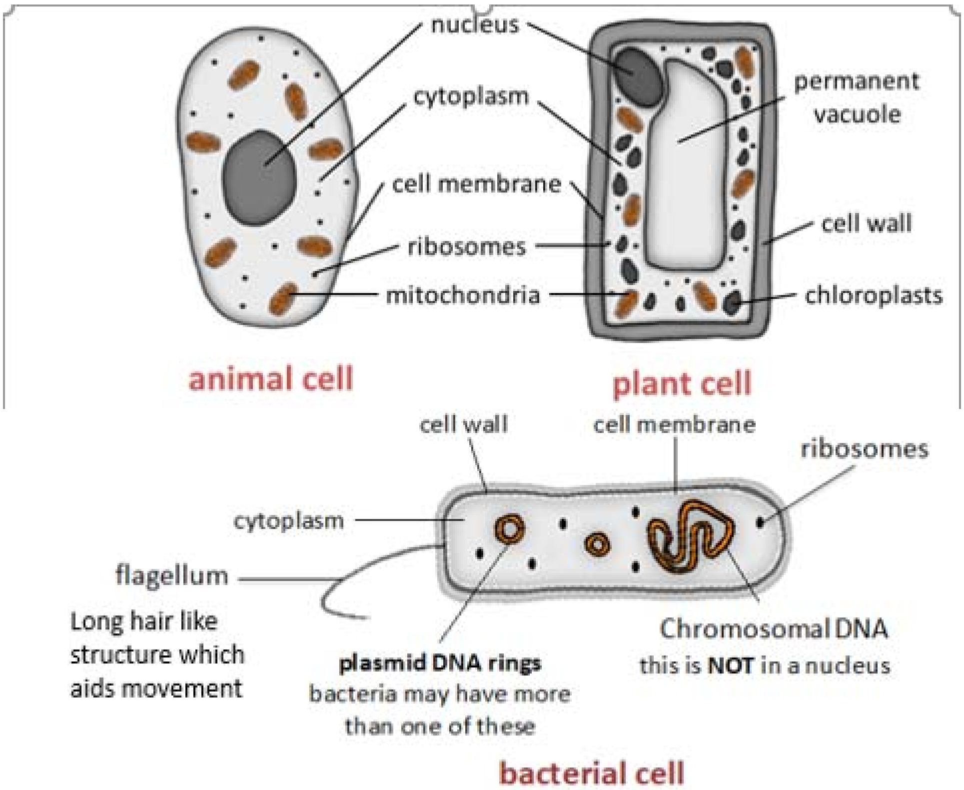
All living things are made of cells; they are the basic unit of all life.
Eukaryotic Cells: have a cell membrane, cytoplasm and genetic material (DNA) enclosed in a **nucleus**. Examples: plant and animal cells

Prokaryotic Cells: **No nucleus**. DNA is a single loop. There may be one or more rings of DNA called plasmids. Examples: Bacteria cells

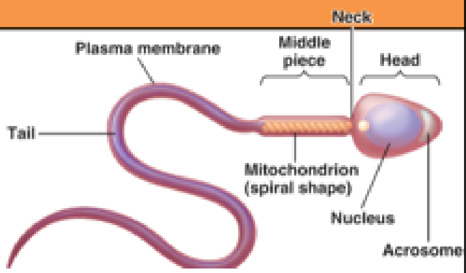
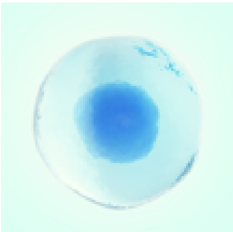
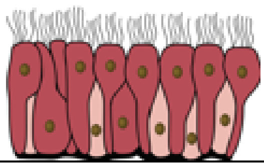


You need to be able to list the similarities and differences of an animal, plant and bacterial cell

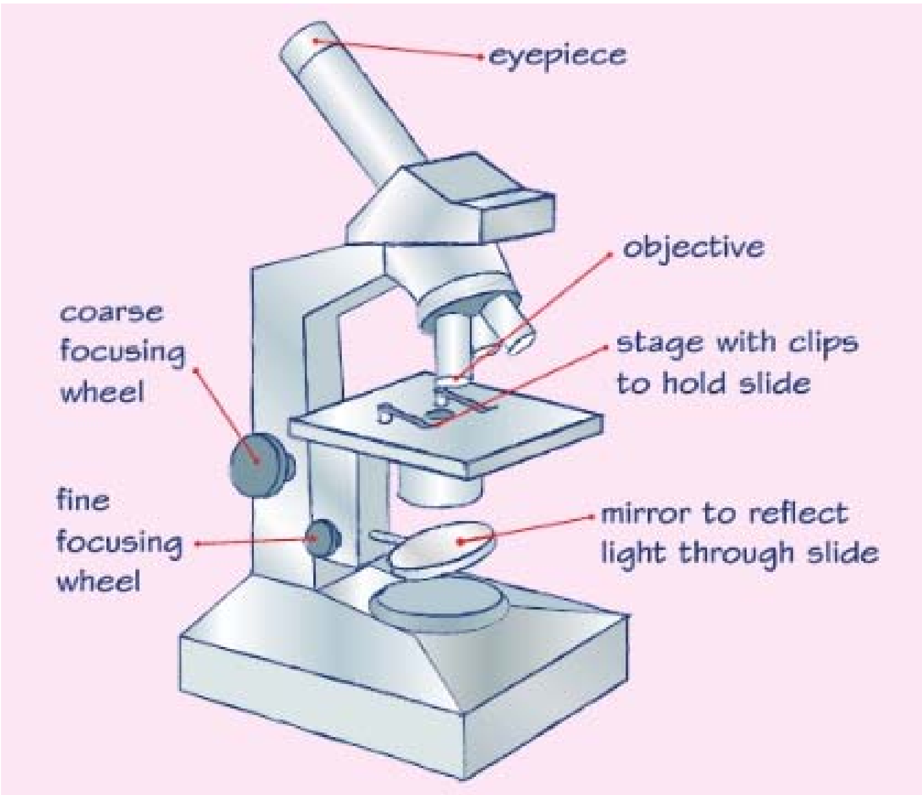
Cell part	Function	Animal	Plant	Bacteria
Nucleus	Contains genetic material which controls the activities of the cell	✓	✓	
Cytoplasm	Most chemical processes take place here, controlled by enzymes	✓	✓	✓
Cell membrane	Controls movement of substances into and out of cell	✓	✓	✓
Mitochondria	Most energy is released by respiration here	✓	✓	
Ribosomes	Protein synthesis happens here	✓	✓	✓
Cell wall	Strengthens the cell – made of cellulose (not bacteria) algal cells also have a cell wall		✓	✓
Chloroplasts	Contain chlorophyll, absorbs light energy for photosynthesis		✓	
Permanent vacuole	Filled with cell sap to help keep the cell turgid		✓	
Chromosomal DNA	Loop of DNA NOT found in a nucleus			✓
Plasmid (DNA)	Small ring of DNA often used as a vector in genetic modification			✓

Specialised Cells (3 types)

The **structure** of different cells helps them to carry out a **particular function** within the organism. These cells are called **specialised cells.**

Name of animal cell	Diagram	Adaptation to function
Sperm		**Function is to fertilise an egg** • Streamlined with a long tail to swim to the egg • Acrosome in the head containing enzymes to digest the egg cell membrane • Large number of mitochondria in the mid section to release energy for movement • Ribosomes for protein synthesis
Egg		**Function is to fuse with sperm and develop into embryo** • Nutrients in the cytoplasm for respiration and cell division • Haploid nucleus • Cell membrane changes to prevent further sperm entry
Ciliated epithelium		**Function is movement of substances** • Surface contains cilia (microscopic hairs) to sweep substances e.g. mucus • Large number of mitochondria to release energy

Microscopes



2 types of microscopes : Light microscope and electron microscope

Feature	Light (optical) microscope	Electron microscope
Radiation used	Light rays	Electron beams
Max magnification	~ 1500 times	~ 2 000 000 times
Resolution	200nm	0.2nm
Size of microscope	Small and portable	Very large and not portable
Cost	~£100 for a school one	Several £100,000 to £1 million plus

magnification M = $\frac{\text{size of image I}}{\text{real size of the object A}}$

MAGNIFICATION: the number of times bigger the image looks compared to the object
IMAGE: what is viewed through the microscope lenses
OBJECT: the **ACTUAL** specimen under microscope.
Make sure the image and object size have the same units.

Example: A magnified animal cell structure has a diameter of 6 mm.
The actual diameter of the structure is 0.15mm.
Calculate how many times the structure has been magnified.

Units used to measure cells

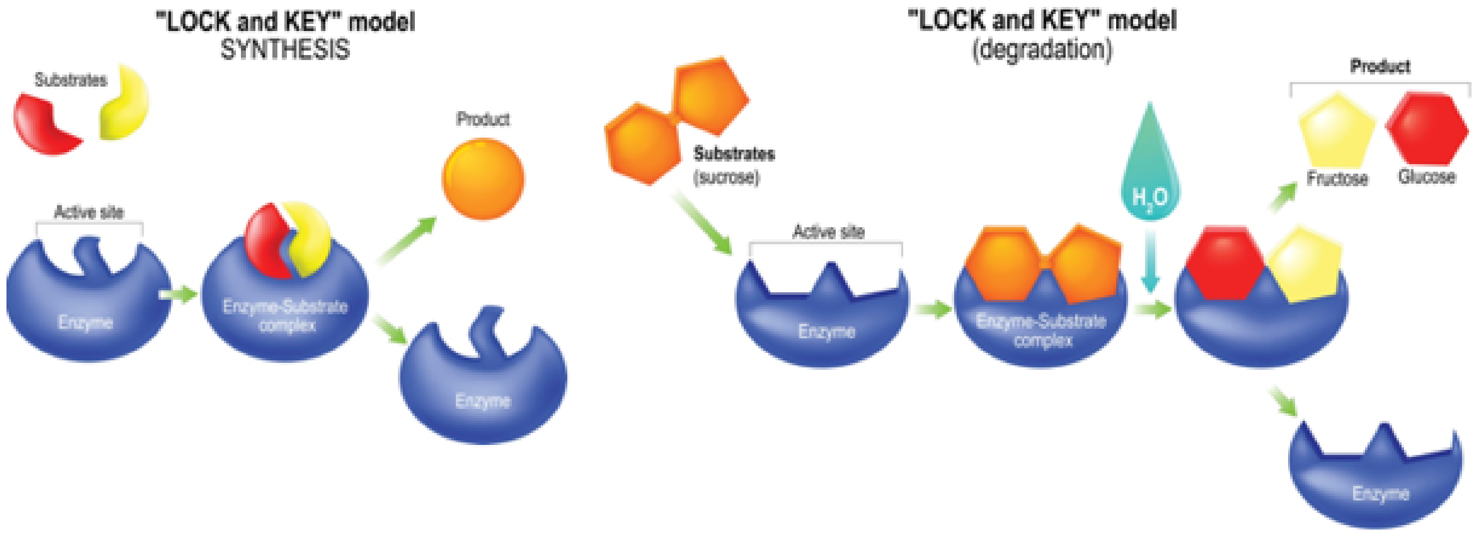
Prefix	Multiple	Standard form
centi (cm)	1 cm = 0.01 m	x 10^{-2}
milli (mm)	1 mm = 0.001 m	x 10^{-3}
micro (µm)	1 µm = 0.000 001 m	x 10^{-6}
nano (nm)	1 nm = 0.000 000 001 m	x 10^{-9}
pico (pm)	1 pm = 0.000 000 000 001m	x 10^{-12}

<u>Enzymes</u>

Enzymes are biological catalysts. A **catalyst** is something that speeds up or slows down a reaction without get involved in the reaction.

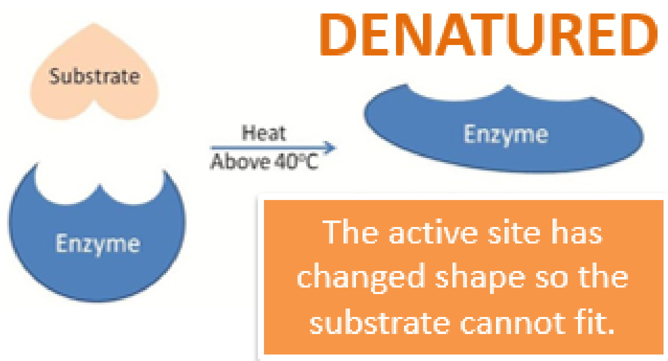
Enzymes are **specific** to a substrate. The activity of an enzyme is affected by temperature, substrate concentration and pH. Specific conditions are needed to keep an enzyme working at its optimum.

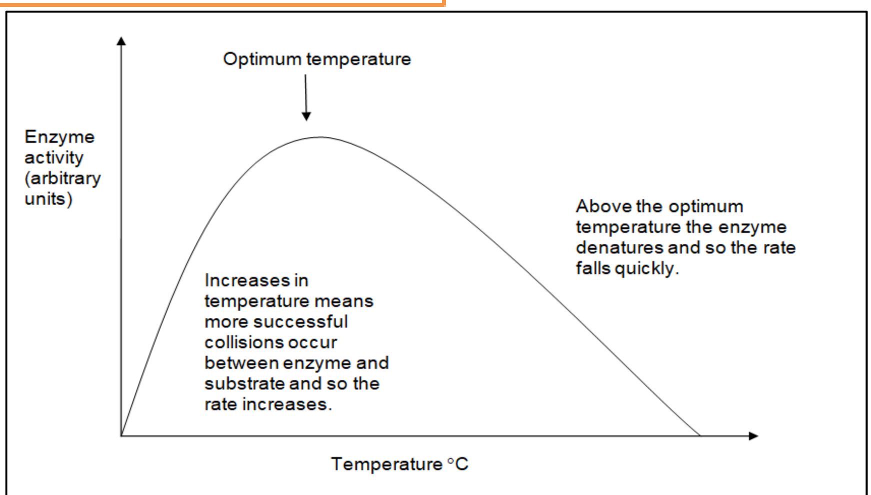
'Lock and Key theory' is a **model** to explain **enzyme action.** **Enzymes** are made of **proteins** and are **biological catalysts** - substances that **increase** the rate of **chemical reactions** without being **used up**. The shape of the **active site** of the enzyme is specific for each substrate (substance the enzyme acts on).

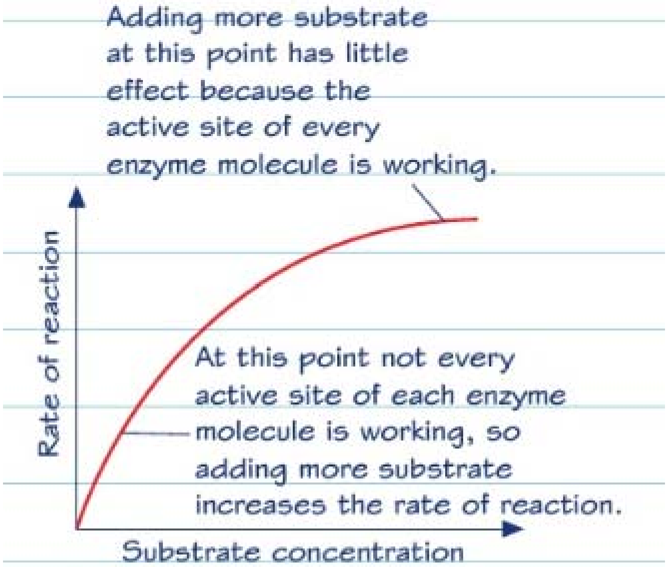


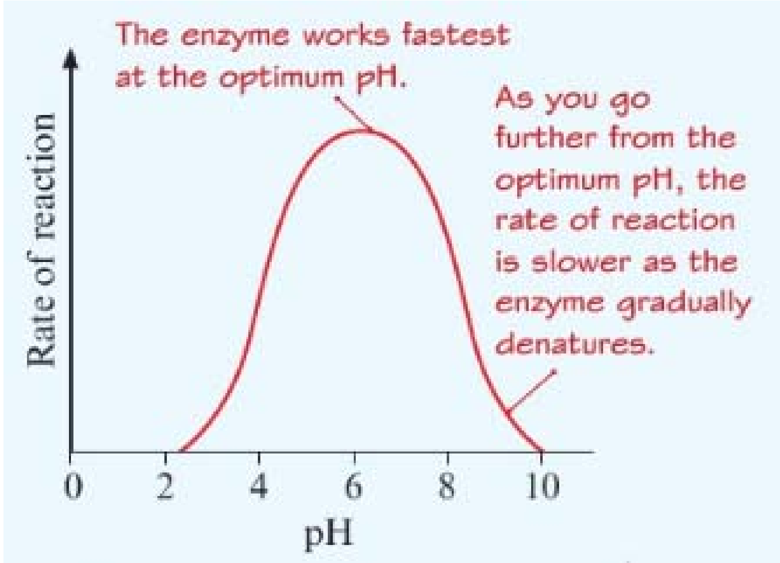
The **products** of digestion are used to **build** new **carbohydrates**, **lipids** and **proteins** in the body. Some **glucose** is used in **respiration**.

In enzyme reactions, **increasing the temperature** will initially increase the **rate of reaction** due to increased **collisions** between the enzyme and substrates. **BUT** if the **temperature** is **too high** the **enzyme** will **denature** because some of the bonds in the protein break so changing its shape.

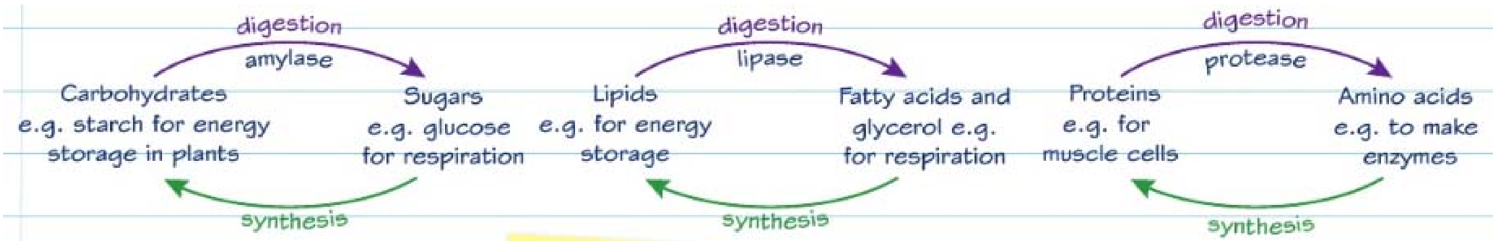








<u>Digestive Enzymes</u>

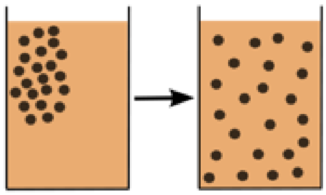


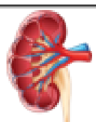
<u>How substances are transported in and out of cells</u>

Diffusion

Diffusion is the spreading of the **particles of a gas or substances in solution**, resulting in a **net movement** of particles from a region where they are of a **higher concentration** ***to an area of*** **lower concentration.**

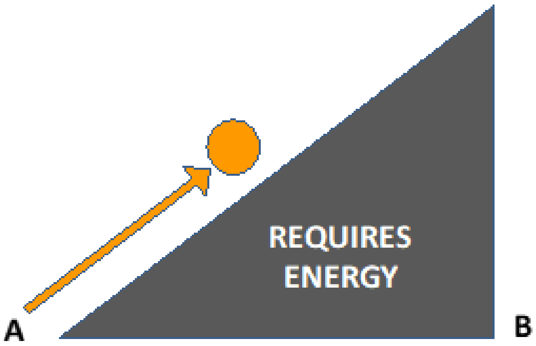
Diffusion can occur in: Air – smells from perfume etc.
Solution – tea from a tea bag, dye in water etc.
Through membranes – small intestines, blood cells etc.

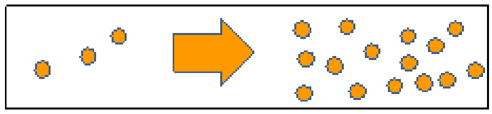


Substances that are transported in and out of cells in humans			
Location	Particles move	From	To
Small Intestine 	**Digested food e.g. glucose, amino acids**	**Small intestine**	**Blood in capillary of villus**
Lungs 	**Oxygen**	**Alveolar air space**	**Blood circulating around the lungs**
Kidneys 	**Urea**	**Cells**	**Blood plasma**

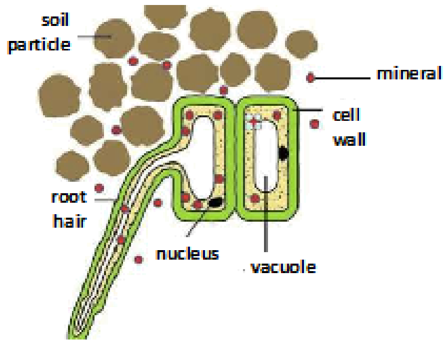
Active Transport

Active transport moves substances from a more dilute solution to a more concentrated solution (against a concentration gradient). The energy is provided by respiration.





Active transport occurs in root hair cells.

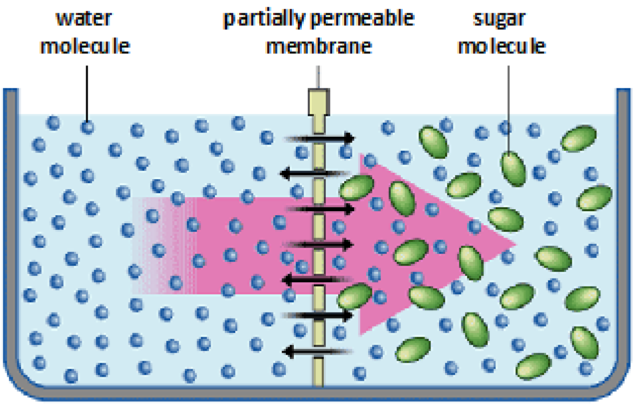


The minerals are at a higher concentration in the root hair cell than in the soil. So the minerals move **into** the cell against the concentration gradient.

Active transport also occurs in the **gut** (small intestines); **sugar** (glucose) molecules are absorbed from lower concentrations in the gut into the blood which has a higher sugar concentration.
The glucose is used for respiration.

Osmosis

Osmosis is the diffusion of water from a dilute solution to a concentrated solution through a partially permeable membrane.

