thick, elastic** walls. Capillaries are where **exchange** takes place, so their walls are **only one cell thick** (for a *short diffusion pathway*). Veins carry the blood back to the heart at low pressure, so their walls are thinner than arteries (much thicker than capillaries though). However, to prevent blood flowing back the wrong way, veins have **valves** in them, which you can see on the diagram.



Key Terms	Definitions
Ventricles	The larger chambers in the heart. The right ventricle pumps blood to the lungs; the left ventricle pumps blood around the whole body.
Atria	Smaller chambers of the heart. These fill with blood from the vena cava and pulmonary vein, then pump the blood into the ventricles.
Aorta	The artery leaving the left ventricle. It branches off to supply, in the end, every cell of the body with blood.
Vena cava	The major vein transporting blood from the whole body back to the heart (to the right atrium)
Pulmonary artery	The blood vessel leaving the right ventricle, carrying blood to the lungs.
Pulmonary vein	Vein leading from the lungs back to the heart (to the left atrium).
Artery	Blood vessel that carries blood away from the heart, at relatively high pressure.
Capillary	Very small, thin-walled blood vessel where exchange of substances between the blood and body cells takes place.
Vein	Blood vessels that return blood to the heart at relatively low pressure. Only these vessels have **valves** in them.
Coronary blood vessel	The heart muscle needs its own blood supply. This comes from branches from the aorta as soon as it leaves the heart called **coronary** arteries.

The lungs

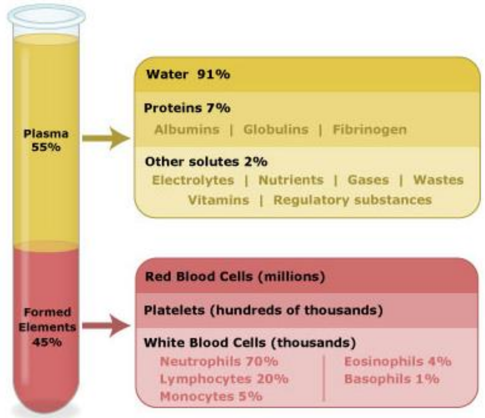
The lungs are the organs responsible for gas exchange in humans and other mammals. Air flows in while breathing in, through the **trachea** (windpipe), through the **bronchi** to each lung, and eventually to the **alveoli**, that you've looked at before. Muscle contraction allows us to breathe in – the **diaphragm** and **intercostal muscles** contract. When they relax, we breathe out.
The lungs are adapted for efficient gas exchange with their short diffusion pathway, huge surface area, and good blood and air supplies.



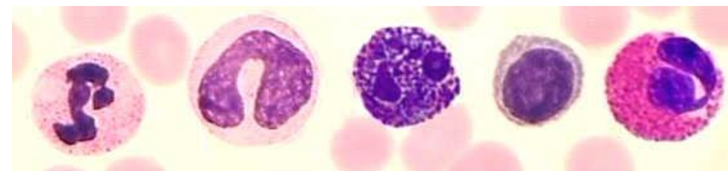
Biology Knowledge Organiser
B4 - Organising animals and plants

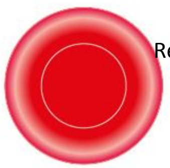
The blood

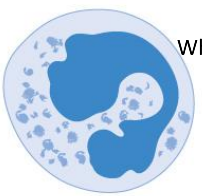
Blood is a tissue. When separated into the component parts as a the diagram shows, we find that just over half of it is made up of plasma. The cells components (mostly red blood cells) are **suspended** in the plasma – meaning they are normally mixed evenly throughout the plasma. The majority of the cell parts is made up of red blood cells, which transport oxygen. The other components are white blood cells and platelets.



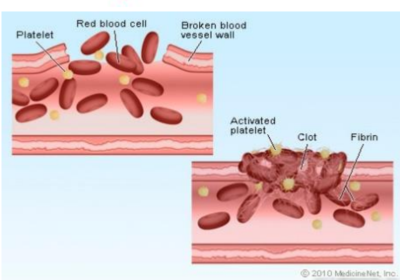
Key Terms	Definitions
Plasma	The liquid part of the blood, mostly made of water, but with substances like glucose, proteins, ions and carbon dioxide dissolved in it.
Red blood cells	Disc-shaped cells that contain **haemoglobin**, which can bind to oxygen, so it can be transported from the lungs to tissues.
White blood cells	Cells in the blood that fight infection caused by pathogens.
Platelets	Fragments of cells that cause clotting of blood at a wound, to reduce blood loss.
Clot	A solid clump of blood formed when there is an injury.




Red blood cell


White blood cell


Platelet



Red blood cells

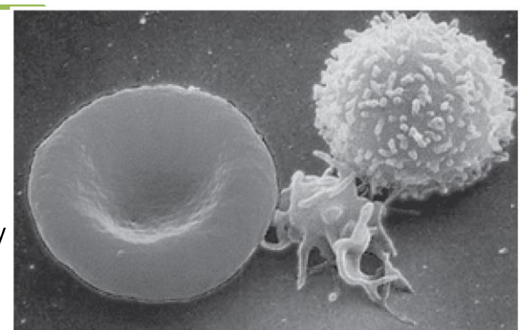
As you can see in the photograph (taken with a microscope of course!), red blood cells are disc shaped and have a concave surface on each side. This increases their surface area for absorbing and transporting oxygen from the lungs to body tissues. Red blood cells are unusual in that they don't have a nucleus or other organelles. This makes more room for **haemoglobin** – the red-coloured chemical that oxygen actually binds to for transport.

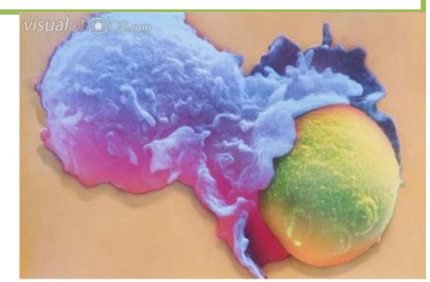
White blood cells

There are actually numerous types of white blood cell, as the photo shows, but they are all part of the immune system and fight communicable disease (disease caused by **pathogens**). They all have large nuclei, because they are very active cells. They can also change shape, which is useful because they can get out of the blood (through tiny gaps in the walls of capillaries) and so they can **engulf** microorganisms – like the photo below of a white blood cell engulfing a yeast cell.

Platelets

Platelets are *fragments* of cells – produced deliberately by your body (they aren't simply broken cells!). The photograph here shows a platelet between a red blood cell and a white blood cell. Their role is to initiate (start off) the process of **clotting** at a wound, as shown in the diagram to the left. They create a clot, which blocks the injury in the blood vessel until proper healing can happen, preventing excessive blood loss.





Biology Knowledge Organiser
B4 - Organising animals and plants

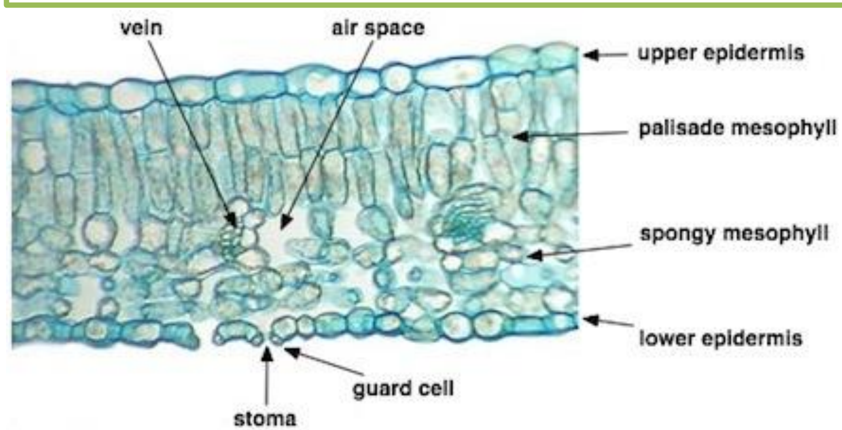
Plant tissues in the leaf and transpiration

Look at the key terms and definitions for the key types of plant tissue. Leaves are **organs** in plants that contain many of those types of tissue. Together with the stem and roots, they form an **organ system** for transport of substances around the plant. The photograph shows the **transverse section** of a leaf – a thin slice through the leaf, looking edge-on.

The **vein** contains the xylem and phloem vessels. The **stomata** (singular: stoma) are the holes through which gases are exchanged. This includes water vapour. Plants absorb **all** their water in the roots (you've already looked at root hair cells), and keep water moving constantly through by losing water as vapour from the leaves. The constant flow of water up the plant is called the transpiration stream. This loss of water vapour from the leaves is called **transpiration**. Transpiration is sped up by:

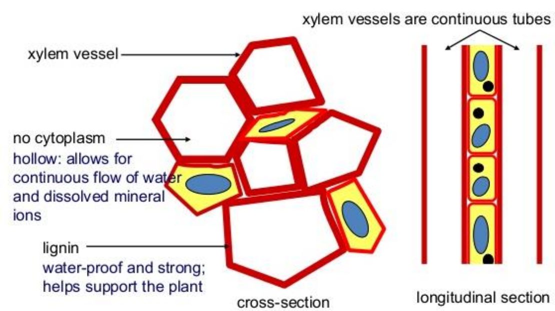
- a *higher temperature*, since water molecules have more kinetic energy so diffusion out of stomata is faster
- *Lower humidity* (drier air), since there is a steeper concentration gradient if the air outside the plant is relatively drier than the air in the air spaces
- *Higher air flow* (being windier!), since this refreshes the concentration gradient all the time, as water vapour is blown away from the leaves
- *Higher light intensity*: this increases the rate of photosynthesis, which uses water, so water flows more rapidly up through the plant.

Key Terms	Definitions
Epidermal	Type of plant tissue that covers the surface of a plant
Palisade mesophyll	Tissue in the leaf where photosynthesis takes place
Spongy mesophyll	Tissue in the leaf with air spaces between cells – specialised for gas exchange
Xylem	Narrow tubes in the roots, stem and leaves, which transport water and mineral ions up the plant from the roots
Phloem	Other tubes that run alongside xylem, but transport sugars dissolved in water instead – a process called **translocation**
Meristem	Type of tissue found at growing tips of roots and shoots, containing stem cells so they can differentiate into different sorts of plant cell
Guard cell	In pairs, guard cells form the stomata on leaves – the holes through which gases are exchanged. They can open and close the stomata as required by the plant.
Transpiration	The process by which plants lose water, as vapour, from their leaves through the stomata.



Stomata, guard cells and transpiration

Stomata must be open at least some of the time, to allow carbon dioxide to enter the leaf for photosynthesis. However, guard cells can control how many stomata are open, and how wide open they are. This is useful in dry conditions, because the plant can conserve water instead of losing lots of it through transpiration.



Xylem and Phloem

Xylem tissue is made of hollow tubes, formed from the cell walls of dead cells, and strengthened by a substance called **lignin**. The diagram shows their adaptations to the function of transporting water and minerals.

Phloem, on the other hand, is a tissue made of living cells. They are elongated and stacked to form tubes. Phloem tubes transport food – dissolved sugars – made in the leaves to other parts of the plant, for use in respiration or for storage. The sugary substance they transport is called cell sap, and its transport is called **translocation**. Cell sap flows from one phloem cell to the next through **pores** (holes) in the ends of the cells.

Biology Knowledge Organiser
B5/7 - Diseases

Cancer – a non-communicable disease

Cancer is a non-communicable disease. There are many types of cancer, but they all involve changes in cells (**mutations**) that lead to the cells growing and dividing in an uncontrolled way. Normally, the **cell cycle** (see topic 6) controls cell growth and division, so the body only replaces lost cells. However, in cancer, the control mechanisms are broken and cells divide out of control, producing a mass of cells called a **tumour**.

- **Benign tumours** are growths of abnormal cells, but these do not invade other parts of the body. This is because the tumour is restricted to one area and often surrounded by a membrane. This makes them much less dangerous than **malignant tumours**.
- **Malignant tumours** cause cancer as you'd normally think of it. The cells grow out of control and invade nearby tissues. When mutated cells break off the tumour and get into the bloodstream, the cancer can spread around the body. The mutated cells can then cause more tumours, elsewhere. These are called **secondary tumours**.

In terms of risk factors for cancer, some are very clearly identified (like smoking as a risk factor for lung cancer). There can be **genetic** risk factors for some types of cancer (so the risk factor is inherited from the parents).

Communicable diseases and pathogens

Communicable diseases are sometimes called infectious disease, since they always result from an infection by a **pathogen**. All organisms can be infected by pathogens, so all organisms can suffer from communicable diseases (yes, including plants, and even bacteria can be infected by viruses!). You need to know details of specific diseases (next page), but here is a general description of how each kind of pathogen causes disease:

- **Bacteria** can cause disease if they enter our bodies. They **reproduce** rapidly and can release poisonous chemicals, called **toxins**, that damage our cells. Examples of diseases caused by pathogenic bacteria include cholera, tuberculosis (TB) and food poisoning.
- **Viruses** need a host to survive. They cause disease symptoms by reproducing **inside** cells, and bursting the cell from the inside. This releases them, so they can be passed onto other host cells or other people (e.g. by coughing or sneezing out mucus that contains the viruses).
- **Fungi** can also cause disease, by growing on living tissue (for example, athlete's foot is caused by a fungus).
- **Protists** can cause disease, as they can live in host organisms. A good example is the malarial protist, that causes malaria.

Key Terms	Definitions
Mutation	Change to DNA, altering its function (this is not necessarily dangerous). In cancer, a specific mutation causes cells to divide uncontrollably.
Protist	Whole kingdom of organisms, including some that cause disease.
Transmission	The passing of a pathogen from one organism to another, leading to the spread of communicable (infectious) disease.
Host	The organism that a pathogen lives in or on. When you have a cold, you are the host for the cold virus.

Spread of communicable diseases is caused by the transmission of pathogens

A big problem with pathogens is that they can be passed from one host to another, so the disease they cause can spread. See the table for the methods by which pathogens can be **transmitted**.

We can attempt to reduce the transmission of pathogens by: vaccinating people; destroying vectors (e.g. killing mosquitos with pesticides); being hygienic (i.e. washing our hands!); isolating people who are infected in special hospital wards.

Direct types of transmission	Indirect types of transmission
Direct contact e.g. shaking hands or kissing	A vector (animal) carries the pathogen e.g. mosquitos carry the pathogen that causes malaria
Sexual contact	Droplet infection: droplets of mucus containing a pathogen are sneezed or coughed out by an infected person, and breathed in by someone else. We can also say the pathogen is airborne.
From mother to foetus over the placenta	Waterborne – the pathogen infects water and moves between people when they drink the water

Biology Knowledge Organiser
B5/7 - Diseases

Health and disease

Health is the state of physical and mental wellbeing. So, 'good health' involves good physical and mental wellbeing. 'Poor health' involves problems with one or both aspects. Diseases are major causes of ill-health. Diseases can be classified as **communicable** (can be passed on, as they are caused by **pathogens**) and **non-communicable** (cannot be passed on). Other factors affect health: such as diet, lifestyle, stress, and genetic inheritance, for instance. Often, ill-health is caused or made worse by an interaction of different factors. Some examples:

- If their immune system has a defect, someone is more likely to suffer from communicable diseases, since their body will be worse at fighting pathogens.
- Some viruses, which live inside cells, can trigger cancers. For instance, the HPV virus can trigger cervical cancer (hence the vaccine in year 9 for girls).
- Severe physical health problems can lead to mental health problems, such as depression.
- Immune reactions to infection by a pathogen can trigger allergic reactions, like skin rashes or asthma.

Non-communicable diseases (B7 - Non communicable diseases)

Diseases that are **not** caused by pathogens – non-communicable diseases – are often linked to many different **risk factors**, and these factors may interact to increase the risk. These risk factors may come from someone's lifestyle, or from substances in their body or substances in their environment. In some cases, the link between a risk factor and a particular disease is very clear: we know the risk factor *actually causes* the disease. For other risk factors, we know the linked diseases but not really how the risk factor causes them.

Here are some causal links we do know:

- ➢ Poor diet, lack of exercise and smoking have a proven link to **cardiovascular disease**.
- ➢ Obesity can cause type 2 diabetes.
- ➢ Alcohol causes liver damage and damages brain function.
- ➢ Smoking causes lung cancer and other lung diseases (like emphysema).
- ➢ Smoking and drinking alcohol during pregnancy causes problems in unborn babies.
- ➢ Carcinogens, such as *ionising radiation* (next topic), can cause cancer.

It is important to realise that while these risk factors are real, they don't guarantee the disease. E.g. not ALL obese people will get type 2 diabetes; however, being obese greatly increases the risk of developing the disease.

Key Terms	Definitions
Disease	Any condition that reduces health/causes ill-health.
Communicable	Type of disease that can be passed on. These diseases are caused by **pathogens**, such as viruses. Be clear that the pathogen is the microorganism, and the disease is the collection of symptoms resulting from infection by the pathogen.
Non-communicable	Describes diseases that are not caused by pathogens and cannot be passed on. These are often caused by many factors acting together, known as **risk factors** for the disease.
Pathogen	A microorganism that can infect another organism (a host) and cause disease in that organism. E.g. bacteria and viruses.
Risk factor	Any factor that increases the chance of developing a non-communicable disease, such as smoking or diet.

Using data to discover risk factors

Risk factors aren't always obvious: it requires scientific research to find out what factors are linked to what disease. For many years, people smoked cigarettes thinking it was perfectly healthy (including doctors!). However, research by a scientist called Richard Doll showed that increased use of tobacco in the UK was linked to increased **incidence** of lung cancer (incidence is just how many people get it), as the graph shows (from his 1950 publication). He **sampled** the population and found this **correlation** between the risk factor (smoking) and the disease (lung cancer).

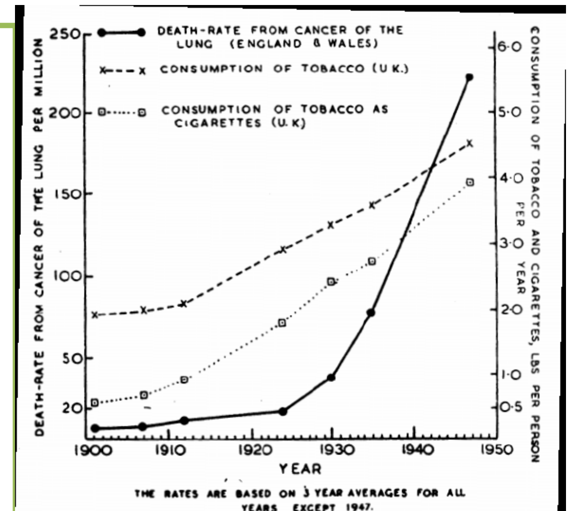


FIG. 2.—Death rate from cancer of the lung and rate of consumption of tobacco and cigarettes.

Biology Knowledge Organiser
B5 - Communicable diseases

Viral diseases

Measles is caused by a virus. It is spread by droplet infection: you'd catch it if you inhaled the droplets containing the virus that someone infected coughed or sneezed out. The symptoms include **fever** and a **red rash on the skin**. Measles is a serious disease – it can even be **fatal** if there are complications. So, most young children are vaccinated against measles.

HIV is a virus that can only be spread by exchange of body fluids: sexual contact or when blood is mixed – which can happen when *intravenous drug users* share needles. HIV cannot be transmitted by kissing or by droplet infection. Infection with HIV causes flu-like symptoms first, but these go away after a couple of weeks. However, the virus has not gone from body – it is living inside immune cells (white blood cells). HIV is NOT the same thing as AIDS, but AIDS can arise from infection by HIV unless treatment takes place. The treatment is **antiretroviral drugs** (so called because HIV is a type of virus called a retrovirus). Without this treatment, AIDS will occur. Here, the body's immune system is so badly damaged it cannot fight off other infections or cancers – so it is very serious.

Tobacco mosaic virus (TMV for short) is a pathogen affecting **plants**. In spite of its name, it affects many species of plant (including tomatoes – see photo). TMV causes discolouration of the leaves, giving a mosaic pattern. This hinders photosynthesis, so plants don't grow very well if they are infected by TMV.

Bacterial diseases

***Salmonella* food poisoning** is caused by a bacteria found in food, or on food where it is prepared in unhygienic conditions. The bacteria can be found in poultry (e.g. chickens), so these animals are **vaccinated** against *Salmonella* to reduce the spread of the pathogen. Inside the body, the bacteria reproduce and produce **toxins** which cause disease. **Symptoms** of *Salmonella* food poisoning include: fever, abdominal cramps, vomiting and diarrhoea.

Gonorrhoea is the name of a **sexually transmitted disease** (STD or STI), rather than the name of the pathogen. The pathogen is a bacterium that is transmitted by sexual contact, so transmission can be prevented with a barrier-type of **contraception**, like a condom. The symptoms include a thick yellow or green discharge from the vagina or penis and pain when urinating (weeing). It used to be that gonorrhoea was easily treated with an **antibiotic** (penicillin, in this case), but there are now many **resistant strains** of bacteria that cause gonorrhoea. (Resistant strains are species of the bacteria on which certain antibiotics do not work.)

Key Terms	Definitions
Fever	Disease symptom linked to raised body temperature, thanks to disruption of the normal homeostasis mechanisms.
HIV	Human Immunodeficiency Virus. A virus that uses immune cells as host cells. HIV infection causes AIDS, but if treated properly, AIDS will never develop in an infected individual.
AIDS	Acquired Immunodeficiency Syndrome. A condition in which the immune system is seriously weakened due to infection by the HIV virus.
Salmonella	A genus of bacteria that can cause food poisoning.
Discharge	A substance being produced by the body that should not be there – a sign of disease.

Fungal diseases

Rose black spot is a fungal disease that affects plants. It causes purple or black spots to develop on leaves (hence the name – see picture). The whole leaf often turns yellow and drops early (i.e. before autumn). Like TMV, the plant's growth is inhibited because the rate of photosynthesis is reduced. The fungus is spread on the wind or in water, transmitting the pathogen to other plants. Treatment options: remove the affected leaves, or use a **fungicide** (a chemical that kills fungi).

Protist diseases

Malaria is a disease caused by a *protist* (see topic 6 for a reminder). The protist has a life cycle that requires it to live inside a **mosquito** for some of the life cycle, and in the body of a mammal – like a human – for other stages of the life cycle. In the mosquito, the protist is found in the salivary glands, which is why the protist can be transmitted to a person when the mosquito sucks their blood. The mosquito acts as a **vector**. In the human, the protist causes malaria. Symptoms include recurrent (repeating) **fever** and malaria can be **fatal**. We can attempt to reduce transmission by targeting the mosquitos: preventing them breeding and avoiding bites using **mosquito nets**.

Biology Knowledge Organiser
B5 - Communicable diseases - Triple science only

Culturing (growing) microorganisms

If conditions are right (correct temperature, plenty of nutrients etc.), bacteria can double their population as often as every 20 minutes. This is because each bacterial cell can make two cells this often, through **binary fission**. It is often useful to deliberately grow microorganisms: for example, to investigate antibiotics or disinfectants. However, you want to only grow the type of microorganism you are trying to study. Without proper care, your **culture** is easily **contaminated**, because there are microorganisms everywhere in the environment. 'Proper care' involves using **aseptic technique**.

Aseptic technique to prepare an uncontaminated culture

Here's how to prepare an uncontaminated culture:

1. Sterilise the Petri dishes and **culture media**. This ensures that there are no microorganisms present at the start.
2. **Inoculating loops** are used to transfer bacteria to the culture medium. These loops are passed through the flame of a Bunsen burner to sterilise them before collecting the bacteria you want to study.
3. After transferring the bacteria under study to the culture medium, the lid of the Petri dish is secured on with tape to prevent other microorganisms from entering. It is stored upside down to prevent condensation flooding the bacteria.
4. The culture is incubated (in schools at 25°C) to allow the microorganisms to grow.

Looking at the results

On the agar plate, bacteria can grow as circular **colonies** or as a **lawn**. The colonies tend to be circles, so you can find their cross-sectional area using $A = \pi r^2$ (area of a circle equation). See first photo for examples of colonies.

On the second photo, a lawn culture has been grown. The small white discs of paper placed on the lawn were soaked in solutions of antibiotic or disinfectant. The antibiotic/disinfectant diffuses into the agar gel and, if it works, it kills the bacteria nearby. This leaves a clear area on the agar plate. Again, the clear area can be calculated since they are circular. The larger the clear area, the more effective the antibiotic/disinfectant on the type of bacteria that's been grown.

Key Terms	Definitions
Culture	A population of microorganisms that has been deliberately grown to study.
Binary fission	How bacteria multiply. One bacterial cell divides into two, forming two identical cells.
Contamination	When unwanted bacteria (or other microorganisms) mix in with the bacteria you are trying to grow.
Aseptic	Without contaminating microorganisms
Culture medium	Substance on which microorganisms are grown, which provides them with nutrients. E.g. agar gel, nutrient broth.
Inoculating loop	Equipment used to transfer microorganisms (e.g. bacteria) to a culture medium for growth and study.
Agar plate	A Petri dish filled with agar gel.
Colony	A population of bacteria. Colonies look like circles of growth in an agar plate.
Lawn culture	An agar plate spread evenly with bacteria. This is useful for testing antiseptics/antibiotics.
Mean division time	The average time it takes for a type of bacteria to divide once, under certain conditions.

The size of bacterial populations

If you know how quickly bacteria divide (mean division time) and how long they've been incubated, you can calculate the population size by working out how many division cycles have occurred.
e.g. the mean division time = 20 min and they've been incubated for two hours. 6 cycles of division have occurred. Say we started with 1 cell. 1 → 2 → 4 → 8 → 16 → 32 → 64, or $2^6 = 64$. When the numbers get very large, standard form is useful.

Biology Knowledge Organiser
B6 - Preventing and treating disease

Monoclonal antibodies

Antibodies are natural tools for recognising specific molecules. This property can be fantastically useful. Monoclonal antibodies are copies of the same antibody, produced in a lab for a specific purpose. Here's how they are made: (also see diagram at bottom of page)

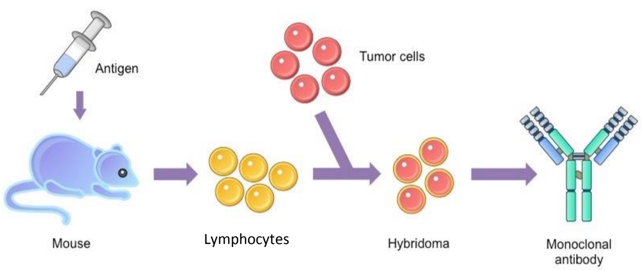
1. Mouse **lymphocytes** are stimulated to make a specific antibody, by giving them a specific antigen
2. These lymphocytes are combined with a type of tumour cell to make a **hybridoma** cell.
3. Like other cancer cells, this hybridoma cell can divide rapidly. It also makes the antibody that is desired.
4. The hybridoma cell is cloned, to there are many identical copies all making the same antibody.
5. After a large amount has been made, the antibody is separated from the cells for use.

Using monoclonal antibodies

There are dozens of uses for monoclonal antibodies: the thing to remember is that they are used when a specific molecule needs to be recognised. Examples to know:

- **Pregnancy tests** use monoclonal antibodies that specifically bind to a hormone made in the placenta – which is only present in pregnant women.
- Lab tests for levels of specific chemicals in blood samples, or to detect specific pathogens.
- To **identify specific molecules** in a cell or tissue. One way to do this is to attach a fluorescent dye to the antibodies, so under a microscope you can see exactly where the specific molecule is located in the cells/tissues.
- **Disease treatment**, although not commonly. Monoclonal antibodies can have drug molecules attached to them, and because they only bind to certain antigens you can get them to stick to cancer cells ONLY – so the chemotherapy hits the tumour, but not the healthy cells of the body. Smart.

Although there's great promise, using monoclonal antibodies in medicine is not so widespread – there are quite a few side effects. They are also expensive to produce.



Key Terms	Definitions
Monoclonal	All the same, due to all coming from cloned cells
Antibody	Protein molecule made by white blood cells to fight pathogens. Each antibody is specific to one antigen.
Antigen	A molecule found on the surface of cells (or viruses), often made of protein. Antibodies, if they are the right sort, bind to antigens.
Bind	Stick to, due to having shapes that fit together.
Lymphocyte	Type of white blood cell that makes antibodies.
Chlorosis	Yellowing of leaves.

Plant diseases

Obviously a plant can't tell you when it is sick. But some easy signs can indicate disease:

- Stunted growth (which may be caused by deficiency in **nitrates**, since nitrates are needed to make protein)
- Spots on leaves
- Areas of decay
- Growths that shouldn't be there (like tumours)
- Malformed stems/leaves
- Discolouration (including **chlorosis**, which is caused by a deficiency in magnesium – since magnesium is used to make chlorophyll)
- Presence of pests

If you see these dreadful signs, you could identify the specific disease by:

- Checking your gardening books/websites
- Taking infected plants to a lab to identify the pathogen
- Using testing kits containing **monoclonal antibodies**!

Plant defences against disease, or against getting eaten

Plants can prevent invasions by microbes with physical defences, such as:

- Cellulose cell walls
- The tough waxy cuticles on their leaves
- Layers of dead cells (e.g. bark) around stems that can be shed (fall off)

Plants also have chemical defences, including:

- Antibacterial chemicals
- Poisons to stop herbivorous animals from eating them

Plants also have mechanical adaptations to defend themselves:

- Thorns and hairs to deter animals from eating them
- Leaves which droop or curl up when they are touched
- **Mimicry** to trick animals into thinking they are poisonous/bad to eat

Biology Knowledge Organiser
B6 - Preventing and treating disease

Human defence systems

Pathogens are all over the place, so humans have evolved defence systems to deal with them. We have **non-specific defences**, which keep pathogens from entering the body (although, of course, they can fail to do this – otherwise you'd never get sick!). If pathogens do get in, we have the **immune system**, which destroys the pathogen inside the body.

Non-specific defences:

- The **skin**! Our main barrier against pathogens getting in. The vast majority of pathogens cannot get through the skin at all – they have to enter somewhere else. Also, the skin scabs over to provide a quick barrier if there is a cut or wound.
- The **nose** has hairs and mucus to trap microorganisms so they don't get any further than the nose. If you don't blow your nose, the mucus ends up in the back of the throat and you swallow it – this is harmless, because the stomach acid kills any microorganisms in there.
- The **trachea** and **bronchi** also contain mucus. This traps microorganisms that are breathed in, and the mucus, again, can be swallowed harmlessly.
- The **stomach** produces hydrochloric acid (at pH 2), which kills most microorganisms that are swallowed.

The immune system responds if pathogens enter the body properly – i.e. if they get into the bloodstream. The most important cells in the immune system are the white blood cells. They help defend against pathogens by:

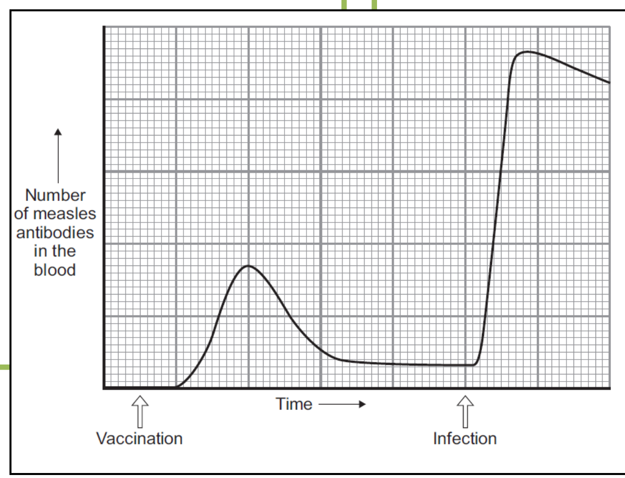
- **Phagocytosis**. This is the *engulfing* and *digesting* of pathogens by white blood cells, destroying the pathogens.
- **Antibody production**. White blood cells produce chemicals called antibodies that bind to pathogens and destroy them. These are *specific*, meaning only one particular antibody type will bind to one particular pathogen.
- **Antitoxin production**. Some pathogens, especially bacteria, produce poisonous toxins. These are neutralised by antitoxins – another sort of chemical produced by white blood cells. Again, antitoxins are specific to specific toxins.

Key Terms	Definitions
Defence systems	Structures and mechanisms we have to prevent pathogens entering the body, and to fight them off if they do enter. Includes non-specific defences (act on any pathogen) and specific defences (target the particular pathogen you've been infected by).
Mucus	A sticky substance produced by many epithelial (surface-covering) tissues in the body, to trap dust particles and microorganisms so they can't enter the body.
Antibody	Chemical produced by white blood cells that destroys specific pathogens.
Antitoxin	Chemical produced by white blood cells that neutralises specific toxins.

Vaccination

Vaccination is great on two fronts: it stops the vaccinated individual from getting ill AND it helps prevent the spread of communicable diseases. If a large proportion of the population is vaccinated, it is very unlikely that an *unvaccinated* person would be exposed to the pathogen, so everyone is protected.

1. A vaccine contains a small quantity of a **dead or inactive** form of a **pathogen** (usually a virus, such as the measles virus – see graph).
2. Delivering a vaccine stimulates a **primary** immune response. White blood cells produce antibodies to destroy the pathogen, but this is slow.
3. Specialised white blood cells (memory cells) remain in the blood afterwards.
4. This means that if an infection by the real pathogen takes place in the future, there is a **secondary** immune response by the white blood cells, which is *quicker* than the primary immune response.
5. The secondary immune response starts faster (see graph), involves the production of far more antibodies (a *stronger* response) and the level of antibodies stays higher for longer.
6. This means the pathogen is destroyed before you even realise you are ill.



Biology Knowledge Organiser
B6 - Preventing and treating disease

Treating disease with drugs

Despite our non-specific defences and our immune systems, we still get sick due to communicable diseases. Fortunately, we've developed a huge range of drugs to treat diseases. (Drugs and medicines are synonymous; we can also say 'medical drugs' to mean those that treat disease rather than drugs taken for recreation.)

Antibiotics

Antibiotics have only been produced since the 1940s, but they have changed the world in that time. The first antibiotic was discovered (not made – it was produced by a fungus!) by Alexander Fleming. He found that a fungus called *Penicillium* worked to kill bacteria he was growing in an agar plate. Named for the fungus that produced the chemical, this was the first antibiotic: penicillin. It is still used today.

Antibiotics treat **bacterial** diseases **only**, because they kill pathogenic bacteria in the body. In this way, they can cure bacterial diseases. Antibiotics are *specific* – so you need to use the right antibiotic to kill the particular bacteria that has infected you. So, antibiotics have saved millions of lives, by successfully treating people with bacterial infections. However, a big issue with the use of antibiotics is that many strains (types) of **resistant bacteria** have emerged (more on this in topic 16).

Antibiotics CANNOT kill viruses, so cannot treat viral diseases. Since viruses live *inside* host cells, it is very difficult to kill viruses without also damaging the body tissues they live in.

Painkillers

Painkillers are examples of medical drugs that treat the **symptoms** of disease, without actually getting to the cause and killing the pathogens. An example is **aspirin**, a painkiller that was first extracted from the bark of willow trees.

Discovering new drugs

There is a constant demand for new drugs – for better treatments, to treat diseases without any current cures, and to deal with antibiotic resistance. Chemicals that *might* work as effective drugs are constantly being discovered or synthesised in labs. Many drugs were discovered in living organisms: e.g. the heart drug **digitalis** originates from **foxgloves**. There are other examples above. However, any of these newly discovered/made chemicals must be thoroughly tested before they can be used in humans.

Key Terms	Definitions
Drug	Any chemical that causes chemical changes in the body. Most drugs are medical – used to treat disease.
Antibiotic	Type of drug that treats bacterial disease by killing pathogenic bacteria.
Antiretroviral	Type of drug that *can* kill viruses: these are used to treat infection by HIV.
Painkiller	Drug that only treats the symptoms of disease, rather than killing pathogens.
Symptoms	Problems with the body arising from disease and indicating that there is a disease. E.g. coughing, headaches, vomiting.
Toxicity	From 'toxic', toxicity means how harmful a drug is to healthy body tissues.
Efficacy	How well a drug actually treats the disease it is designed to treat.
Dose	How much of a drug is given to a patient, and how many times a day and so on.

Development and testing of new drugs

New chemicals, potential medical drugs, are tested to find out if they are **safe** and **effective** (they actually treat the disease they are supposed to!). There are many stages to this testing. We refer to the part before giving the drug to humans as 'preclinical testing' and to the stages where humans received the drugs as ' clinical trials'. Together, these stages tell us about the drug **toxicity, efficacy** and information about the **dose** that should be given. Here's the sequence:

1. **Preclinical testing** is in a lab. The drug is tested on cells and tissues grown for drug testing, and on animals like rats bred for drug testing. This checks that the drug is not toxic, and can give information about efficacy too.
2. **Clinical trials** are tests on humans. First, new drugs are given in very low doses to healthy volunteers, to check that they are not toxic and don't cause major side effects.
3. If the drug is safe, clinical trials using people with the disease take place. These trials test how well the drug works for the disease, and identifies the optimum dose.

In any clinical trial, **double blind** testing is often used. Some patients are given a **placebo** (fake version of the drug), and neither scientist/doctor or patient know who has the placebo and who has the real drug until afterwards. This ensures that effects due to people's expectations can be ruled out.

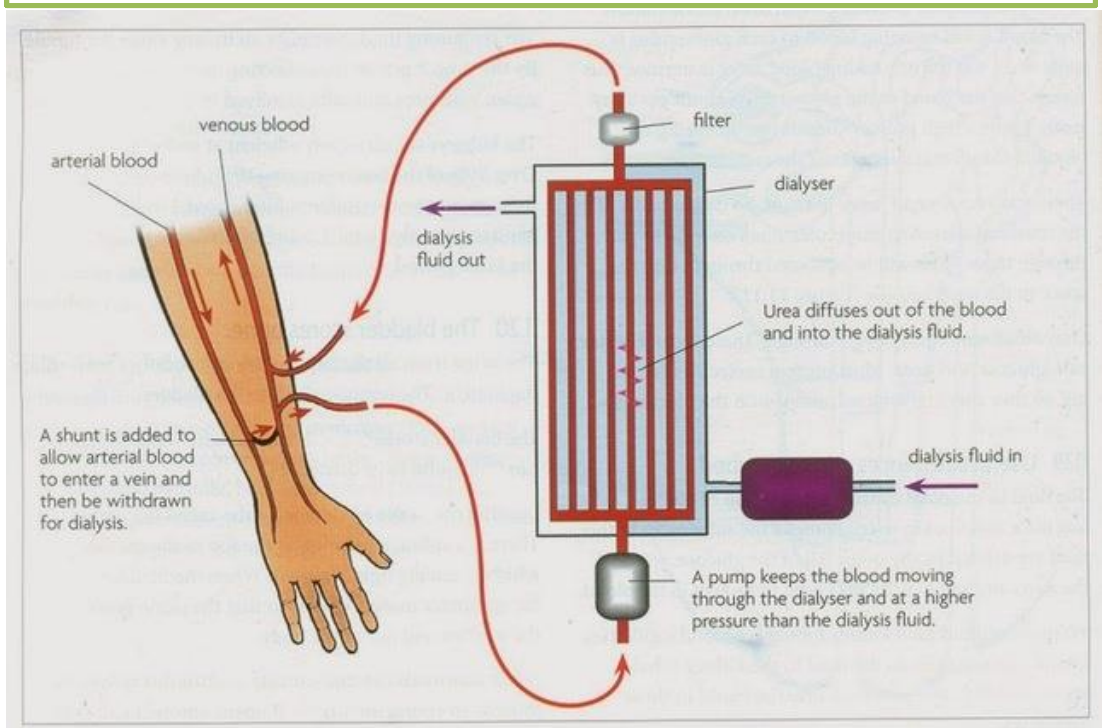
Biology Knowledge Organiser
B7 - Non-communicable diseases

Kidney failure

If they kidneys fail, it is extremely dangerous. Kidney failure can be treated by a kidney **transplant** or using kidney **dialysis.** A transplant has the benefit for the patient of not needing to spend lots of time on a dialysis machine. However, they need to take **immunosuppressant drugs** to prevent rejection of the transplanted kidney. These leave them more susceptible to infections.

Dialysis machines keep people with kidney failure alive because they filter the blood for them. However, the patient would need to spend many hours a week connected to the machine to prevent urea reaching unsafe levels in the bloodstream.

The dialysis machine works as shown in the diagram. Notice that inside the machine, there is a large surface area to increase the rate of diffusion of urea out of the bloodstream.



Key Terms	Definitions
Dialysis	Treatment for kidney failure, in which a machine filters toxic substances from the blood instead of the kidneys.
Diabetes	Condition where blood glucose concentration is not controlled properly by the body.
Insulin	The hormone, produced in the pancreas, that reduces blood glucose concentration by making cells absorb glucose from the blood.
Immunosupp-ressant	Type of drug that reduces the responses of the immune system. This makes sure that 'foreign' organs (like a transplanted kidney) are not fought by the immune system – a situation called rejection.

Diabetes – a non-communicable disease

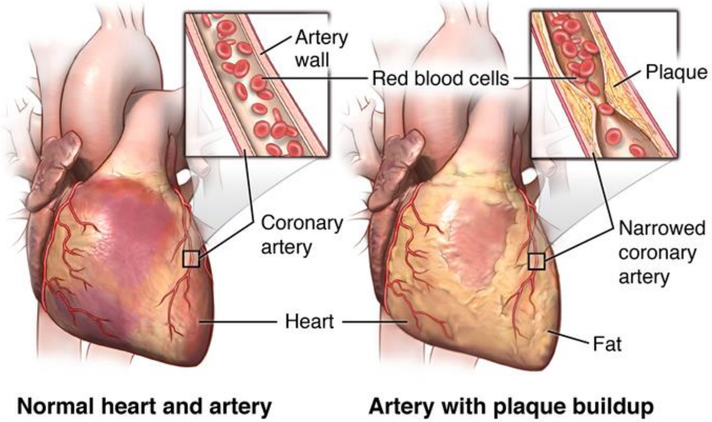
Diabetes is a group of disorders where blood glucose cannot be properly regulated by the body, which is potentially very dangerous. There are two types, with different causes and treatments.

Type 1 diabetes	Type 2 diabetes
Caused by a defect in the pancreas, where the cells that produce insulin don't work.	There is no problem with the pancreas – it produces insulin as usual. BUT, body cells no longer respond to the insulin.
The effect: Blood glucose concentration cannot be controlled by the body.	The effect: Blood glucose concentration cannot be controlled by the body.
Treatment is injections of insulin. The insulin is produced by genetically engineered bacteria.	Insulin injections will have no effect, so the treatment is a carbohydrate-controlled diet and exercise.
The cause is unknown, but we do know it involves the insulin-producing cells getting destroyed.	Obesity is a major risk factor for type 2 diabetes. There is also a genetic risk factor.

Biology Knowledge Organiser
B7 - Non-communicable diseases

Coronary heart disease: a non-communicable disease

Recall that **coronary** arteries are the arteries that provide the heart muscle with blood, so they get oxygen and glucose (and to take away waste products). Coronary heart disease involves the narrowing of these arteries, due to the build up fatty material (called a **plaque** – see diagram) in there. This reduces the blood flow through the coronary arteries, so the heart muscle receives insufficient oxygen. When serious, this leads to a heart attack (where part of the heart muscle dies due to lack of oxygen).



Treatments for coronary heart disease:

- Insert a **stent** into the narrowed artery to widen it again. This is a kind of wire mesh that pushes the artery walls out and keeps the artery open.
- Take **statins**. These drugs reduce blood **cholesterol** levels, which is linked to the fatty material deposits. Lowering cholesterol reduces the rate of fatty material build up.

Heart transplants

If the heart fails (called **heart failure**) and cannot be repaired, the heart can be transplanted. In fact, the heart and lungs can be transplanted together if required. The replacement heart has to come from a **donor** – many people agree to donate their organs after they die to save the lives of others.

However, there is a shortage of donor organs, like hearts. So people with heart failure may have to wait a while. In this case, **artificial hearts** can be used to keep someone alive while they wait. These are pretty amazing – have a look at the photo.

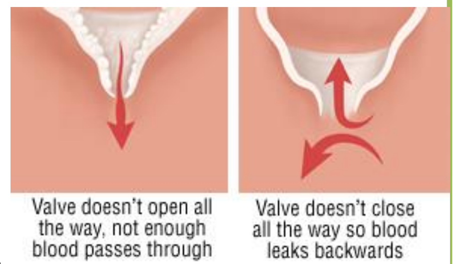
Key Terms	Definitions
Coronary	To do with the heart, especially the blood vessels that supply the heart muscle with blood.
Stent	A mesh or cage-like structure that keeps coronary arteries open so blood can flow through.
Statins	Medicinal drugs used to lower blood cholesterol. High blood cholesterol is a risk factor for coronary heart disease.
Valve	Structures in the heart that prevent blood flowing the wrong way.
Heart failure	Where the heart cannot pump blood around the body properly.

Other heart diseases

The valves in the heart are vital to prevent blood flowing in the wrong direction. In some people there is fault in the heart valves. The valve may get a leak, or might not open fully – see diagram.

- If one or more of the valves **leaks**, blood flows backwards in the heart. This means the blood does not transport oxygen as efficiently and also increases the risk of infection in the heart.
- If a valve **doesn't open fully**, the heart has to work harder to pump the blood as your body requires. This increases strain on the heart, making other heart problems more likely.

These valve problems can be treated by replacing the valves. Replacement valves can be **biological** – from a living organism (including pigs! Their heart is the same size as ours so their valves fit) or **mechanical** – a synthetic version. See the photos – mechanical on the right.



Biology Knowledge Organiser
B8 - Photosynthesis

Photosynthesis.

For us, it is a very good thing that photosynthesis evolved. The process of photosynthesis, carried out by plants and algae, is at the foot of every food chain. It captures light energy from the sun and redistributes it to chemical potential energy – we can make use of chemical potential energy: that's what our food contains! Since photosynthesis involves the transfer of light energy to chemical potential energy in cells, it is an **endothermic** reaction.

The reaction can be shown in these equations:

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

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

The oxygen released by photosynthesis has built up in the atmosphere over millions of years – again, good news for us, since we require oxygen for respiration, just like all living organisms.

Photosynthesis occurs in the **chloroplasts** of plant cells. Simple molecules like carbon dioxide and water can't be used as food. However, glucose and other more complex molecules can – so you can think of photosynthesis as a reaction that produces food.

Using The Glucose From Photosynthesis.

Obviously, plants didn't evolve simply for our benefit. They carry out photosynthesis to meet their own needs. The glucose produced in photosynthesis can be:

- Used in respiration in the cells of the plant/algae
- Converted into **starch** for storage. Starch is good for storage as it is *insoluble*, so it doesn't affect the osmosis occurring in the plant, unlike glucose.
- Used to produce **fats or oils (lipids)** for storage. This is particularly noticeable in seeds and nuts.
- Used to produce **cellulose**, which is a component of the cell wall. Cellulose strengthens the cell wall.
- Used to produce **amino acids**, which in turn are used to synthesise proteins (in the ribosomes). To produce amino acids, plants also require **nitrates** from the soil.

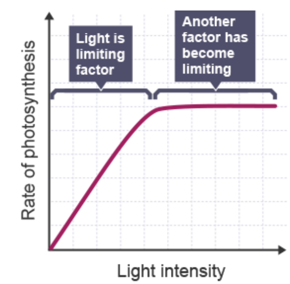
Simple lab tests can be used to identify starch, glucose and protein. Starch turns **iodine** a blue-black colour. Glucose turns **Benedict's solution** orange-red when heated with it. Proteins turn **Biuret's reagent** purple.

Key Terms	Definitions
Photosynthesis	The endothermic reaction that transfers light energy to chemical potential energy. In it, simple molecules (CO_2 and H_2O) are converted into more complex molecules (glucose) that can be used for food.
Nitrates	Ions containing nitrogen and oxygen. These are found in the soil; plants need nitrates to produce amino acids.
Rate	As always, rate means how quickly something happens.
Light intensity	The amount/strength of light. Use this term instead of 'amount of light'.
Chlorophyll	The green pigment in leaves that absorbs light for photosynthesis. Chlorophyll is found in **chloroplasts**.

The Rate Of Photosynthesis.

