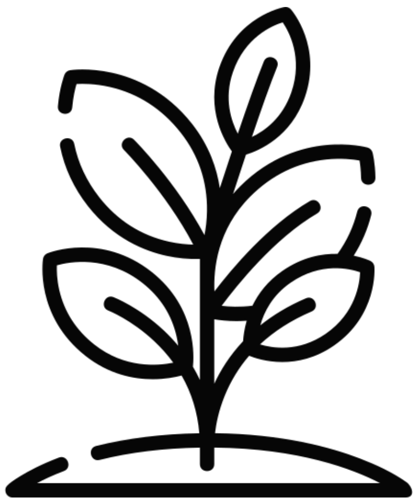
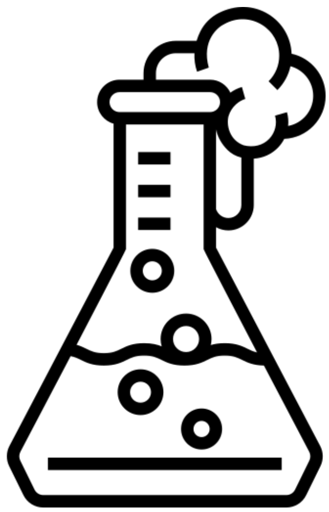
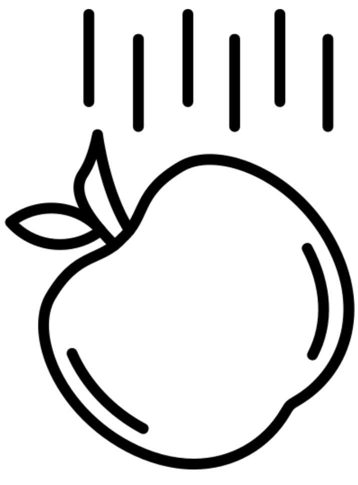
The Science Doctor KS3 Science Workbook







Dr Peter Edmunds

Introduction

This is the free version of the Science Doctor KS3 Science workbook – containing my KS3 Biology, Chemistry and Physics work together. It contains the majority of the content within the paid for version, just without the answers. This is also a “draft” version and will not receive extensive proofreading and ongoing corrections.

I originally started the site sciencedoctor.school.blog to support teachers in their planning and workload. Since then, the support I have received has allowed me to turn the site into something much bigger and, somehow, nearly a million resource downloads have now occurred on the site. “Buy me a coffee” donations have made my hobby of writing a little more financially feasible and, frankly, this workbook wouldn’t exist without them.

If you would like to support my ongoing work then do consider donating or purchasing a physical copy of any of my KS3 workbooks. The physical copies come with the benefit of including answers (and those who know me will know how much I really don’t enjoy writing answers!). “Buy me a coffee” links can be found on the sciencedoctor.school.blog website.

This workbook is not yet fully proofread. It absolutely will contain some mistakes at this stage. If you do encounter a genuine mistake then please report it to @edmunds_dr on X /twitter.

Thanks & I hope you find the resources in this workbook useful.

Peter Edmunds

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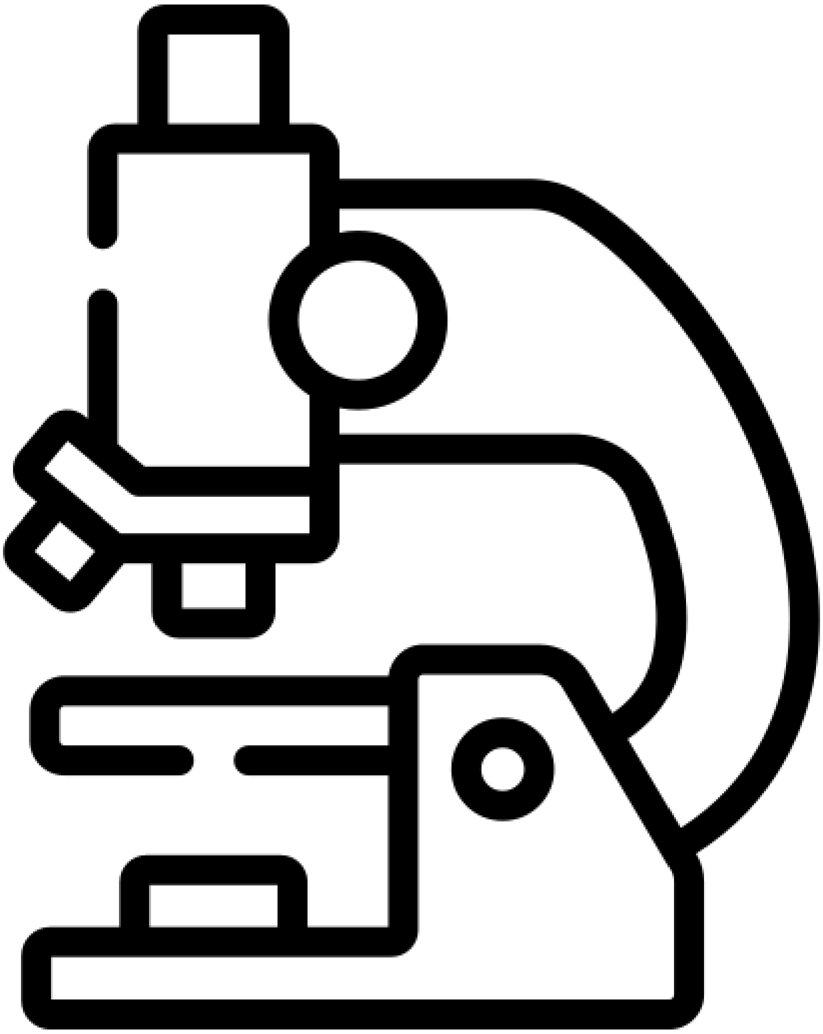
Cells and

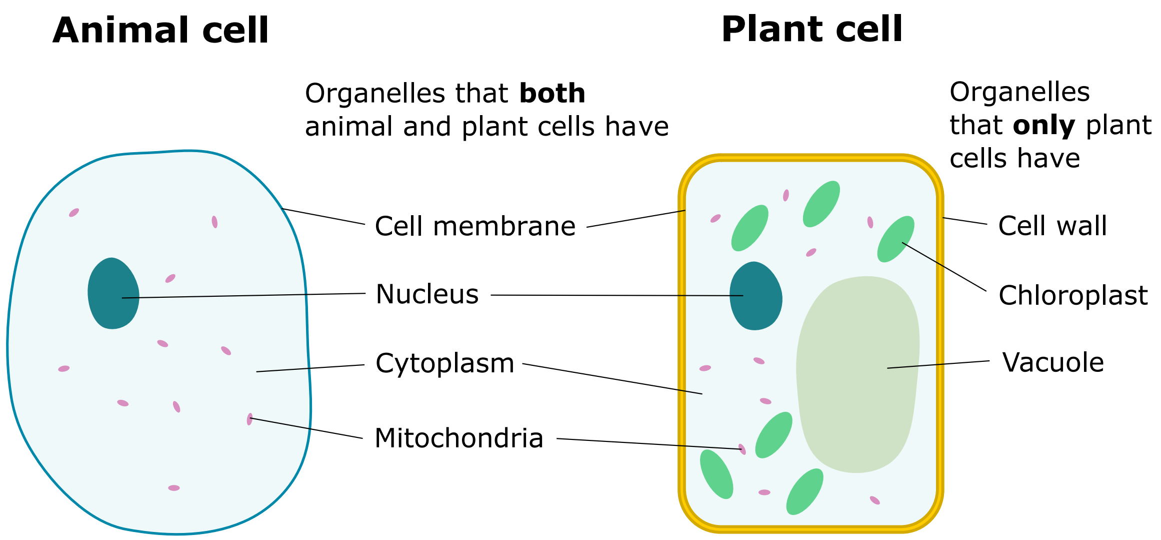


organisation

Plant and animal cells

All animals and plants are made of tiny **cells** that can only be seen with a **microscope**. These cells are the basic building blocks of life and are responsible for carrying out the essential functions that sustain an organism.

Each cell contains **organelles**, which serve different purposes. Most cells have a **nucleus**, **cytoplasm**, **mitochondria** and a **cell membrane**. Plant cells also have a **vacuole**, **chloroplasts**, and a **cell wall**.



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The functions of each organelle can be seen below:

Cell membrane	Controls what goes in and out of the cell.
Nucleus	Controls the activities of the cell by housing the genetic material and coordinating cell functions like growth and reproduction.
Cytoplasm	Chemical reactions happen in the cytoplasm.
Mitochondria	Aerobic respiration happens in the mitochondria. Respiration is a chemical reaction that releases energy stored in glucose so that it can be used to fuel cell activities.
Cell wall	Covers the cell membrane and gives strength to a plant cell.
Chloroplast	Where photosynthesis takes place. Photosynthesis is a chemical reaction that produces glucose. Chloroplasts contain the green pigment chlorophyll.
Vacuole	Contains cell sap (a solution of sugars and salts).

Q1. State the four organelles that plant and animal cells both have:

....

....

....

....

Q2. State the three organelles that only plant cells have:

....

....

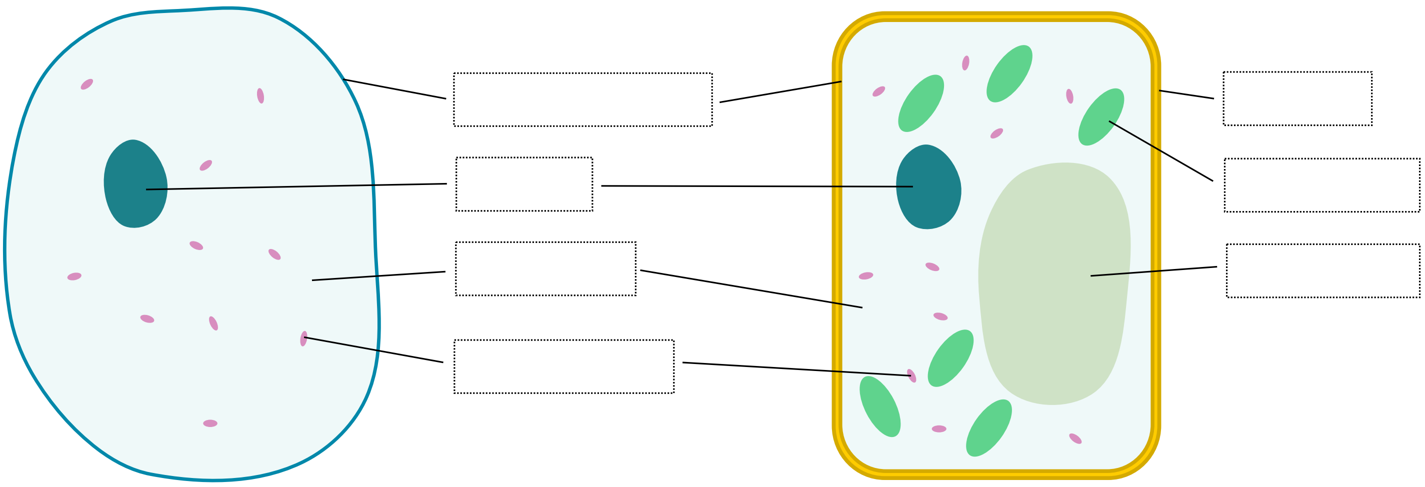
....

Q3. Label the diagrams below, using the words in the box.

Vacuole, cell wall, nucleus, cytoplasm, chloroplast, cell membrane, animal, mitochondria, plant

This is an ___________ cell

This is a ___________ cell



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Q4. The following statements are either true or false. State which are true and which are false.

a) Both plant and animal cells have cell walls.

....

b) Both plant and animal cells have cell membranes.

....

c) Only animal cells contain a nucleus.

....

d) Plant cells contain a vacuole.

....

e) The mitochondria control the activities of a cell.

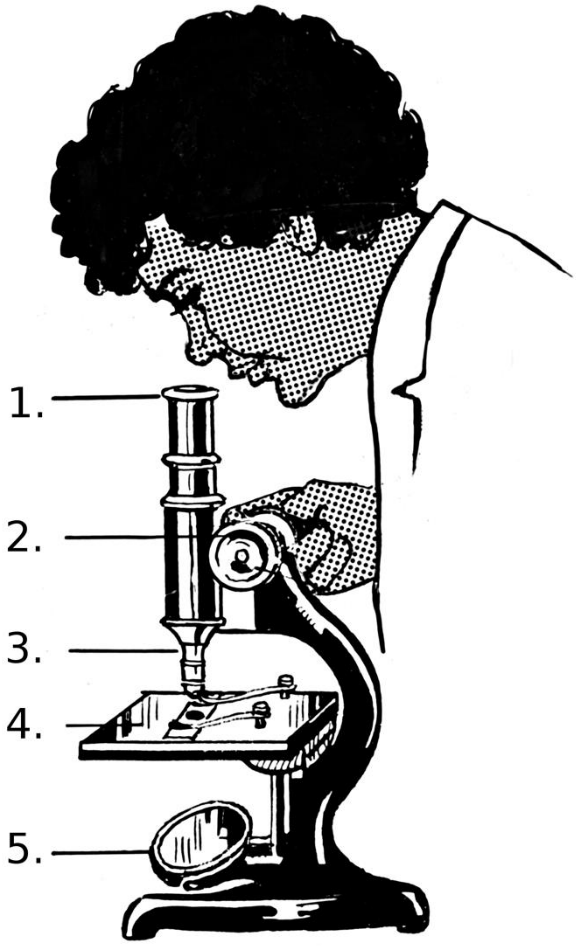
....

Light microscopes

A light microscope is a tool that scientists use to see tiny things that are too small to be seen with the naked eye. Light microscopes use visible light and lenses to **magnify** objects, allowing us to see details of cells and other small structures.

The diagram to the right shows a light microscope. Typical parts include:

1. **Eyepiece lens**. This is the lens that you look through at the top of the microscope.
2. **Focus adjuster**. Used to move the stage up and down to bring the object into focus. Microscopes usually have two adjustment controls – coarse and fine. Generally, the fine adjustment is used to sharpen the focus after using the coarse adjustment. This provides a clear and detailed view.
3. **Objective lens**. These lenses magnify the object. Commonly, microscopes have a rotating nosepiece which allows different lenses to be selected for varying levels of magnification.
4. **Stage**. The flat platform where you place the slides. Clips hold the slides in place.
5. **Mirror or light source**. A lamp or mirror that shines light through the object being viewed, making it easier to see details.



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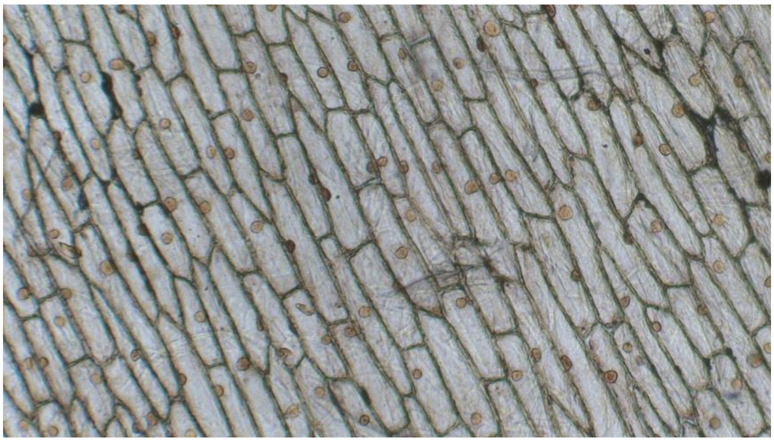
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A common practical that you can do in the classroom is to view onion cells (shown left). To prepare a microscope slide, you would cut an onion and peel off a thin layer (called the epidermis). This thin layer should then be carefully placed onto the slide. To view the cells better, add a drop of iodine to the onion and then gently place a coverslip over the onion. The slide is then placed onto the stage and secured with the stage clips.

Q1. The following statements are either true or false. State which are true and which are false.

a) Light microscopes are used to magnify objects.

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b) The objective lens is the lens that we look through.

……………………………………………………………………………………………………

c) Clips are used to hold microscope slides onto the stage.

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d) The focus adjuster usually has coarse and a fine adjustment.

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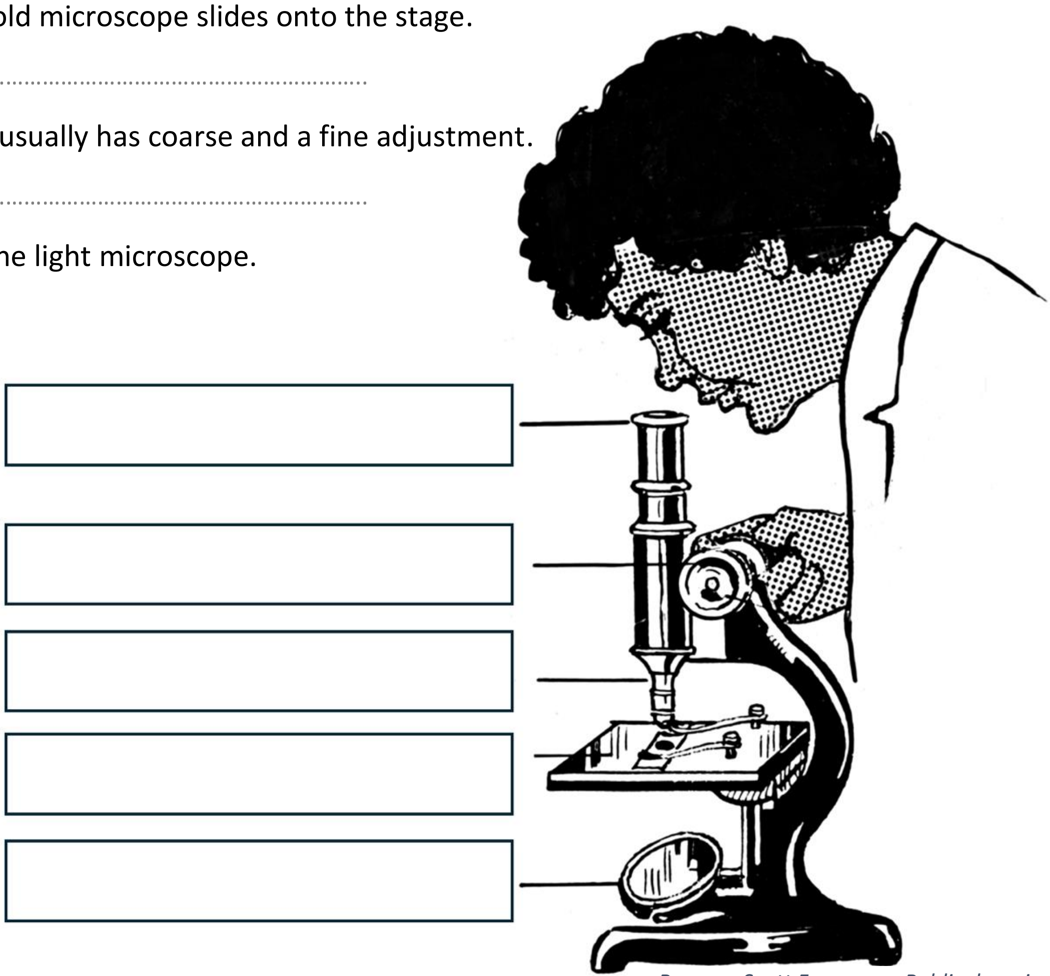
Q2. Label the diagram of the light microscope.



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Q3. Describe the purpose of the mirror on a light microscope.

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Q4. Describe how you would use the focus adjuster to bring an object into focus.

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Q5. Describe how you would prepare a slide to view onion cells.

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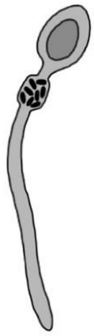
Specialised cells

While many cells look similar, they can have special features that help them perform unique jobs. These are called **specialised cells**. Some examples are below.

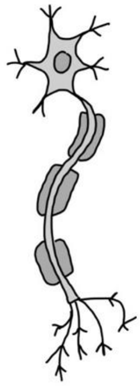
Root hair cells.

These cells absorb water and nutrients from the soil to help a plant grow. Root hair cells have long, hair-like projections that increase their surface area to absorb more water and nutrients efficiently.



Sperm cells.

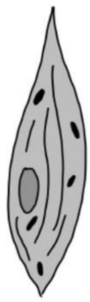
These cells fertilise an egg cell (ovum) for reproduction. They have a long tail, called a flagellum, which helps them swim toward the egg. They are streamlined and have a head that contains enzymes to help penetrate the egg cell. The head also contains the cell's genetic material.



Nerve Cells (Neurons).

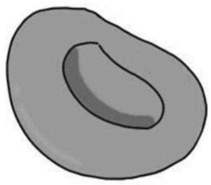
Electrical signals are transmitted through the nerve cells throughout the body to help control body functions, send messages from the brain to other parts of the body, and respond to stimuli.

Nerve cells have long extensions called axons and dendrites that connect with other nerve cells to transmit signals quickly over long distances.



Muscle Cells.

Movement is produced in muscle cells by contracting and relaxing in response to signals from the nervous system. Muscle cells are long and can change shape by contracting. They contain many mitochondria, which provide the energy needed for contraction.



Red Blood Cells.

These cells carry oxygen in the blood to the rest of the body. They have a biconcave shape which increases their surface area for absorbing oxygen. They are small and flexible, allowing them to fit through tiny blood vessels.

Q1. The following statements are either true or false. State which are true and which are false.

a) Specialised cells have the same shape and size as all other cells.

....

b) Red blood cells have a long tail to help them swim through blood.

....

c) Sperm cells fertilise an egg cell for reproduction.

....

d) Electrical signals are transmitted through nerve cells.

....

e) Red blood cells have a large surface area for carrying oxygen.

....

f) Root hair cells are responsible for hair growing on humans.

....

g) Muscle cells contract and relax in response to signals from the nervous system.

....

h) Root hair cells help plants absorb sunlight.

....

Q2. Describe the role of root hair cells in plants. Include how they are adapted for this purpose.

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....

Q3. Describe why muscle cells contain many mitochondria.

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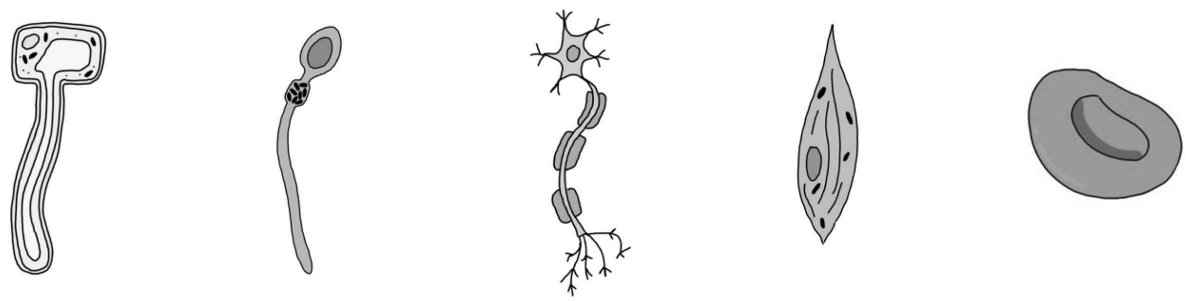
Q4. State the name of each cell in the boxes below.



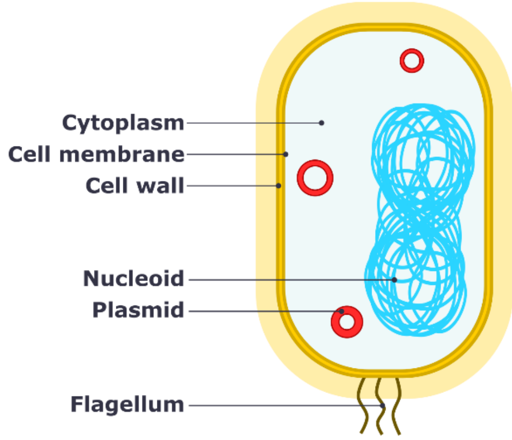
Life processes and unicellular organisms

Unicellular organisms are living organisms made of just one cell. Despite their small size and simplicity, these single-celled organisms perform all seven life processes. We can use the acronym **Mrs. Gren** to help remember all of the life processes:

Movement	All living organisms move in some way. Plants move slowly as they grow towards light, and animals move to find food or escape danger.
Respiration	Respiration is a chemical reaction that releases energy stored in glucose.
Sensitivity	Living things can sense changes in their environment and respond to them. For example, humans can feel heat and move away from it, while plants can grow towards light.
Growth	All living organisms grow. Unicellular organisms grow by increasing in size, and multicellular organisms grow by producing more cells.
Reproduction	Reproduction is the process of producing offspring.
Excretion	This is the process of removing waste products from the body.
Nutrition	Plants photosynthesise, while animals need to eat plants or other animals.

Bacteria are some of the most common and diverse unicellular organisms.

A diagram of bacteria can be seen to the right. Unlike many cells, bacteria do not have a nucleus. Instead, genetic material is located in the nucleoid and plasmids. Some (but not all) bacteria have a long tail, called a **flagellum**, for movement.



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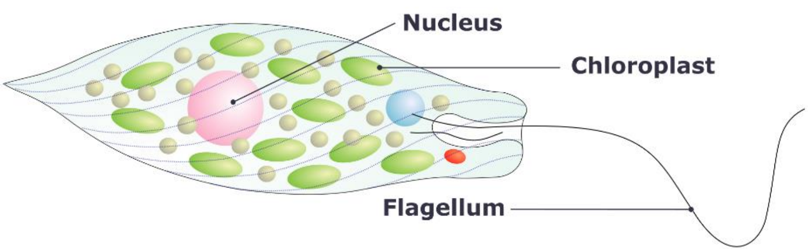

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Euglena is a unicellular organism that is found in water. They also have a flagellum that helps them swim and chloroplasts for photosynthesis. Other examples of unicellular organisms include amoebas and some fungi such as yeast.

Q1. The following statements are either true or false. State which are true and which are false.

a) There are seven life processes that all living organisms perform.

....

b) Unicellular organisms are living organisms made of more than one cell.

....

c) All living organisms carry out respiration.

....

d) All living organisms carry out photosynthesis.

....

e) Bacteria are an example of a unicellular organism.

....

f) Bacteria contain a nucleus.

....

Q2. State the acronym that we use to remember the life processes that living organisms perform.

....

Q3. State all of the life processes that living organisms perform.

....

....

....

Q4. State three examples of unicellular organisms.

....

....

Q5. State three organelles that euglena are made of and describe the purpose of each organelle.

....

....

....

....

Q6. State two organelles that bacteria are made of and describe the purpose of each organelle.

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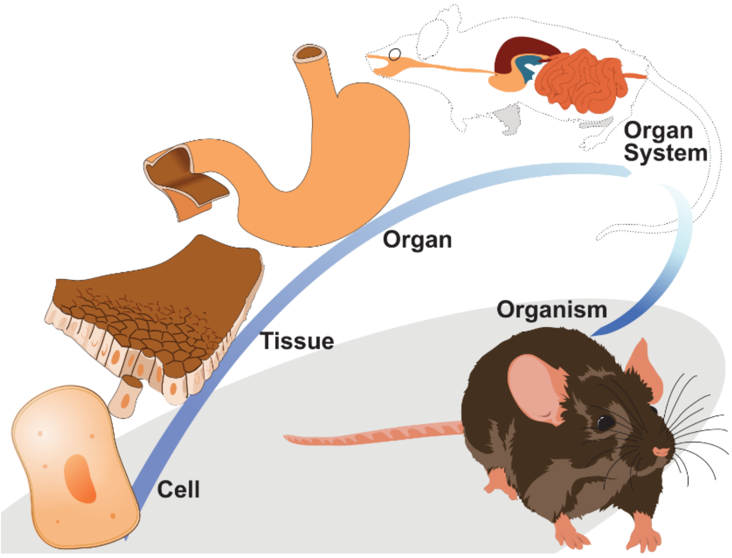
Cell organisation

Multicellular organisms are made of many individual cells and need a way of organising cells so that they can work together. These levels are arranged in a hierarchy from simple to complex: cells, tissues, organs, organ systems, and finally, organisms.



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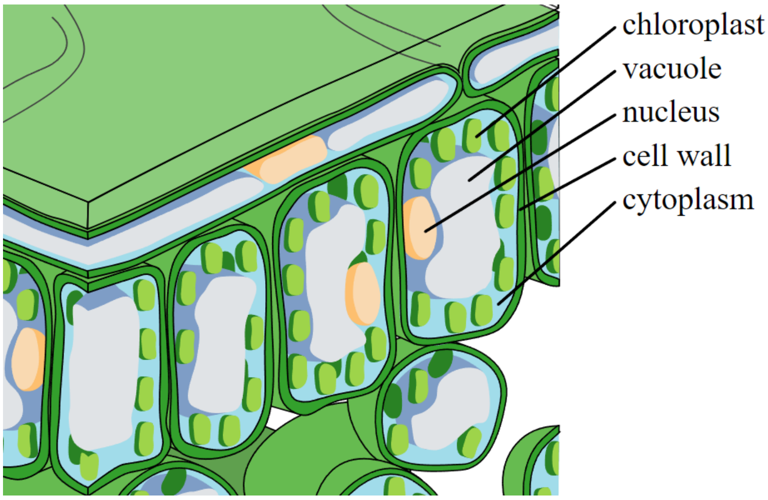
The diagram to the right shows cell organisation to form the digestive system of a mouse. Firstly, epithelial cells are shown. These cells line the stomach, providing a protective barrier and aiding in nutrient absorption.

These cells are arranged into epithelial **tissue** which, in turn, is joined with other tissues to form the stomach. The stomach is an **organ** which is then combined with other organs, such as the intestines, to form the digestive system. Different organs join together to form **organ systems**. Collectively, organ systems form the whole **organism**.



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Another example of cell organisation is the organisation of cells in a leaf. One of the cells in a leaf is called a palisade cell. Palisade cells are near the surface of a leaf and have many chloroplasts for photosynthesis.

Palisade cells join together to form palisade tissue (shown in the image to the left). In turn, different tissues join to form a leaf which is an organ. Leaves combine with other organs to form the shoot system.

A summary of the cell organisation for both examples is below:

Epithelial cells	→	Epithelial tissue	→	Stomach	→	Digestive system	→	Organism
Palisade cells	→	Palisade tissue	→	Leaf	→	Shoot system	→	Organism

Q1. The following statements are either true or false. State which are true and which are false.

a) Multicellular organisms are made of many individual cells.

....

b) The stomach is a tissue.

....

c) A tissue is made from a group of similar cells working together.

....

d) Plant leaves are organs.

....

e) Epithelial cells are needed for photosynthesis.

....

Q2. Describe the difference between tissues and organs.

....

....

Q3. Describe an example of cell organisation in a plant. Include a description of how cells are organised into tissues, organs and organ systems.

....

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Q4. Describe an example of cell organisation in an animal. Include a description of how cells are organised into tissues, organs and organ systems.

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Q5. State three organelles that a palisade cell is made of and describe the purpose of each organelle.