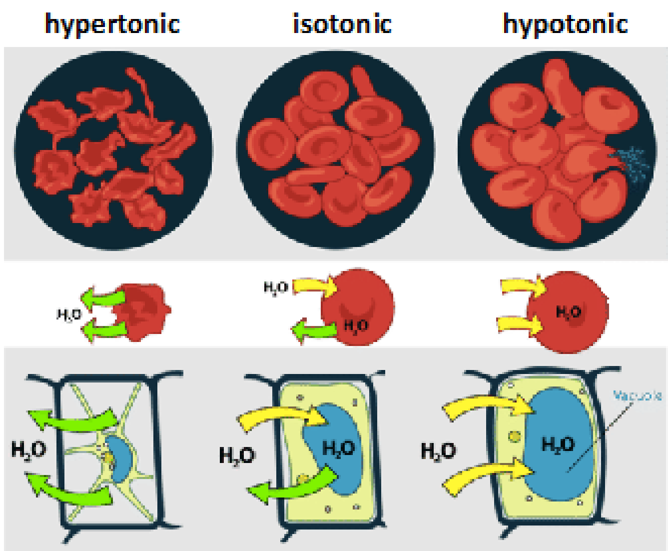


water moves from the dilute side to the more concentrated side

The rate of osmosis changes depending on the concentration gradient and temperature.

Partially permeable membrane – a membrane that lets some but not all substances through.

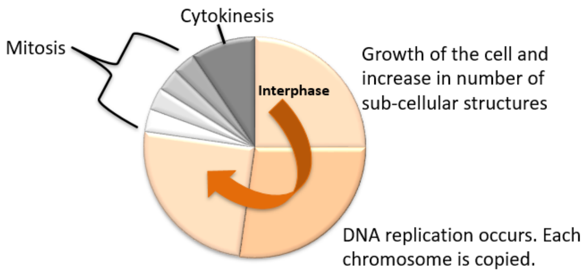
Osmosis in plant and animal cells:



Hypertonic – more concentrated solution than in the cells.
Isotonic – same concentration as the solution in the cell.
Hypotonic – more dilute than the solution in the cells.

The initial mass of a potato slice was 16.52 g. After soaking in a solution the final mass was 20.15 g. Calculate the percentage change in mass.

Mitosis is a type of **cell division.**
Mitosis occurs during **growth** when the number of cells needs to increase and also to **repair** or replace damaged cells.
Asexual reproduction occurs by mitosis in plants and simple animals.
The overall process of growth and division is known as the **cell cycle**.



In the **cell cycle,** cells divide by **mitosis** in a series of **stages**. The **genetic material** is **doubled** and then **divided** into **two identical cells**.

During interphase in the cell cycle…

Growth must occur: Before a cell can divide it needs to grow and increase the number of sub-cellular structures such as ribosomes and mitochondria. DNA is then duplicated to form two copies of each chromosome.

Mitosis now begins. Four stages occur…

Interphase is the longest stage in the cell cycle.

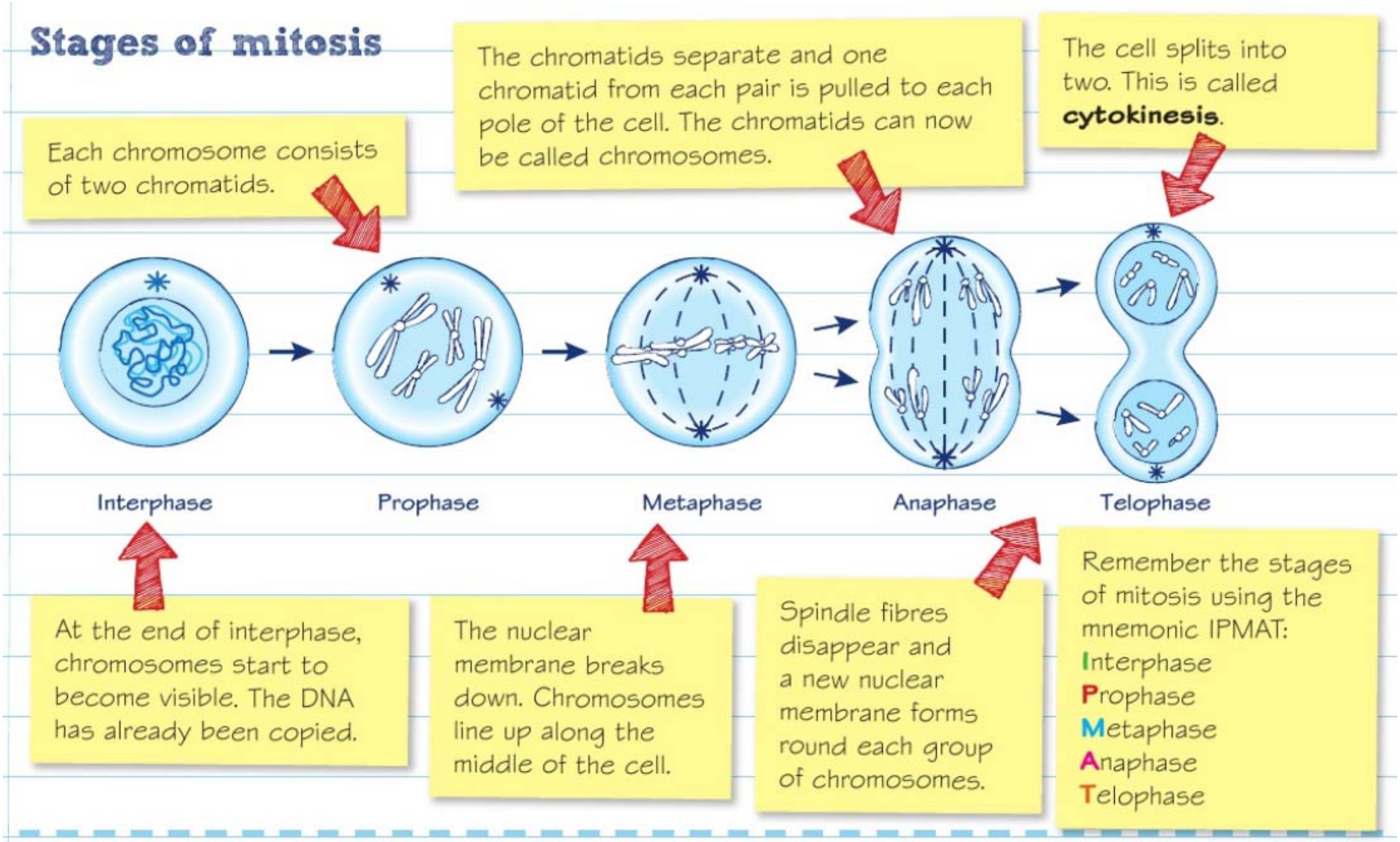
Prophase: the nuclear membrane dissolves and the chromosomes become shorter and fatter.

Metaphase: the spindle forms and the chromosomes line up on the equator.

Anaphase: the spindle fibres pull the identical chromosomes apart to opposite ends of the cell.

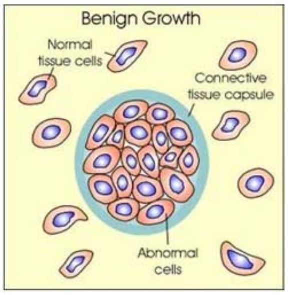
Telophase: Membranes form around the outside of each set of chromosomes. These are the nuclei of the 2 new daughter cells.
The cytoplasm and cell membrane divide and two new identical cells are formed. This process of splitting is called **cytokinesis**.

Two diploid daughter cells are produced each with identical sets of chromosomes in the nucleus to each other and the original parent cell.

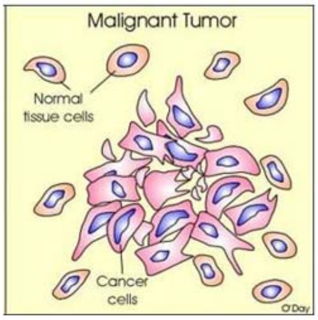


The **rate** at which **a cell divides** by mitosis is **controlled** by its **genetic information.**
A **mutation** might alter a gene controlling cell division allowing cells to start **dividing uncontrollably**.
This can result in the formation of a **tumour.**

- **Benign tumours:**
  - Growths of abnormal cells
  - Contained in one area
  - Usually within a membrane surrounding the cells
  - They do not invade other parts of the body



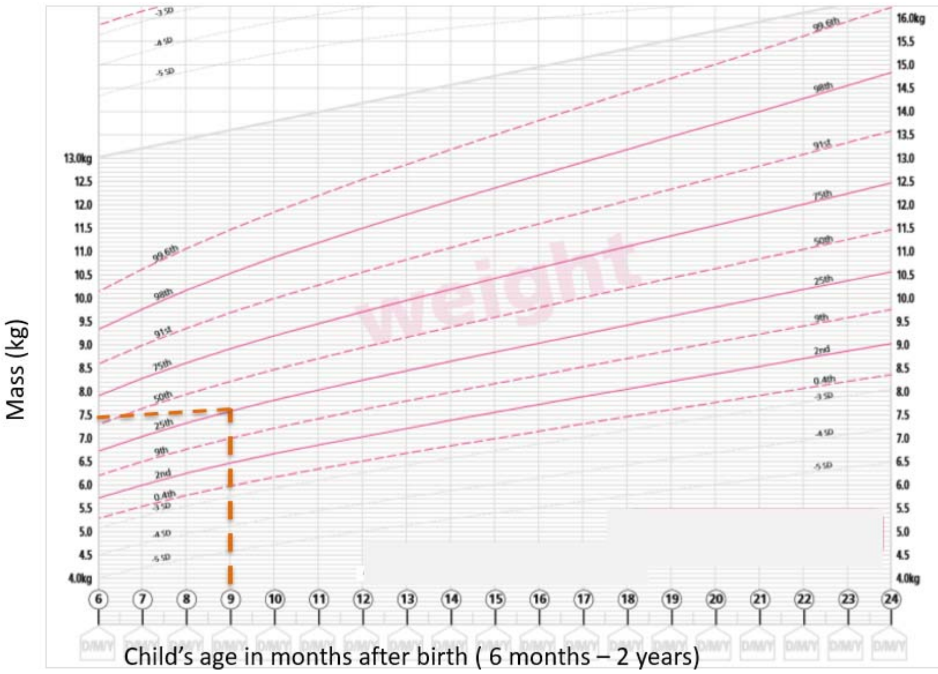
- **Malignant tumour (CANCER):**
  - Growths of abnormal cells
  - These are **cancerous**
  - Invade neighbouring tissues and spread to different parts of the body in the blood where they form secondary tumours
  - Can be caused by lifestyle or genes



Growth is defined as an **increase in size** or **mass**.

Growth occurs in **young animals** by **rapid cell division** all over the body. As animals get **older** most cell division is simply to **replace or repair** damaged cells.

Growth in **plants** occurs by cell division at the **root and shoot** tips. Cells increase in size or height by **cell elongation**.
This happens **throughout the plants life**.



Cell **differentiation** occurs as organisms develop and the cell changes to become **specialised**. As the cell **differentiates,** it forms different sub-cellular structures, e.g. the tail on a sperm cell or the hairs on a root hair cell.

Most types of **ANIMAL** cells **differentiate** in the early stage of development.

Examples: red blood cells, egg and sperm cells

Nerve cells, Bone cells

Most types of **PLANT** cells can **differentiate throughout their life** cycle.

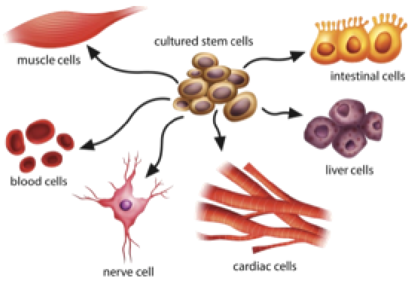
Examples: xylem, phloem, root hair cells,

stoma cells

Stem Cells

Stem cells are **undifferentiated cells** within an organism. They can produce other stem cells that can then differentiate into many different types of cells.

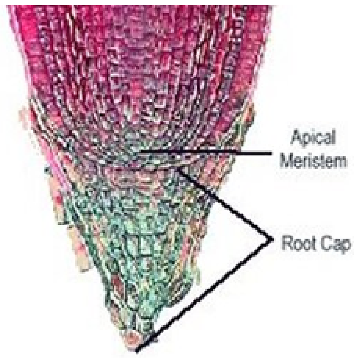
Human embryo stem cells can be cloned and made to **differentiate** into **most** different types of human cells.
Human adult stem cells can form **many** (but not all) types of cells including blood cells.
Human stem cells can be used to **help treat diseases** like **diabetes** and **paralysis.**



Embryos produced by **therapeutic cloning** have the **same genes as the patient**.
This means stem cells from the embryo are **not rejected by the patient's body.**
This is why they can be used for medical treatments.
The **risks** of using stem cells risks such as the **transfer** of **viral infections.**
Some people have objections to stem cell use for **ethical** and **religious** reasons.
During fertility treatment doctors usually fertilise many more eggs than are going to be used. The **embryos** formed are used to **obtain** stem cells.
In the UK, **scientists** can use these embryos for **research** but only under **very strict guidelines**.

Most types of **PLANT** cells can **differentiate throughout their life** cycle.

Undifferentiated stem cells in **plants** are grouped together in **structures called meristems**.
The undifferentiated cells can then specialise e.g. root hair cell, xylem or phloem cells.



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

- **Rare species** can be cloned to protect from extinction.
- **Crop plants** with special features, such as disease resistance, can be cloned to produce large numbers of identical plants for farmers e.g. potatoes, strawberries and dates.

Embryonic stem cells

Embryonic stem cells have many uses, including:

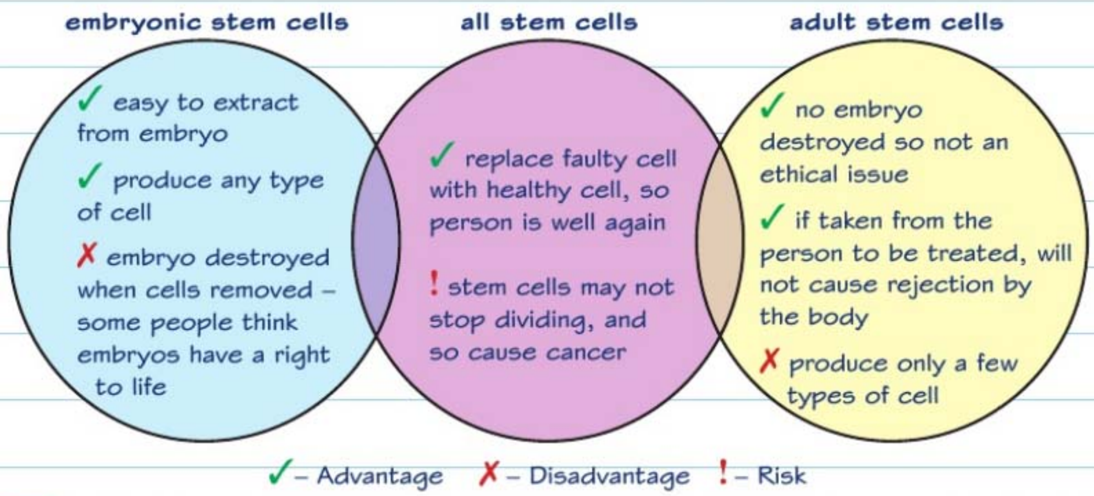
- replacing or repairing brain cells to treat people with Parkinson's disease
- replacing damaged cells in the retina of the eye to treat some kinds of blindness
- growing new tissues in the lab to use for transplants or drug testing.

Adult stem cells

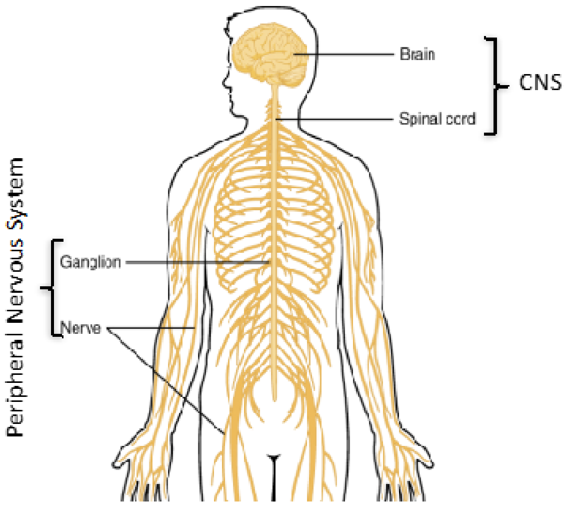
Adult stem cells (from bone marrow) can only form a limited number of cell types. They can be used for:

- treatment of leukaemia
- potentially growing new tissues that are genetically matched to the patient.

Using stem cells



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



A **stimulus** is any change in the soundings. These are detected by **receptors** (cells that detect a change) and information passes along cells (neurones) as **electrical impulses** to the **central nervous system** (CNS).

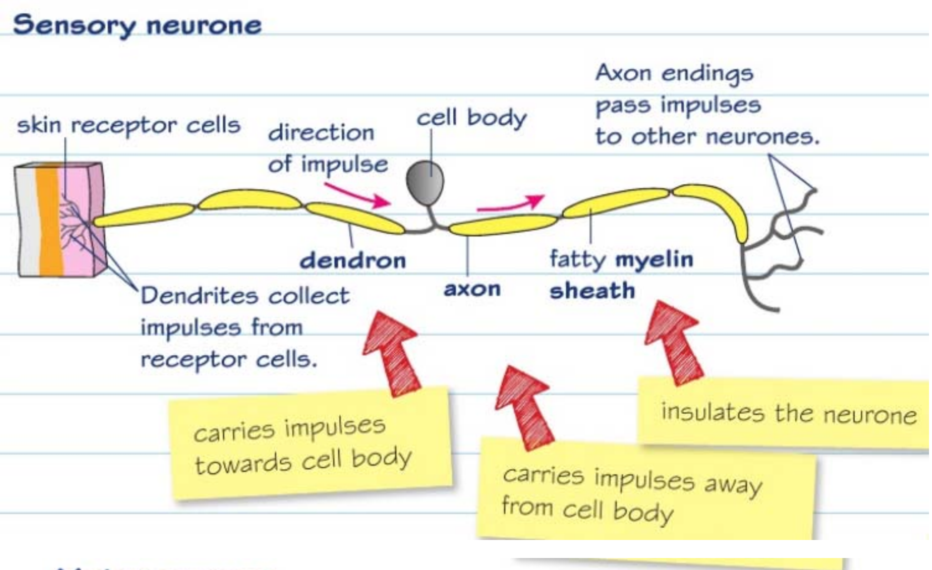
The **CNS** is the **brain** and **spinal cord**.

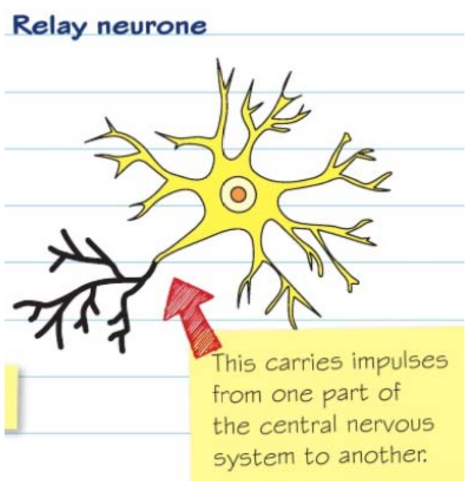
The **CNS coordinates** the **response of effectors** which may be muscles contracting or glands secreting hormones.

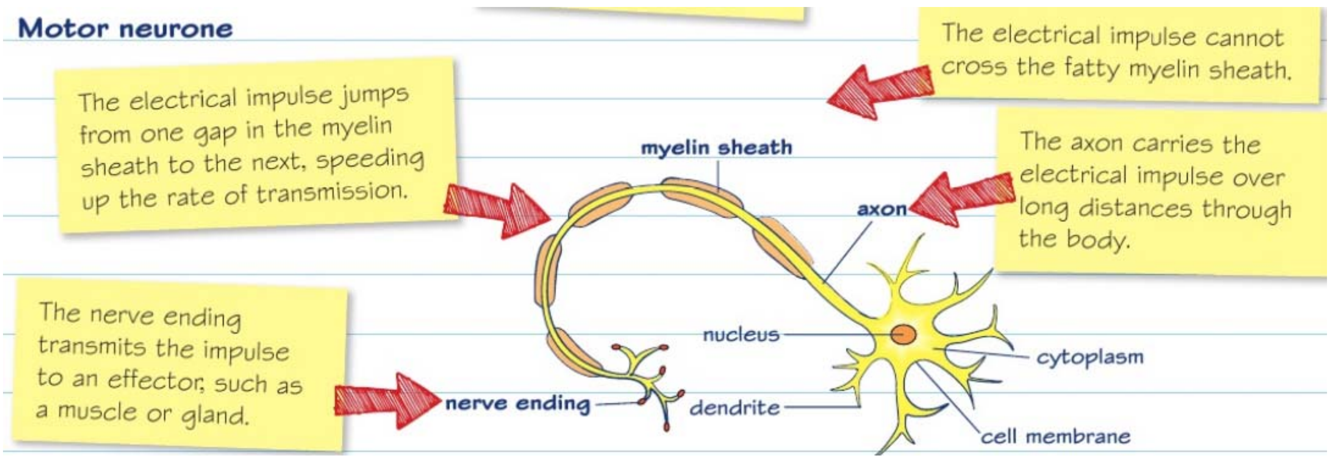
stimulus → receptor → coordinator → effector → response

There are **three main types** of neurones:

A. **Sensory neurones** – these carry impulses from the receptors to the central nervous system (CNS).
B. **Relay neurones** – these connect the sensory neurones to the motor neurones in the CNS.
C. **Motor neurones** – these carry impulses from the CNS to an effector.

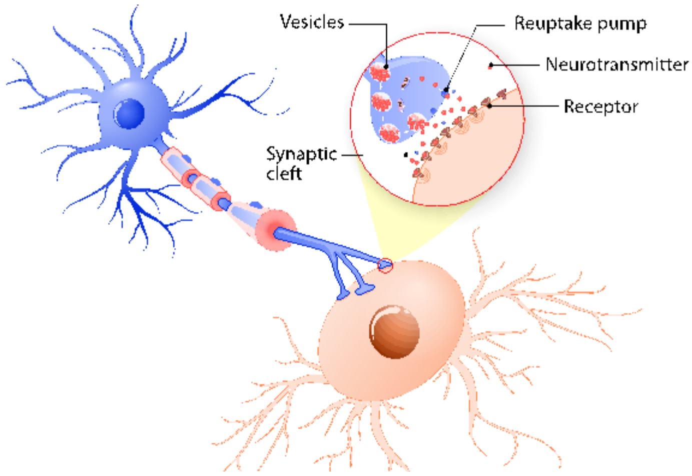






Neurones are not joined together. They have small gap between them. **The gap is called a synapse**

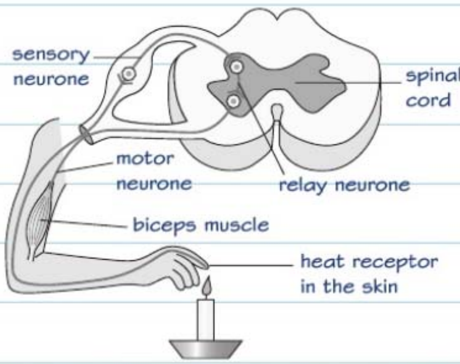
- When an impulse reaches the end of a neurone a chemical (**neurotransmitter**) is released across the gap.
- The chemical then **diffuses** across the synapse.
- When the chemical reaches the next neurone in sufficient quantities this starts **another impulse**.