The following factors affect the rate of photosynthesis:

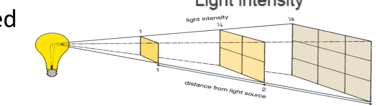
- **Temperature**: because all chemical reactions speed up as the temperature increases. However, as photosynthesis is controlled by enzymes, too high a temperature prevents photosynthesis (more on this in the metabolism section).
- **Carbon dioxide concentration**: the higher the concentration of CO_2 in the air, the more is available for photosynthesis, so the rate of photosynthesis increases as concentration increases.
- **Light intensity**: as the equation shows, photosynthesis requires light energy. So, the higher the light intensity, the higher the rate of photosynthesis.
- **Amount of chlorophyll**: more chlorophyll means more light can be absorbed. Some leaves have pale parts, as you may have seen, due to a lack of chlorophyll. The rate of photosynthesis is obviously much lower in the pale parts compared to the deep green parts.



HT: at any given time, any one of these factors may be **limiting** the rate of photosynthesis. This can be shown on graphs – see example. When it comes to light intensity, it varies with distance according to an *inverse square law*:

$$\text{light intensity} = \frac{1}{\textit{distance from source}^2}$$

In commercial growing of plants (e.g. tomatoes in a greenhouse), the conditions are optimised to maximise the rate of photosynthesis and obtain the highest profit.



Biology Knowledge Organiser
B9 - Respiration

Respiration.

Photosynthesis produces chemicals (like glucose) that can be used as food by all living organisms. In **respiration**, the chemical potential energy stored in food molecules is transferred through **oxidation** reactions (where oxygen, originally from the air, reacts with the food molecules). The energy transferred allows living cells to do **work**.

As you know, doing work means transferring energy. The kinds of work done by cells and organisms include:

- Chemical reactions to build larger molecules from smaller ones. E.g. making proteins such as enzymes from amino acids.
- Movement. E.g. movements of our body are possible due to muscle contractions. This requires energy from respiration.
- Keeping warm. This is an example of homeostasis: using energy from respiration to maintain body temperature at a set point (37°C).

There are two types of respiration: **aerobic** and **anaerobic**.

Aerobic vs. Anaerobic Respiration.

Aerobic respiration occurs when oxygen is used in the reaction. It is shown by these equations:

glucose + oxygen → carbon dioxide + water

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

This reaction releases energy that can be used by organisms, as described above. Compared to anaerobic respiration, aerobic respiration releases much more energy.

Anaerobic respiration occurs when there is insufficient oxygen available for complete oxidation of the glucose. The reaction that happens is different in animal cells compared to plant and yeast cells.

In *animals*: glucose → lactic acid

In *plants* and *yeast*: glucose → ethanol and carbon dioxide

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

Anaerobic respiration releases much less energy than aerobic respiration. In yeast, we call the anaerobic respiration **fermentation**. This is a very useful process: for making bread (the CO_2 makes it rise) and making alcoholic drinks (since ethanol is a type of alcohol).

Key Terms	Definitions
Aerobic	Using oxygen
Anaerobic	Not using oxygen
Oxidation	A reaction with oxygen. In this case, food molecules like glucose reacting with oxygen.
Fatigue	Tiredness. Fatigue in muscles is caused by a build-up of lactic acid, which is produced during anaerobic respiration (when there is insufficient oxygen).
Oxygen debt	After exercise, the lactic acid has built up and caused an **extra** need for oxygen – called the oxygen debt.
Lactic acid	Chemical produced by the incomplete oxidation of glucose (anaerobic respiration).

The Response To Exercise.

During exercise, more energy is required by the body that when resting, due to increased muscle contractions. The body reacts to this increased **demand** for energy:

- ➢ The heart rate, breathing rate, and volume of each breath all increase. Together, these increase the amount of **oxygenated blood** reaching the muscles. The oxygenated blood provides the extra oxygen and glucose needed for respiration in muscle cells, to transfer more energy to meet demand.

However, if insufficient oxygen reaches muscles but exercise continues, the muscle cells use **anaerobic respiration** to transfer energy. From the equation, you can see that incomplete oxidation of glucose takes place and **lactic acid** is produced. The lactic acid builds up and causes an **oxygen debt**. The lactic acid building up also causes **fatigue**. Removing the lactic acid after exercise is the cause of the oxygen debt – the oxygen debt is why you breathe deeply after exercise for some time. You are 'repaying' the oxygen debt.

HT: oxygen debt, to be precise, is the amount of extra oxygen needed to react with lactic acid in muscles and remove it from cells. The blood flow through muscles removes lactic acid and transports it to the liver. In the liver, the lactic acid is converted back into glucose. This reaction requires energy, hence the extra need for oxygen (for aerobic respiration to provide that energy).

Biology Knowledge Organiser
B9 - Respiration

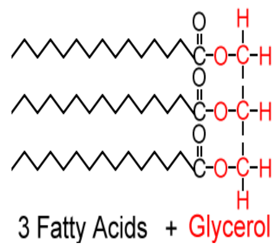
Metabolism.

Metabolism is a very big term in biology. It is the name given to collectively describe ALL the chemical reactions happening in a cell or in the whole body. So, respiration in all cells is an example of metabolism, and so is photosynthesis in plants.

Many reactions that cells perform require **energy**, so metabolism relies on energy transferred by respiration. Furthermore, chemical reactions in cells are controlled by **enzymes**. As we're talking about chemical reactions, *reactants* are used to make *products*: new molecules are synthesised.

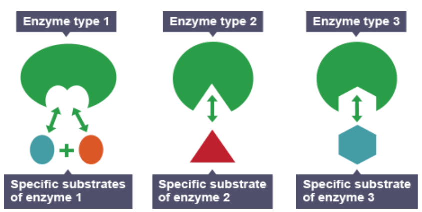
To learn: metabolism includes these reactions:

- Conversion of glucose to glycogen (in animals), or to starch or cellulose (in plants).
- Making lipid (fat) molecules from one molecule of **glycerol** and three molecules of **fatty acids** (see diagram).
- In plants, the use of glucose and nitrate ions to make amino acids. These amino acids are then used to synthesise proteins.
- Respiration, both aerobic and anaerobic.
- Breaking down excess proteins into amino acids, then into **urea** for excretion in the urine.



Factors Affecting Enzymes.

Recap your knowledge of how enzymes work from Topic 7.

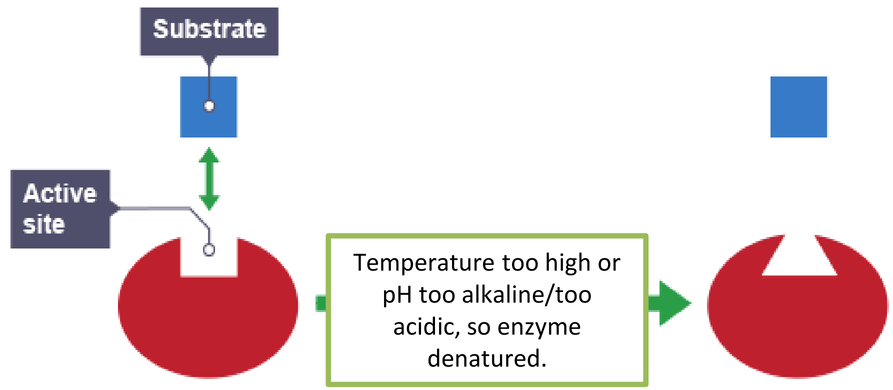


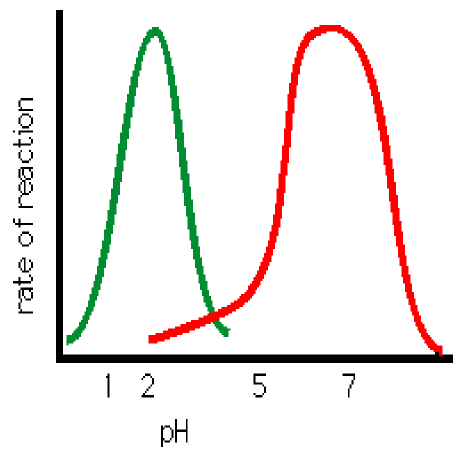
Enzymes are highly **specific**, meaning that each type of enzyme only causes a reaction by one type molecule.
This comes about due to the specific shape of the active site: only one molecule (according to its shape) will fit into the active site. See diagram for an illustration.

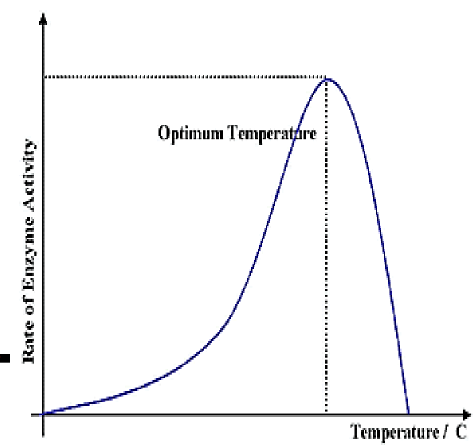
Enzymes have an optimum temperature and pH. If the temperature is **too high** (for most enzymes, above about 45ºC), or the pH is **too acidic** OR **too alkaline**, the enzyme **denatures**. This means the active site changes shape. As a result, the substrate no longer fits into the active site, to the enzyme doesn't work any more (see diagram).

This leads to results with enzyme controlled reactions as shown in the graphs. The rate of the reaction catalysed by the enzyme is on the y-axis. The peak represents the optimum temperature/pH. Notice that different enzymes have different optimums – as shown on the pH graph with the two lines.

Key Terms	Definitions
Metabolism	The sum of all the chemical reactions in a cell or in the body of an organism.
Enzyme	Large protein molecule that acts as a biological catalyst, dramatically speeding up chemical reactions in organisms.
Synthesis	Making something new. E.g. new molecules in metabolism.
Active site	The part of an enzyme molecule into which the substrate fits – so the shape of the active site is vital.
Substrate	The molecule an enzyme 'works on' to make a product/products.
Optimum	The ideal or perfect condition . Enzymes have an optimum temperature and an optimum pH.







Biology Knowledge Organiser
B10 - The human nervous system

Homeostasis

Unless chemical and physical conditions in the body are kept within strict limits, cells die. Thus, our bodies constantly and automatically regulate the internal conditions in the body to maintain optimum functions. This regulation is called **homeostasis**. It is vital for proper enzyme functioning, and indeed all cell functions.

Some factors that need controlling by homeostasis in the human body:

- Blood glucose concentration
- Body temperature
- Water levels
- Nitrogen levels.

The regulation that takes place can be carried out by the **nervous system**, the **endocrine system** (which produces hormones), or a combination of the two. These automatic control systems we use for homeostasis all include:

- Receptor cells – these detect changes in the environment. Changes are called **stimuli**.
- Coordination centres – these receive information from receptor cells (electrical or chemical information) and process the information. Examples include the brain, spinal cord and pancreas.
- Effectors – these are muscles or glands, which carry out the responses as directed by the control centre. Muscles **contract** and glands release chemicals, such as hormones.

The human nervous system

The nervous system is a network of neurones (nerve cells), bundled into nerves. It includes the nerves all over the body and the **central nervous system**, which consists of the **brain** and **spinal cord**. The nervous system allows us to react to the surroundings and control our behaviour. It can act involuntarily (in **reflexes**) or voluntarily.

Information from receptors, in the form of electrical impulses, passes along neurones to the central nervous system (CNS for short); the CNS coordinates the response by transmitting electrical impulses to the effectors (see above).

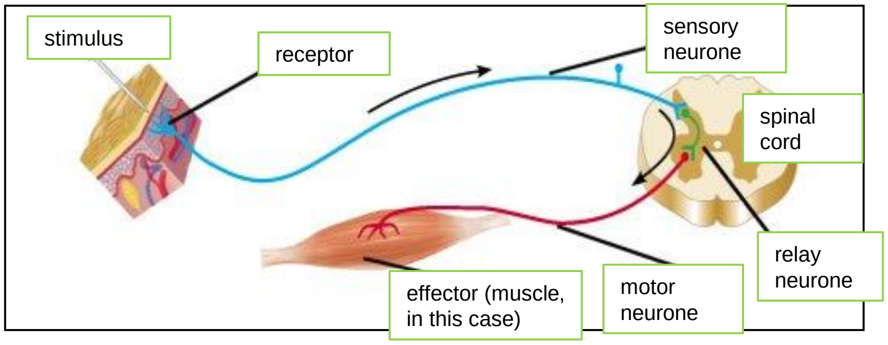
A reflex arc causes reflex actions, which are rapid and automatic (automatic because they don't involve the conscious part of the brain).

Key Terms	Definitions
Homeostasis	Regulating the internal conditions of the body in response to internal or external changes, to maintain optimum conditions for the body's functioning
Endocrine system	The network of hormone-producing glands in the body. Hormones are chemical messengers that travel in the bloodstream to their target tissues.
Blood glucose	Glucose (a simple sugar) is transported in the blood, as all cells require it for respiration. The concentration of blood glucose must be kept within very tight limits at all times.
Stimulus	A change in the environment, detected by a receptor cell. E.g. light, sound, chemicals (smells and tastes), pressure, pain, temperature etc.
Nerve	A nerve is just a collection of many nerve cells; nerve cells are called **neurones**. Neurones transmit (carry) information as **electrical impulses**.

The reflex arc and reflex actions

Reflex actions, for instance pulling your hand away from a pain stimulus, follow a simple pathway.

1. The **receptor** detects the **stimulus** and passes electrical impulses along the **sensory neurone** to the CNS (the spinal cord part, in this case).
2. There is a junction (tiny gap) between the sensory neurone and the **relay neurone** called a **synapse**. Here, a chemical is released that diffuses across the gap and causes an electrical impulse to pass along the relay neurone.
3. There is another synapse between the relay neurone and the **motor neurone**, again a chemical is released that causes the electrical impulse to pass along the motor neurone.
4. The impulse arrives at the **effector** – in this example, a muscle that contracts to pull your hand away from the source of pain.

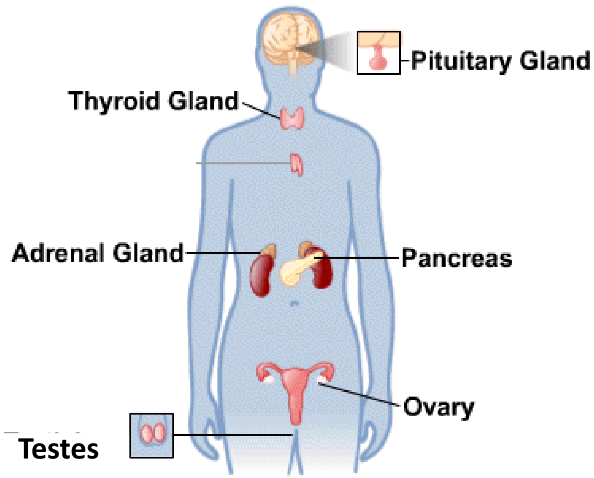


Biology Knowledge Organiser
B11 - Hormonal coordination

The human endocrine system

Hormones are released by endocrine glands directly into the bloodstream so they can be transported to a target organ or tissue and cause an effect. In comparison with the nervous system, the effects caused by the endocrine system are slower but act for longer. The hormones themselves are large chemical molecules.

The most important endocrine gland is the **pituitary gland** – think of it as a master gland that secretes many hormones that act on *other endocrine glands*, which then release hormones of their own. Learn the positions of the endocrine glands indicated on the diagram.



Diabetes

Diabetes is a group of disorders where blood glucose cannot be properly regulated by the body, which is potentially very dangerous. There are two types, with different causes and treatments. More on this in topic 13: how do organisms get sick?

Key Terms	Definitions
Hormone	A large chemical released by an endocrine gland; hormones have target tissues/organs and they produce an effect when they reach them.
Target organ/tissue	The destination of a hormone and the place where the effect caused by the hormone actually happens.
Secrete	The proper term for 'release' of a chemical in the body, such as a hormone from an endocrine gland.
Insulin	The hormone released by the pancreas that lowers blood glucose concentration, by making cells take in glucose from the blood.
Glycogen	Large chemical, made from glucose, that acts as a store of glucose in liver and muscle cells.
Pituitary gland	The 'master gland' of the endocrine system, since, through its hormone release, it can make other endocrine glands release hormones.

Controlling blood glucose concentration

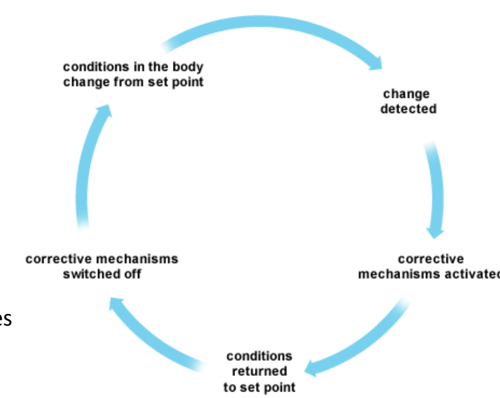
The monitoring and control of blood glucose concentration are both carried out by the **pancreas**. When blood glucose concentration rises (for instance, soon after eating), the pancreas detects this and releases the hormone **insulin**. Insulin causes glucose to move out of the blood and into cells. In particular, muscle and liver cells take in glucose and convert it to a much bigger molecule called **glycogen** for storage, rather than keeping it as glucose in their cytoplasm. This, obviously, *lowers* the blood glucose concentration back down to what it should be.

HT: when blood glucose concentration drops too low, the pancreas detects this and releases a different hormone: **glucagon**. Glucagon causes muscle and liver cells to convert glycogen back into glucose and release it into the blood. This obviously *raises* the blood glucose concentration back up. Therefore, using insulin and glucagon, the pancreas can keep your blood glucose concentration within very tight limits – an excellent example of homeostasis.

HT: negative feedback

Negative feedback is an important concept in homeostasis. Secretion of hormones is stimulated by a change from the normal level of a condition in the body. The hormone brings the condition back under control, so its release is no longer stimulated. In a round about way, hormones end up preventing their own release – this is called negative feedback. The diagram shows this in general. The level of many hormones can be controlled in this way.

Thyroxine, secreted by the thyroid gland, is controlled by negative feedback, for example. Thyroxine stimulates the **basal metabolic rate** – the baseline for the speed of chemical reactions in the body. This is important in growth and development.



Another hormone you need to know about is adrenaline. This is released by the adrenal glands when you are scared or stressed. It increases the heart rate, increasing the delivery of oxygen and glucose to the brain and muscles. This prepares the body for 'fight or flight' – combat or running away.

Biology Knowledge Organiser
B11 - Hormonal coordination

Hormones and Human Reproduction

Hormones, those chemical messengers that travel in the bloodstream, control many aspects of reproduction, including the **menstrual cycle**, which is essential for sexual reproduction in humans (and other animals).

- During **puberty** the reproductive hormones (see key terms) cause the development of **secondary sex characteristics**. These are the distinctive features of men and women that develop during puberty (e.g. beards and breasts).
- **Testosterone** is the main male reproductive hormone. It is produced in the **testes** and it *stimulates sperm production* (sperm cells are also produced in the testes).
- **Oestrogen** is produced in the ovaries (in women), largely responsible for bringing about changes at puberty.

The menstrual cycle is not only the period, although this is where is usually considered to start. The average length of a menstrual cycle is 28 days. The whole purpose of the menstrual cycle is to ready the body for pregnancy, by:

- Shedding (releasing) the uterus lining from the previous cycle – causing the period (aka **menstruation**)
- Allowing an egg to **mature** in the ovary (this is stimulated by the hormone **FSH**).
- Thickening and maintaining the **uterus lining** in preparation for pregnancy (this is controlled by **oestrogen** and **progesterone**).
- Releasing an egg (**ovulation**), about two weeks after the period started (this is stimulated by the hormone **LH**).

Contraception – preventing pregnancy

One class of contraceptive methods is **hormonal contraception**. Oral contraceptives ("the pill") contain hormones to inhibit FSH production so **no eggs mature**. Injections, implants of hormone-releasing devices, or skin patches can be used for slow-release progesterone, which inhibits the maturation and release of eggs for months or even years.

Non-hormonal methods include:

- **Barrier** methods, like condoms or diaphragms. These prevent sperm reaching the egg.
- **Intrauterine devices** (in the uterus) that prevent any embryos produced from implanting in the uterus. They may also release progesterone, like the hormonal methods above.
- **Spermicidal agents** – chemicals that kill or disable sperm. These are not very effective!
- **Abstinence** – obviously, there will be no pregnancy without sex. An ineffective method of contraception is attempting to time abstinence so you don't have sex while an egg is in the oviduct.
- **Sterilisation** with **surgery**: for men, this involves cutting and tying the sperm ducts so no sperm are included in the ejaculate. For women, the procedure is more invasive, involving cutting and tying the oviducts so no eggs reach the uterus, and no sperm can get to them.

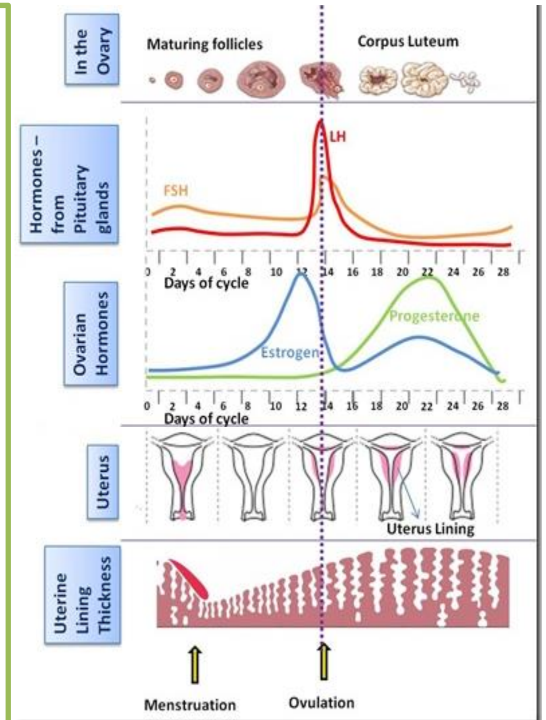
Key Terms	Definitions
Reproductive hormones	Those hormones that control reproduction. Important examples: testosterone (in males); oestrogen and progesterone (in females).
FSH	Follicle Stimulating Hormone. This is released by the pituitary gland and causes maturation of an egg in the ovary.
LH	Luteinising Hormone. This is released by the pituitary gland and it causes release of a mature egg (ovulation).
Uterus lining	The inside of the wall of the uterus. This is where an embryo implants when it is only a few cells in size.
Maturation	Becoming mature. All a woman's eggs are in her ovary when she is born, but they must mature before they are released.

HT: Interactions of hormones in the menstrual cycle

The four hormones involved in the menstrual cycle affect each other. Key points:

- FSH stimulates the released of oestrogen
- High levels of oestrogen stimulate the release of LH
- High levels of oestrogen **inhibit** (reduce) the production of FSH
- Progesterone inhibits the production of both LH and FSH

The changing hormone levels throughout the cycle can be graphed as shown – make sure you are familiar with the sequence and changing hormone levels.



Biology Knowledge Organiser
B11 - Hormonal coordination

HT: Hormones to treat infertility

Hormones can be used not only to prevent pregnancy, but to improve the chances of getting pregnant in cases of infertility. Fertility drugs contain FSH and LH, which may help a woman to get pregnant, as the cause of infertility may be low levels of these hormones. Failing this, **In Vitro Fertilisation (IVF)** can be used. Here's how it works:

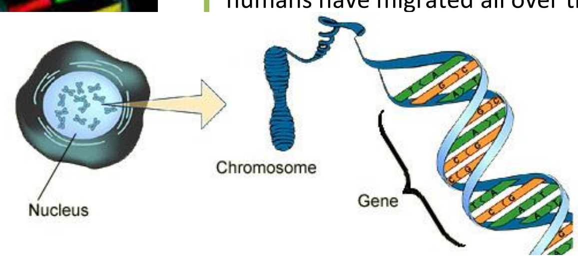
1. The mother is given **FSH** by injection to stimulate eggs to mature – a high dose is given so many eggs mature. **LH** is also given, getting eggs ready for ovulation.
2. Once eggs have had time to mature and are ready for ovulation, but before they actually get released into the oviduct, they are **collected** from the **ovaries**.
3. In a lab ('in glass' – a Petri dish: this is what in vitro means), the eggs are **fertilised** by sperm from the father. The mother can use a sperm donor at this point.
4. Still in the lab, in a Petri dish, these fertilised eggs grow into **embryos** of a few cells.
5. As tiny balls of cells, ready for implantation, one or two embryos are **inserted** into the mother's **uterus**. They used to insert more than this, to increase the chances of pregnancy, but as effectiveness increased the number of *multiple births* (twins, triplets etc.) increased, which are a bit more risky than pregnancies with one baby.

So, IVF has allowed many people to have children who couldn't otherwise. It is stressful though – physically uncomfortable and emotional, because it still only works far less than half of the time. Also, the success rate drops with age. As mentioned, multiple births are more likely in IVF, and these are more risky to mother and baby.

DNA

DNA is a chemical, a compound made of elements you know – carbon, hydrogen, nitrogen, oxygen, phosphorus. It is a polymer – meaning a very long molecule with units that repeat over and over. Each molecule of DNA is in fact made of two strands that run opposite one another and join in the middle (see diagram). These two strands form a spiral we call a **double helix** – double because there are two strands, and helix is just another word for spiral.

DNA is contained in **chromosomes**, where each chromosome contains one molecule of DNA – one long double helix each (there are also protein molecules as part of chromosomes). Short (compared to the whole molecule) sections of DNA called **genes** code for *proteins* (see diagram). This is how DNA gives you characteristics – the genes inherited from the parents, on the chromosomes they pass on to you, code for the *sequence of amino acids to make specific proteins.*



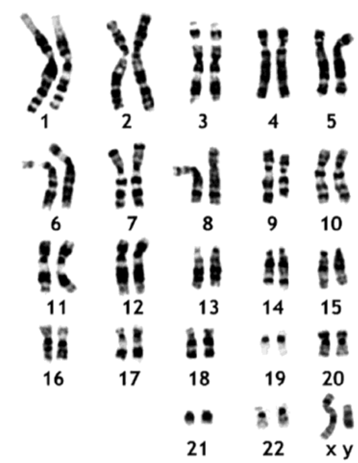
Key Terms	Definitions
Infertility	Problems conceiving (getting pregnant). Treatments for female infertility given left (HT only).
IVF	In Vitro Fertilisation. This means 'in glass' fertilisation – meaning fertilisation happens in a lab.
DNA	The chemical that makes up the genetic material in all cells. DNA is a polymer and arranged as a double helix.
Chromosome	Structure in cells containing one molecule of DNA. Body cells contain two copies of each chromosome – one from each parent.
Genome	The entire genetic material of an organism.
Gene	A section of DNA. Each gene is a code for a sequence of **amino acids**, so each gene codes for a specific protein.

The genome

The genome is the word to describe all the genetic material of an organism. The human genome has been fully sequenced, so we know exactly the order of genes on each chromosome. (Note: in genetic terms, humans are extremely similar so we do have a general human genome. Everyone will vary slightly from it, but by less than 1%.) The micrograph shows the 23 pairs of chromosomes found in human cells, where pair 23 is the sex chromosomes (XY in this person).

Understanding the human genome is very useful for all sorts of reasons, including:

- Helping the search for genes linked to specific diseases
- Understanding inherited disorders (more on these later)
- Using the tiny differences in genetic information between people to track how humans have migrated all over the planet.



Biology Knowledge Organiser
B13 - Reproduction

Genetic inheritance

All the genes you have, you inherited from your parents. They gave you half your genome each. Since they gave you one from each pair of chromosomes you have now, they in fact gave you one copy of each gene each – i.e. genes for the same thing. We call the two different versions of each gene **alleles**. Some characteristics are controlled by one gene – or rather, the two alleles of a single gene. E.g. fur colour in mice, red-green colour blindness in humans. However, most characteristics come about thanks to many genes and their interactions, not just one gene.

The alleles present in an individual organism cause body cells to produce certain proteins, or versions of proteins (as this is what a gene does remember). This is called **expression** of a gene, and leads to physical characteristics we call **phenotypes**.

This is easier with an example. Look at the cats below: the allele for short fur in cats is dominant to the allele for long fur. Let's call the alleles F and f respectively. In the top example, both parents are homozygous dominant (genotype: FF). This means all the gametes they produce will have one F in them, so at fertilisation the only possibility is for the offspring to get FF. So all their offspring have the short fur **phenotype**.

In the second row, both parents have long hair, so they must both have the genotype ff (homozygous recessive). Consequently, all their offspring must have long hair too.

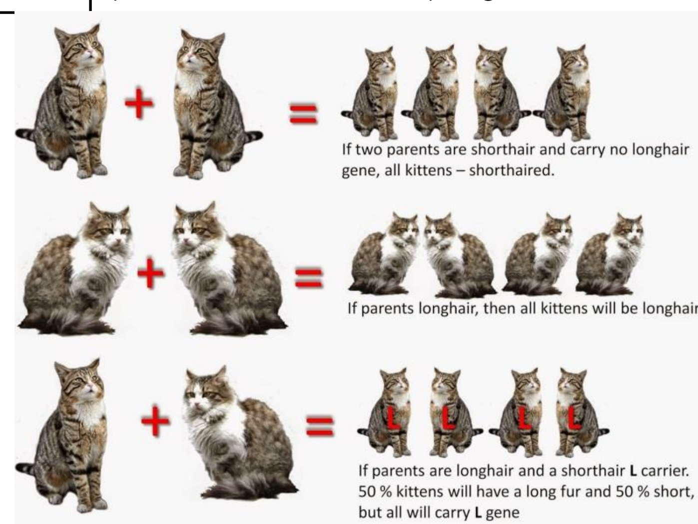
In the third row, the first parent has short hair but is heterozygous (genotype: Ff) – so they still have short hair as the short hair allele is dominant. If they mate with a long hair cat (genotype ff), there are different probabilities for offspring phenotypes, as they will get *either* F or f from the first parent. So, half of them will have short hair (with genotype Ff) and half will have long hair (with genotype ff).

Probability and ratios

Knowing the genotypes of the parents allows you to work out the **probability** of each genotype (and therefore phenotype) in the offspring. It does not guarantee, like in the bottom cat example, that they'll have four kittens, or that half will have long hair. What it tells us is: for each kitten, there is a 50% chance of it having long hair.

The other way of saying this is that the **expected ratio** of offspring genotypes is 1:1 for long:short hair. So if the bottom two cat parents had 50 kittens, we'd expect 25 of each hair length.

Key Terms	Definitions
Allele	A form or version of a gene. Since you inherit a copy of each chromosome from each parent, you have two copies of each gene – we call these two versions alleles.
Express	In genetics, to 'express' a gene means for it to be used by the body to make a protein, causing a characteristic.
Dominant	Describes alleles that are always expressed (so you see the effects in the organism). Indicated with a capital letter to represent the allele e.g. D.
Recessive	Describes alleles that are only expressed if there are two recessive copies (one from each parent). In other words, recessive alleles are only expressed if there is **no** dominant allele present. Indicated with a lower case letter to represent the allele e.g. d.
Genotype	The combination of alleles that an individual has. Often represented with two letters: e.g. DD, Dd or dd.
Phenotype	The physical characteristic that results from a particular genotype.
Homozygous	Describes a genotype where both alleles are the same – e.g. DD is homozygous dominant; dd is homozygous recessive.
Heterozygous	Describes a genotype where the two alleles are different (one dominant, one recessive) – e.g. Dd.



Biology Knowledge Organiser
B12 - Homeostasis in action

Controlling water and nitrogen balance in the body

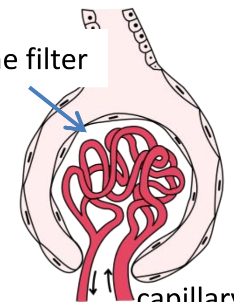
Maintaining water levels in the body is essential for proper functioning of body cells. You must regularly 'top up' your water (by having a drink!), as it is constantly being lost from the body. Water is lost in these ways:

- Water vapour is lost from the **lungs** when we exhale (breathe out)
- Water (along with ions and urea) is lost from the **skin** in sweat
- Water (along with ions and urea) is lost through the **kidneys** in urine.

We can't control the first two methods of water loss – you have to breathe and sweating is unavoidable (and varies according to temperature of the surroundings, of course). However, the amount of water lost in urine can be controlled – by the endocrine system. So, your body can remove excess water in the urine, or keep some water back by not putting so much in the urine.

Kidney function

Kidneys produce urine in two stages: by **filtration** of the blood then **selective reabsorption** of useful substances. Only small molecules can get through the filter (which is why there aren't any red blood cells in your urine). The kidney then **reabsorbs** (takes back in) the substances you need – **all** the glucose, many of the ions and most of the water.



Key Terms	Definitions
Urea	A chemical that must be removed from the body, as it is mildly toxic. It is produced in the liver from excess (too much) amino acids. Urea contains nitrogen.
Urine	Wee! Urine contains water (in variable amounts), ions and, most importantly, urea. Urine is produced in the kidneys.
Excretion	Any process that removes substances from the body.
Filtration	In the kidney, filtration of the blood means large particles/cells/molecules remain in the blood (e.g. red blood cells) and small molecules go through the filter (e.g. water, ions, glucose, urea).
Reabsorption	In the kidney, many substances are taken back into the blood even though they were just filtered out. 100% of glucose is reabsorbed (unless someone has diabetes) and most of the water and ions.

HT: urea formation and hormonal control of water level

Urea is a product made in the liver. The digestion of proteins (from the diet) results in excess amino acids which need to be excreted safely. The liver removes the amino part of the amino acids (NH_3) – a process called **deamination**. The **ammonia** produced is toxic so it is immediately converted to **urea** in the liver cells, which is far less harmful. The urea enters the bloodstream so it can be filtered out in the kidneys.

ADH is the hormone that controls water level in the body. It is released by the pituitary gland when the water level drops (the blood is too concentrated). The target organ for ADH is the kidney – ADH causes the kidneys to reabsorb more water into the blood, so the water level increases again. The release of ADH is controlled by negative feedback.

Biology Knowledge Organiser
B13 - Reproduction

Inherited disorders

Some disorders (or diseases – same thing really) are inherited, so we can also call them **genetic disorders**. If someone inherits a certain allele/combination of alleles, they have the inherited disorder. Two examples to know:

- **Polydactyly**: a condition where people have extra fingers or toes. This is caused by a dominant allele, so only one copy is needed to have the condition.
- **Cystic fibrosis**: a condition where protein pumps in cell membranes don't work properly, leading to thick and sticky mucus being produced in the lungs and intestines. This is caused by a recessive allele, so individuals with cystic fibrosis are all homozygous recessive.

Studying family trees can help genetic scientists decide whether a disorder is caused by a recessive or dominant allele. In the family tree shown, C is the allele for healthy cell membranes, and c is the allele for disordered cell membranes. Both parents must have at least one c to have children with cystic fibrosis, as the family tree shows. (Note: anyone without a genotype shown has the genotype CC).

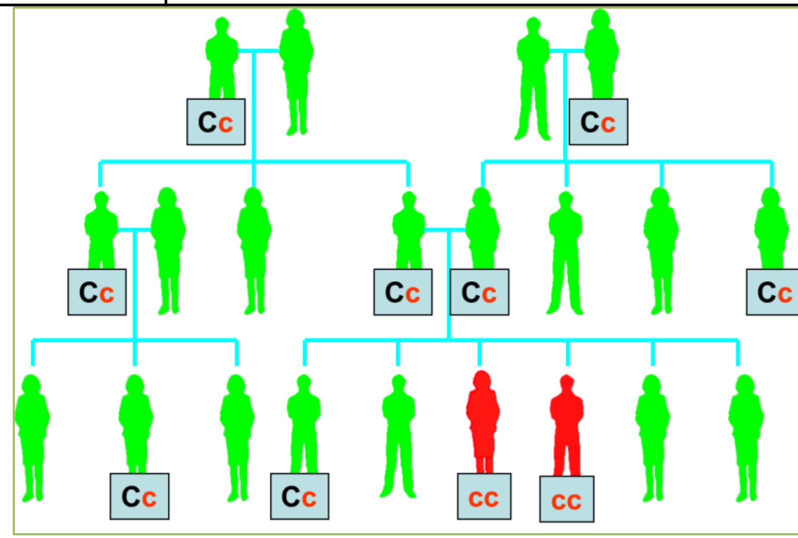
Since we know which alleles cause conditions like these, unborn babies, or embryos produced during IVF, can be checked – or **screened** – to see if they have the inherited disorder. This practice, *embryo screening*, can be used to inform whether an embryo should be implanted in IVF, or, if used during pregnancy, to decide whether an abortion should take place. Obviously, these are huge decisions and the right to life of the embryo must be weighed against the difficulties they'll face with an inherited condition and the personal choice and beliefs of the parents.

Sex determination

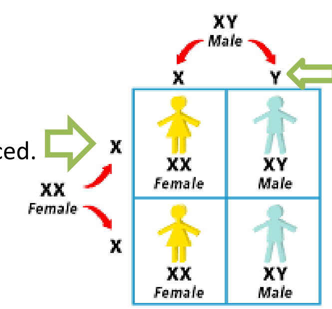
In biology, sex is not short for sexual intercourse. Sex means male or female – so is only relevant to organisms that reproduce sexually. The sex of offspring is determined by the combination of sex chromosomes inherited from the parents. Of the 23 pairs of chromosomes all humans have, 22 control body characteristics and the 23rd pair determines sex. [Note: like all chromosomes, the sex chromosomes carry genes, they just have the extra function of sex determination.] Human females have the combination for pair 23: XX. We say they have two X chromosomes. Human males have the combination XY for pair 23 (they are different).

When having children, then, mothers always pass on one X chromosome to their offspring. Males can pass on an X chromosome OR a Y chromosome – there's a 50:50 chance of each. This is because, when cells divide by meiosis to make gametes, all the female gametes contain an X, but half the sperm cells have an X, half have a Y. How these combine to give a 50% chance of a girl is shown in the **Punnett square** to the right.

Key Terms	Definitions
Screening	The practice of checking for a disease or an inherited disorder.
Carrier	An individual with one copy of the recessive allele that causes an inherited disorder (e.g. Cc for the cystic fibrosis genotype). As a result, they don't have the disorder, but they can pass one allele for it onto their offspring.
Sex chromosomes	Pair 23 in humans. Females have the combination XX, males have the combination XY.
Genetic cross	An unglamorous term given to mating between two individuals, producing offspring.
Punnett square	A tool used to predict the outcome of a genetic cross.



On the side, the possible female gametes are placed.



On the top, the possible male gametes are placed.

The possible combinations are shown. The ratio of female:male is 2:2, simplifying to 1:1.

Biology Knowledge Organiser
B13 - Reproduction

Types of reproduction

Organisms can reproduce sexually or asexually.

- **Sexual reproduction** involves two parents and produces genetically unique offspring. Each parent produces a sex cell (**gamete**), which fuse as part of sexual reproduction. This means that each parent contributes 50% of the genetic information to the offspring, and the offspring is *genetically unique*.
- **Asexual reproduction** involves only one parent and there is **no** fusion of gametes. As a result, there is **no** mixing of genetic information and the offspring are *genetically identical* to the parent (they are **clones** of their parent). No meiosis takes place (since there are no gametes); only mitosis is involved.

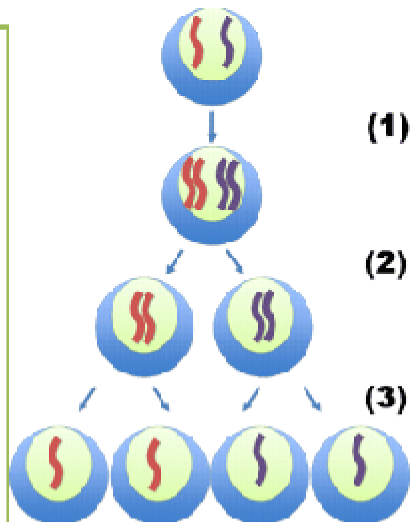
Key Terms	Definitions
Reproduction	Making offspring. All organisms reproduce.
Offspring	Offspring is a generic term for children – it applies to any type of organism.
Gametes	Sex cells, such as pollen, egg cells, sperm cells. Gametes are produced by meiosis.
Meiosis	Type of cell division that produces gametes. Gametes are genetically unique (compare to *mitosis*, where genetically identical daughter cells are produced).
Fusion	The joining/fusing of sex cells in sexual reproduction.
Differentiation	The process of becoming a specialised cell. Specialised cells are the result of differentiation of **stem cells**.

Meiosis

You already know how mitosis is used to replace cells in the body. Meiosis is the other form of cell division, but quite different. Meiosis produces **gametes**, so it happens in **reproductive organs** (e.g. sperm cells are produced by meiosis in the testes; egg cells are produced by meiosis in the ovaries).

DNA in the nucleus of cells is arranged into structures called **chromosomes**. In all body cells, the chromosomes appear in pairs (in humans, there are 23 pairs, so 46 chromosomes altogether). However, in gametes, there are **half** the number of chromosomes of body cells, since they contain one from each chromosome pair (in humans, this means that gametes contain 23 chromosomes).

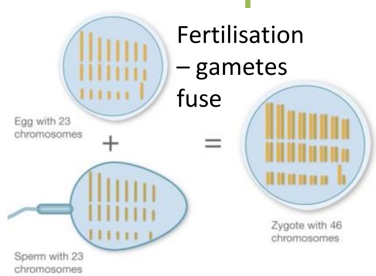
In meiosis, the DNA is replicated to start with (just like mitosis – step 1 in diagram). But then the cell divides **twice** – i.e. divides into *four* cells – so each cell ends up with **half** the genetic information: a single set of chromosomes. At stage 2 – the pairs are split up, then at stage 3 the copies of chromosomes are separated. The four cells produced are **gametes**, and all of them are **different** to each other – they are genetically unique.



Fertilisation

Obviously, fertilisation only happens in sexual reproduction. The male and female gametes **fuse**. Their nuclei join together into one and the genetic information is combined. Consequently, you have 50% of your genetic information from your mother and 50% from your father. The cell that is produced has the full set of chromosomes (in pairs again) – the normal number is restored. Again, this is 46 chromosomes (23 pairs) in humans. The diagram shows this.

The new cell is ready to grow into an embryo. It does this through mitosis, increasing the number of cells. To be precise, each cell divides to make two cells. This means that a young embryo doubles the number of cells each 'round' of mitosis. After a ball of cells is produced, the cells start to **differentiate** – become specialised. So you are no longer just a blob.



Fertilisation – gametes fuse

Cell division by mitosis

Mitosis continues, and many cells differentiate

Biology Knowledge Organiser
B14 - Variation and evolution

Variation

Organisms vary, both organisms of different species (obviously) and organisms of the same species (also obviously!). Variation (differences) are caused by both genetic causes and environmental causes.

- Some differences are only due to **inherited** genes – they are entirely **genetic**;
- Some differences are only due to the conditions in which an organism developed and lives – they are entirely **environmental**;
- Some differences are due to a **combination** of genetic and environmental influences. In this case, we say the genome of an organism and its environment **interact** to affect the phenotype of the organism.

In most populations of most species of organism, there is a lot of genetic variation. The general term for versions of the same organism (i.e. different individuals of a species) is with different genetic information is **variants**. All variants arise from **mutations**. Mutations can be dangerous (remember your work on cancer, for instance), but usually have no effect. Sometimes, they have a beneficial effect. Overall:

- Mutations happen continuously;
- most mutations will not affect the phenotype at all;
- some will influence the phenotype (maybe change it a bit);
- very few mutations cause a total change in phenotype.

The last case is rare, but very important. If a mutation occurs that leads to a new phenotype, and the new phenotype makes the organism better suited to the environment, it will lead to a rather rapid change in the species, by **natural selection**.

Evolution

Evolution is the change in inherited (genetic) characteristics of organisms over time. Many theories of evolution have been suggested, but Darwin's theory of natural selection is the one with by far the most evidence. Darwin noticed that all organisms produce more offspring than they need to replace themselves, and yet population sizes stay pretty steady from generation to generation. He also observed that all species show variation, and that life is tough for organisms – only the best adapted survive. So, based on these observations, we can explain evolution by natural selection like this:

1. A population of organisms shows variation – there are **variants** in the population
2. The organisms are in **competition** to survive
3. **Survival of the fittest** – only the variants with the phenotypes best suited to the environment get to survive
4. **Reproduction** – those who survive get to reproduce
5. **Genetic inheritance** – their offspring inherit the genes from their parents, so the successful phenotype becomes more common in the next generation. This continues from generation to generation.

Key Terms	Definitions
Variation	Differences in the characteristics of individuals in a population.
Genetic variation	Differences in the genome between individuals. This often causes differences in physical characteristics.
Variants	Different versions of the same thing. Often this term is used to describe individuals who are different from others in a specific genetic way – for instance the 'long haired cat variant' from earlier.
Mutation	A change to DNA. Mutations can cause a change in the sequence of amino acids being produced, affecting the protein being produced from the DNA code.
Evolution	Change in the inherited characteristics of organisms over time. Evolution happens through **natural selection**.
Natural selection	The process that changes the inherited characteristics of organisms over time. This explains the adaptations of organisms to their environment AND the formation of new species of organism.
Common ancestor	An ancestor in common. For instance, if you have a sister, your granddad is a common ancestor to you both.

New species

The theory of evolution by natural selection tells us that all species of living things have evolved from a single, simple type of life form. We know this **common ancestor** was alive on Earth over three billion years ago. How we ended up with millions of different species from this single species is also explained by evolution by natural selection.

Essentially, two populations of one species (e.g. a population of fish is divided into two populations by geographical changes such as the joining of North and South America) can become two different species. This happens when the two populations become so different in their phenotypes that they can no longer **interbreed** to produce **fertile offspring**. This is the point when we define them as different species. For example, tigers and lions are different species (the population of their common ancestor has been separated for a long time) – they can interbreed (producing a liger), but ligers are infertile. So their parents are different species.

Biology Knowledge Organiser
B14 - Variation and evolution

Selective breeding

In selective breeding, domesticated animals or plants are bred for particular **genetic** characteristics. This is not a new thing: humans have been choosing which animals/plants to breed together ever since agriculture was invented many thousands of years ago. The organisms with desired characteristics are chosen and deliberately bred together – if all goes well, the offspring have inherited the desired characteristics. The offspring with those characteristics are then bred together, and so on for many generations until all the offspring have the desired characteristic. Some examples of characteristics that selective breeding is used to obtain:

- Disease resistance in food crops
- Animals which produce more e.g. milk or meat
- Domestic (pet) dogs with gentle natures, high intelligence and so on
- Large or unusual flowers.

So, selective breeding is very useful. However, because of the deliberate selection of organisms with certain genetic characteristics for breeding, **inbreeding** can result from its use.

Genetic engineering

Genetic engineering is common and extremely useful. Recall that one gene codes for one protein, which in turn leads to specific characteristic. If an organism has the gene for a characteristic you want, you can transfer that gene into the genome of a different organism altogether. This has allowed, for example, the genetic engineering of plant crops to make them resistant to disease or to produce bigger, better fruit. Another key example is the genetic engineering of bacteria so they produce human insulin for treatment of type 1 diabetes.

How genetic engineering works:
Genes from an organism with a desired characteristic are 'cut out' of their genome and transferred to the cells of other organisms, in such as way that the second organism uses the gene from the first one. The resulting organism is called a **genetically modified** organism.

Good examples of GM crops include those that are now resistant to attack by insects, or are not affected by the herbicides that farmers use to kill weeds (obviously, it would be bad news to use a herbicide that kills your weeds but also your crops). GM crops are also often produced to have higher **yields**.

Key Terms	Definitions
Selective breeding	Also known as **artificial selection**. A technique of improving domesticated animals and plants for humans benefit, by breeding for particular genetic characteristics.
Domesticated	Animals/plants used in agriculture (or for pets!) are called domesticated species.
Inbreeding	The result of selective breeding can be inbreeding, where limited genetic variation can make organisms more prone to disease or inherited defects.
Genetic engineering	Modifying the genome of an organism by introducing a gene from another organism, giving a desired characteristic.
Genetically modified	GM for short. Describes organisms (especially crops) that have had their genome modified by genetic engineering.
Yield	The amount of useful product you get from a plant or animal used in agriculture (e.g. mass of fruit).
Vector (HT)	In the context of genetic engineering, a vector is a piece of genetic material used to transfer a gene. It is usually a bacterial plasmid or virus.

Genetic engineering – the controversy

There are some concerns about GM crops. The most important include concerns about how the GM crops may effect wild flowers and insects. There is not thought to be any risk to human health eating them, but some people call for more research on this.
Research is going on into how genetic modification might be used to overcome inherited disorders in humans.