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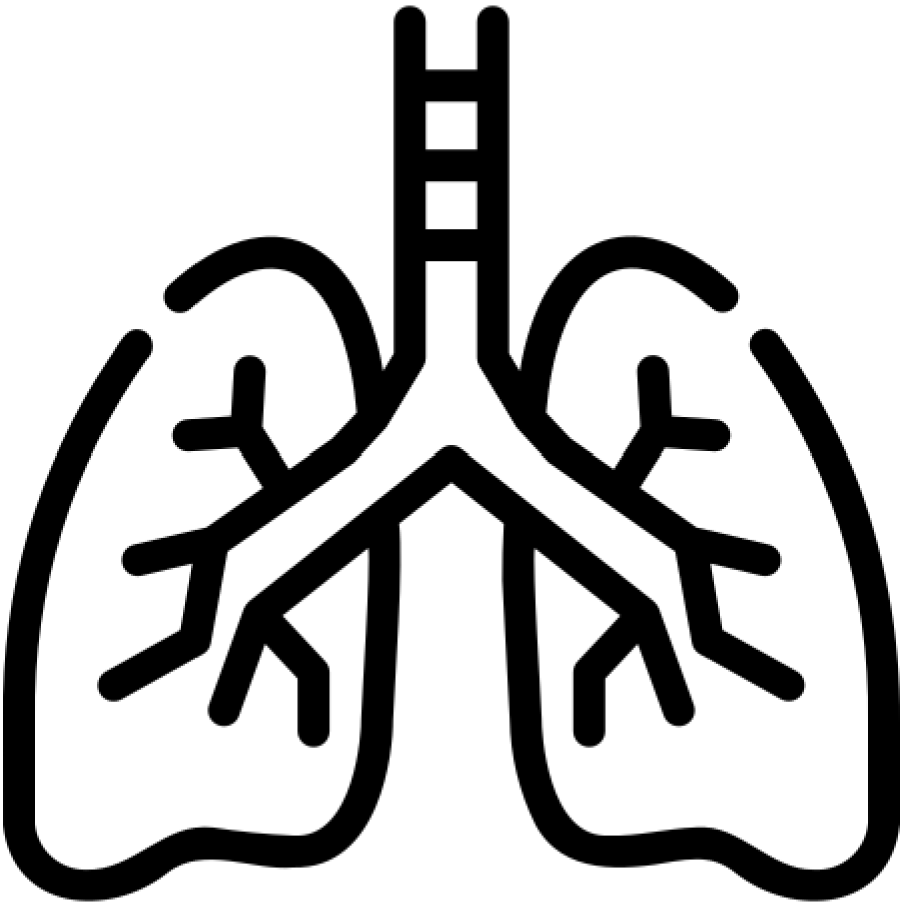
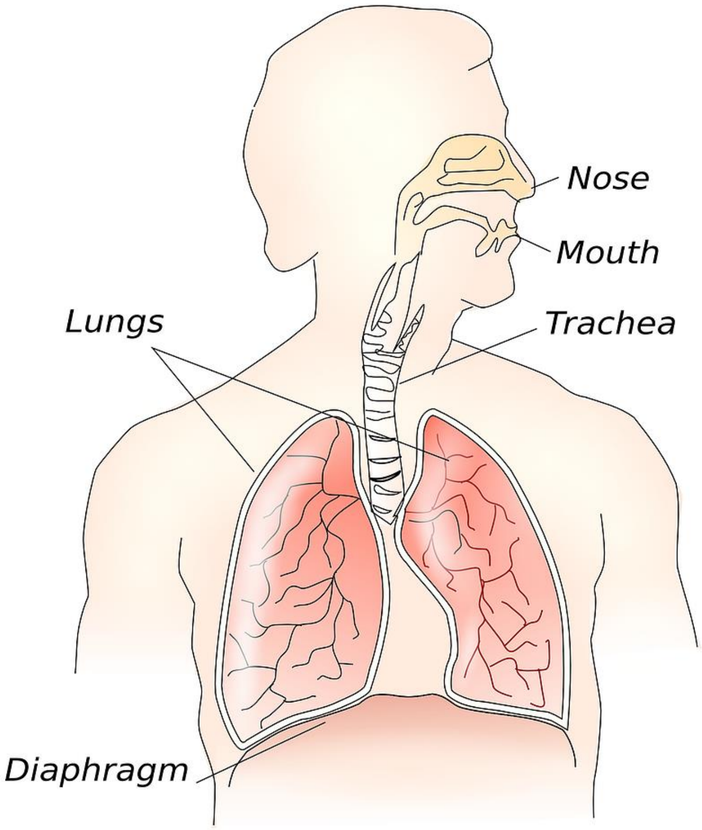
Gas exchange



and respiration

Breathing

Breathing is the mechanical process that moves air in and out of the **lungs**, allowing us to take in **oxygen** and expel **carbon dioxide**. The lungs are an **organ** that is part of an organ system called the **respiratory system**.



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The respiratory system (shown in the diagram) includes the nose, mouth, trachea, lungs and diaphragm. Each part contributes as follows:

1. **Nose and mouth**. Air enters the body through the nose or mouth. The nose warms and filters the air, trapping dust and other particles.

2. **Trachea**. Also known as the windpipe, the trachea connects the throat to the lungs.

3. **Lungs**. The trachea divides into two tubes (called bronchi) one for each lung. The bronchi split into smaller tubes (called bronchioles) which then take the air to small air sacs called alveoli. Gas exchange takes place in the alveoli.

4. **Diaphragm**. The diaphragm is a large muscle located below the lungs. It contracts and relaxes to change the volume of the chest cavity.

Breathing consists of two phases: **inhalation** (breathing in) and **exhalation** (breathing out).

When you inhale, the diaphragm contracts and moves downward. This increases the space in the chest cavity. Muscles between the ribs, called intercostal muscles also contract and pull the ribcage up and out. The increase in chest cavity volume lowers the air pressure inside the lungs compared to outside the body. Due to the lower pressure inside the lungs, air is drawn in through the nose or mouth, down the trachea and bronchi, and into the alveoli.

The opposite happens when you exhale. Both the diaphragm and intercostal muscles relax. This decreases the chest cavity volume and raises the air pressure inside the lungs. This higher pressure forces air out of the alveoli, up the bronchi and trachea and out through the nose or mouth.

Q1. The following statements are either true or false. State which are true and which are false.

a) The diaphragm relaxes during inhalation.

....

b) The lungs are an organ.

....

c) The intercostal muscles relax during exhalation.

....

d) Gas exchange takes place in alveoli.

....

e) Expanding the chest cavity causes a reduction in pressure.

....

f) The nose filters air and traps dust and other particles.

....

g) The trachea contracts during inhalation.

....

Q2. Describe what is meant by breathing.

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....

Q3. Describe how air reaches the alveoli from the trachea.

....

....

Q4. Describe the role of the diaphragm and intercostal muscles in inhalation.

....

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Q5. Explain why the pressure inside the lungs changes during inhalation and exhalation and how this affects air movement.

....

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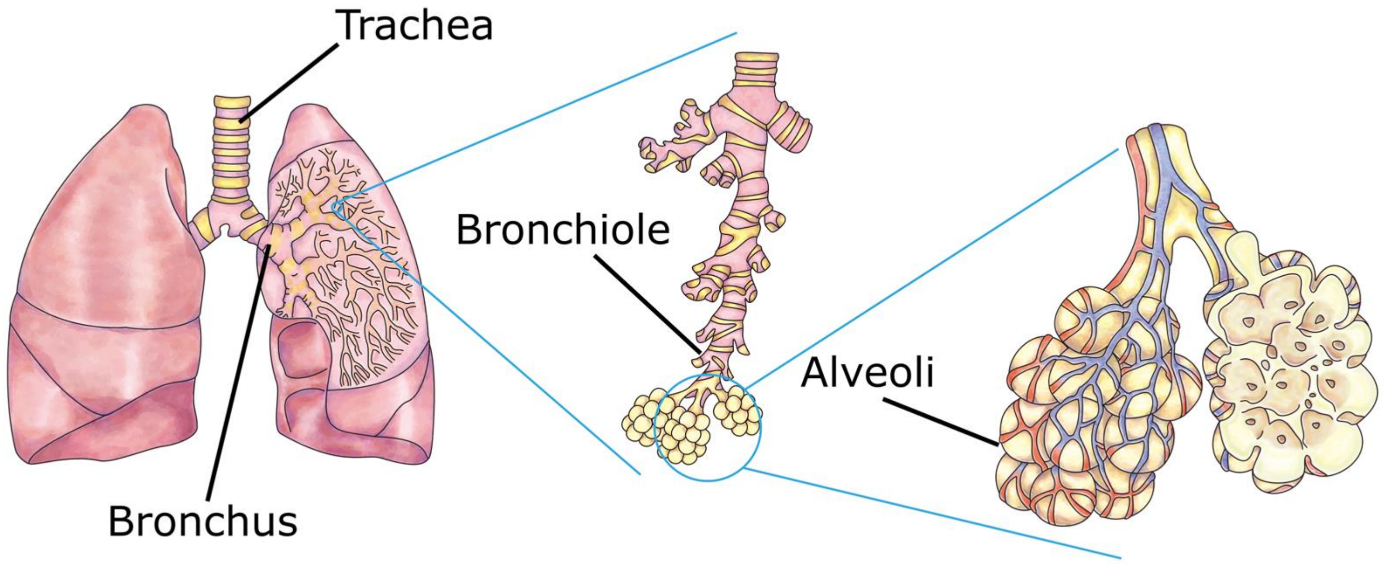
....

Gas exchange in humans

Gas exchange is a vital process in humans that involves taking in **oxygen** from the air and removing **carbon dioxide** from the bloodstream. This exchange takes place in tiny air sacs called **alveoli**. A single one of these air sacs is called an **alveolus**.



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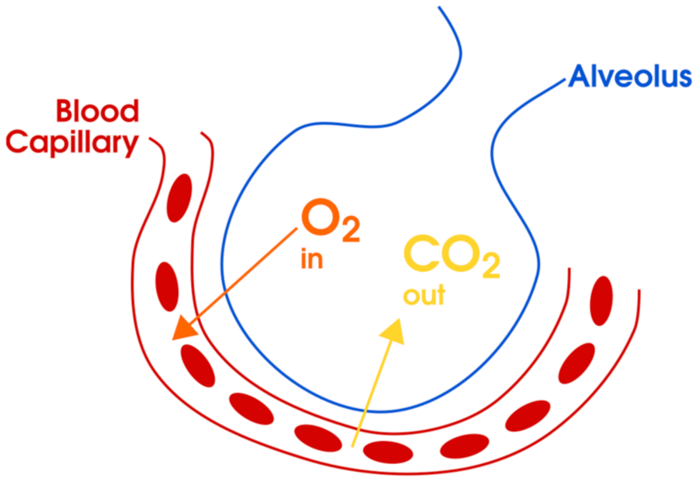
When you inhale, air first travels through the trachea and then through the bronchi and bronchioles before entering the alveoli. Oxygen from the inhaled air diffuses through the thin walls of the alveoli and into the surrounding capillaries. These are small blood vessels that wrap around each alveolus. Diffusion is the movement of particles from a high concentration (of those particles) to a lower concentration.

Carbon dioxide, a waste product of cellular respiration, is carried by the blood back to the lungs. In the alveoli, carbon dioxide diffuses from the blood into the alveoli. When you exhale, carbon dioxide is expelled from the body through the bronchioles, bronchi, trachea, and out through the nose or mouth.

Alveoli maximise diffusion in the lungs by:

- Giving the lungs a large surface area.
- Having a good blood supply, with surrounding capillaries that have thin walls.
- Being moist, so that gases dissolve quickly.

Collectively, this allows for efficient oxygen (O_2) intake and carbon dioxide (CO_2) removal.



domdomegg, CC BY 4.0, via Wikimedia Commons

Q1. The following statements are either true or false. State which are true and which are false.

a) Carbon dioxide is a waste product of respiration.

……

b) Diffusion is the movement of particles from a low concentration to a higher concentration.

……

c) Alveoli give the lungs a small surface area.

……

d) There are small blood vessels called capillaries wrapped around each alveolus.

……

e) Blood capillaries have thick walls to protect them.

……

f) Gas exchange is necessary for providing oxygen to the body's cells.

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Q2. Describe three ways the alveoli maximise diffusion in the lungs.

……

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……

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Q3. When you exhale, describe the route that carbon dioxide takes to be expelled from the body.

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Q4. Compare the concentration of oxygen and carbon dioxide in the blood before and after it passes through the alveoli.

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……

……

Exercise, asthma and smoking

Gas exchange is affected by factors like exercise, asthma and smoking. When you **exercise**, your muscles need more oxygen to produce energy. As a result, your breathing rate increases to take in more oxygen and expel more carbon dioxide. Your heart rate also increases to circulate oxygen-rich blood to your muscles. Regular exercise can increase lung capacity over time, improving the efficiency of gas exchange.

Asthma is a condition that affects the airways, including the bronchi and bronchioles, making it difficult for air to move in and out of the lungs. It can lead to symptoms such as wheezing, coughing, shortness of breath, and chest tightness. During an asthma attack:

- The muscles around the bronchi and bronchioles tighten, reducing their diameter.
- The lining of the bronchi and bronchioles becomes swollen and inflamed.
- Airways produce more mucus, which blocks airflow and makes breathing difficult.

These changes reduce the efficiency of gas exchange in the alveoli by limiting the flow of air into and out of the lungs. Asthma can be triggered by factors like exercise, allergies, cold air, or smoke. Inhalers are often used to relax the muscles around the bronchi and bronchioles, helping to open the airways and make breathing easier.

Smoking has a significant impact on the respiratory system and gas exchange in the lungs. Cigarette smoke contains the following substances:

- **Nicotine**. This addictive substance makes it difficult for people to quit smoking. It stimulates the nervous system, increasing heart rate and blood pressure.
- **Carbon monoxide**. This is a poisonous gas that binds to haemoglobin in red blood cells more effectively than oxygen. This reduces the blood's capacity to transport oxygen, making it harder for oxygen to reach your body's cells.
- **Tar**. This is a sticky substance that can coat the inside of the lungs. It damages the cilia (shown to the right), tiny hair-like structures that help keep the airways clean by removing mucus. Without functioning cilia, mucus builds up and sticks to the airways. This could lead to bronchitis and emphysema. Tar also contains substances that can cause cancer, called carcinogens.

John.devos, CC BY-SA 4.0 via Wikimedia Commons

One simple way to measure lung volume is using water displacement with an upside-down bottle. Fill a large container with water and submerge an empty bottle in it, keeping the opening underwater. Inhale deeply, then exhale into a tube connected to the bottle. The exhaled air displaces the water in the bottle, and the volume of displaced water corresponds to the lung volume.

Q1. The following statements are either true or false. State which are true and which are false.

a) When you exercise, your breathing rate increases.

....

b) Nicotine is addictive.

....

c) Allergies can trigger an asthma attack.

....

d) Tar contains carcinogens.

....

e) Cilia are tiny hair-like structures that remove mucus.

....

Q2. State and explain what happens to your breathing rate and heart rate during exercise.

....

....

....

Q3. Describe how you could measure lung volume.

....

....

....

....

Q4. Describe why tar in cigarettes is harmful.

....

....

Q5. State three potential triggers of an asthma attack.

....

Q6. Describe what happens to the respiratory system during an asthma attack.

....

....

....

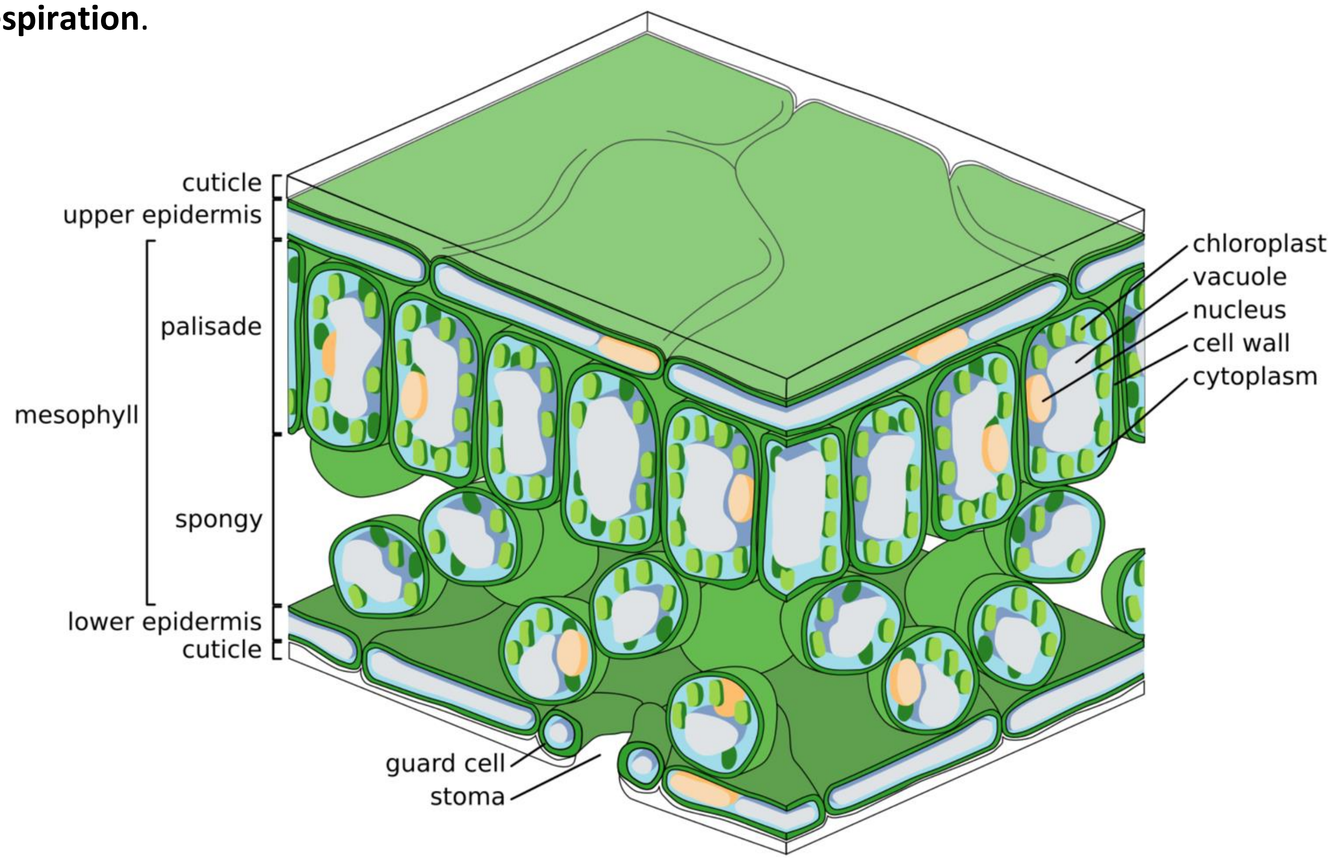
Q7. Describe why carbon monoxide is poisonous.

....

....

Gas exchange in plants

Plants, like animals, need to exchange gases with their environment to survive. Gas exchange in plants mainly involves taking in **carbon dioxide** and releasing **oxygen** during **photosynthesis**. It also involves taking in oxygen and releasing carbon dioxide during **respiration**.



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The leaf (cross-section shown above) is designed for gas exchange, with several key structures playing important roles:

1. **Stomata** are small openings mainly located on the underside of leaves. Each **stoma** is surrounded by two guard cells that control its opening and closing. When stomata are open, carbon dioxide enters the leaf and oxygen and water vapour exit.
2. **Guard cells** are responsible for opening and closing the stomata. When the plant has plenty of water, the guard cells swell and open the stomata to allow gas exchange. When water is scarce, they shrink and close the stomata to prevent water loss.
3. The **spongy mesophyll layer** contains loosely arranged cells with air spaces that facilitate the movement of gases. The air spaces allow carbon dioxide to diffuse through the leaf to the palisade cells for photosynthesis.
4. The **palisade mesophyll layer** consists of tightly packed cells that are rich in chloroplasts, the site of photosynthesis.
5. The **waxy cuticle** is a thin, protective layer that covers the leaf surface. It prevents excessive water loss by reducing evaporation while allowing light to penetrate.

Q1. The following statements are either true or false. State which are true and which are false.

a) Stomata are small openings mainly located on the upper side of leaves.

....

b) The spongy mesophyll layer is tightly packed with cells rich in chloroplasts.

....

c) Guard cells open the stomata when the plant has plenty of water.

....

d) Photosynthesis occurs in the palisade cells.

....

e) During photosynthesis, oxygen is taken in and carbon dioxide is released.

....

f) Only animals undergo respiration, plants do not respire.

....

Q2. Describe the role that guard cells have in gas exchange in plants.

....

....

....

....

Q3. Describe the function of the spongy mesophyll layer in a leaf.

....

....

....

....

Q4. Describe how the structure of the palisade mesophyll layer is suited for photosynthesis.

....

....

Q5. Describe the role of the waxy cuticle.

....

....

Aerobic and anaerobic respiration

Respiration provides energy for all living organisms. It occurs in every cell of every organism, allowing them to perform essential functions. There are two main types of respiration: aerobic and anaerobic.

Aerobic respiration requires **oxygen** to release energy from **glucose**. It occurs in the **mitochondria** of cells and is the main way our bodies get energy. The chemical equation for aerobic respiration is:

glucose + oxygen → carbon dioxide + water + energy

We can see that glucose and oxygen are the reactants, while carbon dioxide and water are the products of aerobic respiration. Aerobic respiration is efficient and produces a large amount of energy. It is the primary method of respiration used during activities that require endurance and sustained energy such as running a marathon, cycling, or swimming long distances.

Anaerobic respiration does not require oxygen and occurs when oxygen levels are low. This process happens in the cytoplasm of cells. The chemical equation for anaerobic respiration in humans is:

glucose → lactic acid + energy

We can see that glucose is broken down without oxygen. Energy is still released, but in lower quantities than in aerobic respiration. Anaerobic respiration is used during intense exercise when oxygen supply to muscles is limited, such as sprinting or weightlifting. In these situations, muscles rely on anaerobic respiration to provide quick bursts of energy, but the buildup of lactic acid can cause muscle fatigue and soreness.

After intense exercise, the body needs to repay the "oxygen debt" incurred from anaerobic respiration. To break down lactic acid and restore the muscles to their normal state, additional oxygen is required. During recovery, increased breathing and heart rate help supply this oxygen, allowing the body to clear lactic acid and replenish energy stores.

Anaerobic respiration can look different in different organisms. For example, yeast can also perform anaerobic respiration. Yeast is a type of fungus and a unicellular organism. This process is known as **fermentation**. The chemical equation for fermentation is:

glucose → ethanol + carbon dioxide + energy

This process is used in bread making and brewing because the carbon dioxide helps dough rise and the ethanol is the alcohol found in drinks like beer and wine.

Q1. The following statements are either true or false. State which are true and which are false.

a) Aerobic respiration occurs without oxygen.

....

b) Anaerobic respiration produces more energy than aerobic respiration.

....

c) Lactic acid can cause muscle fatigue and soreness.

....

d) Yeast undergo anaerobic respiration during fermentation.

....

e) Only animal cells carry out aerobic respiration.

....

Q2. State the products of aerobic respiration.

....

Q3. State which organelle carries out aerobic respiration.

....

Q4. State the products of anaerobic respiration.

....

Q5. State where anaerobic respiration occurs in the cell.

....

Q6. Write a word equation for aerobic respiration.

....

Q7. Write a word equation for anaerobic respiration.

....

Q8. State an example of when anaerobic respiration occurs in humans.

....

Q9. Describe the differences between aerobic and anaerobic respiration.

....

....

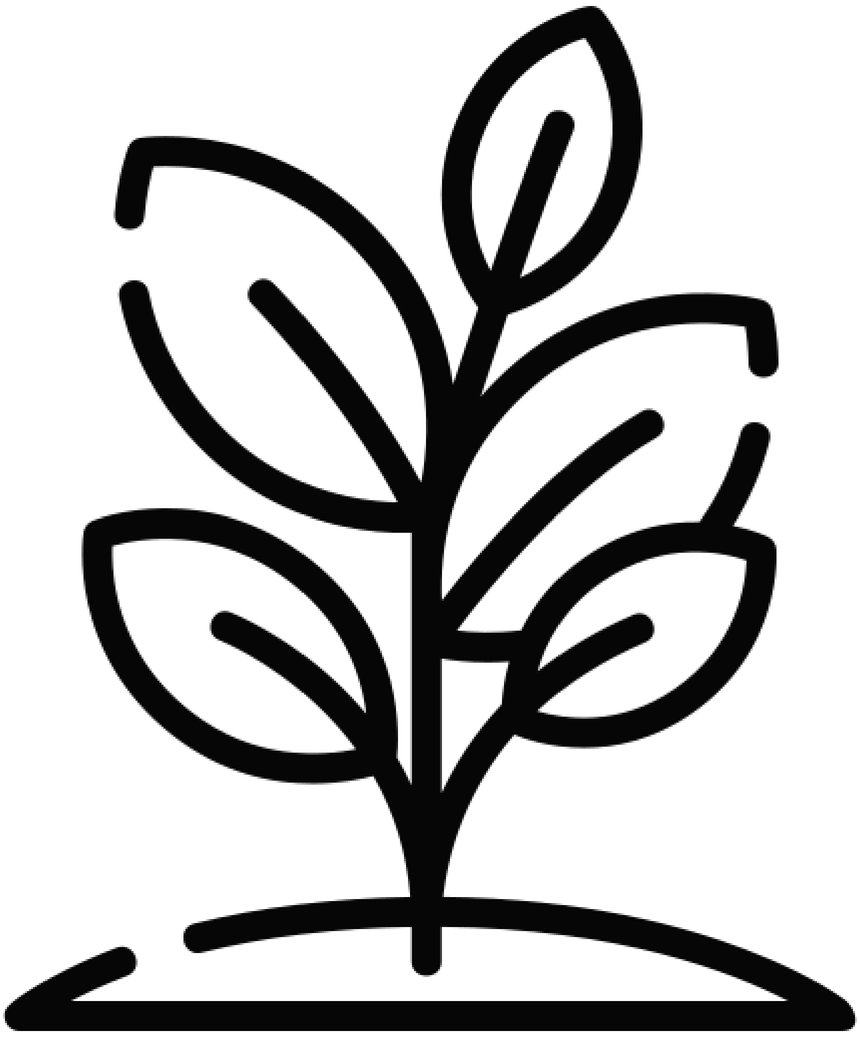
....

....

Q10. State two uses of the anaerobic respiration of yeast.

....

Plants and



photosynthesis

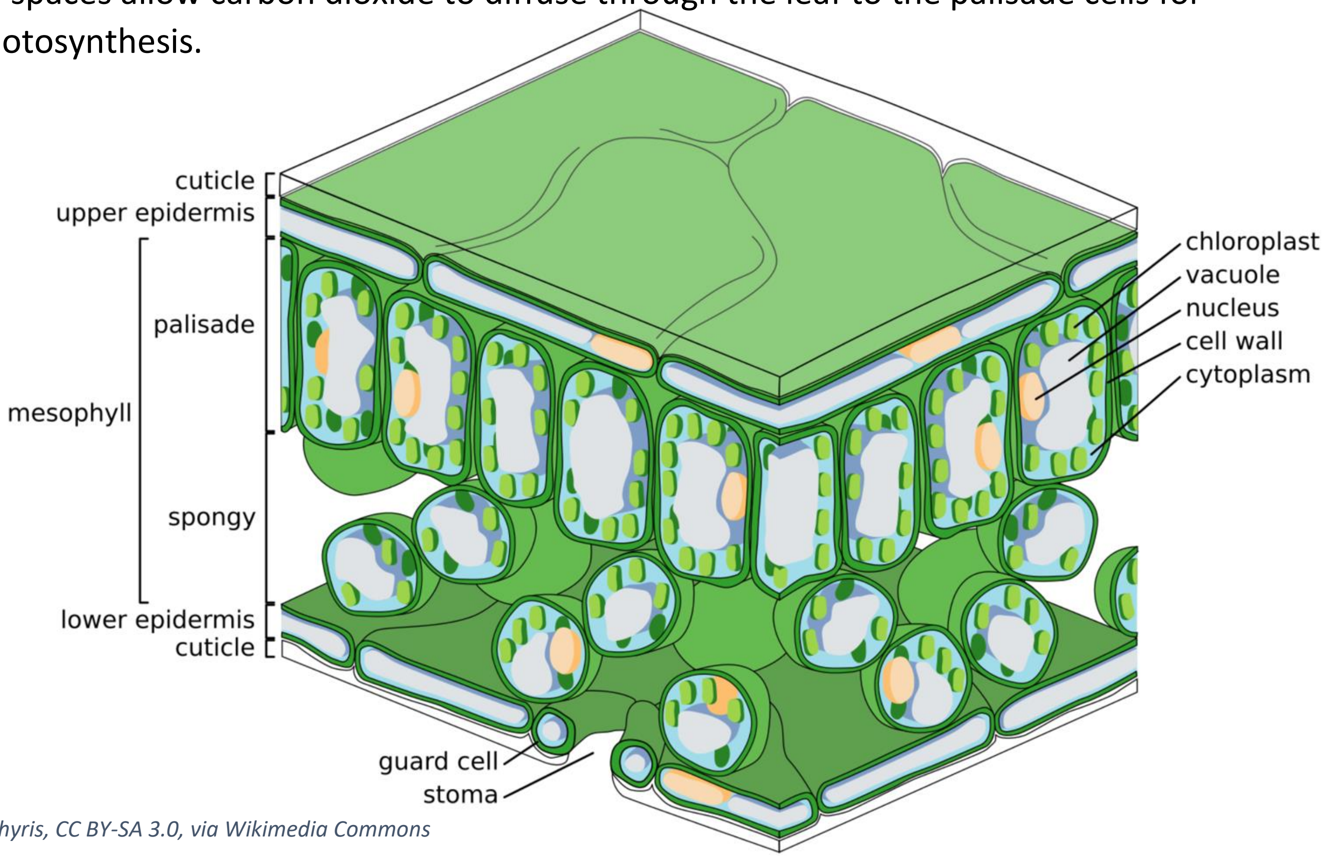
Photosynthesis

Photosynthesis is a chemical reaction that produces **glucose** (a type of sugar). This glucose can then be used for respiration, the process where cells release energy from glucose. During photosynthesis, plants use sunlight to turn carbon dioxide and water into glucose and oxygen. The chemical equation for photosynthesis is:

carbon dioxide + water → glucose + oxygen

Photosynthesis occurs in **chloroplasts**, which contain the green pigment **chlorophyll**. Chloroplasts are an organelle that are particularly found in a leaf's **palisade** cells. These cells are found near the top of a leaf, where they get the most light. Leaves are also well adapted for photosynthesis as they have a large surface area.

Carbon dioxide enters the underside of a leaf through stomata. The spongy mesophyll layer contains loosely arranged cells with air spaces that allow for the movement of gases. The air spaces allow carbon dioxide to diffuse through the leaf to the palisade cells for photosynthesis.



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The rate of photosynthesis is affected by light intensity, carbon dioxide concentration, temperature, and water availability. To measure this rate, you can conduct an experiment using pondweed in water. Cover the pondweed with an inverted funnel and place a water-filled test tube over it to capture the oxygen produced. A lamp can be used to provide a steady light source. By counting the oxygen bubbles released in one minute, you can estimate the rate of photosynthesis. By adjusting variables like light intensity or temperature, you can observe how these factors affect photosynthesis.

Q1. The following statements are either true or false. State which are true and which are false.

a) Photosynthesis is a chemical reaction.

....

b) Plants do not carry out respiration.

....

c) Photosynthesis occurs in chloroplasts.

....

d) Palisade cells contain many chloroplasts.

....

Q2. State the products of photosynthesis.

....

Q3. Write a word equation for photosynthesis.

....

Q4. Describe an experiment that could investigate the effect of light intensity on the rate of photosynthesis. Include a description of how you would change the light intensity.

....

....

....

....

Q5. Other than light intensity, state three other factors that the rate of photosynthesis depends on.

....

....

Q6. Euglena is a unicellular organism that is found in water and carries out photosynthesis. State what organelle it must contain for photosynthesis to occur.

....

Q7. State why it is an advantage that palisade cells are generally found near the top of a leaf.

....

....

Q8. Describe the movement of carbon dioxide from the air into the palisade cells.

....

....