Structure	Function
Receptor	Specialised cells which detect stimuli and turn them into electrical impulses
Axon	Carries electrical impulses **away** from the cell body
Dendron	Carries electrical impulses from receptor **towards** cell body
Dendrite	Branched ends which receive electrical impulses
Myelin sheath	Layer of fatty insulating material around motor and sensory neurones which speeds up transmission of the impulse
Synapse	Gap between neurones which ensures impulses travel in one direction
Neurotransmitter	Chemical involved in passing impulses from one nerve cell to another across a synapse
Effector	Organ, tissue or cell which produces a response

The reflex arc

Stimulus detected by receptor
↓
Impulses pass along sensory neurone to spinal cord
↓
Impulses pass to relay neurone
↓
Impulses pass from relay neurone to motor neurone
↓
Impulses pass along motor neurone to effector, in this case a muscle
↓
Hand moves away from stimulus



If the impulses had to go to the brain to be processed, there would be many more synapses, so the response would take longer.

Reflex arcs involve only three neurones, and impulses pass to and from the spinal cord. This provides a fast response that does not involve the brain. Reflex arcs are:

- immediate (happen very fast)
- involuntary (the brain isn't needed)
- innate (not learned)
- invariable (always exactly the same).

These reflexes help protect us from immediate harm, such as the eye blink reflex which protects the eye if something comes close to it.

Asexual reproduction: involves only one parent. There is no fusion of gametes. No mixing of genetic information occurs. All offspring are genetically identical (called clones). Only mitosis is involved.

Sexual reproduction involves the joining of male and female gametes. Offspring produced show variation.

Gamete: sex cell.

Diploid: means two sets of chromosomes (46)

Haploid: means one set of chromosomes (23)

The gametes are produced by **meiosis**

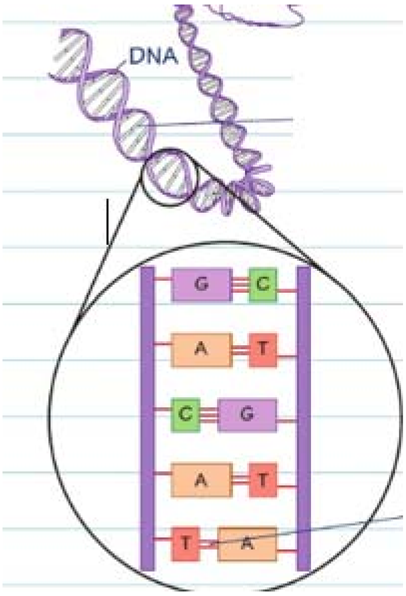
Meiosis leads to non-identical cells being formed.
Mitosis leads to identical cells (clones) being formed.

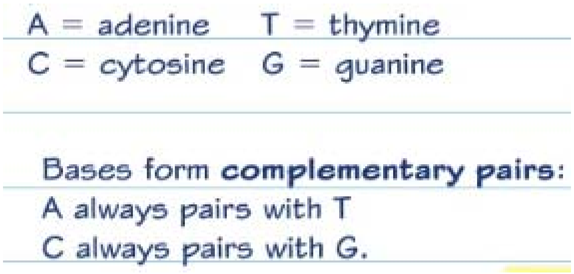
Cells in the **reproductive organs** divide by **meiosis** to form **gametes**.
In animals, the reproductive organs are the **ovaries** and **testes**.

The parent cell is a diploid cell. It has 2 sets of chromosomes. Each chromosome is copied in the cell before division occurs. Four daughter cells are produced with each one getting a copy of one chromosome from each pair making each daughter cell haploid. The daughter cells are NOT all identical.

- You do: Compare Mitosis and meiosis (4 marks)

The genetic material in the nucleus of most cells is made from a chemical called **DNA.**
DNA is a polymer made up of:
- 2 strands coiled to form a double helix
- Strands are linked by a series of complementary base pairs joined together by weak hydrogen bonds
- Nucleotides that consist of a sugar and phosphate group with one of the four different bases attached to the sugar.





DNA extraction from fruit

DNA can be extracted from fruit by:

1. grinding the fruit with sand, using a pestle and mortar, to separate the cells
2. adding a detergent to break open the membranes
3. adding ice-cold alcohol so that the DNA precipitates out.

Key Terms defined

Genome: is all the DNA in an organism.

Gene: is a section of a DNA molecule that codes for a specific protein.

Chromosome: the structures in which DNA is arranged in the nucleus

Allele: Different forms of genes

Dominant:

Recessive:

Homozygous: When the alleles are the same

Heterozygous: When the alleles are different

Genotype: Describes the alleles which are present for the specific characteristic eg Bb, BB, bb

Phenotype: Describes the physical characteristics of the alleles eg Brown, blue

Zygote: when gametes fuse at fertilisation they form a diploid zygote.

The gene for coat colour in rabbits has different alleles. The allele for brown colour (B) is dominant over the allele for black colour (b). The table shows all the possible genotypes and phenotypes for these alleles.

Genotype shows the alleles (forms of the genes) in the individual. Remember that each body cell has two alleles for each characteristic – either two alleles that are the same or two that are different.

Genotype	Phenotype
BB	brown coat
Bb	brown coat
bb	black coat

Phenotype means the characteristics that are produced, including what the individual looks like.

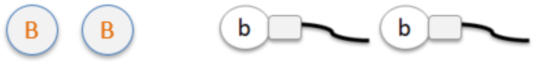
The effect of the **dominant** allele will show when at least one copy is present in the genotype.

The effect of the **recessive** allele will only show when two copies are present in the genotype.

Monohybrid inheritance can be explained using **genetic diagrams** and **Punnett squares.**

Punnett Square

Parent phenotype: Black fur White fur
Parent genotype: BB bb



Gametes	b	b
B		
B		

Explain what would occur :

a) If two homozygous dominant plants were crossed.

Gamete		

b) If two heterozygous plants were crossed

Gamete		

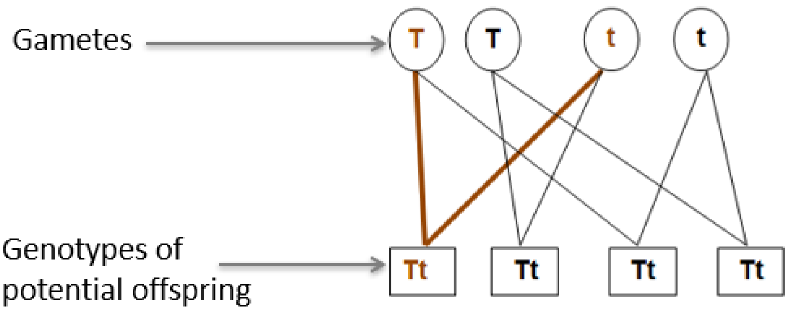
c) If a homozygous dominant plant and a homozygous recessive plant were crossed.

Gamete		

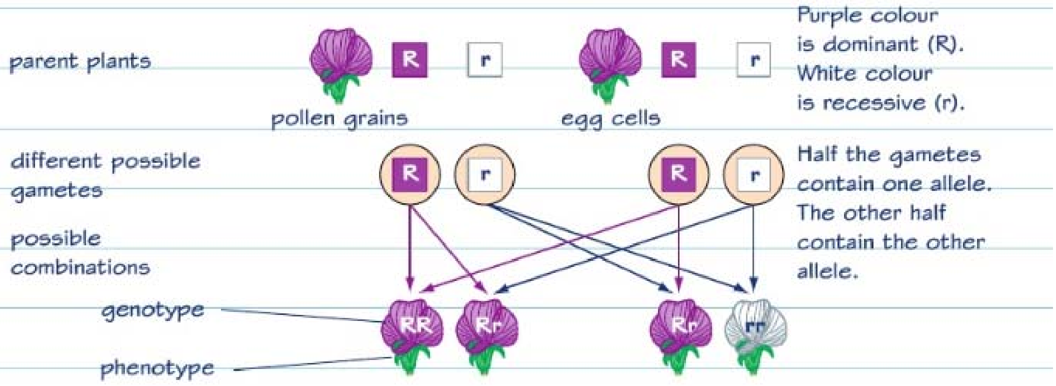
d) If two homozygous recessive plants were crossed.

Gamete		

Genetic Diagrams



Body cells contain two alleles for each gene. In this example, both parent plants are heterozygous – they have one allele for purple flower colour and one allele for white flower colour.

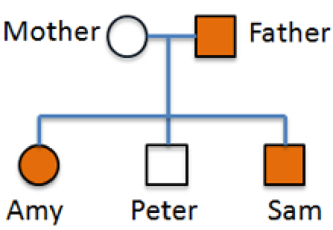


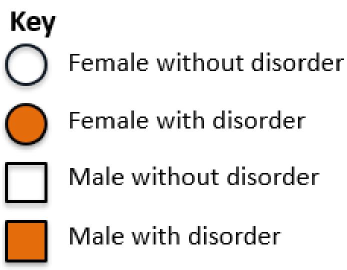
Family Pedigree

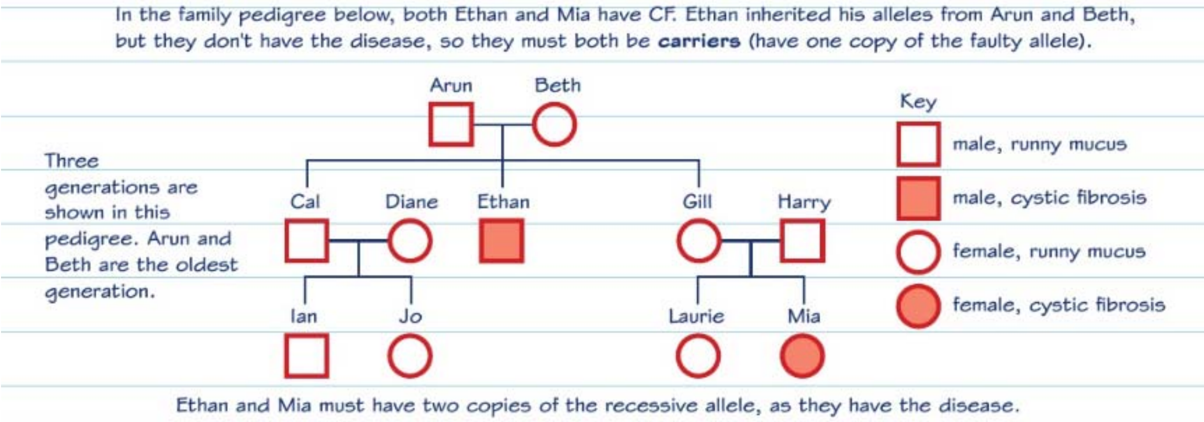
Cystic fibrosis (CF) is a genetic condition caused by a recessive allele. **Pedigree analysis** can be used to study the inheritance of dominant and recessive alleles.

A **family tree** can help to show how **genetic disorders** are inherited in a family. They can be used to work out the **probability** that a member of the family will **inherit** a disorder.
Read the **key** carefully to help you interpret a family tree accurately.

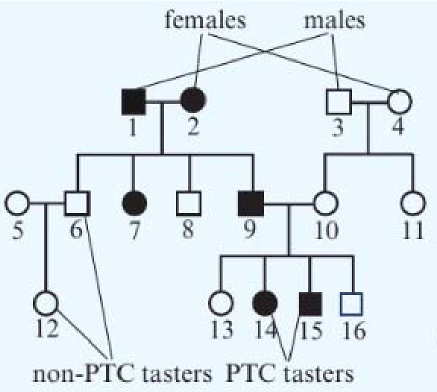
The family tree below shows the inheritance of a disorder caused by a **dominant** allele.







The ability to taste phenylthiocarbamide (PTC) is a dominant condition. The diagram shows the inheritance of PTC tasting in one family. Describe the evidence that PTC tasting is controlled by a dominant allele. **(2 marks)**



Look at the family pedigree in the worked example above.

(a) Give the genotype of individual 2. **(1 mark)**

(b) Individuals 9 and 10 have a fifth child. Calculate the probability that the child will be a PTC taster. **(2 marks)**

How is sex inherited?

The 23rd pair of chromosomes are responsible for determining the sex of a human.

The **Punnett square** is used to show the chances of an offspring being male or female.

A **woman** has the **genotype XX** and a **man** has the **genotype XY**.

Gametes	X	X
X	XX	XX
Y	XY	XY

There is a **1 in 2** chance of the offspring being male or female.

Variation means that individuals in a population show **differences** in characteristics. Population is the number of one species in a habitat. The **genome** and its **interaction** with **the environment** influence the development of a **phenotype** in an organism.

Variation within a **population** of a species is usually **extensive,** mostly arising from **mutations**.

Causes of variation may be:

- ❑ **differences** in the **genes** individuals have inherited due to **mutation** and **sexual reproduction.**
- ❑ **differences** in the **environmental** conditions have led to variation **(acquired characteristics).**
- ❑ or a **combination** of both genetic and environmental causes.

Identical twins are produced from the same egg and sperm. They show **very little** or no **genetic variation**. One twin has a scar and this is **environmental** variation (an **acquired characteristic)**

Factors which are **influenced** by **both genetic** and **environmental** variation are:
skin colour (can be tanned),
weight (can be affected by food availability) or being athletic.

Human phenotypes which are caused by **genetic variation** are:
Eye colour
Natural hair colour
Nose shape
Ear lobe shape
Blood group

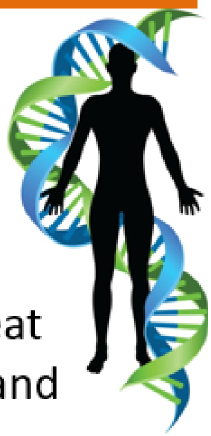
Human phenotypes influenced by the **environment** are:
Hair length
Accents
Tattoos
Scars
Language spoken

- **Most phenotypic features** are actually a result of **multiple genes** interacting, rather than single gene inheritance.
- We are able to describe a **phenotype** for these features **but cannot write down a genotype** because more than one gene is involved.

- Some characteristics in a species show **continuous variation**. There is a **range** of values and an individual can be anywhere in between the maximum and minimum. **Height** is an example.
- **Discontinuous variation** is when there is a limited number of values that an individual can possess. There is **no range**. **Blood group** and **gender** are examples of discontinuous variation.

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

The **Human Genome Project** (HGP) was an international scientific research project set up to **map all the genetic information** in a human being.



It began in 1990 and was completed in 2003. The whole **human genome has now been studied** and this will have great significance for **medicine** in the future. This work to understand the human genome is important for several reasons:

- To enable scientists to search for the **genes linked to different types of disease** to look for possible treatment or correction.
- To enable doctors to better **understand and treat inherited disorders** e.g. cystic fibrosis, sickle cell anaemia, thalassemia.
- To be able to trace historic **human migration patterns.**

All **genetic variations** arise from **mutations**.
A mutation is a change in the DNA sequence of an organism. **Mutations** are occurring **continuously** during cell division. **Most** genetic mutations **do not alter** the **phenotype.** Some mutations will have a small effect on the phenotype, and rarely a single mutation will significantly affect the phenotype. If a **new phenotype** is **suited** to an environmental change, it can **lead** to a relatively **rapid change** in the **species**. An example is seen below:

The peppered moth is camouflaged against tree bark. Birds cannot see it easily. The peppered moth lives long enough to breed and pass on its genetic information. This phenotype is found mainly in the countryside now.

During the industrial revolution, tree bark and buildings in cities and towns became blackened. The peppered moth became easy prey for the birds. A mutation occurred which changed the colour of the moth to black. The black phenotype is now found in large numbers in cities.

Darwin proposed the **theory of evolution by natural selection**.

His theory was based on **three observations**:

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

Antibiotic Resistance in Bacteria

1. Colony of bacteria
2. They are given an antibiotic
3. However due to mutation most of the bacteria are killed by the antibiotics but some of those bacteria are stronger. This group of bacteria are resistant.
4. The stronger group of bacteria left alive reproduce and these bacteria are not resistant to the antibiotic, so we cannot use the antibiotic to treat them.

Preventing Bacteria Resistance

1. Doctors should not prescribe antibiotics inappropriately eg giving antibiotics to treat a virus.
2. Patients to ensure that they complete their course of antibiotics in full to ensure all bacteria are killed off and none can mutate to form resistance
3. Restrict the use of antibiotics in farming

Developing new antibiotics

Scientists are always working on developing new antibiotics. However the issues around this are:

1. Takes time
2. Expensive
3. New resistant bacteria are emerging all the time.

Evidence for human evolution based on fossils

Species	Ardi (*Ardipithecus ramidus*)	Lucy (*Australopithecus afarensis*)	*Homo habilis* ('handy man')	*Homo erectus* ('upright man')	*Homo sapiens* ('wise'/modern man)
height	120 cm	107 cm	< 130 cm	179 cm	wide variety but generally taller than other species
when existed	4.4 million years ago	3.2 million years ago	2.4–1.4 million years ago	1.8–0.5 million years ago	since c. 200 000 years ago
brain size	350 cm^3	400 cm^3	500–600 cm^3	850–1100 cm^3	approx. 1200 cm^3
other details	tree climber, also walked upright	walked upright, face ape-like	flat face like modern humans, used simple stone tools	long-distance walker, strongly built	user of complex tools

Evidence for human evolution based on stone tools

D The stone tool in the upper photo is about 2 million years old. The lower one is about 13 000 years old.

Stone Tools

Stone tools also give us evidence of human evolution. The earliest stone tools are around 2.4 million years old. Over time more complex tools were made and a greater range of tool types.

The ages of the rock layers where the tool was found can be dated by measuring the amount of radiation in the layers.

Scientists used to classify living organisms into the following five big groups, called **kingdoms**. The kingdoms were Plants, Animals, Fungi, Protists and Prokaryotes. Scientists have now classified organisms into three **domains**.

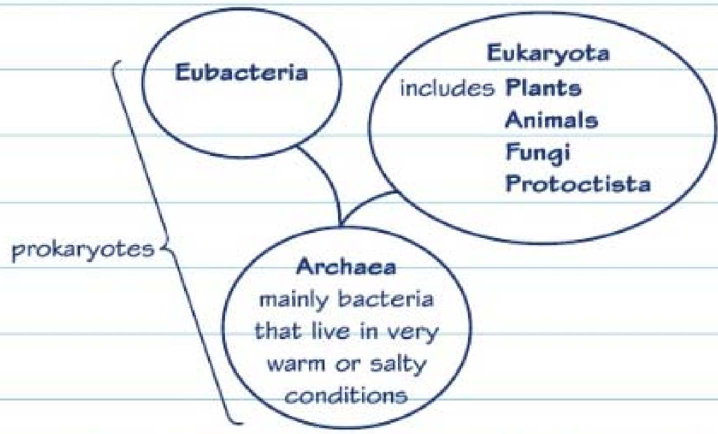
Five-kingdom system

Carl Linnaeus originally proposed the classification of organisms into just two kingdoms, but this was later developed into five kingdoms. These are:

1 Plants
2 Animals
3 Fungi
4 Protists
5 Prokaryotes.

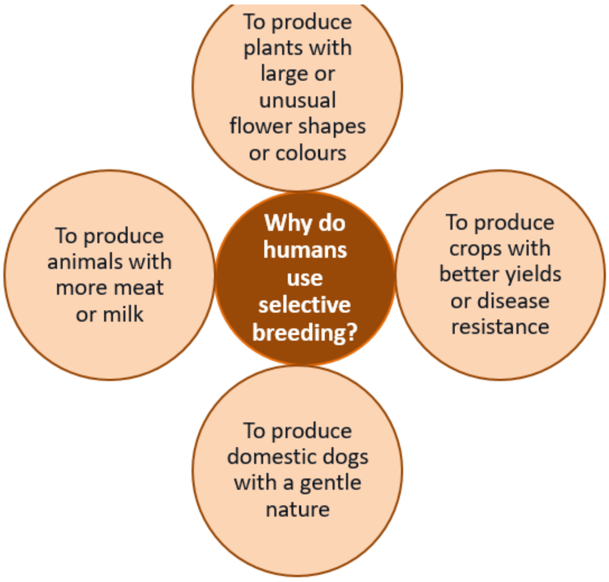
Three-domain system

Genetic research shows that the organisms which were grouped as prokaryotes in the kingdom system should be separated into two groups, which have been named **Eubacteria** and **Archaea**. This is because the genes of organisms in Archaea work more like those in the eukaryotes, while the genes of organisms in Eubacteria work a little differently.



This grouping forms the **three-domain** system of classification.

Selective breeding is also called artificial selection. Selective breeding is where humans breed plants and animals for particular chosen genetic characteristics which are either useful or for appearance.



Selective breeding reduces variation and can lead to "inbreeding".
The population will have the same strengths but also the same weaknesses.
Infectious diseases are more likely to spread through a genetically similar population because of this vulnerability.
Some breeds are particularly prone to disease or inherited defects as a result of inbreeding.

The standards set for a pedigree Pug are :

- Large dark eyes
- Ears must be small and thin
- Muzzle must be short and square.
- Head is large with no indentations.
- Wrinkles must be large and deep.

In order to maintain this standard breeders often mate closely related dogs with good characteristics together. A pedigree pug can be a result of 5-6 generations of inbreeding. Puppies which do not meet the standard may be illegally killed.

Many pugs will go on to develop painful crippling conditions:

- Chronic joint problems
- Severe breathing issues due to a deformed nose and short trachea
- Chronic eye problems due to the wrinkles around the eye folding in and scratching the cornea.
- Skin irritation due to bacteria infections in the deep wrinkles.

Genetic engineering is a process which involves modifying the genome of an organism by introducing a gene from another organism to give a desired characteristic.

Plant crops have been genetically engineered to be resistant to diseases, or be resistant to insect attack, resistant to herbicides or to produce bigger better fruits. These are known as genetically modified or GM crops. GM crops usually show an increased yield.

A herbicide is a chemical which kills plants (also called a weed-killer). If a crop plant is resistant to herbicide, the farmer can spray herbicide to kill all other plants in the field without affecting the crop.

Plants resistant to insect attack have been modified to produce their own pesticide.

Insulin is a naturally occurring hormone produced in the pancreas. In diabetes, a fault in the pancreas means insulin is not made effectively.
Diabetics can inject themselves with insulin. The insulin for injections used to be collected from a pig's pancreas. Some diabetics had severe allergic reactions to pig insulin because it was not the same as human insulin.
Genetic engineering is now used to produce 'human insulin' from genetically modified bacteria. It is cheaper, safer and more ethically acceptable than using specially bred pigs which have to be killed.