HT: Genetic engineering – the steps

The summary is given left. The steps in more detail:

1. **Enzymes** are used to cut out, or *isolate*, the required gene.
2. This gene is placed in a **vector**, so it can be *transferred* to the organism you intend to genetically modify.
3. The vector is used to insert the gene into cells of the second organism (e.g. the food crop). This has to be done at an early stage of development (i.e. as a tiny *embryo*) so the organism develops with the desired characteristic.

[It wouldn't be much help to add the gene to an adult, since you'd have to add it to every cell to give them the desired characteristic.]

Biology Knowledge Organiser
B15 - Genetics and evolution

Classification the traditional way

People have always given living organisms names and attempted to group them together based on their similarities. The first system that has stuck around is the classification system described by Carl Linnaeus, in which he sorted organisms according to their **structure** (anatomy) and **characteristics**. He came up with a **hierarchical** system, where the larger groups contain all the smaller groups below them. It is called the Linnaean system, after him.

These groups, in order of size (based on how many organisms fit in each one) are called: **kingdom, phylum, class, order, family, genus** and **species**. Species are what you think of as individual types of organism – like tigers, oak trees or great white sharks. It is worth remembering that some organisms that are given one name in everyday language actually represent many species. For instance, there are many species of eagle and many species of shark.

When giving the scientific name of an organism, you give the genus and species. E.g. great white sharks are *Carcharodon carcharias*, humans are *Homo sapiens*. This is called the **binomial system** for naming species.

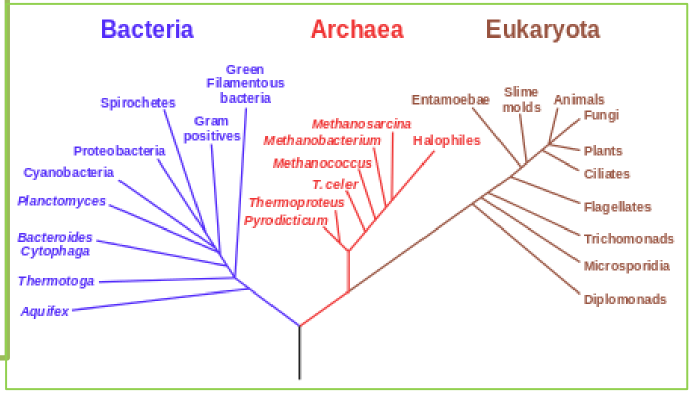
Classification the modern way

The Linnaean system dates back to the 18th century. Since then, knowledge and understanding of the internal structure of cells and biochemistry has developed significantly. Analysis of genetic material in cells has shown that the five kingdoms suggested by Linnaeus are not the best way to divide up life. A **three-domain system** is now used (although the Linnaean system is still very useful, and commonly used). The three-domain system was suggested by Carl Woese.

Woese's chemical analysis showed that there are three distinct groups of life, into which all organisms can fit without overlapping. These are called domains: the Archaea, Bacteria, and Eukaryota. One of the key things about this system is that is recognised that two huge groups of organisms (archaea and bacteria) are actually different. In the Linnaean system, they were bunched together in the 'bacteria' kingdom.

Since it is based on genetic analysis, the three-domain system links to the closeness of the relationship between organisms. We know all life on Earth is related (since we all use the same genetic code). That's why, when you draw an evolutionary tree (right), it starts with one 'trunk' – the first life on Earth (the **common ancestor** for us all). But, clearly, life has split into many different groups, as shown with the examples on the tree here.

Key Terms	Definitions
Classification	Sorting into groups. Traditional classification of organisms depends on their structure, but more modern methods involve analysing the biochemical similarities between organisms to classify them.
Kingdom	The largest group in the Linnaean system. In this model, there are five kingdoms (animals, plants, fungi, bacteria and protists).
Biochemistry	The study of chemicals in living organisms, such as DNA, proteins, carbohydrates and lipids.
Three-domain system	A modern model of classification, based on the genetic differences between organisms.
Archaea	Unicellular, like bacteria, but biochemically very different. These organisms often live in extreme environments, like very hot water around geysers. No-one realised that they were fundamentally different to bacteria before the chemical analysis was performed.
Bacteria	Also called 'true bacteria' – the prokaryotic organisms you think of as bacteria. (Check your knowledge on prokaryotic cells)
Eukaryota	All organisms with a nucleus, like us, plants, fungi and protists. All multicellular organisms fit into this domain (but it does include many unicellular organisms!).
Evolutionary tree	A method used to show how closely related organisms are. For living organisms, we can use genetic analysis; for extinct organisms, the fossil record suggest the relationships.



Biology Knowledge Organiser
B15 - Genetics and evolution

Evidence for evolution

There is a vast haul of evidence to support Darwin's theory of evolution by natural selection. This evidence has built up over time: for example, Darwin didn't know about genes so found it hard to explain inheritance from parents in full. Obviously, we've got this knowledge now.

Thanks to all this evidence, Darwin's theory for evolution is now very widely accepted. Two key bodies of evidence for you to know are: the fossil record, and the evolution of resistant bacteria.

Fossils

Fossils are the remains of organisms. They are always old, typically millions of years old, and are found in rocks. They can form by:

1. The organism or parts of the organism don't **decay** because the conditions are not right for decay by microorganisms. For example, mammoths have been preserved in frozen mud.
2. Parts of the organism are replaced by **minerals** from the surrounding rocks as they decay. Most often, this results in soft tissues (e.g. muscle, skin) *decaying* normally, but the form of bones is preserved by the minerals in bones being swapped for minerals from the *rocks/sediments* that the dead organisms were buried under.
3. Preserved **traces** of organisms – so not their actual bodies, but traces like footprints, droppings, burrows and the traces of roots.

As most fossils are formed from bones, and many early forms of life had **soft bodies** (no bones), there are few traces of early forms of life. Any traces there were tend to have been destroyed by geological activity (movements of tectonic plates, volcanic activity and so on). This means the fossil record is **incomplete** and scientists cannot be totally sure about the origin of life on Earth.

The fossil record helps scientists fill in timelines and **evolutionary trees** to show how life has changed over time on Earth. Using evolutionary trees shows the closeness of relationships between different species.

Extinction

Extinctions of a species can happen for many reasons, and often extinction is due to more than one factor working together. Some key factors that may contribute to extinction of a species:

- Development of <u>new</u> species, so the old species doesn't exist any more
- <u>New</u> diseases affecting a species, which they aren't adapted to and can't survive
- <u>New</u> predators, to which a species cannot adapt fast enough to survive
- <u>Changes</u> to the environment, to which the species cannot adapt by natural selection, including <u>catastrophic</u> events (like the meteor strike that caused extinction of loads of species, e.g. dinosaurs)
- <u>New</u> competitors that are better adapted to the environment than the species.

Key Terms	Definitions
Fossil	The remains of organisms from millions of years ago, found in rocks. They are formed in different ways – see main text.
Strain	A variant of microorganism within a species – so they are not a different species to other variants, but have a key difference in their phenotype (e.g. being resistant to an antibiotic). New strains are produced by **mutations**.
Resistant strain	Describes a variant form of bacteria with resistance (NOT immunity) to a specific antibiotic.
MRSA	An example of a resistant strain of bacteria. It stands for methicillin resistant *Staphylococcus aureus*.
Extinction	When NO individuals of a species remain alive.
Evolutionary tree	A timeline that shows how closely related different species are to each other.

Resistant bacteria

The key factor that affects the **rate** of evolution is how fast an organism reproduces. Bacteria can reproduce as fast as doubling every 20 minutes, so they can evolve rapidly.

Thanks to a **mutation**, strains of bacteria that are **resistant** to an antibiotic can emerge. These are NOT killed by antibiotics used to try to kill them when the bacteria has infected someone. Consequently, they <u>survive</u> and <u>reproduce</u>, so the size of the resistant strain population increases generation to generation, while the non-resistant strain is wiped out. Furthermore, the resistant strain is likely to spread because if it infects other people and:

- They are not immune to it
- And there is no effective treatment.

Society benefits if we <u>reduce</u> the rate of development of antibiotic resistant strains of bacteria. Some methods to help save the day:

- Antibiotics should not be **prescribed** by doctors where they are not needed (especially for viral infections, since antibiotics don't work on viruses).
- Patients need to **finish the full course** of antibiotics they get prescribed, reducing the chance of any surviving and mutating to form resistant strains.
- **Restrict** the use of antibiotics in **agriculture**, as at present many animals receive antibiotics all the time to prevent infections and encourage growth.

We also badly need new antibiotics. However, it is slow and expensive to develop new antibiotic drugs, and at the moment we are not keeping up with the emergence of resistant strains of bacteria.

Biology Knowledge Organiser
B16 - Adaptation, interdependence and competition

Ecology and Interdependence

Ecology is the study of everything from individual organisms to the whole biosphere (everywhere that life is found on Earth). An ecosystem is an interconnecting network of living organisms and their environment.

The feeding relationships are one way in which organisms depend on each other. To begin with, almost all organisms rely on the Sun as the original source of energy for their ecosystem. **Plants** and **algae** can make use of the Sun's energy to produce food molecules, in the process of photosynthesis. This is why they are called **producers**. Other types of organism can't do this, so they rely on the plants and algae. **Consumers** eat the producers, so the energy from the sun flows through the ecosystem. Molecules (which are stores of energy) also flow through, and get recycled when organisms produce waste (poo and wee!) and after they die and decay. The diagram helps to show this.

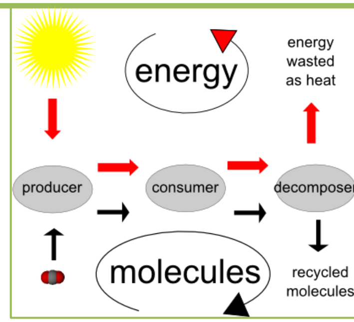
You can see that all the organisms in the ecosystem depend on each other. This is called **interdependence**. The consumers wouldn't survive without the producers capturing energy from the sun, the producers wouldn't survive without the decomposers recycling molecules for them to use (e.g. nutrients from the soil), and the decomposers need the waste from other organisms, and their bodies once they die. A stable community is one where all the species' populations and the abiotic factors are in balance; as a result, population sizes don't change much in stable communities.

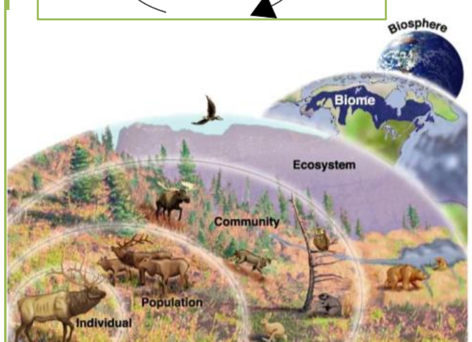
Biotic and abiotic factors affecting organisms

Communities of organisms are obviously affected by the environmental factors of their habitat. Factors that are non-living are called **abiotic** factors; those that are living are called **biotic** factors. These may affect the distribution of organisms (i.e. how they are spread out in the environment), their population size, their growth, behaviour or anything else really.

Examples of abiotic factors: light intensity; temperature; moisture levels; soil pH and mineral content; wind intensity and direction; carbon dioxide level for plants; oxygen levels dissolved in water for **aquatic** animals.

Examples of biotic factors: food availability; new predators arriving; new pathogens; competition between species. Competition can actually lead to extinction of a species – if another species outcompetes it, the first one may end up without sufficient numbers to breed.





Key Terms	Definitions
Biosphere	Wherever life is found on Earth (and in the atmosphere).
Biome	A large zone of life with particular characteristics – e.g. tropical rainforest, arctic tundra.
Ecosystem	A complex network of **communities** of organisms, which all depend on each other and which are adapted to the biotic and abiotic conditions they live in.
Community	A group of **interdependent** organisms. Communities interact with each other and with the physical environment – **ecosystem** refers to the interaction of living communities with the non-living environment.
Habitat	A specific set of conditions, usually a specific location, where an organism (or organisms) is adapted to live.
Population	A whole group of organisms – for instance, all the buffalo on the savannah, or all the greenfly on one rose bush.
Interdependence	All organisms in a community rely on one another – for food, shelter, pollination, seed dispersal, nutrient recycling and so on.
Biotic	Living factors affecting a community.
Abiotic	Non-living factors affecting a community (e.g. light intensity, temperature, soil pH).

Adaptations

ALL organisms, now matter how simple they might seem, are adapted to their natural environment. Their features, or adaptations, enable survival in the particular conditions where they live. Adaptations can be:

- **Structural**: adaptations in terms of body form and shape. This would include examples like: streamlined shape for speed; long stem to maximise light exposure
- **Behavioural**: adaptations of behaviour – for instance, hunting behaviours, using tools, plants growing in the direction of a source of light.
- **Functional**: adaptations in terms of how the body works. For instance: being able to digest a certain food, maintaining a constant body temperature and so on.

Some organisms are adapted to live in what we would consider to be extreme environments – for instance, very high temperatures, high pressures, high salt concentration. The organisms that can survive in these kinds of conditions are called **extremophiles**. A great place to find extreme conditions and extremophiles is around and inside deep sea hydrothermal vents.

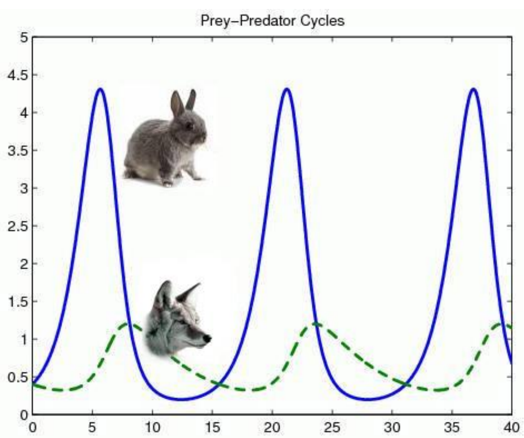
Biology Knowledge Organiser
B17 - Organising an ecosystem

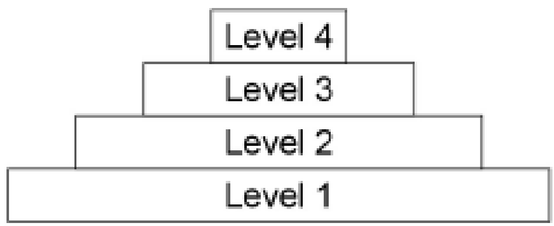
Organisation of ecosystems and trophic levels

Apart from some ecosystems in deep sea vents, ALL biomass on Earth is produced by **photosynthetic** organisms. So, these organisms are called **producers (trophic level 1)**. This is vital for other organisms, since these producers start off food chains. **Food chains** represent the feeding relationships in a community. The producer is usually a green plant or algae, and they make **glucose** by photosynthesis.

The producers are eaten by **primary consumers (trophic level 2)**, which might be eaten by the next trophic level – **secondary consumers (trophic level 3)**. The secondary consumers may be eaten by **tertiary consumers (trophic level 4)**. Of the consumers, if they kill and eat other animals, they are called **predators**. The animals eaten by predators are their **prey**. Carnivores that don't get eaten by anything else are called **apex predators**.

In a *stable* community (one that stays pretty steady in terms of population sizes), the population size of predators and their prey rise and fall in cycles, as the graph shows. When there aren't many predators, the prey population grows rapidly. When it rises, there is more food for predators so their population increases. This puts pressure on the prey so their population drops – cycles, see graph.





Key Terms	Definitions
Photosynthetic	Describes any organism that can carry out photosynthesis, producing biomass from simple chemicals (CO_2 and H_2O)
Biomass	The materials that living things are made from: proteins, carbohydrates and lipids.
Food chain	Used to represent the feeding relationships in a community. Starts with a producer and shows what organism eats what, as well as how energy and biomass are transferred in the community.
Trophic level	Position in a food chain. Producers = level 1.
Ingest	Eat/consume
Egest	Excrete as faeces

Pyramids of biomass

Biomass is simply living mass/material. Biomass is made by producers, but bear in mind they only transfer about 1% of the energy from light that hits them. A pyramid of biomass has trophic level 1 at its base, and each block of the pyramid has a width to represent the amount of mass at each trophic level. See diagram.

The blocks HAVE TO get smaller, because not all biomass is transferred from one trophic level to the next (only about 10% in fact). This is because:

- Not all of the organisms in each trophic level actually get eaten by the trophic level above
- Not all the material that is eaten (**ingested**) is actually absorbed into the body – some is **egested** as faeces
- Large amounts of the biomass absorbed at each trophic level is used in **respiration** (especially glucose, of course) – meaning that the biomass is converted to carbon dioxide and water. These products are released in urine and breathing out. (furthermore, urea is lost in urine, so it isn't available for the next trophic level).

As a result of all this, usually the number of organisms decreases as you go up the trophic levels (although it also depends on the size of the organisms!).

Biology Knowledge Organiser

B17 - Organising an ecosystem

Decomposition

Decomposition is the breaking down, or decay, of biological material. Microorganisms digest dead organic material to simpler molecules, so the complex molecules bodies are made from (like proteins, lipids and carbohydrates) are recycled in the environment. They do this be secreting enzymes into their immediate environment and absorbing the soluble products of digestion by diffusion.

The **rate** of decay is affected by:

- **Temperature** – the activity of decomposers increases as it gets warmer (although decomposers are killed by very high temperatures)
- **Water** – moist conditions speed up decay because molecules to be digested may be dissolved
- Availability of **oxygen** – decay is fastest if there is a good supply of oxygen, simply because the decomposers can then respire more efficiently. This is why compost bins should have hole sin the side!

Compost is just the material left after decay of waste organic material has happened. Compost is very useful to farmers and gardeners as a natural fertilisers for crops.

Where decay happens <u>without</u> oxygen, **anaerobic** decay takes place. This produces **methane** gas. This can be very helpful – methane is a good fuel, so it is deliberately produced like this in many places, especially warm countries. The decay happens in a **biogas generator** – biogas just refers to the methane.

The water cycle and the carbon cycle

Like carbon, water is constantly cycled in ecosystems between abiotic and biotic components of the ecosystem. Water is released in aerobic respiration by all organisms. In terms of the abiotic components, water is constantly evaporated and precipitated (so, goes from land/waterways to the atmosphere and back again). The water precipitated provides fresh water for organisms on land before draining into the sea.

In all ecosystems, many materials have to be cycled through the biotic and abiotic components of the ecosystem – e.g. water, carbon, minerals, nitrogen. Microorganisms play a key role in cycling such materials. Carbon can appear in abiotic locations (the air as CO_2, in soil minerals) and biotic locations (in the carbohydrates, lipids and proteins that living organisms are built from). When we say it is cycled through these components, we mean that carbon atoms don't stay in any material for ever. They are cycled by various processes:

- **Photosynthesis** – takes carbon from the atmosphere (in the form of CO_2) and converts it to biomass
- **Respiration** – all living organisms, including plants and microorganisms, respire, which converts biomass into CO_2, which enters the atmosphere. While decay is taking place, carried out by microorganisms, they respire, which releases CO_2.
- **Feeding** – when consumers eat other organisms, the carbon in the other organism's biomass is transferred to the consumer.

Key Terms	Definitions
Decomposer	An organism that digests dead organic material.
Distribution	Describes how organisms are spread in an ecosystem.
Abundance	How many individuals of a particular species there are.
Quadrat	A square frame used for sampling plants in an ecosystem. Can be used for counting plants for measuring the coverage of the ground by a particular species.
Transect	Sampling method where a quadrat is laid down at regular intervals along a line. This is used to measure the change in distribution of organisms when a particular factor changes, such as light intensity.
Interval	The spaces between measurements – e.g. on a transect, the interval might be 1 m.

Measurements of ecosystems

Biologists measure both the **distribution** and **abundance** of organisms in ecosystems to help us understand them (see definitions). It would be impractical to attempt to count e.g. all the seaweed on a beach, so biologists use **<u>sampling</u>** techniques. If you just want to measure the abundance in an area, or to compare two locations for abundance of e.g. seaweed, ***random sampling*** would probably be used of the area. To count plants, quadrats are used. If, however, you are interested in how the distribution (spread) of organisms changes as a factor changes, you measure along a **transect**. For instance, with the seaweed example, you could set up your transect line down the beach towards the water (just using a long tape measure) and measure the coverage by seaweed at 2 metre **intervals**, or some other suitable interval. Data may be summarised using means, modes or medians, and graphs can be produced to represent differences between locations, or the change in distribution along a transect.

Biology Knowledge Organiser
B18 - Biodiversity and ecosystems

Biodiversity

Biodiversity, the variety of all the species of organisms, can be measured at the level of a community, ecosystem or the whole earth (biosphere). A large biodiversity increases the stability of ecosystems, because it reduces the dependence of one species on another, for instance for food. So, for example, if a species has only one food source (think: pandas and bamboo shoots), it may be easily threatened by environmental changes.

In spite of our future as a species on Earth depends totally on maintenance of biodiversity, many human activities threaten biodiversity. Indeed, in many ecosystems, we have already significantly reduced biodiversity. For instance, deforestation had damaged biodiversity in all kinds of forest. Our waste, polluting land, air and sea, has negatively affected biodiversity in many areas. And the big one: global warming is already having measurable effects on global biodiversity. It is only recently that humans have taken any measures to try to prevent our damage to biodiversity going too much further – obviously, we don't yet know if these measures will be enough.

Land use

Humans reduce the amount of land available for other organisms by: building, quarrying, farming and dumping waste (landfill). This in turn can reduce biodiversity.

Peat bogs are made of peat, a type of fossil fuel formed from dead plants. Peat bogs are destroyed as peat can be used as a fuel and is a very good fertiliser if you're growing plants. This has seriously reduced the area of this habitat and reduced biodiversity as a result. Furthermore, using peat as a fuel produces CO_2 (contributing to global warming) and using it as a fertiliser (in compost) allows it to decay, which also produces CO_2.

Key Terms	Definitions
Evaporated	Water changing state from liquid to vapour.
Precipitated	Water changing from vapour to liquid/solid form – i.e. rain, hail, snow.
Biodiversity	The variety of all the different species of organisms.

Waste management

Since the human population is growing at an incredible rate, and in general people's living standard is going up globally, we (the human population) is using more and more resources and producing more and more waste. Our waste causes pollution, which can occur:

- In water, thanks to sewage, fertilisers running off farmland, or toxic chemicals used in industry;
- In the air, from smoke, waste gases and acidic gases (e.g. sulphur dioxide)
- On land, from landfill (rubbish dumps) and from toxic chemicals.

Pollution kills organisms; therefore it can reduce biodiversity.

Deforestation

Deforestation on a large scale happens to provide land, with the largest areas cleared for raising cattle, to plant rice fields and to grow crops that can be made into biofuels. Our food and fuel needs conflict with the need to preserve forests and rainforests so biodiversity is maintained.

Global warming

As you'll know, since the industrial revolution, human activities have dramatically increased the levels of greenhouse gases in the atmosphere. The main gases involved are carbon dioxide and methane. The molecules of these gases absorb infrared (heat) radiation and re-radiate it, causing gradual but measurable increases the atmosphere's, and therefore Earth's, temperature. Global warming as caused by humans used to be controversial; now, thousands of peer-reviewed publications later, the global scientific consensus is that humans are definitely causing climate change through global warming.

Biology Knowledge Organiser
B18 - Biodiversity and ecosystems

The impact of environmental change

Environmental changes affect the **distribution** of species in an ecosystem. Environmental changes can be seasonal (summer vs. winter), geographic (e.g. flooding, volcanic activity and so on) or caused by human interaction with the environment (e.g. anthropogenic climate change). Changes that affect organisms include temperature, availability of water and the composition of gases in the atmosphere. Be ready to evaluate the impact of examples of environmental changes on distribution of species.

Maintaining biodiversity

As you've seen, many human activities have negative effects on biodiversity. However, as the scale of our negative influence has become more and more apparent, scientists and concerned citizens have brought in programmes to try to reduce our negative influences. Here are the key examples you should know:

- **Breeding programmes** for endangered species. For instance, tigers and pandas are bred in captivity to ensure they do not become extinct.
- **Protection** and **regeneration** of rare habitats. This includes passing laws to ensure people leave certain areas alone (e.g. parts of the Great Barrier Reef). Regeneration means activity trying to bring a habitat back to its former glory.
- Reintroduction of **field margins** and **hedgerows** in agricultural areas where farmers only grow one kind of crop. Growing one sort of crop (called monoculture) is bad for biodiversity because it only provides a habitat for a few species. So, farmers are encouraged to used hedges (not fences) and leave a margin around the edge of their crop fields, so wild plants can grow there, which in turn allows other organisms (e.g. insects) to survive there too. This improves biodiversity on agricultural land.
- Reduction of **deforestation** and carbon dioxide by some governments. There have been numerous attempts, not always totally successful, to get governments of countries around the world to agree to specific targets for how much carbon dioxide they emit, since global warming is, of course, a worldwide problem. As with many things in politics, agreement is very difficult to obtain… but progress has been made in these international agreements.
- **Recycling** resources rather than dumping in landfill. You are used to recycling as much of your household waste as you can. Work continues to increase the range of materials that can be recycled so we can continue to reduce the amount of waste dumped in landfill.

Key Terms	Definitions
Breeding programme	Producing offspring, especially of endangered species to protect their population.
Field margin	The area around the edge of a field between the crop and the fence/hedge/wall.
Hedgerow	The barrier at an edge of a field made of growing plants, as opposed to a fence or wall.

A lovely big field margin, and hedgerow on the left

Biology Knowledge Organiser
B18 - Biodiversity and ecosystems

Food security

Food security is having enough food to feed a population. Unfortunately, many populations around the world suffer from a lack of food security. Numerous biological factors threaten food security, including:

- Increasing **birth rate** raising the population
- Changing **diets**, which often results in scarce foods being imported to countries where they can't grow them, or results in people eating more meat
- New **pests** (insects that eat plants) or pathogens that affect crops
- **Environmental changes** (including effects of climate change) that affects food production
- The **cost** of doing agriculture – e.g. price of seeds for crops, or farming equipment
- **War** can affect the availability of water for crops/animals, or directly affect the availability of food.

So, a major global challenge is finding sustainable methods to feed everyone on Earth. Whoa.

Farming techniques

Food production efficiency links to the flow of biomass in food chains and pyramids of biomass, so check you know that. The basic idea is that if you reduce energy transfers from food animals (like chickens, pigs and cows) to the environment. This means they don't have to respire so much, meaning that more of the biomass the animal **consumes** is converted to biomass in their bodies.

- Keeping the animals **warm** (indoors) reduces the use of respiration to maintain their body temperature. Therefore more of the biomass they eat is used to build their bodies, rather than being used up in respiration.
- **Limiting** their **movement** – which yes, does sound rather cruel. Again, this reduces the need for energy from respiration; therefore less of the biomass eaten is used in respiration and more is converted to biomass in the animals' bodies.
- Feeding animals a **high protein** diet to speed up growth.

Key Terms	Definitions
Sustainable	Able to continue/maintain something. For instance, sustainable food production won't use up all of food resource.
Fishery	A farm where fish are bred for food OR a part of the sea/lake where fish are caught for food.
Biotechnology	Technology that involves manipulating living things.

Sustainable fisheries

The amount of fish in the ocean that people eat (**fish stocks**) is dropping. The solution is to restrict fishing so there are enough left to breed and replace those caught. There are two main ways to keep people from catching too many, so **fisheries** stay sustainable:

1. Control **net sizes** so not too many fish are caught
2. **Fishing quotas** – this is a legal limit on how many fish a company can catch. They get fined if they catch more than their quota.

Without methods like this, certain species may die out altogether.

Role of biotechnology

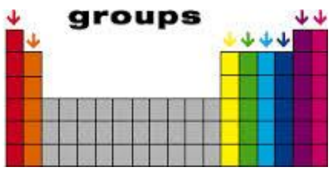
Modern biotechnology can help with food security.

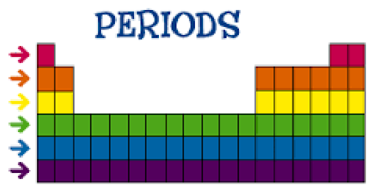
- Genetic modification (genetic engineering) can produce crops with higher **yields** (more food per plant) or better nutritional value. An example is Golden Rice, which provides vitamin A.
- **Mycoprotein** (e.g. Quorn) is grown in tanks. The fungus *Fusarium* grows on glucose syrup in aerobic conditions, then the biomass is harvested. Huge quantities can be cultured at a time, so it's a pretty efficient way of making food.

Chemistry Knowledge Organiser
C1 - Atomic structure

Elements

- An ***element*** contains only one type of atom. All elements are given a symbol and are found on the periodic table. You need to learn the symbols for the first 20.
- The Periodic Table is arranged into groups (columns) and periods (rows), as shown below.





Elements in the same group have:
- The same number of electrons in their outer shell
- Similar properties

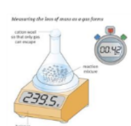
Elements in the same period have:
- The same number of electron shells

Compounds

- Compounds are 2 or more elements that are chemically bonded
- These are made in chemical reactions.
- Compounds are given a formula for example carbon dioxide is CO_2 means 1 carbon atom and 2 oxygen atoms.
- Another example is calcium hydroxide $Ca(OH)_2$ which means 1 calcium, 2 oxygen atoms and 2 hydrogen atoms

Chemical Reactions

- In some chemical reactions it may appear that there are less products than there were reactants; however this is often because a gas has been made and this has escaped into the atmosphere.



Key Terms	Definitions
Element	A substance that contains only one type of atoms
Mixture	A mixture is two or more different atoms which are not chemically bonded
Compound	Two or more elements that are chemically bonded
Group	The columns on the Periodic Table
Period	The rows on the Periodic Table
Reactant	What you start with in a chemical reaction
Product	What is made in a chemical reaction

The Conservation of Mass

- In a chemical reaction, chemical bonds are broken the atoms are rearranged and the chemical bonds are made again.
- In a chemical reaction, ***mass is never lost***, you must start and finish with the same mass.

Balancing Equations

- We need to write balanced chemical equations represent chemical reactions and the conservation of mass.
- For example: The equation below shows hydrogen and oxygen making water but there are more oxygen atoms on the right than the left.

$$H_2 + O_2 \rightarrow H_2O$$

- In the equation below there are 4 hydrogen atoms on the left and right of the equation and 2 oxygen atoms on each side

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

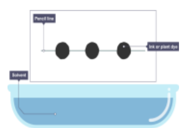
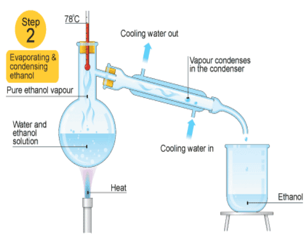
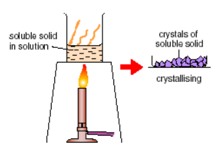
Chemistry Knowledge Organiser
C1 - Atomic structure

Key Terms	Definitions
Pure	A substance made of only ONE type of element or compound
Impure	A mixture of elements and/or compounds
Chromatography	A technique where mixtures can be separated based on their solubility.
Distillation	A separation technique which means a mixture of two liquids is heated
Crystallisation	Method of mixture separation where a solvent is evaporated, leaving the solute behind.

Pure and Impure Substances

- A pure substance contains only <u>one</u> type of **element** or **compound.**
- **An impure substance** contains more than one type of element or compound in a mixture, for example salt water contains NaCl and H_2O. All mixtures are impure substances.
- Mixtures are much easier to separate than elements or compounds as they are not chemically bonded
- There are a variety of ways that mixtures can be separated and they are outlined below. Remember that these are all physical changes and chemical bonds are not broken during any of these processes.

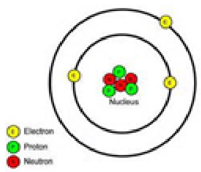
Separating Impure Substance

Name	Diagram	Explanation
Chromatography		• Different substances travel different distances up the paper depending on their solubility in the solvent used (it is often water but not always). The more soluble, the further it moves up the paper • Line must be drawn with pencil because pencil will not run. • Artificial colours in foods can be identified using chromatography. Additives do not necessarily have a colour and therefore are identified using chemical analysis.
Distillation		• **Distillation is** when two liquids with *different boiling points* are separated • For example ethanol (alcohol) boils at 78 °C and water boils at 100 °C • If you heat a mixture of water and ethanol to 80°C the ethanol will **evaporate** but the water will not. • You then **condense** the ethanol and collect the pure ethanol
Crystallisation	 Evaporation	• Crystallisation is when a solvent is evaporated from a solute.

Chemistry Knowledge Organiser
C1 - Atomic structure

The structure of the Atom

- All matter is made from atoms. Atoms are very small. The radius of atom is about $1x10^{-10}$ m (this is also known as 0.1 nanometres).
- The central part of the atom is known as the nucleus. It is only $1x10^{-14}$m across, which is 10,000 times smaller than the total atom.
- An atom is made up of three subatomic particles: **protons**, **electrons** and **neutrons**.
- Protons and neutrons are found in the nucleus
- Electrons are found orbiting the nucleus in shells (also known as *energy levels*).

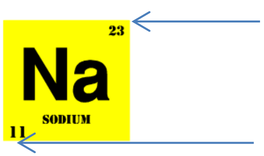


- The mass and charges of the sub atomic particles is shown below:

	Mass	Charge
Proton	1	+1
Neutron	1	0
Electron	0	-1

- Atoms have **no overall charge** because they have the same number of positive protons as negative electrons.

Atomic Number and Mass Number



Mass number: This is the total of protons+neutrons

Atomic number: This is the number of protons

Therefore sodium has 11 protons, 11 electrons and 23-11= 12 neutrons

Key Terms	Definitions
Atom	The particles that make up all substances with mass, they contain protons, neutrons and electrons.
Nucleus	The centre of an atom, it contains protons and neutrons.
Nanometre	A unit of measurement: $1x10^{-9}$m
Proton	A sub atomic particle found in the nucleus, it has a charge of +1 and a relative mass of 1.
Electron	A sub atomic particle found in the shells of an atom, it has a charge of -1 and a negligible mass
Subatomic	These are the smaller particles that make up an atom
Neutron	A sub atomic particle found in the nucleus of an atom, it has a charge of 0 and a mass of 1
Atomic Number	The number of protons in an atom.
Mass Number	The total of protons and neutrons in an atom.

Electron Configuration

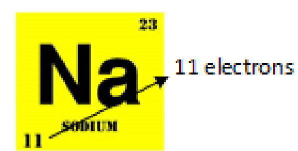
There are very strict rules about how electron fill up the electron shells, the inner shell is always filled first. Each shell has a maximum number of electrons it can take.

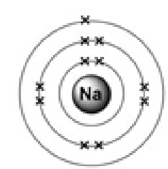
Shell 1: maximum 2 electrons

Shell 2: maximum 8 electrons

Shell 3: maximum 8 electrons

Example:





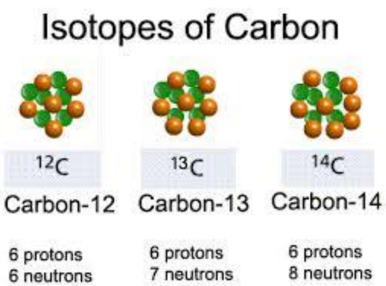
The electronic configuration of Sodium (Na) can also be written like this 2,8,1. This shows there is 2 electrons in the 1st shell, 8 electrons in the second shell and 1 electron in the 3rd shell.

Chemistry Knowledge Organiser
C2 - The periodic table

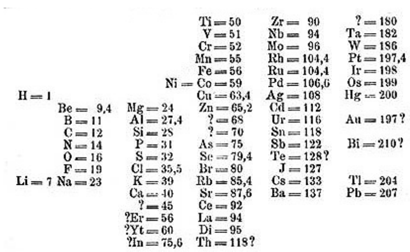
Key Terms	Definitions
Dimitri Mendeleev	A Russian Chemist, who in 1869 published a Periodic Table containing gaps.
Periodic Table	The table which organises the 118 elements based on atomic structure
Isotope	Two atoms with the same number of protons and electrons but a different number of neutrons
Metal	An element which loses electrons to form a positive charge
Non Metal	An element which gains electrons to form a negative charge
Ion	An element with a positive or negative charge

The History of the Periodic Table

- Throughout history scientists have tried to classify substances and many scientists attempted to construct a Periodic Table.
- Before the knowledge of protons, neutrons and electrons, scientists arranged the Periodic table by **atomic weight**. This meant the groups were not always correct.
- In 1869 Dimitri **Mendeleev**, a Russian Scientist, published his Periodic Table. It was slightly different to those that had been before. He still arranged elements by atomic weight but he also left gaps for where he predicted elements would be.
- He very accurately predicted the properties of elements that were not discovered until many years later; for example, Gallium.
- Mendeleev's Periodic Table is still different from the modern one as some of his masses were wrong due to the existence of **isotopes**
- Isotopes are elements with same number of protons and electrons but a different number of neutrons and therefore different atomic weights.

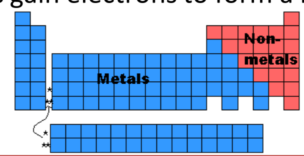


Mendeleev's Periodic Table



Metals and Non-Metals

- Metals are found on the left hand side of the Periodic Table, the majority of elements are metals.
- When metals react, they lose an electrons to form positive ions.
- Non metals gain electrons to form a negative charge.



Groups in the Periodic Table

	Physical properties	Chemical Properties	Equation	Trends/Explanation
Group 1 (Alkali metals)	Soft, low density	React vigorously with water releasing hydrogen	Sodium + Water→ Sodium Hydroxide + Hydrogen	More reactive as you go down, outermost electron further from the nucleus so it's easier to lose
Group 7 (Halogens)	Low melting point, exist as pair (Cl_2)	React with group 1 metals to form compounds . Can carry out displacement reactions	Sodium + Chlorine → Sodium Chloride Sodium Bromide + Chlorine → Sodium Chloride + Bromine	Higher melting point as you go down the group (higher molecular mass). Less reactive as you go down the group.
Group 0 (Noble Gases)	Low melting point/boiling point Eight electrons in outer shell (except helium)	Unreactive, as they have a full outer shell	N/A	Higher melting point and boiling point as you go down the group (due to increase in density)

Chemistry Knowledge Organiser
C2 - The periodic table

Transition Metals Continued

- Transition metals also differ from group 1 elements as they can form multiple different ions (sometimes called oxidation states). Elements in group 1 can only form a +1 ion.
- The ability to form different ions, gives transition metals other properties, firstly it makes them good catalysts in chemical reactions, see more on this in the rate of reaction topic.
- Different ions also form different coloured compounds for example if vanadium forms a +3 ion it is green, +4 is blue and +5 is yellow. This means transition metals are often used in paints.
- The table below shows the ions that different period 4 transition metals can form. You are not expected to memorise this table:

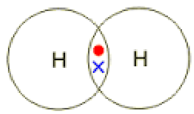
Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
	+2	+2	+2	+2	+2	+2	+2	+2	+2
+3	+3	+3	+3	+3	+3	+3	+3	+3	
	+4	+4	+4	+4	+4	+4	+4		
	+5	+5	+5	+5	+5	+5			
			+6	+6	+6				
				+7					

Chemistry Knowledge Organiser
C3 - Structure and bonding

Key Terms	Definitions
Covalent Bonding	Bonding between 2 (or more) atoms where electrons are shared
Molecule	A substance which contains two or more covalently bonded atoms
Lone Pair	A pair of electrons that are not part of the covalent bond

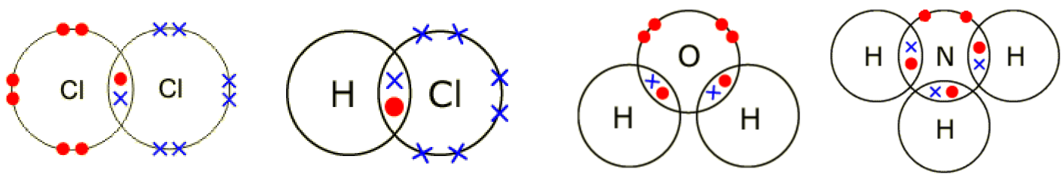
Covalent Bonding

Covalent bonding occurs between non metals. E**lectrons are shared between the atoms**, so that they have a full outer shell. Covalent bonds are strong and require a lot of energy to break. The simplest example is hydrogen: both hydrogen atoms have **one electron in their outer shell. Therefore both hydrogen atoms share one electron each,** to give them both a full outer shell, we can show this bond on a dot and cross diagram.

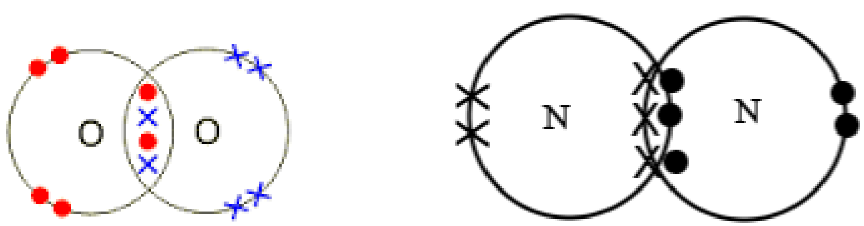


When drawing covalent molecules we use "dot cross diagrams" as we do with ionic compounds. It is important to represent the electrons on one atom with a dot and on the other atom with an X.

The first five examples, **hydrogen, chlorine, water, hydrogen chloride and ammonia (NH_3)** all share one electron per atom in a to make a full outer shell of electrons on each atom.

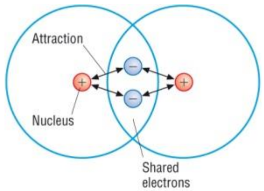


Some atoms need more than one electron to give them a full outer shell, for example oxygen needs 2 electrons to complete its outer shell. Oxygen therefore shares two electrons per atom to **make a double bond.** Nitrogen needs three electrons to complete its outer shell, this forms a triple bond between the two **nitrogen atoms, to make a nitrogen molecule.**



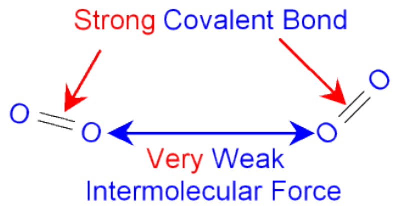
The Nature of a Covalent Bond

Covalent bonds are strong because there is electrostatic attraction between the electrons in the covalent bond and the positively charged nucleus. This means a lot of energy is required to break a covalent bond.



Properties of Simple Covalent Compounds

Simple covalent compounds have low melting points and are often gases at room temperature, for **example oxygen and carbon dioxide.** Although the covalent bonds between the atoms are strong, the **intermolecular forces between the molecules are weak. It is very important to remember that covalent bonds are strong but the intermolecular forces are weak .** This means that only a small amount of energy is required to overcome these weak forces.



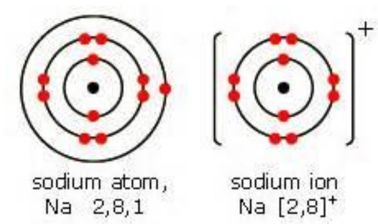
Please see the next page for more properties of covalent compounds.

Chemistry Knowledge Organiser
C3 - Structure and bonding

Key Terms	Definitions
Metal	An element which loses electrons to form positive ions
Non Metal	An element which gains electrons to form negative ions
Ion	An atom (or particle) with a positive or negative charge, due to loss or gain of electrons
Ionic Bond	A bond formed by the electrostatic attraction of oppositely charged ion
Electrostatic	The force between a positive and negative charge.

Ions

All atoms are more stable with a full outer shell of electrons. Some atoms will lose electrons to get a full outer shell: these are metals. Some atoms will gain electrons to get a full outer shell: these **are non metals**. An ion is an atom with a positive or negative charge, these are formed by an atom gaining or losing electrons. For example, sodium has one electron in it's outer shell, it therefore loses one electron to form a Na^{+1} ion. We represent ions with square brackets around the ion and the charge in the top right corner.

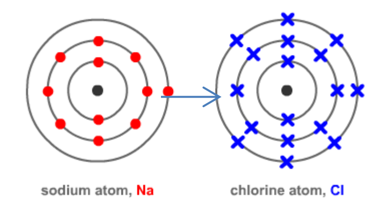


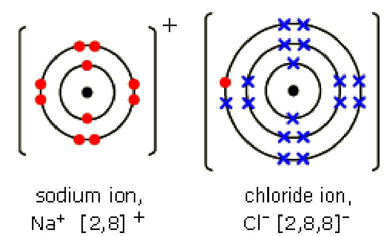
The **group number** indicates how many electrons an atom would have to lose or gain to get a full outer shell of electrons. See below to see what ions different groups form

Group	What happens to the electrons?	Charge on ions
1	Lose 1	+1
2	Lose 2	+2
3	Lose 3	+3
5	Gain 3	-3
6	Gain 2	-2
7	Gain 1	-1

Ionic Bonding

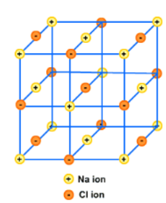
When a metal atom reacts with a non-metal atom electrons in the outer shell of the **metal atom are transferred to the non metal atom**. This means the metal has a positive charge and the non metal has a negative charge. This means there is an **electrostatic attraction** between the two ions, this is what forms an ionic bond. Both atoms will have **a full outer shell** (this is the same as the structure of a noble gas) see example below of sodium chloride.





Ionic Lattice

Ionic compounds have **regular structures (giant ionic lattices)** in which there are strong **electrostatic forces** of attraction in all directions between oppositely charged ions.

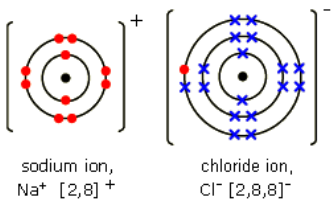


Chemistry Knowledge Organiser
C3 - Structure and bonding

Ionic Bonding- Models

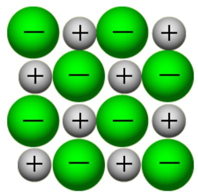
There are a number of ways we can represent ionic bonding all; of these have **advantages and limitations.** For example all the diagrams below show ways we can represent **sodium chloride**

1. **Dot and cross diagrams-** These show clearly how the electrons are transferred. It does not, however, show the 3D lattice structure of an ionic compound or that this is a giant compound.



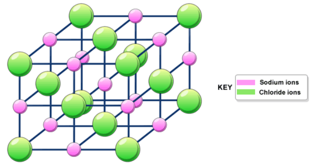
2. **2D ball and stick model of ionic bonding**

This has the advantage of showing that electrostatic forces happen between oppositely charged ions in an ionic compound. However, does not show the 3D structure of an ionic compound.



3. 3D Ball and Stick model of ionic bonding

This clearly shows the 3D structure of the **ionic lattice** and how different ions interact with other ions **in all directions** to create an ionic lattice.



Key Terms	Definitions
Ionic Lattice	The regular 3D arrangement of ions in an ionic compound
Giant	When the arrangement of atoms is repeated may times, with large numbers of atoms or ions
Aqueous	When a substance is dissolved in water
Empirical Formula	The simplest ratio of atoms in a compound

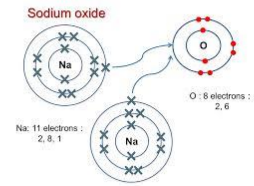
Properties of Ionic compounds

Ionic compounds have **high melting points, due to strong electrostatic forces between the oppositely charged ions.** This means a lot of energy is required to break these bonds. For example the melting point of sodium chloride is 801 °C.

Ionic compounds **do not conduct electricity** as a solid. They **do conduct electricity** if they are dissolved in water (aqueous) or in the liquid state. This is because the ions are free to move, carrying the electric charge.

Empirical Formula of Ionic Compounds

In sodium chloride, 1 sodium atom gives an electron to a chlorine atom, therefore the empirical formula is NaCl. However there are some examples where the ratio of atoms is not 1:1. For example when sodium bonds with oxygen, sodium only wants to lose one electron but oxygen needs to gain two. So you need two sodium atoms for every oxygen so the **empirical formula is Na_2O.**



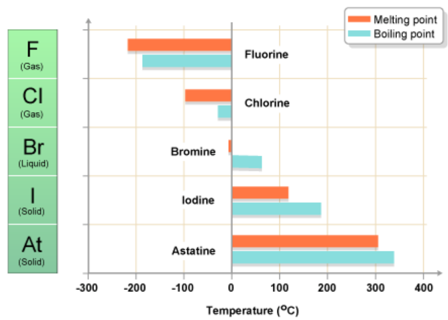
Chemistry Knowledge Organiser
C3 - Structure and bonding

Key Terms	Definitions
Polymer	A very large molecule, made from monomers
Repeating Unit	The shortest repeating section of a polymer
Intermolecular Forces	The force of attraction between two molecules

Properties of Covalent Compounds-Continued

The size of the intermolecular force between molecules increases as the molecules get larger. This is because a force called the van der Waals force increases (you do not need to know that for GCSE). For example as you go down group 7, the boiling points increase because **the molecules get larger**.