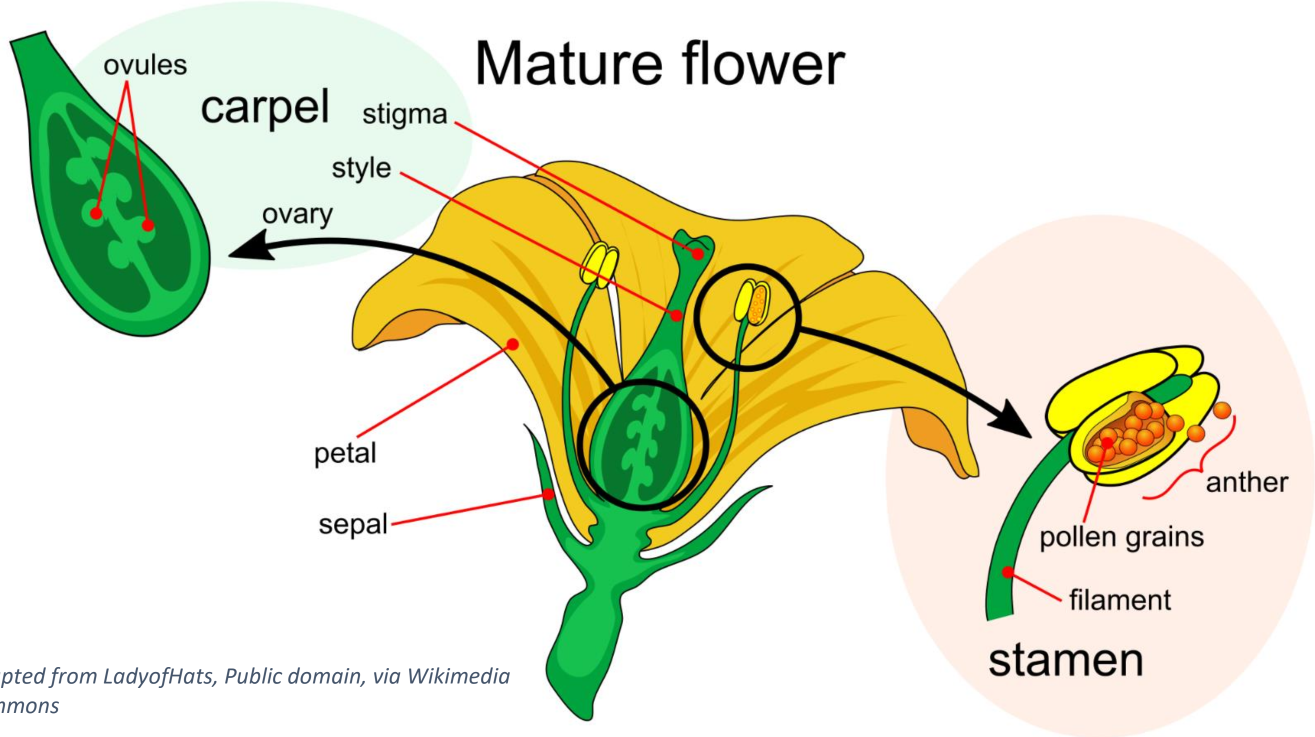
....

....

Pollination

Pollination involves the transfer of pollen from the male part of the flower (the stamen) to the female part (the carpel). This process allows plants to reproduce and create seeds for the next generation of plants. Before understanding pollination, we first need to know the different parts of a flower:

1. The **stamen** is the male reproductive part of the flower. It consists of:
    - The **anther**, which produces **pollen grains** that contain the male sex cells.
    - The **filament**, a stalk which supports the anther.
2. The **carpel** is the female reproductive part of the flower. It includes:
    - The **stigma**, the sticky surface at the top that captures pollen.
    - The **style**, a tube that connects the stigma to the ovary.
    - The **ovary**, which contains female sex cells inside **ovules**.
3. **Petals** are often brightly coloured to attract pollinators such as bees and butterflies.
4. **Sepals** are green and leaf-life and protect the flower bud before it opens.



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There are two main types of pollination:

1. **Self-pollination** occurs when pollen from the anther of a flower lands on the stigma of the same flower or another flower on the same plant. This can happen without the need for external pollinators.
2. **Cross-pollination** involves the transfer of pollen from the anther of one flower to the stigma of a flower on a different plant of the same species. Cross-pollination often requires the help of pollinators like insects such as bees or butterflies or the wind.

Once pollen reaches a stigma, a **seed** can be made.

Q1. The following statements are either true or false. State which are true and which are false.

a) The male reproductive part of the flower is called the carpel.

....

b) The stigma produces pollen grains.

....

c) Petals are often brightly coloured.

....

d) The anther is supported by the filament.

....

e) Pollination allows plants to reproduce and create seeds.

....

f) Pollination occurs when pollen reaches a stigma.

....

g) Wind can lead to pollination.

....

Q2. Describe what the stamen is and what it consists of.

....

....

....

Q3. Describe what the carpel is and what it consists of.

....

....

....

Q4. Describe the difference between self-pollination and cross-pollination.

....

....

....

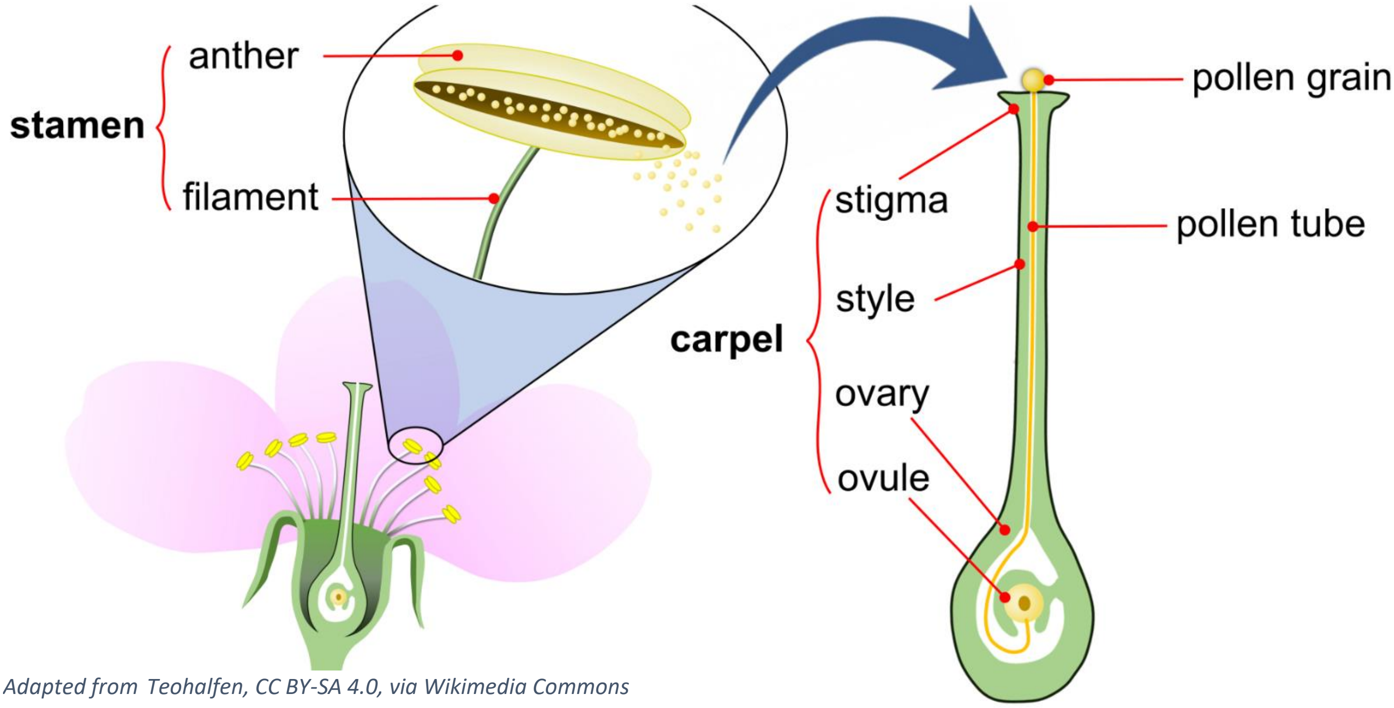
....

Q5. State two pollinators.

....

Fertilisation and seed formation

Fertilisation occurs after successful pollination, when **pollen** from the **stamen** (the male part of the flower) reaches the **carpel** (the female part of the flower).



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Once the pollen grain lands on a **stigma**, it germinates and grows a pollen tube down through the style towards the ovary. The nucleus of a male sex cell then moves through this tube and joins with the nucleus of the ovule. The process of the two nuclei joining is called **fertilisation**.

The fertilised ovule becomes a **seed**. Each seed contains an embryo plant and is equipped with a food store to nourish the embryo as it grows. The seed is protected by a seed coat. As seeds develop, the ovary transforms into a fruit, which helps protect the seeds and can aid in their dispersal. Fruits come in many forms, such as berries, nuts and pods.

Many of the crops that form the basis of the human diet, such as fruits, vegetables, and nuts, depend on pollination by insects like bees, butterflies, and beetles. These pollinators transfer pollen from flower to flower, enabling plants to produce seeds and fruit. Without insect pollination, crop yields would decrease significantly, leading to reduced food availability and increased prices. This would have a direct impact on global food security, affecting both the quantity and diversity of foods available.

Louise Docker, CC BY 2.0, via Wikimedia Commons

Q1. The following statements are either true or false. State which are true and which are false.

a) Fertilisation happens before pollination.

………………………………………………………………………………………………

b) After pollination, a pollen tube grows from the stigma to the ovary.

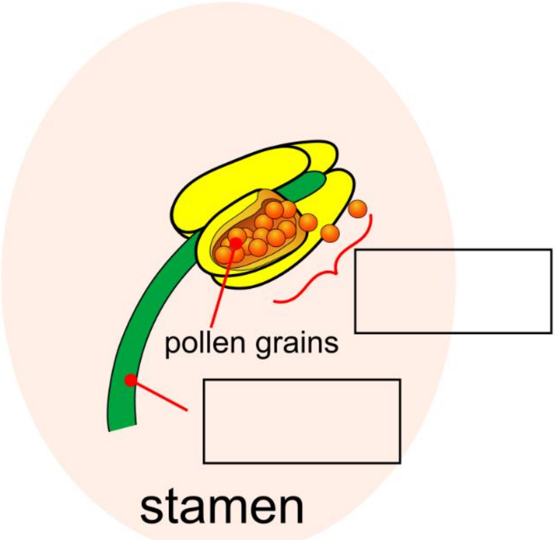
………………………………………………………………………………………………

c) The stamen is the male part of the flower.

………………………………………………………………………………………………

d) The anther and filament make up the carpel.

………………………………………………………………………………………………



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Q2. A diagram of the stamen is shown to the right. Fill in the missing labels in the boxes.

Q3. Describe how plant fertilisation occurs.

……

……

……

……

Q4. Describe how a fruit is formed.

……

……

……

……

Q5. State three parts of a seed.

……

……

Q6. Bee populations are declining in the UK. Explain the effect that this might have on food availability and prices.

……

……

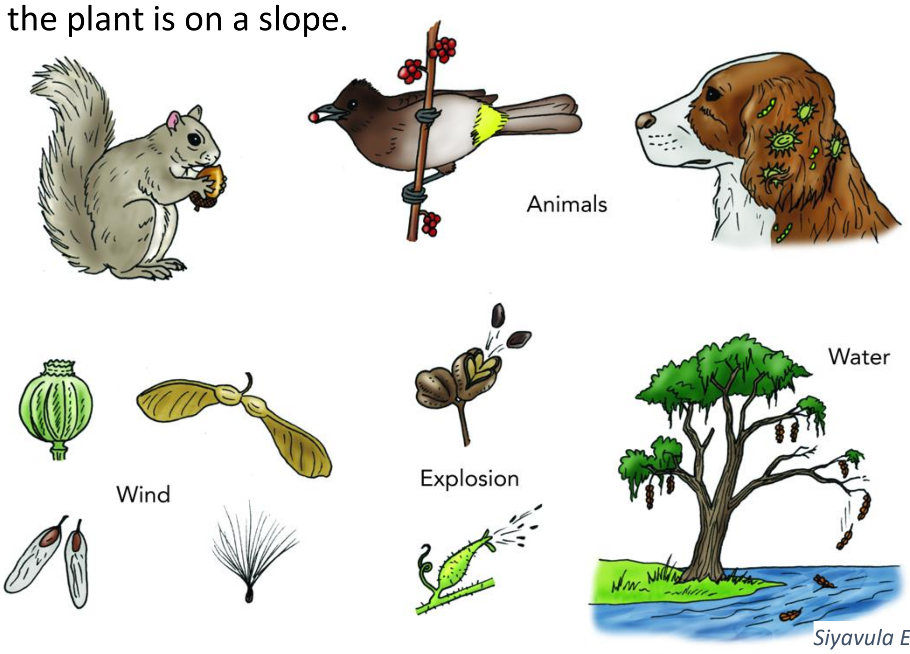
……

……

Seed dispersal

For new plants to grow, seeds need to be **dispersed** away from the parent plant. This helps plants to spread to new areas, promotes genetic diversity and reduces competition for resources such as water and light. Different plants have evolved various seed dispersal mechanisms to ensure their seeds are carried away from the parent plant. These mechanisms include:

- **Wind dispersal.** Some seeds are light and have special structures that help them catch the wind. For example, dandelion seeds have feathery bristles, and maple seeds have wings that allow them to be carried by the wind.
- **Water dispersal.** Seeds that are dispersed by water often have waterproof coverings that enable them to float. Coconuts, for instance, can travel long distances across oceans and still germinate.
- **Animal dispersal.** Animals can disperse seeds in several ways. Seeds with hooks or spines, like burrs, attach to the fur or feathers of animals and are carried to new locations. Some seeds are eaten by animals and later excreted in different areas.
- **Explosive dispersal.** Some plants have seed pods that dry out and burst open, flinging seeds in all directions. An example of this are pea pods.
- **Gravity dispersal.** Fruit simply falls from the plant and relies on gravity to roll away, especially if the plant is on a slope.



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You can investigate how effectively different types of seeds are dispersed by the wind with a simple experiment. In a clear, open area, use a fan or hairdryer to create a steady breeze. Drop a seed from a marked starting point and let the wind carry it. Measure the distance the seed travels and record the result. Repeat this with different types of seeds and compare which ones travel the furthest. This experiment shows how different seed structures help or hinder wind dispersal.

Q1. The following statements are either true or false. State which are true and which are false.

a) Coconuts are an example of seeds dispersed by wind.

....

b) Animal fur can carry seeds to new locations.

....

c) If many plants grow in the same location, they compete for resources.

....

Q2. State four seed dispersal mechanisms.

....

....

Q3. Explain why it is necessary for seeds to be dispersed away from the parent plant.

....

....

....

Q4. Describe an experiment to investigate how effectively different types of seeds are dispersed by the wind.

....

....

....

....

Q5. Describe how maple seeds are adapted for dispersal.

....

....

Q6. Describe how animals can disperse seeds.

....

....

....

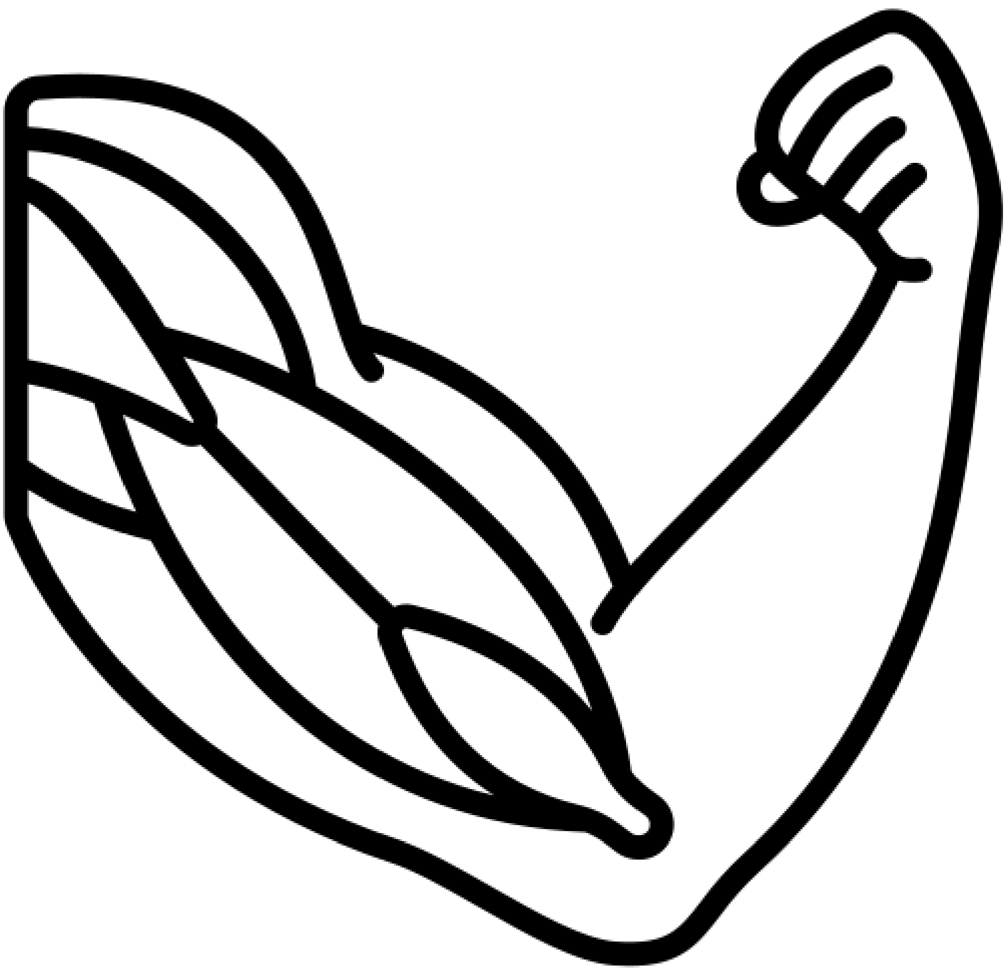
....

Q7. Describe how seeds can be dispersed by water.

....

....

The human

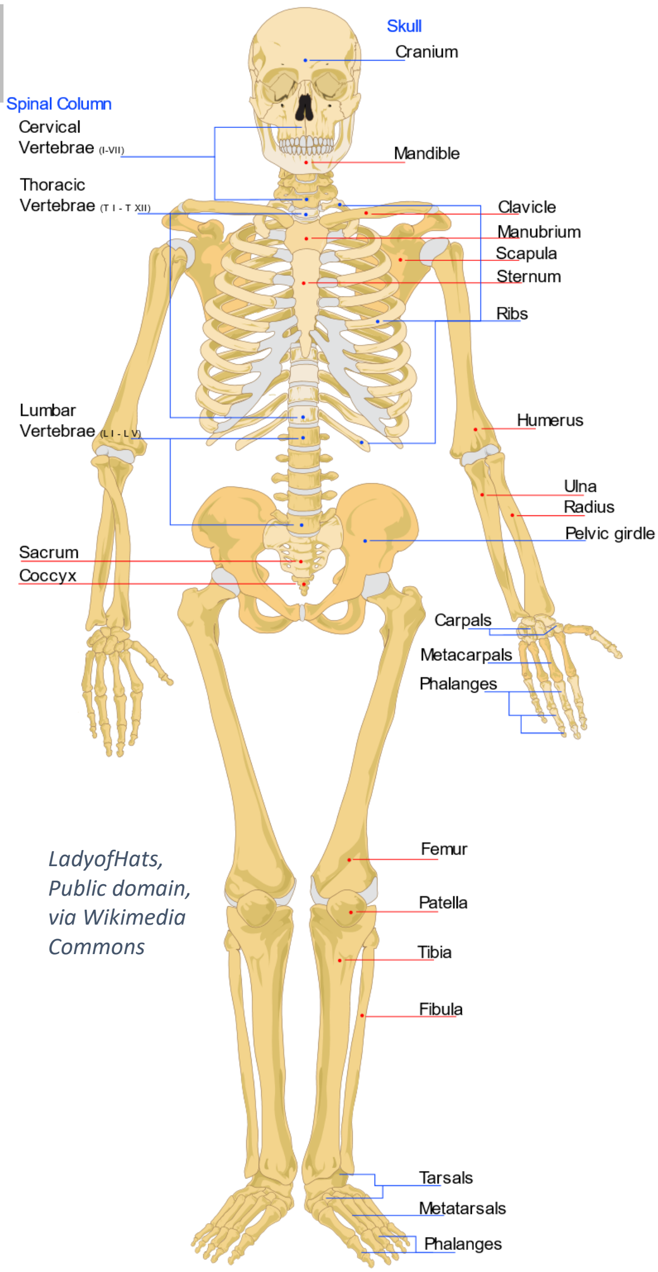


body

The skeleton

The human skeleton has 206 bones, all working together to support the body and enable movement. The skeleton's main functions are:

1. **Support**. The skeleton provides a solid framework that supports the body's shape.
2. **Protection**. The skeleton protects vital organs. For example, the ribcage protects the heart and lungs.
3. **Movement**. Bones work with muscles to allow movement. Muscles are attached to bones by tendons. When the muscles contract they pull on the bones, creating movement at the joints.
4. **Production of Blood Cells**. Inside some bones is bone marrow, a soft tissue where red and white blood cells are produced.
5. **Storage**. Bones store minerals such as calcium and phosphorus, which are important for bone strength and can be released into the body when needed.



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Major parts of the skeleton include:

- **Skull**. The skull is made up of many bones fused together. It protects the brain and forms the structure of the face.
- **Spine (Vertebral Column)**. The spine is made up of 33 vertebrae stacked on top of each other. It supports the body's weight and protects the spinal cord, which is a bundle of nerves that sends messages between the brain and the rest of the body.
- **Ribcage**. The ribcage consists of 12 pairs of ribs that protect the heart and lungs. It also supports the upper body and plays a role in breathing.
- **Pelvis**. The pelvis is a bowl-shaped structure that supports the weight of the upper body and protects the organs in the lower abdomen, such as the bladder and intestines.
- **Limbs**. The arms and legs are made up of long bones. In the arms, the main bones are the humerus, radius and ulna. In the legs, the main bones are the femur, tibia and fibula. The hands and feet have many small bones that allow for a wide range of movements.

Q1. The following statements are either true or false. State which are true and which are false.

a) The human skeleton has 206 bones.

....

b) The femur is one of the main bones in the arm.

....

c) Bone marrow produces white and red blood cells.

....

d) Muscles are attached to bones by tendons.

....

Q2. State five functions of the human skeleton.

....

....

Q3. Describe the role of the spine in the human body.

....

....

Q4. Describe the role of the pelvis in the human body.

....

....

Q5. Describe the role of the ribcage in the human body.

....

....

Q6. Describe how muscles and bones work together to create movement.

....

....

Q7. State three bones that are in the human leg.

....

Q8. State three bones that are in the human arm.

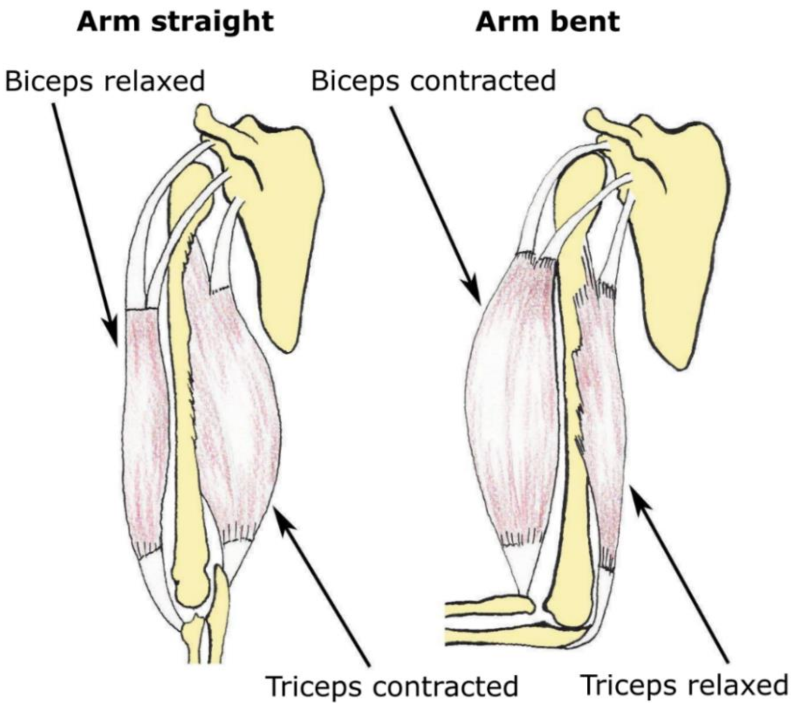
....

The muscular system

The muscular system is made up of over 600 muscles that work together to help your body move, maintain posture, and perform essential functions like breathing and digestion. Muscles are attached to bones by tough, fibrous tissues called **tendons**. When muscles contract, they pull on the bones, creating movement at the **joints**. Joints are where two or more bones meet.

Muscles can only pull and they cannot push. Because of this, muscles work in pairs called **antagonistic** pairs. This means that while one muscle **contracts** (shortens), the other muscle in the pair **relaxes** (lengthens).

One example of this can be seen in the image to the right. To straighten your arm, the triceps contract and the biceps relax. When the arm bends, the opposite happens. The biceps contract and the triceps relax. This coordinated action allows for smooth and controlled movement.



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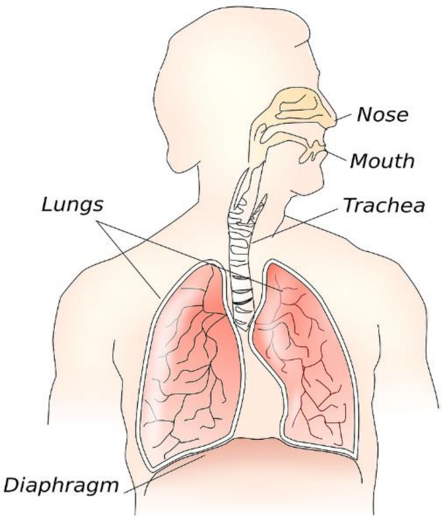
The leg also has two antagonistic muscles and bends in a similar way. To bend your leg, your hamstring contracts and your quadriceps relax. To straighten, your quadriceps contract and your hamstring relaxes.



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Muscles do much more than just help us move. They are involved in a variety of functions essential to life. For example, the **heart** is made up of a special type of muscle called **cardiac muscle**. Unlike the biceps and triceps, which are under voluntary control, cardiac muscle works involuntarily. It contracts rhythmically and continuously, pumping blood throughout the body.

Another example of a muscle is the **diaphragm** (shown to the left). This is a muscle located below the lungs and plays an important role in breathing. When you inhale, the diaphragm contracts and flattens. This allows the lungs to expand and fill with air.

Q1. The following statements are either true or false. State which are true and which are false.

a) When a muscle contracts, it pushes on the bone it is attached to.

....

b) The biceps and triceps are antagonistic muscles.

....

c) The heart is made of cardiac muscle.

....

d) There are over 600 muscles in the human body.

....

Q2. Describe what is meant by a joint.

....

....

Q3. Describe what is meant by antagonistic muscles.

....

....

Q4. Describe how the biceps and triceps straighten and bend the arm.

....

....

....

....

Q5. Describe how the hamstring and quadriceps straighten and bend the leg.

....

....

....

....

Q6. Describe how the diaphragm helps us to breathe.

....

....

....

....

Measuring forces exerted by muscles

A moment is the **turning effect** of a force around a point. When a muscle pulls on a bone, it creates a **moment** around the joint (which is the point where two bones meet). The size of this moment depends on two things: the amount of force the muscle generates and the distance from the joint to where the force is applied.

We can calculate a moment using the following equation:

Moment = force × distance

where the distance (measured in metres) is the **perpendicular distance to the pivot**. Forces are measured in **Newtons** (N) and moments are therefore measured in **Newton metres** (Nm).

To calculate the force applied by a muscle, we need to rearrange to make force the subject of the equation. This rearranged equation is:

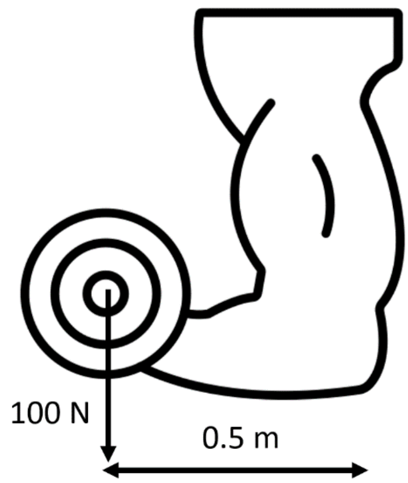
Force = moment ÷ distance

To directly measure the size of a force applied by a muscle, we could use a **Newton meter**.

Example question 1:

A person is doing a biceps curl and is holding a 100 N weight stationary. The distance from the centre of the weight to the person's elbow is 0.5 m.

Calculate the moment of the weight from the person's elbow.



Step 1. Write down equation:

Moment = force × distance

Step 2. Insert variables into equation:

Moment = 100 × 0.5

Step 3. Calculate answer. Remember units:

Moment = 50 Nm

Note that in the question above, the force applied by the person's biceps is the same size as the 100 N weight. This is because if the weight is stationary, then the forces on the weight must be balanced. The person must therefore be applying a 100 N force upwards to hold the weight still.

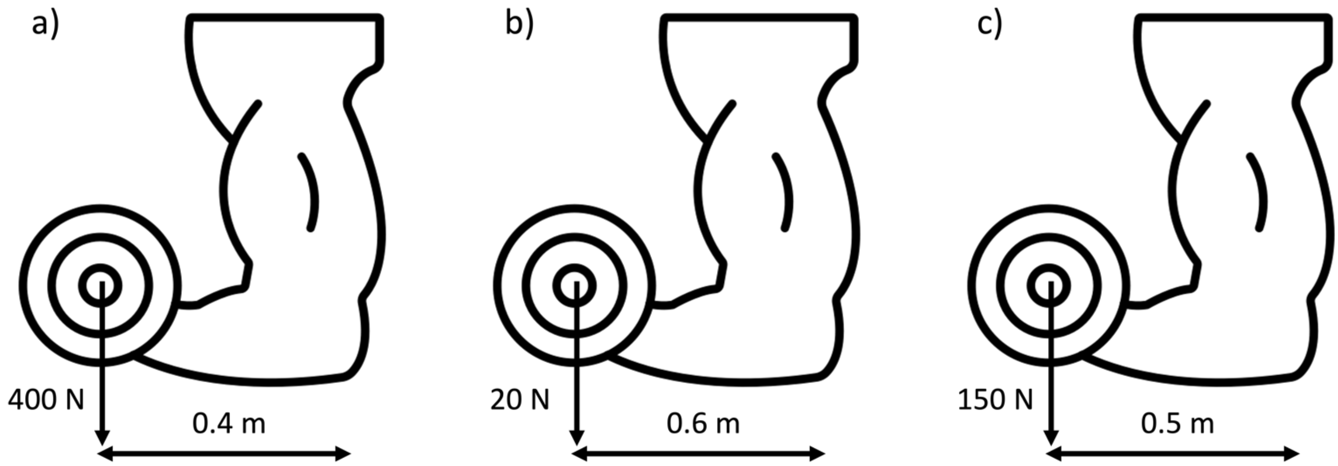
Q1. The following statements are either true or false. State which are true and which are false.

a) A moment is measured by a Newton meter.

b) A moment depends on both force and perpendicular distance to a pivot.

c) Muscles create a moment around a joint.

Q2. Using the diagrams below, calculate the moments of the weight from the person's elbow.



a)

b)

c)

Q3. A person's hamstring applies a moment of 1200 Nm at a distance of 0.6m from their knee. Calculate the force applied by the hamstring.

Q4. A person's biceps applies a moment of 120 Nm at a distance of 0.5m from their elbow. Calculate the force applied by the biceps.