Genetic engineering is a new technology that can be **very useful** but there are also **ethical issues** to consider.

Some benefits of genetic modification

Bigger crop yields or drought resistant/pest resistant crops may mean more food can be produced. This might solve the world food shortage.

Human insulin protein can be **mass produced** by **genetically engineered bacteria** meaning pigs do not have to be slaughtered and costs are reduced.

Allergic reactions are reduced. Human genes that produce **other useful proteins** have been transferred to sheep and cows. These proteins have then been extracted from their milk.

Medical research is exploring the possibility of **genetic modification** to **overcome** conditions such as **arthritis, cystic fibrosis, cancer and MS.**

Some concerns regarding genetic modification

We **do not know the effect** of growing **GM crops** on nearby **populations** of **wild flowers** and **insects**.

GM crops which **produce their own pesticide** may **kill insects** which are needed to **pollinate** other plants.

Some people feel that the **effects** of **eating GM** crops on **human health** have not been fully explored.

Should humans be inserting genes from one organism into a totally different organism?

video

The World Health Organisation (WHO) definition:

Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.

Disease can be:
- **Communicable** – these are **infectious** diseases caused by viruses, bacteria, protists and fungi and are **spread** in animals (and plants) e.g. malaria, measles, athletes foot
- **Non-communicable** – these diseases are not caused by **infection** and cannot be **spread** e.g. heart disease, diabetes, Alzheimer's, asthma

Different **types of disease** may **interact** (work together) to make a person more **susceptible** to other diseases.
- **Defects in the immune system** mean that an individual is more likely to suffer from infectious diseases
- **Viruses** living in cells can be the trigger for cancers to form
- **Immune reactions** initially caused by a pathogen can trigger allergies such as skin rashes and asthma
- **Severe physical ill health** can lead to depression and other mental illness

Pathogens are **micro-organisms** that cause **infectious disease.**

Pathogens can be **bacteria, viruses, fungi** or **protists.**

Examples of Viral Disease

HIV (human immunodeficiency virus)
- HIV is a sexually transmitted infection (STI)
- Initially causes a flu-like illness and spread by sexual contact or exchange of body fluids such as blood when drug users share needles.
- Unless HIV is successfully controlled with antiretroviral drugs, the virus will destroy white blood cells leading to the onset of AIDS.
- Late stage HIV or AIDS occurs when the body's immune system can no longer deal with other infections or cancers.

Examples of Bacterial Diseases

Cholera
- Cholera is a disease which is spread via contaminated drinking water.
- Cholera causes diarrhoea and can kill if left untreated.
- Cholera is often a consequence of a humanitarian crisis.
- Clean drinking water and good sanitation reduces the spread of cholera.

Tuberculosis
- Tuberculosis (TB) bacteria are spread through the air in tiny droplets when an infected person sneezes or coughs.
- It can cause lung damage.
- A vaccination programme is in place to reduce the spread.

Example of a Fungal Disease

Chalara ash dieback

- Chalara causes **leaf loss** and **lesions** in the bark. Trees usually die from the infection or become weakened to attacks by other pests or pathogens.
- There is **no cure** known for this disease.
- Chalara ash dieback is spread through **airborne** transmission of **fungal spores**.
- Infected **leaves fall** to the ground during autumn and spores are carried on the **wind** and deposited on healthy ash trees.

Example of a Protist Disease

Malaria

- The malaria causing protist is spread by mosquitoes feeding on infected blood and then biting a human.
- Mosquitoes are animal vectors as they pass on malaria but do not suffer themselves.
- Malaria causes damage to blood and the liver. It can be fatal.
- Control the spread by preventing mosquitoes breeding and use mosquito nets to avoid being bitten.

Disease	Symptom	Method of transmission	Control spread of disease by:	Caused by:
Malaria	Recurrent fever	Animal vector	Preventing breeding of mosquitoes or use of a net to prevent being bitten.	Protist
Chalara ash dieback	Leaf loss and bark lesions	Airborne	Remove infected leaf litter. Clean all tools, vehicles and footwear.	Fungus
Cholera	Diarrhoea	Waterborne	Clean drinking water and good hygiene and sanitation.	Bacteria
Tuberculosis	Lung damage	Airborne	Vaccination programme. Treat infection with antibiotics.	Bacteria
HIV	Flu like illness	Sexual contact or bodily fluids. Direct contact.	Use of condoms / clean needles. Treat infection with antiretroviral drugs.	Virus

Sexually transmitted infections (STI) are passed from one person to another through **unprotected sex** or **genital contact**.

HIV is an STI which is spread via infected **bodily fluids**. Spread can be reduced by wearing a **condom**, not sharing needles if a drug user and use of medication to prevent an infected person passing on the STI to another e.g. a mother to her unborn child.

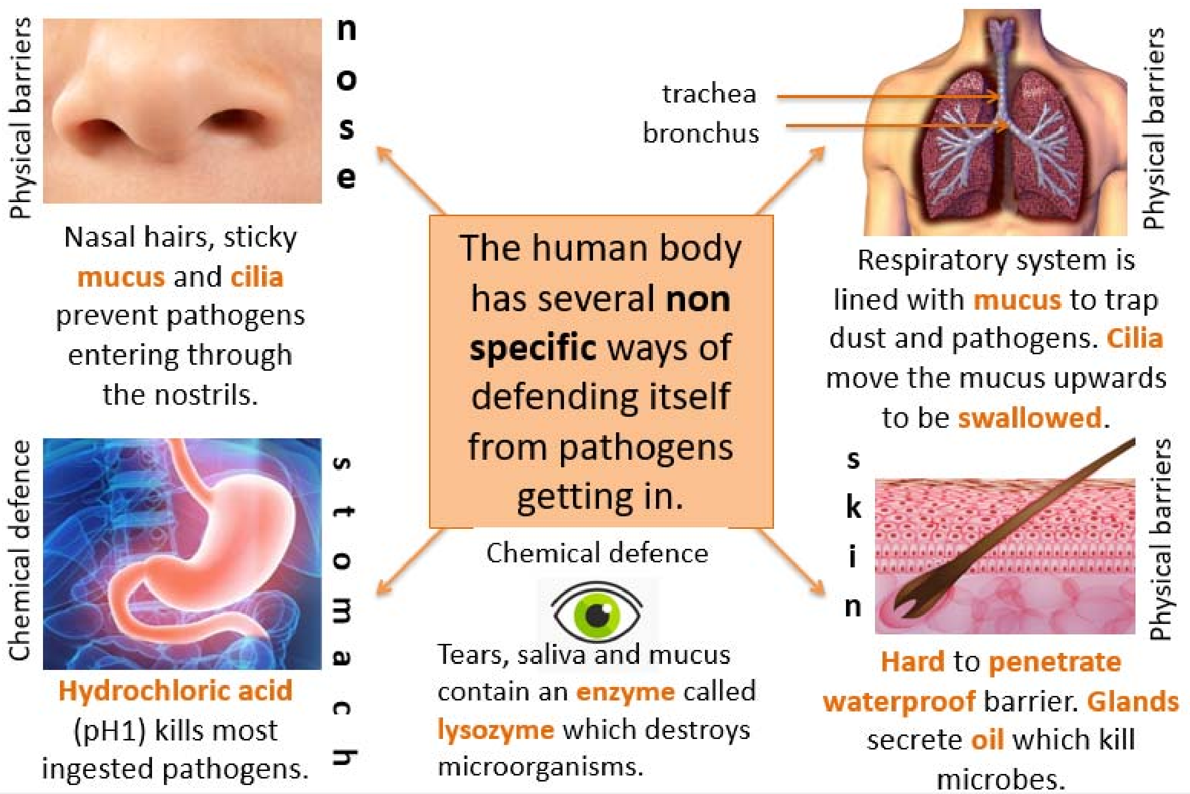
Chlamydia is the most common STI in the UK. It is a **bacterial** infection. The bacteria are spread through infected **bodily fluids**. To **reduce** the chance of catching Chlamydia, people should use **barrier methods of contraception** such as a condom.

Most people have no symptoms and so do not know they are infected. In **women**, Chlamydia can cause **pain** or a **burning sensation** when **urinating**, vaginal **discharge**, **pain** in the lower abdomen and **heavy periods**.

In **men**, Chlamydia can cause pain or a **burning sensation** when **urinating**, a **discharge** from the tip of the penis and **pain** in the **testicles**.

Chlamydia can be **detected** using a **urine test** or a **swab** of the affected area. It can be **treated with antibiotics**. Chlamydia can be passed by an infected pregnant woman to her unborn baby.

If left **untreated**, Chlamydia can cause **long term health problems** and infertility.



The **specific immune system** defends the human body against disease by:

Detection

- The body is **exposed** to the pathogen which enters the body. **Antigens** (foreign proteins on the surface of the pathogen) are **detected** by the immune system.

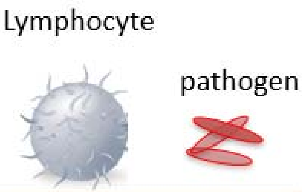
Activation

- The antigens **trigger** an **immune response** which causes the **lymphocytes** to produce **<u>specific</u> antibodies** which destroy the pathogens.

Memory

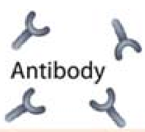
- The antigen triggers the production of **memory lymphocytes**. If the body is **re-infected** with the **same pathogen** the memory lymphocytes respond by producing **antibodies** much more **rapidly**. This is called the **secondary response** to the antigen.

Communicable diseases can be dangerous leading to epidemics or pandemics. **Vaccination** can be used to **enhance** the immune system and reduce the chances of this happening. A vaccine contains a small amount of **dead or inactive** form of the pathogen that can be introduced into the body and cause an immune response.



White blood cells detect inactive pathogens from the vaccine. → Antibodies are released into the blood. → Pathogens are destroyed by antibodies.

If the body becomes **re-infected** with the same pathogen then the white blood cells are prepared.
The white blood cells can respond much more **quickly** and make **more** of the right type of **antibodies** much more quickly.



White blood cells detect pathogens. → Antibodies are made and released into the blood much faster and in larger amounts. → Pathogens are destroyed by the antibodies much faster.

This means that the person is **unlikely to suffer** the symptoms of the harmful disease.
Infection has been prevented by **enhancing** the immune system.

Advantages of vaccinations:

- The chances of falling ill or dying from a disease might be far greater than the chance of experiencing a side effect.
- Vaccination is cheaper than treating a seriously ill person.
- When fewer people are vaccinated the number of cases of the disease increases.
- If enough people in a community are vaccinated against a pathogen it makes it difficult for the disease to spread because there are so few susceptible people left to infect.
- This is called herd immunity. It is crucial for protecting people who cannot be vaccinated such as very young children, people with immune system problems and those who are too ill such as cancer patients.

Immunisation means that a person has become resistant to a pathogen. Immunisation can be a result of natural exposure to a pathogen or artificial by being given a vaccination containing the pathogen. These both require the body to react by producing antibodies and so are called active immunity. Passive immunity can also occur when a baby receives antibodies in the mothers milk or when an injection contains antibodies.

Disadvantages of vaccinations:

- There are risks that come with vaccinations. Some people have side effects.
- People do not like having vaccinations.

An antibiotic is a drug that helps to cure a bacterial disease by only inhibiting cell processes in the infective bacteria inside the body, without affecting the host organism.

Different bacterial infections need a different antibiotic.

Antibiotics cannot be used to treat viral pathogens.

Penicillin is a well known antibiotic medicine.

Using antibiotics has greatly reduced deaths.

It is difficult to develop drugs to kill viruses without harming body tissues because viruses live and reproduce inside cells.

A doctor will not prescribe antibiotics for a viral infection as they do not work.

Antibiotics can only be used for bacterial infections

Painkillers, steroids or anti-inflammatory medicines can be used to relieve the symptoms of viral infections.

Symptoms may include: fever, muscle ache, headache or a runny nose.

Development of new drugs

The initial chemical used to make a drug may have been **discovered** from a plant. Most new drugs are **developed** and **synthesised (made)** in a laboratory by chemists in the pharmaceutical industry.

Preclinical tests must be carried out before humans are allowed to take the drug.

These preclinical tests are done on **cells**, **tissue** samples and live **animals**.

New drugs must be tested and trialled to check:

- ✓ **Efficacy** - that the drugs work
- ✓ **Toxicity** - that the drug is not poisonous
- ✓ **Dose** - the most suitable **amount** to take

If successful the new drug will proceed to **clinical testing**.
The stages of a clinical trial are:

- Stage 1
  - Healthy volunteers try small doses of the drug to check it is **safe** and has **no side effects**
- Stage 2
  - A small number of **patients** try the drug at a **low dose** to see if it works
- Stage 3
  - A larger number of patients take the new drug and different doses are trialled to find the **optimum dose**
- Stage 4
  - **A double blind trial** will occur to see how effective the new drug is. The patients are divided into groups

Non-communicable diseases (NCDs) can have a significant human and financial cost for individuals, local communities, nationally and globally.

There are **lifestyle factors** that can also affect health and increase the risk of getting a non communicable disease, these can be:

- **aspects of a persons lifestyle**
  - e.g. lack of exercise, stress levels, exposure to too much sunlight, exposure to ionising radiation (e.g. X-rays, gamma rays)
- **substances (chemicals) taken**:
  - **into a persons body** – e.g. high fat/sugar diet, cigarette smoke, alcohol
  - **in their environment** - e.g. air/water pollution, asbestos, ionising radiation

These are called **RISK FACTORS**

HAZARD → **RISK FACTOR** → **HARM**

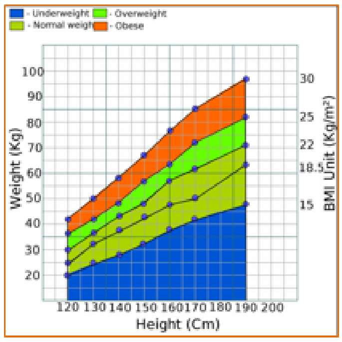
HAZARD	RISK FACTOR	HARM
The potential source of harm e.g. smoking, lack of exercise	The combination of the chances of the hazard causing harm and the severity of that harm	The damage to health or a disease that can occur

MANY DISEASES ARE CAUSED BY THE INTERACTION OF A NUMBER OF RISK FACTORS

Excess weight (obesity) can make a person at **risk of cardiovascular disease**, a stroke and Type 2 diabetes. If there are no underlying health concerns then obesity is best tackled through a combination of a **healthy balanced diet** and **exercise**.

A tool called the **Body Mass Indicator** (BMI) can be used to calculate whether a persons weight lies within a healthy range.

$$BMI = \frac{\text{mass (kg)}}{(\text{height (m)})^2}$$



Being **underweight** (malnourished) can also be **of concern**. This can indicate a person is not getting sufficient food of a good nutritional quality or indicate medical problems such as an overactive thyroid gland.
A person who is suffering from **malnutrition** may have a **weakened immune system** and be at risk of developing **fragile bones**, **fertility** problems and a lack of **energy.**

The use of **BMI** has **limitations** because it simply shows if a person is carrying too much weight. It does not calculate if this is excess fat, muscle or bone.
Very muscular adults and athletes may be classed as overweight or obese even though their body fat is low.
The **waist to hip ratio** should be considered alongside the BMI figure.

Male (waist : hip ratio)	Female (waist : hip ratio)	Health risk based on Waist : hip ratio
0. 95 or below	0.80 or below	Low risk
0.96 to 1.0	0.81 to 0.85	Moderate risk
1.1 or more	0.86 or more	High risk

Many non communicable diseases are caused by the interaction of a number of factors.

CARDIOVASCULAR disease can be affected by a number of lifestyle risk factors:

- **Diet** – a diet high in saturated fats can increase the levels of LDL (low density lipoproteins – cholesterol plus a protein that can cause atherosclerosis).

- **Smoking** – tobacco smoke **damages** the lining of the arteries leading to atherosclerosis, **carbon monoxide** in tobacco smoke reduces the amount of oxygen in the blood so the heart has to pump harder, the **nicotine** in tobacco smoke causes the heart to beat faster and raises blood pressure.

- **Lack of exercise** – exercising regularly lowers blood pressure and stress.

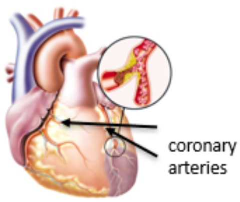
OBESITY is a lifestyle risk factor for Type 2 diabetes:

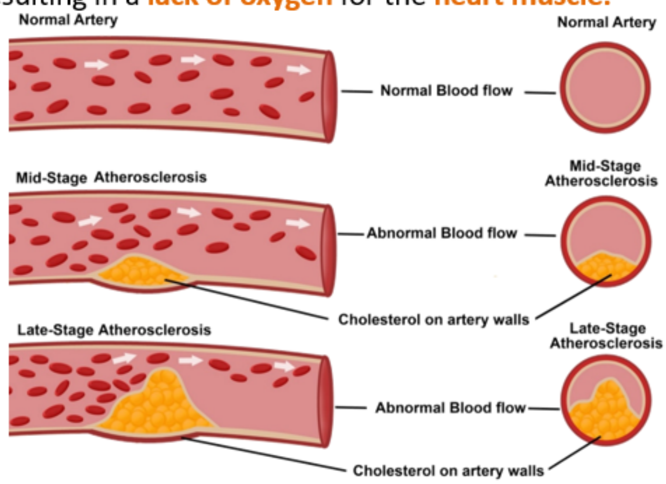
- **Type 2 diabetes** – is where the cells in the body are less sensitive or resistant to insulin so the body cannot control the concentration of glucose in the blood correctly.
- **Obesity** increases the risk of developing Type 2 diabetes, the more fat you have around your abdomen

Alcohol is a lifestyle risk factor for Liver disease and Brain damage:

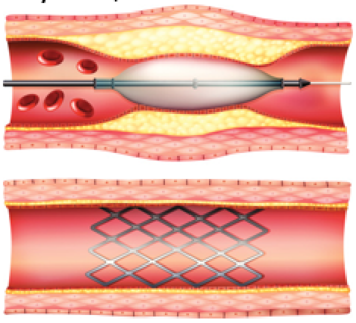
- **Liver disease** – the liver breaks down toxins in alcohol. If you have too much alcohol, the first stage of liver disease is when the liver becomes fatty. Eventually **cirrhosis** of the liver develops if you continue to drink too much alcohol.
- **Brain function damage** – alcohol affects the way the nerve cells in the brain work and the cells then become damaged. The brain mass may also shrink.

Cardiovascular disease (CVD) is a general term for disease which involve the **heart** or **blood vessels. Atherosclerosis** is a cause of **coronary heart disease** where **layers** of **fatty material** build up inside the coronary arteries, **narrowing** them. This **reduces** the flow of blood through the coronary arteries, resulting in a **lack of oxygen** for the **heart muscle.**





Atherosclerosis can be **treated** in two main ways by placing a **stent** in the coronary artery and/or using **lifelong medication** called **statins**. Lifestyle changes such as a healthy diet, exercise and no smoking are also vital in reducing the risk of CVD.



Stents are metal cylinder grids which can be **inserted** into an artery to maintain blood flow by **keeping the artery open** so that the heart continues to receive **enough oxygen** to function effectively.

Statins are drugs that lower harmful **cholesterol** in the blood and stop the **liver** producing too much cholesterol and reduce the rate at which it is deposited. Patients should change their **lifestyle** and have a healthy **diet**. This **reduces** the risk of heart disease.

Heart disease can lead to **heart failure**. Patients with heart failure can be given **heart** or **heart and lung transplants**. Donor hearts come from a **person who has died.** These only have a **few hours** to get to the person needing the heart. Often hearts and lungs are transplanted together. In this country you have to give **consent** for your organs to be donated.

Conditions that may require a heart transplant include:

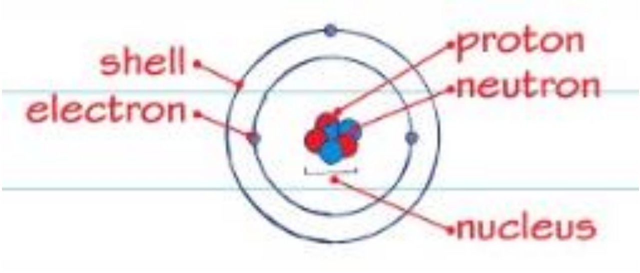
- **Atherosclerosis** (coronary heart disease) – a build-up of fatty substances in the arteries supplying the heart
- **Cardiomyopathy** – where the walls of the heart have become stretched, thickened or stiff
- **Congenital heart disease** – birth defects that affect the normal workings of the heart

Artificial hearts are occasionally used to keep patients alive whilst waiting for a heart transplant, or to allow the heart to rest as an aid to recovery. Artificial hearts can only be used as a **short term** measure.

Atomic Structure

C3/C4

Structure of an atom



Relative Charges and Relative Mass

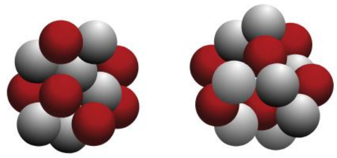
- Most of the mass of an atom is found within the nucleus.
- The overall charge of an atom is neutral due to the atom having the same number of positively charged protons and negatively charged electrons.

Particle	Relative charge	Relative mass
Proton	+1	1
Neutron	0	1
Electron	-1	1/1836

Mass Number: protons + neutrons
(Does not have to be an integer)
Atomic Number: the number of protons
(also equal to the number of electrons and unique to the element)

5 B 10.811	6 C 12.01115	7 N 14.0067	8 O 15.9994	9 F 18.9984
13 Al 26.9815	14 Si 28.086	15 P 30.9738	16 S 32.064	17 Cl 35.453

Isotope: A different atom of the same element. The atomic number is the same but the mass number is different due to the change in the number of neutrons.



C^{12}_{6} C^{14}_{6}

Using atomic number and mass number

- Complete the table:

Element	Symbol	Mass number	Atomic number	No. of protons	No. of neutrons	No. of electrons
Lithium	Li	7	3	3	7 - 3 = 4	3
Sodium						
	Pb					
	Ti					
					0	
				72		
						15

Mendeleev arranged the elements, known at that time, in a periodic table by using properties of these elements and their compounds.

Mendeleev used his table to predict the existence and properties of some elements not yet discovered.

Mendeleev thought that he had arranged elements in order of increasing mass number but this was not always true because of the abundance of isotopes of some pairs in the periodic table.

If the elements are arranged in terms of increasing atomic number then Mendeleev's **pair reversals** are explained.

Iodine should be placed before Tellurium according to its mass number, but after Tellurium using the atomic number. Mendeleev did not know about atomic structure.

Relative atomic mass	128	127
Element symbol	Te	I
Atomic number	52	53

In the periodic table elements are arranged in order of increasing atomic number, in **rows called periods**. Elements with similar properties are placed in the same vertical **columns called groups**.