As you can see from the graph below, the boiling point of fluorine is -188°C and is therefore a gas at room temperature, whereas the melting point of astatine is 302°C and is therefore a solid at room temperature. This is because the intermolecular forces between the larger astatine molecules are larger than between the **smaller fluorine molecules.**

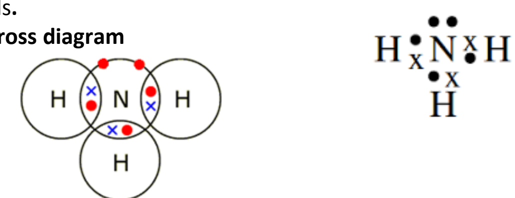


As well as having low melting points, covalent compounds **do not conduct electricity. T**his is because they have no free electrons or ions and therefore there is nothing to carry the electric charge**.** Remember pure water does not conduct electricity, only when it has ions dissolved in it will it conduct.

Representing Covalent Compounds

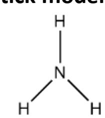
Like ionic compounds, there are variety of ways that scientists use to represent covalent compounds**.**

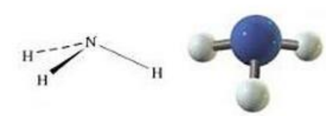
1. Dot cross diagram



There are two dot cross representations of ammonia shown above. The advantages of these diagrams are that it is very clear, which electrons are used in bonding and which are lone pairs. However it does not show the 3D structure of the molecule and this can be extremely important for scientists.

2. Ball and stick model



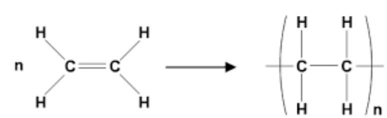


Ammonia (Ball and stick model)

A ball and stick diagram can either be 2D or 3D. While the 2D version clearly shows which atoms are bonded together, the 3D version gives the scientist more information about the 3D shape and the angles between the bonds of the molecule.

Polymers

Polymers are large covalent compounds which can be many thousands of atoms in length. They are made from small molecules known as **monomers.** Rather than drawing out all the atoms in a polymer we draw a **repeating unit** which is the structure of the monomer in square brackets, with a n representing a very large number of atoms. Polymers have higher melting points than smaller covalent compounds like carbon dioxide as the intermolecular bonds are stronger. However the bonds are not as strong as they are in ionic or giant covalent compounds so the melting points are lower than those compounds.



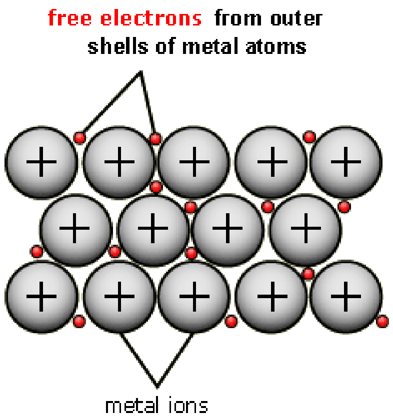
n = a big number of monomers

Chemistry Knowledge Organiser
C3 - Structure and bonding

Key Terms	Definitions
Metallic Bonding	A type of bonding which occurs only in metals
Alloy	A mixture of 2 or elements, one of which is a metal (the other element may be metal or non metal)
Delocalised electron	An electron that is not attached to an atom
Malleable	The ability of a material to be bent into shape.

Metallic Bonding

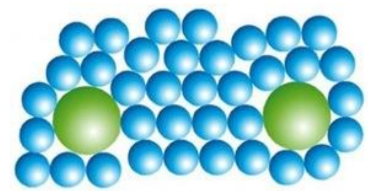
Metals form giant structures. The metal atoms form a regular pattern and the donate their outer electron to the **"sea of delocalised electrons".** These electrons are free to move. The 2D structure of metallic bonding looks like this:



This would be the structure of a group 1 metal like sodium, if it were a group 2 metal like magnesium then the charge on the ions would be Mg^{2+}.

Alloys

Alloys are mixtures of **2 or more elements, one of which is a metal.** Examples of alloys include brass and steel. Metals are alloyed so that the regular structure of metals is changed and the layers of ions can no longer slide over one another; therefore making it much stronger.



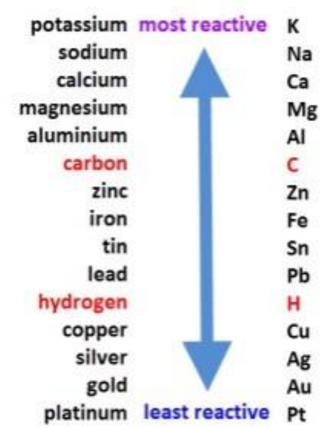
Properties of Metals

Metals are **good conductors of electricity**, due to the delocalised electrons, which can carry the electric charge. Metals are also **good conductors of heat** as the free electrons can transfer the heat energy through the metal.

Metals are also **malleable** (bendy) as the layers of ions can easily slide over one another. This means that many pure metals are too soft for uses such as building.

Reactivity of metals

When a metal reacts it **forms a positive ion.** The easier it is for a metal to form a positive ion, the more reactive it is. This is shown in the reactivity series; you should memorise the position of different elements:



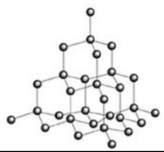
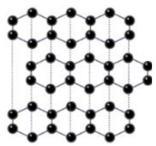
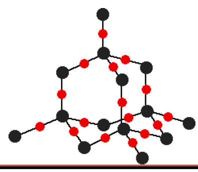
Chemistry Knowledge Organiser
C3 - Structure and bonding

Key Terms	Definitions
Giant Covalent	Giant covalent structures contain a lot of non-metal atoms, each joined to adjacent atoms by covalent bonds
Delocalised electron	An electron that is not attached to an atom
Allotrope	Different forms of the same element for example diamond and graphite are allotropes of carbon
Macromolecule	A molecule which contains many atoms

Giant Covalent Compounds

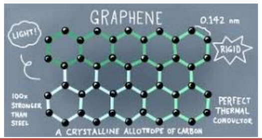
In a giant covalent structure all atoms are bonded to each other by strong covalent bonds. Giant covalent compounds have a **high melting point** because many strong covalent bonds need to be broken and this requires a lot of energy.

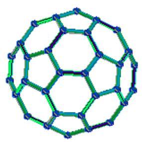
There are three examples you need to know, diamond, graphite and silica (see table below)

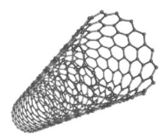
Substance	Diagram	Description	Properties
Diamond		Each carbon is covalently bonded to four other carbons	Vey hard, very high melting point, due to strong covalent bonds. Does not conduct electricity.
Graphite		Each carbon is covalently bonded to 3 other carbons, there are weak (non covalent) bonds between the layers.	High melting point, conductor of electricity due to **delocalised electrons.** Slippery as layers can slide over each other
Silica		Every silicon atom is bonded to 2 oxygen atoms and vice versa	High melting point

Graphene and Fullerenes

There are other forms of carbon which have been discovered recently: **graphene is a single layer of graphite** so it is 1 atom thick. Fullerenes are molecules of carbon with hollow shapes. The most famous example is Buckminsterfullerene (C_{60}). Fullerenes have use in drug delivery and as catalysts. Carbon nanotubes are cylinder shaped fullerenes, these are strong and are excellent conductors of both **heat and electricity.**







Chemistry Knowledge Organiser
C3 - Structure and bonding

Nanoparticles

Nanoparticles have a diameter **between 1 nm and 100 nm**, this means they are only a few hundred atoms in size. There is a field of Science known as nanoscience which is dedicated to the study of nanoparticles.

Nanoparticles are smaller much **than coarse particles**, which have a diameter between 1 x 10^{-5} m and 2.5 x 10^{-6} m. They are also smaller than **fine particles,** which are defined as having a diameter of 100 and 2500 nm.

Nanoparticles have an **extremely large surface area to volume ratio**, this gives them a variety of useful properties.

Uses of nanoparticles

The high surface area to volume ratio means nanoparticles will make excellent catalysts, see more on this in the rate of reaction topic.

Nanoparticles also have many potential applications in medicine for example:

- The targeted delivery of drugs- they are more easily absorbed into the body and therefore could be use to deliver drugs to specific tissues.
- Making synthetic skin

Nanoparticles are also used in the following items:

- Silver nanoparticles have antibacterial properties. These can be used in things like clothing, deodorants and surgical masks.
- Some nanoparticles are electrical conductors, these can be used to make components in very small circuit boards.
- Nanoparticles are also used in cosmetics, to make them less oily
- Nanoparticles are also used in sun creams, they provide better protection from UV than conventional sun creams. They also provide better skin coverage.

Key Terms	Definitions
Nanoparticles	A particle between 1nm and 100nm in diameter.
Surface area to volume ratio	The surface area of a substance divided by the volume.
Nanometre	A unit of measurement: 1x10^{-9}m
Catalyst	A substance which speeds up a reaction, without being used up.

Dangers on Nanomaterials

The long term affects of nanomaterials on the body have not been well researched. For example when using suncream, nanoparticles are absorbed through the skin. The affects of long term exposure to these has not been well researched.

Some people believe anything containing nanoparticles should be clearly labelled.

Chemistry Knowledge Organiser
C4 - Chemical calculations

Relative formula mass (M_r):

This is the mass in grams of 1 mole of the substance. To calculate it you need to add up the atomic mass (bigger number) of all of the atoms in the molecule.
e.g 1. NaCl = Na + Cl = 23 + 35.5 = 58.5
e.g 2. MgF_2 *= Mg + (2 x F) = 24 + (2 x 19) = 62*

The Mole

A mole of an element is simply **6.02×10^{23} atoms (this number is known as Avogadro's number)**. Obviously, if the atoms are larger then 1 mole of that atom will be heavier. For example, one mole of hydrogen atoms weighs 1 gram but 1 mole of carbon weighs 12 grams. To calculate the number of moles in an element you need to divide the mass by the relative atomic mass:
For example, how many moles are there in 6 grams of carbon?
6/12= 0.5

To work out the number of moles in a compound you divide the mass of the compound by the relative formula mass, for example how many moles in 30 grams of magnesium oxide (MgO)?
M_r of MgO=24+16= 40
Moles= 30/40=0.75 **Moles**

HT: Calculating Masses in Reactions

An understanding of the mole will allow to calculate the mass made in a chemical reaction. Take the chemical reaction below:

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

This equation shows that one mole of magnesium reacts with two moles of hydrochloric acid to produce one mole of magnesium chloride and one mole of hydrogen gas. Suppose you started with 5 grams of magnesium, how much magnesium chloride would you make?
Step 1: Calculate the moles of the element or compound you were given in the equation:
5/24=0.21 moles of magnesium
Step 2: Look at the balanced equation, you must therefore have 0.21 moles of magnesium chloride, as the ration between magnesium and magnesium chloride is 1 to 1.
Step 3: Calculate the M_r of the relevant product: what you want to find is the M_r of magnesium chloride:
M_r of $MgCl_2$ =24+35.5+35.5= 94
Step 4: Now find the mass of that number of moles of the product
Mass = moles x M_r, so 0.21 x 94= 19.7 grams

Key Terms	Definitions
Mole	**6.02×10^{23} atoms of an element or molecules in a compound**
Avogadro's number	**6.02×10^{23}**
Relative Formula Mass	The total atomic mass of elements in compound

Equation	Meanings of terms in equation
$moles = \frac{mass}{M_r}$	*Mass is the mass of the substance in grams* *M_r is the relative formula mass of the compound (or use the relative atomic mass if it is an element)*

Calculating moles from masses -Higher Tier

If you know the mass of each reactant and product you can calculate a balanced equation from the masses, for example: Calculate the balanced equation when 12 grams of magnesium reacts completely with 19.25g of HCl, to make 99 grams of $MgCl_2$ and 1 gram of H_2

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

Step 1: work out the moles of each reactant and product.
Mg=12/24= 0.5 HCl=19.25/38.5= 0.5 MgCl2 =99/99 =1 H2 ½ = 0.5
Step 2 divide through by the smallest number

Mg=0.5/0.5=1 HCl=0.5/0.5 = 1 $MgCl_2$ =1/0.5=2 H_2 ½ = 0.5/0.5=1

Step 3 write the balanced equation:

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

Chemistry Knowledge Organiser
C4 - Chemical calculations

% Yield

In reactions in chemistry it is very rare that we make the exact mass predicted by calculation, for a variety of reasons we often make a lot less. The equation to calculate percentage yield is outlined in the equation box. **A percentage yield is always 100% or less**, the law of conservation of mass states that we cannot make mass in a chemical reaction.

It is extremely rare that the yield of a chemical reaction is 100% reasons fro this are:

- The reaction is reversible and may not go to completion
- There may be side reactions
- Some maybe lost when the product is transferred from the reaction vessel

Atom Economy

Some reactions make more than one product, atom of these products will be waste products. The atom economy is a measure of the atoms that form useful products. Like percentage yields we express atom economy as a percentage so that comparisons can be easily made between reactions.

For example below two ways of making hydrogen are outlined:

1. $Zn + 2HCl \rightarrow ZnCl_2 + H_2$

M_r of $H_2 = 1 + 1 = 2$

M_r of $ZnCl_2 = 65 + 35.5 + 35.5 = 136$

Atom economy = $\frac{2}{136+2} \times 100 = \frac{2}{138} \times 100 = 1.45\%$ Very low atom economy

2. $CH_4 + 2H_2O \rightarrow CO_2 + 4H_2$

M_r of $H_2 = 1 + 1 = 2$

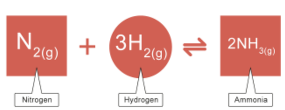
M_r of $CO_2 = 12 + 16 + 16 = 44$

Atom economy = $\frac{4 \times 2}{44 + (4 \times 2)} \times 100 = \frac{8}{52} \times 100 = 15.4\%$ Higher atom economy

In the second example the atom economy is higher, therefore in terms of atom economy reaction 2 is better. Chemists often need to balance atom economy and percentage yield. A poor atom economy is bad for a number of reasons:

1. A lot of reactant is wasted, this costs money.
2. The waste products have to be disposed of, this can be expensive. Some companies try to get around this problem by reusing the waste product.

The best reactions in terms of atom economy are those that only make one product, for example the Haber process, the atom economy here is 100%:



Key Terms	Definitions
Yield	The amount of product made in a chemical reaction
Atom Economy	The percentage of atoms that form useful products
Limiting Reagent	The reagent which is used up first in a chemical reaction.

Equation	Meanings of terms in equation
$\%Yield = \frac{Mass\ of\ products}{Mass\ of\ theoretical\ producti} x100$	*Mass of products is the mass made in a chemical reaction* *Mass of theoretical products is the mass we expected to make based on calculations* *Both these masses must be in the same unit.*
$Atom\ economy = \frac{Reltive\ formula\ mass\ of\ DESIRED\ products}{Total\ relative\ formula\ mass\ of\ products} x100$	*See the previous page for how to calculate relative formula mass*

Limiting Reagent

When a chemical reaction is carried out, one or more reagents are in excess and one reagent is the limiting reagent. The **limiting reagent** is the reagent which is used up first in a chemical reaction, if all of this reagent is used up the reaction can no longer continue, for example, if a tiny amount of sodium is dropped into a large bowl of water there are a lot more water particles that there are sodium atoms. We therefore say that the sodium is the **limiting reagent** and the water is in **excess.**

The amount of product formed is **directly proportional** to the amount of limiting reagent. Therefore if you double the amount of limiting reagent you will get double the amount of product.

Chemistry Knowledge Organiser
C4 - Chemical calculations

Titration Calculations

We can use the information that we get from a titration to work out the concentration of an alkali or acid. For example a titration was carried using hydrochloric acid and sodium hydroxide, the equation for this reaction is:

$$HCl + NaOH \rightarrow NaCl + H_2O$$

This means that one mole of hydrochloric acid will neutralise 1 mole of sodium hydroxide.

Therefore we can calculate the following:

27.5 cm^3 of 0.2 mol/dm^3 hydrochloric acid is needed to titrate 25.0 cm^3 of sodium hydroxide solution. What is the concentration of the sodium hydroxide solution?

Step 1: Convert all volumes to dm^3

27.5 cm^3 = 27.5 ÷ 1000 = 0.0275 dm^3

25.0 cm^3 = 25.0 ÷ 1000 = 0.025 dm^3

Step 2: Calculate the number of moles of the substance where the volume and concentration are known

number of moles = concentration × volume

number of moles of hydrochloric acid = 0.2 × 0.0275 = 0.0055 mol (5.5×10^{-3} mol)

Step 3: Calculate the unknown concentration

We can say that 0.0055 mol of acid will react with 0.0055 mol of alkali

concentration of alkali = moles ÷ volume = 0.0055 ÷ 0.025 = **0.22 mol/dm^3**

Moles of a Gas

We know that one mole of any gas occupies **24 dm^3 at room temperature and pressure.** Room temperature and pressure is defined as 20 ˚c and 1 atm of pressure. There fore if we know the volume that the gas occupies, we can divide this number by 24 and this will give us the number of moles. For example if we had 12 dm^3 of argon gas at room temperature and pressure, then to find out the moles we would simply do 12/24= 0.5 moles.

We can also use balanced equations to work out volumes of gas, for example:

$2CO + O_2 \rightarrow 2CO_2$

If we start with 24 $dm^{3\ of}$ oxygen we will make 48 dm^3 of carbon dioxide, as the ration in the equation shows that one mole of oxygen will make 2 moles of carbon dioxide.

You may also be asked to calculate the volume a gas occupies after being given the mass in the equation. For Example: What volume would 2 grams of carbon dioxide occupy at room temperature and pressure?

Step 1: Calculate the moles of carbon dioxide= 2/44= 0.05 moles

Step 2: Multiply this number by 24 as we know 1 mole occupies 24 dm^3 0.05x24= 1.2 dm^3

Key Terms	Definitions
Decimetre	A unit of volume, often used in chemistry. It is the same as 1000 cm^3
Atmosphere	A unit of gas pressure. It is the same as 101325 Pa

Equation	Meanings of terms in equation
Volume= $\frac{Mass\ of\ gas}{Mr\ of\ gas}$x24	*Mass of gas in grams* *Volume of gas will be in* dm^3

Limiting Reagent

When a chemical reaction is carried out, one or more reagents are in excess and one reagent is the limiting reagent. The **limiting reagent** is the reagent which is used up first in a chemical reaction, if all of this reagent is used up the reaction can no longer continue, for example, if a tiny amount of sodium is dropped into a large bowl of water there are a lot more water particles that there are sodium atoms. We therefore say that the sodium is the **limiting reagent** and the water is in **excess.**

The amount of product formed is **directly proportional** to the amount of limiting reagent. Therefore if you double the amount of limiting reagent you will get double the amount of product.

Chemistry Knowledge Organiser
C4 - Chemical calculations

Key Terms	Definitions
Concentration	A measure of the number of moles or mass in a given volume.
Titration	An experimental techniques where unknown concentrations of solutions can be found.
Burette	A piece of apparatus used to accurately measure volumes of solution.

Concentration

Most chemical reactions are done in solution. The concentration can be measured in grams per dm^3

For example what is the concentration in grams/dm^3 of 2.4 grams of sodium chloride dissolved in 0.5 dm^3 of water?

Conc= Mass/Vol

Conc= 2.4/0.5

Conc= 4.8 g/dm^3

In Chemistry we use dm^3 (decimetres cubed) to measure volume, a decimetre cubed is the same as a litre or 1000 cm^3.

However it is far more common to calculate a concentration in moles per dm^3. This is sometimes written as M.
For example, what is the concentration of 2.4 grams of sodium chloride dissolved in 0.5 dm^3 in mol/dm^3 ?
Moles of NaCl= 2.4/58.5= 0.041 moles

Conc=moles/vol

Conc= 0.041/0.5

Conc=0.082 mol/dm^3

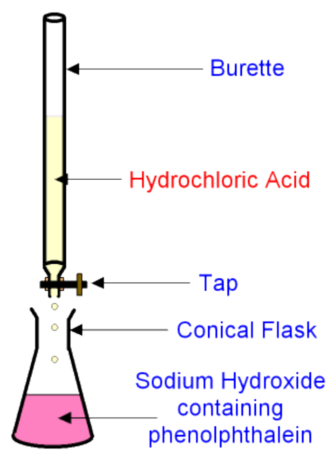
It is also possible to convert between mol/ dm^3 and g/ dm^3 for example. If I had 0.5 mol/ dm^3 HCl solution. We can work out the concertation in g/ dm^3 :
Step 1: Work out the Mr of HCl: 35.5+1= 36.5
Step 2= Mass= Moles x Mr= 36.5 x 0.5 = 18.25 g/ dm^3

Equation	Meanings of terms in equation
$\text{conc} = \frac{mass}{vol}$	*Mass is the mass of the solute in grams* *Vol is the volume of the solventin* dm^3 *Conc is the concentration in* grams/dm^3
$\text{conc} = \frac{Moles}{volume}$	*Moles is the number of moles of the solute* *Vol is the volume of the solution in* dm^3 *Conc is the concentration in* grams/dm^3

Titrations

Titrations are used to find out an **unknown concentration of a solution**, this is often used to find out the concentration of an acid or an alkali in a neutralisation reaction. To carry out a titration to find the concentration of an alkali you need to do the following:

1. A pipette is used to measure 25 cm^3 of alkali, this is then transferred to a conical flask.
2. 3-4 Drops of indicator is added (phenolphthalein).
3. An acid of known concentration is placed in the burette
4. The solution from the burette is allowed to slowly run into the conical flask. As the end point approaches the acid is added one drop at a time. When phenolphthalein is used as an indicator, the end point is where the solution turns from colorless to pink.
5. The volume of acid used from the burette is noted to calculate the concentration of the alkali in the conical flask. See the next page for how to carry out these calculations.



Indicators

For titrations universal indicator is not a suitable indicator to use. As the colour changes are too gradual. For a titration, a sharp colour change is required . Suitable indicators are listed below.

	In acid	In alkali
Litmus	Red	Blue
Methyl Orange	Red	Yellow
Phenolphthalein	Colourless	Pink

Chemistry Knowledge Organiser
C5 - Chemical changes

Key Terms	Definitions
Oxidation	The loss of electrons from an atom OR when an atom gains an oxygen atom
Reduction	The opposite to oxidation, when an atom gains electrons OR when an atom loses an oxygen atom
REDOX Reaction	A reaction where one atom is oxidised and another atom is reduced

Reactions of Metals

When a metal reacts with water it produces a metal hydroxide and **hydrogen gas.**

The more reactive the metal is**,** the more vigorous the reaction. For example:

Lithium + Water → Lithium Hydroxide + Hydrogen

You see a similar pattern for the reaction between metals and acids however the products in these reactions are different, in this case you will make a salt and water, the salt will depend on the type of acid that you have used.

Lithium + Hydrochloric Acid → Lithium Chloride + Water

If sulphuric acid is used the salt made will be a sulphate, if nitric acid is used the salt will be a nitrate**.**

Metals also react with oxygen to form metal oxides; in this reaction the metal donates electrons to the oxygen. This means the metal is **oxidised as it has lost electrons. The oxygen is reduced as it has gained electrons.**

Extraction of Metals

A metal ore is a compound found in rock, dug out of the ground, that contains enough metal that it is **economical** to extract it. For example, magnesium oxide. In order for us to use the magnesium we need to **extract** it from the oxide.

Metals more reactive than carbon are extracted from their ore using **electrolysis**.

Metals which are less reactive than carbon are extracted from their ore using **reduction** (by adding carbon). Reduction is the removal of oxygen as seen in the example.

Example: Iron Oxide + Carbon → Iron + Carbon Dioxide

The least reactive metals such as gold and silver are found on their own—they do not form a compound. This means they do not need to be extracted from their ore.

Other methods of extraction

The amount of some metals is running out, this means people are finding new ways to extract metals like copper.

Phytomining uses plants to absorb copper from the soil, the plants are then burnt and the copper extracted.

Bioleaching involves using bacteria to make a l**eachate** that contains metal compounds.

Scrap iron can also be used to **displace copper** from a solution.

Oxidation Reactions

When working out whether a reaction is oxidation or reduction: in terms of electrons, remember OILRIG. This stands for oxidation is loss and reduction is gain.

HT - Oxidation Reactions of Acids

When an acid reacts with a metal a salt and hydrogen are produced. For example the symbol the symbol equation for an acid reacting with lithium is:

$$2Li + 2HCl \rightarrow 2LiCl + H_2$$

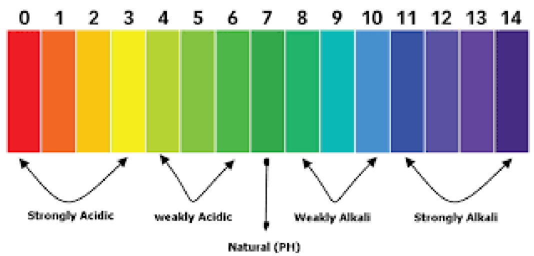
In this reaction, lithium has been oxidised because it has lost an electron to form a +**1 ion** and hydrogen has been reduced from a +1 ion to a **hydrogen molecule.**

Chemistry Knowledge Organiser
C5 - Chemical changes

Key Terms	Definitions
Acid	A substance which forms H+ ions in aqueous solution
Alkali	A substance which forms OH- ions when dissolved: these are soluble bases
Neutralisation	A reaction between an acid and an alkali making a salt and water
Strong Acid	An acid which totally dissociates in water
Base	A substance that can neutralise an acid to make a salt and water

Acids and Alkalis

Acids produce hydrogen ions (**H^+) in aqueous** solutions. Aqueous solutions of alkalis contain **hydroxide ions (OH^-).**
We measure the acidity of a substance using the **pH scale which runs from 0-14** between 0 and 6 the substances are acidic, 7 is neutral and between 8 and 14 is alkaline. The pH scale is a logarithmic scale: a decrease of 1 on the pH scale makes a substance **10 times more acidic.**



The pH scale is a measure of H^+ concentration: the lower the pH the higher the concentration of H^+ ions.

Neutralisation

To work out the names and formulae of salts you will need to know the names and formulae of the common acids

Acid	Name of salt	Ion that forms salt
Hydrochloric	Chloride	Cl^-
Sulphuric Acid	Sulphate	SO_4^{2-}
Nitric Acid	Nitrate	NO_3^{1-}

Neutralisation

When an acid reacts with an alkali a salt and water are produced. The ionic equation for the reaction of an **acid and an alkali is:**

$H^+ + OH^- \rightarrow H_2O$

HT - Strong and Weak Acids

Acids can be defined as either a **strong or weak acid** a strong acid is one which fully dissociates in water for example hydrochloric acid

$HCl \rightarrow H^+ + Cl^-$

A weak acid is defined as one which only partially dissociates in water.
Strong acids are **not the same** as concentrated acids. Concentration is the number of particles in a given volume and not how much they dissociate.

Neutralisation

When an acid reacts with an alkali it will produce salt and water, below are the general equations for different types of neutralisation reaction:

Metal oxide+ Acid → Salt + Water
Copper oxide +Hydrochloric Acid→ Copper chloride +Water
$CuO + HCl \rightarrow CuCl_2 + H_2O$
Metal carbonate + acid → Salt +Water + Carbon Dioxide
Magnesium Carbonate + Sulphuric Acid → Salt +Water +Carbon Dioxide
$MgCO_3 + H_2SO_4 \rightarrow MgSO_4 + H_2O + CO_2$
Metal Hydroxide + Nitric Acid → Sodium Nitrate + Water
Sodium Hydroxide + Nitric Acid→ Sodium Nitrate + Water
$NaOH_+ + HNO_3 \rightarrow NaNO_3 + H_2O$

Some of the reactants (for example copper oxide) are insoluble but these can still carry out a neutralisation reaction. We call these **bases** not **alkalis.**

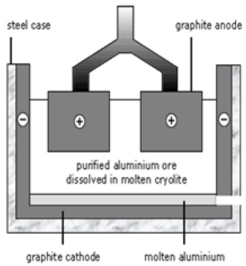
Chemistry Knowledge Organiser
C6 - Electrolysis

Extracting Aluminium

Aluminium oxide is dissolved in molten cryolite .
Cryolite reduces the melting point of aluminium oxide meaning the process requires less energy.
Aluminium ions (Al+) are attracted to the negative electrode.
Aluminium atoms are formed at the negative electrode (gain 1 electron)
Oxide ions are attracted to the positive electrode
Oxygen is formed at the positive electrode (each ion loses 2 electrons)
Oxygen reacts with carbon to make carbon dioxide. This electrode needs to be replaced constantly.

At the negative electrode:
$Al^{3+} + 3e^- \longrightarrow Al$

At the positive electrode
$2O_{2-} \longrightarrow O_2 + 4e^-$



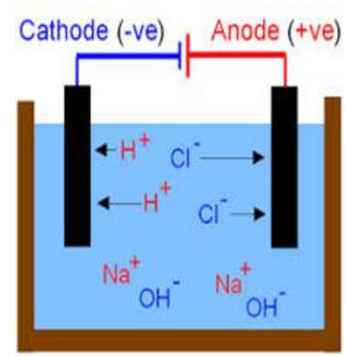
Overall equation:
$2Al_2O_3 \rightarrow 4Al + 3O_2$

Electrolysis of Brine

Which elements form at which electrode depends on the **reactivity** of the elements involved.
For example, the electrolysis of brine, is the electrolysis of a solution of sodium chloride, however there are also H^+ and OH^{-1} ions form the water which is used as the solvent. This means there is more than one possible ion that can go to each electrode.

· **Positive ions:** sodium (Na^+) and hydrogen (H^+)
· **Negative ions:** chlorine (Cl^-) and hydroxide (OH^-)

When there is a mixture of ions, the products formed depend on the reactivity of the elements involved.
Hydrogen is less reactive than sodium, so hydrogen gas (H_2) is produced at the negative electrode.
Chlorine gas (Cl_2) is produced at the positive electrode.
Sodium hydroxide is produced from the ions that remain in solution.



Gas Tests

During electrolysis the products made are often gases. Below are the tests for three common gases you need to know:

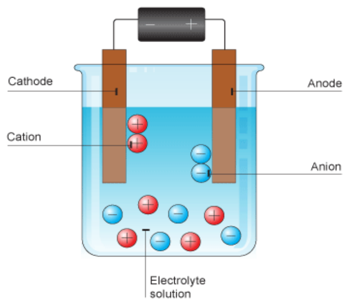
Gas	Test	Result
Hydrogen	Place a lit splint into the gas	If a squeaky pop is heard hydrogen is present
Oxygen	Place glowing splint into gas	If splint is relighted then oxygen is present
Chlorine	Damp litmus paper placed in gas	If paper bleaches, chlorine is present
Carbon Dioxide	Bubble the gas through limewater	If the limewater goes cloudy carbon dioxide is present

Chemistry Knowledge Organiser
C6 - Electrolysis

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.**

If an electric current is passed through this solution the ions will move to the electrodes. **Remember-opposites attract**. **The positive ions (cations) will go to the negative electrode (cathode), the negative ions (anions) go to the positive electrode (anode).**
For example in the electrolysis of lead bromide, Lead (Pb^{2+}) goes to the negative electrode and bromine (Br^{-1}) goes to the positive electrode.



Electrolysis of Copper Sulphate

Which elements form at which electrode depends on the **reactivity** of the elements involved. For example, in the electrolysis of aqueous copper sulphate is the electrolysis of copper sulphate, however there are also H^+ and OH^{-1} ions form the water which is used as the solvent. This means there is more than one possible ion that can go to each electrode.

- **Positive ions:** sodium (Cu^{2+}) and hydrogen (H^+)
- **Negative ions:** sulphate(SO_4^{2-}) and hydroxide (OH^-)

When there is a mixture of ions, the products formed depend on the reactivity of the ions involved.
Copper is **less reactive** than hydrogen, so copper (Cu) is produced at the negative electrode.
The half equation is:
$Cu^{2+} + 2e^- \rightarrow Cu$
The hydroxide ion is more reactive than the sulphate ion, therefore this **forms water (H_2O) and oxygen** at the positive electrode.
$4OH^- \rightarrow O_2 + 2H_2O + 4\ 2e^-$

As a rule if a halide ion is present , this will form at the positive electrode, however if no halide is present then oxygen and water will form at the positive electrode.

Key Terms	Definitions
Electrolysis	The breaking down of a substance using electricity
Electrolyte	The solution which is being broken down during electrolysis
Oxidation	The loss of electrons
Reduction	The gain of electrons
Anode	The positive electrode
Cathode	The negative electrode
Half Equation	An equation that shows the reaction at each electrode

Oxidation and reduction

When a positive Ion reaches the negative electrode, it gains electrons. This is a reduction reaction.
When the negative ion reaches the positive electrode, it loses electrons, this is an oxidation reaction.
We can represent these using half equations A half equation can represent the reaction at each electrode. Half equations show how electrons are transferred and an electron is represented in an equation by an e^- symbol
Half equations show electrons (e^-) and how ions become atoms.
For example $Cu^{2+} + 2\ e^- \longrightarrow Cu$.
1. Write down the ion and atom: $Cl- \longrightarrow Cl_2$
2. Adjust the number of ions (if needed) and add electrons to balance the charges if required $2Cl^- \longrightarrow Cl_2 + 2\ e^-$

Remember that non metal ions will typically form diatomic molecules.

Ionic equations

Half equations can be combined to form an ionic equation, which shows the overall reaction.
For example in the electrolysis of copper chloride the two half equations are:

At the negative electrode (cathode):
$Cu^{2+} + 2\ e^- \longrightarrow Cu$
At the positive electrode (anode):
$2Cl^- \longrightarrow Cl_2 + 2\ e^-$
Combing these 2 equations gives us:

$Cu^{2+} + 2\ e^- + 2Cl^- \longrightarrow Cu + Cl_2 + 2\ e^-$ The electrons either side of the equation cancel out, meaning the final ionic equation is:
$Cu^{2+} + 2Cl^- \longrightarrow Cu + Cl_2$
In an ionic equation it is important to check both the atoms and the charges balance

Chemistry Knowledge Organiser
C7 - Energy changes

Energy in Reactions

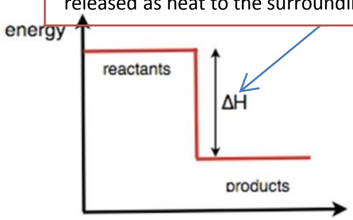
Energy is conserved in chemical reactions. The amount of energy in the **universe at the end** of a chemical reaction **is the same as before the reaction** takes place. In a chemical reaction, bond breaking and bond making occur. To break a chemical bond you need to overcome the force of attraction in the bond, this process requires energy therefore it is **endothermic.** The process of bond formation is **exothermic,** energy is released when bonds form. In a chemical reaction the difference between the energy required to break the bonds and the energy gained from making the bonds will decide whether a reaction is exothermic or endothermic.
Chemical reactions can therefore be divided into exothermic and endothermic chemical reactions.

	What happens?	Why?	Example
Exothermic	Heat energy is transferred to the surroundings.	The energy required to break chemical bonds is less than the energy gained from making chemical bonds. Therefore the excess is given off as heat to the surroundings.	Combustion reaction, reactions used in hand warmers
Endothermic	Heat energy is taken in from the surroundings	The energy required to break chemical bonds is more than the energy gained from making chemical bonds. Therefore heat is taken in from the surroundings.	The reaction of citric acid and sodium hydrogencarbonate, the reactions used in ice packs

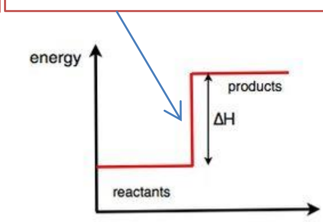
Reaction Profiles

Reminder from topic 15: Chemical reactions can occur only when reacting particles collide with each other and with sufficient energy. The minimum amount of energy that particles must have to react is called the **activation energy**.
Reaction profiles can be used to show the relative energies of reactants and products, the activation energy and the overall energy change of a reaction.

This is the reaction profile of an **exothermic reaction,** the energy of the products is lower than that of the reactants. The difference in energy is released as heat to the surroundings.



This is the reaction profile of an **endothermic reaction,** the energy of the products is higher than that of the reactants. The difference in energy is taken in from the surroundings.



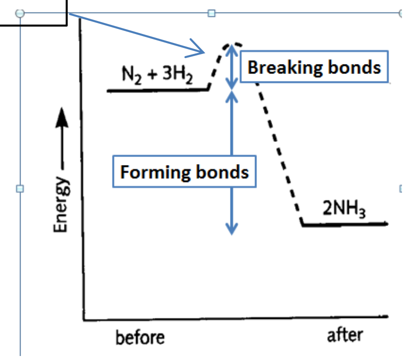
Key Terms	Definitions
Reaction Profile	A graph which shows the energies of the products and reactants in a chemical reaction
Exothermic	A reaction that gives out heat to the surroundings
Endothermic	A reaction that takes heat in from the surroundings

Reaction Profiles- In more detail

The profile below shows the reaction which makes ammonia from nitrogen and hydrogen. The equation is given below:

$$N_2 + 3H_2 \rightarrow 2\,NH_3$$

This hump shows the activation energy



There are some key features to highlight on this graph ,firstly the curved section represents the **activation energy** for this reaction, this hump shows how much energy is required to break the bonds in the reactants. To overcome the activation energy we often need to heat our reactants. The products are lower in energy than the reactants, this means it is an **exothermic reaction.** As the excess energy is given out to the surroundings. as heat **energy.**

Calculating bond energies -higher tier.

The difference between the sum of the energy needed to break bonds in the reactants and the sum of the energy released when bonds in the products are formed is the overall energy change of the reaction.
For example consider the reaction:

$$N_2 + 3H_2 \rightarrow 2\,NH_3$$

To work out the overall energy change you will need to subtract, the energy gained from forming the bonds in ammonia, from the energy required to break the nitrogen and hydrogen bonds. This will give you the overall energy change, if the value is negative then the reaction is exothermic, if the value is positive the reaction is endothermic

Chemistry Knowledge Organiser
C7 - Energy changes

Bond Energies continued- Higher Tier

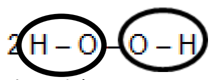
You can calculate the energy change in a reaction from bond energies given to you in a question. For example consider the reaction below:

$$2\,H-O-O-H \longrightarrow 2\,H-O-H \quad + \quad O=O$$

This shows that hydrogen peroxide breaks down to make water and oxygen. We can use bond energies to work out the energy change in the reaction.

Bond	Bond energy in kJ per mole
H – O	464
O – O	146
O = O	498

The energy required to break the reactant bonds is:



2 x464 (for the O-H bonds) = 928 + 146 (for the O-O bond)=1074 however as there is a 2 in the equation this number needs to be doubled.

2 x 1074 = 2148 klj/mol

The energy gained from making the product bonds is:

2x464= 928 but there is a 2 in the equation so this doubled to 1856 and we also need to add the 498 for the double bond in O_2

1856+498=2354 kj/mol

Therefore we do energy required to break reactant bonds- energy gained from making product bonds:

2184-2354=-170kj/mole

If the value is negative then the reaction is **exothermic**
If the value is positive the reaction is **endothermic.**

Key Terms	Definitions
Equilibrium	A reaction that is reversible
Le Chatelier's principle	A principle which states, "If a system is at equilibrium and a change is made to any of the conditions, then the system responds to **counteract the change"**
Dynamic Equilibrium	An equilibrium where the forward and backward reactions are happening at the same rate

Equilibrium

Some chemical reactions are reversible, this means they can happen in both the **forward and reverse directions.** The symbol we use to represent an equilibrium reaction is shown in the equation below:

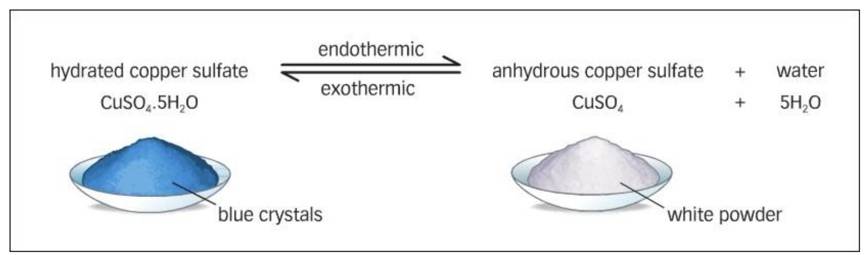
$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

In a dynamic equilibrium reaction, the forward and reverse reactions are happening at the **same rate.**

A dynamic equilibrium has to occur in a **closed system**, where no reactants and products are allowed to escape.

If the equilibrium lies to the left, it means that there is a **greater concentration of reactants than products**
If the equilibrium lies to the right it means there is a **greater concentration of products than reactants.**

Most equilibrium reactions are endothermic in one direction and exothermic in another direction. A good example is the hydration and dehydration of copper sulphate. It is exothermic when water is added to the copper sulphate, it is endothermic when water is removed.



Chemistry Knowledge Organiser
C8 - Rates and equilibrium

Changing Conditions-Le Chatelier's principle- Higher Tier

The Haber process is a good example to explain Le Chatelier's principle, the equation for the Haber process is shown below. The reaction is carried out in the gaseous state. Remember this is one of many reactions but the principles always stay the same.

Endothermic in this direction $N_2 + 3H_2 \rightleftharpoons 2NH_3$ Exothermic in this direction

Condition Change	Effect
Increase the temperature	Shifts the equilibrium to the left as this is the endothermic direction. The amount of reacrtants increases.
Decrease the temperature	Shifts the equilibrium to the right as this is the exothermic direction. The amopunt of product increases
Increase the concentration of reactants	Equilibrium shifts to the right to make more product, to reach equilibrium again
Increase the concentration of products	Equilibrium shifts to the left to reach equilibrium again
Increase the pressure in the gas	Equilibrium shifts to the right, where there are fewer molecules of gas, this will decrease the pressure.
Decrease the pressure in the gas	Shifts the equilibrium to the left as there are more gas molecules on that side of the equation.

Key Terms	Definitions
Equilibrium	A reaction that is reversible
Le Chatelier's principle	A principle which states, "If a system is at equilibrium and a change is made to any of the conditions, then the system responds to **counteract the change**"
Dynamic Equilibrium	An equilibrium where the forward and backward reactions are happening at the same rate

Equilibrium- Changing Conditions-Higher tier

The amounts of all the reactants and products at equilibrium depend on the conditions of the reaction. For example if we change things like **temperature, concentration of a reactant or product and pressure in gases.**

The French scientist Le Chatelier devised a principle to explain how equilibrium reactions, respond to a change in conditions, it states that:

"If a system is at equilibrium and a change is made to any of the conditions, then the system responds to counteract the change"

For example if the temperature is raised the equilibrium will shift to try to cool the surroundings down.

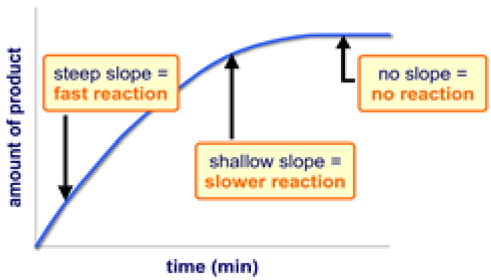
Chemistry Knowledge Organiser
C8 - Rates and equilibrium

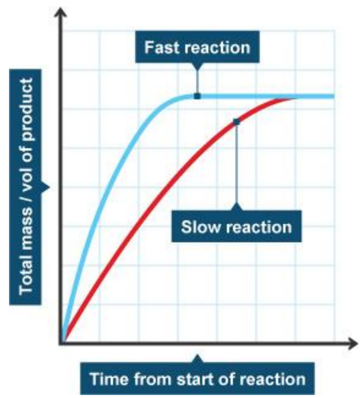
Key Terms	Definitions
Activation Energy	The minimum energy required for a chemical reaction to take place
Collision Theory	The theory that states for a chemical reaction to happen, particles must collide with sufficient energy
Gradient	The measurement of how steep a line is on a graph
Frequency	The amount of times something happens in one second
Concentration	The number of particles in a given volume

Interpreting Rate of Reaction Graphs

The results from rate of reaction experiments can be plotted on a line graph. For example how the mass changes against time or how much gas is made against time. Different lines can be plotted for different conditions, the **steeper the gradient, the faster the reaction.**

It is important to remember that the graphs flatten off (plateau) at the same point as the same amount of reactant is being used.





Factors which affect Rate of Reaction

Being able to slow down and speed up chemical reactions is important in everyday life and in industry. We can change the rate of a reaction by:

- Changing temperature
- Changing pressure
- Changing the concentration of a solution
- Changing the surface area
- Adding a catalyst

Collision Theory

Collision Theory: reactions occur when particles **collide** with a certain amount of **energy**.

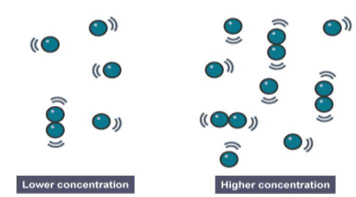
The minimum amount of energy needed for the particles to react is called the **activation energy**, which is different for each reaction.

The rate of a reaction depends on two things:

- the **frequency** of collisions between particles. The more often particles collide, the more likely they are to react.
- the **energy** with which particles collide. If particles collide with less energy than the activation energy, they will not react.

Collision Theory- in more detail Concentration

If the concentration of a solution is increased then there are more particles in a given volume, therefore collisions are **more frequent** and the chemical reaction is faster. Concentration **is directly proportional** to rate of reaction (if you double the concentration you double the rate



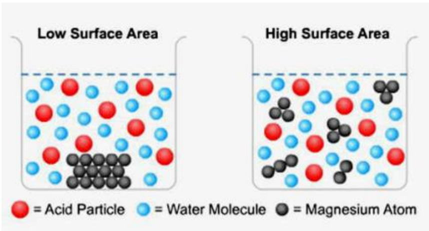
Chemistry Knowledge Organiser
C8 - Rates and equilibrium

Collision Theory in more detail Temperature

When you increase the temperature of something the particles will move around faster, this increases the **frequency of the collisions.** As well as that, as the particles are moving faster the particles collide with more energy making it more likely that collisions exceed the **activation energy.**

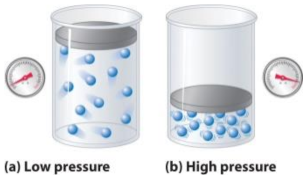
Collision Theory in more detail Surface Area

When you increase the surface area of a solid (you cannot increase the surface area of a liquid or gas). You increase the number of particles that are available for collision, therefore increasing the frequency of collisions therefore increase the rate of reaction.



Collision Theory- in more detail gas pressure

If the reaction is carried out in the gaseous state, then increasing the pressure will increase the rate of reaction. If there are more particles in a given volume of gas, then collisions will be more frequent and therefore the reaction will be faster.



Enzymes

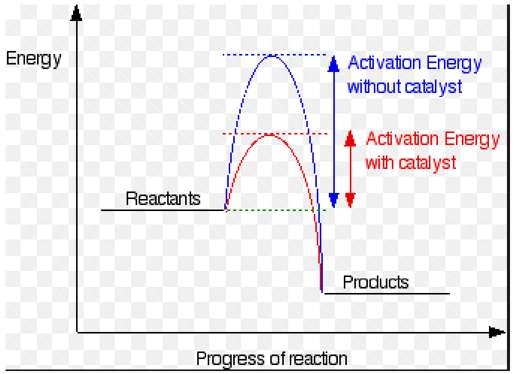
Enzymes **are biological catalysts**, they speed up chemical reactions in biological systems for example in digestion in animals. Unlike catalysts enzymes have an optimum temperature where they work best, this is usually around 37

Key Terms	Definitions
Enzymes	A biological catalyst
Reaction Profile	A graph which show the energies of the reactants and products at different stages of the chemical reaction

Collision Theory in more detail Catalysts

A catalyst is a substance which speeds up a chemical reaction without being used up. It speeds up a reaction because it lowers the activation energy by providing an alternative pathway and this means that there are more **successful collisions and a faster reaction.**

The effect of a catalyst is shown on the reaction profile below:



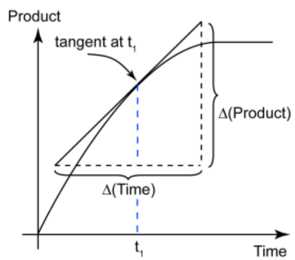
Catalysts are not included in a chemical equation as they are not used up in a chemical reaction.