Q5. A person's triceps applies a moment of 60 Nm at a distance of 0.4m from their elbow. Calculate the force applied by the triceps.

Drugs

Drugs are substances that can change how the body and mind work. Some drugs are used for medical reasons, like painkillers, but others are used for recreation. Recreational drugs can have serious effects on health and behaviour. Four types of drugs are described below:

Type of drug	Effect of the drug	Examples
Painkillers	Blocks pain signals from reaching the brain. They don't treat the cause of the pain but help to relieve discomfort.	Paracetamol, aspirin, ibuprofen.
Depressants	Slow down the brain's activity. They can make you feel relaxed or sleepy. However, they can also affect your coordination and make reaction times slower	Alcohol, heroin.
Stimulants	Increase brain activity, making you feel more awake and alert. They can also increase heart rate and blood pressure.	Caffeine, nicotine, cocaine.
Hallucinogens	Change your perception of reality. They can make you see, hear, or feel things that aren't really there.	LSD, magic mushrooms.

Alcohol is a legal drug. When consumed, alcohol enters the bloodstream and affects the brain, slowing down its functions. This is why alcohol is classified as a depressant. Drinking alcohol can cause slurred speech, blurred vision, and impaired judgment. It also affects coordination and reaction times, which is why it's dangerous to drive after drinking.

Regular and heavy drinking can lead to liver disease (like cirrhosis), heart disease, and an increased risk of certain cancers. Alcohol can also damage the brain, leading to memory problems and mental health issues. While alcohol can make you feel more relaxed, it can also lead to aggressive or risky behaviour. Excessive drinking can lead to addiction.

Addiction is when your body or mind becomes dependent on a substance, like drugs or alcohol. People with an addiction may feel a strong need to keep using the drug, even when they know it's harmful. When someone who is addicted to a drug stops using it, they may experience **withdrawal** symptoms. These can include anxiety, shaking, nausea and other physical and mental health issues.

Certain drugs are illegal because of their highly addictive nature and the severe harm they can cause to both mental and physical health. Examples of this include heroin and cocaine.

Q1. The following statements are either true or false. State which are true and which are false.

a) Stimulants slow down brain activity and make you feel sleepy.

....

b) Paracetamol is an example of a painkiller.

....

c) Alcohol is a stimulant.

....

d) Heroin and cocaine are examples of illegal drugs.

....

Q2. Explain why it is dangerous to drive after drinking alcohol.

....

....

....

....

Q3. Explain what is meant by addiction.

....

....

....

Q4. State three withdrawal symptoms.

....

....

Q5. Explain why some drugs, such as heroin and cocaine, are illegal.

....

....

Q6. Describe how painkillers work.

....

....

Q7. Describe the effects of taking a hallucinogen.

....

....

Q8. Describe the effects of taking a stimulant.

....

....

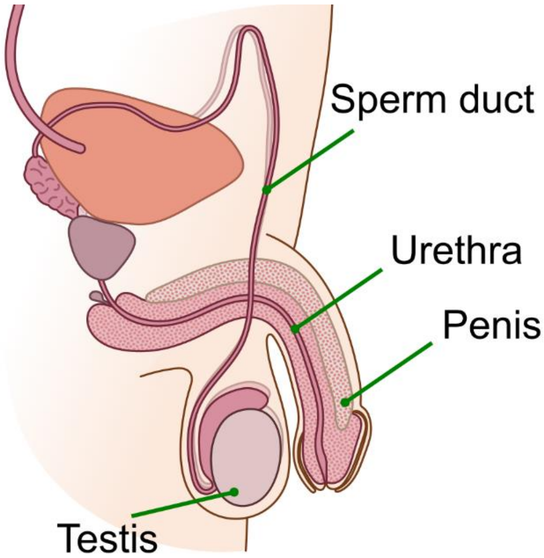
Human reproductive system

To reproduce, both males and females have specialised organs that work together. The main organs of the male reproductive system are the testes, penis and sperm ducts.

The **testes** (singular testis) are two oval-shaped organs that produce sperm, the male reproductive cells. The testes also produce the hormone testosterone.

Sperm is carried from the testes to the urethra (the tube that runs through the penis) through **sperm ducts**. Along the way, sperm mixes with fluids from glands to form semen.

The **penis** is the organ that delivers sperm into the female reproductive system. During sexual intercourse, the penis becomes erect, allowing for the transfer of semen.



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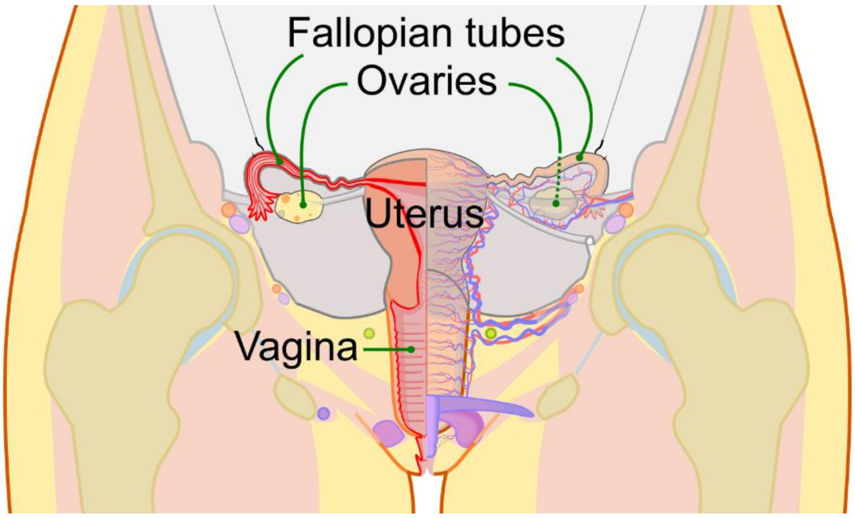

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The main organs of the female reproductive system are the ovaries, fallopian tubes, uterus and vagina.

The **ovaries** are located on either side of the uterus. They produce egg cells (ova) and release them during the menstrual cycle. The ovaries also produce the hormones oestrogen and progesterone, which regulate the menstrual cycle.

When an egg is released from the ovary, it travels through the **fallopian tube** toward the uterus. Fertilisation, which takes place when a sperm cell joins with an egg cell, usually occurs in the fallopian tube. The fertilised egg then implants and develops into a baby in the **uterus** (also known as the womb). The lining of the uterus thickens each month in preparation for a possible pregnancy.

The **vagina** connects the uterus to the outside of the body. It is the passage through which sperm enters the female reproductive system and also serves as the birth canal during childbirth.

Q1. The following statements are either true or false. State which are true and which are false.

a) The testes produce sperm and testosterone.

....

b) The fallopian tubes connect the ovaries to the uterus.

....

c) Fertilisation usually occurs in the vagina.

....

d) Sperm is carried from the testes to the urethra through the fallopian tubes.

....

e) Ovaries produce egg cells.

....

Q2. State the name of three organs that the male reproductive system consists of.

....

Q3. State the name of four organs that the female reproductive system consists of.

....

Q4. Describe the function of the uterus in the female reproductive system.

....

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Q5. Describe the function of the penis in the male reproductive system.

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Q6. Describe the function of the ovaries in the female reproductive system.

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Q7. Describe the function of the vagina in the female reproductive system.

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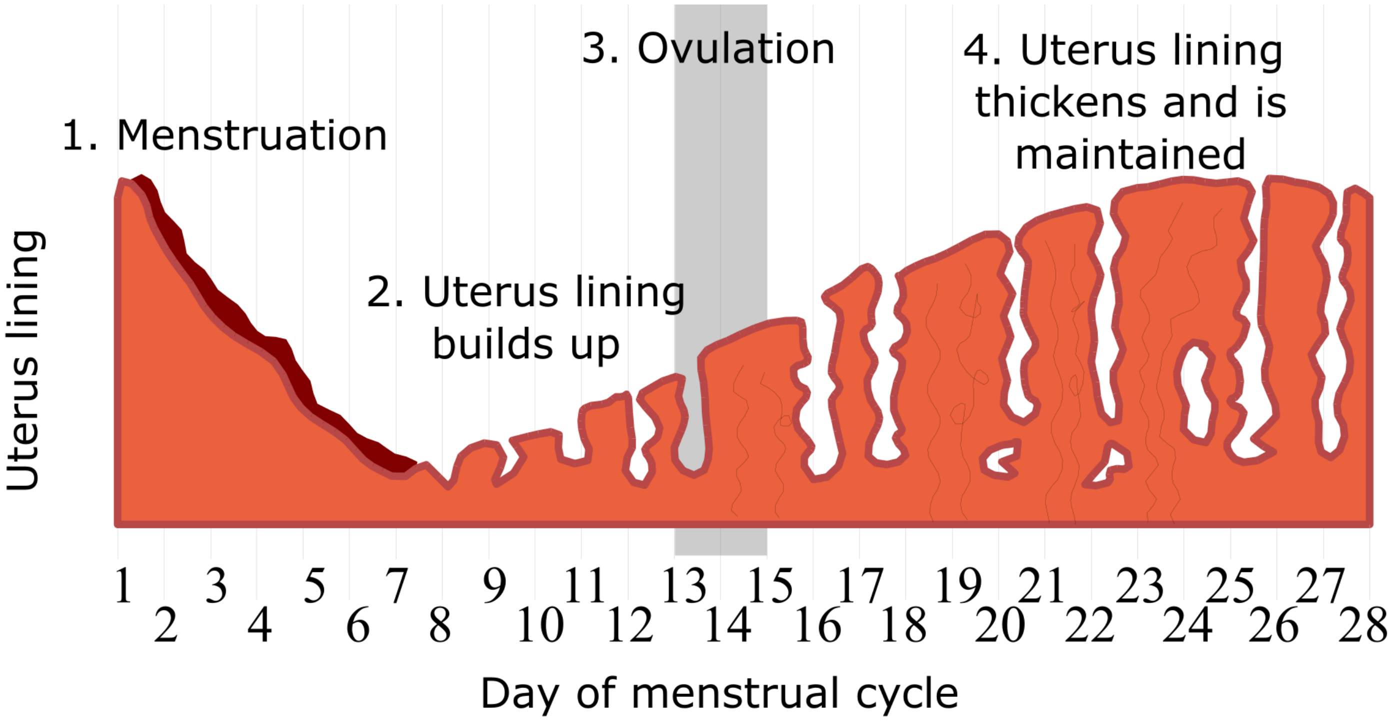
The menstrual cycle

The menstrual cycle is a monthly process that prepares the female body for pregnancy. It typically lasts around 28 days, but it can vary from person to person. The cycle involves the release of an egg from the ovaries, the preparation of the uterus for a possible pregnancy, and the shedding of the uterus lining if pregnancy does not occur.



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The four stages of the menstrual cycle are:

1. **Menstruation** (days 1-5). The first stage of the menstrual cycle is menstruation, also known as a period. During this time, the lining of the uterus breaks down and is shed from the body through the vagina. Menstruation usually lasts between 3 to 7 days.
2. **Uterus lining builds up**. The body gets ready to release an egg from the ovary. The hormone oestrogen helps to thicken the uterus lining to get ready for a possible pregnancy.
3. **Ovulation** (day 14). Ovulation usually happens around the middle of the cycle. This is when the ovary releases an egg. The egg travels down the fallopian tube, and this is the time when a woman is most fertile.
4. **Uterus lining thickens and is maintained**. After the egg is released, the body produces another hormone called progesterone. This hormone makes the lining of the uterus even thicker. If the egg isn't fertilised, the uterus lining breaks down and the cycle starts all over again with menstruation.

Q1. The following statements are either true or false. State which are true and which are false.

a) Ovulation is when an ovary releases an egg.

....

b) The menstrual cycle usually lasts around 28 days.

....

c) A woman is most fertile before they ovulate.

....

Q2. Describe what happens in the first five days of the menstrual cycle.

....

....

....

Q3. State which day of the menstrual cycle ovulation usually happens on.

....

Q4. Describe what ovulation is.

....

....

....

Q5. Describe what happens to the uterus lining if an egg isn't fertilised.

....

....

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Q6. Describe the role of oestrogen in the menstrual cycle.

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....

Q7. Describe the role of progesterone in the menstrual cycle.

....

....

....

Pregnancy

Pregnancy begins when a sperm cell from the father fertilises an egg cell from the mother. This usually happens in the fallopian tube. The fertilised egg, now called a **zygote**, travels down the fallopian tube and into the uterus. Once in the uterus, the zygote **implants** itself into the thickened lining of the uterus.

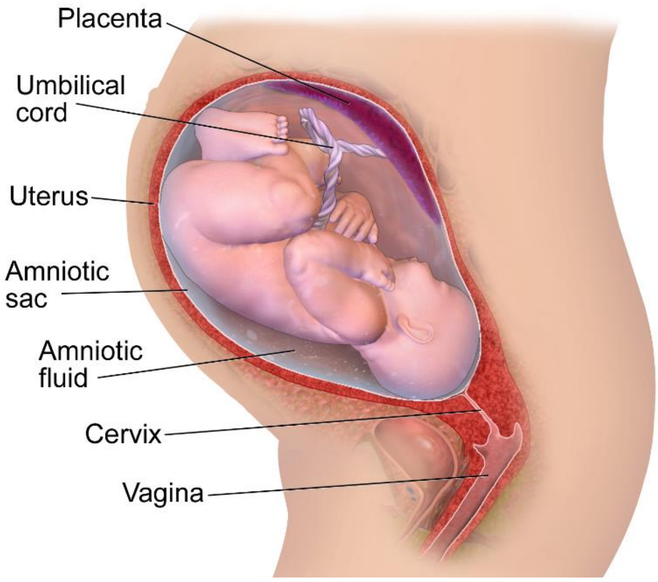
Pregnancy can be split into three **trimesters**:

First trimester (weeks 1-12). In the early weeks of pregnancy, the baby is called an **embryo**. The heart, brain, and other organs begin to form. By the end of this period, the baby is about the size of a lemon and is now called a **foetus**.

Second trimester (weeks 13-26). The baby continues to grow, developing muscles, bones, and more detailed features like fingers, toes, and facial expressions. The baby can move, and the mother may start to feel these movements. The baby also begins to hear sounds.

Third trimester (weeks 27-40). During the final weeks, the baby grows rapidly and gains weight. The lungs mature, and the baby moves into a head-down position, ready for birth. By the end of this period, the baby is fully developed and ready to be born.

Several structures help support and protect the baby as it grows:



Blausen.com staff (2014). "Medical gallery of Blausen Medical 2014". WikiJournal of Medicine 1 (2). DOI:10.15347/wjm/2014.010. ISSN 2002-4436., CC BY 3.0, via Wikimedia Commons

- The **placenta** is an organ that develops in the uterus during pregnancy. It connects to the baby through the **umbilical cord** and provides nutrients and oxygen from the mother's blood. It also removes waste products from the baby's blood.
- The **uterus** is the organ where the baby develops. It stretches and grows as the baby gets bigger.
- The **amniotic sac** is a thin but strong bag that surrounds the baby in the uterus. Inside the sac, the baby is cushioned by **amniotic fluid**, which protects the baby and allows it to move around easily.
- The **cervix** is the lower part of the uterus that connects to the vagina. During pregnancy, the cervix remains closed to keep the baby inside the uterus. As the time for birth approaches, the cervix gradually opens to allow the baby to be born.
- The **vagina** is the passage that connects the uterus to the outside of the body. During birth, the baby passes through the vagina.

Q1. The following statements are either true or false. State which are true and which are false.

a) A fertilised egg is called a zygote.

....

b) The zygote implants itself into the thickened lining of the uterus.

....

c) An embryo turns into a zygote.

....

d) Pregnancy usually lasts around 40 weeks.

....

e) Fertilisation usually happens in the fallopian tube.

....

Q2. Describe the role of the placenta and umbilical cord during pregnancy.

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Q3. Describe the role of the amniotic fluid during pregnancy.

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Q4. Describe what happens during the third trimester to prepare the baby for birth.

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Q5. Describe what happens to the cervix as the time for birth gets close.

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Nutrition and

digestion

Nutrition

A **balanced diet** involves consuming an appropriate amount of each food group. A balanced diet is important to keep us healthy. Each of these food groups are in the table below:

Name of food group	How the body uses this food group	Examples of foods that include this
Carbohydrates	The body breaks carbohydrates into simple sugars like glucose. Glucose is used for respiration.	Bread, pasta, potatoes, rice.
Lipids (fats)	Long term energy storage.	Oil, cheese, butter, some meats.
Proteins	Needed for growth and repair of tissues.	Meat, fish, eggs, cheese, milk, nuts.
Vitamins	Different vitamins are needed for many different aspects of our health (some examples below).	Fruit and vegetables.
Minerals	Different minerals are needed for many different aspects of our health (some examples below).	A wide variety of foods (examples below).
Fibre	Needed to help food move through the intestines.	Cereals, fruit and vegetables.
Water	Needed to keep us hydrated.	Any drink, fruit and vegetables.

If we do not eat enough of one of the food groups, we're at risk of developing a **deficiency disease**. Some examples of these are below:

- **Anaemia**. This is caused by a lack of the mineral iron. Eating meat is a good source of iron. Anaemia causes pale skin, tiredness and shortness of breath.
- **Rickets**. This is caused by a lack of vitamin D. If a child does not get enough vitamin D then they can develop rickets. This causes problems with bone growth, fragile bones and painful bones.
- **Scurvy**. This is caused by a lack of vitamin C. Scurvy can cause tiredness, swelling of gums and loss of teeth.
- **Kwashiorkor**. This is caused by a lack of protein. Developing kwashiorkor means that the body can't grow and repair its tissues. It can cause stunted growth.

Q1. Explain why a balanced diet is important.

……

Q2. Name the seven food groups.

……

……

Q3. State the reason why we need to eat fibre.

……

Q4. State the reason why we need to eat carbohydrates.

……

Q5. State the reason why we need to eat lipids.

……

Q6. Give an example of a food that contains a lot of protein.

……

Q7. Give an example of a food that contains a lot of lipids.

……

Q8. The following statements are either true or false. State which are true and which are false.

a) Carbohydrates are needed for growth and repair of tissues.

……

b) Pasta is an example of a food that contains a lot of carbohydrates.

……

c) Cheese is an example of a food that contains a lot of fibre.

……

Q9. State what we're at risk of developing if we do not eat enough of one of the food groups.

……

Q10. Calcium is a mineral that helps us to maintain strong bones. Name another mineral.

……

Q11. Somebody suffers from anaemia. Suggest what food they could eat to resolve this. Explain your reasons why.

……

Q12. Somebody suffers from kwashiorkor. Suggest what food they could eat to resolve this. Explain your reasons why.

……

Food energy requirements

We need to eat a certain amount of food to survive. Food is a store of **chemical energy**. When we eat food, that chemical energy is transferred to us. The unit of energy is the **joule (J)**, but when referring to food we use the unit **kilojoule** (kJ). Another unit that you may have heard of is the **calorie**. One calorie is equal to 4.2 J.

If we do not eat the right amount of food or have an unbalanced diet, then we're at risk of becoming **malnourished**.

If somebody eats too little food, then they lose weight. If this persists for a long period of time, then it could lead to **starvation**. If starvation persists, then it can eventually lead to death.

If somebody eats too much food, then they gain weight. If this persists for a long period of time, then it could lead to **obesity**. Obesity is when somebody has too much body fat.

Obesity can lead to **heart disease** and **diabetes**.

Our **basal metabolic rate** is a measure of the energy content of food that we need to eat to survive if we are **inactive** (doing no physical exercise).

If we are active, then we need to eat more. Our **physical activity level** is a measure of the energy content of food that we need to eat because of our activity. Together, our basal metabolic rate and our physical activity level combine to form our overall **metabolic rate**.

Various factors affect our overall metabolic rate:

- **Age** (young children require less food than fully grown adults. As adults get older, they also require less food).
- **Gender** (men require more food than women).
- **Body mass** (the larger somebody's body mass, the more food they require).
- **Exercise levels** (the more somebody exercises, the more food they require).
- **Pregnancy** (while pregnant, someone requires more food).

The average man needs to consume 10 500 kJ a day from their food, while the average woman needs 8400 kJ a day.

It is important that food is clearly labelled to show its energy content and how much of each food group it contains. This is so that we can make sure what we're eating forms a balanced diet. An example food label is shown to the right.

Chicken sandwich

Kilojoules	**1100 kJ**
Carbohydrates	**34 g**
Protein	**22 g**
Fat	**5 g**
Fibre	**8 g**

Q1. State the unit of energy that we use when referring to food.

Q2. Describe what might happen if we eat too little food.

Q3. Describe what might happen if we eat too much food.

Q4. Explain what basal metabolic rate means.

Q5. Describe how somebody's overall metabolic rate depends on the amount they exercise.

Chicken sandwich	
Kilojoules	**1100 kJ**
Carbohydrates	**34 g**
Protein	**22 g**
Fat	**5 g**
Fibre	**8 g**

Tuna baguette	
Kilojoules	**2247 kJ**
Carbohydrates	**58 g**
Protein	**25 g**
Fat	**23 g**
Fibre	**5 g**

Egg mayonnaise sandwich	
Kilojoules	**1063 kJ**
Carbohydrates	**32 g**
Protein	**14 g**
Fat	**6 g**
Fibre	**4 g**

Q6. Using the diagrams above, state which sandwich has:

a) The highest energy content.
b) The highest amount of carbohydrates.
c) The least amount of fat.
d) The most amount of fibre.
e) The least amount of protein.

Q7. Using the diagrams above, state which sandwich would be most suitable for someone who does a lot of exercise. Explain why.

Q8. State two risks of obesity.

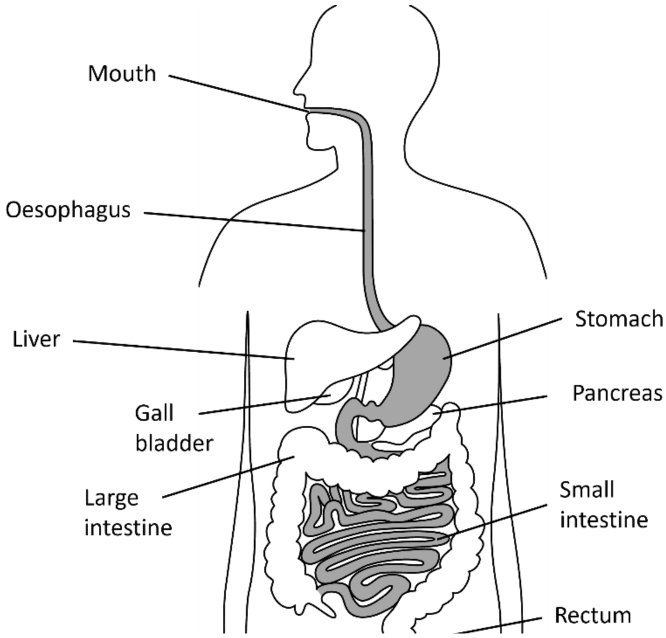
Q9. Describe why it is important that food is clearly labelled, showing the amounts of each food group.

Digestive system

Food that we eat is broken down by our **digestive systems** into small molecules. The digestive system consists of many different **organs** which serve a specific role in the process of digestion.

Enzymes have an important role in digestion and help chemically break the food down. Enzymes are biological **catalysts**. Catalysts increase the rate of a chemical reaction.

Some **bacteria** also live in our digestive systems. They live mainly in the large intestine and protect against harmful bacteria and help with the digestion of food



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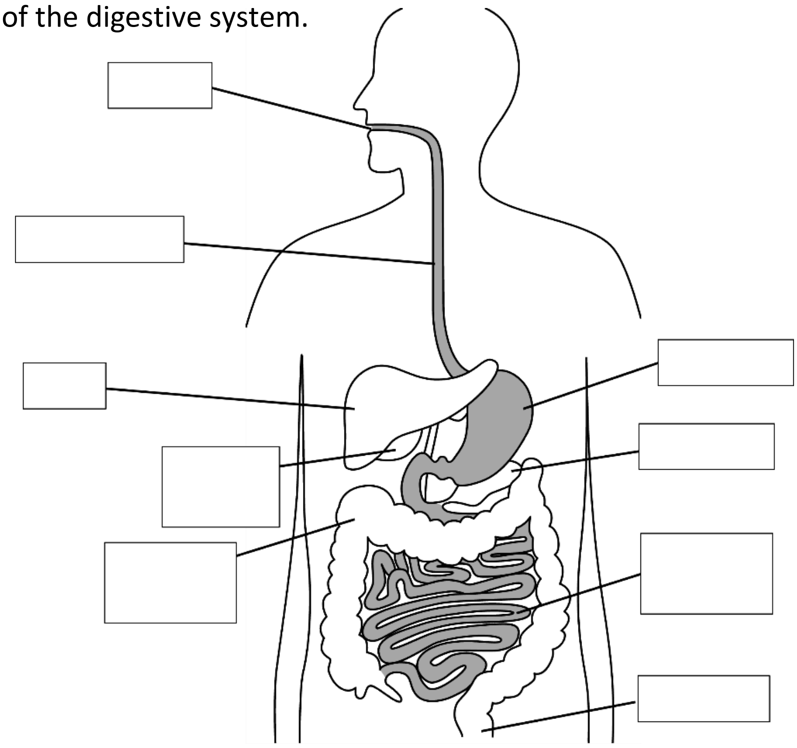
A diagram of the digestive system is shown above, food travels through each of the structures and organs in the order of the table below:

Mouth	Contains **teeth** that mechanically break food down. **Saliva** in the mouth contains the enzyme **amylase** which breaks down starch (a carbohydrate).
Oesophagus	After food is swallowed, the walls of the oesophagus squeeze together and moves the food towards the stomach.
Stomach	The stomach has muscular walls that mechanically breaks food down. It also contains hydrochloric acid that kills bacteria. The enzyme **protease** works best in acidic conditions. Protease breaks down proteins.
Small intestine	Contains **villi** which have a very large surface area. This allows digested food to be absorbed more quickly into the blood stream.
Large intestine	The large intestine is where **water** is absorbed.
Rectum	Waste material (called **faeces**) is stored here before it leaves the body through the **anus**.

Food does not travel through the below organs, but they still play a vital role in digestion.

Liver	Produces **bile**, which is used to **neutralise** stomach acid.
Gall bladder	Stores bile and releases it into the small intestine.
Pancreas	Produces the **enzymes** protease, amylase and lipase which are passed into the small intestine. Lipase breaks down lipids.

Q1. Label the diagram of the digestive system.



Q2. State the name of the organ that contains hydrochloric acid.

....

Q3. State the name of the organ where digested food is absorbed into the blood.

....

Q4. Describe the purpose of bile and state the name of the organ where bile is produced.

....

Q5. State where villi are found and describe why it is advantageous for them to have a large surface area.

....

Q6. State the name of the organ where water is absorbed.

....

Q7. State the name of an organ where food is mechanically broken down.

....

Q8. Describe what faeces is and state the name of the organ where faeces is stored.

....

Q9. State an organ that produces an enzyme.

....

Q10. Describe the role of enzymes in digestion. Include the name of a specific enzyme and the purpose of that enzyme.

....

....

Food Tests

We can carry out **food tests** to test what substances are in our foods. These food tests are:

- To test for the presence of **protein** we use **Biuret solution**.

  To carry out the test, add a sample of the food to a test tube and then add a few drops of Biuret solution (which is coloured blue).

  If the colour of the solution remains **blue**, then there is no protein in the food. If the colour of the solution changes to **purple**, then protein is present in the food.

  Examples of foods that contain protein are meat, fish, eggs, cheese, milk and nuts.

- To test for the presence of **sugar** we use **Benedict's solution**.

  Again, the solution needs to be added to a sample of the food. The reaction is slow, though, and so it needs to be heated in a water bath for a few minutes.

  If there is sugar in the food, then it will turn **green, yellow, orange or red**. The colour it turns depends on the concentration of sugar in the food.

  Examples of foods that contain sugar are fizzy drinks, fruit juices, sweets and cakes.

- To test for the presence of **starch** (a carbohydrate) we use **iodine solution**.

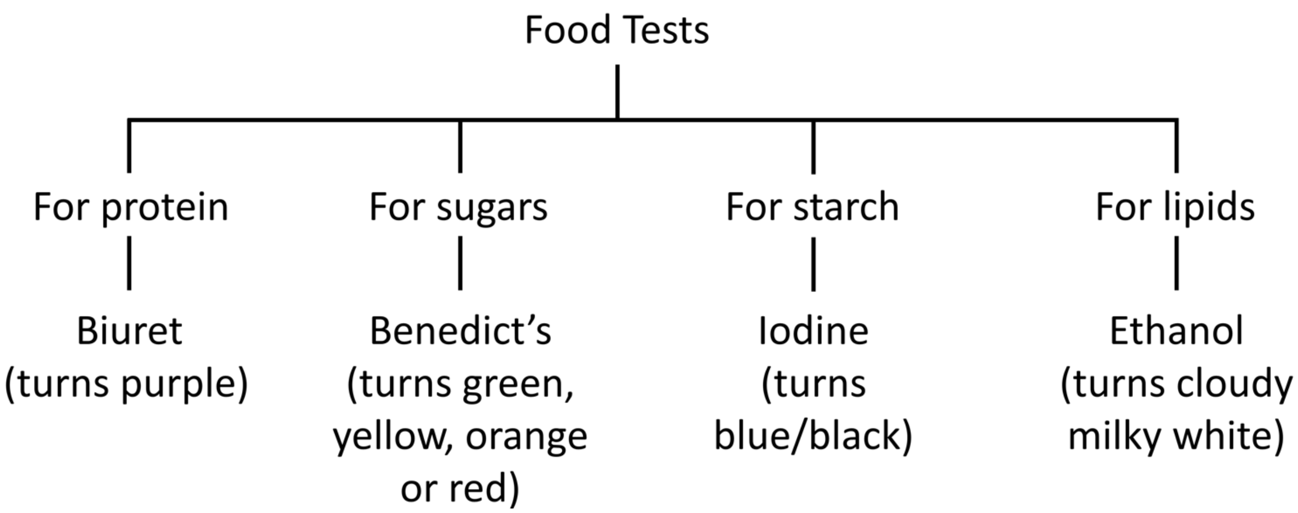
  The iodine reagent is initially **yellow/brown** but when it comes into contact with starch it quickly turns **blue/black**.

  Examples of foods that contain carbohydrates are bread, pasta, potatoes and rice.

- To test for the presence of **lipids (fats)** we can use **ethanol**.

  If fats are present in the sample of food, then the ethanol will turn a **cloudy milky white**.

  Examples of foods that contain lipids are oil, cheese, butter and some meats.



Q1. State an example of a food that contains a lot of lipids.

....

Q2. State an example of a food that contains a lot of protein.

....

Q3. State an example of a food that contains a lot of sugars.

....

Q4. State an example of a food that contains a lot of carbohydrates.

....

Q5. An investigation is carried out to determine if a food sample contains sugars. State which food test we should use and what colour changes will occur if sugar is present.

....

....

Q6. An investigation is carried out to determine if a food sample contains lipids. State which food test we should use and what colour changes will occur if lipids are present.

....

....

Q7. An investigation is carried out to determine if a food sample contains protein. State which food test we should use and what colour changes will occur if protein is present.

....

....

Q8. Some iodine solution is dropped onto a slice of bread. Describe what we will see. Explain why.

....

....

Retrieval questions:

Q9. State the reason why we need to eat carbohydrates.

....

Q10. State the reason why we need to eat lipids.

....