Metals can be found on the **left hand side** and in the centre. **Non-metals** are on the **right hand side**.

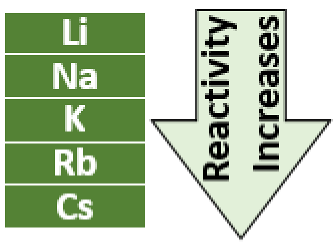
Electrons fill their shells 2.8.8.2 You must be able to draw and write the electronic configurations of the fist 20 elements in the periodic table.

Groups in the periodic table

Paper 4

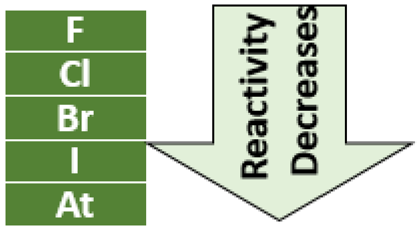
Group 1 – Alkali Metals

- Soft metals
- Low melting points
- Lithium, sodium and potassium all react **vigorously** with water.
  When you add them to water, the metal **floats**, **moves** around and **fizzes**.
  e.g. **potassium + water → potassium hydroxide + hydrogen**
  $2K(s) + 2H_2O(l) \rightarrow 2KOH(aq) + H_2(g)$
- Stored in oil to keep air and water away.
- Li, Na and K are less dense than water so they float on water.
- The reactivity of the alkali metals increases down the group. This is because the outer electrons become further from the nucleus each time and the force of attraction between the positive nucleus and negative electron become weaker. This allows for the outer electron to be lost more easily as we go down the group.



Group 7 – The Halogens

- Melting point increase down the group
- Boiling point increases down the group
- The intermolecular forces, going down the group become stronger.
- **Chlorine** is a **yellow/green gas**
- **Bromine** is a **red/ brown liquid**
- **Iodine** a **grey solid**.
- As elements, the halogens exist as **diatomic** molecules **F_2, Cl_2, Br_2, I_2 and At_2**



- **Reactivity:** When Group 7 elements react, the atoms **gain** an electron in their outermost shell. Going down the group, the outermost shell's electrons get **further away** from the attractive force of the nucleus, so it is **harder** to **attract** and **gain** an extra electron.

- The halogens react with **hydrogen** to form **hydrogen halides**. The reactions with hydrogen become **less** reactive as you go **down** the group.
  E.g. **fluorine + hydrogen → hydrogen fluoride**
  $F_2(g)$ + $H_2(g)$ → $2HF(g)$

- The halogens also react with **metals**. The halogen atoms **gain** a single electron to give them a stable arrangement of electrons. They form **ionic compound**.
  E.g. **sodium + chlorine → sodium chloride**
  $2Na(s)$ + $Cl_2(g)$ → $2NaCl(s)$

- **Test for Chlorine:** The test for chlorine uses **litmus paper**. When **damp** litmus paper is put into chlorine gas, the litmus paper is bleached and turns **white**.

Group 0 – Noble Gases

- They are **unreactive/inert** because their atoms have stable arrangements of electrons.
- The atoms have **eight** electrons in their **outermost shell**, apart from helium which has just two but still has a complete outer shell.
- The **stable electronic structure** explains why they exist as single atoms; they have **no tendency to react** to form molecules.
- The **boiling points** of the noble gases **get higher going down the group**.

Uses:

- Helium: lifting gas in party balloons and air ships. Less dense than air and inflammable.
- Argon, Krypton, Xenon: filling gas in filament lamps. The filament becomes hot enough to glow, the gas prevents it burning away.
- Argon: Shielding gas during welding. Argon is denser than air so keeps air from the metal and prevents oxidisation of the metal.

Ions

Papers 3 & 4

Ion: is an atom or group of atoms with a positive or negative charge

Cation: a positively charged ion. Usually formed from Groups 1 & 2

Anion: a negatively charged ion. Usually formed from Groups 7 & 6

Draw 3 ions from each of the above groups

Ionic Bonding

Papers 3 & 4

Ionic Bonding is the total **swapping of electrons**

Formation and naming of Ionic Bonds**:**

Formula	Name	
H^+	hydrogen	
Li^+	lithium	
Na^+	sodium	group 1
K^+	potassium	
Mg^{2+}	magnesium	
Ca^{2+}	calcium	group 2
Ba^{2+}	barium	
Al^{3+}	aluminium	group 3
Ag^+	silver	
Cu^{2+}	copper	
Zn^{2+}	zinc	transition metals
Fe^{2+}	iron(II)	
Fe^{3+}	iron(III)	
NH_4^+	ammonium	compound ion

Positively charged ions formed from hydrogen or metal atoms take the name of the element.

Negatively charged ions formed from a single non metal atom take the name of the element, but end in **-ide**

Negatively charged ions in compounds containing three or more elements, one of which is oxygen, end in **-ate**

Formula	Name	
F^-	fluoride	
Cl^-	chloride	group 7
Br^-	bromide	
I^-	iodide	
O^{2-}	oxide	group 6
S^{2-}	sulfide	
NO_3^-	nitrate	
CO_3^{2-}	carbonate	compound ions
SO_4^{2-}	sulfate	
OH^-	hydroxide	

OH^- does not follow the -ate rule.

Properties of Ionic Compounds

- Bonds are strong due to strong electrostatic forces
- Bonds form a lattice structure which has a regular arrangement of ions
- Ionic compounds usually have high melting points and high boiling points
- Solid at room temperature
- No delocalised (free) electrons, therefore don't conduct electricity in solid state
- Soluble in water
- Once dissolved in aqueous solution electrons are free to move so they conduct electricity

Covalent Bonding: is formed when a pair of electrons are shared between 2 atoms

Covalent bonds are:
- Strong
- Form between non-metal atoms
- Often produce molecules, which can be elements or compounds

Draw a dot cross diagram of the following covalent substances:
Hydrogen, hydrogen chloride, water, methane, oxygen, carbon dioxide

Simple Molecular Substances
- A simple molecule consists of a few atoms joined by strong covalent bonds
- Have low melting points
- Have low boiling points
- Usually a gas or liquid at room temperature
- Do not conduct electricity in any state, because they are not electrically charged and do not contain any delocalised electrons.
- They don't conduct in a solution of water as they are insoluble in water
- Can conduct when dissolved in an acid.

Giant Molecular Substance
- Contain many atoms rather than a few
- Strong covalent bonds
- Regular lattice structure
- High melting point
- High boiling point
- Solid at room temperature

Examples: Diamond and Graphite (similarity and differences)

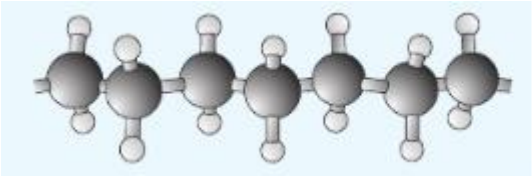
Diamond	Graphite
Carbon bond Where each atom is bonded to four others	Carbon bond Where each atom is bonded to three others
Covalently bonded	Covalently bonded
Lattice structure	Layer structure
Strong intermolecular forces	Weak intermolecular forces between the layers
No delocalised electrons	Delocalised electrons
Cannot conduct electricity	Can conduct electricity
Used in jewellery and cutting tools. Drill bits are diamond tipped	Used in pencils and as a lubricant in industrial engines as the layers can slide over one another. Also used for electrodes as it can conduct electricity due to delocalised electrons

Examples: Graphene and Fullerenes

Graphene	Fullerene
Single layer of graphite	Sheet of graphene rolled to form a buckyball
Carbon atom bonded to three others	C_{60} Buckminsterfullerene has carbon atoms arranged in pentagons and hexagons
Regular lattice structure	Hollow sphere
Conducts electricity due to delocalised electrons	Conducts electricity due to delocalised electrons
Strong and flexible	Soft when solid due to weak intermolecular forces

A **polymer** is a large molecule made from many smaller molecules, called monomers, joined together.

The diagram shows a section of polyethene a simple polymer. It consists of large molecules containing chains of carbon atoms. The atoms are joined to each other, and to hydrogen atoms, by covalent bonds.



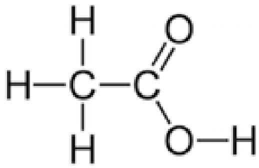
Metals

Property	Metals	Non-metals
Appearance	Shiny	dull
Electrical conduction	Good conductors (delocalised electrons)	Bad conductors
Density	High density	Low density
Melting Point	High melting point (strong electrostatic forces)	Low melting point
Boiling Point	High boiling point (strong electrostatic forces)	Low boiling point
Malleable	Malleable (can be pressed into shape without shattering)	brittle
Solubility in water	Insoluble in water (however, some are soluble in water group 1)	Soluble in water

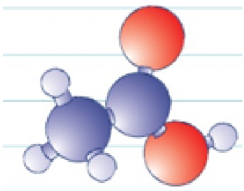
Limitations of models

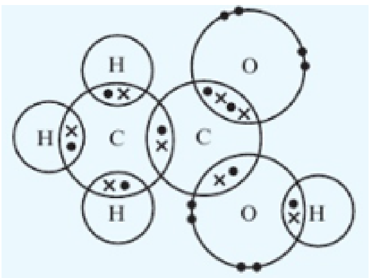
The structure and bonding of different substances are represented using models.

Drawn structures do not show: the 3D shape or the bonding and non-bonding electrons



Ball and Stick models: show how each atom is bonded to the other atoms and its 3D shape. They do not show the bonding and non-bonding electrons or the elements chemical symbol





Dot and Cross Diagram: shows the symbol for each atom in the molecule. It shows how each atom is bonded to other atoms. The pairs of electrons in the covalent bond are shown by the dots and crosses. Non-bonding pairs of electrons in the outer shells are included.

It does not show the 3D shape of the molecule.

Calculations involving Masses

Papers 3 & 4

Hydrogen (H_2)
Water (H_2O)
Potassium Carbonate (K_2CO_3)
Calcium Hydroxide ($Ca(OH)_2$)
Ammonium Sulfate ($(NH_4)_2SO_4$)

The symbol for **relative formula mass is** $\boldsymbol{M_r}$
To get M_r add together the relative atomic masses of all atoms.
Work out the M_r of the following compounds

An **empirical formula** is the simplest whole number ratio of atoms of each element in a compound.
Example: A 10g sample of compound X contains 8g of carbon an 2g of hydrogen.
Calculate the **empirical formula** of compound x

Steps
A 10g sample of compound X contains 8g of carbon an 2g of hydrogen.
Step 1: Write the symbol of each element
Step 2: Write down the mass of each in g
Step 3: Write the atomic mass number of each
Step 4: for each work out the mass divided by atomic mass
Step 5: Divide each answer by the smallest answer
Step 6: Make all numbers whole (integers)

You do: What is the empirical formula of a compound that contains 7.83g of iron and 3.37g of oxygen?

Find the **percentage mass** of Sulphur in Sulfuric Acid (H_2S0_4)

Formula = $\frac{Atomic\ Mass\ x\ no\ of\ element}{M_r} x\ 100$

$\boldsymbol{M_r}$ of Sulphur =
How many Sulphurs =
$\boldsymbol{M_r}$ of Sulfuric Acid =

Example: The empirical formula of Compound G is CH_3
The relative mass (M_r) of compound G is 30
Find the **molecular formula** of compound G

Step 1: Calculate the M_r of the empirical formula
Step 2: Divide M_r of G by empirical M_r
Step 3: Multiply answer by each amount in the empirical formula

<u>Conservation of mass</u>
The total mass of the reactants and products must stay constant during a chemical reaction.
The total mass before a reaction equals the total mass after a reaction.
Closed System: is when no substance can enter of leave the during the reaction.
Non-closed system: is when substances can leave or enter a reaction.

A **solution** is a mixture of a solute in a solvent.
The **solute** is the substance that dissolves.
The **solvent** Is the substances that the solute dissolves in.

The **concentration of a solution** is measured in g/dm^3 or g dm^{-3}

Note: To change cm^3 to dm^3 divide it by 1000

Formula concentration of a solution (g/dm^3) = $\frac{\text{mass of solute (g)}}{volume\ of\ solution\ (dm^3)}$

Example: 2.50g of sodium hydroxide is dissolved in 250cm^3 of water. Calculate the concentration of the solution formed in g dm^{-3}

You do:

1 Calculate the concentrations of the following solutions formed:

(a) 0.40 g of glucose dissolved in 0.50 dm^3 of water.

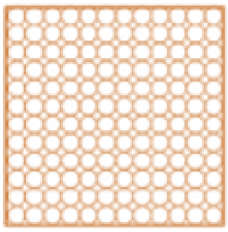
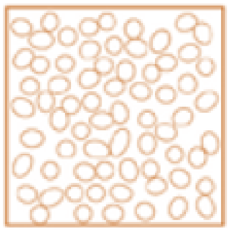
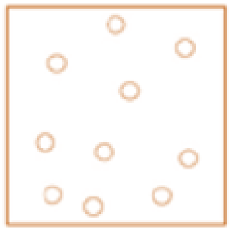
(b) 1.25 g of copper chloride dissolved in 100 cm^3 of water.

2 Calculate the mass of sodium hydroxide needed to make 150 cm^3 of a 40 g dm^{-3} solution.

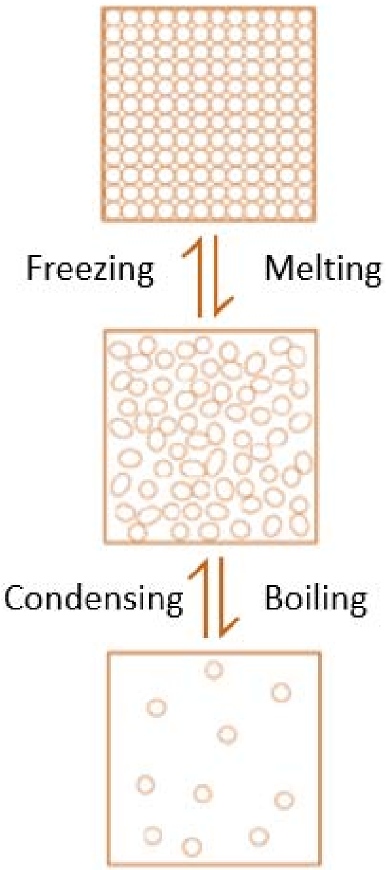
States of Matter and Mixtures

Paper 1

There are **three** states of matter – **solid, liquid** and **gas**. To explain the properties of the states, the **particle theory** is used.
It is based on the fact that all matter is made up of tiny particles and describes the **movement** and **distance** between particles.

Solid	Liquid	Gas
Close together Regular pattern Vibrate on the spot.	Close together Random arrangement Move around each other	Far apart Random arrangement Move quickly
		

In chemical equations, the three states are shown as (s), (l), (g) and (aq) for aqueous solutions.



Melting and **freezing** take place at the **melting point**.
Boiling and **condensing** take place at the **boiling point**.

The **amount of energy** required to change the state depends on the **strength of the forces** between the particles of the substance.

The **stronger the forces** between the particles the **higher the melting and boiling point** of the substance.

The type of bonding and the structure of the substance depend on the particles involved.

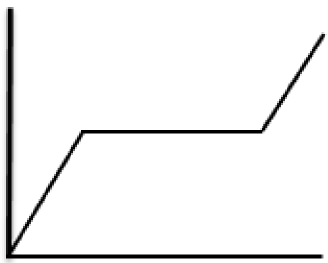
These are PHYSICAL changes and can easily be reversed, unlike CHEMICAL changes.

A **physical change** is one where **no new chemical substance** is formed and it is **easily reversed**.

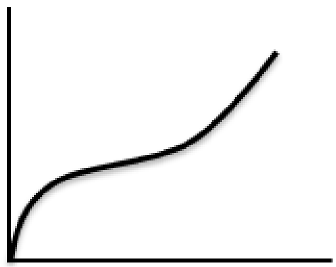
A **chemical change** results in the formation of a **new chemical substance** and is **not easily reversed**.

In chemistry, a **pure substance** is a **single element or compound not mixed** with any other substance.

Pure substances have **specific** melting and boiling temperatures.
These can be used to distinguish pure substances from mixtures.



Melting point of a pure substance



Melting point of an impure substance

In science we would not refer to a substance such as milk as being pure as it is a mixture of a number of different substances.

A mixture consists of **two or more** elements or compounds **not** chemically combined together.
The chemical properties of each substance in the mixture are **unchanged**.

Solvent	the liquid in which a solute dissolves
Solute	the substance that dissolves in a liquid to form a solution
Solution	is the mixture formed when a solute has dissolved in a solvent
Soluble	describes a substance that will dissolve
Insoluble	describes a substance that will not dissolve

FILTRATION: This technique separates substances that are insoluble in a solvent from those that are soluble

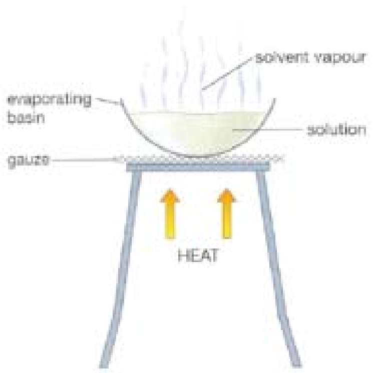
Mixtures can be separated by **physical processes** including:

1. Filtration
2. Crystallisation
3. Simple distillation
4. Fractional distillation
5. Chromatography

These physical processes do not involve chemical reactions and no new substances are made.

Crystallisation

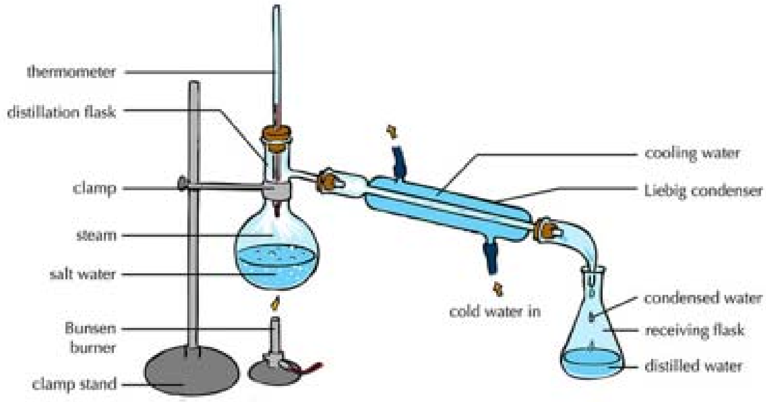
This technique separates a soluble substance from a solvent by evaporation



Example - crystallisation of sodium chloride from salt solution

Simple distillation

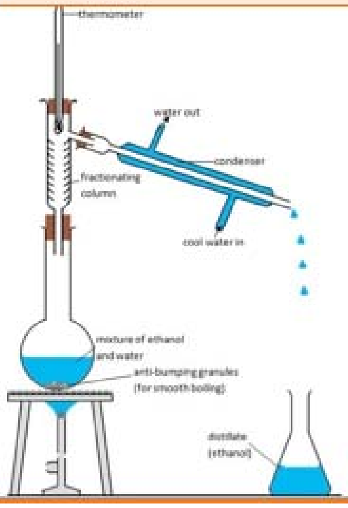
This technique separates a liquid from a mixture by evaporation, followed by condensation



Example - obtaining water from sea water

Fractional distillation

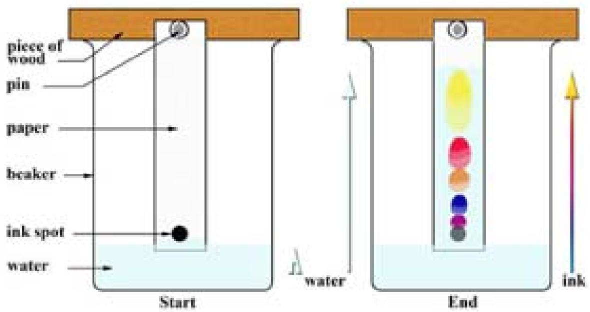
This technique separates a mixture into a number of different parts, called **fractions**. Substances with **high** boiling points **condense at the bottom** and substances with **low** boiling points **condense at the top**.
Fractional distillation works because the different substances in the mixture have different boiling points.



Example - obtaining ethanol from a mixture of ethanol and water

Chromatography

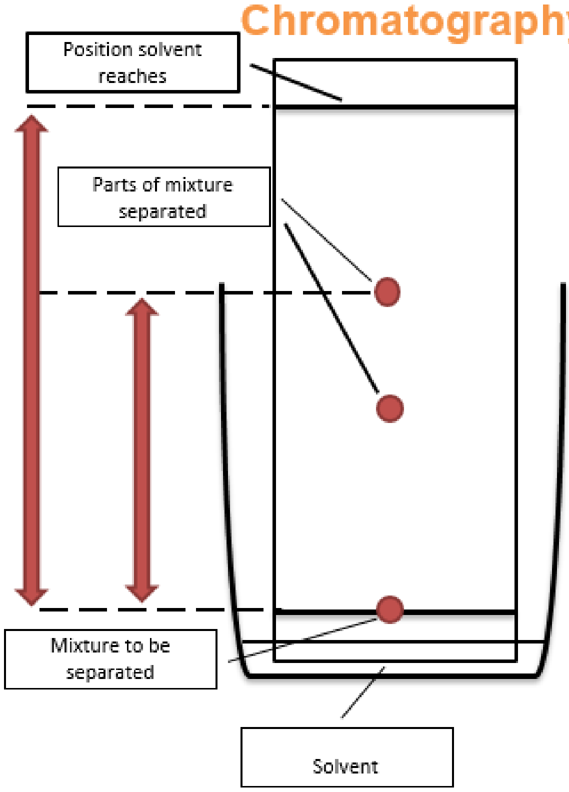
This technique separates mixtures of soluble substances.



Example - separating the different colours in ink

Chromatography

Chromatography can be used to separate **mixtures of soluble substances** by running a solvent (**mobile phase**) through the mixture on the paper (**stationary phase**) causing the substances to **move at different rates**.



The ratio of the distance moved by a compound (centre of spot from origin) can be expressed as its R_f value:

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

When calculating the R_f value, remember the **solvent will always travel further than the substance** so the **R_f value can never be greater than 1**.

Different compounds have different R_f values in different solvents, which can be used to help identify the compounds. A pure compound will produce a single spot in all solvents.

Water used in chemical analysis **must not** contain any **dissolved salts**.

Water that is **safe to drink is called potable water**.
Potable water is **not pure water** in the chemical sense because it **contains dissolved substances**.

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**.

Most potable water is produced by;

- choosing an appropriate source of fresh water
- sedimentation
- passing the water through filter beds
- chlorination.

Urban lifestyles and industrial processes produce large amounts of waste water that require treatment before being released into the environment.

Sewage and agricultural waste water require removal of

- organic matter
- harmful microbes.

Industrial waste water may require removal

- organic matter
- harmful chemicals.