Chemistry Knowledge Organiser
C8 - Rates and equilibrium

Rate of Reaction

The rate of reaction is the speed at which a chemical reaction is happening. This can vary hugely from reaction to reaction.
The rate of reaction can be calculated either by measuring the quantity of **reactant used or the quantity of product made in a certain length of time**. The quantity can either be a volume measured in cm^3 or a mass measure in grams (g).

Measuring Rate of Reaction-Higher Tier

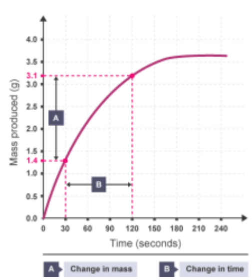


The gradient of a volume or mass/time graph will give you the rate of reaction at a given point. However when the line is a curve you need to draw **a tangent** to measure the gradient. To draw a tangent follow the following steps

1. Line you ruler up across your graph, so that it touches the line on the point that you want to find out the gradient
2. Adjust the ruler until the space between the ruler and the curve is equal on both sides
3. Draw the line and pick two easy pints that will allow you to calculate the gradient of the line.

Calculating the Mean Rate of Reaction -Higher Tier

To calculate the mean rate of reaction from a graph you need to pick two y values on the graph and two x values, subtract the largest from the smallest and the divide the value on the y axis by the valued on the x axis.



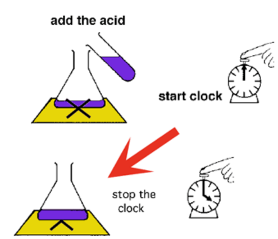
Key Terms	Definitions
Rate of Reaction	The rate at which reactants are being turned into products
Reactant	What is used in a chemical reaction
Product	What is made in a chemical reaction
Catalyst	A substance which speeds up a chemical reaction without being used up
Tangent	A straight line that touches a curve at a point

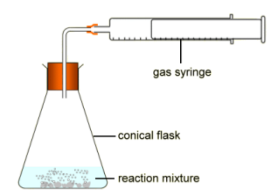
Equation	Meanings of terms in equation
Rate of Reaction= $\frac{Reactant\ used}{time}$	*Reactant used can either r be measured in grams or cm^3*
Rate of Reaction= $\frac{Product\ \ Made}{time}$	*Reactant used can either r be measured in grams or cm^3*

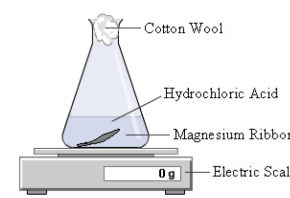
Measuring the Rate of Reaction

There are several experiments that can be used to measure the rate of a chemical reaction.

1. Measuring the mass lost in a chemical reaction (marble chips and acid is a good example)
2. Measuring the volume of gas produced (decomposition of hydrogen peroxide is a good example)
3. Time taken to make an X disappear (sodium thiosulphate and acid is a good example)







Chemistry Knowledge Organiser
C9 - Crude oil and fuels

Key Terms	Definitions
Hydrocarbon	A compound which contains only hydrogen and carbon (covalently bonded)
Fractional Distillation	The process where crude oil is separated into different compounds through evaporation
Viscosity	The ability of a liquid to flow

Neutralisation Reaction

When a salt is made in a neutralisation reaction, it will either be **soluble** or **insoluble**. For example, sulphuric acid can be neutralised with copper oxide to make copper sulphate and water. The **copper sulphate is soluble in water.**
The steps outlined below can be used to make copper sulphate:

1. Add several spatulas of copper oxide to sulphuric acid in a **conical flask**
2. Stir until all the sulphuric acid has reacted
3. Filter off any excess copper oxide
4. Place solution in evaporating basin
5. Allow water to evaporate and blue crystals of copper oxide should be left

Crude Oil

Crude oils is a mixture of chemicals called hydrocarbons. These are chemicals that contain **hydrogen and carbon only. It made from ancient biomass, mainly plankton.** Crude oil straight out of the ground is not much use, as there are too many substances in it, all with **different boiling points**.

Before we can use crude oil we have to separate it into its different substances. We do this by fractional distillation.

How does fractional distillation work?

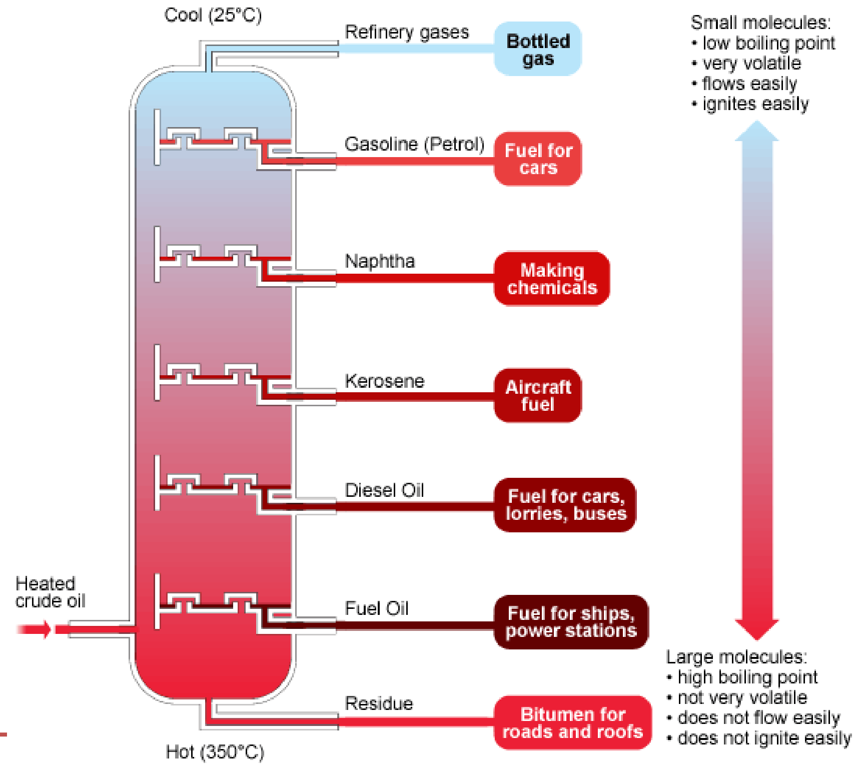
· Crude oil is heated and vaporises/boils.
· Vapours rise up the column, gradually cooling and condensing.
· Hydrocarbons with different size molecules condense at different levels/temperatures
· The crude oil is separated into a series of fractions with similar numbers of carbon atoms and boiling points. These are called fractions.

As the number of carbon atoms increases:

· Molecules become larger and heavier
· Boiling point increases
· Flammability decreases (catches fire less easily)
· Viscosity increases (liquid becomes thicker)

Fractional Distillation Column

Below is a diagram of a fractionating column; you need to know the uses but not the names of each fraction:



Chemistry Knowledge Organiser
C9 - Crude oil and fuels

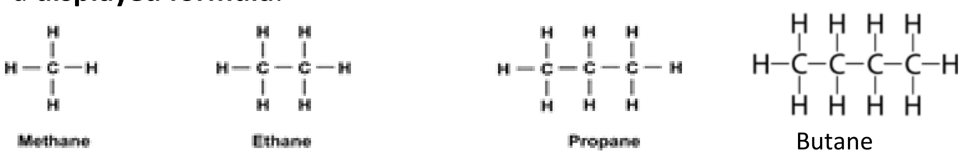
Key Terms	Definitions
Alkane	A hydrocarbon that contains only carbon to carbon single bonds
Cracking	A process where longer chain hydrocarbons are broken down into smaller more useful ones.
Alkene	A hydrocarbon that contains at least one carbon to carbon double bond.

Alkanes

Crude oil is largely made up of a family of hydrocarbons called alkanes; these contain only a single (covalent) carbon to carbon bond.
You can either represent alkanes with a **molecular formula**, e.g.:

CH_4	C_2H_6	C_3H_8	C_4H_{10}
Methane	Ethane	Propane	Butane

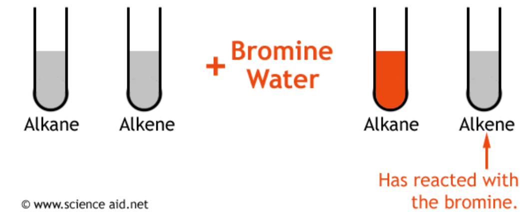
Or a **displayed formula**:



[H = Hydrogen, C = Carbon, - indicates a chemical bond between atoms]

Alkenes

These hydrocarbons have at least one double bonds between the carbon atom. The general formula for alkenes is $\mathbf{C_nH_{2n}}$
Alkenes are **more reactive** than alkanes. They react with bromine water and make it go from orange to colourless.
Alkanes do not have a double bond so the bromine water stays orange.



Cracking

Smaller hydrocarbons make better fuels as they are easier to ignite. However, crude oil contains a lot of longer chain hydrocarbons. To break a longer chain hydrocarbon down into a smaller one we use a process known as **cracking.**

Cracking

So large/long alkanes get CRACKED, which means they get broken in two.
· They are **heated**, turned into a vapour and passed over a hot catalyst
· Cracking produces two molecules:
1. One shorter (useful as a fuel) alkane
2. One alkene (used to make polymers).

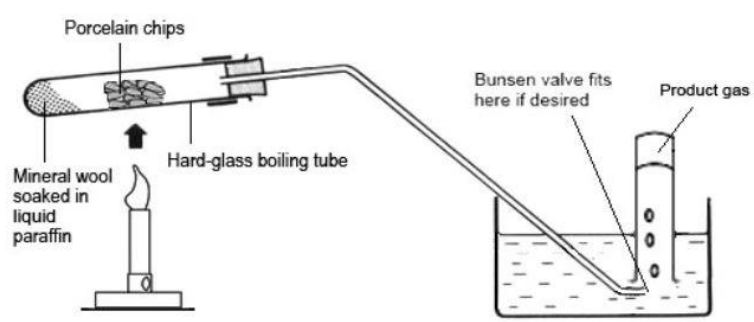
Summary

Long Chain Alkane → Short Chain Alkane + Alkene

$C_{10}H_{22} \rightarrow C_8H_{18} + C_2H_4$

Cracking

Experimental set up for cracking:



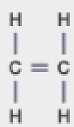
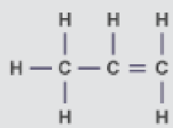
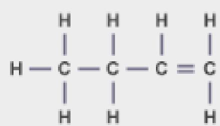
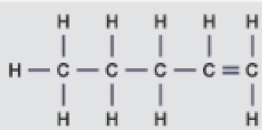
Chemistry Knowledge Organiser
C9 - Crude oil and fuels

Alkenes

A second family of hydrocarbons is alkanes; these contain at least one double (covalent) carbon to carbon bond. The general formula for alkenes is **C_nH_{2n}**
Alkenes are **unsaturated as** there is room for 2 more hydrogens around some of the carbons. You need to know the names and structures of the first 4 alkenes. You can either represent alkanes with a **molecular formula**, e.g.:

C_2H_4	C_3H_6	C_4H_8	C_5H_{10}
Ethene	Propene	Butene	Propene

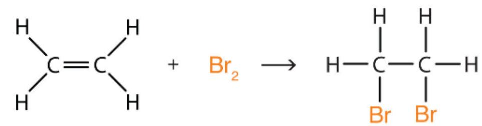
Or a **displayed (structural) formula**:

Name	Molecular formula	Full structural formula
Ethene	C_2H_4	
Propene	C_3H_6	
Butene	C_4H_8	
Pentene	C_5H_{10}	

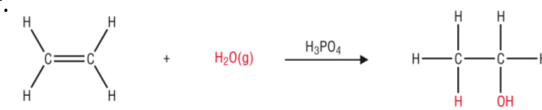
Key Terms	Definitions
Alkene	A hydrocarbon that contains at least one carbon to carbon double bond.
Unsaturated	A compound that contains at least one carbon to carbon double bond. An alkene is an example of something that is unsaturated.
Addition Reaction	A chemical reaction where an element or compound is added across a a double bond.

Alkenes

Alkenes undergo **addition reactions**, this is where another element or compound is added across the double bond**.**
Below is an example of bromine being added across a double bond:



Bromine could be replaced in this equation with another halogen, hydrogen or water. The same type of reaction would take place, however the products formed would be different. For example, the reaction of ethene with water.

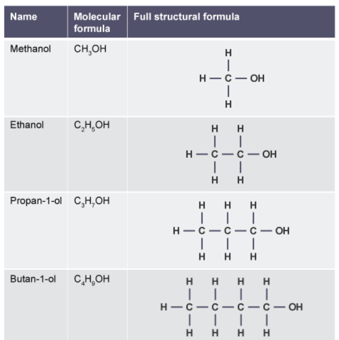


Reagent	Conditions	Product
Hydrogen	Nickel catalyst, 60ºC.	Alkane
Water	Steam, high temperature, high pressure. Phosphoric acid catalyst	Alcohol
Halogen	Halogens in solution for example bromine water	Haloalkane

Chemistry Knowledge Organiser
C10 - Organic reactions

Alcohols

Another family of chemicals are alcohols. They are similar in structure to alkanes except that one of the C-H bonds is replaced with a C-OH. To name an alcohol, you user the same system as naming an alkane except the **–ane section is replaced by –ol** for example methanol.



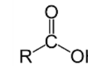
Name	Molecular formula	Full structural formula
Methanol	CH_3OH	
Ethanol	C_2H_5OH	
Propan-1-ol	C_3H_7OH	
Butan-1-ol	C_4H_9OH	

Making ethanol

There are two techniques for making ethanol:

1. Fermentation
2. Hydration of ethane (see page on alkenes)

Process	Description	Advantages	Disadvantages
Fermentation	Sugar and yeast (anaerobic respiration) produces ethanol	Uses plants so is renewable, carbon neutral. Needs low temp 37˚C	Slow, relies on crops
Hydration of ethene	Ethene reacted with steam at a high temp and pressure	Fast, produces ethanol in large quantities	Ethene from crude oil is non renewable. Lots of energy required

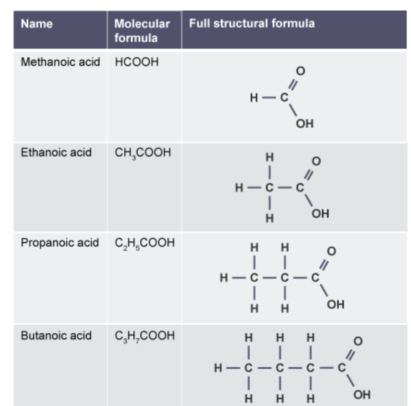
Key Terms	Definitions
Alcohol	A family of chemicals containing a C-OH functional group
Carboxylic acid	A family of chemicals containing a  unctional group.
Fermentation	When bacteria or yeast is used to break down a chemical.

Reactions and uses of Alcohols

The first four alcohols are flammable and this means that they will undergo **complete combustion** in air making carbon dioxide and water. This means they make very good fuels.
Unlike carboxylic acids alcohols **will not form** acids when dissolved in water.
Alcohols with react with metal producing **hydrogen gas.**
Alcohols are also **excellent solvents**, which means they are useful in the chemical industry.
Alcohols can be **oxidised** to carboxylic acids
They can react with carboxylic acids to form **esters.**

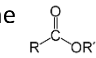
Carboxylic Acids

Another family of chemicals are carboxylic acids. They contain a COOH functional group. To name carboxylic acids you **add –oic acid** to the end of the name. For example ethanoic acid. Carboxylic acids can be made from the oxidation of an alcohol.



Name	Molecular formula	Full structural formula
Methanoic acid	HCOOH	
Ethanoic acid	CH_3COOH	
Propanoic acid	C_2H_5COOH	
Butanoic acid	C_3H_7COOH	

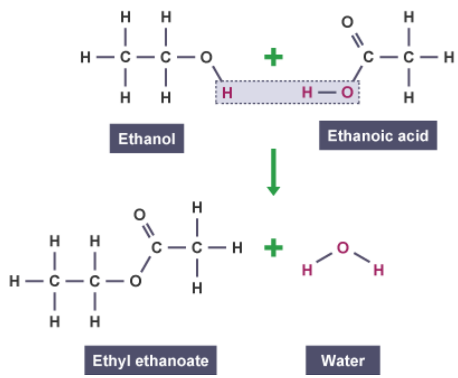
Chemistry Knowledge Organiser
C10 - Organic reactions

Key Terms	Definitions
Esters	A family of chemicals containing the  functional group
Condensation Reaction	A reaction when two molecules make a larger molecule and a smaller molecule, usually water.
Diol	An alcohol which contains 2 C-OH groups
Condensation Polymer	A polymer that has been formed through a condensation reaction

Reactions and properties of carboxylic acids

When dissolved in water carboxylic acids will **form a weak acid**. This means they will partially dissociate. This means that they will undergo similar reactions to other acid, for example, they will react with a metal to form hydrogen gas, they will also react with a **metal carbonate to form carbon dioxide.**

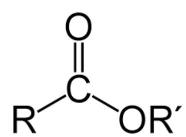
An alcohol and a carboxylic acid will react together to form **an ester.** This reaction needs to be done with **a strong acid catalyst** present, for example concentrated sulphuric acid.



This is known as a **condensation** reaction as two molecules have reacted to make a larger molecule and a small molecule. This small molecule is usually water but can be other small molecules.

Esters

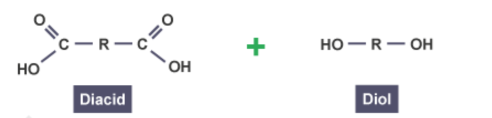
Esters are chemicals with the following functional group:



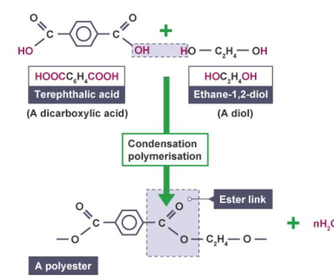
Esters have a pleasant smell this means they are used in many artificial scents and flavours.

Condensation Polymers

There is a second type of polymer which is known as a condensation polymer. These are formed from a condensation reaction. For condensation polymerisation to occur, you need to have reagents that have the correct functional groups at **both ends of the molecule.** For example to make a polyester, you will need, a diol and a diacid.



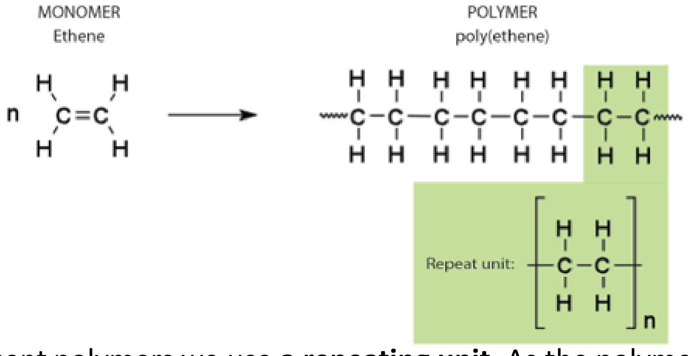
The R in the diagram above just represents the rest of the molecule, to make different sorts of polyester, you simply change the R group. Below is an example showing the formation of one type of polyester.



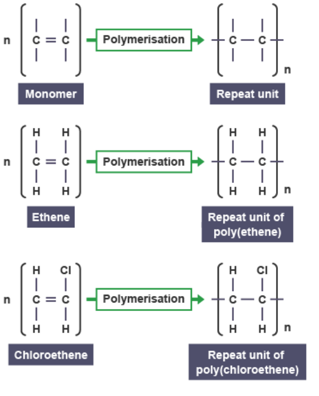
Chemistry Knowledge Organiser
C11 - Polymers

Addition Polymers

Plastics are materials made from **polymers**, which are long chain molecules containing covalent bonds. Polymers are made by joining **monomers** together. Monomers have to have a carbon to carbon double bond.This happens when one of the bonds in a double bond is broken and the monomer joins to the next one, making a long chain. The name of a polymer comes from putting poly- in front of the name of the monomer. This type of polymerisation is known as **addition polymerisation.** Different monomers will give polymers with different properties.



To represent polymers we use **a repeating unit**. As the polymers are typically many thousands of carbon atoms long we use an n to represent a large number.



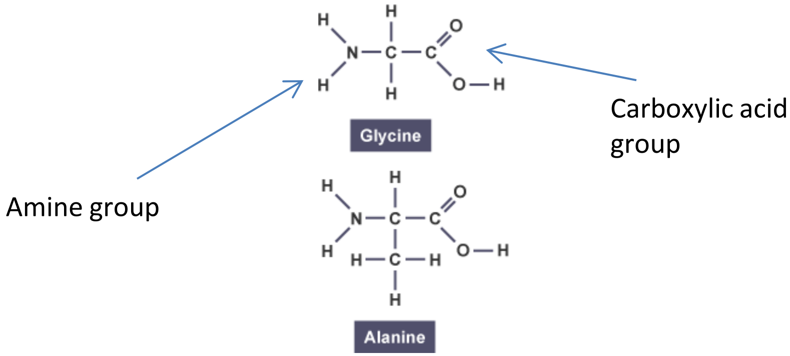
Key Terms	Definitions
Addition Polymer	An addition polymer is a polymer which is formed by an **addition reaction**, where many monomers bond together with no loss of atoms or molecules.
Monomer	A molecule that can be bonded to other molecules to form a polymer. An alkene is an example.
Repeating Unit	A **repeating unit** is a part of a polymer whose repetition would produce the complete polymer chain.

Chemistry Knowledge Organiser
C11 - Polymers

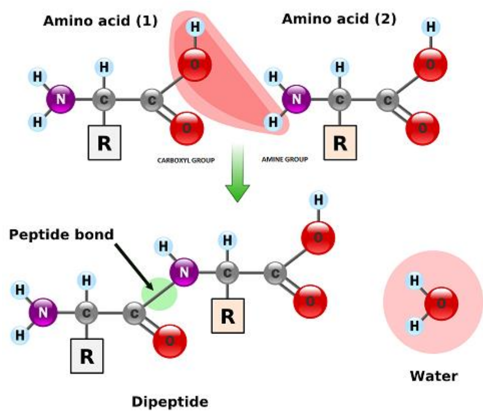
Key Terms	Definitions
Amino Acid	A molecule which contains a carboxyl and amino group.
Peptide bond	A bond formed between an amino and carboxyl group.

Condensation Polymers

Other examples of condensation polymers include proteins. These are polymers of amino acids. Amino acids contain two functional groups, **a carboxyl group and an amino group**. Below is the diagram of two amino acids, alanine and glycine:



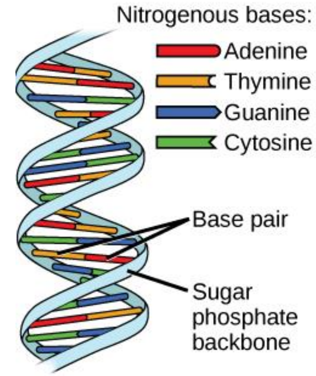
The carboxyl acid can react with the amino group on another amino acid molecule. This will form a peptide bond and as this reaction continues a large **polypeptide or protein** will form.



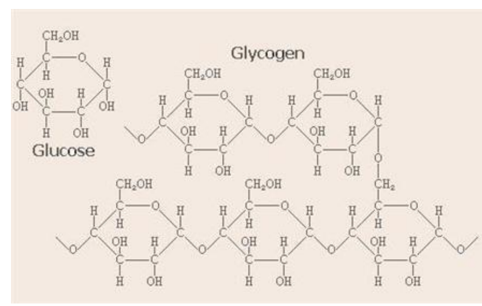
Proteins form molecules like enzymes, haemoglobin and a wide variety of body tissues.

DNA

DNA is made up of a nucleotide strands with bases to form the double helix structure. The nucleotide strands (sugar phosphate backbones) are condensation polymers.



Sugars can also form condensation polymers. For example glucose can be stored as **glycogen, a polymer**. Plants also make a polymer called **cellulo**se to make their cell walls.



Chemistry Knowledge Organiser
C13 - The Earth's atmosphere

Key Terms	Definitions
Greenhouse Layer	The layer of gases which absorb infra red radiation emitted from the Earth

The Atmosphere

For 200 million years, the amount of different gases in the atmosphere have been much the same as they are today:

- 78% nitrogen
- 21% oxygen
- The atmosphere also contains small proportions of various other gases, including carbon dioxide, water vapour and noble gases.

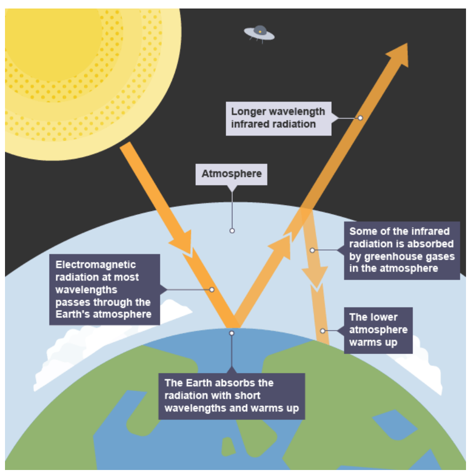
The Greenhouse Effect

The Earth has a layer of gases called the **Greenhouse layer.** These gases, which include carbon dioxide, methane and water vapour**,** maintain the temperature on Earth high enough to support life.

The greenhouse layer allows the short wave infrared radiation emitted by the Sun to pass through it but absorbs the long wave infra red radiation which is emitted by the Earth. This is how it insulates the Earth.

Some human activities increase the amounts of greenhouse gases in the atmosphere. These include:

- combustion of fossil fuels
- deforestation
- methane release from farming
- more animal farming (digestion, waste decomposition)



The Evolution of the Atmosphere

Scientists are not sure about the gases in the early atmosphere, as it was so long ago (4.6 billion years) and the lack of evidence. Many scientists believe the early atmosphere was made up of mainly carbon dioxide, water vapour and small amounts of methane, ammonia and nitrogen, released by **volcanoes. There was little or no oxygen around at this time.** The early Earth was very hot, but as it cooled the water vapour in the atmosphere condensed and **formed the oceans.**

As the oceans formed, carbon dioxide dissolved in the ocean. The carbon dioxide formed carbonates and precipitated out (formed solids). This process reduced the amount of carbon dioxide in the atmosphere.

Approximately 2.7 billion years ago, plants and algae evolved. This decreased the amount of carbon dioxide in the atmosphere and increased the amount of oxygen in the atmosphere.

When sea animals evolved they used the carbon dioxide in the ocean to form their shells and bones (which are made of carbonates). When these sea creatures died their shells and bones became limestone (calcium carbonate), which is a sedimentary rock.

Once enough oxygen was in the atmosphere, it could support animals, which carry out respiration. These processes have caused the levels of gases in the atmosphere to be where they are today.

Changes in the atmosphere

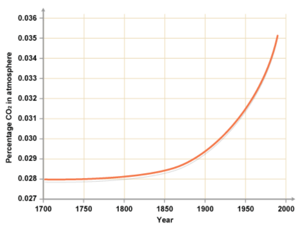
Recent activity by humans has changed the composition of the atmosphere. Combustion of fossil fuels has increased the amount of carbon dioxide in the atmosphere as well as other harmful gases such as nitrous oxides, which are made by nitrogen reacting with oxygen in the air.
Sulphur is also present in many fuels, this has increased the amount of sulphur dioxide which causes acid rain. Carbon particles can also released as can carbon monoxide from incomplete combustion.

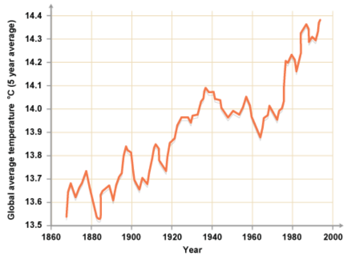
Chemistry Knowledge Organiser
C13 - The Earth's atmosphere

Key Terms	Definitions
Carbon Footprint	The **carbon footprint** is the total amount of carbon dioxide and other greenhouse gases released over the life of a product
Carbon Neutral	There is no net increase in **carbon dioxide in the atmosphere**

The Enhanced Greenhouse Effect

In the last 100 years humans have added to the greenhouse layer through combustion of fossil fuels, increased farming and deforestation. Many scientists believe this has lead to a **rise in global temperature.**





However, this is such a complex system that misunderstandings of it can lead to **inaccurate or biased** opinions being reported in the media.

Consequences of Climate Change

An increase in average global temperature is a major cause of **climate change.**
The potential effects of global climate change include:

- sea level rise, which may cause flooding and increased coastal erosion
- more frequent and severe storms
- changes in the amount, timing and distribution of rainfall
- water shortages for humans and wildlife
- changes in the food producing capacity of some regions
- changes to the distribution of wildlife species.

Students should be able to discuss the scale, risk and environmental implications of global climate change.

Waste water and Sewage

Water water from houses and farming needs to **be treated** before it can be released into rivers and lakes. It is firstly filtered to remove large particles and is then left so that the sediment drops to the bottom. The "sludge," this is the name given to the sediment at the bottom, is then anaerobically digested (broken down by bacteria) to make methane gas. Any remaining **effluent** is broken down by aerobic respiration. The water is then released back into the rivers and lakes.

Carbon Footprint

The **carbon footprint** is the total amount of carbon dioxide and other greenhouse gases released over the life of a product. Many people or businesses look to reduce their carbon footprint by:

- increased use of alternative energy supplies
- energy conservation
- carbon capture and storage
- carbon taxes and licences

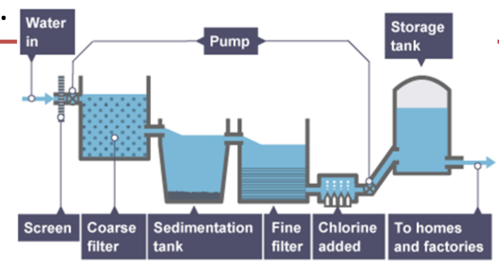
People also try to **offset** their carbon by planting trees.
If something is carbon neutral, this means that there is no net increase in **carbon dioxide in the atmosphere** when it is used.

Water

Water of appropriate quality is **essential for life**. For humans, drinking water should have low levels of dissolved **salts and microbes.** Water that is safe to drink is called **potable water**.
The methods used to produce potable water depend on available supplies of water and local conditions.
In the United Kingdom (UK), rain provides water with low levels of dissolved substances (fresh water) that collects in the ground and in lakes and rivers, and most potable water is produced by:

- passing the water through filter beds to remove any solids
- sterilising to kill microbes, using chlorine or UV light

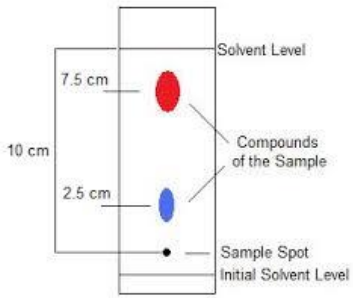
In some parts of the world there is not enough fresh water so the salt has to be removed from water. This process is called **desalination.**
Desalination can be done by distillation or reverse osmosis. This requires a **large amount of energy.**



Chemistry Knowledge Organiser
C12 - Chemical Analysis

Chromatography and Rf values

- When carrying out chromatography we can calculate an Rf (retention factor) value/
- The retention factor is a ratio between the distance travelled by the solvent and the distance travelled by a compound.
- Chromatography has two phases- a stationary phase where particles can't move (the filter paper in most cases), a mobile phase where particles can move (a solvent for example water).
- Different compounds will have different Rf values in different solvents, this allow us to see whether a substance is pure or impure.
- To calculate Rf value you need to divide the distance moved by the solvent by the distance moved by the spot.
- For example to work out the Rf for the spot further up the paper:
- Rf= $\frac{B}{A}$ Rf= $\frac{7.5}{10} = 0.75$
- There are no units as the answer is a ratio
- The higher the Rf the further the spot has moved up the paper, compared to the solvent.



Transition Metals

- The central block (between group 2 and 3) of the Periodic Table is known as the transition metals.
- Compared to group 1 elements, transition metals have different physical properties. For example transition metals have a higher melting point and are more dense.
- The exception is mercury which is a liquid at room temperature.
- Transition metals also have different physical properties to group 1. They are much less reactive and do not react vigorously with oxygen or water.

Key Terms	Definitions
Retention Factor	The ratio between the distance travelled by the substance and the distance travelled by the solvent.

Equation	Meanings of terms in equation and units
Rf= $\frac{B}{A}$	*Rf = Retention Factor (no units)* *B = Distance travelled by substance (cm)* *A= Distance travelled by solvent (cm)*

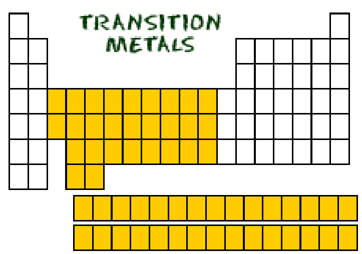
Melting Point and Boiling point

- A chemically pure substance will melt or boil at a very specific temperature.
- If a substance is chemically impure it will melt or boil at a lower temperature and across a broader range.
- The closer the substance is to the melting point the purer the substance.

Formulations

- Formulations are mixtures made using a precise amount of each substance, so they can serve a particular purpose.
- For example in paints or in pills.

Transition Metals



Chemistry Knowledge Organiser
C12 - Chemical analysis

Testing for positive ions

Positive ions (metal ions) can be identified by flame tests:

Metal and ion	Colour of flame test
Sodium Na^{+}	Yellow
Lithium Li^{+}	Crimson
Potassium K^{+}	Purple
Copper Cu^{2+}	Green
Calcium Ca^{2+}	Red/Orange

To carry out a flame test you need to do the following:

1. Dip platinum loop in dilute HCl, hold in Bunsen burner flame (blue flame), until no colour is seen.
2. Dip the loop into the sample you are testing
3. Place this into the flame and observe the colour

Testing for negative ions

Ion	Test	Equation
Carbonate (CO_3^{2-})	Add metal carbonate to dilute acid in a boiling tube. Connect the boiling tube to a test tube containing limewater. If the limewater turns cloudy then a carbonate ion is present	$K_2CO_3 + 2HCl \rightarrow 2KCl + CO_2 + H_2O$
Sulphate (SO_4^{2-})	Add 5 drops of dilute HCl, followed by 5 drops of barium chloride. If sulphate ions are present then a white precipitate will be formed.	$Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$ This is the ionic equation for the reaction.
Halides (Cl^{-1}, Br^{-1}, I^{-1})	Add 5 drops of dilute nitric acid and 5 drops of silver nitrate, the colour of the silver halide precipitate formed will vary depend on the halogen Cl^{-1} – White Br^{-1}- Cream I^{-1}-Yellow	$Ag^{+} + Cl^{-} \rightarrow AgCl$ This is the ionic equation for the reaction.

More tests for metal ions

Some metal hydroxides are insoluble. Therefore if some drops of sodium hydroxide are added to a solution of the metal hydroxide a precipitate may form. Transition metal hydroxides are usually coloured. Where as main group elements normally form a white precipitate.

Gas	Colour of precipitate	Ionic Equation
Magnesium Mg^{2+}	White	$Mg^{2+} + 2OH^{-} \rightarrow Mg(OH)_2$
Calcium Ca^{2+}	White	$Ca^{2+} + 2OH^{-} \rightarrow Ca(OH)_2$
Iron(II) Fe^{2+}	Green	$Fe^{2+} + 2OH^{-} \rightarrow Fe(OH)_2$
Iron(III) Fe^{3+}	Brown	$Fe^{3+} + 3OH^{-} \rightarrow Fe(OH)_3$
Copper Cu^{2+}	Blue	$Cu^{2+} + 2OH^{-} \rightarrow Cu(OH)_2$
Aluminium Al^{3+}	White initially. In excess NaOH it dissolves to form a colourless solution.	$Al^{3+} + 3OH^{-} \rightarrow Al(OH)_3$

Chemistry Knowledge Organiser
C14 - The Earth's resources

Key Terms	Definitions
LCA	An evaluation of the environmental impact a product had over its lifetime

LCAs

Life cycle assessments (LCAs) are carried out to assess the environmental impact of products in each of these stages of a products life:

1. extracting and processing raw materials
2. manufacturing and packaging
3. use and operation during its lifetime
4. disposal at the end of its useful life, including transport and distribution at each stage.

Some things for example the energy required to make the product are easy to measure. However some things like how much pollution it releases are hard to measure and therefore difficult to give a value to.

Example of an LCA

	Plastic Bag	Paper Bag
Raw Material	Crude Oil	Timber
Manufacturing and Packaging	Made form crude oil by fractional distillation, then cracking and polymerisation, high energy process. Little waste as other fractions are used for other things	Made by pulping timber. Lots of waste, high energy process
Use of product	Has multiple uses, can be reused.	Usually only used once.
Disposal	Can be recycled but are not biodegradable	Can be recycled and are biodegradable

Recycling

Many of the Earth's resources are finite: for example, metals and crude oil. It is therefore vital we recycle resources. The processes for extracting these materials are often high energy and damaging to the environment.

Metals can be recycled by melting and **recasting or reforming** into different products.

Some products, such as glass bottles, can be reused. Glass bottles can be **crushed and melted t**o make different glass products. Other products cannot be reused and so are recycled for a different use.

Physics Knowledge Organiser
P1 - Conservation and dissipation of energy

Power

Going past measuring and describing energy transfers, we can consider how fast the energy transfer is (or, how fast the work is done). The rate (speed) of energy transfer is the **power**. The top two equations below show this.

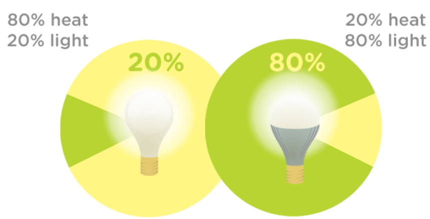
Two things might transfer the same amount of energy (do the same amount of work), but if one does it faster than the other, it has a higher power. For instance, if two people of the same mass run the same distance, they transferred the same amount of energy. However, if one of them completing it faster than the other, they had a higher power. (The 't' in the equation would be smaller, leading to a larger value for 'P'.)

Efficiency of Energy Transfers

As you know, energy cannot be created or destroyed, just transferred. It is often useful to measure how much energy is transferred in the way we want, and how much is dissipated. This measure is called **efficiency** (see equations). Since there is **always** some wasted energy, efficiency must always be less than 1, or less than 100% if you convert the efficiency to a percentage.

To improve efficiency, we reduce the energy transferred in ways that are not useful (i.e. reduce the wasted energy). In a simple example, the light bulb on the left wastes 80% (efficiency = 0.2 or 20%) of the input energy as heat energy, but the one on the right only wastes 20% (efficiency = 0.8 or 80%).

Similarly, the methods such as insulation or lubrication improve efficiency, since they reduce the energy transfer to wasted forms of energy.



Key Terms	Definitions
Power	Power is the **rate** of energy transfer – also known as the rate at which work is done. (Remember, energy transferred is the same as work done.) Since it is a rate, like speed, power is calculated by dividing by time (see equations).
Watt (W)	The watt is the unit for power. One watt is one joule transferred in one second – or 1 J/s (1 joule per second).
Efficiency	The measure of how much of the stored energy in a system is transferred usefully. More efficient devices transfer more energy usefully, which is the same as saying they waste less energy.

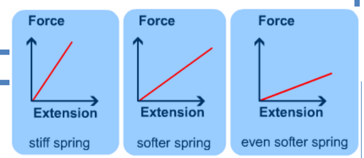
Equation	Meanings of terms in equation and units
$P = \frac{E}{t}$ *	*P = power (watts, W)* *E = energy transferred (joules, J)* *t = time (s)*
$P = \frac{W}{t}$ *	*P = power (watts, W)* *W = work done (J)* *t = time (s)*
$efficiency = \frac{useful\ output\ energy\ transfer}{total\ input\ energy\ transfer}$ *	*Efficiency doesn't have a unit. You can convert the efficiency (which will be a decimal) to a percentage by multiplying by 100.*
$efficiency = \frac{useful\ power\ output}{total\ power\ input}$ *	

Physics Knowledge Organiser
P1 - Conservation and dissipation of energy

Potential Energy

You already know how energy transfers take place when **work** is done. In these cases, energy is *changing form*. However, it is also possible for energy to be **stored** by an object or system. We call the stored energy **potential energy**. When something has potential energy, you won't be able to see anything going on, but if that energy is transferred to a new form, work will be done and you might be able to observe the results.

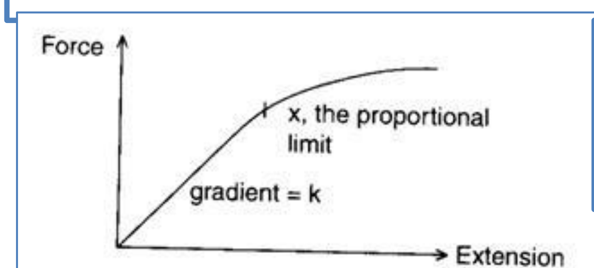
Chemical potential energy is an example: energy is stored in chemical bonds, and is transferred when a chemical reacts. Another example is gravitational potential energy – the energy stored by objects when they are above the ground in a gravitational field. Elastic potential energy is the form of energy stored by an object that is under **elastic deformation**. Think of a stretched rubber band – it isn't doing anything, but if you release it the stored elastic potential energy is transferred to kinetic energy, so you can fire it at someone.



Force and Extension/Compression

The extension of an elastic object, like a spring, is directly proportional to the force applied to it, provided the limit of proportionality of the spring is not exceeded. This also works with the compression of an object – you can use the equations below too, '*e*' just means the amount of compression. The **spring constant** measures how much extension you get for your force. A large spring constant means it won't stretch far compared to a spring with a small spring constant, if the same force is applied (see examples above). The spring constant can be calculated from the gradient of a graph of force against extension.

When force is applied to a spring, it moves a distance, so **work is done.** In other words, energy is transferred. The energy gets stored in the spring (or elastic object) as **elastic potential energy** ***(E_e)***. The amount of elastic potential energy is calculated by the equation shown on the right.



On graphs showing force against extension, you can see when the limit of proportionality is reached by looking at where the graph starts to curve. (Labelled x on this example)

Key Terms	Definitions
Elastic	Describes objects that return to their original shape after being deformed by a force, once the force is removed
Elastic deformation	Deformation (bending, stretching or compressing an object) is elastic if the object returns to its original shape once the force is removed
Deformation	Bending, stretching or compressing an object
Extension	The change in length of an object such as a spring. Subtract length when NO force is applied from the length when a force is applied.
Directly proportional	This term describes a type of relationship between two variables. The two variables are directly proportional if, for every increase of one variable by one unit, the other increases by the same amount. It is shown by a straight line on a graph that goes through the origin.
Limit of proportionality	The limit of a directly proportional relationship. It can be shown on a graph if the line is straight to being with (indicating a directly proportional relationship) then curves.
Linear relationship	Simply, a relationship between two variables that is graphed as a straight line.
Non-linear relationship	A relationship between two variables that is shown with a curved line on a graph.
Gradient	The gradient of a graph is how steep it is. Calculate gradient by dividing the change in the variable on the y-axis by the change in the variable on the x-axis.

Equation	Meanings of terms in equation
$F = k\,e$ *	*F = force (newtons, N)* *k = spring constant (newtons per metre, N/m)* *e = extension (metres, m)*
$E_e = \frac{1}{2} k\, e^2$	*E_e = elastic potential energy (joules, J)* *k = spring constant (newtons per metre, N/m)* *e = extension (metres, m) – this is* ***squared*** *in this equation*

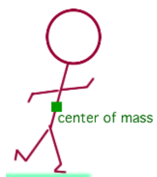
Physics Knowledge Organiser
P1 - Conservation and dissipation of energy

Weight

Weight is often mistaken for **mass**; for instance, when people say they are losing weight, they really mean they are losing mass. As a result, their weight will also drop (see equation), but really it is their mass they seek to change. Mass measures how much material there is (in kg), whereas weight measures the **force** acting on an object due to a **gravitational field**.

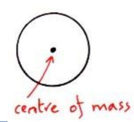
Looking at the equation, you can see that a person with a mass of 65 kg will have a weight of 65 x 10 = 650 N. You can also see that a mass of 100 g (=0.1 kg) has a weight of 1 N on Earth.

As the equation shows, weight and mass are **directly proportional**. We can show this like: $W \propto m$, using the symbol for a directly proportional relationship. On Earth, as mass increases by one unit, weight increases by ten units (as *g* = 10 N/kg).



Centre of Mass

When drawing force diagrams and performing calculations, it is useful to show the weight (or other forces) acting on just a single point on the object. This is the exact centre of a symmetrical object (it will be more complicated for an asymmetrical object), and is called the **centre of mass**. Think of the centre of mass as the point where we consider weight to act: as a result, force arrows should start on the centre of mass.



Measuring Weight

Weight can be determined by calculation using the equation, or directly measured using a **calibrated** (adjusted so the scale is right) spring balance – a newtonmeter. This can be mechanical or digital – a digital newtonmeter will likely have higher <u>**resolution**</u> (detects smaller differences in weight).

Key Terms	Definitions
Weight	Weight is different to mass. Weight is a **force** (hence, it is a vector quantity), caused by gravity acting on a mass. Since it is a force, it is measured in newtons.
Mass	Mass measures the amount of material in an object, and is measured in kilograms (kg). The weight of an object depends on the mass, but mass does not depend on weight. Mass is a scalar quantity.
Gravitational field strength	Simply, the measure of how strong the gravitational field of a large object is. For instance, the gravitational field strength on Earth is about 10 N/kg. This means that a weight of 10 N acts on each kg of mass on Earth.
Centre of mass	The point at which the weight of an object is considered to act – the 'middle' of the object's mass.
Newtonmeter	A device to measure weight. It simply consists of a spring and a calibrated scale.

Equation	Meanings of terms in equation
$W = m\ g$ *	*W = weight (newtons, N)* *m = mass (kilograms, kg)* *g = gravitational field strength (newtons per kilogram, N/kg) – on Earth, this is about 10 N/kg*

Physics Knowledge Organiser
P1 - Conservation and dissipation of energy

Power

You should recall that power is **the rate of energy transfer**, or the rate at which work is done. In electrical components, including any electrical appliance, the power relates to the potential difference across the component and the current through it. If either p.d. or current increases, the power increases. In other words, the rate of energy transfer increases. This should be clear from the first equation.

The second equation also finds the power. The equation comes from substituting in $V = IR$. The second equation is useful if you don't know the p.d. across a component.

Energy transfers in electrical appliances

The whole point of electrical appliances is to transfer energy. The electrical potential energy from the supply is transferred to something useful – such as light and sound in your TV. The other way of saying this is that **work is done** when **charge flows** in a circuit.

Some examples of energy transfers in electrical appliances:

- In your mobile phone, electrical potential energy from the dc supply (the battery) is transferred to light, sound and thermal energy. This means the energy from the battery is **dissipated** to the surroundings.
- A washing machine transfers electrical potential energy from the ac mains supply to kinetic energy in the electric motor (that's why it spins), along with heat. Eventually, all the energy of the input is dissipated to the surroundings.
- An electric heater transfers the electrical potential energy of the supply to thermal energy. The energy stored in the supply ends up stored in the air, the walls, the floor and so on around the heater: stored in the heat of the materials.

The amount of energy transferred by an appliance depends on the **power** of the appliance and the **time** it is switched on for. To find the amount of energy transferred, simply multiply the power of the appliance by the time it is on for (see third equation).

Furthermore, since p.d. is a measure of how much work is done per coulomb of charge, you can find out how much work is done (aka energy transferred) by a circuit by multiplying the charge flow by the p.d. (see fourth equation).

Key Terms	**Definitions**
Power	The rate of energy transfer. In electrical components, the power is found by multiplying p.d. by current.
Work	Transfer of energy.
Appliance	Any device that transfers electrical energy to other forms. The supply of electrical energy can be a cell, battery, or the mains ac supply.

Equation	**Meanings of terms in equation**
* $P = V\,I$	*P = power (watts, W)* *V = potential difference (volts, V)* *I = current (amps, A)*
* $P = I^2\,R$	*P = power (watts, W)* *I = current (amps, A)* *R = resistance (ohms, Ω)*
* $E = P\,t$	*E = energy transferred (joules, J)* *P = power (watts, W)* *t = time (seconds, s)*
* $E = Q\,V$	*E = energy transferred (joules, J)* *Q = charge flow (coulombs, C)* *V = potential difference (volts, V)*

High power, low power

The power of an appliance determines how much energy is transfers in a given length of time. If an appliance has a high power (e.g. a washing machine), it transfers lots of energy in a given time. If it has a low power (e.g. a lamp), it doesn't transfer much energy in a given time, in comparison.

The other way of looking at it is how long the appliance takes to transfer a given amount of energy, e.g. 1000 J. A washing machine will transfer the energy in a very short length of time, whereas a lamp will take much longer to transfer this energy.