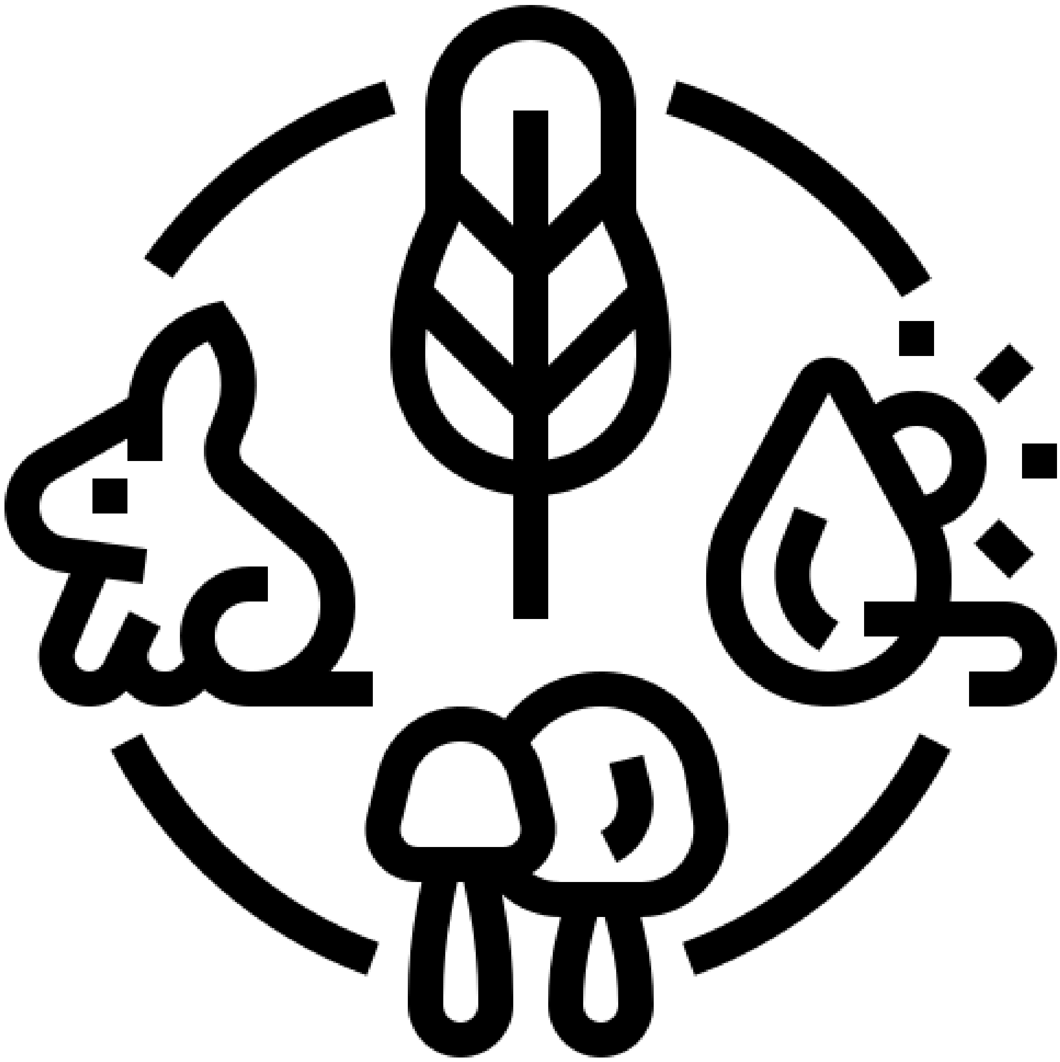
Q11. State the reason why we need to eat proteins.

....

Q12. State the name of the deficiency disease caused by a lack of protein.

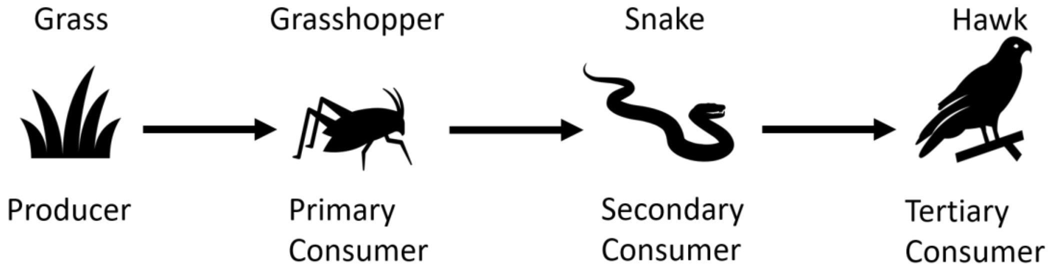
....

Ecosystems



Food chains and webs

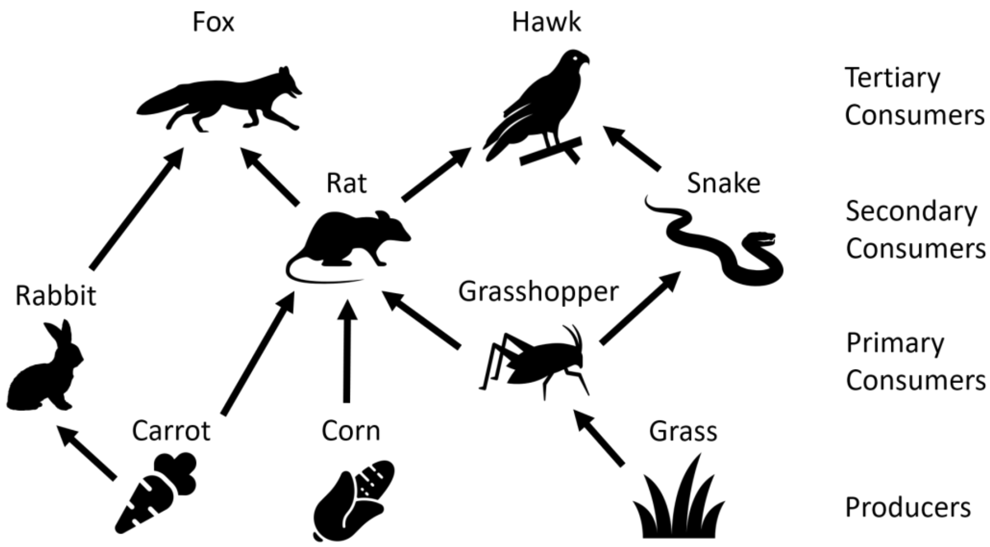
A **food chain** is a way of showing what eats what. For example, the diagram below shows that grasshoppers eat grass.



Below are some important definitions:

Producers	Organisms that make their own food through **photosynthesis**.
Primary consumer	Animal that eats the **producer**.
Secondary consumer	Animal that eats the **primary consumer**.
Tertiary consumer	Animal that eats the **secondary consumer**.
Herbivore	Animal that eats only plants.
Carnivore	Animal that eats other animals.
Omnivore	Animal that eats both plants and animals.
Predator	An organism that eats another organism.
Prey	The organism that a predator eats.

Usually, patterns of eating are more complicated than a simple food chain. A **food web** contains lots of food chains linked together.



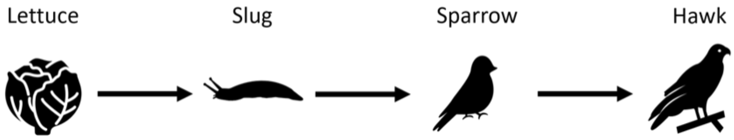
Each part of a food chain/web is linked to others. For example, if all the carrots in the food web above died then there would be fewer rabbits (as they'd have less food to eat).

Q1. Describe what a producer is.

....

Q2. Describe what a herbivore is.

....



Use the food chain above to answer the following questions.

Q3. The producer is ....

Q4. The secondary consumer is ....

Q5. The prey of the hawk is ....

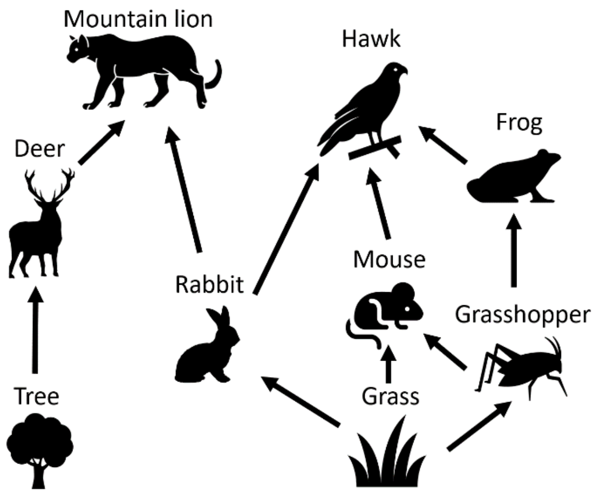
Q6. The predator of the slug is ....

Q7. State what would happen to the sparrow population if most of the slugs died.

....

Q8. State what would happen to the lettuce population if most of the slugs died.

....



Use the food web above to answer the following questions.

Q9. Name a primary consumer.

....

Q10. Name the predators of a rabbit.

....

Q11. Name a tertiary consumer.

....

Q12. Name a carnivore.

....

Relationships in an ecosystem

An **ecosystem** is a community of living and non-living things interacting with each other. Plants, animals and microorganisms depend on water, soil, climate and each other for survival. These interactions create a web of relationships that keep the ecosystem balanced and functioning.

In an ecosystem, all organisms are **interdependent**. This means they rely on each other to survive. For instance, plants need sunlight to make glucose through photosynthesis. Some animals depend on these plants for food, and predators rely on other animals as their food source. If one part of this chain is disturbed, it can impact the entire ecosystem.

One key example of interdependence is **pollination**. Many plants, including those that humans rely on for food, need insects like bees to pollinate them. Pollination is the process of transferring pollen from one flower to another, allowing the plant to produce seeds and fruit. Without pollinators, many plants would struggle to reproduce. This would affect the animals that rely on them for food.

Humans heavily depend on insect pollination for a lot of the food we eat, such as fruits, vegetables and nuts. Without pollinators, these crops would produce less food. This would lead to food shortages and higher prices. The health of ecosystems, therefore, has a direct impact on human food security.

However, the use of **insecticides** (chemicals designed to kill insects) can also harm beneficial insects like bees. When these chemicals reduce pollinator populations, it can lead to lower crop yields and disrupt the entire food chain. This reduction in pollinators can also decrease biodiversity, making ecosystems less resilient to other threats.

In addition to issues like insecticide use, ecosystems can also be disrupted by **invasive species**. An invasive species is a non-native organism introduced to an ecosystem, often causing harm. These species can outcompete native organisms for resources like food and habitat, disrupt food chains and reduce biodiversity.

For example, the introduction of grey squirrels to the UK from North America has led to a decline in the native red squirrel population. Grey squirrels compete with red squirrels for food and carry a disease that is deadly to red squirrels but not to themselves. This has significantly reduced red squirrel numbers and upset the balance of the local ecosystem.

Q1. The following statements are either true or false. State which are true and which are false.

a) Bees are an example of a pollinator.

....

b) Invasive species are needed to keep ecosystems balanced.

....

Q2. Describe why pollination is important for both plants and animals.

....

....

....

....

Q3. Describe how the use of insecticides can affect an ecosystem.

....

....

....

Q4. Describe what is meant by an ecosystem.

....

....

....

Q5. Describe what is meant by an invasive species.

....

....

....

Q6. State an example of an invasive species.

....

Q7. Describe what is meant by interdependence in an ecosystem.

....

....

....

Q8. Describe what might happen to the human food supply if pollinator populations decrease.

....

....

....

....

Assessing ecosystems

When we study ecosystems, we often need to assess the number of different species in a specific area. It isn't possible to count every single one of an organism within a large area, so we instead carry out an estimate using **quadrats**.

A quadrat is a square frame, usually made of wood or metal, that is used to give a sample area within an ecosystem. The size of a quadrat can vary, but it's often 1m x 1m. The quadrats are placed randomly in an area they want to study and count the organisms within the frame. By doing this in multiple places within the area, we can estimate the population size.

To do this correctly, we should use the following method.

1. **Random Placement**. To avoid bias, the quadrat should be placed randomly in the area to be studied. This can be done by using a random number generator to determine coordinates within the area.
2. **Counting Organisms**. Once the quadrat is placed, all organisms within the frame are identified and counted.
3. **Repeating the Process**. The process is repeated multiple times in different parts of the area. A mean number of organisms can then be calculated per quadrat.
4. **Multiply mean by area**. The mean number of organisms per quadrat gives the number in each m^2. Multiplying this by the total area gives an estimate of the population size.

Example question

A field has an area of 10 000 m^2. Some students use quadrats of area 1 m^2 to estimate the number of daisies in the field. They find an average of 12 daisies per quadrat. Calculate an estimate for the total number of daisies in the field.

Giulia Castiglioni, CC0, via Wikimedia Commons

Step 1. Write down equation:

Total population = average number per quadrat × total area

Step 2. Insert variables into equation:

Total population = 12 × 10 000

Step 3. Calculate answer.

Total population = 120 000 daisies

By studying ecosystems, we can detect changes over time, such as a decline in a particular species or the impact of human activities like pollution or deforestation. This information can help us make decisions about how to protect and manage ecosystems.

Q1. The following statements are either true or false. State which are true and which are false.

a) To calculate the population of an organism within a large area, it's easiest to count them all.

....

b) Quadrats usually have an area of 1 m^2.

....

c) To calculate an estimate for the total population in an area, we can divide the average number per quadrat by the total area.

....

Q2. A meadow has an area of 5000 m^2. Students use quadrats of 1 m^2 to estimate the number of clover plants in the meadow. They find an average of 20 clover plants per quadrat. Calculate an estimate for the total number of clover plants in the meadow.

....

....

....

Q3. A field has an area of 2,500 m^2 and the average number of dandelions per m^2 quadrat is found to be 8. Calculate the estimated total number of dandelions in the field.

....

....

....

Q4. After placing 15 quadrats in a 4,000 m^2 area, the average number of organisms counted per m^2 quadrat is 10. Calculate an estimate for the total population of the organisms in the area.

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Q5. Describe what a quadrat is and how it is used in studying ecosystems.

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Q6. Describe a reason why it's useful to assess ecosystem populations.

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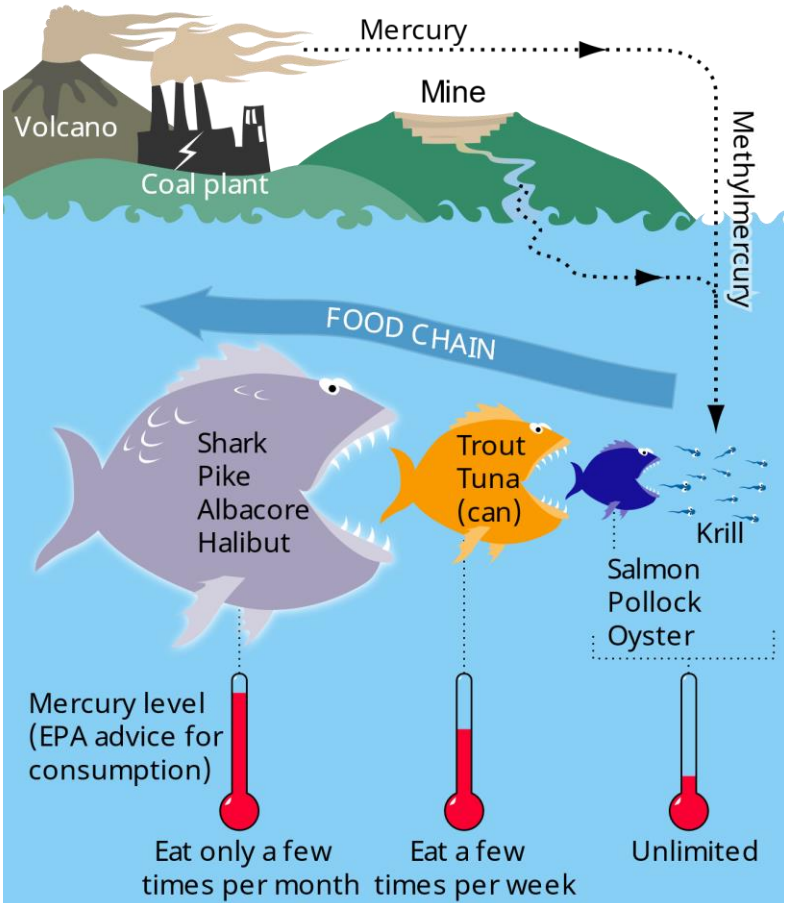
Bioaccumulation

Bioaccumulation is the process by which toxic substances build up in the tissues of organisms over time. These toxic substances can include chemicals like pesticides, heavy metals (such as mercury or lead) and other pollutants that enter the environment through air, water or soil. Once these toxins are in an ecosystem, they can move through the food chain and become more concentrated in the bodies of animals higher up the food chain.



Bretwood Higman, Ground Truth Trekking., CC BY 3.0, via Wikimedia Commons

One common example of bioaccumulation involves **mercury**, a heavy metal that can be released into the environment from industrial processes like coal burning. In aquatic ecosystems, mercury is absorbed by small organisms like plankton. Small fish eat the plankton and the mercury accumulates in their bodies. When larger fish (like tuna or trout) eat these smaller fish, they take in the mercury as well. By the time these large fish are eaten by humans or other top predators, the mercury concentration can be dangerously high, leading to health risks such as neurological disorders.

Another example of bioaccumulation is the pesticide DDT. DDT was used extensively in agriculture to control insects. However, it also accumulated in the environment and particularly in aquatic ecosystems. Small organisms in the water absorbed the DDT and, as it moved up the food chain, it became highly concentrated in birds of prey like eagles and ospreys. The high levels of DDT caused these birds to lay eggs with very thin shells, which often broke before the chicks could hatch. This led to a significant decline in bird populations before DDT was banned in many countries.

Preventing bioaccumulation involves reducing the release of harmful chemicals and pollutants into the environment. This can be achieved by using less toxic alternatives to pesticides, enforcing stricter regulations on industrial waste and ensuring that toxic materials are properly disposed of.

Q1. Define bioaccumulation and describe how it occurs in an ecosystem.

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Q2. State two examples of toxic substances that can lead to bioaccumulation.

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Q3. A small fish in a polluted river absorbs 2 units of a toxin. If a larger fish eats 10 of these small fish, state how many units of toxin the larger fish has.

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Q4. A top predator in a food chain eats 15 animals, each with 10 units of toxin. State how many units of the toxin the predator accumulates from eating these animals.

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Q5. Describe how human activities contribute to bioaccumulation and suggest ways to reduce its impact on ecosystems.

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Q6. NHS advice is for an adult to eat no more than 2 tuna steaks a week. Describe why this advice is in place.

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Q7. Describe why the pesticide DDT has been banned in many countries.

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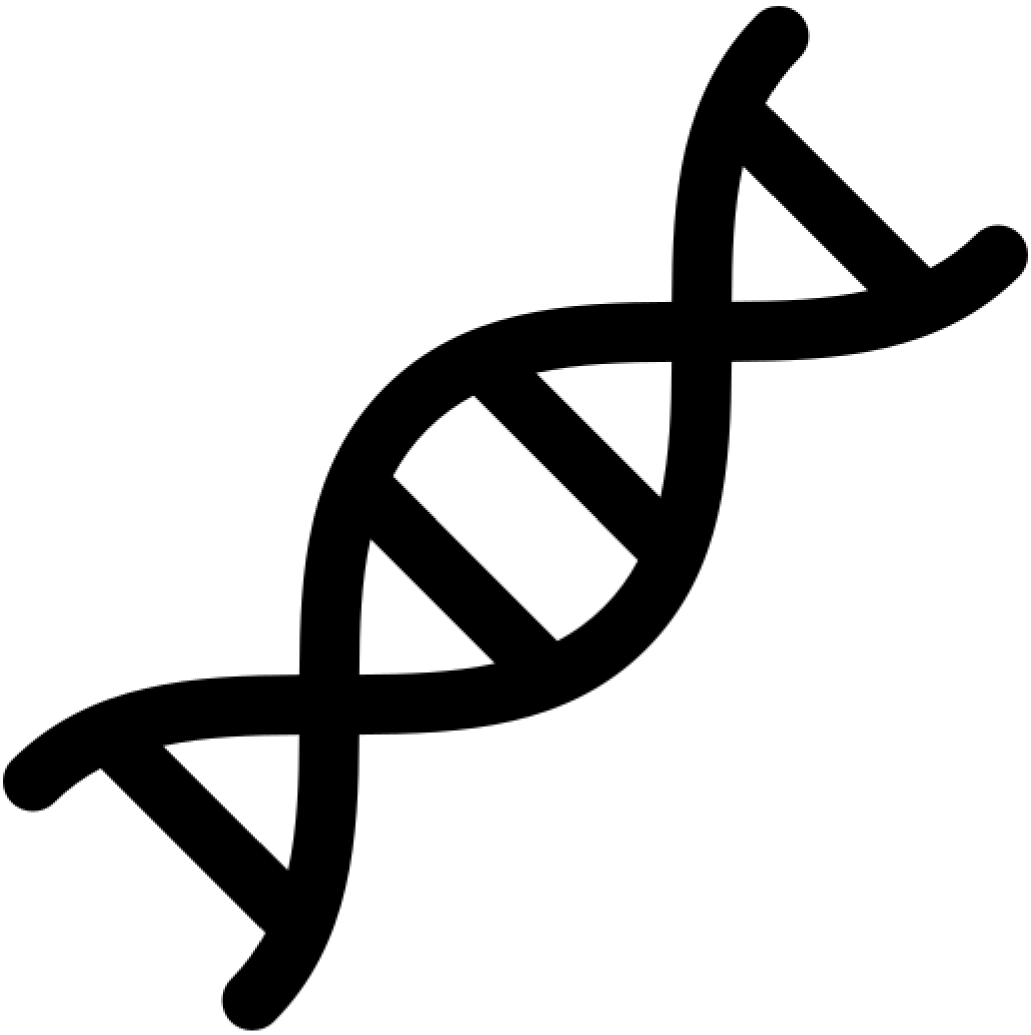
Genetics and

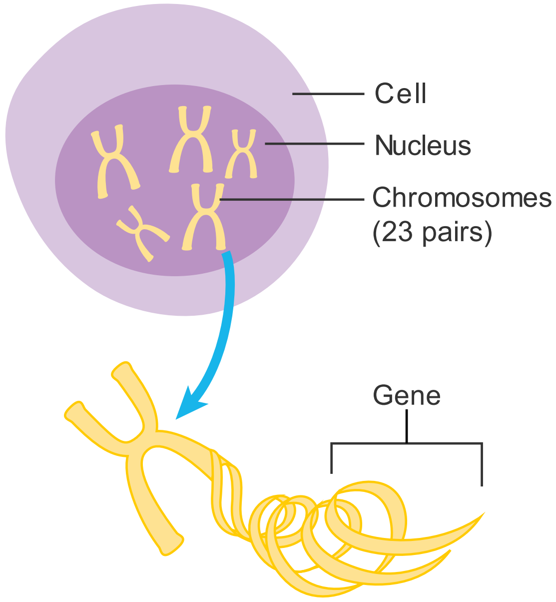


evolution

DNA and inheritance

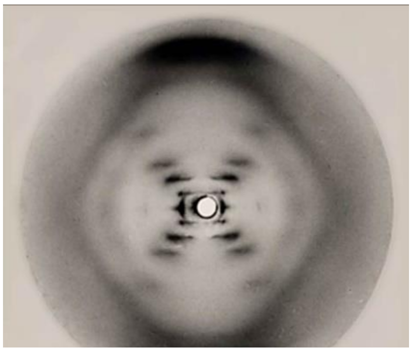
When we look at living things, from the smallest bacteria to the largest animals, we can see that they all have characteristics that make them unique. These characteristics (like eye colour or height) are passed down from one generation to the next. This passing on of traits is known as **inheritance**. To understand inheritance, we need to learn about chromosomes, DNA and genes:

- **Chromosomes** are thread-like structures found in the nucleus of every cell. Humans have 46 chromosomes, arranged in 23 pairs. You inherit one chromosome from each pair from your mother and the other from your father. This is why you have some characteristics from your mother and some from your father.
- **DNA** (deoxyribonucleic acid) is the molecule that makes up chromosomes. DNA carries the genetic instructions that tell your cells how to function and determine your traits.
- **Genes** are specific segments of DNA that carry the instructions for a specific characteristic. For example, one gene might carry the instructions for your eye colour while another might determine your blood type.



Cancer Research UK, CC BY-SA 4.0, via Wikimedia Commons

Humans have thousands of genes, and they all work together to determine your physical traits and even some aspects of your personality. Some genes are dominant, meaning that if you inherit the dominant version of a gene from one parent, that trait is more likely to show up in you. Other genes are recessive, meaning that the trait will only appear if you inherit the recessive version from both parents.


By Raymond Gosling/King's College London - http://www-project.slac.stanford.edu/wis/images/photo_51.jpg, Public Domain

In the 1950s, James Watson and Francis Crick were working to uncover the structure of DNA. They were able to build on the work of Rosalind Franklin and Maurice Wilkins, who used X-ray crystallography to take images of DNA. Raymond Gosling, a student working under Franklin and Wilkins, produced the famous “Photo 51” which provided crucial clues that helped Watson and Crick determine that DNA has a double-helix structure, which looks like a twisted ladder. Photo 51 is shown in the image to the left.

Q1. The following statements are either true or false. State which are true and which are false.

a) DNA is short for deoxyribonucleic acid.

....

b) Humans have 46 chromosomes, arranged in 23 pairs.

....

c) DNA has a double helix structure.

....

d) DNA is made of chromosomes.

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e) If you inherit a recessive version of a gene from one parent, that trait is more likely to show up in you.

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Q2. Describe what is meant by inheritance.

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Q3. Describe what chromosomes are and where there are usually found.

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Q4. Describe what DNA is.

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Q5. Describe what genes are.

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Q6. Describe the history of how the structure of DNA was discovered.

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Variation

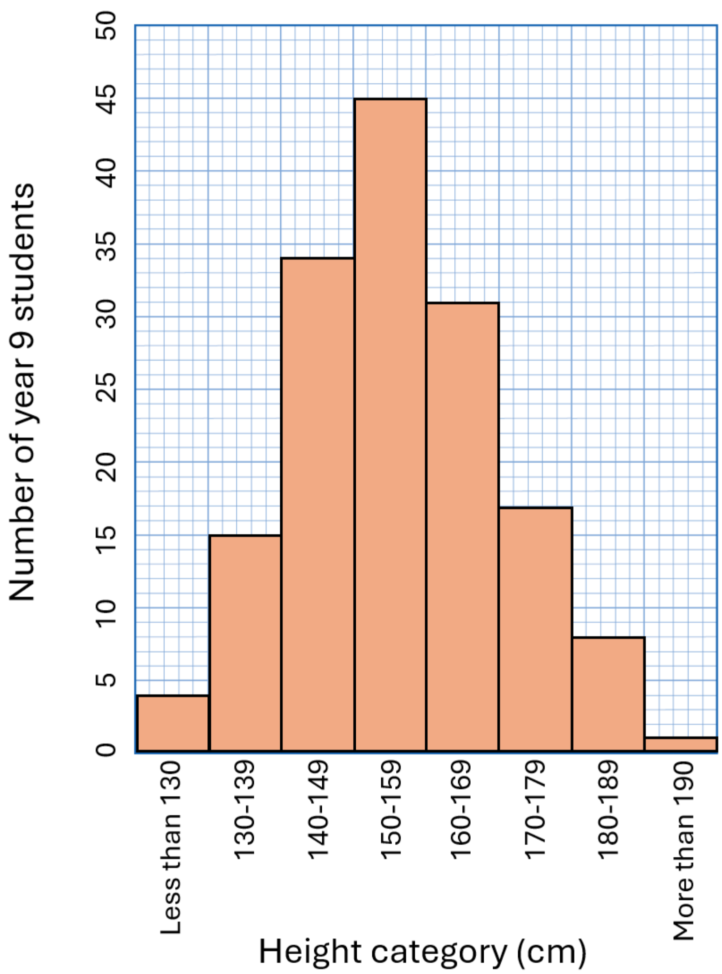
When we observe the natural world, we notice that living things are diverse and have a wide range of shapes, sizes and colours. This diversity is referred to as **variation**. Variation can be seen between different species as well as within the same species.

Different species have different sets of genes, which lead to the different characteristics we see between them. For example, the genes in a bird are different from those in a fish. This leads to traits like feathers and the ability to fly in birds, and scales and the ability to swim in fish.

Variation also exists within a species. This means that even though individuals of the same species share many of the same genes, there are still differences between them. For example, all humans share the same basic set of genes that make us human but each person has a unique combination of these genes that results in differences like eye colour, height and hair type. This variation within a species is what makes each individual unique.

Variation within a species can be classified as **continuous** or **discontinuous**:

1. **Continuous variation** shows a range of differences that gradually change, with no clear divisions between them. For example, human height is a continuous variation. People can be any height within a range, and there are no fixed categories. Continuous variation is often represented using a **histogram**. For example, the histogram to the right shows the distribution of the heights of 155 year 9 students.



2. **Discontinuous variation** is characterised by distinct categories with no intermediate forms. For example, blood type in humans is a discontinuous variation. You can have type A, B, AB, or O, but there are no in-between types. Discontinuous variation is usually controlled by a small number of genes and is represented using a **bar chart**.

Q1. The following statements are either true or false. State which are true and which are false.

a) Variation refers only to differences between different species.

....

b) Continuous variation shows a range of differences that gradually change.

....

c) Blood type is an example of continuous variation.

....

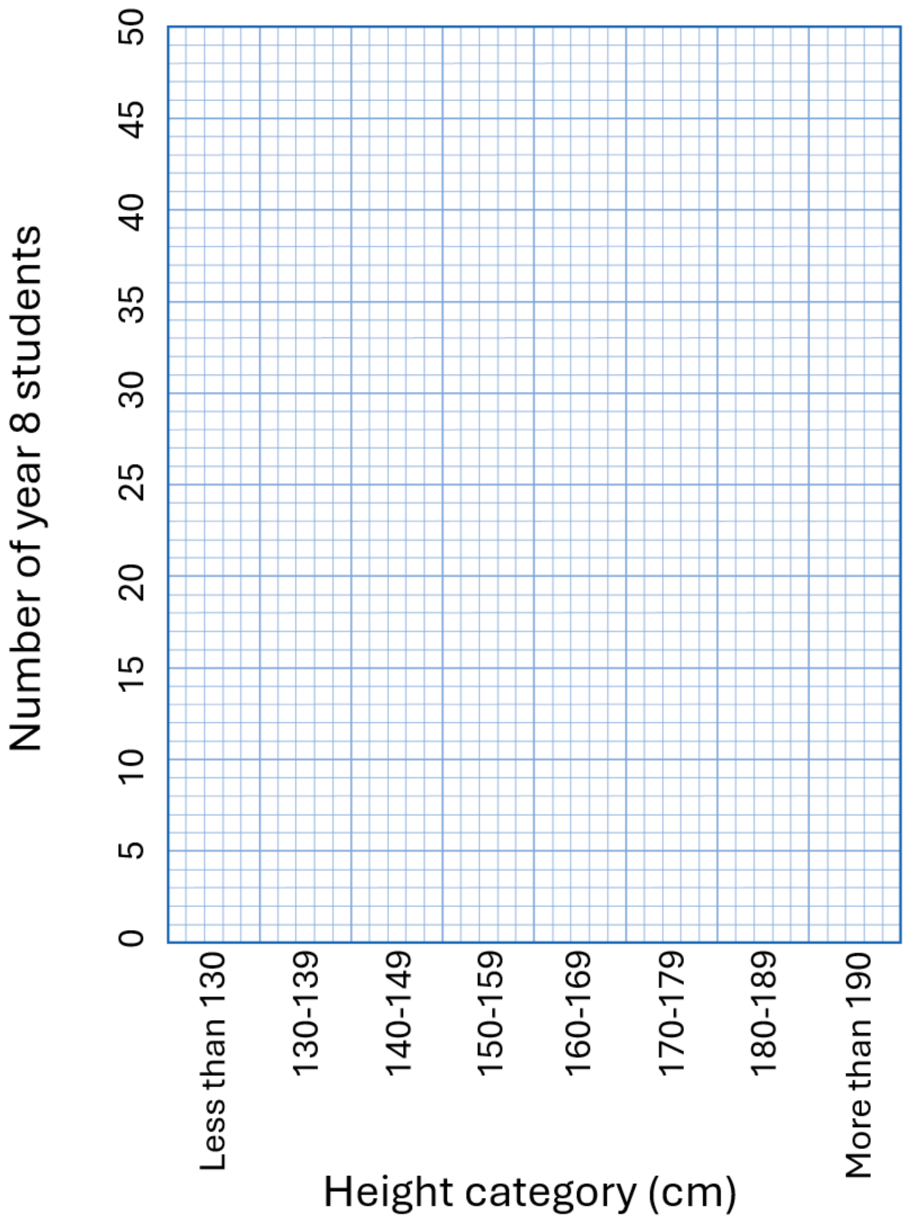
Q2. The table below shows the distribution of heights of 150 year 8 students.

a) State whether height is an example of continuous or discontinuous variation.