Sewage treatment includes

- filtration and grit removal
- sedimentation to produce sewage sludge and effluent
- chlorination to kill bacteria.

If supplies of fresh water are limited, **desalination** of salty water or sea water may be required. Desalination can be done by **distillation.**

Desalination by distillation in Hamburg Germany

Desalination requires **large amounts of energy**

Extracting metals and equilibria

Paper 3

Metals can be arranged in order of reactivity in a **reactivity series**.

Order of reactivity	Reaction with water	Reaction with acid
Potassium	Fizz, giving off hydrogen gas and leaving an alkaline solution of metal hydroxide	Reacts violently and explodes
Sodium		
Lithium		
Calcium		Fizz, giving off hydrogen gas and forming a salt
Magnesium	Very slow reaction	
Aluminium		
Zinc		
Iron		
Tin	No reaction with water at room temperature	React slowly with warm acid
Lead		
Copper	No reaction	No reaction
Silver		
Gold		

Metals can be arranged in order of reactivity in a **reactivity series**.

When metals react with other substances the metal atoms form **positive ions** called **CATIONS**.

The reactivity of a metal is linked to its tendency to form cations.

The **non-metals hydrogen** and **carbon** are often included in the series as they can be used to extract less reactive metals.

metal + acid → salt + hydrogen

Potassium
Sodium
Lithium
Calcium
Magnesium
CARBON
Zinc
Iron
Lead
HYDROGEN
Copper
Silver
Gold

OILRIG

Oxidation **I**s **L**oss of electrons
Reduction **I**s **G**ain of electrons

When reactions involve **oxidation and reduction**, they are known as **redox reactions**

Metal Oxides, oxidation and reduction

A **metal compound** within a **rock** is an **ore.** Ores are **mined** and then **purified.**
Unreactive metals are found in the Earth's crust as **uncombined elements**.

Whether it is worth extracting a particular metal depends on:

- **How easy it is to extract it from its ore**
- **How much metal the ore contains**
- **The changing demands for a particular metal**

Most **metals** in ores are **chemically bonded** to **other elements** in compounds. Many of these metals have been **oxidised** (have oxygen added) by oxygen in the air to form their oxides.

$$\text{Iron} + \text{oxygen} \rightarrow \text{iron (III) oxide}$$
$$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$$

To extract metals from their oxides, the metal oxides must be **reduced** (have oxygen removed).

The **reactivity** of a metal determines the **method** of **extraction.**
A metal's **relative resistance to oxidation** is related to its position in the reactivity series.

Metals **above** carbon must be extracted from their ores using **electrolysis.**

Metals **below** carbon can be extracted from their ores by **reduction** using **carbon.**
REDUCTION involves the loss of oxygen.

metal oxide + carbon → metal + carbon dioxide

Gold and **silver** do not need to be extracted.
They occur **native** (naturally).

Potassium
Sodium
Calcium
Magnesium
Aluminium
CARBON
Zinc
Iron
Lead
HYDROGEN
Copper
Silver
Gold
Platinum

Increasing reactivity

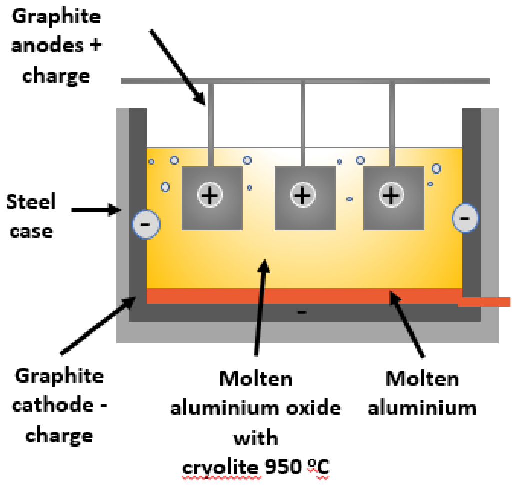
Metals can be extracted from **molten compounds** using electrolysis.

It is used if the metal is too reactive to be extracted by reduction with carbon or if the metal reacts with carbon.

Large amounts of **energy** are used in the extraction process to melt the compounds and to produce the electrical current.

Aluminum is manufactured by electrolysis of molten aluminum oxide.

aluminium oxide → aluminium + oxygen



Aluminium oxide has a very **high melting point** so is mixed with molten **cryolite** to lower the temperature required to carry out the electrolysis.

Aluminium goes to the negative electrode and sinks to bottom.

Higher: $Al^{3+} + 3e^- \rightarrow Al$

Oxygen forms at positive electrodes.

Higher: $2O^{2-} \rightarrow O_2 + 4e^-$

The oxygen reacts with the carbon electrode making carbon dioxide and causing damage. The electrode needs **replacing** due to this reaction.

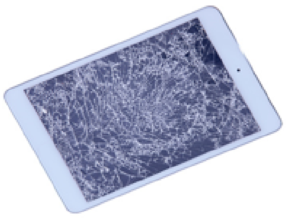
$C + O_2 \rightarrow CO_2$

Life cycle assessments (LCA's) are carried out to assess the **environmental impact of products** in each of these stages.

Obtaining the raw materials

Manufacturing and packaging

Uses and operation during it's lifetime



Disposal at the end of it's useful life, including transport and distribution at each stage

Use of **water**, **resources**, **energy sources** and production of some **wastes** can be fairly easily quantified. Allocating numerical values to pollutant effects is less straightforward and requires value judgements, so life cycle assessment is not a purely objective process.

Selective or abbreviated life cycle assessments can be devised to evaluate a product but these can be **misused** to reach **pre-determined conclusions**, e.g. in support of claims for advertising purposes.

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

Advantages of recycling metals:

- Cheaper than extracting from their ores
- Preserves the environment by reducing the environmental impact of mining
- Avoids the need for mining as metal ores are a finite resource.

Reversible reactions and dynamic equilibrium

In some chemical reactions, the products of the reaction can react to produce the original reactants. Such reactions are called reversible reactions and are represented by:

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

This is different to the usual → or = sign, which signify that all the reactants change to products in the reaction. In reversible reactions, there are always some reactants and some products.

The direction of reversible reactions can be changed by changing the reaction conditions.

When a reversible reaction occurs in apparatus which prevents the escape of reactants and products (a closed system), dynamic equilibrium is reached as the rate of the forward and reverse reactions occur at exactly the same rate.

The production of ammonia is a reversible reaction that can reach a dynamic equilibrium:

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

The reactants for the reaction come from the following:

- Nitrogen is extracted from the air
- Hydrogen is obtained from natural gas

The conditions for the Haber process are:

- A temperature of 450°C
- A pressure of 200 atmospheres
- An iron catalyst

Acids

- Acids in solution are sources of **hydrogen ions**.
- Acidic solutions have **lower** pH values **than** neutral **pH 7**.

Bases

- A **base** is any substance that reacts with an acid to form a **salt and water only**.
- **Alkalis** are **soluble bases.**
- Alkalis in solution are sources of **hydroxide ions.**
- Alkaline solutions have **higher pH** values **than** neutral **7**.

H^+ OH^-

Indicators are substances which change **colour** when you add them to acids and alkali.

Litmus goes red in acid and blue in alkali.

Methyl orange is red in acidic conditions, yellow in neutral and alkaline conditions.

Phenolphthalein is colourless in acidic and neutral conditions and pink in alkaline conditions.

Universal indicator, made from many dyes, is used to tell you **pH.** The scale runs from 0 (most acidic) to 14 (most alkaline). Aqueous solutions of **acids** have a pH value **less than 7**, and for **alkalis greater than 7** and anything in the middle is **neutral** (pH 7). You can use a pH meter to record the change of a pH over time.

pH	Examples of solutions
0	Battery acid, strong hydrofluoric acid
1	Hydrochloric acid secreted by stomach lining
2	Lemon juice, gastric acid, vinegar
3	Grapefruit juice, orange juice, soda
4	Tomato juice, acid rain
5	Soft drinking water, black coffee
6	Urine, saliva
7	"Pure" water
8	Sea water
9	Baking soda
10	Great Salt Lake, milk of magnesia
11	Ammonia solution
12	Soapy water
13	Bleach, oven cleaner
14	Liquid drain cleaner

Acids react with some **metals** to produce **salts** and **hydrogen.**

Metal + acid → salt + hydrogen

Reactions between metals and acids only occur if the metal is **more reactive** than the **hydrogen** in the acid. If the metal is too reactive, the reaction with acid is **violent**.

The **salt** that is made depends on the **metal** and **acid** used.

Salts made when metals react with *nitric acid* are called *nitrates*.

Zinc + Nitric acid → Zinc Nitrate + Hydrogen

Salts made when metals react with *sulfuric acids* are called *sulfates*.

Iron + Sulfuric Acid → Iron Sulfate + Hydrogen

Salts made when metals react with *hydrochloric* acid are called *chlorides*.

Magnesium + Hydrochloric acid → Magnesium Chloride + Hydrogen

Acids are neutralised by **alkalis** (**e.g.: soluble metal hydroxides**) and **bases** (**e.g.: insoluble metal hydroxides and metal oxides**) to produce **salts** and **water** and by **metal carbonates** to produce **salts**, **water** and **carbon dioxide**.

H^+ and OH^- ions combine to form H_2O

The salt **name** depends on the **acid** used and the **positive ions** in the **alkali, base or carbonate**.

Making Soluble Salts from acids and alkalis

Salts can be made by reacting an acid with an alkali.

Acid + Alkali → Salt + Water

Making Soluble Salts from acids and bases

Salts can be made by reacting an acid with a insoluble base.

Acid + Bases → Salt + Water

Making Soluble Salts from acids and metal carbonates

Salts can be made by reacting an acid with a metal carbonate.

Acid + Metal carbonate → Salt + Water + Carbon dioxide

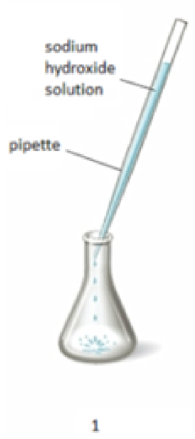
Test For Hydrogen

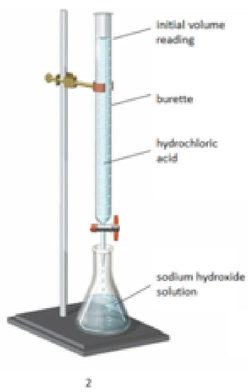
The test for hydrogen uses a **burning splint** held at the open end of a test tube of the gas. Hydrogen burns rapidly with a **pop sound**.

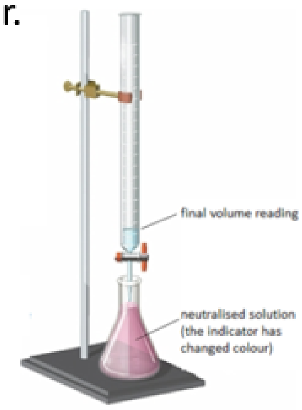
Test For Carbon Dioxide

The test for carbon dioxide uses an aqueous solution of calcium hydroxide (**lime water**). When carbon dioxide is shaken or bubbled through limewater the limewater turns **milky** (**cloudy**).

The **volumes** of acid and alkali solutions that react with each other can be measured by **titration,** using a suitable indictor.







1. Use the pipette to add 25 cm^3 of alkali to a conical flask and add a few drops of indicator.
2. Fill the burette with acid and note the starting volume. Slowly add the acid from the burette to the alkali in the conical flask, swirling to mix.
3. Stop adding the acid when the end-point is reached (the appropriate colour change in the indicator happens). Note the final volume reading. Repeat steps 1 to 3 until you get consistent readings.

You must learn these rules and be able to predict whether a precipitate will be formed, and be able to name it.

- All common **sodium, potassium** and **ammonium salts** are **soluble**
- All **nitrates** are **soluble**
- Common **chlorides** are **soluble** **except** **silver chloride** and **lead chloride**
- Common **sulfates** are **soluble** **except** those of **lead**, **barium** and **calcium**
- Common **carbonates** and **hydroxides** are **insoluble** **except** those of **sodium, potassium** and **ammonium.**

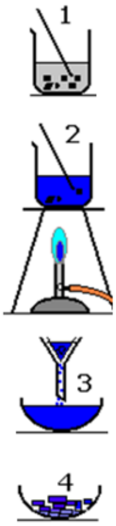
Soluble

- All nitrates
- Common sodium, potassium and ammonium salts INCLUDING CARBONATES
- Most chlorides and sulfates

Insoluble

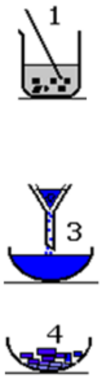
- Silver chloride and lead chloride
- Lead sulfate, barium sulfate and calcium sulfate
- Most carbonates

Soluble salts can be made from **acids** by reacting them with **solid insoluble substances**, such as **metals, metal oxides, hydroxides or carbonates**.



1. Measure the required volume of acid with a measuring cylinder and add the weighed solid (insoluble metal, oxide, hydroxide or carbonate) in small portions with stirring.
2. Safety goggles required - the mixture may be heated to speed up the reaction. When no more of the solid dissolves, it means ALL the acid is neutralised and there should be a little excess solid.
3. Filter the solution to remove the excess solid metal/oxide/carbonate into an evaporating dish. On filtration, only a solution of the salt is left.
4. Then hot concentrated solution is left to cool and crystallise.
5. After **crystallisation**, you collect and dry the crystals with a filter paper. If the solution is heated, the solvent will evaporate faster. Heating a solution until all the solvent has evaporated is known as **heating to dryness**.

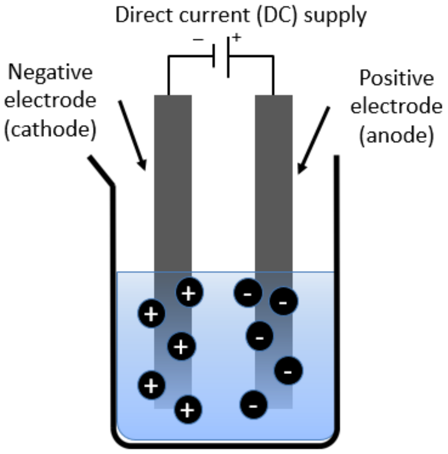
Insoluble salts can be made from two soluble salts.



1. Mix together solutions of soluble salts.
2. Insoluble salt will form a precipitate in the solution.
3. Filter off the precipitate and wash several times with pure water.
4. Dry precipitate in an oven.

Electrolysis - PART 1

When an **ionic compound** is **melted** or **dissolved in water**, the **ions** are **free** to **move** about the liquid or solution. These liquids and solutions are able to **conduct electricity** and are called **electrolytes**. Passing an **electric current** though electrolytes causes the ions to move to the electrodes.



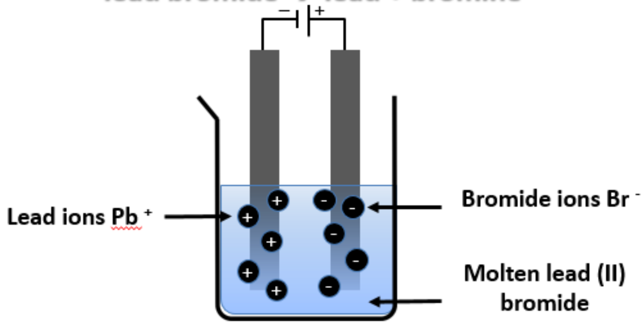
Cations (positive ions) go to **negative** electrode (cathode).

Anions (negative ions go) to the **positive** electrode (anode).

Ions are **discharged** at the electrodes producing **elements**. This is called **electrolysis**.

When an **ionic compound** is electrolysed in a **molten** state using inert electrodes, the **metal** is produced at the **cathode** and the **non metal** is produced at the **anode**.

lead bromide → lead + bromine



The positively charged lead ions Pb + (cations) are attracted to the cathode and the negatively charged bromide ions Br - are attracted to the anode.

The **ions** discharged when an **aqueous solution** is electrolysed using inert electrodes depend on the relative **reactivity** of the elements involved.

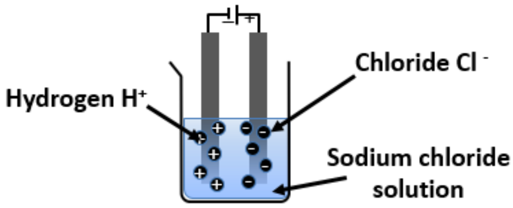
At the **negative** electrode:

Metal will be produced on the electrode if it is **less** reactive than **hydrogen**.
Hydrogen will be produced if the metal is **more** reactive than hydrogen.

At the **positive** electrode:

Oxygen is formed at positive electrode. If you have a **halide** ion (Cl^-, I^-, Br^-) then you will get **chlorine, bromine or iodine** formed at that electrode.
This happens because in the aqueous solution, **water molecules** break down producing **hydrogen** ions and **hydroxide** ions that are discharged.

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



sodium chloride → hydrogen + chlorine + sodium hydroxide

Uses of the products:
Chlorine: Bleach and PVC
Hydrogen: Margarine **Sodium hydroxide**: Bleach and soap

Copper chloride	Sodium sulfate	Acidified (H_2SO_4) water
Forms Cu and Cl_2	Forms H_2 and O_2	Forms H_2 and O_2

Scalar quantity: has magnitude(size) only. Examples: mass, speed, distance, energy and temperature.

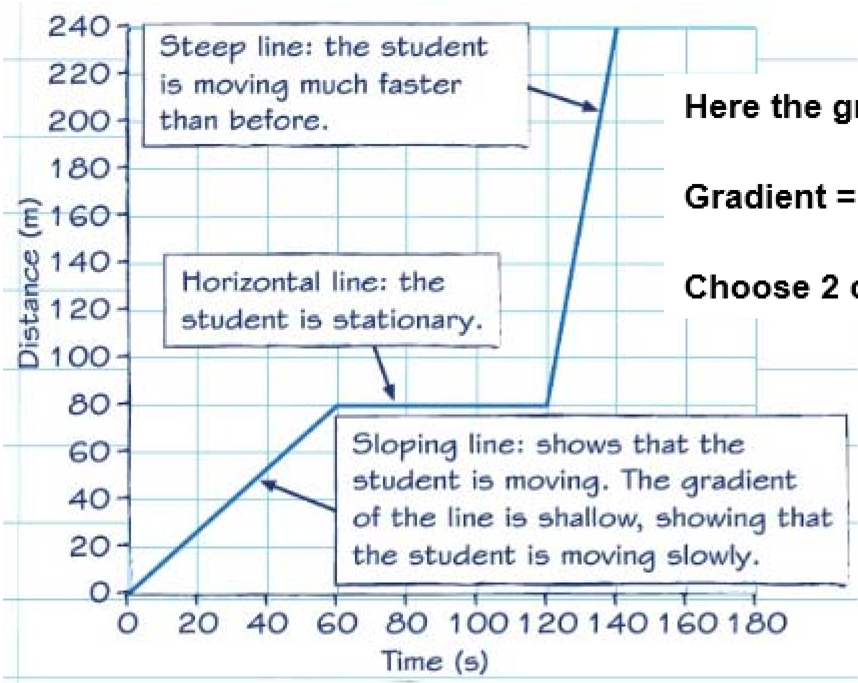
Vector quantity: has magnitude and direction. Examples: force, weight, velocity, displacement, acceleration and momentum.

Velocity is speed in a given direction. Unit: m/s or ms^{-1}

$$Speed = \frac{distance}{time}$$

$$Velocity = \frac{displacement}{time}$$

Speed Time Graphs



Here the gradient is the speed

Gradient = $\frac{Y_2 - Y_1}{X_2 - X_1}$

Choose 2 coordinates on the line (X_1, Y_1) **and** (X_2, Y_2)

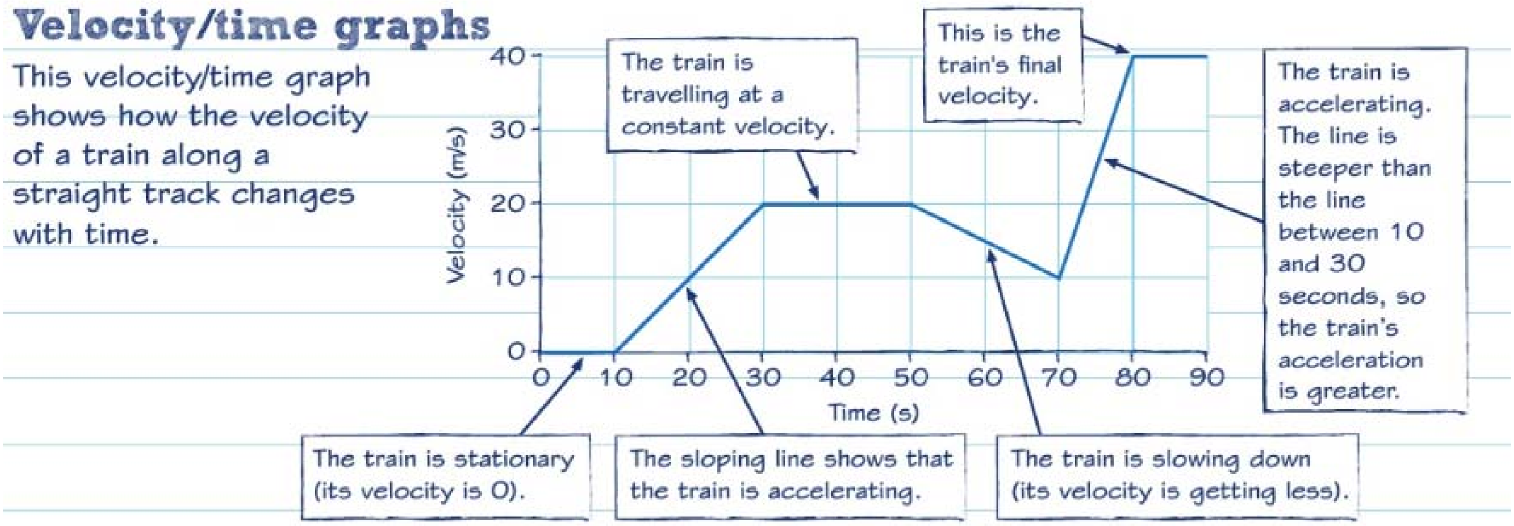
Acceleration = $\frac{change\ in\ velocity}{time}$

A cat changes its speed from 2.5 m/s to 10.0 m/s over a period of 3.0 s. Calculate the cat's acceleration.