Physics Knowledge Organiser
P1/2 - Energy transfer by heating

Energy Stores and Systems

A **system** is simply a small part of the universe that we choose to study. It consists of an object or objects, and we use systems to describe how energy changes in terms of how it is stored. Energy has to be conserved in a system, so it cannot be created or destroyed. However, it can change from one store to another, in an **energy transfer**.

For example:

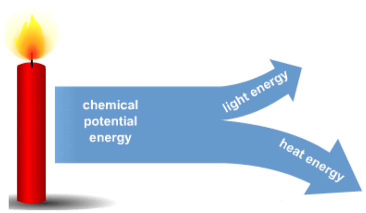
- Firing an object upwards transfers kinetic energy to gravitational potential energy
- When boiling water in kettle, electrical potential energy is transferred to thermal energy
- When using your phone, chemical potential energy is transferred to electrical energy, which is transferred to the surroundings, where it is stored as thermal energy.

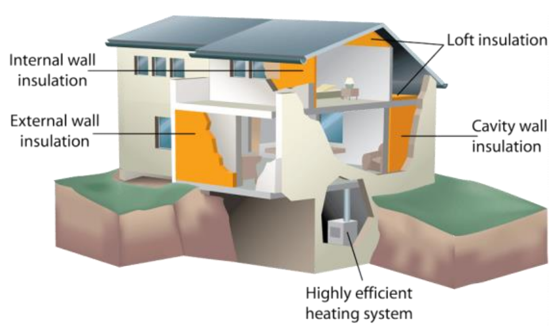
The amount of energy that a moving object has, the amount of energy stored by a stretched spring, and the amount of energy gained by lifting up an object can all be calculated. The equations for E_k, E_e, and E_p are on preceding pages.

Energy Transfers

In a system, the energy in the stores to start with can change form – we can say the overall energy in the system is **redistributed** – meaning it is transferred into other forms. In the end, the energy in the store is transferred to the surroundings. Often, the transfer to the surroundings is in the form of heat (thermal energy). With the candle example here, the chemical potential energy (energy store) is transferred to thermal energy, which is transferred to the surroundings in the end.

It is, in practice, very hard to go back the other way – for example, to transfer the heat energy from the candle back into chemical potential energy. This is what is really meant when people talk about 'saving energy' – overall, energy can't be destroyed so it can't be saved – but, we should try to save the energy stores we rely upon, such as fossil fuels (a huge store of chemical potential energy).





Key Terms	Definitions
Energy store	A system or object can act as an energy store. Energy allows work to be done (since work done = energy transferred). Good examples of energy stores are objects up high (they have gravitational potential energy), fuels (they have chemical potential energy), and stretched springs (they have elastic potential energy).
Energy transfer	The change of energy from one store to another. *Aka* work.
Dissipate	Simply, this means 'spread out'. When applied to energy being dissipated, this means that during energy transfers, some energy is stored in less useful ways. This can be called 'wasted' energy, since it is not transferred to form that is wanted.

Equation	Meanings of terms in equation and units
$\Delta E = m\,c\,\Delta\theta$	*ΔE = change in thermal energy (joules, J)* *m = mass (kg)* *c = specific heat capacity (joules per kilogram per degree Celsius, J/kg °C)* *Δθ = temperature change (°C)*

Unwanted Energy Transfers

During any energy transfer, energy can be transferred usefully, meaning that the stored energy is transferred in a way that does useful work. However, some **dissipation** of the stored energy, in ways that are not useful, is unavoidable. We call the energy transferred in this way 'wasted energy' – meaning unwanted energy transfers have taken place.

Unwanted energy transfers can be reduced by, for instance, oiling/lubricating moving parts (reducing friction, therefore transfer to thermal energy) or insulating systems.

Thermal insulation is insulation that reduces transfer of thermal energy to the surroundings. Thermal conductivity measures how rapidly thermal energy is conducted by a material (so, metals have high thermal conductivity). For effective thermal insulation, you want materials with very low thermal conductivity. The thickness of the material also affects the effectiveness of thermal insulation. Not surprisingly, the thicker the material, usually the better the insulation. Always a consideration in house building – see diagram for examples.

Physics Knowledge Organiser
P3 - Energy resources

Energy Resources

Don't get energy resources and stores of energy mixed up. Energy resources are energy stores that we know how to make use of for our needs, such as electricity. Stores of energy are the ways we find energy in objects or systems – e.g. chemical potential energy, gravitational potential energy, or thermal energy.

The main energy resources on Earth are: fossil fuels (oil, coal and gas); nuclear fuel; biofuel; wind; hydroelectricity; geothermal; tides; the Sun and waves in the sea. These all are stores of energy we can access and transfer usefully, usually to electrical energy. We can also use these energy resources for transport (especially fossil fuels) and heating (especially geothermal – although not in the UK!).

Using Energy Resources

Some energy resources are more reliable than others. For instance, as you may have noticed, the Sun as an energy resource (using solar panels) is not totally reliable in the UK. So we couldn't totally rely on the Sun as an energy resource. Fossil fuels are reliable for the time being, as the supply is good, but they are non-renewable, so this may change in the future. Fossil fuels are also relied upon for transport. This is changing, but still the vast majority of vehicles use fossil fuels as their energy resource.

Environmental considerations about the use of energy resources should also be made. For instance, the combustion of fossil fuels adds to greenhouse gases in the atmosphere, causing climate change. On the other hand, renewable methods like hydroelectricity involve building dams that may displace people and destroy habitats. There are always ethical factors to weigh up too. Although science can identify issues such as environmental problems, scientists are not politicians and big decisions to deal with issues are out of their hands a lot of the time. Political, social, ethical or economic factors also affect decisions made about the use of Earth's energy resources.

Key Terms	Definitions
Energy resources	Stores of energy on Earth that we can access and transfer to useful forms, such as electricity.
Nuclear fuel	Elements that can be used to release massive amounts of energy for generating electricity. Nuclear fuel is based on uranium.
Fossil fuel	A fuel, made from hydrocarbons, that formed millions of years ago from the bodies of animals and plants. Fossil fuels are a store of chemical potential energy.
Geothermal	The energy resource found in Earth's crust, due the thermal energy of the rock of the crust is certain places on Earth.
Biofuel	Any type of fuel made from the bodies of organisms – such as fuels made from plants.
Hydroelectricity	Water stored behind a dam has gravitational potential energy, so it is a store of energy we can make use of.
Tidal energy	Tides in the sea come in and out twice a day. This is a massive movement of water, whose kinetic energy can be transferred usefully to electrical energy.
Wave energy	Waves in the ocean have kinetic energy. With the right equipment, this energy can be transferred usefully to electrical energy.
Solar energy	The Sun is an abundant source of energy. Using solar panels, we can transfer light energy directly into electrical energy. We can also use the thermal energy from the Sun for heating and for generating electricity.
Electricity	A form of energy that we find extremely useful, since it can be used to run so many devices. We use the energy resources described here mainly (but not only) to generate electricity.
Renewable	Describes energy resources that are, or can be, replenished (replaced) as they are used. E.g. biofuels, geothermal.
Non-renewable	Describes energy resources that cannot be replenished. In other words, they get used up. E.g. fossil fuels, nuclear fuel.

Physics Knowledge Organiser
P4 - Electric circuits

Static charge

Every atom contains particles with an electric charge: protons and electrons. The electrons can be transferred from one material to another. When certain insulating materials are rubbed together, they both become charged because electrons are transferred from one material to the other.

- The material gaining electrons becomes negatively charged
- The material losing electrons becomes positively charged
- The size of the charge one each material is the same magnitude, but opposite in direction (+ vs -)

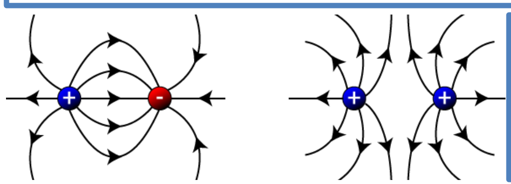
Electrically charged objects affect other charged objects. Like charges repel, whereas oppositely charged objects are attracted to each other. This is a **non-contact force**.

If there is a big enough difference in charge between two places, sometimes the charge can seem to 'jump'. This is seen as a spark. The charge does not, in fact, jump, but flows through the air, heating the air up enough to make it glow. This neutralises the charged objects, so is known as a **discharge**. In fact, this is the basic idea behind how lightning works.

Electric fields

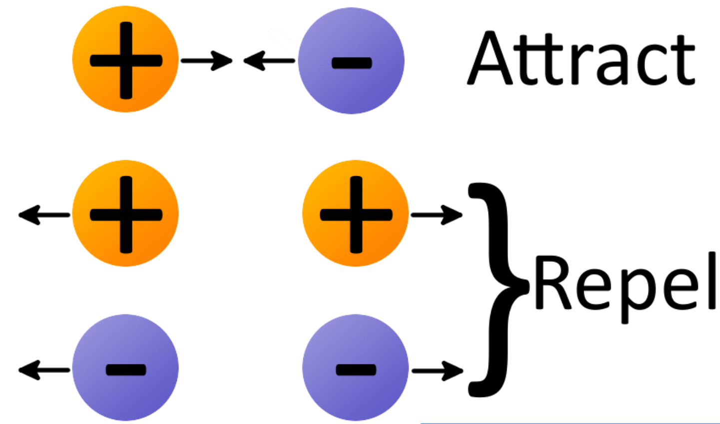
Any charged object produces an **electric field** around it, which extends in all directions away from the object. Other charged objects in this electric field are affected by it – either attracted or repelled as described above. The electric field gets weaker with distance from the charged object, which is obvious when you look at the diagram, right, because the **field lines** (the arrows) spread out going away from the charged object.

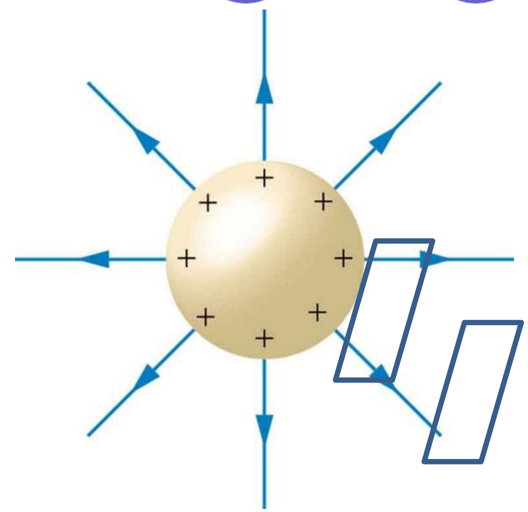
These field lines are not 'real things', but they represent the electric field. If you look at how many lines pass through a certain area, you can get a sense of the strength of the electric field. The more lines pass through the area, the stronger the field. When we say a field is stronger, it means it will exert more force on other charged objects. This concept of the electric field helps explain why electric attraction/repulsion is a non-contact force: the objects don't need to touch, but do need to be within each other's electric fields.



This diagram shows how field lines cause attraction between opposite charges and repulsion between like charges. Again, they don't need to touch to exert these forces on each other.

Key Terms	Definitions
Electric charge	Just a positive or negative charge!
Static	Not moving.
Insulator	Material that does NOT conduct electric current
Attraction	Being pulled together
Repulsion	Being pushed apart
Discharge	Movement of a charge from a charged object, making it neutral





A charged sphere on its own (*isolated*). The arrows point the other way if the object is negatively charged. The rhombuses show how more lines cut through the same area if you are closer to the charged object. This indicates that the field is stronger closer to the charged object.

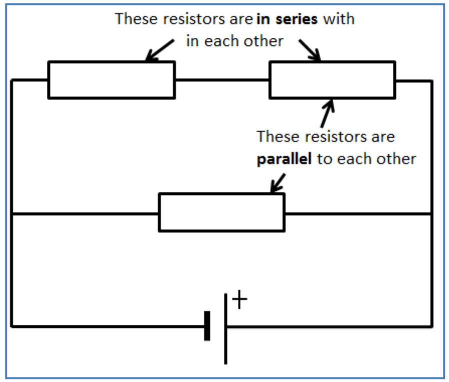
Physics Knowledge Organiser

P4 - Electric circuits

Series and parallel circuits

We can connect components in a circuit in series or in parallel. In some circuits, there are components in series AND components in parallel – see the example in the diagram.

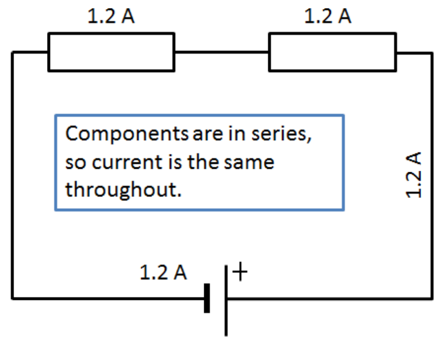
The quantities of resistance, current and potential difference behave differently in components connected in series compared to components connected in parallel. Study the table and diagrams carefully.

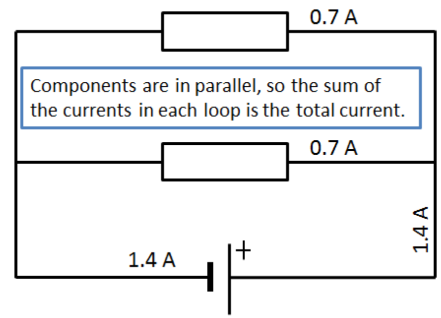


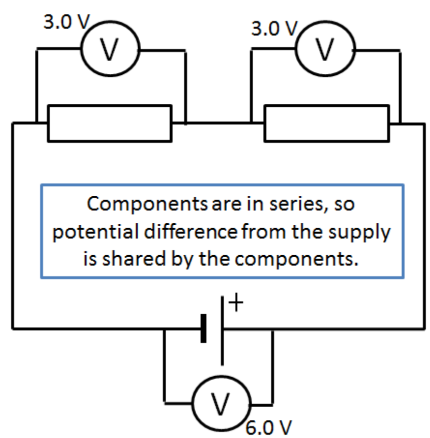
Quantity	Components connected in series…	Components connected in parallel…
Current	The current through each component is identical	Shared between the loops. The total current through the whole circuit is the **sum** of the currents through each loop of the circuit.
Potential difference	The potential difference provided by the power supply is shared between the components in series (not necessarily equally shared out – it depends on the resistance of each component).	Each loop receives the full potential difference provided by the power supply. If we are dealing with just two components in parallel, the potential difference across each is exactly the same, and exactly the same as the potential difference provided by the power supply.
Resistance	The total resistance of two components is the **sum** of the resistance of each component (see equation). So, adding more resistors in series *increases* the total resistance.	The total resistance of two components in parallel is always **less** than the smallest resistance of the components. As a result, adding **more** resistors in parallel actually *decreases* the overall resistance.

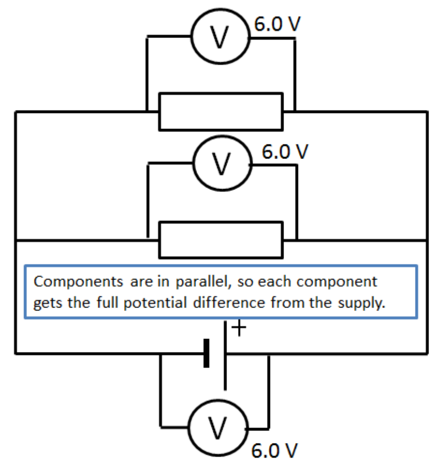
Key Terms	Definitions
Series	Components connected one after another in a closed loop.
Parallel	Components connected in different loops of a circuit.
Resistor	An electrical component that regulates current in a circuit. Bear in mind, all electrical components have **resistance**, so are resistors in some sense, as well as being e.g. bulbs.

Equation	Meanings of terms in equation
for series circuits: $R_{total} = R_1 + R_2$ *	R_{total} = *total resistance (ohms, Ω)* R_1 = *resistance of first component (Ω)* R_2 = *resistance of next component (Ω) – and so on*









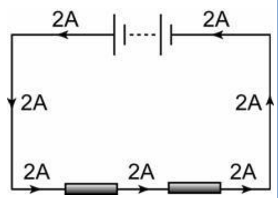
Physics Knowledge Organiser
P4 - Electric circuits

Electric charge and current

Every atom contains particles with an electric charge: protons and electrons. By getting electric charges to **flow**, we can get them to do work (i.e. transfer energy) in all sorts of useful ways. For that is what happens in any electric circuit you can think of: *flowing charges transfer energy*.

If we want to get electric charges to flow, we must make a **closed**, or complete circuit – a loop of conducting materials, like metal wires. Then, we must provide a source of **potential difference**. The source of potential difference could be a cell, battery or the mains. What these sources do is to create a *difference* in electrical *potential* energy – hence the name. This provides the force to make the **electric charges** in the conductors **flow**. When electric charges, like electrons, are flowing, we call it an **electric current**.

The size of an electric current is simply the **rate** of flow of electric charge.
So current (I) = $\frac{Q}{t}$ or $Q = It$



In a circuit, in any closed loop of the circuit, the size of the current is the same throughout the loop. As shown on the diagram, the current is the same in all parts of the loop, including through the battery and through the resistors.

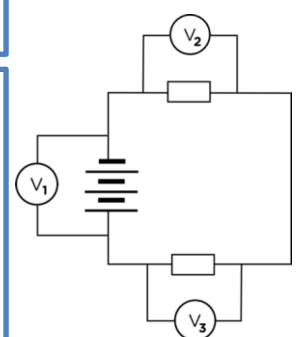
Current, resistance and potential difference

Cells and batteries etc. are **sources** of potential difference. This means they boost the potential energy of charges in a circuit. Other components, like resistors or bulbs, do **work** – so they take the potential energy of the charges and **transfer** it into some other form, like light or heat. In a circuit, all the energy provided by the cell/battery is transferred by the components in the circuit all together. So, in components like bulbs, the charges do work – i.e. they transfer energy. By definition, this means they have a potential difference **across** them. We say 'across' since it is a difference, from one side of the component to the other.

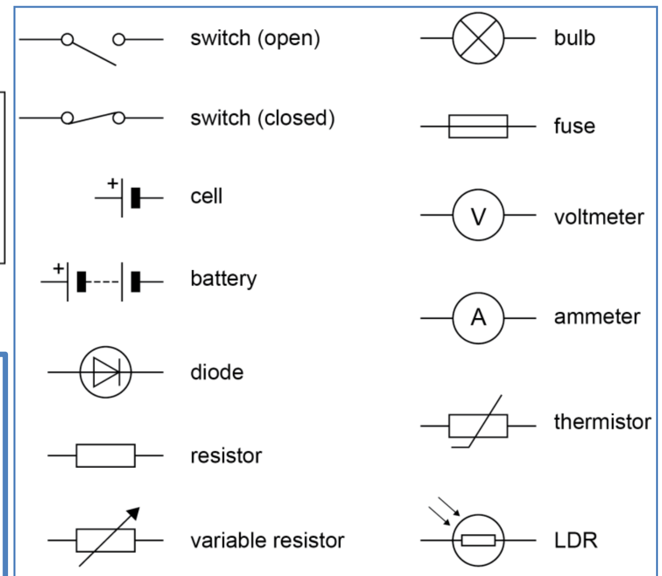
The current through a component depends on this potential difference across the component, but also its **resistance**. Without any resistance, a component would <u>do no work</u> (try putting a 0 in the equation!), so things like bulbs HAVE TO have resistance. The resistance of a component, along with the potential difference across it, determines the current through it, as shown in the second equation. It shows us that: if we keep the potential difference the same, but increase the resistance, the current must *decrease*. If we keep the potential difference the same, but decrease the resistance, the current must *increase*.

Key Terms	Definitions
Electric charge	Just a positive or negative charge! In most electrical circuits, the electric charges that are flowing are **electrons** – which are of course negatively charged. Symbol: Q
Current	The rate of flow of electric charge (i.e. speed). Calculated by dividing the size of the charge by the time. Symbol: I
Potential difference	Also known as voltage, or p.d.. The potential difference is a measure of how much work is done per coulomb of charge.
Resistance	Resistance determines the size of the current for a particular potential difference.

Equation	Meanings of terms in equation
$Q = I\,t$ *	*Q = charge flow (coulombs, C)* *I = current (amperes, A)* *t = time (seconds, s)*
$V = I\,R$ *	*V = potential difference (volts, V)* *I = current (amperes, A)* *R = resistance (ohms, Ω)*



Look how the voltmeters are added **across** the components to measure the potential difference across them.

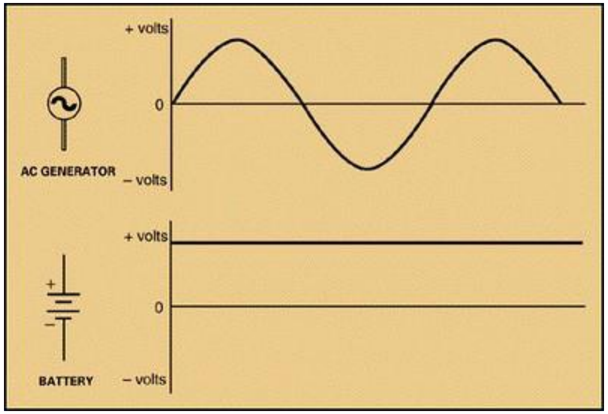


Yes, you need to learn these symbols.

Physics Knowledge Organiser
P5 - Electricity in the home

Direct and alternating potential difference

The flow of charge (current) in a circuit can travel in one direction around the circuit only. This is due to a **direct** supply of potential difference, also known as dc. Cells and batteries provide a direct potential difference. However, it is possible for the direction of the current to change back and forth in a circuit. This happens when there the supply provides an **alternating** potential difference – also known as ac. This means the p.d. is constantly switching from positive to negative, which you can see if you measure the p.d. and produce an image of is on an **oscilloscope**, as the diagram shows. The rate at which the p.d. switches from positive to negative is called the frequency of the supply. The bottom image, since the supply is a battery, shows a direct potential difference.



Three-core cables

We connect most electrical appliances to the mains with a three-core cable. The three pins on a plug are just the three ends, or terminals, of the three wires in the cable. Each wire in insulated in a different colour.

Mains electricity

Mains electricity (the supply into your house/school etc. that comes through the plugs) is an ac supply. In the UK, we have a supply with a p.d. of about 230V, and the frequency is 50 Hz.

Wire in three-core cable	Colour code of the insulation	Function
Live wire	Brown	Carries the alternating p.d. from the supply to the appliance
Neutral wire	Blue	Completes the circuit. The neutral wire is at 0 V (earth potential).
Earth wire	Yellow and green stripes	Earth wires are at 0 V. They are safety wires, and only carry a current if there is a fault and the appliance has become live (electrified).

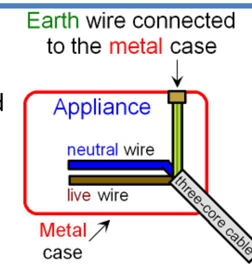
Key Terms	Definitions
Direct p.d.	A supply where the potential difference is fixed at a certain value, so the current flows in one direction only
Alternating p.d.	A supply where the p.d. switches between positive a negative, reversing the direction of the current frequently.
Frequency	The number of times the p.d. reverses direction every second. Measured in Hertz (Hz).

The national grid

The national grid connects power stations to consumers of the power – like you. It consists of a network of cables (i.e. power lines) and **transformers**. There are two types of transformers; together they improve the efficiency of the energy transfer from power station to homes and schools etc.:

1. Step-up transformers ***increase*** the p.d. from the power station to the transmission cables. This reduces the current so less energy is lost as heat.
2. Step-down transformers ***decrease*** the p.d. from the cables to a much lower value (230V, generally) for domestic use. This increases the current to suit electrical appliances used at home.

DANGER (and safety)



The earth wire carries current to the ground (literally, earth). This makes circuits safer because if there is a fault, it conducts the current to the ground rather than making the appliance 'live'. Appliances become live if the live wire touches the case. This is particularly a problem with metal-cased appliances, like cookers or toasters.

The live wire is the most dangerous one, since it is at 230 V. it should never touch the earth wire (unless the insulation is between them, of course!), because this would make a complete circuit from your mains supply to the ground (earth). A shock or fire would be highly likely.

Even if a circuit is switched off (i.e. the switch is **open**), the live wire can still be dangerous. If you touch it, you may complete a circuit between the live wire and the earth (because you'll be standing on the floor), so you get a shock.

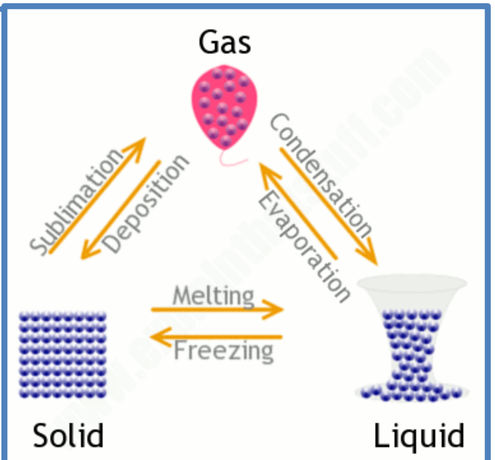
Physics Knowledge Organiser
P6 - Particle model of matter

States of matter and changes of state

Study the diagram. The particle model is used to explain differences between solids, liquids and gases, and to explain how changes from one state to another happen. Make sure you know how to draw the particles arrangement in each state, and know all the names for each state change shown on the diagram.

In a solid, the particles are **fixed in position** and only vibrate – they can't flow around. In a liquid, the particles are still **very close together** but they can **flow** past each other. In a gas, the particles move **randomly** and there is **empty space** between them.

In changes of state, no new substance is produced and there is <u>no</u> change in the **mass** of the substance. This is because no particles are created or destroyed.

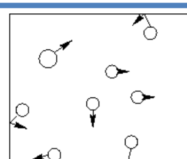


Density and the particle model

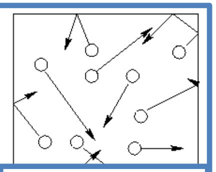
The particle model explains why 1 kg of a gas will have a **much** larger volume than 1 kg of a solid. This is because there is <u>empty space</u> between the particles in a gas, whereas in a solid, they are tightly packed together. Looking at the equation below, you should see that in this example the *m* is the same (1 kg), but the volume for the gas is much larger. Since we <u>divide</u> by volume, this must mean that the **density** of the gas is much smaller than the density of the solid.

Pressure in gases

Particles in a gas are constantly moving – so they store **kinetic energy**. They <u>collide</u> with the walls of their container, and exert a force when they do. The total force exerted on a certain area of the wall is the **gas pressure**.



Cooler gas – less kinetic energy



Hotter gas – more kinetic energy

The amount of kinetic energy that the particles have is related to the temperature of the gas. The higher the temperature, the more kinetic energy they have. This means they move faster, on average. Therefore, there are more collisions with the container walls and they exert a greater force when they collide with the walls. Thus, **increasing** the <u>temperature</u> of a gas (keeping the volume the same) **increases** the <u>pressure</u> of the gas.

Key Terms	Definitions
Model	Models are used all the time in science. A model represents the real world and can explain many things about the universe. However, models are never perfect and there are limits to what they can explain. That doesn't stop them being extremely useful though!
Particle model	The model that represents molecules or atoms as small, hard spheres. The important things to think about when using the particle model are the **arrangement** of the particles in each state of matter and the **kinetic energy** of the particles.
State of matter	The physical arrangement of particles determines the state of a particular substance: solid, liquid or gas. Changing from one state of matter to another is a physical process, NOT a chemical process. No new substance is produced, and if you reverse the state change, you have a substance with exactly the same properties as the stuff you started with.
Density	The quantity that defines how much material (i.e. mass) is in a certain volume. See equation. If you have two objects the same size but different densities, the more dense object will feel heavier in your hand as there is more mass in the same volume.
Melt/freeze	The change of state from solid to liquid/liquid to solid.
Evaporate/ condense	Change of state from liquid to gas/ gas to liquid.
Boil	Like evaporation, boiling is a change of state from liquid to gas. However, boiling involves heating of the liquid so it boils, rather than particles on the surface of the liquid becoming gas (like in evaporation).
Pressure	Pressure is caused by the force exerted by particles in a gas when they hit the walls of a container.

Equation	Meanings of terms in equation
$\rho = \frac{m}{V}$ *	*ρ = density (kilograms per metre cubed, kg/m^3)* *m = mass (kg)* *V = volume (metres cubed, m^3)*

Physics Knowledge Organiser
P7 - Radioactivity

Key Terms	Definitions
Isotopes	Isotopes of an element have the same number of protons but different numbers of neutrons in the nucleus.
Energy level	The other name for electron 'shells'. Each energy level is a specific distance from the nucleus and holds a limited number of electrons.
Radioactive decay	The process of an unstable nucleus becoming stable and giving out nuclear radiation in the process.
Nuclear radiation	Types of radiation that come from the nucleus of atoms during decay. Four types: alpha, beta, gamma, and neutrons.

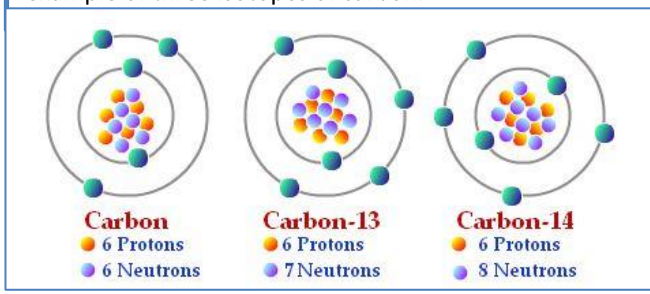
The structure of the atom and isotopes

You've already studied the structure of the atom – the small central nucleus surrounded by electrons – in the first chemistry topic. Go back and recap that first.

An important point about the shells, or energy levels, where electrons are found is that the energy level of an electron can *change*:

- Electrons move *up* an energy level with the **absorption** of a specific wavelength of EM radiation
- Electrons move *down* an energy level by **emitting** a specific wavelength of EM radiation.

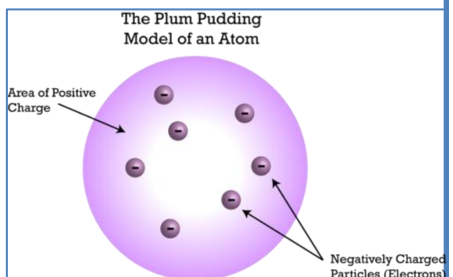
Atoms of a particular element always have the same number of protons (the atomic number in the periodic table). However, they don't all have to have the same number of *neutrons* to be the same element. If the number of neutrons varies between atoms of an element (but number of protons stays the same), we call the atoms **isotopes** of the element. Look at the diagram for the example of three isotopes of carbon.

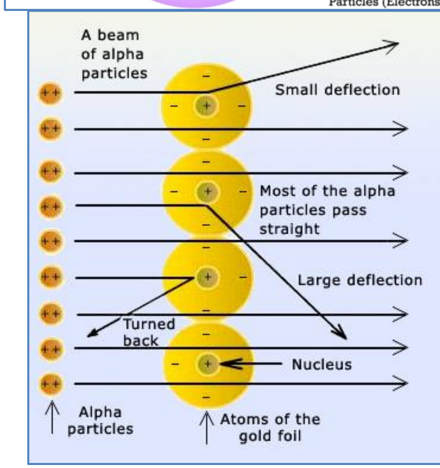


Radioactive decay

Some atomic nuclei are **unstable**. For instance, carbon-14 above is unstable. The nucleus will spontaneously and randomly change to become more stable. When the nucleus does this, it gives out nuclear radiation.

Since it is a random process, it is impossible to predict which particular nucleus will decay next. However, with a huge number of them, it is possible to measure the rate at which the whole source of radiation is decaying. This rate is measured in number of decays per second: the unit is the **becquerel (Bq).** One Bq = 1 decay per second. This can be measured with a detector called a Geiger-Muller tube – in this case, 1 Bq = 1 count per second.





How the modern model of the atom was developed

The model of the atom that you know all about has changed over time. Here's a brief timeline:

1. Before electrons were discovered, atoms were thought of as simply tiny, hard spheres that couldn't be divided into smaller particles.
2. Electrons were discovered (which are smaller than atoms!), so the model was modified. The **plum pudding** model of the atom was described: the atom as a ball of positive charge with negative electrons embedded in it like pieces of fruit in a pudding (see diagram).
3. A famous experiment by the scientists **Rutherford** and **Marsden** showed that the plum pudding model was wrong. Particles named **alpha particles** (more on these later) were fired at a sheet of atoms and some rebounded, some were deflected and others went straight through (see diagram). This showed that atoms have a hard, very small concentration of mass in the centre – which was named the **nucleus**. It also showed that the nucleus was charged, and we now know that is due to the protons in the nucleus. This model, that you use, is sensibly called the **nuclear model** of the atom.
4. The nuclear model was further developed to include the idea that electrons orbit at specific distances from the nucleus: in energy levels. The key scientist presenting this model was **Niels Bohr**.
5. Next, the nucleus was investigated further. It was found that the nucleus can be split up, producing particles with an equally-sized positive charge. These particles are named 'protons' – of course!
6. Then, in 1932, a scientist named **James Chadwick** proved that there were also uncharged particles in the nucleus. He called these particles 'neutrons' as they are neutral: no charge. This was about 20 years after the nucleus had already been accepted as the right idea about atoms.

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P7 - Radioactivity

Types of nuclear radiation

As you've seen, the rate of decay is measured in Bq, or can be measured as the count rate in Bq. What it actually 'counts' is the amount of radiation hitting the detector each second. The radiation emitted from the nucleus thanks to radioactive decay can be:

- An **alpha particle** (symbol: α). An alpha particle is made of two protons and two neutrons (making it identical to the nucleus of helium atoms). Since there are four subatomic particles in one alpha particle, it has a mass number of 4. Since there are two protons in an alpha particle, it has a proton number of 2.
- A **beta particle** (symbol: β). A beta particle is a high speed electron. Beta particles are emitted during a type of radioactive decay where a neutron turns into a proton. This process also makes an electron, and electrons aren't 'allowed' in nuclei, so it gets fired out.
- A **gamma ray** (symbol: γ). Yes, the same wave as in the electromagnetic spectrum. It has a very high frequency and very short wavelength.
- A **neutron** (symbol: n). An uncharged particle – you know all about them already.

Alpha, beta and gamma

As well as being different in form, alpha, beta and gamma are also different in terms of how they behave after emission from a nucleus.

Type of nuclear radiation	Range in air	Penetrating power	Ionising power
Alpha	A few centimet-res	Not very penetrating at all: absorbed by a thin sheet of paper.	Strongly ionising (as alpha particles are large and have a +2 charge)
Beta	A few metres	Fairly penetrating: completely absorbed by a sheet of aluminium 5mm thick.	Moderately ionising (as not as big as alpha particles and their charge is smaller, -1)
Gamma	Enormous distances	Penetrates most materials. Absorbed only by several metres of concrete or a thick sheet of lead.	Only weakly ionising.

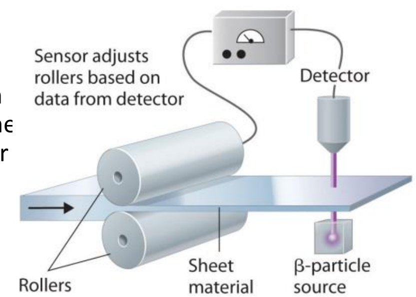
Key Terms	Definitions
Emission	Releasing or giving out. Nuclear radiation is **emitted** during radioactive decay.
Penetration	Passing through a material. Different types of nuclear radiation can penetrate different materials, and are absorbed by certain materials.
Ionisation	The process of making an ion by 'knocking off' electrons. Ionising radiation causes this, and can break up molecules into ions which go on to react with other chemicals. This is very dangerous in living organisms.

Using nuclear radiation

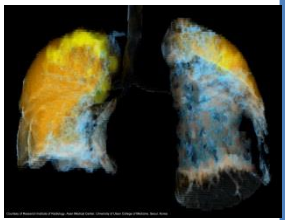
Nuclear radiation can be very useful. Here are some examples: notice that the type of nuclear radiation used depends on exactly what you need it for, so it links to the properties in the table opposite.

Radiotherapy: this is a treatment for cancer, using gamma rays. Gamma rays easily penetrate body tissues, so they can reach a tumour e.g. in the brain. The gamma rays can kill the cancer cells. However, since gamma rays are dangerous to healthy tissue, they use beams of gamma rays from many angles to the tumour, so healthy cells between source and tumour are not affected too badly.

Monitoring thickness of paper in a factory: As the diagram shows, a beta source is used. This is because beta will pass through materials such as paper. The detector on the other side of the sheet will measure a lower count rate if the sheet gets too thick, and a higher count rate if it gets too thin. The rollers can be automatically adjusted to fix this.



Medical diagnosis: sources of radiation can be taken into the body and the nuclear radiation monitored from the outside to give information about body function. Obviously, alpha is NOT suitable for this as it won't penetrate body tissues to get to the detector! For example, a radioactive xenon isotope can be inhaled to check lung function. On the image, the left lung isn't getting much air to the bottom parts.



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P7 - Radioactivity

Nuclear equations

To show what happens to an atom when it radioactively decays, we use nuclear equations. In these equations, we represent alpha and beta particles as shown in the key terms table.

Recalling what an alpha particle actually is (2 protons and 2 neutrons), it is clear that a nucleus going through alpha decay loses 4 subatomic particles (so the mass number has to **decrease** by *four*). Two of those are *protons*, so the *atomic number* must decrease by 2. Here's an example:

$$^{219}_{86}\text{radon} \longrightarrow\ ^{215}_{84}\text{polonium} +\ ^{4}_{2}\text{He}$$

This shows that a radon nucleus decays to produce a polonium nucleus and an alpha particle.

Beta decay results in a beta particle, and happens because a neutron turns into a proton and an electron. The electron is ejected from the nucleus. Since neutrons and protons have the same mass, the mass number does not change. However, there is an *extra proton*, so the atomic number must increase by one (therefore the charge of the nucleus increases by 1). Here's an example:

$$^{14}_{6}\text{carbon} \longrightarrow\ ^{14}_{7}\text{nitrogen} +\ ^{0}_{-1}\text{e}$$

This shows that the carbon nucleus decays to produce a nitrogen nucleus and a beta particle.

NB: emission of a gamma ray DOES NOT cause any change to the mass or atomic number.

Radioactive contamination

It is vital to realise that being exposed to nuclear radiation DOES NOT make something radioactive! (Despite what comic books show.) We say the exposed material/object is **irradiated**, and it is dangerous for living cells, as you know.

So, **radioactive contamination** is NOT being exposed to nuclear radiation. It means getting unwanted radioactive materials onto other materials. For instance, spilling a powdered radioactive source onto clothes. This is dangerous because the radioactive material keeps on emitting nuclear radiation through nuclear decay, so it can keep on irradiating the thing its on.

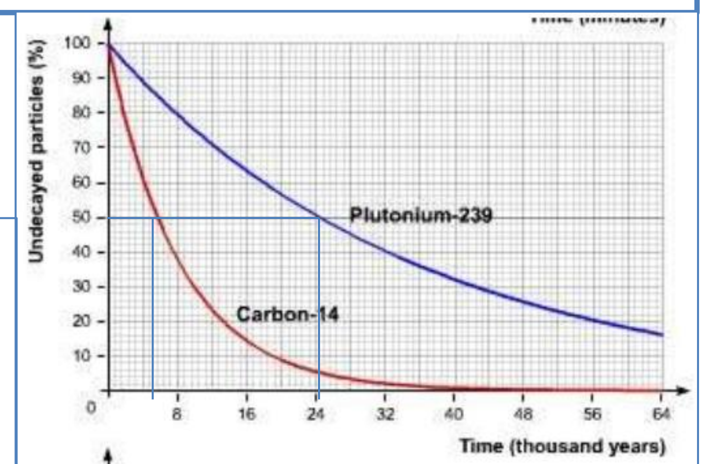
The hazards due to irradiation or contamination mean that *precautions* must be taken. For instance, the radioactive materials (e.g. uranium) used in nuclear power plant is only transferred, stored and used in containers that nuclear radiation can't penetrate. There is ongoing research by scientists into the effects of nuclear radiation on human health. Like all scientific findings, this research should be **published** and receive **peer review** – where other scientists check the methods and analysis performed, to make sure it is right!

Key Terms	Definitions
Mass number	The total number of subatomic particles in the nucleus of an atom (protons + neutrons).
Atomic number	The number of protons in the nucleus of an atom. In other words, the number of positive (+1) charges in the nucleus.
Alpha particle	Can be represented with the symbol: $^{4}_{2}\text{He}$
Beta particle	Can be represented with the symbol: $^{0}_{-1}\text{e}$
Half-life	The half-life of a radioactive isotope is the average time it takes for the number of radioactive nuclei to halve. It can be also be measured as the time it takes for the count rate of the sample to decrease to half its starting count rate.

Half life

Radioactive decay is **random** – so you don't know which nucleus will decay next. However, with a large number of radioactive nuclei, the time it takes for HALF of them to decay *is* predicable. This differs depending on the particular isotope involved. This length of time is called a **half-life** (see definitions too). Plotting the number of radioactive nuclei OR the count rate against time makes half-life easy to find. Read off the time it takes for the number on the y-axis to decrease by a half. So, in this example, we can see that the half-life of carbon-14 is 5.5 thousand years, whereas the half-life of plutonium-239 is 24 thousand years.

The y-axis could also show count rate (Bq) – the shape of the graph would be identical



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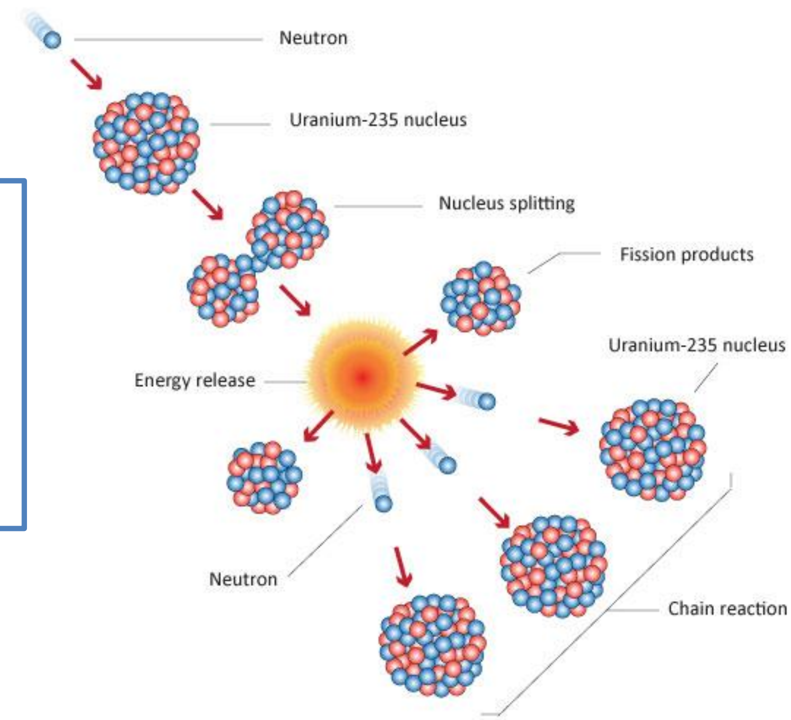
P7 - Radioactivity

Key Terms	Definitions
Nuclear fission	Splitting of a large atomic nucleus into smaller nuclei, with release of energy
Chain reaction	A reaction where the first reaction starts another one of the same sort, which then sets off another reaction, and so on.
Uranium	Heaviest naturally occurring element (a metal). It has numerous isotopes, where U-235 can be used for fission in nuclear power stations. So it is nuclear fuel.
Nuclear fusion	Joining to two light atomic nuclei to form a new nucleus with higher mass number (i.e. a heavier element), with the release of energy.

Nuclear fission

When people say 'splitting the atom', they mean **nuclear fission**. Nuclear fission is the splitting of a large, unstable atomic nucleus. This rarely just happens spontaneously, but we can force it to happen by making a large, unstable atomic nucleus first absorb a **neutron**. Then it will split into two nuclei, but of smaller atoms. During this split, 2 or 3 neutrons will also be released, and gamma rays are emitted. LOTS of energy is released by this process – which is why it is used in nuclear power stations.

In nuclear power stations, the large, unstable nuclei used is usually uranium (but plutonium can also be split). The neutrons released by the fission of one nucleus can then be absorbed by other large, unstable nuclei. This is a **chain reaction** (shown in diagram). In nuclear power stations, some of the neutrons are absorbed to control the reaction and stop it getting out of control. In nuclear weapons, the chain reaction *does* get out of control, causing the massive explosion.

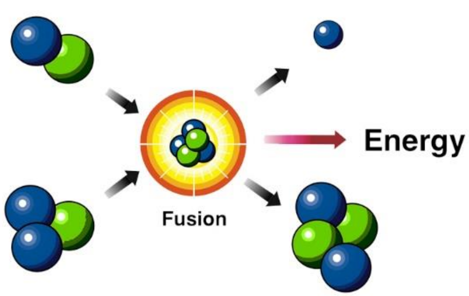


Nuclear fusion

Nuclear fusion involves small atomic nuclei, like hydrogen isotopes, joining – or *fusing* – together to make a heavier nucleus (such as helium). This occurs in stars. At the moment on Earth, this can be done, but not in a way that is any use for generating electricity, at least not yet. Very extreme conditions are required for nuclear fusion – extreme temperatures and pressures, which is why you only find it occurring naturally in stars.

An example of a fusion reaction is shown below.

Some of the **mass** of the fusing isotopes can be converted into energy, transferred by radiation.

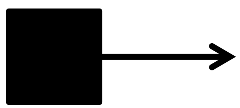


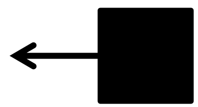
$$^{2}_{1}H + ^{3}_{1}H \longrightarrow ^{4}_{2}He + ^{1}_{0}n$$

Physics Knowledge Organiser
P8 - Forces in balance

Representing Forces and Other Vector Quantities

Since forces are a vector quantity, it is useful to show their magnitude (size) AND direction using an arrow. The arrow points in the direction that the force acts, and its **length** shows the magnitude. For instance: in the first diagram, the force acting on the object is larger than in the second, and is opposite in direction.





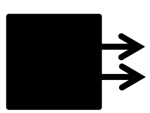
Contact and Non-contact Forces

Forces are always the result of objects **interacting** with each other. For instance, the force of gravity keeping this piece of paper on the desk is the result of the interaction between the Earth's mass and the paper's mass. All forces can be classified as contact or non-contact forces.

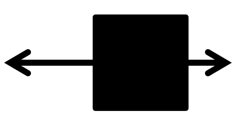
Examples of contact forces: friction, air resistance, tension, the normal contact force.
Examples of non-contact forces: gravitational force, electrostatic force and magnetic force.

The Resultant Force

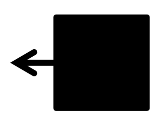
In real life, there are usually a few forces acting on any particular object. All the forces can be shown with vectors (arrows – see above). When we take all the forces into account, we can draw just one vector arrow to show a single force, which has the same effect on the object as all the other forces acting at once. This is simplest when the forces are in a straight line:



two forces are acting; by adding them we get the resultant force….



this time, the forces are opposite in direction, and are different in magnitude. We subtract one from the other to get the resultant force…



Key Terms	Definitions
Quantity	Anything that can be given a numerical value.
Magnitude	Size of a quantity. E.g. a distance of 5 metres has a higher magnitude than 2 metres.
Scalar	Describes quantities that only have a magnitude (size). E.g. speed (how fast something is moving).
Vector	Describes quantities that have a magnitude AND a specific direction. E.g. velocity (speed in a particular direction)
Force	A vector quantity. Forces are pushes or pulls that act on an object. Forces have size and direction. Forces are the result of objects interacting with each other.
Contact forces	For these forces to act, the interacting objects have to be physically touching.
Non-contact forces	For these forces to act, the interacting objects don't have to be touching (they are physically separate).
Resultant force	The single overall force acting on an object. It has the same effect as all the forces acting on the object all together. The resultant force is the vital thing in working out how an object will move. If there is a resultant force, the object's speed will change; or the shape of the object will change; or the direction of the object will change. If the resultant force is nothing (the forces cancel out), the object will keep doing what it was doing – either not moving at all, or moving along at a steady speed.

Resultant Force continued

If the forces acting on an object are equal in magnitude and opposite in direction, then the resultant force ends up being ZERO. You can say the forces are balanced. Reading the definition above should make it clear that a resultant force of zero means that an object's movement will not change. So if it was moving to start with, a resultant force of zero means it keeps moving at the same speed. Also, zero resultant force means the direction can't change.

The resultant force is…. nothing!