....

b) Plot a histogram using the data in the table.

Height category (cm)	**Number of year 8 students**
Less than 130	12
130-139	21
140-149	46
150-159	35
160-169	17
170-179	13
180-189	5
More than 180	0



Natural selection

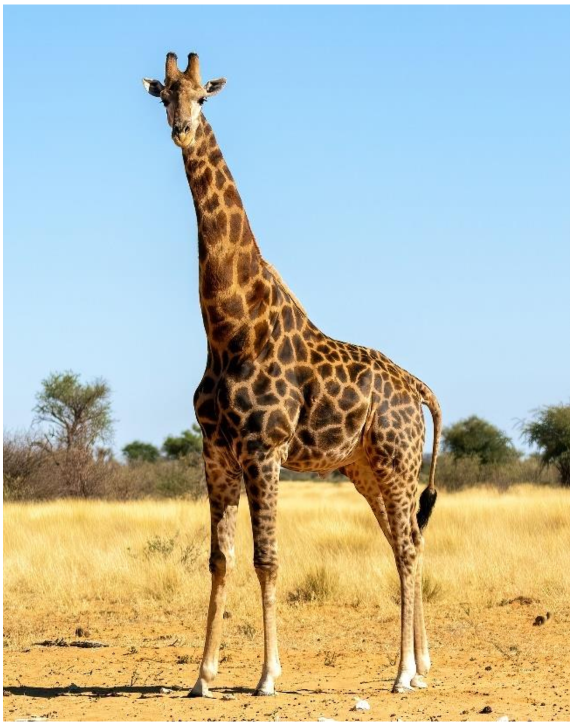
Natural selection is a process that explains how species change over time. In any group of organisms, there is always **variation**. Variation means that not all individuals are exactly the same. Some are taller, faster or stronger, while others might be smaller, slower or weaker. This variation is due to differences in their genes, which they inherit from their parents.

Because resources like food, water, and shelter are limited, not all individuals in a species can survive. This leads to **competition**. Organisms that have traits that give them an advantage in their environment are more likely to survive. The longer they survive, the more likely it is that they reproduce and pass on their genes. For example, in a population of rabbits, some might have thicker fur, which helps them survive in cold climates. Those with thicker fur are more likely to live longer, find mates and have offspring.

This idea, often summarised as "**survival of the fittest**", means that the individuals best suited to their environment are the ones most likely to survive. However, "fittest" doesn't necessarily mean the strongest or the fastest. It means the individuals whose traits are best matched to their environment.

For example, in a forest where the ground is covered with brown leaves, brown beetles might be less likely to be seen and eaten by predators than green beetles. As a result, the brown beetles are more likely to survive and reproduce, passing on their brown colour to their offspring. Over many generations, the population of beetles might become mostly brown.

Natural selection can lead to significant changes in a species over time. If a certain trait helps an organism survive, that trait becomes more common in the population. Over many generations, these changes can add up, leading to the development of new species.



AfricanConservation, CC BY-SA 4.0, via Wikimedia Commons

Another example of natural selection is the giraffe. Giraffes are known for their long necks, which allow them to reach leaves high up in trees. Originally, giraffes had shorter necks, but in times of food scarcity, those with slightly longer necks were able to reach leaves that others couldn't. This gave them an advantage, as they were more likely to survive and reproduce. Over many generations, this led to the population of giraffes having longer and longer necks, which we see in giraffes today.

Q1. The following statements are either true or false. State which are true and which are false.

a) All individuals within the same species are exactly the same.

....

b) Individuals that survive for longer are more likely to reproduce.

....

Q2. Describe what is meant by "survival of the fittest".

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Q3. Describe how variation within a species can lead to competition.

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Q4. Describe how giraffes evolved to have such long necks.

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Q5. Describe why brown beetles might survive longer in a forest compared to green beetles.

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Q6. In a population of birds, some have longer beaks and some have shorter beaks. The environment changes so that food is only available in deep crevices. State which birds are more likely to survive and explain why.

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Extinction

Extinction is the process where a species completely disappears from the Earth. This can happen when the environment changes in ways that make it difficult for certain species to survive. If a species can't adapt quickly enough to these changes, they may struggle to compete for resources like food and water. When this happens, fewer individuals survive to reproduce, and over time, the entire species can become extinct.

There are many ways the environment can change, leading to extinction. For example:

- **Climate change**. If the climate becomes too hot, too cold, too dry or too wet, some species might not be able to survive in the new conditions.
- **Habitat loss**. When forests are cut down or wetlands are drained, the animals and plants that lived there may have nowhere to go.
- **Pollution**. Chemicals released into the air, water and soil can harm or kill species that are sensitive to these pollutants.
- **Introduction of new species**. Sometimes, new species are introduced to an environment where they have no natural predators. These new species can outcompete native species for resources, leading to the extinction of the native species.

Biodiversity refers to the variety of all living things on Earth, including plants, animals and microorganisms. High biodiversity means that there are many different species living in an ecosystem. Maintaining biodiversity is important for several reasons:

- **Ecosystem stability**. Different species often depend on each other. If one species goes extinct, it can affect many other species in the ecosystem.
- **Resources**. Many of the resources we rely on, such as food, medicine and clean water, come from biodiversity. Losing species can reduce the availability of these resources.
- **Resilience to change**. Ecosystems with high biodiversity are often more resilient to changes, such as climate change, because they have more species that can fill different roles if some species are lost.

One way to help prevent the loss of species and maintain biodiversity is by using **gene banks**. Gene banks are places where genetic material (like seeds, sperm, eggs or embryos) is stored. This genetic material can be used to help protect endangered species or bring back species that have become extinct. Gene banks are important for several reasons:

- **Preservation and research**. By storing genetic material, scientists can preserve and study the genetic material in gene banks to learn more about how to protect endangered species.
- **Restoration**. In some cases, gene banks can be used to reintroduce species into the wild by breeding new individuals from the stored genetic material.

Q1. The following statements are either true or false. State which are true and which are false.

a) Ecosystems with a high biodiversity are often less resistant to change.

....

b) If one species in an ecosystem goes extinct, it won't affect any other species.

....

c) One way to help prevent extinction is to use gene banks.

....

Q2. State four ways the environment can change, leading to extinction.

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Q3. Describe what is meant by biodiversity.

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Q4. Describe why maintaining biodiversity is important.

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Q5. Describe what a gene bank is.

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Q6. Explain how gene banks help in preserving species.

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Q7. Explain how habitat loss can lead to extinction.

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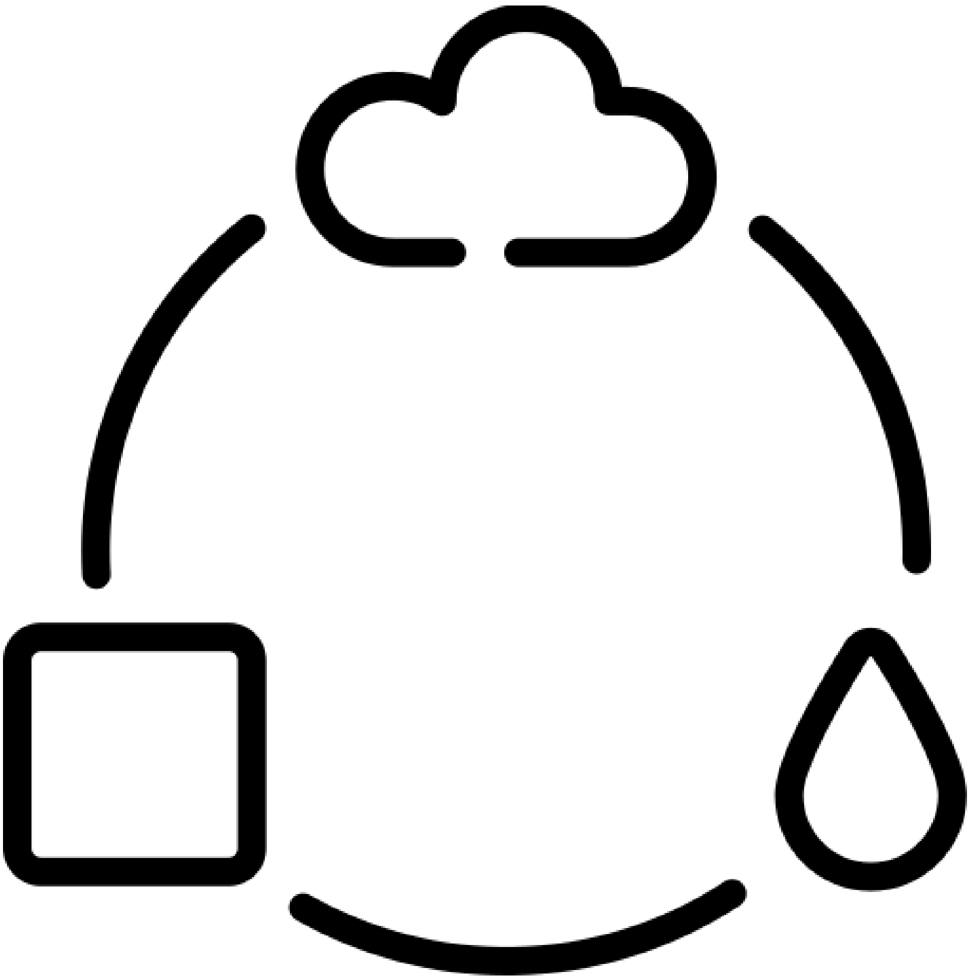
The particle



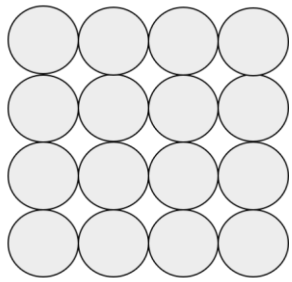
model

Solids, liquids and gases

All matter is made of **particles**. Depending on the substance, the particles could be **atoms** or **molecules**.

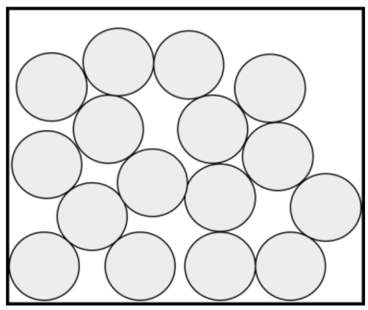
The three **states of matter** are **solid**, **liquid**, and **gas**. They all have different properties due to the arrangement and movement of their particles.

Solid



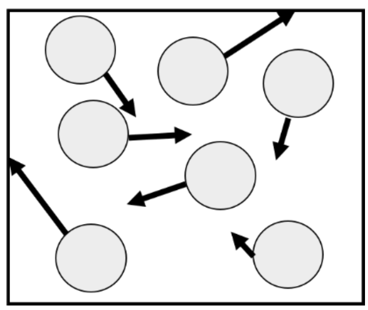
Solids have particles that are held tightly together, this means that they are **dense**. The particles are arranged in a regular pattern and **vibrate around fixed positions.** Solids have a definite shape and volume and **cannot be compressed** easily because the particles are already packed closely together. Solids have the least amount of energy.

Liquid



In a **liquid** the particles are held closely together but the particles can also move past each other. This means that a liquid has a changing shape and can **flow**. Liquids are **dense** and **cannot be compressed** easily. A liquid can change its shape but not its volume.

Gas



There are only **very weak forces** between **gas** particles, which are far apart. Because of this gases can be **compressed**, and so they have no fixed volume. The particles move around quickly in random directions, at a range of different speeds. They cause pressure when they collide with the walls of a container. Gases have a **low density** and they do not have a fixed shape or volume. Gases have the most energy. As you heat a gas, the particles move more quickly.

While solids are usually the most dense state of matter; water and ice are an exception. Water (a liquid) is more dense than ice (a solid). That’s why ice cubes float in a drink.

Q1. In the spaces below, draw the particle arrangement for solids liquids and gases.

Solids	Liquids	Gases

Q2. Name the state of matter that can be compressed. ....

Q3. Name the state of matter that can change its shape but not its volume. ....

Q4. Name the state of matter that has no fixed volume. ....

Q5. Name the state of matter that has a low density. ....

Q6. Name the state of matter that has particles that vibrate around fixed positions. ....

Q7. Name the state of matter that is used in hydraulics. ....

Q8. Name the state of matter that has particles that flow but are still close together. ....

Q9. State what happens to the speed of gas particles when the temperature of a gas is increased.

....

Q10. Describe the movement of gas particles.

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....

Q11. Describe how the particle arrangement changes as a material changes from a solid into a liquid.

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Q12. Describe how the particle arrangement changes as a material changes from a liquid into a gas.

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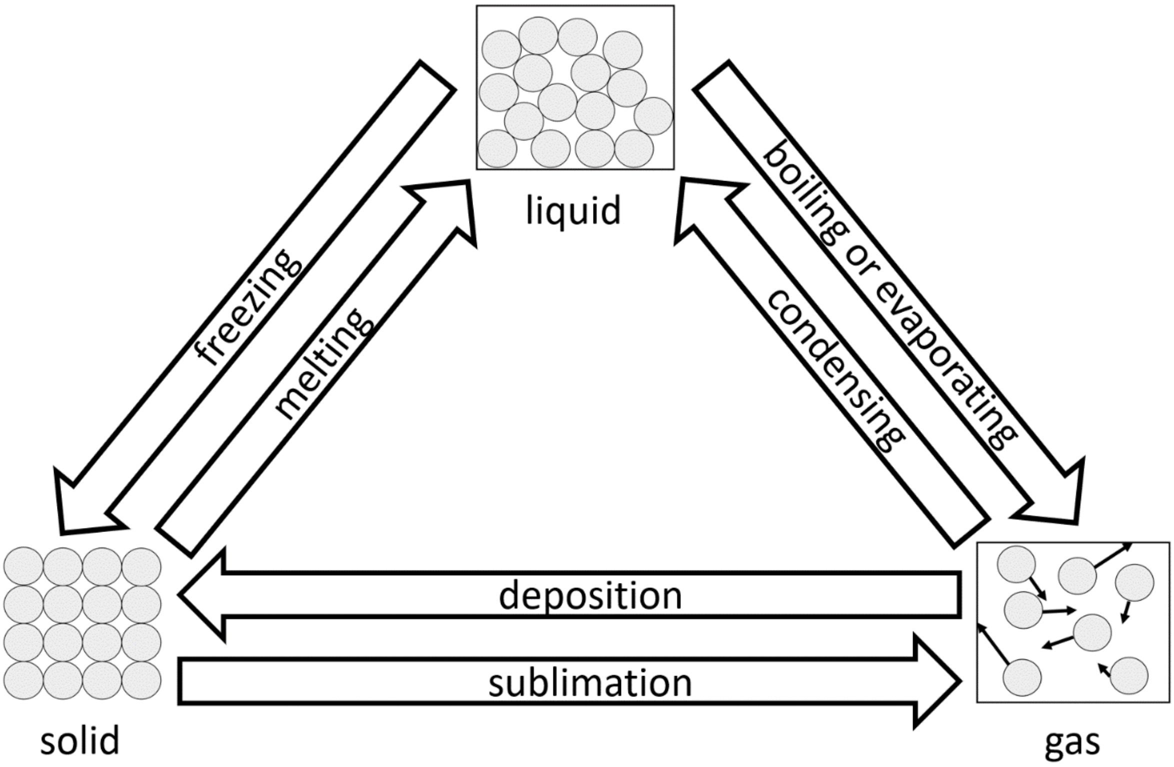
Q13. State the reason why ice cubes float in water.

....

Changes of state

As the temperature of particles changes, they **change state**. In the process of changing state, the overall number of particles stays the same. This means the mass before a state change is the same as the mass after a state change. This is called the **conservation of mass**. The different state changes are shown in the diagram below:



A **solid** has particles that are held together in a regular pattern. The particles vibrate around their fixed positions. As the solid is heated, these vibrations increase until it reaches its **melting point**. One example of a melting point is that of water at 0°C.

While the solid is melting, it stays at the same temperature. The particles start to be freed from their fixed positions until they are free to move past each other. Particles are still in contact. When the process of melting is complete, all the particles are in the **liquid** state.

If we continue heating the liquid, the particles again move more quickly. When the liquid reaches its **boiling point**, it starts boiling and turning into a **gas**. Here, the particles are moving quickly enough so they separate from one another. Particles in a gas are far apart and move around quickly in random directions. One example of a boiling point is that of water at 100°C.

When a gas is cooled to its boiling point, it **condenses** into a liquid. If a liquid is cooled to its melting point, it **freezes** to form a solid.

If cooled enough, gases can also undergo **deposition** so they are turned directly into a solid. If heated enough, solids can undergo **sublimation** so they are turned directly into a gas.

Q1. During a state change, mass is conserved. Describe what conservation of mass means.

....

....

Q2. Name the state change in going from solid to liquid. ....

Q3. Name the state change in going from gas to liquid. ....

Q4. Name the state change in going from liquid to gas. ....

Q5. Name the state change in going from gas to solid. ....

Q6. Name the state change in going from solid to gas. ....

Q7. Name the state change in going from liquid to solid. ....

Q8. State the melting point of water. ....

Q9. State the boiling point of water. ....

Q10. Describe the particle arrangement in a solid.

....

....

Q11. Describe the particle arrangement in a gas.

....

....

Q12. The following statements are either true or false. State which are true and which are false.

a) As a solid melts, the temperature increases.

....

b) As a gas is heated, the particles move more quickly.

....

c) Regardless of temperature, particles in a solid vibrate the same amount.

....

d) If particles in a liquid evaporate into a gas, the gas has less mass than the liquid.

....

Q13. Some water is at a temperature of −10°C. State which state of matter the water is in. Explain why.

....

Q14. Some water is at a temperature of 200°C. State which state of matter the water is in. Explain why.

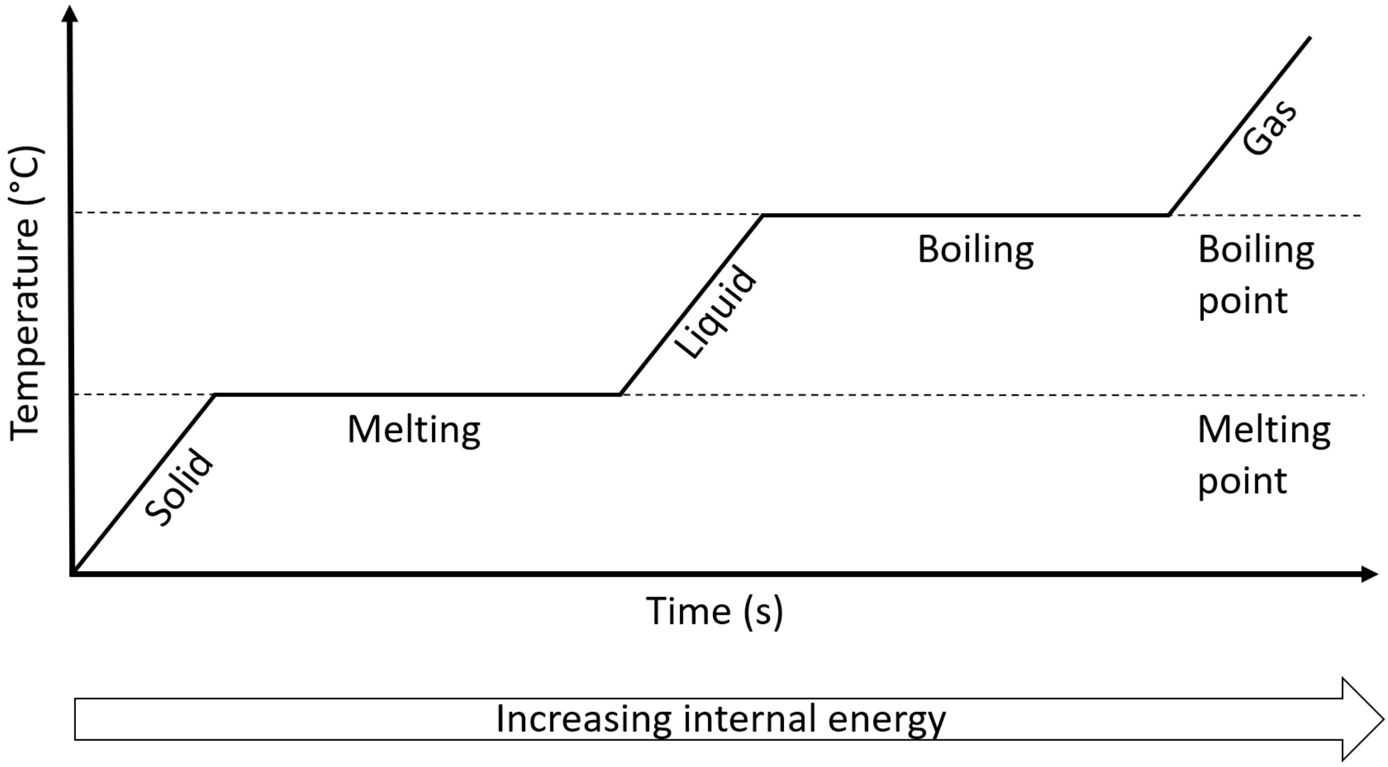
....

Q15. Some water is at a temperature of 50°C. State which state of matter the water is in. Explain why.

....

Heating and cooling curves

The graph below shows the heating curve of a **pure** substance. A pure substance is made from only one element or compound. Note how the temperature of the substance remains constant during a state change.



As thermal energy is transferred to the substance, the **internal energy** of the particles in the substance increases. The internal energy consists of the **kinetic energy** and **potential energy** stores of the particles.

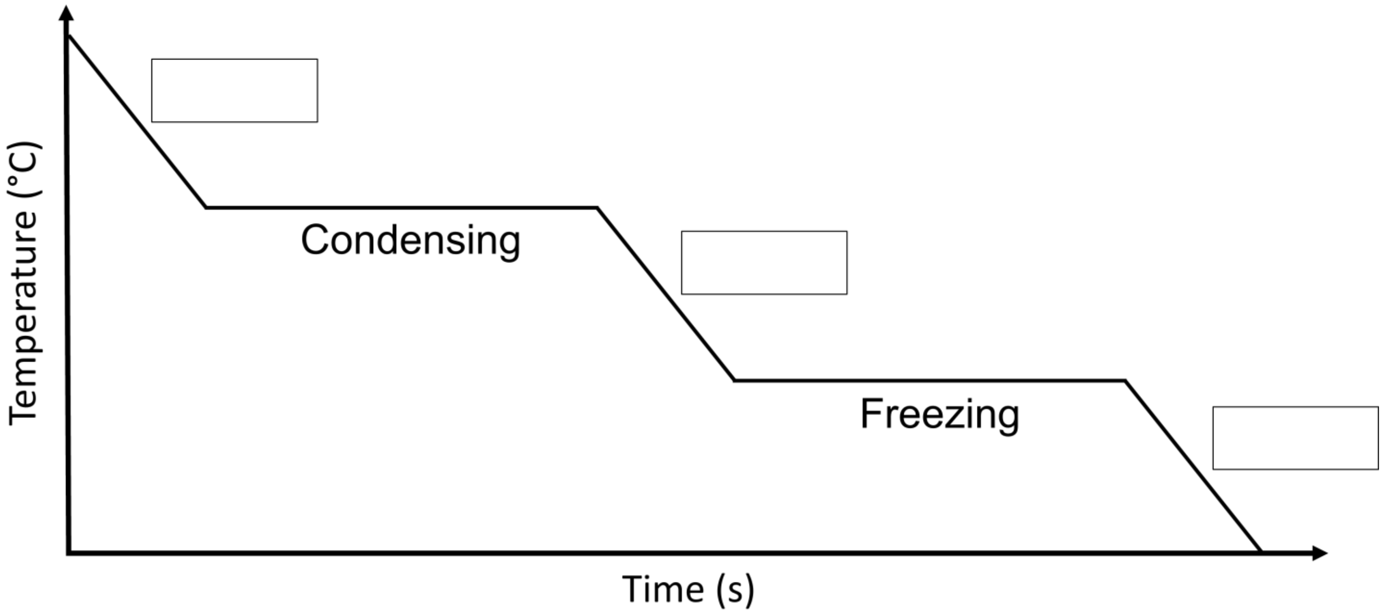
While the substance is increasing in temperature, the kinetic energy store of the particles in the substance increases. As a solid increases in temperature, the vibrations of the particles in the solid increase.

Eventually, the solid start melting. During this time, some bonds are broken but the temperature remains constant. The potential energy store of the particles in the substance increases. The thermal energy supplied to the material is called "latent" here. Latent comes from the Latin for "hidden".

Similar happens with liquids and gases. As a liquid or gas increases in temperature, particles move more quickly and their kinetic energy store increases. As a liquid is boiled, bonds are broken and the potential energy store of particles increases.

An **impure** substance contains more than one element or compound. We could also say the substance contains **impurities**. For an impure substance, there is not a single temperature for melting and boiling. Instead, this happens over a range of temperatures.

Q1. The diagram below shows the cooling curve of a pure substance. Label the three states of matter that are missing from the diagram.



Q2. Describe what a pure substance is.

....

....

Q3. Describe what happens to the motion and kinetic energy of gas particles as they cool.

....

....

Q4. Describe what internal energy is.

....

....

Q5. Describe what an impure substance is.

....

....

Q6. Describe how the heating curve for an impure substance is different to that of a pure substance.

....

....

Q7. Describe why the temperature of a pure substance stays constant while it melts.

....

....

Q8. State what happens to the internal energy of a substance as it increases in temperature.

....

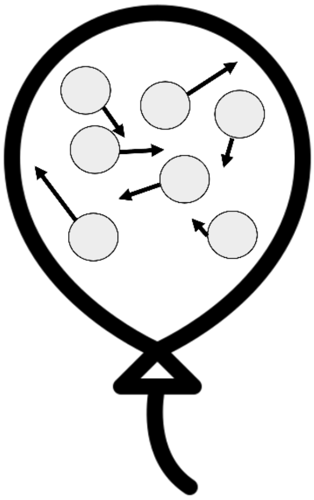
Pressure in gases

Particles in a gas move **in random directions** and at a range of different speeds.

We know this because of something called **Brownian motion**. In 1827, Robert Brown (which Brownian motion is named after) noticed that pollen particles moved around in a random way. Smoke particles move in a similar way in air. This is because of collisions with air particles that are moving in random directions and at a range of different speeds.

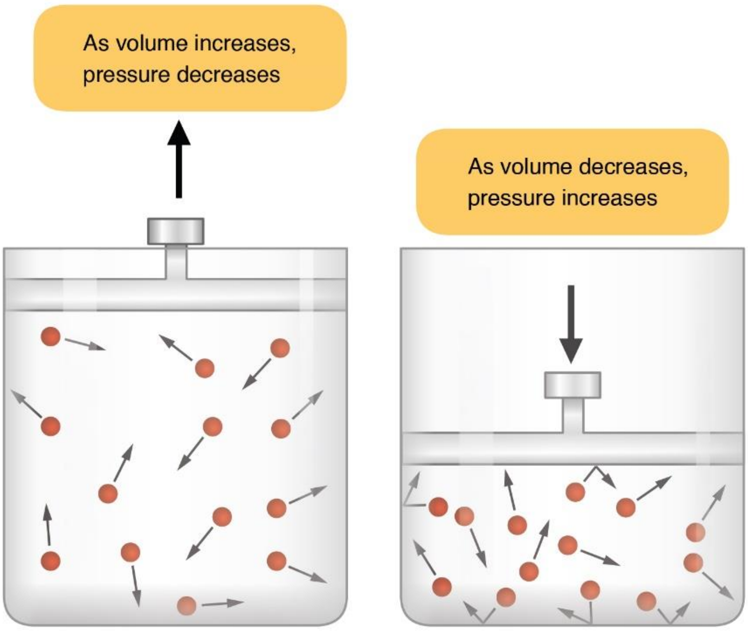
While the smoke particles are much larger than the air particles, the air particles are moving much faster and so they affect how the smoke particles move when they collide.

When a gas particle collides with a surface, **pressure** is exerted on that surface.



The reason balloons get bigger when you blow them up is because you are adding air into the balloon.

More air means **more particles** inside the balloon. In turn, this leads to **more collisions** between air particles and the walls of the balloon. More collisions cause a **higher force** on the walls, which then leads to a **higher pressure**. This makes the balloon **expand**.



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If we reduce the volume of a container, a similar thing happens. This is shown in the diagram to the left.

If the volume of a container is reduced, gas particles collide with the walls of the container more often.

This leads to a higher force on the walls of the container, and therefore a higher pressure.

If we increase the temperature of a gas in a container, the **kinetic energy** and speed of the gas particles also increase. This also means the gas particles collide with the walls of the container more often (again leading to a higher force and a higher pressure on the walls of the container). This is why a balloon expands if we heat it.

Q1. Smoke particles are observed to move in a random way in air. State the name of this process and explain why this happens.

....

....

Q2. Air is being pumped into a balloon.

a) State what happens to the number of air particles inside the balloon.

....

b) State what happens to the number of collisions between the air particles and the walls of the balloon.

....

c) State what happens to the force exerted by the air particles on the walls of the balloon.

....

d) State what happens to the pressure inside the balloon.

....

e) State what happens to the size of the balloon.

....

Q3. Some gas is inside a container. The volume of the container is slowly increased.

a) State what happens to the force exerted by the air particles on the walls of the container.

....

b) State what happens to the pressure inside the container.

....

Q4. State what happens to the average speed of gas particles as the temperature of the gas is increased.

....

Q5. Two containers have the same amount of gas particles inside them. Container A is smaller than container B. State and explain which container has the higher pressure.

....

....

Q6. Two containers have the same amount of gas particles inside them. Container A is at a lower temperature than container B. State and explain which container has the higher pressure.

....

....

Q7. A balloon is cooled. State and explain what happens to the size of the balloon.

....

....

Diffusion

Particles in liquids and gases move with a **random motion**. Particles in a liquid are in contact with each other and free to flow past each other. Particles in a gas are separate from one another and move quickly in random directions at a range of speeds. We also know that this causes **Brownian motion**.

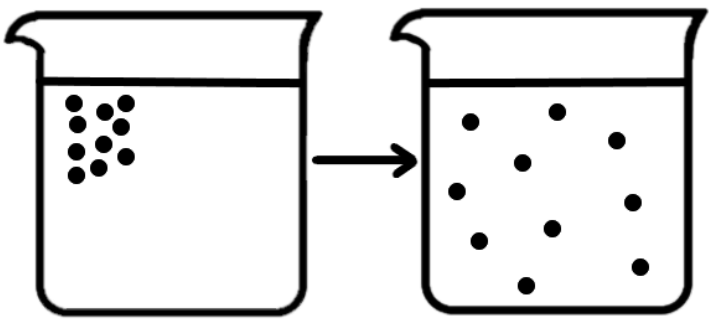
Diffusion happens in fluids (liquids and gases). Diffusion is the movement of particles from a high concentration (of those particles) to a lower concentration.