$v^2 - u^2 = 2\ x\ a\ x$ x , where v = new velocity in m/s, u = old velocity in m/s , a = acceleration in ms^{-2}, x = distance in m

A motorcyclist passes through green traffic lights with an initial velocity of 4 m/s and then accelerates at a rate of 2.4 m/s², covering a total distance of 200 m. Calculate the final velocity of the motorcycle. **(4 marks)**

Velocity Time Graphs



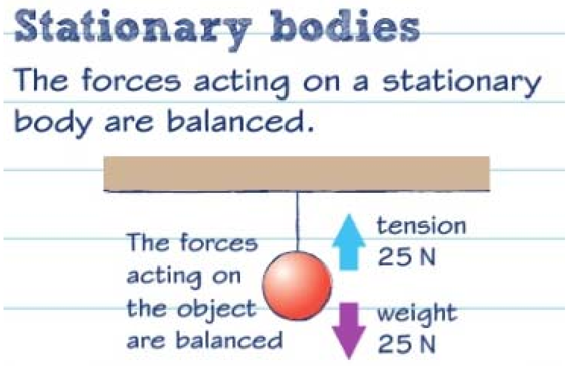
Here the gradient is the acceleration

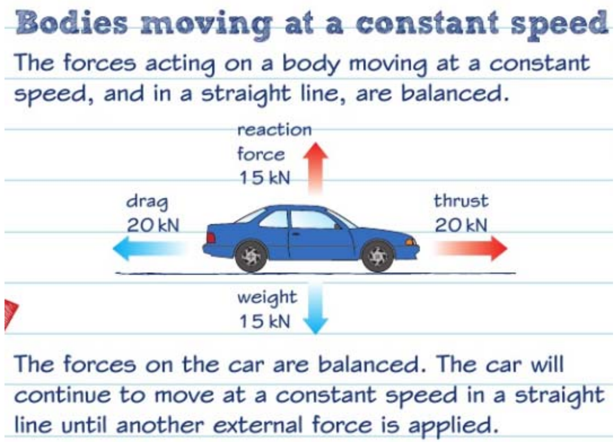
Typical Speeds

Activity	Typical Speed
Walking	1.5 m/s
Running	3.0 m/s
Cycling	6.0 m/s
Driving	12 m/s
Gale force wind	15 m/s
Train	55m/s
Airliner	250 m/s
Speed of sound in air	330 m/s

Acceleration due to gravity, **g**, in free fall is 10 m/s^2

Newton's First Law: A body will remain at rest or continue in a straight line at a constant speed as long as the forces acting on it are balanced.





Unbalanced Forces:

Examples:

Explain the effect that each of these forces will have on a car.

(a) 300 N forward force from the engine, 200 N drag. (3

(b) 200 N forward force from the engine, 400 N friction from brakes.

(c) 300 N forward force, 300 N drag.

Newtons's Second Law: Force = Mass x Acceleration

Example:

A resultant force of 6 N acts on a toy car, giving it an acceleration of 2 m/s^2. Calculate the mass of the toy car. **(3 marks)**

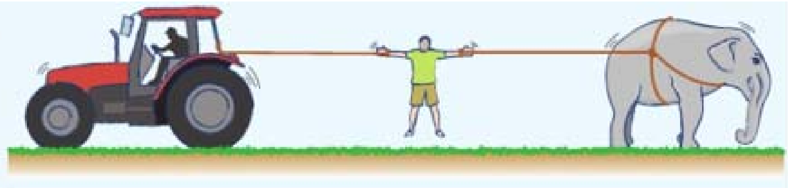
The diagram shows the horizontal forces acting on a boat. The boat has a mass of 400 kg.

Calculate the acceleration of the boat at the instant shown in the diagram. **(3 marks)**

Newton's Third Law: states that for every action there is an opposite and equal reaction.

Example:

Identify five action–reaction pairs that are present in the diagram. **(5 marks)**



1.
2.
3.
4.
5.

Weight: is the force that a body experiences due to its mass and the size of the gravitational field that it is in.
Formula: Weight = mass x acceleration due to gravity
Unit: Newtons (N)
How to measure weight: Newtonmeter

Human Reaction Time: is the time between a stimulus occurring and a response.
Typical reaction time is between 0.20s and 0.25s
Measuring the human reaction time by using the ruler drop test. Steps:
Formula:

The reaction time is determined from the equation:

$$\text{reaction time} = \sqrt{\frac{2 \times \text{distance ruler falls}}{\text{gravitational field strength}}}$$

Repeats can be used to get a mean value for the reaction time.

Stopping distance is the total distance over which a vehicle comes to rest.
Stopping distance = thinking distance + braking distance

Factors that can affect the thinking distance

- Driver being too tired
- Driver being distracted
- Driver having taken alcohol or drugs

Factors that can affect the braking distance

- The amount of friction between the tyres and the road (icy or wet conditions)
- The brakes are worn
- The tyres are worn
- The mass of the car
- Cars speed

Large decelerations release high amount of heat energy, which can cause the brakes to snap and a driver to lose control of their vehicle.

Conservation of Energy: states that energy cannot be created or destroyed but can be changed from one form to another.

Main Energy Stores

Energy store	Example
chemical	fuel, food, battery
kinetic	moving objects
gravitational potential	raised mass
elastic	stretched spring
thermal	hot object
magnetic	two magnets
electrostatic	two charges
nuclear	radioactive decay

Closed systems

When there are **energy transfers** in a closed system, there is no net change to the total energy in the system.

A **closed system** is one where energy can flow in or out of the system, but there is no transfer of mass. An example of a closed system is a pan of water being heated that has a lid on it so that no steam can escape.

Energy Transfers can occur in 4 different ways.

Mechanically: by a force moving through a distance

Electrically: by use of an electric current

Thermally: because of a difference in temperature

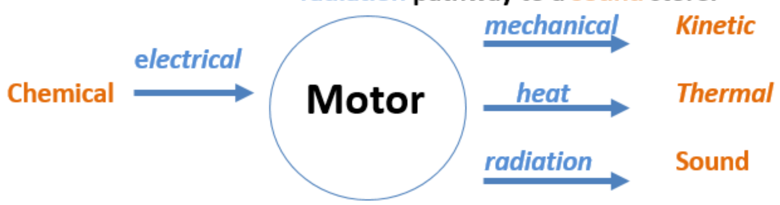
Radiation: by waves such as sound or electromagnetic

Some of the energy is **useful energy** and some energy is wasted or **dissipated**

Energy Flow Diagram

Consider the energy flow diagram for an electric shaver.

The battery has a store of chemical energy.
The current flows through an electrical pathway to the motor.
Energy from the motor follows a mechanical pathway to a kinetic store of the moving blades, a heat pathway to a thermal store and a radiation pathway to a sound store.



You do: Show the energy flow diagram for :

a) a camping gas stove

b) a car going up a hill

Energy Stores when:

a) an object is projected upwards or up a slope

- As the **ball leaves** your **hand** it has a **store** of **kinetic energy**.
- At its **highest point** it has a **store** of **gravitational potential energy (G.P.E)**.
- As you are about to catch it just **before it hits your hand** it has a **store** of **kinetic energy.**

b) a moving object hitting an obstacle

- As you move the muscles of your arm to throw the ball the **chemical energy store** in your muscles **decreases** and the **kinetic energy store** of the bowling ball **increases.**
- At the ball hits a pin some of the **kinetic energy** has been transferred to a **store** of **internal (thermal) energy** this causes the ball and its surroundings to warm up a little.
- You will hear a **sound** when the ball hits the pin, the **energy of the sound** is also transferred to the **internal energy store** of the **surroundings**.

c) an object being accelerated by a constant force

- At its **highest point** the ball has a **store** of **gravitational potential energy (G.P.E)**.
- As it is dropped **gravity** does work on the ball (assuming there is no air resisitance).
- The ball then constantly accelerates towards the ground.
- Just **before the ball hits the ground** it has a **store** of **kinetic energy.**

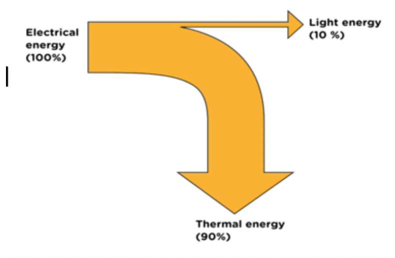
d) A vehicle slowing down

- The **moving** lorry has a **store** of **kinetic energy**.
- At the **brakes** are applied the **kinetic energy store decreases** the energy is transferred to the **internal (thermal) energy store** in the brakes and the brakes get hot.
- You will hear a **sound** when the brakes of the lorry are applied, the **energy of the sound** is also transferred to the **internal energy store** of the **surroundings**.
- When the lorry **stops** its **kinetic energy store** is **zero**.

e) Bringing water to a boil in an electric kettle

- Energy is transferred **electrically** from the mains to the **heating element** in the kettle.
- The **internal (thermal) energy store** of the water **increases.**
- The temperature of the water increases and as bubbles form the **kinetic energy store** of the water increases.

Mechanical processes become wasteful when they cause a rise in temperature so dissipating energy in heating the surroundings. For example: The light and sound energy from a TV will eventually be absorbed by the walls and by people leading to a rise in their temperature.



Unwanted energy transfers result in energy stores that are not useful.

The F1 car below shows that eventually all the chemical energy (fuel) put in the car ends up as unwanted thermal energy which is dissipated to the surroundings. Unwanted energy is often described as being 'wasted'

Chemical →

→ Kinetic → Thermal

→ Sound → Thermal

→ Thermal

Kinetic energy is dissipated by the tyres, brakes and air resistance to become unwanted thermal energy stores.
Sound energy is absorbed by materials and becomes thermal energy.
Thermal energy is produced by the engine as fuel is burnt.

Oil is used in the engine, gearbox and other moving parts as a lubricant to reduce friction and reduce unwanted thermal energy in these parts.

Thermal insulation is often used to reduce unwanted energy transfers.

All the energy used to heat a home is eventually transferred as thermal energy to the surroundings.
The diagram, shows the percentage energy lost through different parts of the building.

Material	Thermal Conductivity W/m C
Air	0.03
Polyurethane foam	0.03
Fibreglass	0.04
Wool felt	0.05
Wood	0.15
Plaster	0.50
Glass	0.80
Brick	1.00
Concrete	1.04

The higher the thermal conductivity, the quicker heat is transferred through the material.

Houses are often built from brick, concrete, wood and glass. All have quite high thermal conductivity values. Insulation uses materials with low thermal conductivity, such as fibreglass in the loft, foam in wall cavities and trapped gases in double glazing.

Formulas:

$$\text{Efficiency} = \frac{(useful\ energy\ transferred\ by\ the\ device)}{(total\ energy\ supplied\ to\ the\ device)}$$

When an object is raised above ground level it gains **gravitational potential energy** (GPE). This **stored energy** can be released if the object is allowed to **fall**.

change in G.P.E (J) = mass (kg) × gravitational field strength (N/kg) × change in height (m)

$$\Delta GPE = m \times g \times \Delta h$$

Moving objects have **kinetic energy**.

kinetic energy (J) = ½ × mass (kg) × speed^2 (m/s)

$$KE = \tfrac{1}{2} \times m \times v^2$$

Application

A motor transfers 100 J of energy by electricity. 60 J are transferred as kinetic energy, 12 J as sound energy and 28 J as thermal energy. Calculate the efficiency of the motor. **(3 marks)**

Calculate the efficiency of a lamp that transfers 14 J of energy into useful light energy for every 20 J of electrical energy input. **(2 marks)**

(a) A mass of 5 kg is moving at 8 m/s. Calculate its kinetic energy. **(3 marl**

(b) A mass of 800 g is moving at 14 m/s. Calculate its kinetic energy. **(3 marks)**

(a) A body of mass 73 kg is lifted through a vertical height of 26 m. Calculate how much gravitational potential energy it has gained. **(3 marks**

(b) A book of 600 g is lifted through a vertical height of 3 m and placed on a shelf. Calculate how much gravitational potential energy the book has gained. **(3 marks)**

1 A mass of 5 kg is raised through a vertical height of 18 m. Calculate the change in gravitational potential energy. **(3**

2 A girl of mass 60 kg is running with a velocity of 5 m/s. Calculate her kinetic energy. **(3**

3 A motorbike of mass 80 kg is moving at 30 km/h. Calculate its kinetic energy. **(4 marks)**

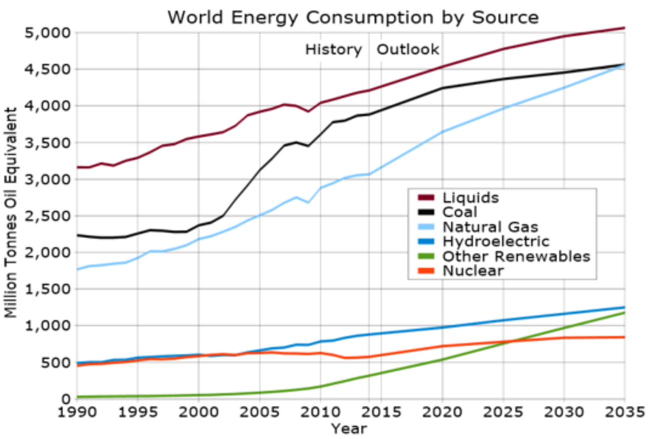
ENERGY RESOURCES	
Non-renewable	
Coal	Fossil fuels They are becoming more difficult to find and extract
Oil	
Gas	
Nuclear	Plentiful but difficult to extract / purify
Renewable	
Bio-fuel	Plant matter usually used as a fuel
Wind	Turbines spin a generator to produce electricity
Hydro-electric	Falling water spins a turbine to produce electricity
Tides	Rise and fall of the tide can be used to turn a turbine
Sun	To directly heat things or produce electricity

Non-renewable energy sources are those which will **eventually run out** – there is a finite supply. New supplies are more difficult to find and extract.
Renewable energy sources are those which can **replenish themselves in the short term,** and so will never run out.
Nuclear energy resources are technically non-renewable but they can be produced on an almost indefinite basis.

How energy resources are used.
Transport – cars, trains, buses, planes etc.
Electricity generation – industry, homes, commerce, lighting etc.
Heating – homes, industrial processes, schools and hospitals etc.

Energy use is usually divided between the four economic sectors - **residential, commercial, transportation**, and **industrial**.

World energy use trends and predictions



The total amount of energy used in the world is increasing as the population increases and each person is using more energy.

Renewable energies only make up around 20% of total energy consumption and this trend is unlikely to change until after 2035.

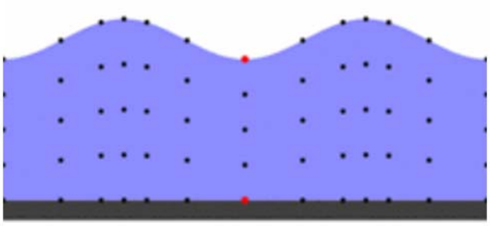
- **Future world agreements on emissions are likely to determine the trend of using fossil fuels.**
- **As reserves of coal, oil and gas dwindle, an increase in the use of renewable energies is likely.**

Waves transfer **energy** and **information** without transferring **matter**.

Evidence for this:

Water Waves

- If you throw a small rock into a duck pond (obviously avoiding the ducks)
- You will see ripples form and move across the waters surface
- The **ripples** cause water particles to **vibrate up and down**
- The duck **does not** get carried to the edge of the pond it just bobs up and down

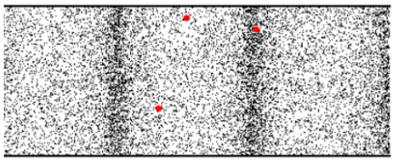


In this GIF the red dot represents the duck

Sound waves

- If you hit a drum you will create a **sound wave**
- The sound wave travels to your ear and you hear the drum sound
- Sound waves cause **air particles** to **vibrate back and forth**
- The air particles do not travel from the drum to your ear
- Only **energy** is transferred and **not** the particles

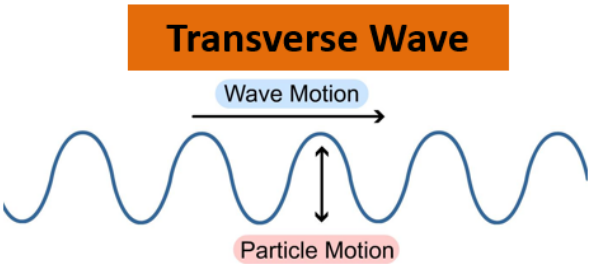
Sound wave



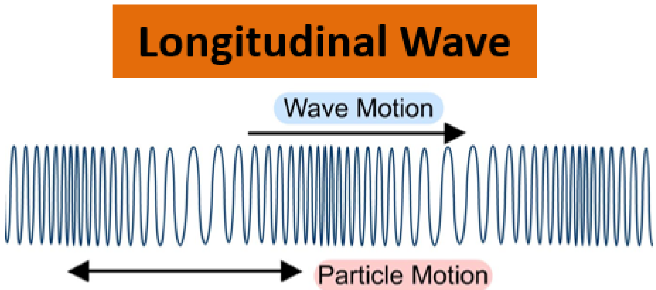
In this GIF the red dots represents air particles

Transverse and Longitudinal Waves

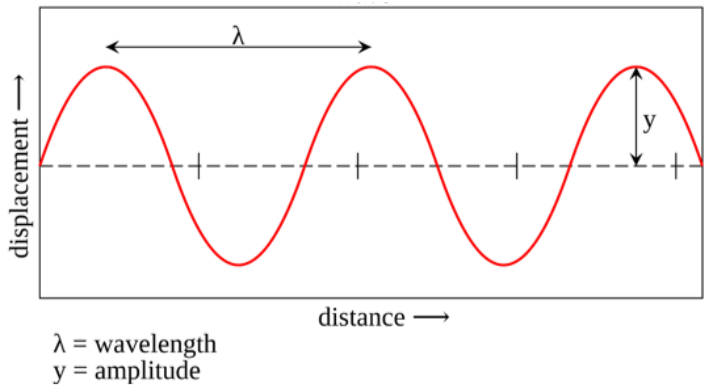
In a **transverse wave** the particles within the wave move perpendicular (at 90°) to the direction the wave is travelling.
This is the wave produced in a rope when it is flicked **up and down**.
Examples of transverse waves are:
Water waves, electromagnetic (light) waves and guitar strings.

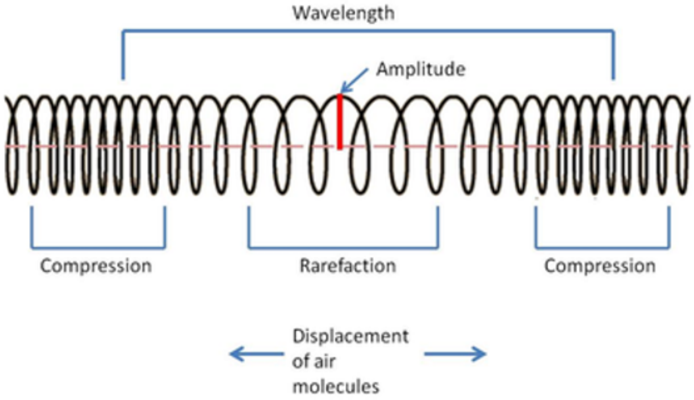


Longitudinal waves are compression (squash) waves where the particles are vibrating in the same direction as the wave movement.
This is the wave produced when a spring is **squashed** and released.
Examples of longitudinal waves are:
Sound waves and a type of seismic (P) wave.



Note: the particles in a wave move up and down or backwards and forwards only.
It is energy, NOT the particles, that move from one place to another!





Wavelength (m) – the distance from one point on a wave to the same point on the next wave.
Amplitude (m) – the waves maximum displacement of a point on a wave from its undisturbed position.
Frequency (Hz) – the number of waves passing a point per second.
Period (s) - the time taken to produce one complete wave.

The displacement of a transverse wave is described as **peaks and troughs**. In a longitudinal wave these are described as **compressions and rarefactions**.

Formula:

wave speed (m/s) = frequency (Hz) x wavelength (m)

$$v = f\,\lambda$$

wave speed (m/s) = distance (m) ÷ time (s)

$$v = \frac{x}{t}$$

Questions

A seismic wave has a frequency of 15 Hz and a wavelength of 270 m. Calculate the wave speed of the seismic wave. **(3 marks)**

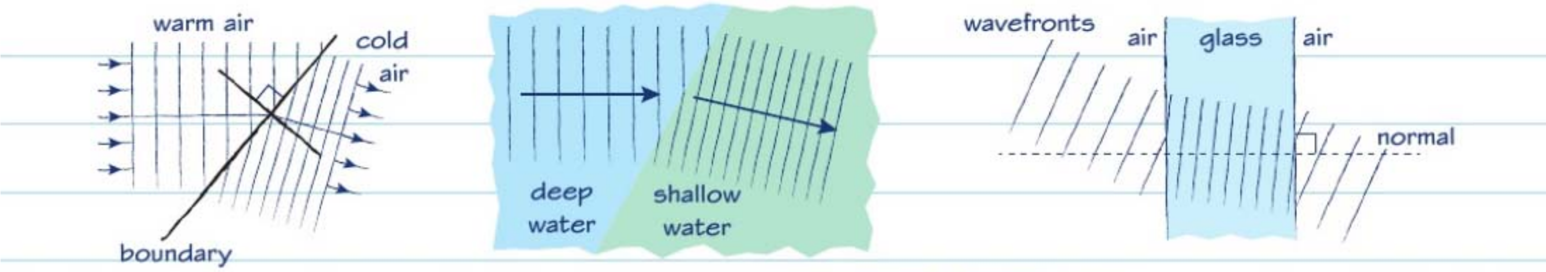
A wave on the sea travels 20 m in 5 s. Calculate the speed of the water wave. **(3 marks)**

(a) A sound wave has a wavelength of 3.3 m and a frequency of 100 Hz. Calculate its speed. **(3 marks)**
(b) Another sound wave, with the same speed as in (a), has a frequency of 1650 Hz. Calculate its wavelength. **(3 marks)**

A wave in the sea travels at 25 m/s. Calculate the distance it travels in one minute. **(4 marks)**

Required Practical: Measuring the speed of ripples on a water surface and calculating the speed of sound in air

Refraction: is the change in the direction of a light ray that happens when it travels from one transparent material into another.



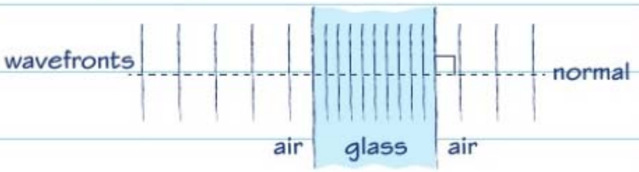
Sound waves travel faster in warmer air than in cooler air, as the molecules move faster in warmer air.

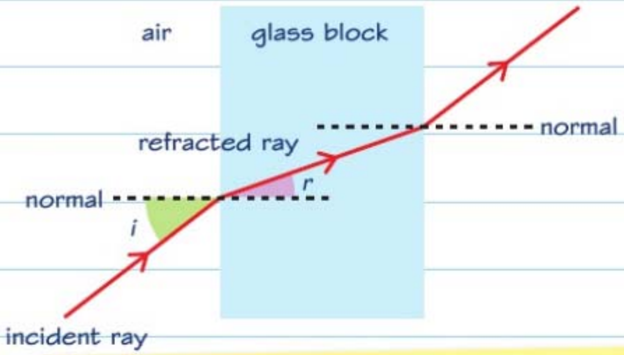
Water waves change direction and bend towards the normal when they move from deep water to shallow water.