Physics Knowledge Organiser
P8 - Forces in balance

Work Done and Energy Transfer

'Work' has a particular meaning in physics. Whenever work is done, it means that energy has been transferred (in other words, energy has changed form). Work is always done as a result of a force acting on an object. The amount of work done is easily calculated: $W = F\ s$

For example, if a force of 1000 N makes this car move 200 m to the left…

The work done is calculated by: W = 1000 x 200 = 200 000 J
This means 200 000 J of energy was transferred.

Work Done Against Frictional Forces

When objects move, they are almost always moving *against* frictional forces – so the friction arrow is opposite to the direction of motion. As you know if you rub your hands together, doing work against frictional forces causes an energy transfer to heat (thermal) energy. This raises the temperature of the object (and the surrounding air!).

Remember, there are frictional forces even when an object moves through the air – often this is called air resistance (but it's just a type of friction).

The Joule

The joule (J) is the unit for energy, and therefore the unit for work done. It has a particular definition, based on the equation for work done. 1 joule = 1 newton metre. This means that 1 J is the amount of work done when a force of 1 N causes an object to move 1 m. This is because $W = F\ s$ and 1 = 1 x 1!

Distance vs. Displacement

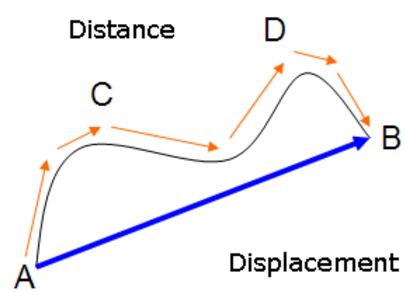
Displacement is different to distance because it involves the direction that an object has moved. The displacement is always measured in a straight line from start to end of a journey, missing out any wiggles along the way.

Key Terms	Definitions
Work done	The measure of how much energy is transferred when a force makes an object. You can say: 'a force does work on an object when it makes it move'. Doing work always involves the transfer of energy. This is a scalar quantity.
Joule	The unit joule (J) is how the amount of energy transferred by doing work is measured. 1 joule = 1 newton metre (thanks to the equation, below).
Distance	How far an object moves. It does not include direction , so distance is a scalar quantity.
Displacement	The distance an object moves from where it started. This is measured in metres. It is a vector quantity, because it includes the direction an object moved.
Friction	A contact force that results when two objects move past each other. They have to be touching.

Equation	Meanings of terms in equation and units
$W = F\ s$ *	*W = work done (joules, J)* *F = force (newtons, N)* *s = distance (metres, m) – aka displacement*

Distance vs. Displacement Diagram

Look how displacement is simply a straight line from A to B.
Distance is the total, with visits to C and D during the journey.



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P8 - Forces in balance

Newton's First Law

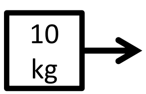
Read the definition. Newton's first law tell us:

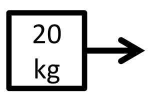
- Vehicles moving at a constant speed have a driving (push) force exactly equal to the resistive forces (like friction);
- Velocity (speed and direction) will only change if there is a resultant force acting (so the resultant force is NOT zero).
- If an object changed direction, it must have been because of a resultant force.

Newton's Second Law

Read the definition. This law follows on very sensibly from the first law. It reminds us that an object will only change in velocity (accelerate) if there is a resultant force acting on it. It also shows that the amount of acceleration depends on the resultant force and the mass of the object.

For instance, if a resultant force of 20 N acts on this object, the acceleration will be 20 / 10 = 2 m/s^2.





But with this object, the same resultant force only causes 20 / 20 = 1 m/s^2 acceleration.

Newton's Third Law

Read the definition. This law is often written as: 'for every action, there is an equal and opposite reaction'. In this version, action means the force exerted by object A on object B, and reaction means the force exerted by object B on object A.

This law explains why pushing **down** with your legs makes you jump **up** (the ground pushes back with the same size force as your push). It also explains why rockets can fly through space: the gases pushing out the back cause the rocket to move forward.

Key Terms	Definitions
Stationary	Not moving. The velocity is 0.
Newton's First Law	The law says that if the resultant force on an object is zero: ➢ Stationary objects stay stationary ➢ Moving objects keep moving at the same velocity (same speed and direction)
HT inertia	Inertia is the tendency of objects to stay at the same speed or stay stationary.
Newton's Second Law	Objects accelerate if there is a resultant force acting on them. The amount of acceleration is proportional to the magnitude of the resultant force and inversely proportional to the mass of the object. (see equation)
Proportional	Just like in maths: if the magnitude of one quantity increases because another quantity increases, they are proportional. The symbol is ∝.
Inversely proportional	The opposite of proportional: if one quantity **decreases** because another one increases, they are inversely proportional.
Newton's Third Law	This law says that when objects interact, the forces they cause to act on each other are equal and opposite.

Equation	Meanings of terms in equation and units
$F = m\,a$ *	*F = resultant force (N)* *m = mass (kg)* *a = acceleration (m/s^2)*

HT only: Inertial mass

Inertial mass measures how difficult it is to change the velocity of an object. It is defined as the ratio of force over acceleration.

For instance, it requires more force to slow down (change the velocity) a lorry compared to a bike. It also requires more force to make a lorry accelerate compared to a car.

Physics Knowledge Organiser
P8 - Forces in balance

Moments

Forces can cause rotation. There has to be a resultant force on a rotating object, because it rotation involves changes in direction! Even when pushing on a door, you are using an applied force to cause rotation of the door. The centre of rotation (the **pivot**) is the hinge of the door. The turning effect is called the **moment** of the force.
If an object is balanced (for example, a see saw or a shelf with stuff on it), in the system the **clockwise moment is equal to the anticlockwise moment**. Notice that this doesn't mean the forces are the same each way (unless the distance from the pivot is the same) – but you can calculate the moment and/or the forces involved using the equation shown.

Levers

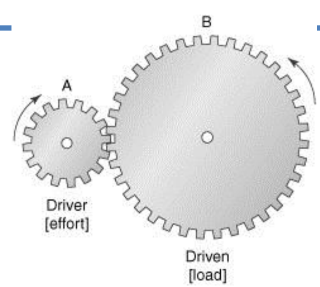
A lever is a simple system used to transmit a force. Levers can be distance multipliers or force multipliers.
Distance multiplier – this means the lever allows one end of the lever to move much further than where the force is applied, but this does reduce the force at that end. An example is a broom – see diagram.
Force multiplier – this means the lever is used to produce a larger force for the force applied, but this does mean the other end moves a smaller distance. A ring pull on a drinks can is an example – you apply a force at one end of the ring pull, the other end doesn't move as far but there is a big enough force to open the can. The pivot is in the middle.

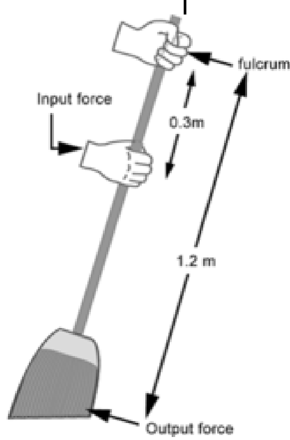
Gears

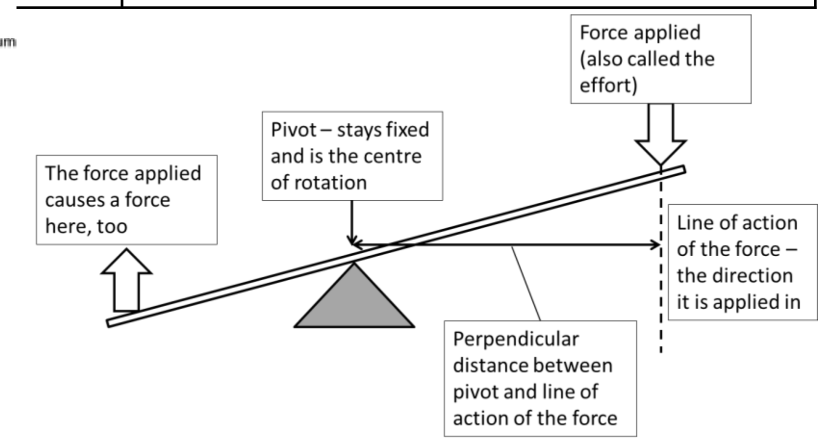
Systems with gears are force multipliers or speed multipliers. One gear is the 'driver', which is where the force is applied in the first place. Other gears are driven by this one – they can be connected directly like in the diagram or indirectly, like how gears are joined by a chain on a bike.
Force multipliers – if the driver gear (aka cog) is smaller than the one it drives, the force is multiplied. This is as shown in the example in the diagram.
Speed multipliers – if the driver is larger than the driven gear, the driven gear goes faster. So it's a speed multiplier.

Key Terms)	Definitions
Rotation	Turning motion
Moment	Full name: "moment of a force". This is the turning effect of a force
Pivot	The centre of rotation of a turning object. It stays in a fixed position while other parts move – for example, the hinges of a door.
Line of action	The line along which a force arrow points.
Clockwise moment	The turning effect of a force in the direction hands move around a clock face.
Anticlockwise moment	The turning effect of a force in the direction opposite to the way hands move around a clock face.
Lever	A simple system in which something turns around a pivot, and where a force applied is transmitted to somewhere else.
Gear	A simple system in which wheels transmit the turning effect of a force to somewhere else.

Equation	Meanings of terms in equation and units
$M = F\,d$ *	*M = moment of a force* (Nm) *F = force* (N) *d = perpendicular distance from the pivot to the line of action of the force* (m)







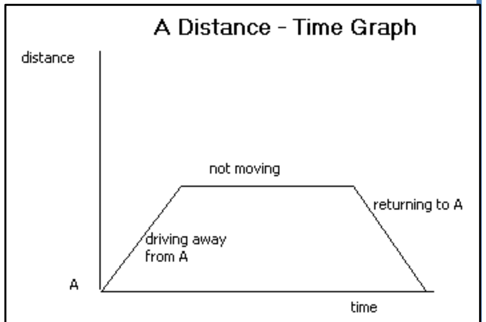
Physics Knowledge Organiser
P9 - Motion

Speed vs. Velocity

Speed and velocity are both quantities that measure the rate of change of distance, but velocity includes the direction. This makes velocity a vector quantity, so we can show velocity with an arrow.

Distance-time Graphs

A distance-time (DT) graph shows how far an object has gone from its starting point at a certain time.
A slope means the object is moving, because distance is changing as time changes. If the line of the graph is horizontal, the object cannot be moving because distance is not changing with time.
The gradient (steepness of the slope) tells you the speed of the object.

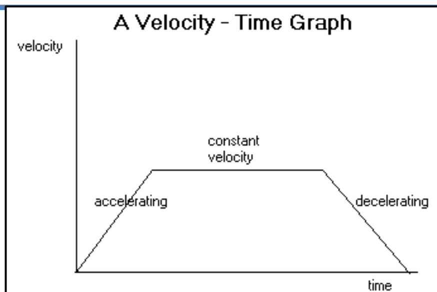


Acceleration

Acceleration is the measure of how quickly velocity changes. It is a vector quantity, because direction is included. (see equation)
Acceleration is shown on a DT graph by a line whose gradient *changes* – i.e. a curve, rather than straight line.

Velocity-time Graphs

A velocity-time (VT) graph shows the velocity of an object at any particular time on its journey. Using the gradient of a slope, you can find the acceleration.
The distance travelled during the journey is also shown on a VT graph – but you have to work it out by calculating the area under the line on the graph.
Sometimes the area can be found by counting squares, other times you'll need to use area of a rectangle/ triangle to find the area and therefore distance.



The distance travelled is area under graph.
The acceleration and deceleration can be found by finding the gradient of the lines.

Key Terms	Definitions
Speed	The measure of how quickly distance changes. Speed does not include direction, so it's a scalar quantity. It is measured in metres per second (m/s).
Velocity	Velocity is a vector quantity. Like speed, it is a measure of how quickly distance changes BUT it includes the direction of movement. It is measured in m/s **HT**: moving in a circle, even if speed is the same, involves a constantly changing velocity because the **direction** is constantly changing.
Gradient	Gradient means slope. The gradient of a line on a graph is found by dividing the vertical (y-axis) change by the horizontal (x-axis) change.
Acceleration	Acceleration is the rate of change in velocity. It usually means speeding up, because we use the term **deceleration** for slowing down. You must recall that objects in freefall near Earth's surface have an acceleration of 10 m/s^2.
Deceleration	A **negative** acceleration – slowing down.

Equation	Meanings of terms in equation and units
$s = v\,t$ *	*s = distance (m)* *v = speed (m/s)* *t = time (s)*
$a = \frac{\Delta v}{t}$ *	*a = acceleration (metres per second squared, m/s^2)* *Δv = change in velocity (m/s)* *t = time (s)*
$v^2 - u^2 = 2\,a\,s$	*v = final velocity (m/s)* *u = initial (starting) velocity (m/s)* *a = acceleration (m/s^2)* *s = distance travelled (m)*

Freefall through a fluid (gas, like air, or a liquid)

Freefalling object initially accelerate due to gravity, but friction (/air resistance) increases with speed until the forces are balanced (resultant force = 0 N). Then, the object is falling at its **terminal velocity**.

Physics Knowledge Organiser
P10 - Force and motion

Momentum – *whole page is HT only*

Momentum is a property that any moving object has. It is defined as the product of mass and velocity of the object, so if the velocity is 0 m/s (stationary), the momentum is also 0.

Since momentum is calculated using **velocity**, which has a direction, momentum is a vector quantity. Just like with velocity, you can show the momenta (the plural of momentum) of objects moving in opposite directions by using a + sign for one of them and a – sign for the other.

Conservation of Momentum

Momentum is a property that is conserved in closed systems. This means the total momentum before an event is exactly equal to the total momentum after the event. This is called **conservation of momentum**. You can see conservation of momentum in action when objects collide (like snooker balls or cars in a crash) or when something stationary separates (e.g. firing a bullet from a gun or jumping off a stationary skateboard – it also explains why you should be very careful when jumping from a small boat onto the bank).

In this example: the boat is stationary at the bank, meaning its momentum is 0 kg m/s. When the person jumps out, they have a velocity and therefore a momentum. The boat **must** move away from the bank, since momentum is conserved (so must add up to 0 **after** the event too) so the boat has momentum in the opposite direction to the person – the boat moves away from the bank.

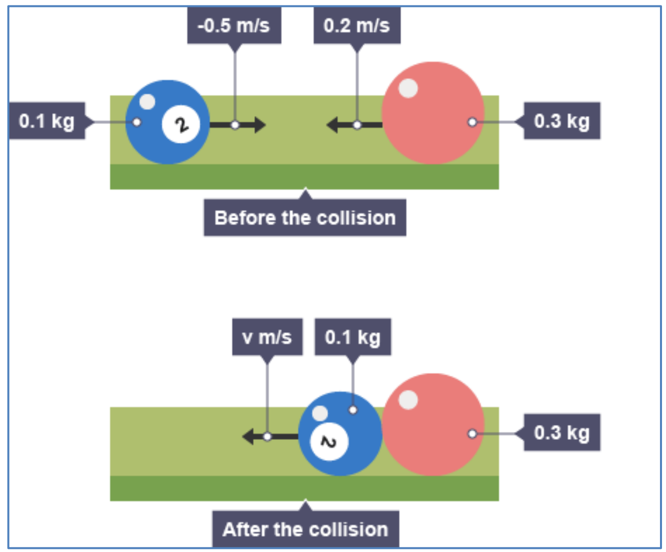
Conservation of Momentum in a Collision

Look at the diagram far right. The '2' ball has a negative velocity because it is moving in the opposite direction of the other ball. The total momentum before they collide = (0.1 x -0.5) + (0.2 x 0.3) = 0.01 kg m/s. According to the rule of conservation of momentum, the total momentum after the collision is also 0.01 kg m/s. Also, by looking at the diagram, you can see that both balls are now moving to the left, together. The total mass is 0.1 + 0.3 = 0.4 kg.

Rearranging to make velocity the subject, $v = \frac{p}{m}$,
v = 0.01/0.4 = <u>0.025 m/s</u> is the velocity after the collision.

Key Terms	Definitions
Momentum	A property of any moving object, calculated as the product of mass and velocity. Measured in kg m/s.
System	Systems are how physicists divide up the universe. Systems involve an object or objects and their interactions. They can be very simple (e.g. a falling object) or very complicated (e.g. our whole galaxy).
Closed system	A system where objects are not thought to be affected by external forces or other objects outside the system. We only think about the objects inside the system, which means the quantities *momentum* and *energy* are **conserved**.
Conservation	Simply means 'keeping the same.' To add detail, conservation of a quantity means that the total amount of it is the same before and after an event. In any closed system, the total amount of energy and momentum before and after an event is equal.

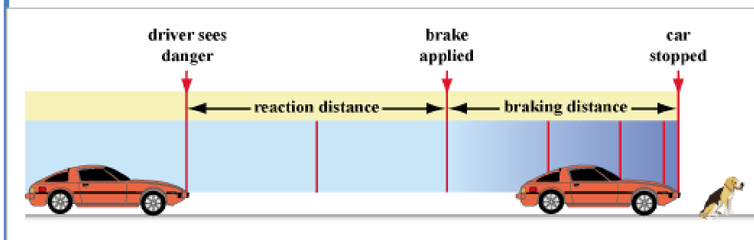
Equation	Meanings of terms in equation and units
$p = m\,v$ * HT only	*p = momentum (kilogram metres per second, kg m/s)* *m = mass (kg)* *v = velocity (m/s)*



Physics Knowledge Organiser
P10 - Force and motion

Forces and Braking

Stopping a vehicle requires a force to be applied, since the speed must change – the vehicle must decelerate to 0 m/s. The **stopping distance** of a vehicle depends on two factors, which add up to make the stopping distance. These are the **thinking distance** (distance travelled while the driver reacts) and the **braking distance** (distance travelled under the braking force).



Things which affect stopping distance

Thinking distance

(all these things are to with the drive)

drinking alcohol, taking drugs, tiredness, illness, not concentrating,

Braking distance

(all these things are to do with the car and road conditions)

worn tyres, poor brakes, wet roads, icy conditions, oil or grease on the road, etc.

For a particular braking force, the greater the speed of the vehicle, the greater the stopping distance. This is because going from a higher speed to 0 m/s is a bigger change in speed than going from a lower speed to 0 m/s. The thinking distance is longer at a higher speed, because reaction times won't change according to the speed – so you'd go further in the same time if you're going faster. Typical reaction times vary from 0.4 s to 0.9 s. Different factors affect the thinking and braking distances – see the box.

Braking Force and Work Done

When force is applied to the brakes, work is done by the friction force between the brake pads and the wheel. The **kinetic energy** of the vehicle is transferred to **thermal energy** – this is why brakes get hot.

To stop a vehicle in a certain distance, the faster the vehicle the larger the force needed, since a larger deceleration is needed ($F = ma$ again). However, this can lead to overheating of the brakes and/or loss of control of the vehicle.

Forces cause a change in momentum

$F = ma$ tells us a resultant force causes an acceleration. Substituting the equation for acceleration into $F = ma$ gives you the equation above. It tells us that **reducing** the time taken to change momentum **increases** the force. This is why it hurts more to land on pavement than a trampoline. It also explains seatbelts, air bags, cycle helmets and cushioned tiles in playgrounds: all of these **increase** the time taken to slow to a stop, therefore **decreasing** the force acting on the object.

Key Terms	Definitions
Stopping distance	The distance a vehicle travels after the driver spots a danger and decides to stop. It is the sum of the thinking distance and braking distance.
Thinking distance	Distance travelled during a driver's reaction time.
Braking distance	Distance travelled while the driver is applying the brake (i.e. distance travelled under the braking force).
Kinetic energy	The form of energy of any moving object. Since the equation uses speed, not velocity, this is a scalar quantity.
Thermal energy	The form of energy associated with heat. The thermal energy of an object is proportional to its temperature.
System	An object or group of object, and its/their interactions.
Conservation of energy	A fundamental concept in physics. In a system, total energy is always conserved (it cannot be created or destroyed). However, it can be transferred from one store of energy to another.

Equation	Meanings of terms in equation and units
$E_p = m\,g\,h$ *	*E_p = gravitational potential energy (joules, J)* *m = mass (kg)* *g = gravitational field strength (newtons per kilogram, N/kg)* *h = height (metres, m)*
$E_k = \frac{1}{2} m\,v^2$ *	*E_k = kinetic energy (joules, J)* *m = mass (kg)* *v = speed (m/s) – this is **squared** in this equation*
$F = \frac{m\,\Delta v}{t}$	*F = force* (N) *m = mass (kg)* *Δv = change in velocity (m/s)* *[and remember m Δv is change in momentum]* *t = time (s)* ***NOTE: This equation can be stated as: "force equals the rate of change of momentum"***

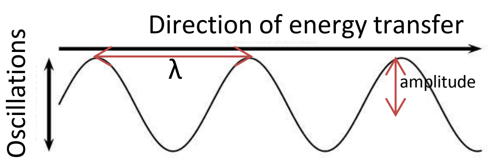
Physics Knowledge Organiser
P12 - Wave properties

Types Of Wave

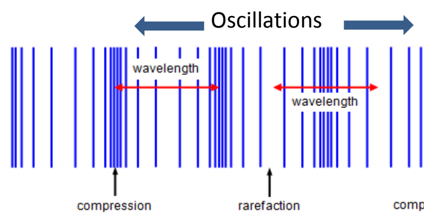
You can see waves easily in the sea, or if a tap is dripping into a sink of water. However, waves are far more common than just that. Waves can be **mechanical**, which means they involve particles moving, or **oscillating**, such as waves in the sea or sound waves in the air. Or, they can be **electromagnetic**, which don't involve any particles oscillating – instead, EM waves involve vibrations or oscillations of the electromagnetic field. All waves involve the transfer of energy.

The other way of defining types of wave is whether they are **longitudinal** or **transverse**. Which one they are depends on the direction of the oscillations compared to the direction of energy transfer by the wave.
- In **transverse waves**, the oscillations are **perpendicular** to the direction of energy transfer.
- In **longitudinal waves**, the oscillations are **parallel** to the direction of energy transfer. They show areas of compression and rarefaction – see diagram.

Examples: ALL electromagnetic waves are transverse. Mechanical waves can be either longitudinal or transverse. For instance: sound waves are mechanical and are longitudinal. Ripples in water are mechanical waves, and are transverse.



Transverse wave

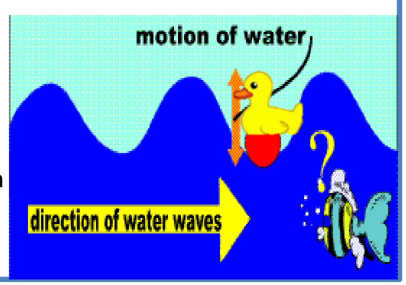


Longitudinal wave

Particles Don't Travel, But The Wave Does. Particles Just Oscillate.

An easy way to see that the particles aren't travelling but the wave is (so energy is being transferred): put a rubber duck in a tank of water where waves are moving across. The duck goes up and down, just like the water particles (oscillations perpendicular to direction of energy transfer, remember), while the waves move across.

With longitudinal waves, you can tell the particles aren't flowing either – just oscillate. When you speak, you don't breathe into someone else's ear! Also, when a tuning fork is vibrating to produce a sound wave, it doesn't create a vacuum around it due to air particles travelling away.



Key Terms	Definitions
Wave	A wave transfers **energy** from one place to another, and can also carry information. All waves involve movements or **oscillations**, allowing energy to be transferred **without** particles having to flow or travel from one place to another.
Oscillations	Vibrations or movements. These movements are of particles in **mechanical** waves, or of the electromagnetic field when it comes to **electromagnetic** waves.
Perpendicular	At right angles to.
Amplitude	The amplitude of a wave is the <u>maximum</u> <u>displacement</u> of a point on the wave from the undisturbed position. *Translated*: the distance from a peak or trough to the 'midline' of the wave.
Wavelength	The distance from a point on one wave to the equivalent point on the next wave along. This is easiest to measure at the distance from the centre of one area of compression to the next (longitudinal waves) or the distance from peak to peak (transverse waves). Symbol: λ
Frequency	The frequency of a wave is the number of complete waves that pass a point per second. Symbol: f
Period	The period, or time period, of a wave is the time it takes to complete a full wave. Symbol: T

Equation	Meanings of terms in equation
$T = \frac{1}{f}$	*T = time period (seconds, s)* *f = frequency (hertz, Hz)*
* $v = f\lambda$	*v = wave speed (m/s)* *f = frequency (Hz)* *λ = wavelength (metres, m)*

The Wave Equation

The equation is directly above. You could measure the speed of sound in air, with a long distance between you and a friend. They make a loud noise (you start your clock when you see them do it) and you time how long it takes to get to you. Just use distance/time to calculate the speed.

Physics Knowledge Organiser
P12 - Wave properties

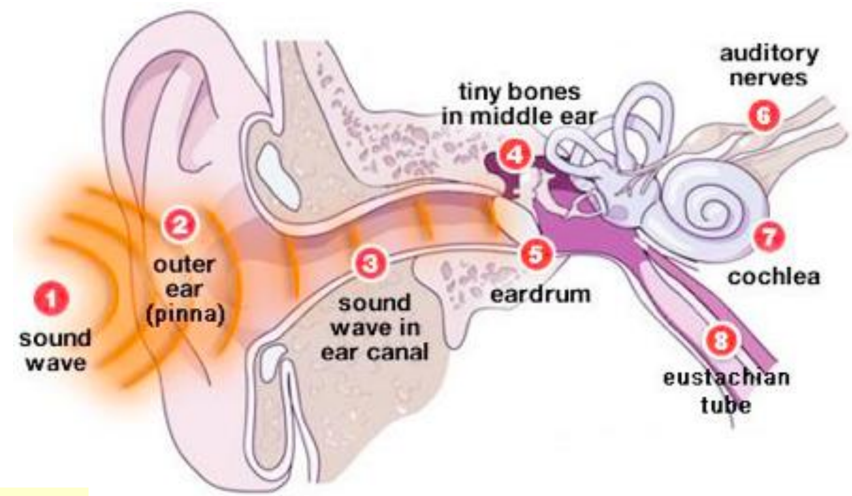
Sound waves

Sound waves a longitudinal waves caused by **vibrations** in matter. Sound waves can travel through solid, liquid or gas media, but not in vacuum because there is no matter (no particles) to actually vibrate.

We **hear** sound waves because the vibrations travel in the air into our ears, and cause the eardrum to vibrate. In turn, this transmits the vibrations to the inner ear where the vibrations cause electrical impulses, which travel along the auditory nerves to the brain. However, this conversion of vibrations in the air to vibrations in the solid of our eardrum only happens over a certain range of frequencies of vibration. As a result, some sounds are too low pitched for us to hear and some are too high pitched.

The human auditory range is 20 – 20 000 Hz. Sounds with a higher frequency than 20 000 Hz (20 kHz) are called ultrasound.

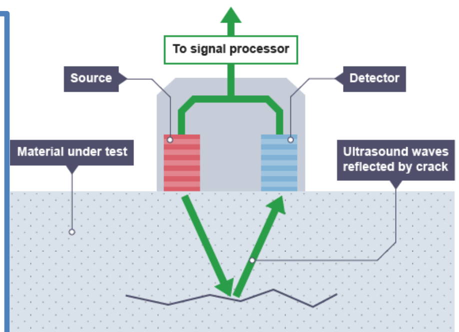
Key Terms	Definitions
Medium	Material a wave is travelling through (or being **transmitted** through). Plural = media.
Auditory	Anything relating to hearing or parts of the ear.
Ultrasound	Sounds too high in pitch to be heard (higher frequency than 20 kHz)
Seismic waves	Vibrations caused by earthquakes that travel through the Earth
P – waves	Longitudinal seismic waves
S – waves	Transverse seismic waves
Echo	Reflection of a sound (including ultrasound)

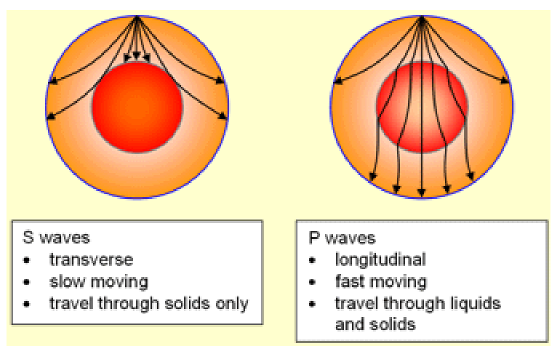


Using waves for detection and exploration…

Ultrasound is useful for <u>detection</u> – finding things that you can't directly see. It can be used for medical diagnosis (such as scans of a foetus), for finding things in a medium – e.g. cracks in a solid block, or shoals of fish in the sea, or where the bottom of the sea is. This works because ultrasound is **partially reflected** when there is a change in medium (some ultrasound waves continue through). By detecting the waves reflected – or echoed – back, you can work out how far away the boundary between the two media is. This can be calculated if you know the speed of the ultrasound and the time it takes to reflect back – use $s = vt$. See diagram.

Seismic waves are produced by earthquakes, and they can be detected. There are two kinds: S-waves and P-waves, with different properties, as shown on diagram. This is very helpful, because they provide evidence that there is a liquid outer core to the Earth, and evidence that the mantle is solid – fantastic news, because no-one can dig down to find these structures. So waves help us <u>explore</u> the deep structure of the Earth.





Physics Knowledge Organiser
P13 - Electromagnetic waves

Electromagnetic Waves (EM Waves): Producing Them

EM waves can be generated by changes in atoms or the nuclei of atoms. For instance, gamma rays are produced due to changes in the nucleus of an atom (nuclear decay – more on this in a later topic).

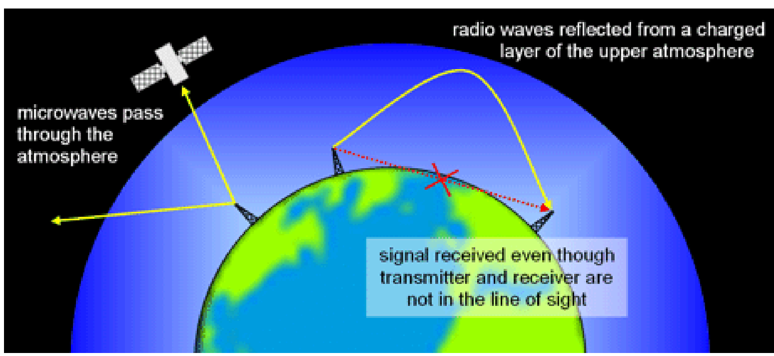
HT: radio waves can be produced by oscillations in electrical circuits. This is how a TV/radio broadcast is produced. It is received (e.g. by your TV aerial) by another electrical circuit; the radio waves create an alternating current with the same frequency as the radio wave itself. More on alternating current in the electricity topic – but it is enough to say for now that it involves oscillations.

Dangers Of EM Waves

Ultraviolet waves, X-rays and gamma rays are potentially dangerous types of EM waves, since they can have hazardous effects on human tissues. How severe the effects are depends on the type of radiation and the size of the **dose** received.

Doses of radiation are measured according to how great the risk of harm to the body is. The radiation dose, or danger due to **exposure** to radiation, is measured in **sieverts** (Sv).

A specific risk due to exposure to ultraviolet waves: they cause skin to prematurely age and increase the risk of skin cancer.
X-rays and gamma rays are **ionising** types of radiation. This means they can damage DNA, causing mutations and therefore increasing the risk of cancer.



Key Terms	Definitions
Radiation dose	The risk of harm due to exposure to radiation.
Exposure	Receiving and absorbing radiation (by the body).
Sievert	The measure of radiation dose. As with the usual prefix: 1000 millisieverts (mSv) = 1 sievert (Sv)
Ionising	Describes radiation that forms ions by 'knocking' electrons off atoms to make ions.
Cancer	Type of disease caused by specific mutations to DNA, resulting in cells dividing out of control (making a tumour).

Applications Using EM Waves

It is not exaggerating to say that EM waves dominate our technology and our lives. Here are some examples of the practical applications of EM waves:

- **Radio waves**: used for *television*, *radio* and Bluetooth. A signal carried by radio waves can get from a transmitting mast to a receiver by being reflected off a layer in the atmosphere.
- **Microwaves**: obviously, cooking food, but also communication with *satellites* and *mobile phones*; Wi-Fi internet. Unlike radio waves, microwaves can pass through the atmosphere (see diagram bottom left). In microwave ovens, the microwaves cause the water particles in the food to vibrate, heating it up.
- **Infrared**: electrical heaters, cooking food, infrared cameras. All objects emit infrared, but hotter objects emit more. An infrared camera detects infrared instead of visible light, so it can see hotter objects in the dark – night vision.
- **Visible light**: *fibre optic communication* (like the best broadband). Optical fibres reflect pulses of light all the way along their length. The pulses of light transmit the information.
- **Ultraviolet**: *sun tanning* beds… however, look at the dangers of UV in the other box.
- **X-rays**: both medical imaging for *diagnosis* (like broken bones) and medical *treatments*. X-rays can pass through soft tissue (like muscle), but not bone. That's why an X-ray image works to show up bones, and any breaks.
- **Gamma rays**: used in medical treatments such as radiotherapy.

Physics Knowledge Organiser
P13 - Electromagnetic waves

Electromagnetic Waves (EM Waves)

EM waves are always **transverse waves**. They transfer energy from the source of the waves to an **absorber** – object that absorbs the wave. EM waves occur all over the universe naturally, and we can produce them ourselves for all sorts of uses.

EM waves all travel at the **same velocity** through empty space (a vacuum) – at what we call the speed of light. However, the wavelength of EM waves varies from a few kilometres to wavelengths even smaller than an atom. The EM waves form a **continuous spectrum**, but for convenience we've grouped the infinite types of waves into seven groups of wavelengths, based on their properties. Learn the order of EM waves in the EM spectrum. Notice that a *longer* wavelength equates to a *lower* frequency and vice versa – this is clear from the wave equation.

Long wavelength → Short wavelength

Radio waves	Microwaves	Infrared	Visible light	Ultraviolet	X-rays	Gamma rays

Low frequency → High frequency

Visible light is the only kind of EM wave we can detect with our eyes (hence the name). Thus, we can only detect a limited range of EM waves without special equipment. However, it is easy to understand examples of how EM waves transfer energy. If you are standing in front of a fire, you feel the warmth thanks to infrared. Getting sunburn is due to the transfer of energy by ultraviolet waves from the Sun. Using Wi-Fi means a transfer of energy by microwaves.

Properties Of EM Waves

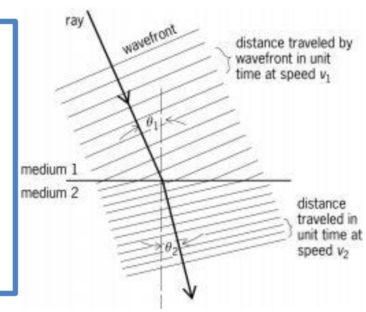
All EM waves can be **reflected**, **refracted**, **absorbed** or **transmitted** *depending* on the wavelength of the EM wave and the **medium** they are travelling through, or surface they are reaching. Reflection is shown in the ray diagram far right – the angle of incidence is equal to the angle of reflection for any ray of light.

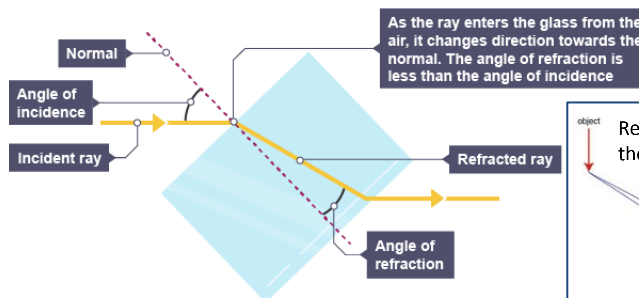
Refraction occurs when a wave changes the medium it is travelling through. Refraction is a change in direction of the wave, and it happens at the boundary, or junction, between the media – for instance, the surface of a sheet of glass would be the boundary between the glass and the air. You need to be able to draw diagrams to show refraction, like the example opposite. Notice that the light ray refracts *towards* the normal as it enters the glass (this is because it slows down), and refracts *away* from the normal as it leaves the glass (it speeds back up), ending up parallel to the original ray in air.

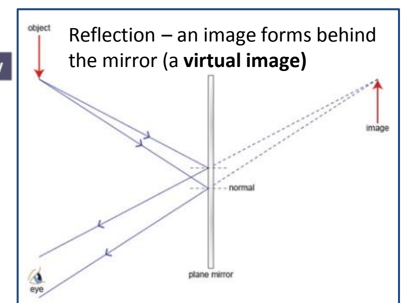
Key Terms	Definitions
Reflection	Rebounding of a wave from a surface. The angle between the **incident** (in-going) wave and the **normal** is the same as the angle between the reflected wave and the normal.
Refraction	Changing direction of a wave due to a change in the **medium** it is travelling through.
Absorption	'Taking in' energy from a wave and transferring it to another form, usually heat. For instance, you warming up if you lie in the sunshine (revising science, of course).
Transmission	A wave travelling through a material. Right now, visible light waves are being transmitted through the air to your eyes.
Media	*Singular 'medium'*. The medium is the material through which a wave travels.
Normal	A 'construction line' (made up line to help with diagram drawing) at right angles to a surface at the point where the wave hits the surface.

HT: More On Refraction

Refraction is due differences in the velocity of the waves in difference media. The diagram shown here represents the **wave fronts**. The wave slows down as it enters medium 2, but the near edge slows first. The other end is faster, as it is still in medium 1. This is what causes the 'bending' of the wave towards the normal.







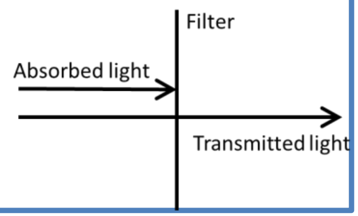
Reflection – an image forms behind the mirror (a **virtual image)**

Physics Knowledge Organiser
P13 - Electromagnetic waves

Visible light

We can only see a miniscule proportion of the EM spectrum. The visible light part of the spectrum is divided into narrow bands of frequencies (and therefore wavelengths) that we see as different colours. We can separate mixtures of colours of light (e.g. white light, which is a mixture of all colours) using filters. These work by absorbing certain wavelengths of light by allowing others through (**transmitting** them). This is shown on the diagram.

The colour of an **opaque** object depends on which wavelengths of visible light it absorbs, and which it reflects. Whichever it reflects, that's the colour it looks. If it reflects all colours, the object looks white. If it doesn't reflect any, but absorbs them all, it looks black.

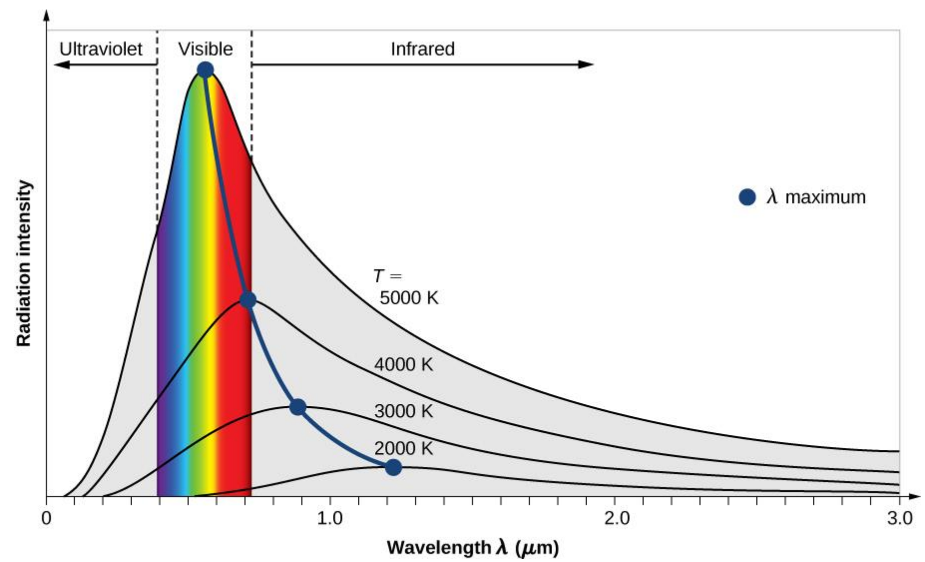


Infrared radiation

All objects (called 'bodies' in this topic!), at any temperature, will emit and absorb infrared radiation. The hotter the object, the more infrared radiation it radiates per second (or per minute, or whatever). The amount of infrared also depends on the colour of the object/body. Black surfaces are better absorbers and emitters than pale coloured surfaces. In theory (but not real life), there exist **perfect black bodies**, which absorbs ALL the radiation that hits it. These perfect black bodies would also be the best possible emitters of radiation. Although they don't really exist, black bodies are helpful models for understanding infrared radiation.

- Any body/object at a constant temperature is absorbing and emitting radiation at the same rate (because otherwise its temperature would change). If it absorbs radiation at a faster rate than it is emitted, then the body warms up.
- Increasing the temperature of a body increases the intensity of the radiation it emits increases (as already stated), but the intensity of the *shorter* wavelengths increases faster than the others (as shown on the graph). This is why, if you get something hot enough, it will glow with visible light.
- We can model the Earth as a black body, absorbing infrared radiation from the Sun and emitting it back into space. If this is in perfect balance, the temperature of the Earth stays exactly the same. Awkwardly, however, the emission of infrared radiation back into space is being disturbed somewhat by greenhouse gases.

Key Terms	Definitions
Specular reflection	Reflection of light from a smooth surface in a single direction
Diffuse reflection	Reflection of light from a rough surface in many directions. The light is 'scattered'.
Opaque	Object that is not transparent, so it does not transmit light. It reflects (some) light instead.
Transparent	Object that transmits all light wavelengths. See-through.
Translucent	Object that transmits some light, so not totally see-through, but partially.
Body	When talking about infrared radiation, we refer to objects as bodies.
Black body	A hypothetical perfect absorber and emitter of radiation.



Black body radiation

The graph shows the distribution of wavelengths of radiation emitted by a body at four different temperatures (shown on the Kelvin scale). The peak emission shifts into the visible part of the spectrum if the body is hot enough. At everyday temperatures, bodies don't glow because they simply aren't hot enough to emit in that part of the spectrum.

Physics Knowledge Organiser
P14 - Light

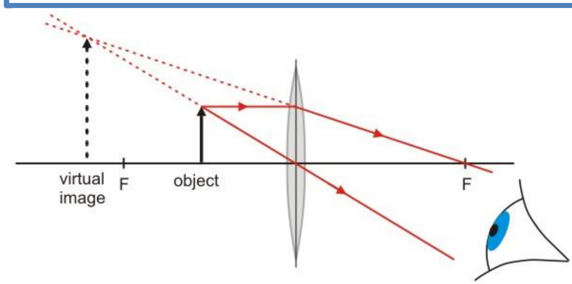
Lenses

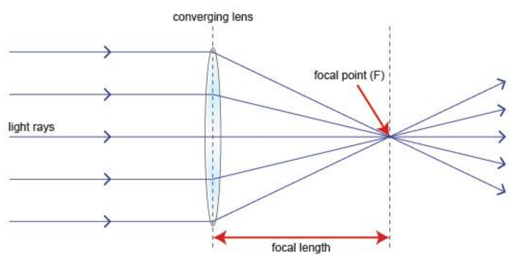
Lenses are curved bits of glass. They **refract** light coming from an **object** to produce an **image**. How the image looks depends on the type of lens and where the object is positioned relative to the lens.

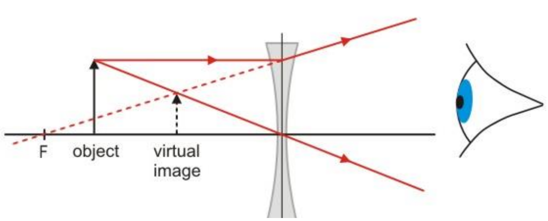
You can work out how the image looks (e.g. bigger/smaller than the object) by drawing ray diagrams, which are drawn to show the whole situation from the side. There are just a few simple rules to follow:

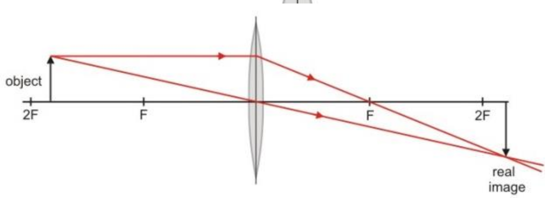
- To produce your **image**, draw rays of light from the top of the **object**. Two rays will do: wherever they cross is where the top of the image will be.
- The first ray goes from the top of the object through the centre of the lens. It does not refract, because this is already the shortest route through the medium.
- Draw the next ray from the top of the object to the lens parallel with the principal axis. At the lens, it refracts.
    - For a **convex lens**, the ray refracts to go through the focal point. Keep it going until it crosses the other ray. If it won't meet your first ray, a virtual image will form. Follow both of the rays back behind the lens until they cross – this produces a magnified virtual image.
    - For a **concave lens**, the ray refracts 'outwards' – it diverges. It should continue as though it came from the focal point, which is behind the lens. This makes it virtual – because it looks like it came from somewhere it didn't.

There are three example diagrams – you'll see they follow these rules.









Types of image

Images produced by convex lenses can be real or virtual, depending on where the object is placed relative to the lens. Images produced by concave lenses are always virtual, because the image forms from **diverging** rays.

Convex lenses magnify objects if the object is closer to the lens than the focal point. You already know about magnification, but you can work it out from ray diagrams too – measure the image and object height in matched units and divide. See equation.

Key Terms	Definitions
Lens	A curved piece of transparent material (like glass) used to produce images of objects.
Convex lens (symbol -)	A lens that is fatter in the middle than the edges. It causes parallel rays of light heading for the lens to refract so they come together at the **focal point/principal focus**. We say the rays of light **converge**. See diagram.
Concave lens (symbol -)	A lens that is fatter at the edges than the middle. It causes parallel rays of light heading for the lens to refract so they spread apart, or **diverge**.
Object	The thing you look at through a lens.
Image	The way the object looks when viewed through a lens.
Principal focus	The point near a lens where the rays of light converge (for a convex lens) OR the point where they look like they come from (for a concave lens).
Principal axis	Line through the middle of the lens. Rays of light travelling along the principal axis don't refract – they go straight through the lens.
Converge	Bring together.
Diverge	Spread apart.
Real image	An image produced by converging rays of light.
Virtual image	An image produced by diverging rays of light.

Equation	Meanings of terms in equation
$magnification = \frac{image\ height}{object\ height}$	*Magnification has no unit* *Heights must be in matched unit (e.g. mm)*

Physics Knowledge Organiser
P15 - Electromagnetism

Magnets

The poles of a magnet are where the magnetic forces are strongest. This is because the magnetic field lines are *most concentrated* at the poles, as you can see on the diagram below.

Magnets exert forces on one another when they are brought together: a **non-contact** force. If like poles (N-N or S-S) are brought together, the force is of repulsion. If unlike poles are brought together (N-S), the force is of attraction.

Magnets can be classified as **permanent** or **induced** (temporary). Permanent magnets have their own magnetic field, and it doesn't go away. Induced magnets are made when a material is placed in a magnetic field. (In most cases, this needs to be a magnetic material. The only magnetic materials are iron, steel, cobalt and nickel.) Induced magnets are always **attracted** to the magnet that turned them into a magnet – this is why you can pick up paper clips or nails with a bar magnet: the paper clip becomes an induced magnet with poles that are aligned so there is a force of attraction. See the poles labelled on the diagram. Induced magnetism is quickly lost when the material is removed from the magnetic field that induced it.

Magnetic fields

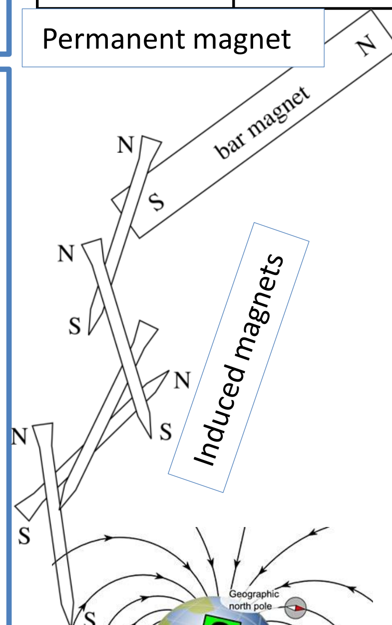
Magnetic fields are around all magnets (permanent or induced). The **direction** of the magnetic, as the diagram shows, is from **north** to **south**. The north pole of a magnet is properly defined as: *the pole that causes a force **away** from it, if a north pole is placed at that end.* This makes sense when you remember that like poles repel. So you can decide which end in north on an 'unknown magnet' by looking at the direction of the force that acts if a north pole (on another magnet) is brought to one end of your magnet. Repulsion (force away) means that end must be a north pole. Sometimes the north pole is called the **north seeking pole**, because it will point north on Earth if left freely suspended.