The diagram below shows some dye being introduced to a glass of water. Because the water particles are moving in random directions, this leads to diffusion of the dye.

Immediately after the dye has been dropped it is at a high concentration in that area. Diffusion means that particles move from this high concentration to the surrounding areas (where there is a low concentration). Eventually the dye is evenly spread throughout the water.

BruceBlaus, CC BY 3.0, via Wikimedia Commons

The diagram to the right also shows the initial and final stages in terms of particles. If we leave the water and dye for long enough then the dye particles are evenly distributed throughout the water.



Christinelmiller, CC BY-SA 4.0, via Wikimedia Commons

If we wanted to speed this process up, then we could heat the water. Particles move faster in a hotter liquid or gas. Therefore diffusion would also be faster. We could also speed up diffusion by stirring the liquid.

Q1. The following statements are either true or false. State which are true and which are false.

a) In diffusion, particles move from a low concentration to a high concentration.

....

b) Diffusion happens at the same rate, regardless of the temperature of the liquid.

....

c) Diffusion happens only in liquids.

....

d) Diffusion in a liquid can be sped up by stirring the liquid.

....

Q2. Describe how particles move in liquids.

....

....

Q3. Describe how particles move in gases.

....

....

Q4. Describe what diffusion is.

....

....

Q5. State what happens to the average speed of particles in a liquid as the temperature of the liquid is increased.

....

Q6. Two beakers are full of water. Some red dye is dropped in each. Beaker A contains water at 20 °C, Beaker B contains water at 50 °C. State and explain in which beaker diffusion will be fastest.

....

....

Q7. Some deodorant is sprayed in a room. Explain how the deodorant spreads throughout the room.

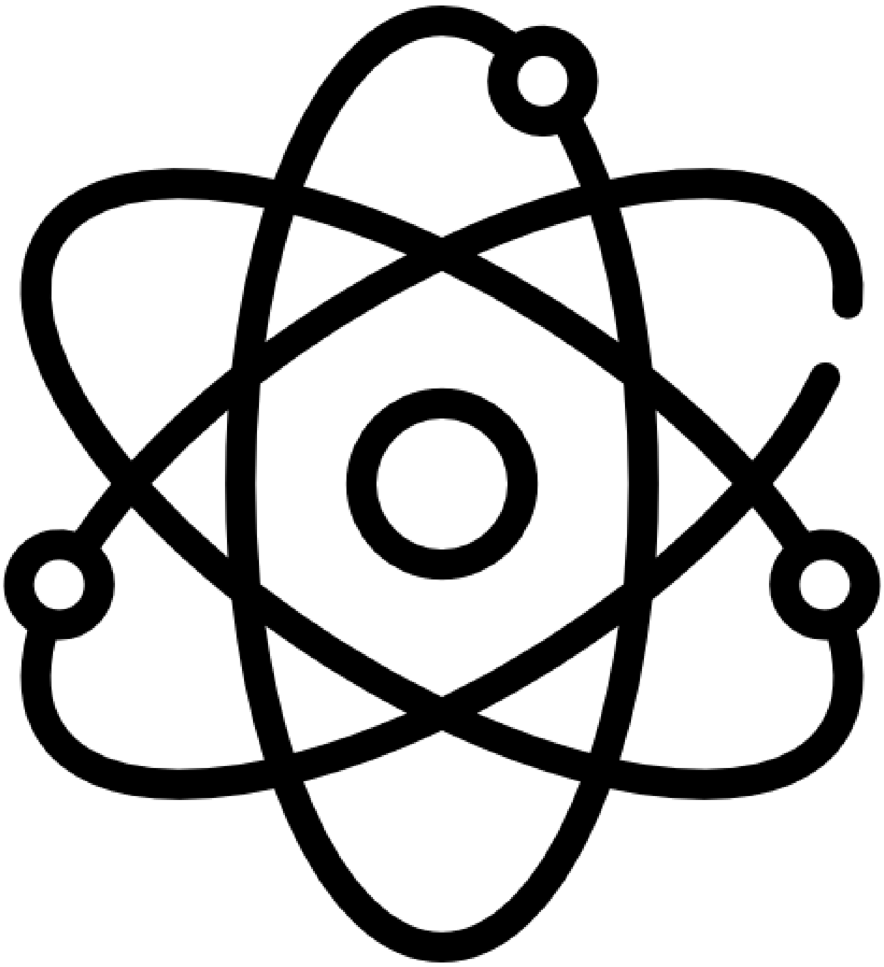
....

....

Q8. A fan is on in the same room. State what this would do to the rate of diffusion.

....

Atoms, elements



and compounds

The atom

We have already learnt about the **particle model**, where matter is made of particles. This is one example of a **scientific model**.

Scientific models are usually simplified versions of an object or a phenomenon. This makes them easier to understand, while still representing the key features.

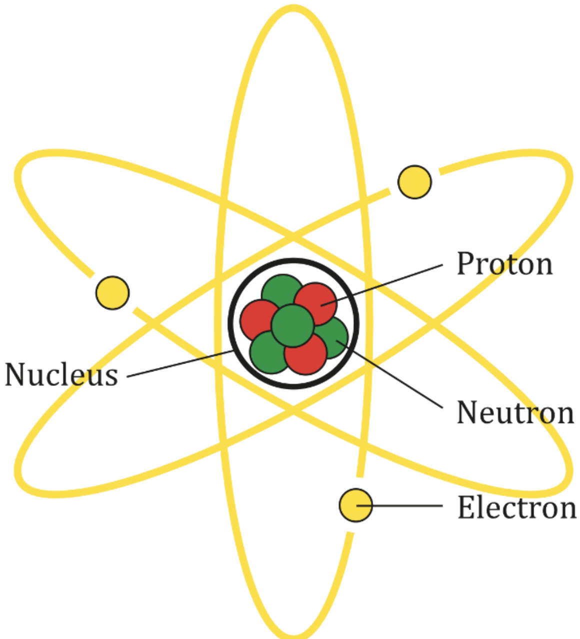
The particle model is used to explain and predict the behaviour of solids, liquids and gases. This is a simplification, as we know that particles are made of atoms and molecules (which, in turn, consist of smaller parts).

Models are also changed and updated over time, and the atomic model is one example of this. Previously, it was thought that atoms were indivisible (could not be broken down into anything smaller). This is the **Dalton model** of the atom.

However, newer evidence from experiments suggested the atom was made of **sub-atomic particles**. They are called sub-atomic because they are smaller than the atom itself.

In the current model of the atom, there are three subatomic particles:

1. **Protons**. These have a positive charge and are contained in the centre of atom. The centre of the atom is called the **nucleus**.
2. **Neutrons** are also contained in the nucleus, but neutrons are neutral. Something that is neutral has no charge.
3. **Electrons** orbit around the nucleus. They have a negative charge.



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Most of the mass of an atom is contained in the nucleus, with neutrons and protons having around 2000 times more mass than an electron.

Overall an atom is **neutral** as there are equal numbers of electrons and protons.

Generally, evidence is required to change a scientific model. New evidence and research go through a process called **peer review**.

Peer review is when other scientists look at the new evidence and decide whether or not it is valid. This is important as otherwise incorrect models and theories could be spread. After peer review, new research can be published. After this, other scientists may decide to try and **reproduce** the research to check whether the results are **repeatable**.

Q1. Describe the Dalton model of the atom.

....

....

Q2. The following questions are asking about the current model of the atom.

a) Describe where the nucleus of an atom is.

....

b) Name the two sub-atomic particles that are in the nucleus.

....

c) Name the sub-atomic particle that orbits around the nucleus.

....

d) State the charge on a proton.

....

e) State the charge on an electron.

....

f) State the charge on a neutron.

....

g) Name the sub-atomic particle that has the least mass.

....

Q3. Describe what a scientific model is.

....

....

Q4. Describe an advantage of using scientific models.

....

....

Q5. Describe what peer review is.

....

....

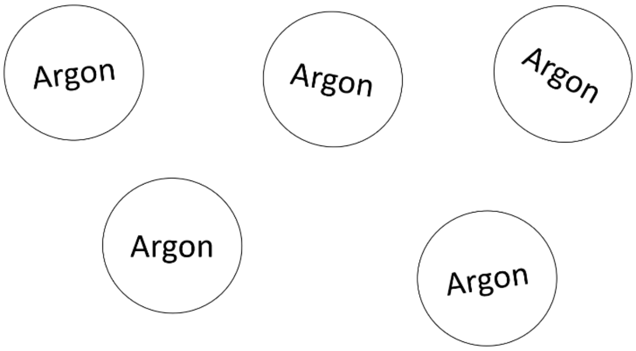
Q6. Describe the difference between the Dalton model and the current model of the atom.

....

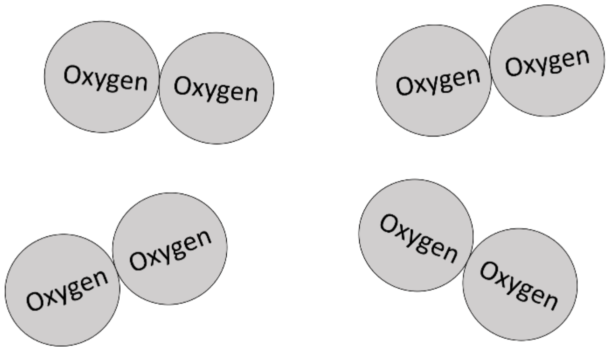
....

Elements, compounds and mixtures.

An **element** is made from only one type of **atom**. There are over 100 known elements and they are listed on the **periodic table**. For example, argon and oxygen are both elements as they both contain only one type of atom.

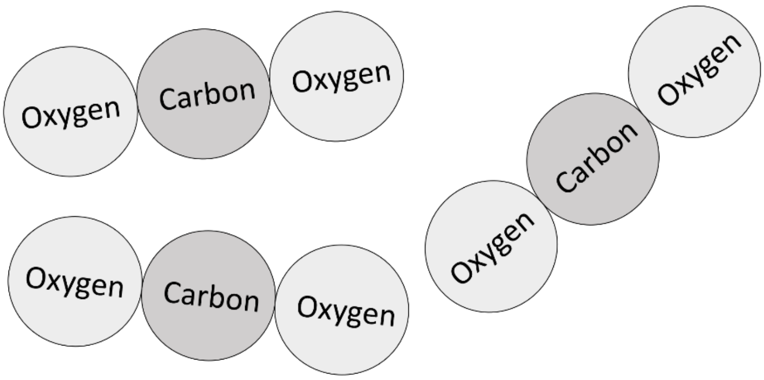


Here, we have the element argon. We know that we have an element because there is only one type of atom.



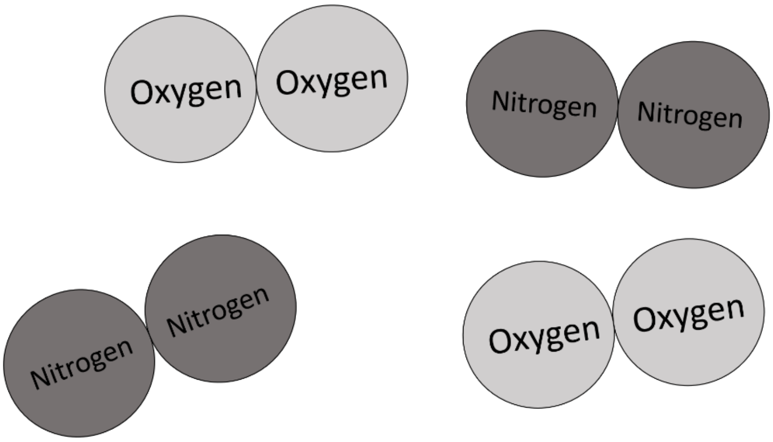
Here, we have the element oxygen. Oxygen is a diatomic gas as it contains two atoms that are chemically joined. A monatomic gas contains only single atoms that are not chemically joined.

A **compound** is a substance where two or more atoms (of different elements) are **chemically joined**. For example, carbon dioxide is a compound as it contains the elements carbon and oxygen.



Carbon dioxide is a compound; it has two different types of atom that are chemically joined.

A **mixture** is a substance that contains two or more elements or compounds that are not chemically joined together. For example, nitrogen gas mixed with oxygen gas is a mixture of elements. Carbon dioxide mixed with carbon monoxide is a mixture of compounds.



Here we have a mixture of two different elements; nitrogen and oxygen.

Q1. Describe what an element is.

....

....

Q2. Describe what a compound is.

....

....

Q3. Describe what a mixture is.

....

....

Q4. Below is a list of substances. State which are elements and which are compounds.

Iron	Iron Oxide	Nitrogen	Oxygen
Carbon dioxide	Aluminium	Hydrochloric acid	Water

Elements:

....

Compounds:

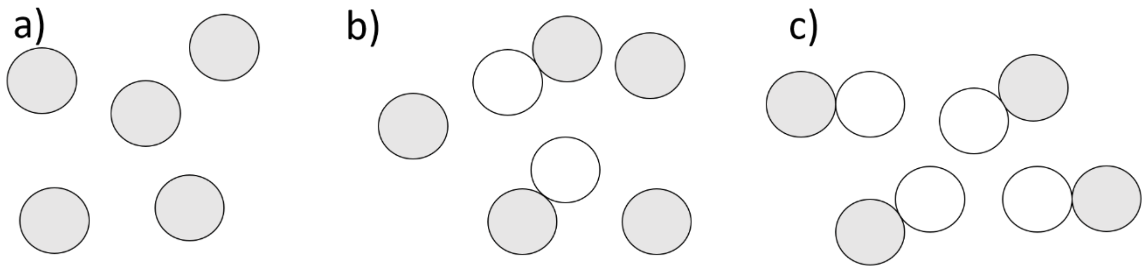
....

Q5. For the compounds you've listed in Q4. State what elements each compound contains.

....

....

Q6. Below are diagrams of three different substances. State which is an element, which is a compound and which is a mixture.



....

....

Q7. Describe the difference between an element and a compound.

....

....

Q8. Describe the difference between a compound and a mixture.

....

....

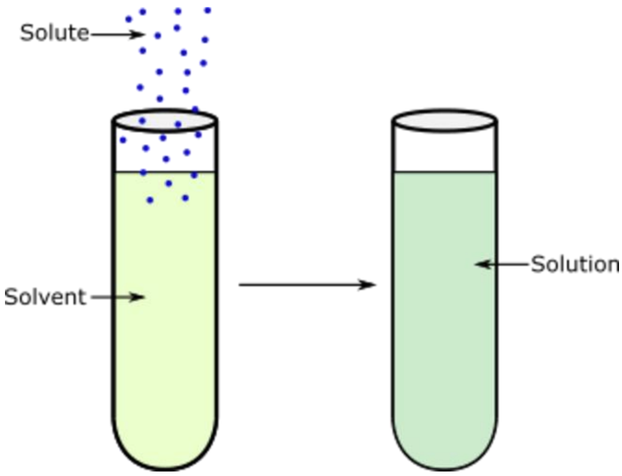
Making and separating solutions

If we add a sugar cube to water, the sugar **dissolves**. It looks like the sugar has disappeared, but the particles are just mixed in with the water.

To make the sugar dissolve faster, we could heat the water and stir it.

A substance that dissolves is called the **solute**, while something that dissolves other substances is called a **solvent**.

In the example above, sugar is the solute and water is the solvent. Once a solute is dissolved in a solvent, a **solution** is formed.



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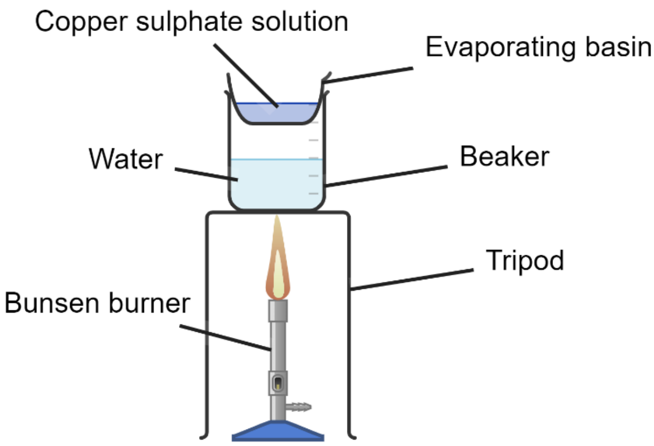
If a substance can dissolve, it is called **soluble**. If it is not able to dissolve it is **insoluble**. While salt dissolves in water, sand does not. Sand is insoluble in water.



Created with Chemix (https://chemix.org)

To separate out a solute we can use a setup like that in the diagram to the left. Here, we are trying to obtain copper sulphate crystals from the solution.

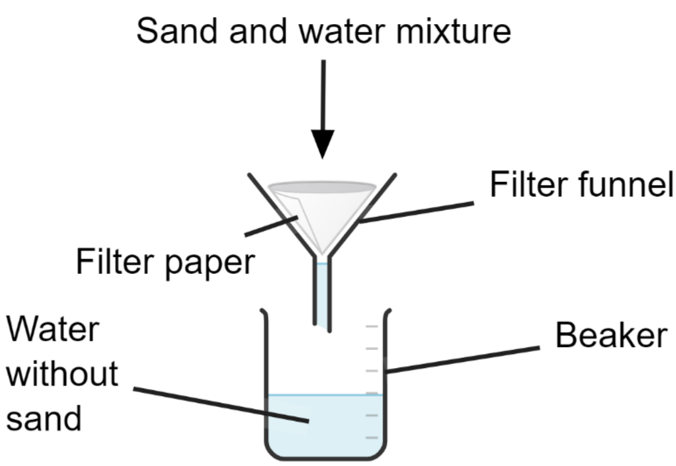
The solution is poured into an evaporating basin and gently heated. When some of the solvent has evaporated, the solution is removed from the heat.

Eventually, copper sulphate crystals are formed as the solvent evaporates.

Because sand is insoluble in water, this method cannot work for a sand and water mixture.

Instead, we use **filtration**. The sand and water mixture is poured onto some filter paper.

Because the water molecules are smaller than the sand particles, water passes through the filter funnel but the sand doesn't. Therefore, we can separate the water and sand.



Created with Chemix (https://chemix.org)

Q1. The following statements are either true or false. State which are true and which are false.

a) Sand is soluble in water.

....

b) Salt is soluble in water.

....

c) Sugar dissolves faster in hot water than it does in cold water.

....

d) You can filter out the salt from a saltwater solution by passing the solution through filter paper.

....

Q2. In fizzy drinks, the bubbles are caused by carbon dioxide. The carbon dioxide is initially dissolved in the water.

a) State the solute.

....

b) State the solvent.

....

Q3. Describe what the word soluble means.

....

Q4. Describe what the word insoluble means.

....

Q5. State two ways of making salt dissolve faster in water.

....

Q6. Describe how you would separate sand from a sand and water mixture.

....

....

....

Q7. Describe how you would separate sugar from a sugar and water solution.

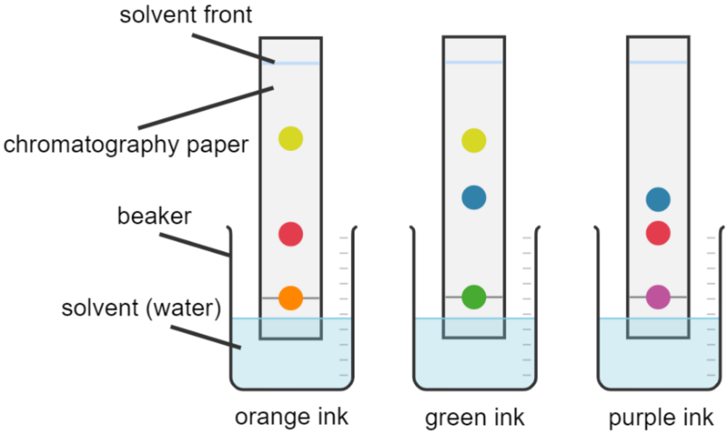
....

....

....

Chromatography and distillation

Chromatography allows us to separate different substances in a mixture. For example, the diagram to the right shows three inks undergoing chromatography.



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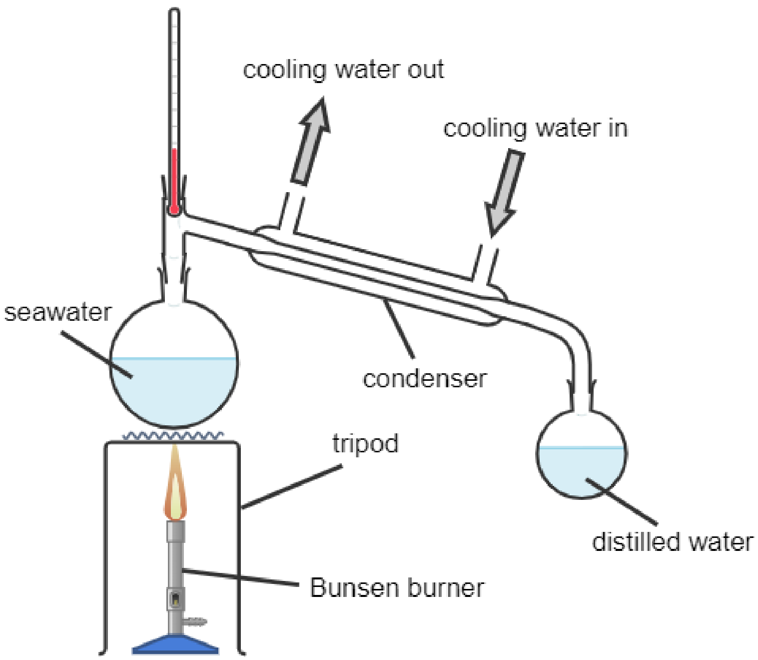
Here, a spot of ink is placed on **chromatography paper** and the paper is placed in water. The water rises up the paper and acts as a **solvent**. The ink is made of different dyes that are **soluble** in water.

As the water rises, it brings the dyes up the chromatography paper with it. However, different dyes move up the chromatography paper at a different rate. Therefore, the different dyes are separated.

If we look at the diagrams above, we can see that both orange ink and purple ink both have one dye in common. We know this because the dye has risen by the same amount up the chromatography paper.

The green and purple inks also have one dye in common, as do the orange and green inks.



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The apparatus to the left shows **simple distillation**.

Here, a Bunsen burner applies heat to some seawater. The water evaporates, leaving the salt in the seawater behind.

The water vapour then travels through a **condenser** where cooling water passes through.

Because the condenser is cool, it condenses the water vapour. The distilled water can then be collected.

This method can also be used to separate liquids with different boiling points.

Q1. The following statements are either true or false. State which are true and which are false.

a) In chromatography, ink is the solvent.

....

b) In chromatography, the dyes are soluble in water.

....

c) Chromatography allows us to separate different elements in a compound.

....

d) Simple distillation allows us to separate liquids with different boiling points.

....

e) Cooling water is used in a condenser to condense hotter gases.

....

Q2. Name the state change in going from gas to liquid.

....

Q3. Name the state change in going from liquid to gas.

....

Q4. Describe what the word soluble means.

....

Q5. Describe what the word solvent means.

....

Q6. A mixture of liquids undergoes simple distillation. Liquid A has a boiling point of 100°C. Liquid B has a boiling point of 300°C. As the mixture is heated, state and explain which liquid will evaporate and be collected first.

....

....

Q7. Describe how chromatography is used to separate dyes in an ink.

....

....

....

Q8. A student claims that salt can be filtered out of seawater by passing seawater through filter paper. Explain why the student is wrong and describe a correct method for obtaining pure water from seawater.

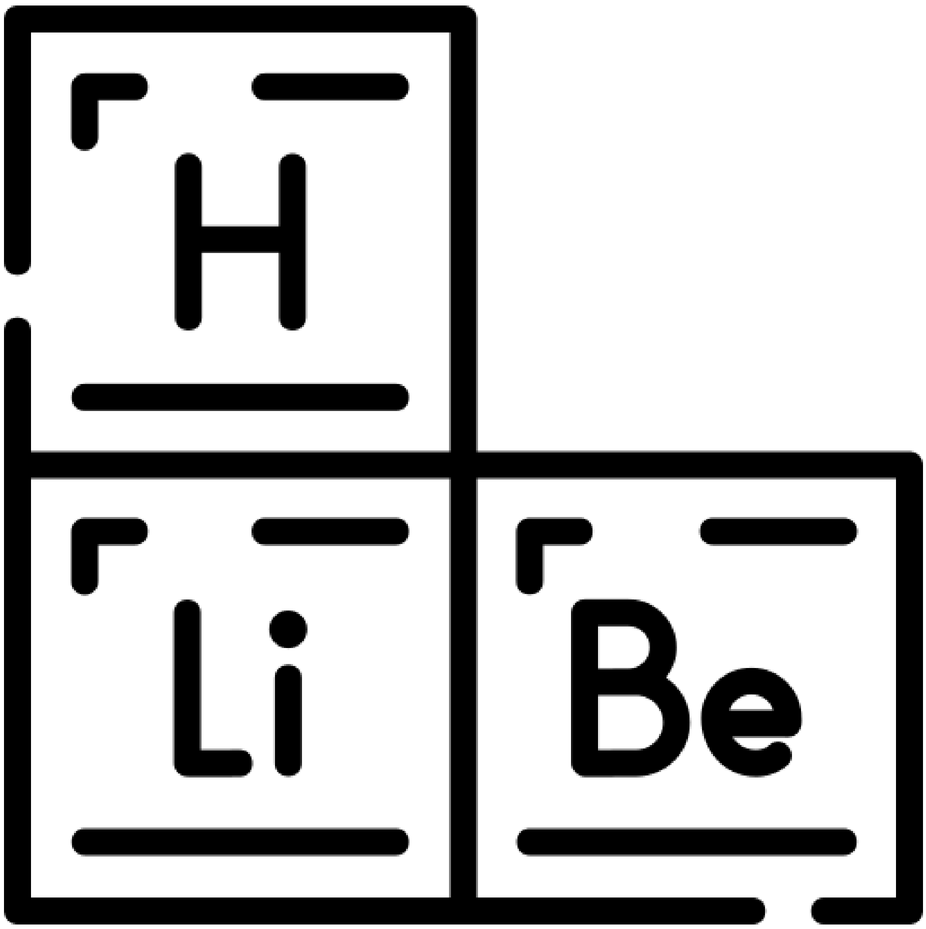
....

....

....

....

The periodic



table

Metals and non-metals

As there are over 100 known elements, it is important to have a written way of organising them that makes finding each element easy.

We now organise elements in the **periodic table** according to their properties and the number of protons in the element (called the atomic number). This means that making predictions about the properties of different elements is easy.

Elements are also categorised as **metals** and **non-metals**. This is because metals and non-metals have different properties to one another.

Properties of metals and non-metals are summarised in the table below:

Properties of metals	Properties of non-metals	Example
Metals are good **electrical conductors**. Good electrical conductors have a low resistance. Resistance is a measure of how hard it is for current to flow through something.	Non-metals are normally poor electrical conductors. A poor electrical conductor is also called an **electrical insulator**. Electrical insulators have a high resistance.	Copper is often used as wires in an electrical circuit. This is because it is a good **electrical conductor**.
If a material is able to conduct heat well, it is a good **thermal conductor**. Metals are good thermal conductors.	Non-metals are often poor conductors. Non-metals are usually **thermal insulators**.	Cooking pans are often made of aluminium as it is a good **thermal conductor**.
Metals are generally **malleable** (easy to make into different shapes), **ductile** (can be drawn out into thin wires) and **strong**.	Non-metals are generally **brittle**.	Steel is often used in construction as it is **strong**. Copper is used in electrical wires as it is **ductile**.
Metals usually have **high melting and boiling points**.	Non-metals often have **low melting and boiling points**. Many non-metals are gases at room temperature.	The melting point of iron is 1500 °C, whereas the melting point of oxygen is -220 °C.

Q1. The following statements are either true or false. State which are true and which are false.

a) Metals are good thermal insulators.

....

b) Metals are good electrical conductors.

....

c) There are over 100 known elements.

....

d) Non-metals are ductile.

....

e) Metals usually have high melting and boiling points.

....

f) Metals are generally brittle.

....

g) The atomic number is the number of neutrons in an element.

....

Q2. Describe what a material being a good electrical conductor means.

....

....

Q3. Describe how the melting point of a metal generally compares to the melting point of a non-metal.

....

....

Q4. State an element that would make a good material for an electrical wire. Give two reasons describing why that element is suitable for that purpose.

....

....

Q5. Describe what the word malleable means.

....

Q6. Describe why cooking pans are made of metals.

....

....

Q7. Describe why we organise elements in the periodic table in groups where elements have similar properties.

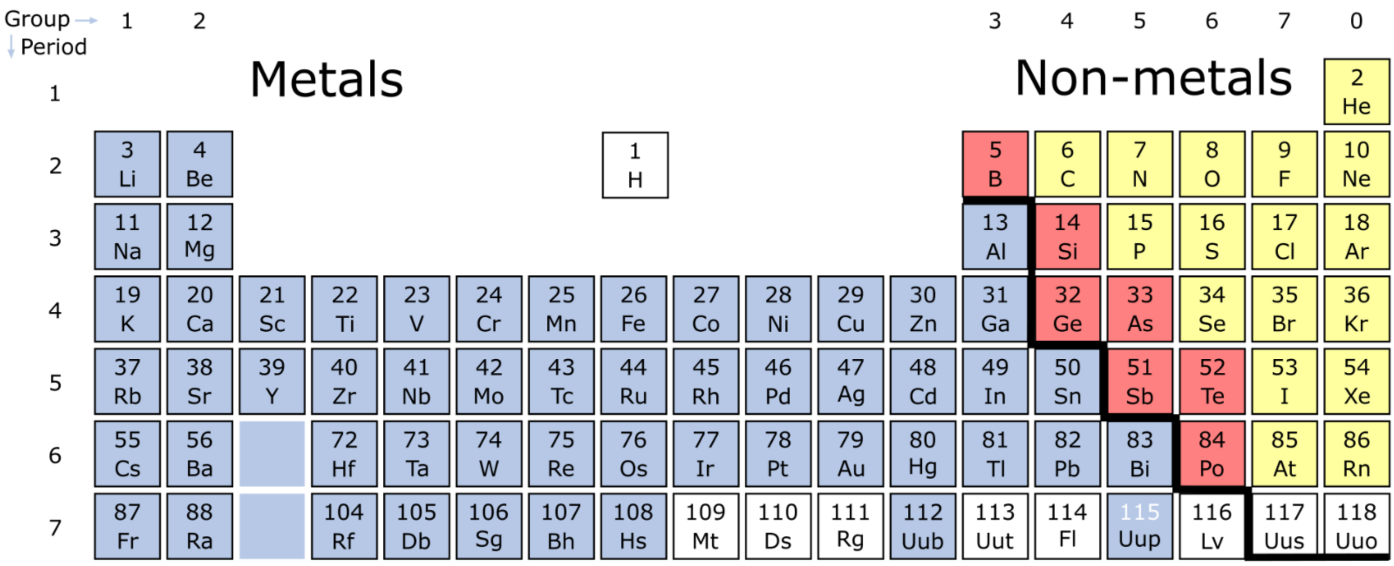
....

The periodic table

In early versions of the periodic table, elements were arranged according to their atomic weight. This had some problems, though, as the order of the atomic weights did not align with the order of the properties of the elements.

In 1869, Dmitri Mendeleev made several changes to this arrangement. He put elements together in groups where elements had the same properties. As these properties are in a repeating pattern, it is called the **periodic table**.

The order of elements was no longer in the exact order of the atomic weight (although most elements were in this order) to allow for elements with similar properties to be in the same group. Gaps were also left for elements that had not yet been discovered. When new elements were discovered, they followed the pattern that Mendeleev predicted and were placed into the gaps. Below is a copy of the periodic table.



Elements are arranged by increasing atomic number (the number of protons that an element has). Elements are also represented by their chemical symbol. Here, the atomic number is written above the chemical symbol.