Light waves bend towards the normal when they move from air into glass. They bend away from the normal when they move from glass back into air.

Refraction special case

When light, sound or water waves move from one material into another their **direction does not change** if they are moving along the normal.

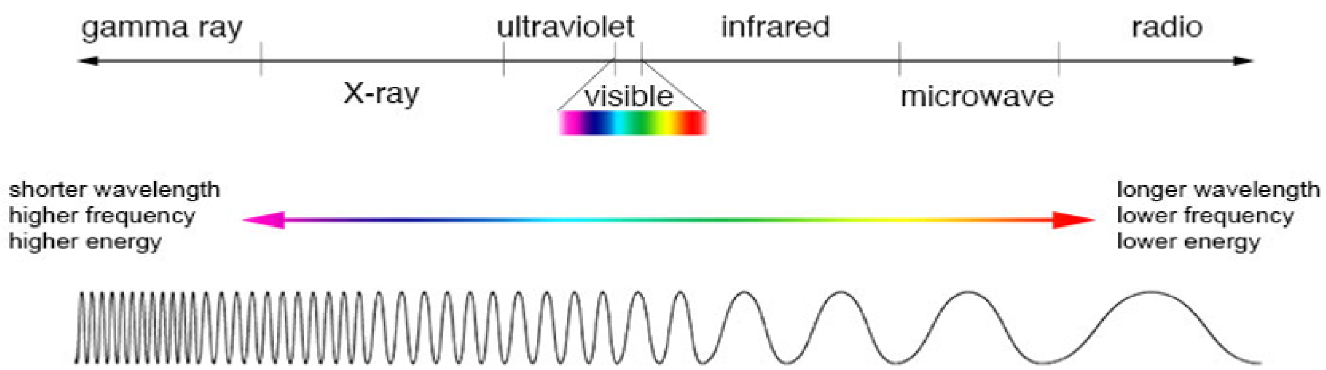




Notice that the ray of light bends *towards* the normal as it enters the glass and *away* from the normal when it leaves the glass.

P5: Light and The Electromagnetic Spectrum

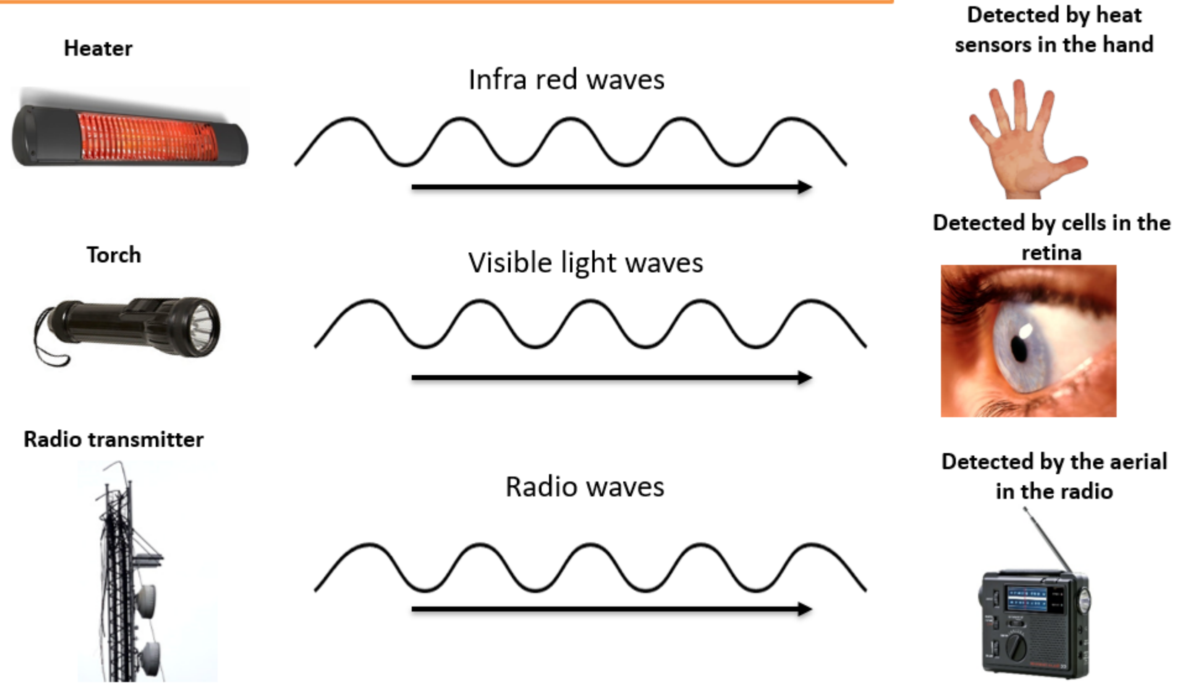
All Electromagnetic waves are transverse, they travel at the same speed in a vacuum.



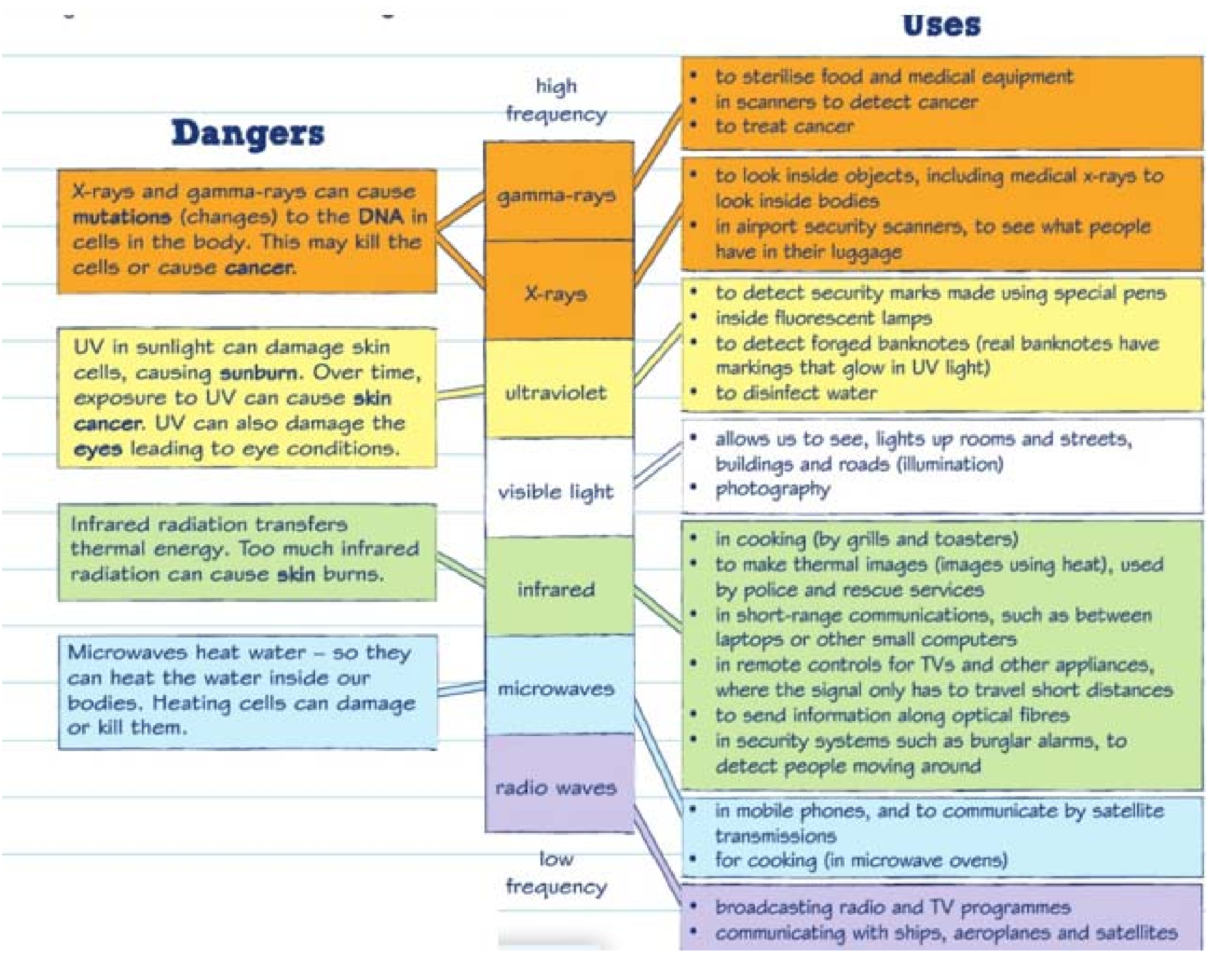
Our eyes are only able to detect a small range of these waves shown as the visible range above. Some animals can see in ultra violet and some can detect infra red.

Required Practical: Investigate refraction in a glass block in terms of interaction of electromagnetic waves with matter.

Examples of transfer of energy by electromagnetic waves



You must recall the main groups of the electromagnetic waves, in order, including the colours of the visible spectrum. You need to be able to identify decreasing wavelength and increasing frequency.



Radiation is **absorbed** or **emitted** when **electrons** jump between **energy levels.**

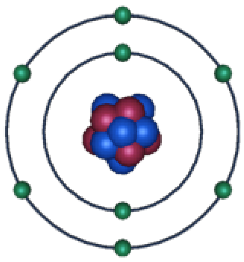
Electrons move up energy levels when they absorb energy and when they fall down to lower energy levels they emit energy.

Energy is emitted from the nuclei of unstable atoms. When energy changes occur in the nucleus, high energy gamma-rays are emitted.

An **atom** has a positively charged **nucleus** containing **protons and neutrons**, surrounded by negatively charged **electrons in shells**.
The nuclear radius much smaller than that of the atom and with almost all mass **of an atom** is **concentrated in the nucleus**.
An atom contains **equal numbers of protons and electrons**.
Atoms have **no overall electrical charge** because the number of positive protons equals the number of negative electrons.

number of protons = atomic number

All atoms of an element have the **same number of protons in the nucleus**. This number is **unique to that element**.

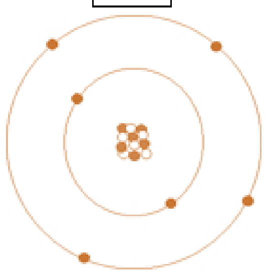


	Mass	Charge	Location
Proton	1	+ (positive)	nucleus
Neutron	1	no charge	nucleus
Electron	1/1835 negligible	- (negative)	shells

Isotopes are elements with **different atomic masses (nucleon number)**.
The number of **protons** can not change or it would not be the same element so **an isotope is an element with different numbers of neutrons.**

Carbon 12

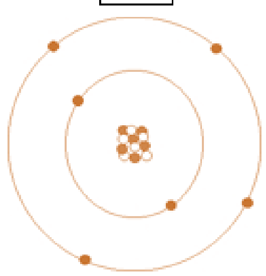
$^{12}_{6}C$



6 protons
6 neutrons

Carbon 13

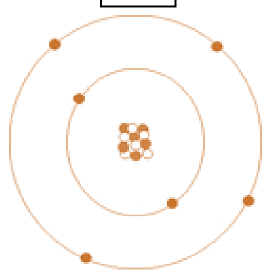
$^{13}_{6}C$



6 protons
7 neutrons

Carbon 14

$^{14}_{6}C$

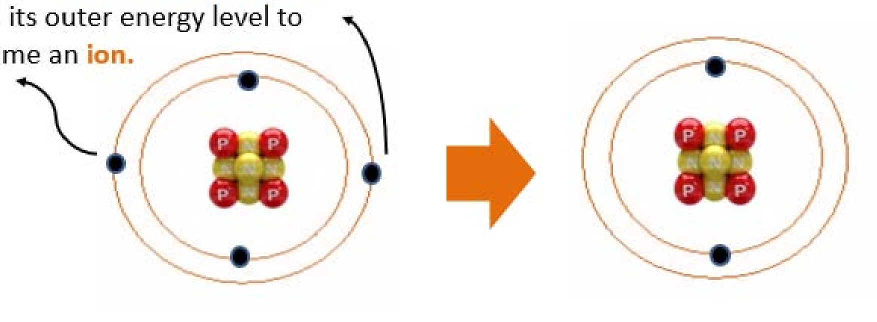


6 protons
8 neutrons

The isotopes have the **same number of protons** and the **same number of electrons**. Only the number of **neutrons changes** in an isotope.

Atoms can form **ions** if they gain or lose **electrons.** Atoms do this so they have **full outer energy levels.**

Beryllium **can lose 2 electrons** from its outer energy level to become an **ion.**



If Beryllium **loses 2 e^-** it now has:

4 protons 4+
2 electrons 2-
2+

Berylium $^{2+}$

$${}^{9}_{4}\mathrm{Be} \rightarrow {}^{9}_{4}\mathrm{Be}^{2+}$$

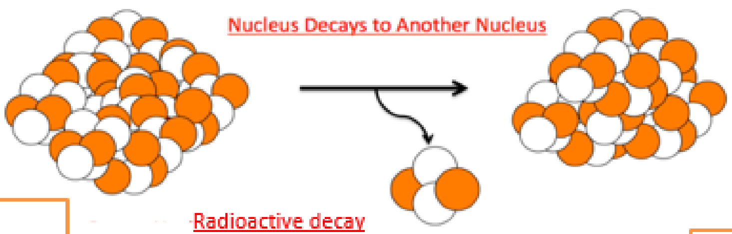
Atoms can **lose (-) electrons** to become **positive (+) ions** or **gain (-) electrons** to become **negative (-) ions**.

Radioactivity can be detected by using Geiger–Müller tube.

Radioactivity is measured using Becquerels (Bq).

The nuclei of some atoms are unstable. To become more stable these nuclei give out radiation. This process is called radioactive decay.

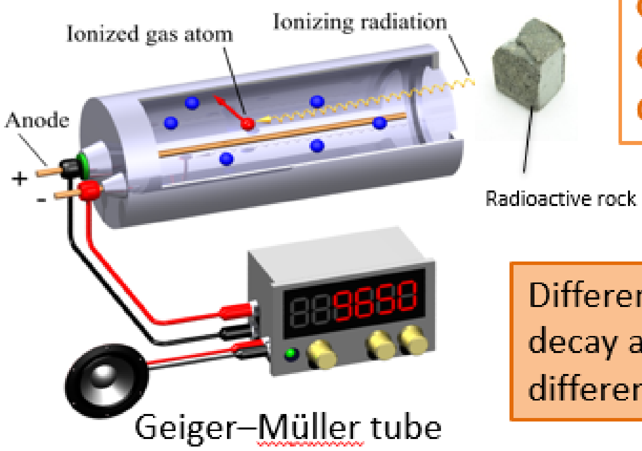
Unstable atom



Stable atom

Activity = **rate at which a source of unstable nuclei decays**, measured in **becquerels (Bq).**

Count-rate = **number of decays recorded each second by a detector**

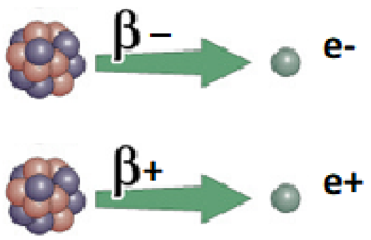


Radioactivity can be detected by using Geiger–Müller tube or photographic film.

Different radioactive isotopes decay at different rates and emit different types of radiation.

There are three types of radioactive decay, **alpha, beta (β– beta minus and β+ positron) and gamma**. All come from an unstable **nucleus of an atom**.
In the examples below, only the nucleus is shown. This is a random process

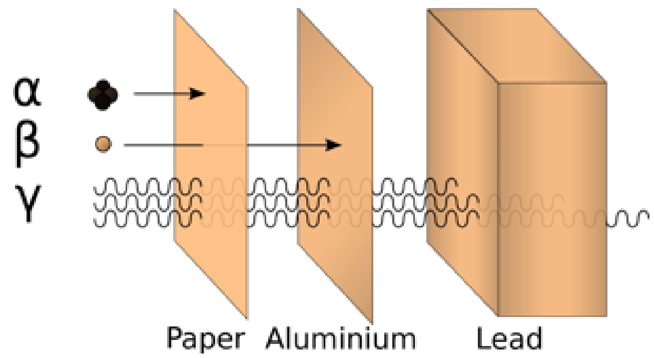
Alpha decay (symbol ^4_2He or) consist of **2 protons and 2 neutrons** emitted from the nucleus. They have a **positive** charge as they contain 2 (+) protons.



β– (beta minus) decay , consist of an **electron** emitted from the nucleus. This results from a neutron splitting into a proton and an electron.
β+ (positron) decay , consist of an **positron** emitted from the nucleus. This results from a proton splitting into a neutron and an positron.
(A positron is has the same mass as an electron).

Gamma rays (symbol γ) are **electromagnetic radiation** emitted from the nucleus. Gamma radiation has **no mass** and **no electrical charge.**

Properties of alpha, beta and gamma radiation.



Alpha, beta and gamma radiation can penetrate different materials due to their differing nature.
Alpha – easily stopped by **a few sheets of paper**.
Beta – penetrates paper but stopped by a thin **sheet of aluminium**.
Gamma – only stopped by **thick lead** or several metres of **concrete**.

All three types of radiation cause **ionisation** of other atoms. If these atoms are in **living cells** it can cause damage which could lead to **cancer.**

Name	Symbol	Speed	Range in air	Ionising power
Alpha	α	Slowest	6 - 8 cm	High
Beta	β	Medium	1 – 2 m	Medium
Gamma	γ	Fastest	300 - 500 m	Low

Background radiation is the constant , low level radiation in the environment. This can be natural radiation from rocks, building materials, cosmic rays etc.
Radioactive pollution from nuclear testing, nuclear power and industrial/medical waste also contributes to background radiation.

Sources of radioactive exposure and contamination.

- 14% Medicine
- 1% Nuclear Industry
- 42% Radon
- 18% Buildings/Soil
- 14% Cosmic
- 11% Food/Drinking Water
- 85% Natural Radiation

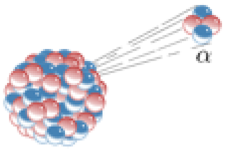
Radiation dose is measured in: **sieverts (Sv)**

1 Sv = 1000 millisieverts

Everyone receives background radiation but people who **work or live** in locations with high levels of radiation **receive additional doses of radiation**.
Some nuclear workers, medical staff, military and industrial workers may have higher doses due to working with radioactive sources.

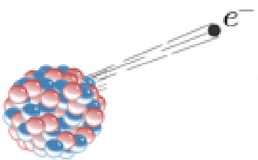
Nuclear equations show the changes to an atom when it emits radiation.

Alpha emission



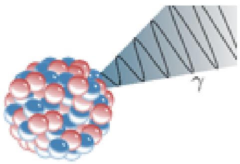
$^{238}_{92}U \longrightarrow$

Beta emission



$^{14}_{6}C \longrightarrow$

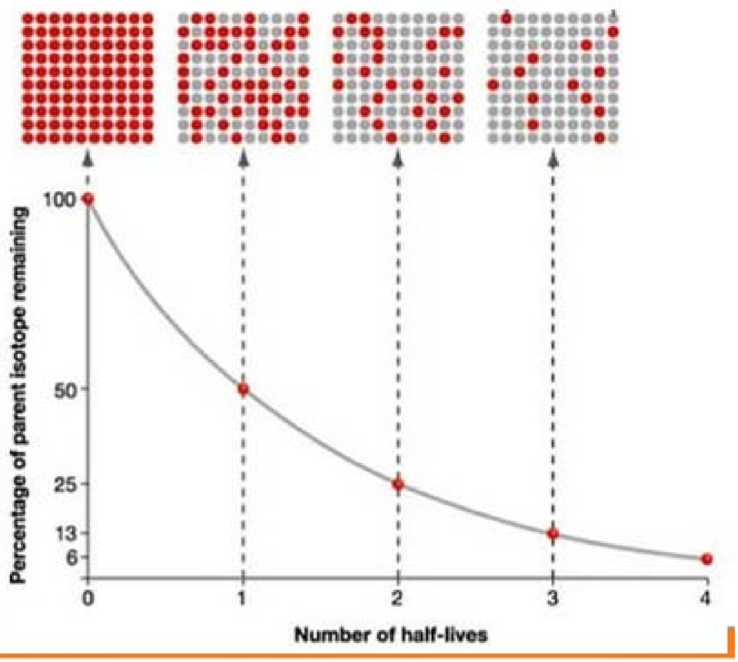
Gamma emission



$^{99}_{43}Tc \longrightarrow$

Radioactive decay is a random process so the likelihood of a decay taking place is a probability problem. For this reason, the **half-life** of an isotope is given rather than saying how long it will take to fully decay.

The **half-life** of a radioactive isotope is the time it takes for the **number of nuclei** of the isotope in the sample to halve.



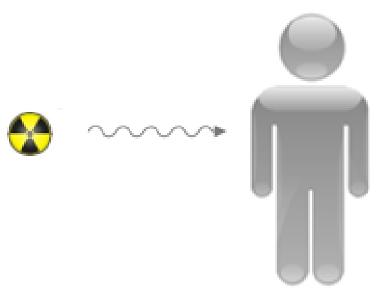
Calculating the half life of a radioactive isotope.

Example:
The count rate of an isotope is 1008 Bq.
This falls to a count rate of 126 over a period of 21 days.
What is the half life of the isotope?

Radioactive materials are **hazardous** to **life**. **Nuclear radiation** can **ionise** (add or remove electrons) substances **within** the human body. This can **change** the way cells behave, **damage** DNA or **destroy** human cells.

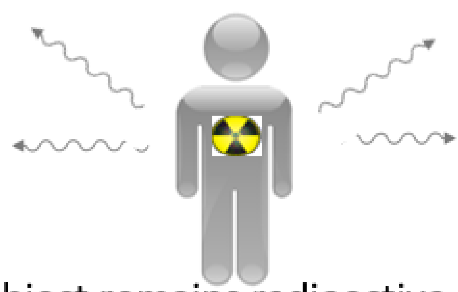
Body part	Effect of ionising radiation
Hair	Hair loss
Skin	Can cause burns or lead to skin cancers
Reproductive organs	High doses can cause sterility or mutations in offspring
Thyroid	Exposure to radioactive iodine can destroy the cells in the thyroid or cause cancers
Bone marrow	Can cause leukaemia or other blood cancers

Irradiation is when an object or person is **exposed** to radiation. Protection from irradiation means stopping the radiation from reaching you.



Medical dressings are often irradiated but present no danger to the user.

Contamination is when a radioactive source is in **contact** with an object or person. The radioactive substance rather than the emissions are present.



The object remains radioactive until the contamination is removed or decays naturally.