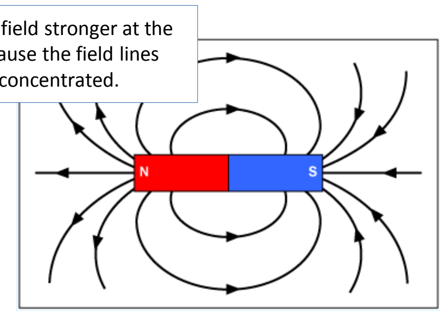
Magnetic fields are *strongest* at the poles and get weaker as the distance from the magnet increases. Using a **magnetic compass** (sometimes called a plotting compass), we can find out the direction of a magnetic field – the diagram shows how to do this.

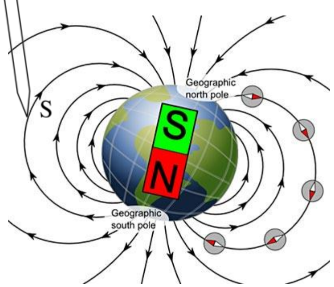
Earth has a **magnetic field**. Using a compass, you can tell that the magnetic field points towards the north pole (Santa's house), so this actually means that the geographic north pole of Earth is a south pole of a magnet! See diagram.

Furthermore, we know it is the **core** of the Earth that is magnetic (not the whole thing) because a compass at the north pole (in the Arctic circle) points down below your feet. It is worth realising, too, that the geographic north pole (the top of Earth's axis) is in a different location to 'magnetic north' – the latter is actually in northern Canada. So a magnetic compass actually wouldn't be much use if you were trying to get to Father Christmas's house.

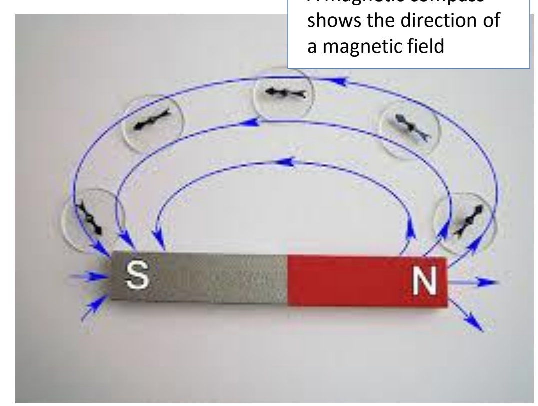
Key Terms	Definitions
Permanent magnet	A magnet that always has its own magnetic field. Attracts magnetic materials, and can attract or repel other magnets.
Induced magnet	A temporary magnet: make one by putting a suitable material in a magnetic field.
Poles	The ends of a magnet. Named north and south, based on which way on Earth they'd point if suspended freely. The other name is 'north seeking' or 'south seeking' as a result.
Magnetic field	The region around a magnet where a force acts on other magnets or on magnetic materials. (3D, unlike diagrams usually show)
Magnetic compass	A small bar magnet balanced on a pin so it can spin around. Points towards Earth's magnetic north due to Earth's magnetic field, but can also be used to find the direction of a magnetic field for another magnet.







A magnetic compass shows the direction of a magnetic field



Physics Knowledge Organiser
P15 - Electromagnetism

Electromagnetism – current and magnetic fields

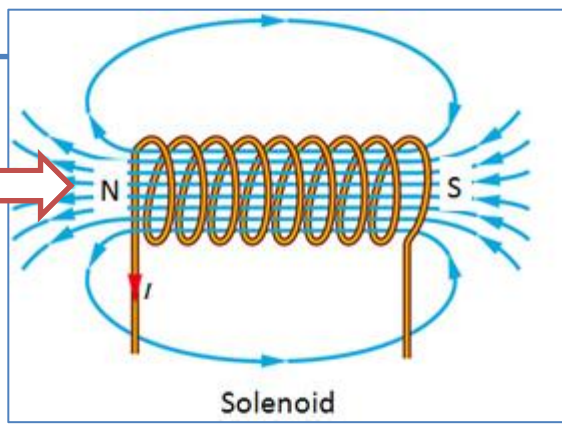
A wire that is carrying a current has a magnetic field around it. No current means no magnetic field, but switch it on and you get a magnetic field. As the diagram shows, switching the direction of the current switches the direction of the magnetic field. Also notice that the magnetic field gets stronger as you get closer to the wire carrying the current – this is shown by the field lines getting closer together (more concentrated).

Not surprisingly, increasing the current increases the strength of the magnetic field. You can easily check the *direction* of the magnetic field with a magnetic compass, just like with bar magnets. We can dramatically increase the strength of the magnetic field by winding the current-carrying wire into a coil called a **solenoid**. Even with the same size current, the magnetic field is stronger in a solenoid. Once you've made a solenoid, notice that the magnetic field is very similar in shape to the magnetic field of a bar magnet – it has a north and south pole, and it strongest at the poles. The magnetic field is also strong *inside* the coil – as the concentrated field lines show.

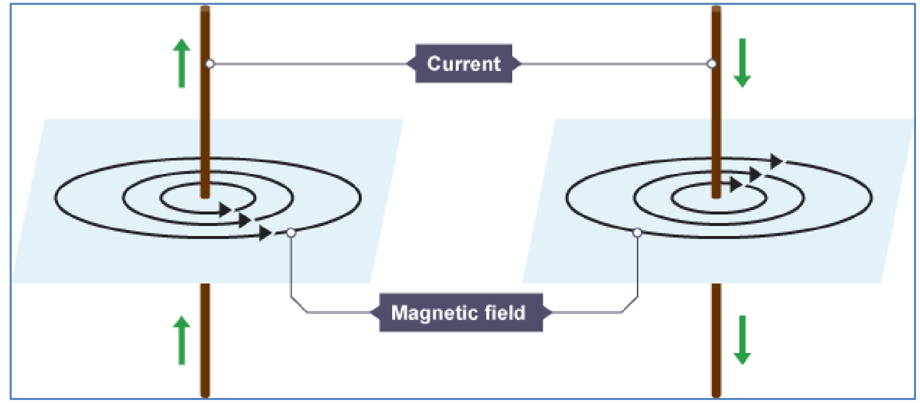
We can increase the strength of the magnetic field even further by putting a magnetic (e.g. iron) **core** in the solenoid – literally a cylinder of iron. We call this an **electromagnet**. (see diagram)

You can make an electromagnet **stronger** by:
- Increasing the **current** in the wire (probably by increasing the potential difference of the power supply)
- Increasing the **length** of wire in the solenoid – perhaps by adding more turns to the coil of wire.

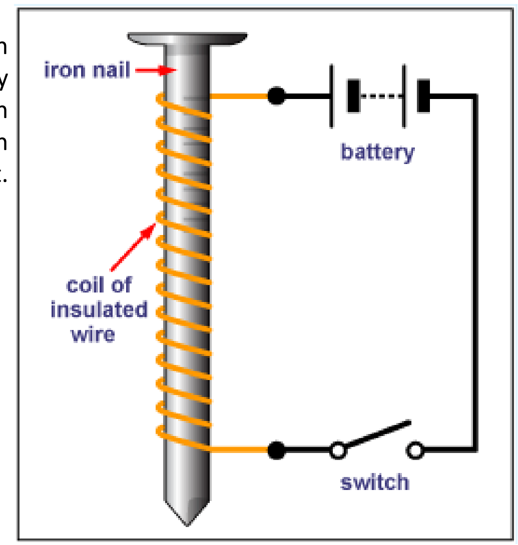
A north pole, since another north pole brought to this end would be repelled.



Key Terms	Definitions
Current	The rate of flow of charges in a circuit. If a current is flowing in a component, charges (e.g. electrons) are flowing through it.
Solenoid	A coil of wire.
Iron core	A piece of iron placed in the middle of a solenoid.
Electromagnet	A coil of wire with an iron core



In school, an iron nail is an easy choice for the iron core of an electromagnet.



Physics Knowledge Organiser
P15 - Electromagnetism

Fleming's left hand rule and the motor effect

If you have a current-carrying wire and a permanent magnet, each have their own magnetic fields. This means that if you put them near each other, there'll be a force acting on each other – just thanks to magnetic attraction or repulsion. This is called the **motor effect**. You can work out the direction that the force acts if you know the direction of the magnetic field and the direction of the current – we use **Fleming's left hand rule**. It has to be your left had to work. Hold it as shown, and you can work out the direction of whichever thing you don't know. You have to think in three dimensions here. You can twist your hand at the wrist to get it right – confirm using the example of the wire cutting through the magnetic field in the diagram – field from N to S with first finger, current with middle finger pointing downwards, meaning force must be out of the page towards you, like the diagram shows.

Now, the size (or *magnitude*) of the force on the conductor (the bit of wire) depends on three factors:

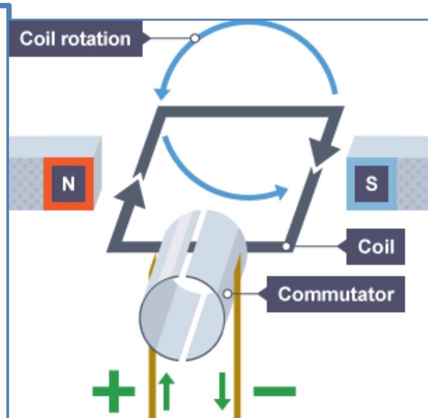
1. The **length** of the wire in the magnetic field, measured in metres
2. The **strength** of the magnetic field (formally, the **magnetic flux density**, in teslas, T)
3. The **size** of the **current** (A, as usual).

As the equation shows, increasing any or all of these factors will increase the size of the force on the conductor. [NB this equation only applies when the current and magnetic field are at right angles to each other]

Electric motors

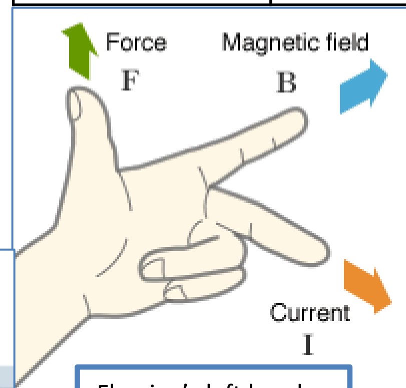
Electric motors make use of the motor effect. A coil of wire carrying a current is placed in a magnetic field; as you know, the magnetic fields interact to cause a force each other. If the coil is set up so it can spin, it most certainly will. In fact, it will spin round and round (**rotate**). This is thanks to the force acting **up** on one side of the coil, and **down** on the other – see the diagram and use Fleming's left hand rule to understand why…

The magnetic field goes from N to S of course, and the arrows on the coil show the direction of the current. So, the left side of the coil has a force **downwards** exerted on it (use the left hand rule). The right side of the coil has a force **upwards** exerted on it, so it rotates as shown. (NB the commutator just allows the coil to spin without the wires getting tangled up!)

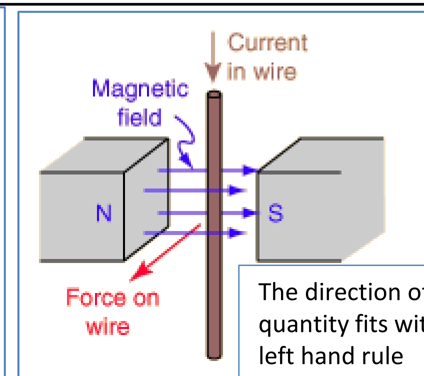


Key Terms	Definitions
Motor effect	The forces exerted on each other by a wire carrying a current and a magnetic field, thanks to the two magnetic fields interacting.
Magnetic flux density	A measure of the strength of a magnetic field – think of it as the number of magnetic field lines going through a set area – see diagram to help explain.
Electric motor	Device that causes rotation of a coil of wire carrying a current when it is placed in a magnetic field.

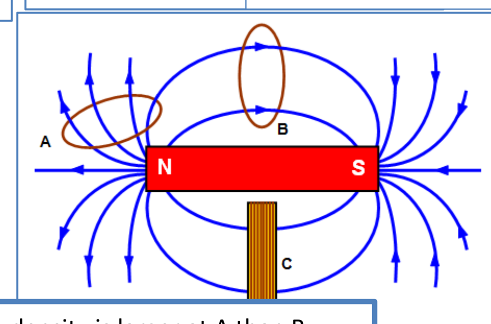
Equation	Meanings of terms in equation
$F = B\,I\,l$	*F = force (newtons, N)* *B = magnetic flux density (tesla, T)* *I = current (amps, A)* *l = length (m)*



Fleming's left hand rule. FBI – easy to remember!



The direction of each quantity fits with the left hand rule



Magnetic flux density is larger at A than B since more magnetic field lines cut through a given area (shown by the oval).

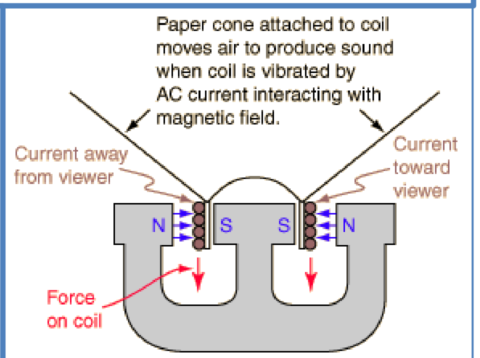
Physics Knowledge Organiser
P15 - Electromagnetism

Key Terms	Definitions
Moving coil	Describes a loudspeaker that involves a coil of wire moving in a magnetic field, to vibrate a cone and produce sound waves.
Induce	To cause something to happen.
AC	Alternating potential difference – the direction of the current switches back and forth.
Cone	Literally a cone-shaped piece of material found in loudspeakers. They vibrate, causing pressure changes in the air – i.e. sound waves.
Induced potential	A potential difference caused by either: a) moving a coil in a magnetic field, or b) changing the magnetic field around a coil.
Generator effect	Using the interaction between a magnetic field and a conductor to generate electric current.

Loudspeakers and microphones

The motor effect is also put to good use in loudspeakers and headphones. They have a 'moving coil' which moves in a magnetic field according to the current running through the coil. This moving coil is connected to a cone that moves with it. The cone causes vibrations in the air around it – in other words, it causes sound waves. Microphones do the exact opposite: sound waves (pressure variations) cause the cone the move, which causes a changing current in the coil.

Study the diagram. Just like in a motor, a force is produced on the coil of wire by placing it in a magnetic field (that's a permanent magnet at the bottom) and turning on the current. As the current alternates in direction (i.e. AC is used), and the size of the current is varied, the coil moves back and forth. As you can see, the coil is joined to a cone, which moves with it. The cone vibrates the air according to the current, then. The current transfers the information about the sound being played.



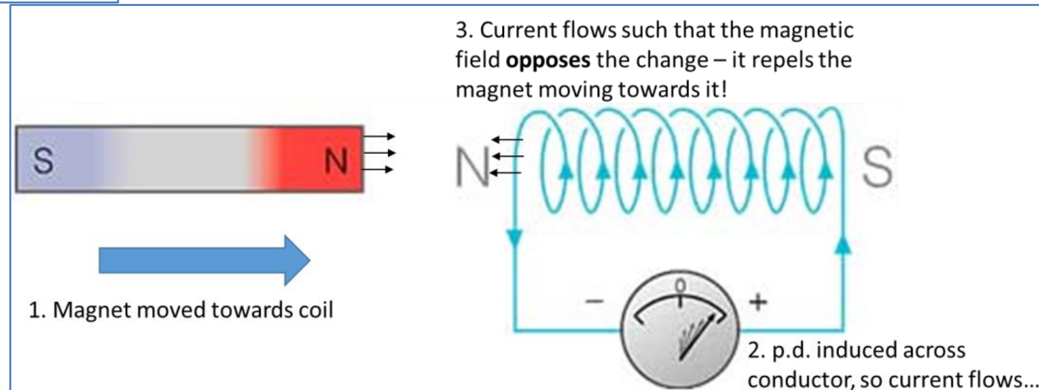
Induced potential and the generator effect

You can switch the motor effect around – instead of using interacting magnetic fields to produce movements, you can use movements to produce a current in a wire.
Here's how it works:

1. Place a conductor (e.g. coil of wire/solenoid) in a magnetic field and move it around (e.g. rotate the coil)
2. OR keep the coil still but change the magnetic field (e.g. flip N and S back and forth)
3. Either of these **induces** a potential difference across the ends of the conductor
4. Assuming your conductor is part of a complete circuit, a current starts to flow in the conductor thanks to this potential difference.

This is called the GENERATOR EFFECT, because the method is used to generate electricity. It is also known as electromagnetic induction.

Now, importantly, the current in the conductor produces a magnetic field, as always. But the direction of the magnetic field <u>acts to oppose the change</u>, the 'change' being the original 1 or 2 from the steps above. This is shown in the diagram right.



Factors affecting induced potentials

The size of the induced potential in the generator effect depends on:

- The size/strength of the magnetic field (larger magnetic field → larger induced potential)
- The number of turns on the solenoid (more turns → larger induced potential)
- The speed of movements/changes to magnetic fields (faster → larger induced potential)

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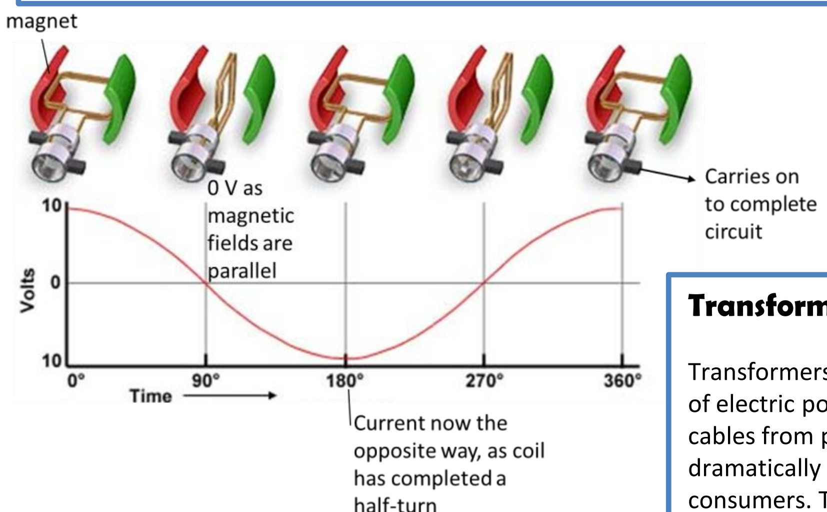
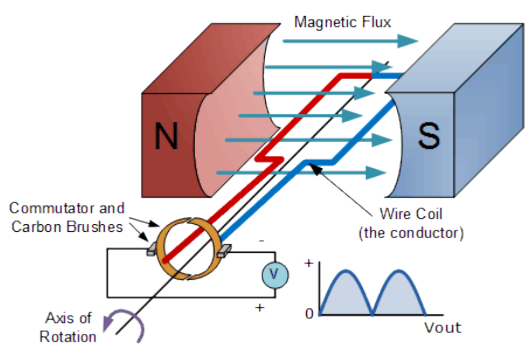
Using the generator effect

Depending on the set-up, you can use the generator effect to generate ac or dc.

- ac is generated in an alternator. In this set-up, each end of the coil of wire spin inside, and make contact with, a complete loop of conductor that's connected to the rest of the circuit. Since every 180° of turn of the coil the current flips direction (just like the left hand rule tells us), you get ac. This is shown on the diagram below, with a graph showing alternating potential difference.
- dc is generated in a dynamo. To prevent the current flipping direction every half-turn, a clever **commutator** is used. This ensures the current is restricted to one direction only in the coil – i.e. direct potential difference. See second diagram and graph.



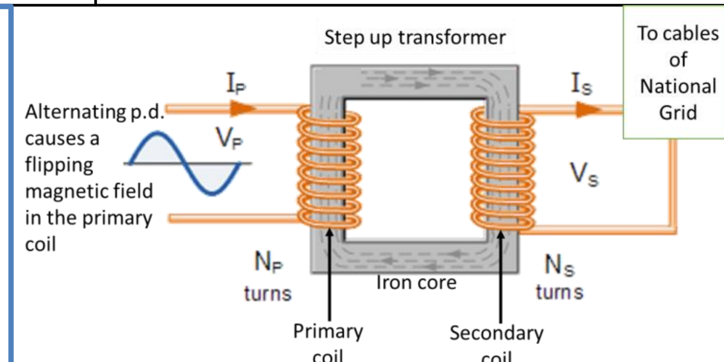


Key Terms	Definitions
National Grid	A system of cables and transformers linking power stations to consumers of electricity. The National Grid is used to transfer electrical power from the power stations to users.
Commutator	Device used in dynamo, made of two half-rings of conductor, not quite joined up to each other. Keeps the current flowing one way only.
Step-up transformer	Device that increases potential difference in an electric supply, using more turns on the secondary coil than the primary coil. Step-down transformers do the opposite.

Equation	Meanings of terms in equation
$\frac{V_P}{V_S} = \frac{N_P}{N_S}$	V_p = *potential difference across primary coil* (V) V_s = *potential difference across secondary coil* (V) N_p = *number of turns on primary coil* N_s = *number of turns on secondary coil*
$V_p \times I_p = V_s \times I_s$	V_p = *potential difference across primary coil* (V) V_s = *potential difference across secondary coil* (V) I_p = *current in primary coil* (A) I_s = *current in secondary coil* (A)

Transformers

Transformers exist to firstly, massively increase the p.d. of electric power to transmit it efficiently through cables from power stations, then, secondly, to dramatically decrease it again for safe use by consumers. They work using the second sort of generator effect – a changing magnetic field inducing a p.d. in a conductor nearby. Transformers are made of two coils of wire, wrapped around each end of a square-shaped iron core. Iron is used because it is easily magnetised. An alternating current in the primary coil causes a magnetic field in this coil, that constantly changes direction. This in turn induces a changing magnetic field in the iron core, which then induces a changing magnetic field (and therefore current) in the secondary coil.



Transformer equations

In transformers, the ratio of the potential differences across the coils is equal to the ratio of the number of turns on each coil. This is shown in the first equation.

Assuming transformers are 100% efficient, the power input is equal to the power output. This leads to the second equation (since $P = IV$).

Physics Knowledge Organiser
P16 - Space

Our solar system

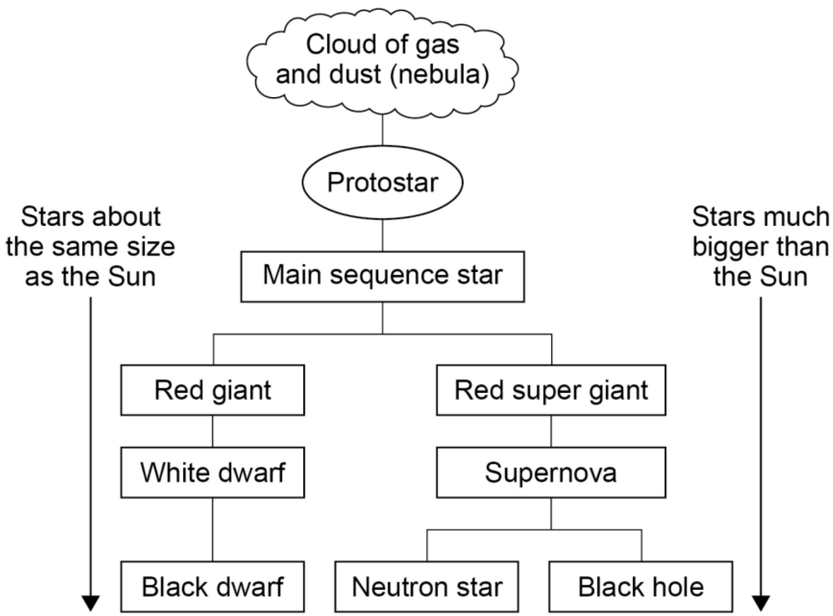
Our solar system consists of:

- One star: the Sun;
- Eight planets, which orbit the Sun;
- Dwarf planets, such as Pluto, which also orbit the Sun;
- Natural satellites: the moons that orbit some of the planets (including our moon);
- Other objects like asteroids and comets.

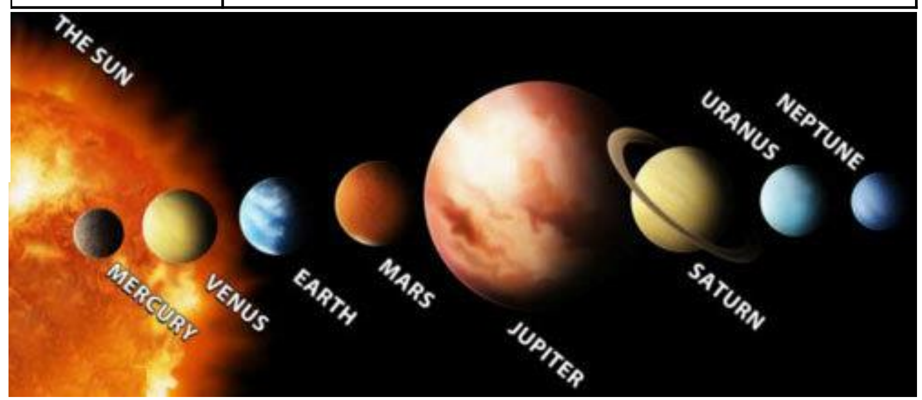
Our solar system is a very small part of the Milky Way galaxy. Galaxies consist of millions of stars, held together by their gravitational attraction to one another.

Stars and their life cycle

Stars form when a huge cloud of gas and dust (a **nebula**) comes together thanks to the **gravitational** attraction between the particles from which it is made. The diagram outlines the stages a star goes through during its life cycle. Note that the stages of the life cycle depend on the **initial mass** of the star. Lower mass stars (like the Sun) end more discreetly than others with much larger masses.



Key Terms	Definitions
Star	A huge (compared to Earth) sphere of superhot gas (plasma) undergoing nuclear fusion reactions.
Planet	A spherical object much smaller than a star, made of rocky or gaseous material (or a combination), which orbits a star.
Dwarf planet	Small planets that have not cleared their orbit of other material. Like planets, they orbit a star.
Satellites	Object that orbit a planet. Natural satellites are not launched by humans – so moons are natural satellites. Ones that we launch are called artificial satellites.
Orbit	To follow a path around another object due to the gravitational attraction between the objects, while being physically separated. Orbits can be circular, or elliptical (oval shaped).
Galaxy	A giant cluster of stars held together by their gravitational attraction to one another. Our galaxy is called the Milky Way.
Nebula	A cloud of gas and dust in space.
Nuclear fusion	A nuclear (not chemical) reaction in which the nuclei of atoms are joined together to make larger nuclei, releasing energy. For example, hydrogen nuclei are fused to helium nuclei in the Sun and other stars. Thus, fusion processes cause the formation of new elements. This can only happen at immense pressures and temperatures, when gases have ionised to become plasma. Nuclear fusion allows **nucleosynthesis** - making new nuclei.



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P16 - Space

Stages of star life cycles

You've seen the basic life cycle. Now for some detail.

- A **protostar** is a dense region in a nebula, which is still gathering mass by pulling in material from the nebula by its gravitational pull. So, at this stage, the star is still forming and has **not** yet started nuclear fusion reactions.
- **Main sequence** star: the Sun is a main sequence star. During this stage of a star's life cycle, the star is stable in size because the forces acting towards the centre and the outward forces caused by the nuclear fusion processes are in **equilibrium**. With an object as big as a star, the gravitational force acting on any particular particle is intense, so the star might be expected to collapse. However, there is an outward force leading to expansion, caused by the fusion processes occurring in the star. Essentially, this outward force is due to gas pressure (ok, plasma pressure) in the star. Pressure in gases increases if their temperature increases, making the star expand; in turn, this decreases the pressure and therefore cuts the rate of nuclear fusion. Therefore, main sequence stars are nicely self-regulating systems (using negative feedback).
- **Red giant** and **red super giant** stages: as the diagram showed, this is where the life cycle diverges according to the mass of the star. Stars finish their main sequence when the hydrogen in the core runs out (it has all been fused to helium). This reduces the outward pressure, so the star begins to collapse inwards due to gravity. In turn, this allows some of the hydrogen *outside* the core (the layer of a star we actually see) to begin going through nuclear fusion, and at a much more rapid rate than during the main sequence. This higher rate of nuclear fusion produces a larger outward pressure, so the outer layer of the star expands by a great deal, perhaps as far as the orbit of Venus in the case of the Sun! (Hence the 'giant' in the name.)
- The red giant or red super giant stage ends as the fuel runs out. This causes a drop in outward pressure, so gravity wins out and causes the collapse of the star. This is really rapid, though, and causes a shock wave outwards. In stars like the Sun, this is violent but not crazy – the outer layers of the star are ejected relatively slowly out. However, in larger stars this outwards shock wave is extremely violent, resulting in a **supernova**. A supernova is such a colossal explosion that a red supergiant entering its supernova stage can outshine its whole galaxy! This spreads the new elements made in the star by nuclear fusion (or **nucleosynthesis**) out across the universe. This is actually the reason why large elements (anything larger than iron) are found on Earth – the atoms were spread out after their formation in supernovae.
- The core of the Sun, and similar sized stars, will become a **white dwarf**. When it has totally cooled off, it will be a **black dwarf** – just the cold remnants of its core. The core of larger stars will be left as **neutron stars**, which are insanely dense objects: as illustrative values, a neutron star may be only 20 km in diameter but have a mass *twice* that of the Sun! Should the star have started as a *really* massive star, the core will collapse to make a **black hole**, which is even more dense than a neutron star and a place where conditions are so extreme that physicists are struggling to express the rules that govern the behaviour of matter in black holes.

Key Terms	Definitions
Protostar	An early star – basically a big dense part of a nebula that is gathering mass but hasn't started nuclear fusion yet.
Main sequence	The stable stage of a star's life cycle, where inward and outward forces are in equilibrium.
Plasma	The 'fourth state of matter' – a superhot gas, where electrons are stripped from nuclei, leaving a sea of positive nuclei and negative electrons.
Red giant	The stage after the main sequence for stars with a similar mass to the Sun.
Red supergiant	The stage after the main sequence for stars much more massive than the Sun.
White dwarf	The collapsed core of a star like the Sun. Very dense (about 200 000 times more dense than Earth), but not as dense as neutron stars or black holes.
Black dwarf	When a white dwarf has fully cooled down, it no longer emits any radiation so it is a black dwarf. So in the universe, there aren't any black dwarves because it isn't old enough for white dwarves to have cooled off yet!
Supernova	The enormous explosion resulting from the collapse and resulting shock wave of a star much more massive than the Sun.
Neutron star	The collapsed core of a star after a supernova (but not of a star large enough to form a black hole).
Black hole	The collapsed core of really massive stars – about five or more times the mass of the Sun.

Physics Knowledge Organiser
P16 - Space

Orbits

Gravity is the force that allows orbits to be maintained. Since an object in motion is moving in a circle, its direction and therefore velocity is constantly changing, even as its speed stays constant. The orbiting object is accelerating towards the object it orbits, as the diagram shows. The velocity at any moment you pick (called the **instantaneous velocity**) is at a tangent to the orbital path.

For an orbit to remain stable, the radius of the orbital path must change if the speed changes. This means, for example, Mercury travels much faster on its orbital path around the Sun than Earth, since the radius of its orbital path is much smaller than ours.

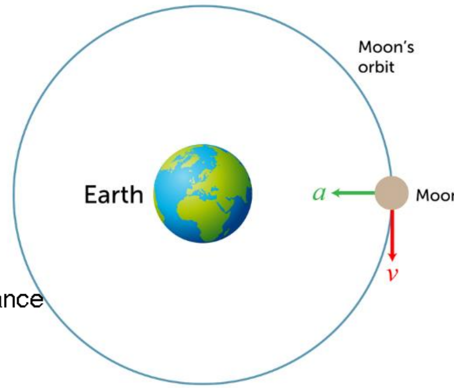
Red Shift

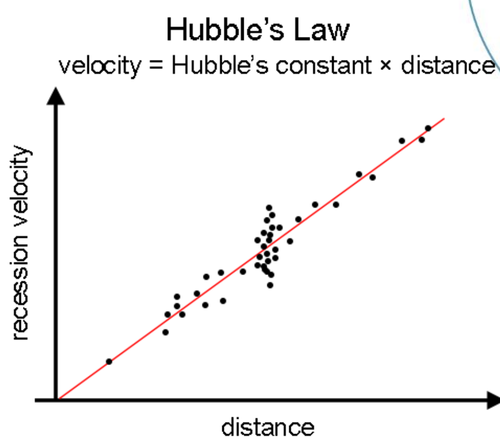
When we examine the light (electromagnetic radiation) from distant galaxies in space, the wavelength is *increased* compared to what is 'should be'. This stretching of waves that are emitted from a wave source moving away from an observer is called the Doppler effect in general, and **red shift** when we're talking about electromagnetic radiation. Working backwards logically, we know that distant galaxies are *receding* (moving away from us). This shows that the universe (i.e. space itself) is expanding. In turn, this provides great evidence for the Big Bang theory, since when you turn the clock back, the galaxies must have been much closer together in the past, all the way back until the whole universe (space and all the matter in it) was a single hot, dense point.

In 1998 some breakthrough studies of supernovae in distant galaxies showed that the rate of recession of galaxies is greater the further away they are, findings that have been confirmed in numerous studies since. The findings showed that the more distant the galaxy is, the greater the red shift of its light, showing that they are moving away faster than nearer galaxies. The graph shows this – each dot is a galaxy which has been observed and its red shift used to calculate its recessional velocity (how fast it is moving away from us, the observers).

There are still many unsolved questions about all this, though. No-one knows what is causing the acceleration of the universe's expansion (so it often gets the opaque name 'dark energy'). Another giant mystery is 'dark matter' – astronomers know there is a giant 'halo' of matter around objects in space like galaxies, but have no idea what it is made of, hence the name.

Key Terms	Definitions
Instantaneous velocity	Velocity at a single moment (remember it is vector quantity, with both direction and magnitude).
Red shift	The observed increase in wavelength of light emitted by objects moving away (receding) from an observer.
Big Bang theory	The theory, which is by far the dominant scientific theory for the origin of the universe, that states that the whole universe was once tiny and very hot and dense.
Recessional velocity	How fast something (like a galaxy) is moving away from an observer.
Dark matter	Aka dark mass. A mysterious type of matter that is known to exist (from observations of other galaxies), but no-one knows what it is made of.
Dark energy	The name given to the mysterious energy driving the acceleration in the expansion of the universe.



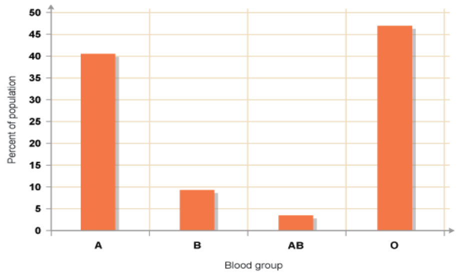


Practical Methods Knowledge Organiser: Processing Data

Key Terms	Definitions
Continuous	Data which take any value for example temperature
Discontinuous	Data which can only take certain values for example blood group
Correlation	The relationship between 2 variables

Continuous vs Discontinuous data

Discontinuous data can only take certain values for example eye colour and blood group, these should be plotted on a bar graph.



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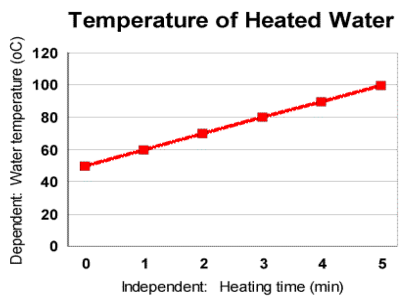

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Correlation

You can describe the relationship between 2 variables in terms of their correlation (how they are related to each other). There are three types of correlation :

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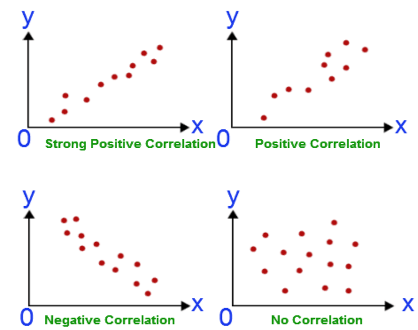
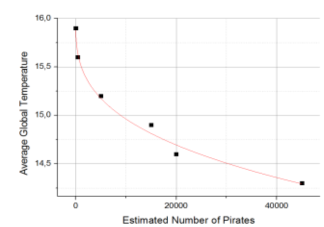


Correlation does not however **mean causation.** Just because two variables are linked does not mean that one variable causes the other . For example the number of pirates has decreased as global temperatures have increased. This does not mean that pirates were keeping the Earth cool! Just because data is correlated does not mean one variable caused the change in the other.



Correlation could also be down to:

1. Chance
2. A third variable

You can only be sure one variable causes a change in another variable, if all the other possible variables are controlled.

Practical Methods Knowledge Organiser: Processing Data

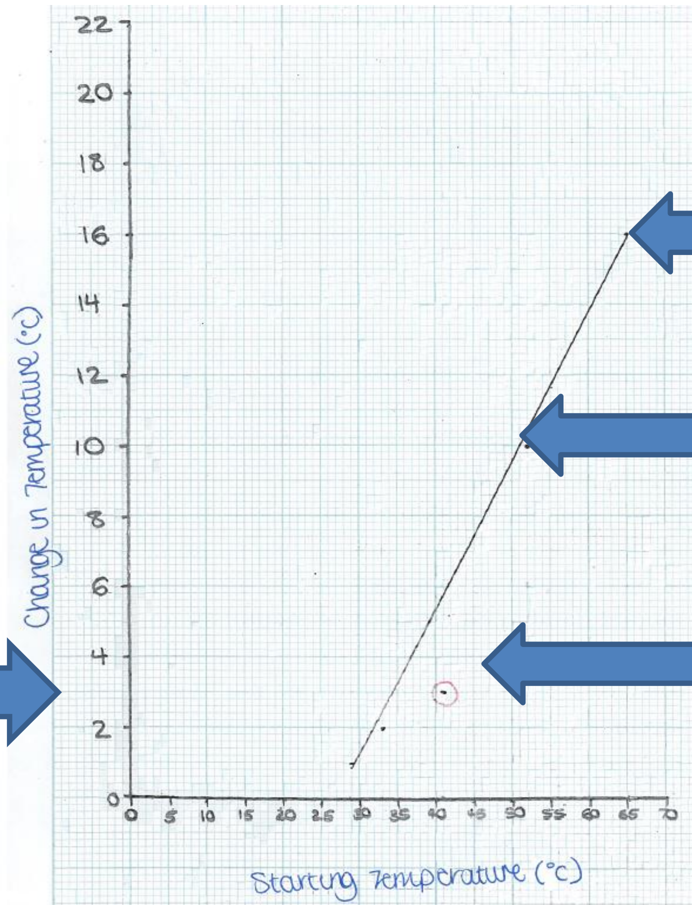
Equation
Gradient= $\frac{Change\ in\ y}{C\ hange\ in\ x}$

Drawing good graphs

This is an excellent example of a good graph by a Nova student. When drawing a graph, you should plot the dependent variable on the **y axis** and independent variable on the **x axis**. To calculate the gradient you on a straight line need to select two points on the line and divide the change in y by the change in x. To calculate the gradient on a curve, you need to draw a tangent to the curve, see topic 15 knowledge organiser.

Labels for axes, with units given in brackets

Both axes have suitable scales (equal intervals)



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Neat, accurately placed plots. Marked with a small x.

Anomaly recognised and highlighted on the graph

Practical Methods Knowledge Organiser: Designing Experiments

Variables

When designing experiments, there are three types of variable that we need to consider. The dependent variable is what we measure, the independent variable is what **we change** in the experiment. And the control variables are the variables we **keep the same.**
For example, consider the investigation below:
How does the concentration of hydrochloric acid affect the rate at which magnesium reacts?
I.V- Concentration of Hydrochloric acid
D.V- Rate of Reaction
C.Vs- Volume of acid, mass of magnesium, temperature of acid.

Reproducibility, repeatability and validity

Experiments should always be repeatable, reproducible and valid. Reproducibility means that if someone were to follow your method, they would get a similar pattern in their results.

An experiment is repeatable if the same person completes the same experiment , following the same method , with the same equipment and they achieve similar results. To ensure that your results are repeatable you should complete the experiment **at least three times**

Valid results are repeatable and reproducible.

Error

When doing practical work you will come across error. This can cause **anomalous results** i.e. a result which does fit the expected pattern. There are three types of error that could effect your results:

1. **Random error-** this error is unpredictable and can be caused by things like human error when measuring . Repeating an experiment three times can minimise the effect of random errors and will allow you to spot anomalous results.
2. **Systematic error-** this is an error in your measurement and will be the same every time you do a repeat .For example if you read a length from the end of a ruler rather than from 0. **Doing repeats will NOT prevent systematic error**.
3. **Zero error -**this is a type of systematic error, for example if a balance does not read 0g when you add a substance to it, you will need to take this into account when weighing chemicals.

Key Terms	Definitions
Reproducible	A set of results that can be found again by someone else if they carry out the same method
Repeatable	Results that you can find if you do the same test again – it shows the result wasn't just a random finding.
Independent variable	The variable YOU change to find out its effect on the DV
Dependent variable	The variable you MEASURE to see how it changes
Control variable	Any variable that you must keep the SAME in your investigation, to ensure it doesn't affect the DV
Resolution	The smallest measurable change by a piece of apparatus
Random Error	An unpredictable error which could be caused by human error in measurement
Systematic Error	An error in measurement that is the same every time .

Resolution

The resolution of apparatus is the smallest measurable change by that piece of apparatus. For example some balances will only measure to the nearest 1 gram whereas others will measure to the nearest 0.1gram. We say the balance that measures to the nearest 0.1g **has a higher resolution.** Therefore using equipment of higher resolution will improve the accuracy of your investigation.

When selecting equipment to use in your experiment you should select equipment with an appropriate resolution. For example if your experiment requires you to weigh 2.3 g of a substance out you will need to use the balance that measures to the nearest 0.1g

Accuracy and Precision

Consider the set of results below:

	Experiment 1	Experiment 2
	Time (s)	Time (s)
1	12	11
2	12	15
3	11	19
Mean	12	15

We want our experiments to be accurate and precise.
If a measurement is accurate it is close to its true value. If a measurement is precise the results 'cluster' closely. For example experiment 1 is more precise than experiment 2.
Precision can be improved by taking readers at smaller intervals .

Practical Methods Knowledge Organiser: Processing Data

Key Terms	Definitions
Uncertainty	The amount of error your measurements might have
Mean	The total of the values divided by the number of values
Median	The middle value in a set of data
Mode	The most commonly occurring value in a set of data

Results Tables

When drawing a results table the following things are good practice::

1. Show all repeat measurements
2. Include the units in the headings
3. When calculating means ensure you quote to an appropriate number of significant figures
4. Circle anomalies and discount these when calculating a mean

For example:

Concentration of acid (M)	Time taken for reaction to complete (s)			Mean (s)
0.1	102.1	105.6	103.4	103.7
0.2	88.8	86.5	87.2	87.5
0.3	69.1	67.3	64.2	66.866667
0.4	56.2	40.1	53.3	54.8
0.5	32.1	30.1	33.2	31.8

The table above shows how a results tables should be drawn. However, there is one mistake. If you look at the mean in the row for 0.3 M, you will see it has been calculated to 9 significant figures , however the equipment we used only had a resolution to 3 significant figures. You can not quote a mean to greater level of accuracy than you measured it to in the experiment. Therefore this mean would need to be rounded 66.9, this causes uncertainty in results. See later for how to calculate uncertainty.

Mean, mode and median

For some sets of data it is appropriate to calculate the mean, mode and median.
To calculate the **mean** you add all the values in the data and then divide by the number of values. For example in the table above for 0.1 M the mean was calculated by (102.1+105.6+103.4)/3.
The mode is the most commonly occurring value in a data set.
The median is the middle value in a data set.

Equation

Uncertainty= $\frac{Range}{2}$

Uncertainty

There will always be some uncertainty in the results you collect, there are two main reasons for this.
When you repeat an experiment you often get different results, this is due to random error. The resolution of your equipment will also cause uncertainty. There will therefore be a degree of uncertainty in your mean. For example take the two sets of results below:

	Time for a piece of magnesium to disappear in 2M HCL (s)			
	1	2	3	Mean
Experiment 1	12.3	12.5	12.7	12.5
Experiment 2	13	15	17	15

We can calculate the uncertainty in the mean of the two experiments by dividing the range of results by 2:
Experiment 1= 0.5/2= +/-0.25s
Experiment 2= 4/2= +/-2s

Experiment 1 therefore is more precise than experiment 2. This is partly because they used a stopwatch with a **higher resolution.**

Increasing the quantity of something can help to reduce the uncertainty. For example in the table above, if I had used a larger piece of magnesium, then it would have taken longer to disappear and this could reduce the percentage uncertainty.

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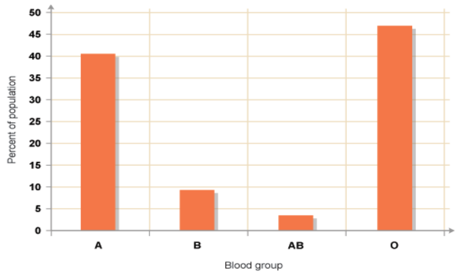

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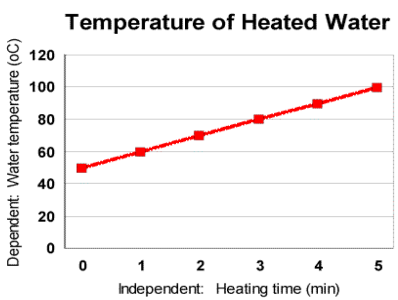

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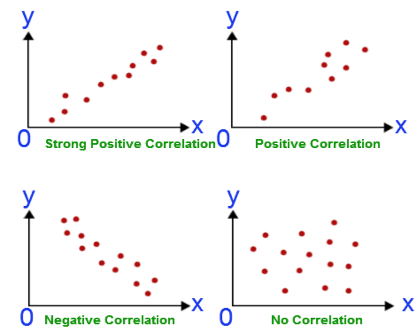

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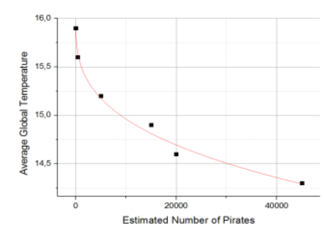

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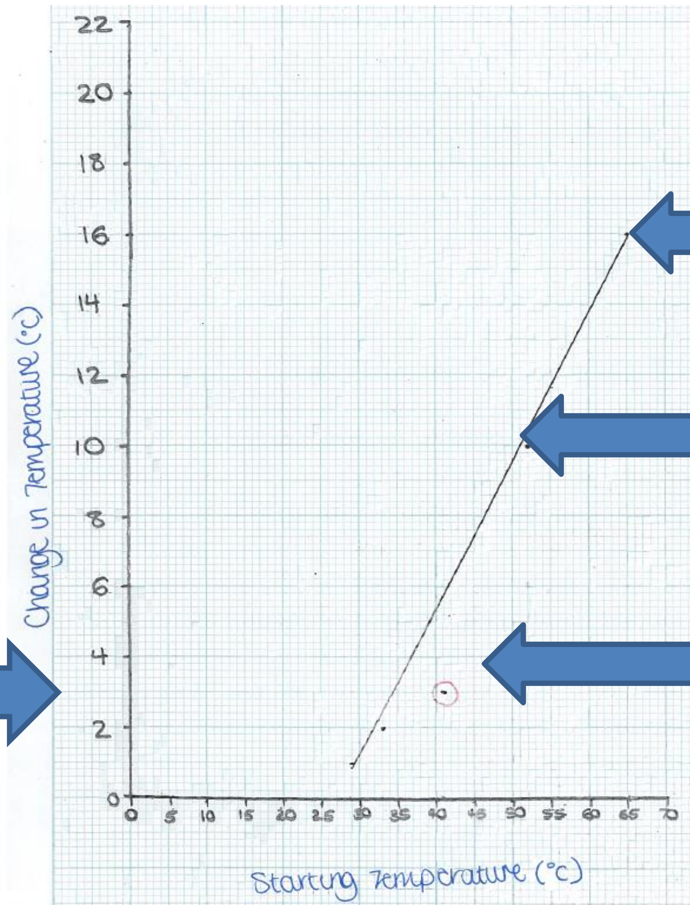

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