The columns are called **groups**. Each group contains elements that have similar properties. For example, the metals in group 1 are known as the alkali metals. They all react vigorously when placed in water. As elements that have similar properties are in the same group, it makes it easy to predict what properties certain elements have.

Rows are called **periods**. Metals are to the left of the bold line, non-metals to the right. For example, Aluminium (with chemical symbol Al and atomic number 13) is a metal as it is to the left of the bold line.

Q1. The following statements are either true or false. State which are true and which are false.

a) Elements in the same period have the same properties.

....

b) In the periodic table, elements are ordered according to their atomic mass.

....

Q2. For each of the elements, write the atomic number of the element and whether it is a metal or a non-metal.

a) Iron (chemical symbol Fe).

....

b) Carbon (chemical symbol C).

....

c) Helium (chemical symbol He).

....

d) Copper (chemical symbol Cu).

....

e) Sodium chemical (symbol Na).

....

f) Gold (chemical symbol Au).

....

g) Oxygen (chemical symbol O).

....

h) Silver (chemical symbol Ag).

....

Q3. Describe why it is advantageous that elements with similar properties are kept in the same group.

....

....

Q4. State and explain which of aluminium (chemical symbol Al) or silicon (chemical symbol Si) is likely to make a better electrical wire.

....

....

Chemical formulae

In the periodic table, different **elements** are represented by different **symbols**. The first letter of a symbol is always a capital letter. If an element is represented by a symbol that has more than one letter, then the second letter is lower case. For example, the letter "C" represents carbon, whereas the letter "Cu" represents copper (some symbols come from the Latin for the elements).

Sometimes elements are found in pairs of atoms. For example, oxygen (with symbol "O") is found in a gas that is written as "O_2". The subscript 2 shows that two oxygen atoms are joined together.

Compounds can also be represented by chemical formulae. A compound is a substance where two or more atoms (of different elements) are **chemically joined**. Compounds have different properties to the elements that they are made from.

For example, the chemical formula for water is H_2O. Note that this formula means that water has two hydrogen atoms (with symbol "H_2") and one oxygen atom (with symbol "O").

Be careful as the chemical formulae of some compounds look very similar to the symbols of some elements. For example, the element "Co" is cobalt while the compound "CO" is carbon monoxide. Carbon monoxide has one carbon atom (symbol "C") and one oxygen atom (symbol "O"). We can tell the difference between the two as carbon monoxide has a capital letter "O". The table below shows a small number of common compounds:

Name of compound	Chemical formula	Elements in compound
Aluminium oxide	Al_2O_3	Two aluminium atoms (Al_2) and three oxygen atoms (O_3).
Carbon dioxide	CO_2	One carbon atom (C) and two oxygen atoms (O_2).
Hydrochloric acid	HCl	One hydrogen atom (H) and one chlorine atom (Cl).
Magnesium oxide	MgO	One magnesium atom (Mg) and one oxygen atom (O).
Silicon dioxide	SiO_2	One silicon atom (Si) and two oxygen atoms (O_2).
Sodium chloride	NaCl	One sodium atom (Na) and one chlorine atom (Cl).
Sulfuric acid	H_2SO_4	Two hydrogen atoms (H_2), one sulfur atom (S) and four oxygen atoms (O_4).
Water	H_2O	Two hydrogen atoms (H_2) and one oxygen atom (O).

Q1. The following statements are either true or false. State which are true and which are false.

a) Compounds have different properties to the elements that they are made from.

....

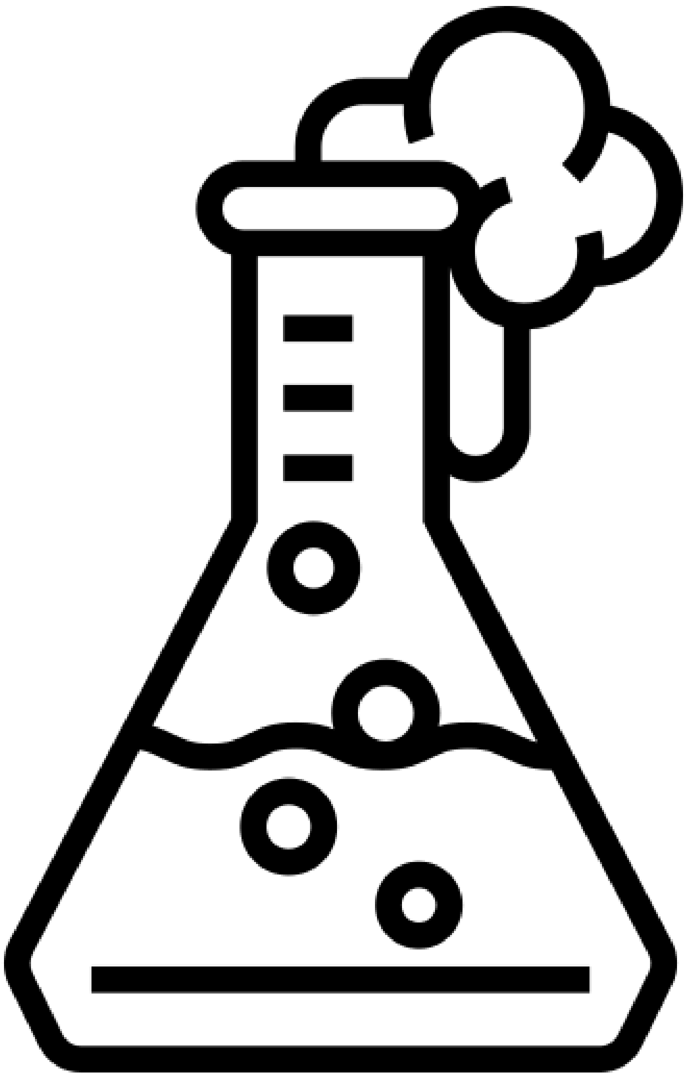
b) The chemical formula for carbon monoxide is Co.

....

Q2. Fill in the gaps in the table below. If you need to complete the "elements in compound" column, then include the names of each element and how many of each element there are. Use a copy of the periodic table to help.

	Name of compound	Chemical formula	Elements in compound
a)	Sodium hydroxide	NaOH	....
b)	Iron sulfide	FeS	....
c)	....	....	Two hydrogen atoms and one oxygen atom.
d)	Ammonia	NH_3	....
e)	Calcium oxide	....	One calcium atom and one oxygen atom.
f)	....	CO_2	....
g)	Lithium oxide	Li_2O	....
h)	Calcium chloride	$CaCl_2$	....
i)	Methane	....	One carbon atom and four hydrogen atoms.
j)	Sodium carbonate	Na_2CO_3	....
k)	Potassium sulphate	K_2SO_4	....

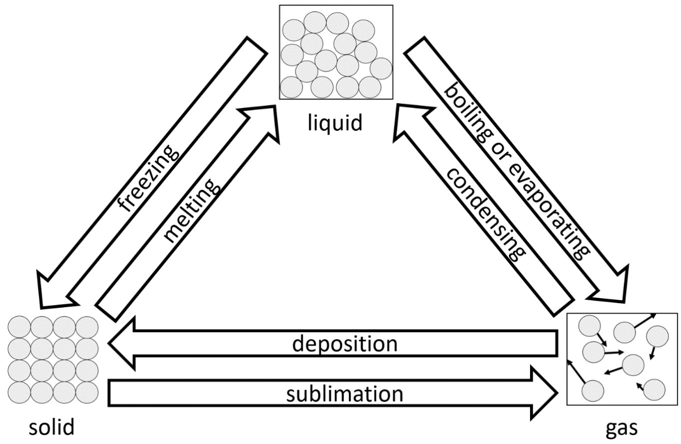
Chemical



reactions

Physical changes and chemical reactions

When a substance undergoes a **physical change**, the chemical composition of the substance does not change. Because of this, a physical change is **reversible**.



One example of a physical change is that of ice melting to form water. Both ice and water have a chemical formula of H_2O, so there is no change to this. Water can also be frozen to form ice again. All the state changes are physical changes. The state changes are shown in the diagram to the right.

Another example of a physical change is the dissolving of sugar in water. This could also be reversed by heating the solution until all the water has evaporated. The sugar would be left behind.

In a physical change, **mass is conserved**. If 100 g of ice melts, it will form 100 g of water.

In a **chemical reaction**, the chemical composition of substances change. One example of this is the rusting of iron. Iron rusts when it reacts with oxygen to form iron oxide. The chemical composition has changed.

There are several signs that a chemical reaction has taken place. These include:

1. A colour change.
2. A temperature change.
3. Gas being given out – this might show as effervescence (bubbles in a liquid).
4. Light being emitted.
5. Precipitation (a precipitate is a solid formed in a chemical reaction).

Going back to the example of iron rusting – the iron is initially a grey/silver colour. After it rusts it becomes a reddish/brown colour. The colour change is a sign that a chemical reaction has occurred. The temperature will also rise.

As the chemical composition of substances change during a chemical reaction, it cannot be easily reversed.

Mass is also conserved in a chemical reaction. The mass of the reactants (the substances that undergo a reaction) will be equal to the mass of the products of the reaction. This is called **the conservation of mass**. If a mass of 70 g of iron reacts with 30 g of oxygen, it will form 100 g of iron oxide.

Q1. The following statements are either true or false. State which are true and which are false.

a) A chemical reaction is easily reversible.

....

b) When a mass of 200 g of water evaporates, the mass of the water vapour is less than 200 g.

....

c) A change in colour is a sign of a physical change.

....

d) Gas being given out is a sign of a chemical reaction.

....

Q2. Describe what is meant by the conservation of mass.

....

....

Q3. A mass of 50 g of copper reacts with 12 g of oxygen to form copper oxide. The colour changes from a reddish/brown colour to black.

a) State the mass of copper oxide formed.

....

b) State two reasons why we know that this is a chemical reaction.

....

....

c) Aside from your reasons above, state three other signs that could show a chemical reaction has taken place.

....

....

Q4. A substance is changing from being a gas to being a liquid.

a) State the name of the state change.

....

b) State whether this is a physical change or a chemical reaction.

....

c) Explain your answer to part b).

....

Q6. Some table salt is dissolved in some water. Describe how we could reverse this physical change to have table salt again.

....

....

Oxidation and combustion

One example of a chemical reaction is that of **oxidation**. Oxidation is when a substance gains oxygen. A general chemical equation for a metal undergoing oxidation is:

metal + oxygen → metal oxide

In a chemical equation, the **reactants** go on the left hand side of the equation. The reactants are the substances that undergo a reaction. An arrow then shows what the reactants turn into. The **products** of the reaction go on the right hand side of the equation.

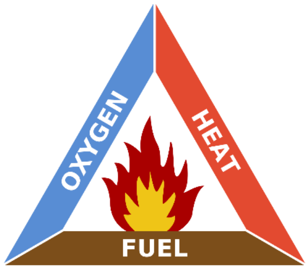
In the general chemical equation above, metal and oxygen are the reactants. The product is the metal oxide. Two specific examples of oxidation are:

iron + oxygen → iron oxide

copper + oxygen → copper oxide

Another example of a chemical reaction involving oxygen is **combustion**. Combustion is the scientific word for the burning of a **fuel**. The fuel is generally made of hydrogen and carbon. A compound of hydrogen and carbon is called a **hydrocarbon**.

Three things are required for combustion to occur – oxygen, heat and fuel. This is shown in the **fire triangle** to the right.



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There are two types of combustion – **complete combustion** and **incomplete combustion**.

A general equation for complete combustion is:

fuel + oxygen → carbon dioxide + water

Carbon dioxide is formed as the carbon in the fuel reacts with the oxygen. Water is also formed as the hydrogen in the fuel reacts with oxygen. The fuel can be any fuel (petrol, propane, methane etc.). One specific example of complete combustion is:

propane + oxygen → carbon dioxide + water

Incomplete combustion occurs if there is not enough oxygen available. A general equation for incomplete combustion is:

fuel + oxygen → carbon monoxide + water

Incomplete combustion is dangerous as carbon monoxide is a poisonous gas. Carbon monoxide is also a colourless and odourless gas – so it is very difficult to tell if the gas is present. Carbon monoxide detectors can be used in homes to make sure that we are safe. An alarm sounds if the levels of carbon monoxide are too high.

Q1. Three substances undergo oxidation. Complete the word equations below:

a) magnesium + oxygen → ……………………………………………………

b) ……………………………… + oxygen → calcium oxide

c) aluminium + oxygen → ……………………………………………………

Q2. State the products of complete combustion.

……

Q3. State the products of incomplete combustion.

……

Q4. State what elements hydrocarbons consist of.

……

Q5. State the three things that are required for combustion to occur.

……

Q6. Describe why incomplete combustion is dangerous.

……

……

Q7. Three substances undergo complete combustion. Complete the word equations below:

a) methane + oxygen → ………………………………………………………………………………

b) ethane + oxygen → ………………………………………………………………………………

c) butane + oxygen → ………………………………………………………………………………

Q8. The same substances undergo incomplete combustion. Complete the word equations below:

a) methane + oxygen → ………………………………………………………………………………

b) ethane + oxygen → ………………………………………………………………………………

c) butane + oxygen → ………………………………………………………………………………

Q9. Oxidation is one example of a chemical reaction. State three ways that we can tell a chemical reaction has occurred.

……

……

Q10. Describe when incomplete combustion might occur.

……

……

Balancing chemical equations

When we write a chemical equation for the oxidation of copper, we can do so in words as in the equation below:

copper + oxygen → copper oxide

We can also represent this reaction using chemical symbols and formulae. The chemical symbol for copper is "Cu" and for oxygen is "O". However, oxygen exists as a diatomic molecule meaning that we write it as "O_2" (instead of just "O" by itself). The symbol for copper oxide is "CuO" meaning that each copper oxide particle has one copper atom and one oxygen atom. If we just used these symbols instead of words, then we'd end up with:

	$Cu + O_2$	**→ CuO**
Number of Cu atoms	1	→ 1
Number of O atoms	2	→ 1

As we can see, there are two oxygen atoms on the left side of the equation but only one oxygen atom is on the right side of the equation. This is not correct – there must be the same number of each of the atoms on each side of the chemical equation. We must **balance** the chemical equation to fix this.

The first step in balancing this equation will be to look at increasing the number of oxygen atoms on the right hand side of the equation. The only way that we can do this is to increase the number of "CuO" particles. We could change this to "2CuO" – this means that we have two lots of copper oxide particles. Changing the number in front of a compound is the only way that we can try to balance the equation. We cannot, for example, change "CuO" to "CuO_2" as that is changing what compound we have.

However, we now would have two copper atoms on the right side of the equation. We can fix this by changing the number of copper atoms on the left side of the equation to two. We now have:

	$2Cu + O_2$	**→ 2CuO**
Number of Cu atoms	2	→ 2
Number of O atoms	2	→ 2

The number of copper and oxygen atoms on each side of the equation is now the same. We have balanced the equation.

Note that if, for example, we have two lots of water particles (written as "$2H_2O$") then we will have a total of four hydrogen atoms and two oxygen atoms. Changing the number in front of a compound multiplies the number of all the atoms by that amount.

Q1. Hydrogen has the chemical symbol “H”. State how many hydrogen atoms there are in each of the below:

a) H_2O …………………
b) $2H_2O$ …………………
c) $10H_2O$ …………………
d) CH_4 …………………
e) C_2H_4 …………………
f) $4C_2H_4$ …………………
g) $2C_7H_{16}$ …………………
h) $Ca(OH)_2$ …………………

Q2. a) Write a word equation for the oxidation of zinc.

……

b) Balance the chemical equation for the oxidation of zinc by filling in the gaps

……… $Zn + O_2 \rightarrow 2ZnO$

Q3. Balance the chemical equations below by filling in the gaps:

a) Oxidation of magnesium.

$2Mg + O_2 \rightarrow$ ……… MgO

b) Complete combustion of methane.

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

c) Incomplete combustion of ethene.

$C_2H_4 + 2O_2 \rightarrow$ ……… $CO + 2H_2O$

d) Oxidation of silver.

……… $Ag + O_2 \rightarrow 2Ag_2O$

e) Photosynthesis

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

f) Reaction of sodium and chlorine.

……… $Na +$ ……… $Cl_2 \rightarrow$ ……… $NaCl$

Thermal decomposition

One example of a chemical reaction is that of **thermal decomposition**. Thermal decomposition is when a compound is heated and breaks down into smaller and simpler products.

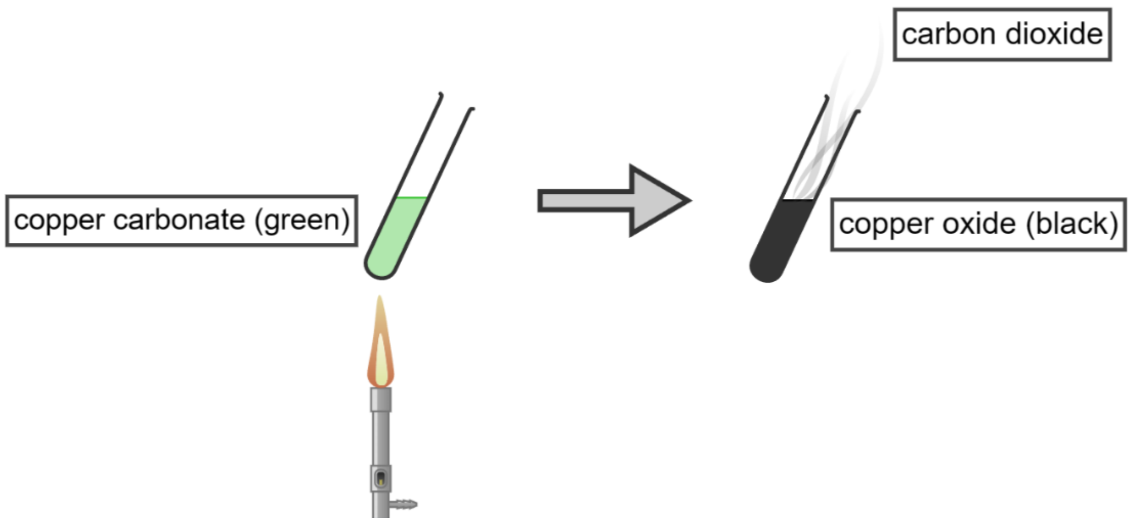
If we heat copper carbonate with a Bunsen burner, it will undergo thermal decomposition. The word equation for this process is:

copper carbonate → copper oxide + carbon dioxide

And in symbols, the balanced chemical equation for this is:

$$CuCO_3 \rightarrow CuO + CO_2$$

The carbon and some of the oxygen in copper carbonate have now formed carbon dioxide (CO_2). When heated, a metal carbonate will generally decompose into a metal oxide and carbon dioxde.



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Copper carbonate is green coloured, while copper oxide is black. This change in colour is a sign that a chemical reaction has occurred. Another sign that a chemical reaction has occurred is that a gas (carbon dioxide) is released.

We could verify that the gas is carbon dioxide by passing it through a calcium hydroxide solution (commonly known as **limewater**). If the gas is carbon dioxide, the limewater will turn milky or cloudy white.

Another example of thermal decomposition is that of hydrogen peroxide:

hydrogen peroxide → water + oxygen

This reaction creates oxygen gas. The test for oxygen is whether it will relight a glowing splint.

Q1. Describe what thermal decomposition is.

....

....

Q2. State two ways that we might know that a chemical reaction has taken place.

....

....

Q3. Magnesium carbonate undergoes thermal decomposition to form magnesium oxide and carbon dioxide.

a) State the reactant in this reaction.

....

b) State the products of this reaction.

....

c) Complete the chemical equation.

$MgCO_3 \rightarrow$ .... + ...

d) Describe how we could confirm that the gas produced was carbon dioxide.

....

....

Q4. Complete the chemical equation for the thermal decomposition of calcium carbonate.

$CaCO_3 \rightarrow$ .... + ...

Q5. Balance the chemical equation for the thermal decomposition of silver oxide by filling in the gaps.

.... $Ag_2O \rightarrow$ .... $Ag + O_2$

Q6. Hydrogen peroxide undergoes thermal decomposition to form water and oxygen.

a) Balance the chemical equation of this process by filling in the gap:

$2H_2O_2 \rightarrow$ .... $H_2O + O_2$

b) Describe how we could confirm that the gas produced was oxygen.

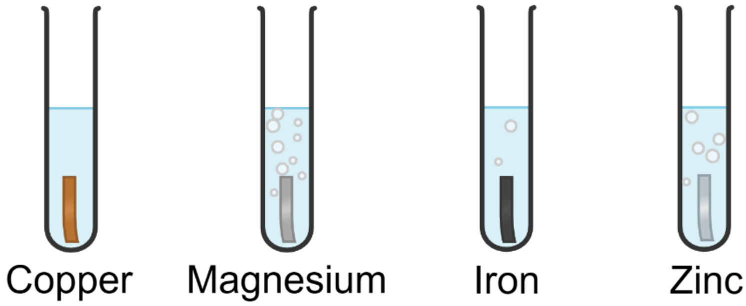
....

....

Reactivity series and displacement reactions

If we place different metals into water or an acid, then some metals react much more strongly. This is because some metals are more **reactive** than others.

The diagram to the right shows four metals that have been placed into hydrochloric acid. We can see that magnesium is the most reactive metal as the most bubbles (of hydrogen) are released. Remember that a gas being released is a sign of a chemical reaction. Copper is the least reactive metal shown as there are no bubbles.



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		Reactivity
Potassium	K	Most reactive
Sodium	Na	
Lithium	Li	
Calcium	Ca	
Magnesium	Mg	
Aluminium	Al	
Carbon	C	
Zinc	Zn	
Iron	Fe	
Hydrogen	H	
Copper	Cu	
Gold	Au	Least reactive

We can also test the reactivity of metals by looking at their reactions with water. If we study this over a larger range of metals, then we end up with an order of reactivity that we call the **reactivity series**.

Even though they are not metals, carbon and hydrogen are often included in the reactivity series as it makes it easy to predict what will happen in certain chemical reactions.

During a **displacement reaction**, an element that is more reactive replaces another less reactive element in a compound. One example of this is if some iron is placed into a copper sulfate solution. As iron is more reactive than copper, it displaces the copper in the solution.

iron + copper sulfate → iron sulfate + copper

In this case, we can tell that a chemical reaction has taken place as copper sulfate is a blue solution and iron sulfate is a green solution. A change in colour is another sign of a chemical reaction. However, no displacement occurs in the example below. This is because gold is less reactive than copper.

gold + copper sulfate → gold + copper sulfate (no reaction)

Another example of a displacement reaction is below. Aluminium displaces the iron in iron oxide as aluminium is more reactive than iron.

aluminium + iron oxide → aluminium oxide + iron

Q1. The following statements are either true or false. State which are true and which are false.

a) Magnesium is more reactive than sodium.

....

b) Calcium would not displace iron from iron oxide.

....

c) One way of telling how reactive a metal is by how vigorously it reacts with water.

....

Q2. The reaction below is a displacement reaction.

magnesium + copper sulfate → magnesium sulfate + copper

As the reaction progresses, the blue copper sulfate colour fades and the solution becomes colourless.

a) Describe why a displacement reaction occurs.

....

....

b) State how we know that a chemical reaction has taken place.

....

Q3. A chemical reaction occurs between magnesium and lead nitrate as follows:

magnesium + lead nitrate → lead + magnesium nitrate

State which of magnesium and lead is more reactive. Explain the reason for your answer.

....

....

Q4. Describe why the below reaction is not possible.

calcium + sodium carbonate → sodium + calcium carbonate

....

....

Q5. Complete the word equation for the displacement reaction between aluminium and iron oxide.

aluminium + iron oxide → .... + ...

Q6. Complete the word equation for the displacement reaction between magnesium and copper chloride.

magnesium + copper chloride → .... + ...

Q7. Complete the word equation for the displacement reaction between zinc and iron sulfate.

zinc + iron sulfate → .... + ...

Group 7 elements

Elements in group 7 of the periodic table are known as the **halogens**. As the halogens are all in the same group, they all have similar properties. The halogens are all **non-metals** and therefore do not conduct electricity or heat well. They also have low melting and boiling points. As you go down group 7, the melting and boiling points increase. This is because larger molecules have larger inter-molecular forces.

The halogens are also **very reactive** and, because of this, they are **toxic**. For example, chlorine gas was used as a weapon in World War One. In low concentrations, it is also used to limit bacteria growth in swimming pools.

As you go down group 7, the reactivity decreases. A summary of these trends are shown in the diagram below.

		Reactivity		Melting and boiling point
Fluorine	F	↑ Most reactive	↓	Lowest melting and boiling point
Chlorine	Cl			
Bromine	Br			
Iodine	I			
Astatine	At	Least reactive		Highest melting and boiling point

During a **displacement reaction**, an element that is more reactive replaces another less reactive element in a compound. Both metals and halogens can undergo displacement reactions.

Before we see an example, it's useful to know that if fluorine is in a compound the compound will generally end with "fluoride". Chlorine will form a "chloride", bromide will form a "bromide", iodine will form an "iodide" and astatine will form an "astatide". Collectively, these compounds are known as **halides**.

One example of this is the reaction between sodium bromide and chlorine. Chlorine is more reactive than bromine and so it displaces the bromine.

sodium bromide + chlorine → sodium chloride + bromine

However, no displacement occurs in the example below. This is because iodine is less reactive than bromine.

sodium bromide + iodine → sodium bromide + iodine (no reaction)

Another example of a displacement reaction is below. Chlorine displaces the iodine in potassium iodide as chlorine is more reactive than iodine.

potassium iodide + chlorine → potassium chloride + iodine

During this reaction, the colour changes from colourless to brown. A change in colour is one sign of a chemical reaction.

Q1. The following statements are either true or false. State which are true and which are false.

a) Chlorine is an example of a halogen.

....

b) Bromine is less reactive than iodine.

....

c) Fluorine has a higher melting point than astatine.

....

d) Group 7 elements are all good electrical conductors.

....

e) Group 7 elements are toxic and highly reactive.

....

f) Group 7 elements have high melting and boiling points.

....

Q2. Describe what a displacement reaction is.

....

....

Q3. The reaction below is a displacement reaction.

potassium bromide + chlorine → potassium chloride + bromine

a) Describe why a displacement reaction occurs.

....

....

b) Balance the chemical equation of this process by filling in the gaps:

.... $KBr + Cl_2 \rightarrow$ .... $KCl + Br_2$

c) State one way that we might know that a chemical reaction has taken place.

....

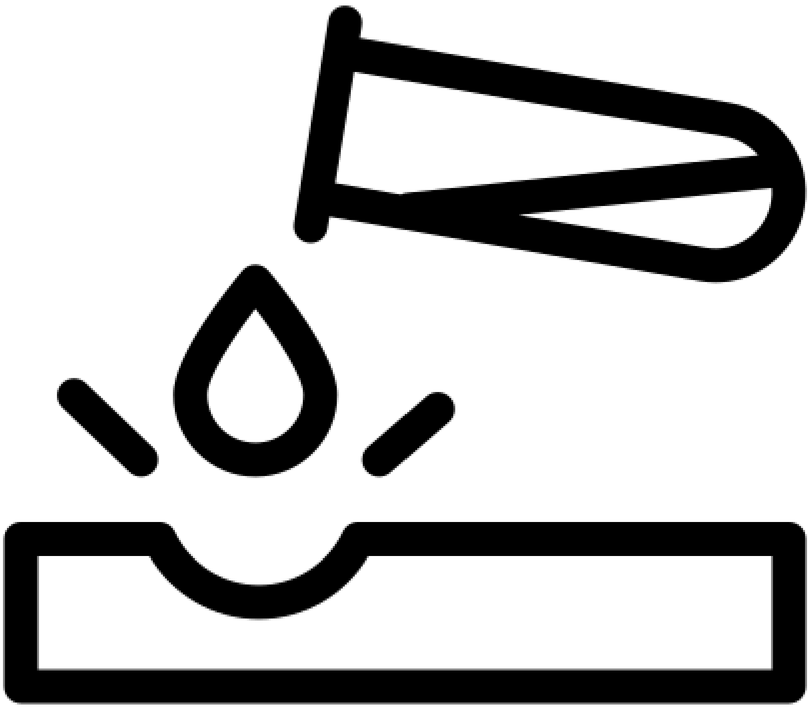
Q4. Complete the word equation for the displacement reaction between potassium iodide and bromine.

potassium iodide + bromine → .... + ...

Q5. Complete the word equation for the displacement reaction between sodium chloride and fluorine.

sodium chloride + fluorine → .... + ...

Acids and



alkalis

Acids, bases and alkalis

You might have already heard of a group of chemicals called **acids**. Certain foods like lemons and vinegar are **acidic** - these foods have a sharp taste to them. Our stomach contains an acid called hydrochloric acid to help us digest food. Some batteries also contain an acid.

Acids can be hazardous and some need to be stored in containers labelled with **hazard symbols**. If an acid is strong, then it is likely to be labelled as an **irritant** (can cause irritation to skin and eyes), as **toxic** (can cause harmful health effects) or as **corrosive** (can damage substances that it comes in contact with). The hazard symbols for these are below.


Harmful / Irritant


Toxic


Corrosive

We use a scale called the **pH scale** to show how acidic a substance is. The pH scale ranges from 0 to 14 and acids have a pH of less than 7. Strong acids have lower pH values compared to weak acids. If a substance has a pH of 7, then we call this substance **neutral**. Pure water is neutral.

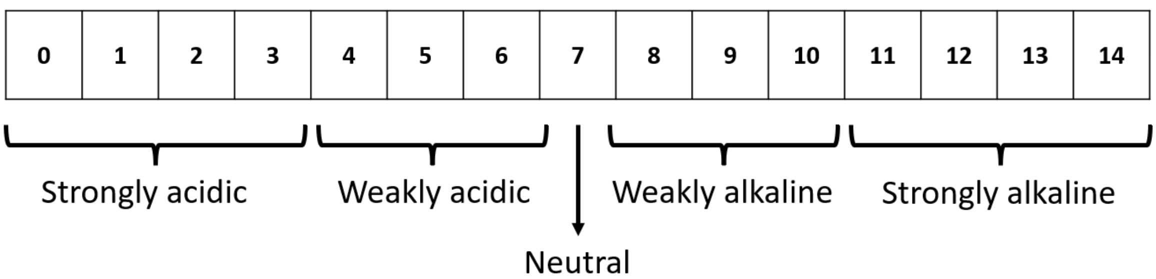
Examples of acids that you might use in a lab include hydrochloric acid (with chemical formula HCl), sulfuric acid (H_2SO_4) and nitric acid (HNO_3). These are all strong acids and so would have a pH of less than 3.

A **base** is a substance that **neutralises** an acid. Neutralisation is a chemical reaction – if an acid is neutralised then the pH will be raised to 7.

If a base is soluble (can be dissolved) in water then we call it an **alkali**. An alkali has a pH of more than 7. Strong alkalis have higher pH values compared to weak alkalis. Common examples of alkalis are soap and bleach. Just like acids, alkalis can also be irritants, toxic and corrosive.

Examples of alkalis used in a lab include sodium hydroxide (NaOH), potassium hydroxide (KOH) and calcium hydroxide ($Ca(OH)_2$).

A diagram showing the pH scale is shown below.



Q1. The following statements are either true or false. State which are true and which are false.

a) Some foods are acidic.

....

b) Acids have a pH of less than 8.

....

c) Pure water is alkaline.

....

d) Neutral substances have a pH of 7.

....

e) A base is a substance that neutralises an acid.

....

f) If a base is insoluble in water then we call it an alkali.

....

Q2. a) State three hazard symbols that a strong acid might be labelled with.

....

....

b) State what pH value a strong acid might have.

....

Q3. Describe what neutralisation is.

....

....

Q4. State the pH value of pure water.

....

Q5. State what pH value a weak alkali might have.

....

Q6. State two examples of common acids.

....

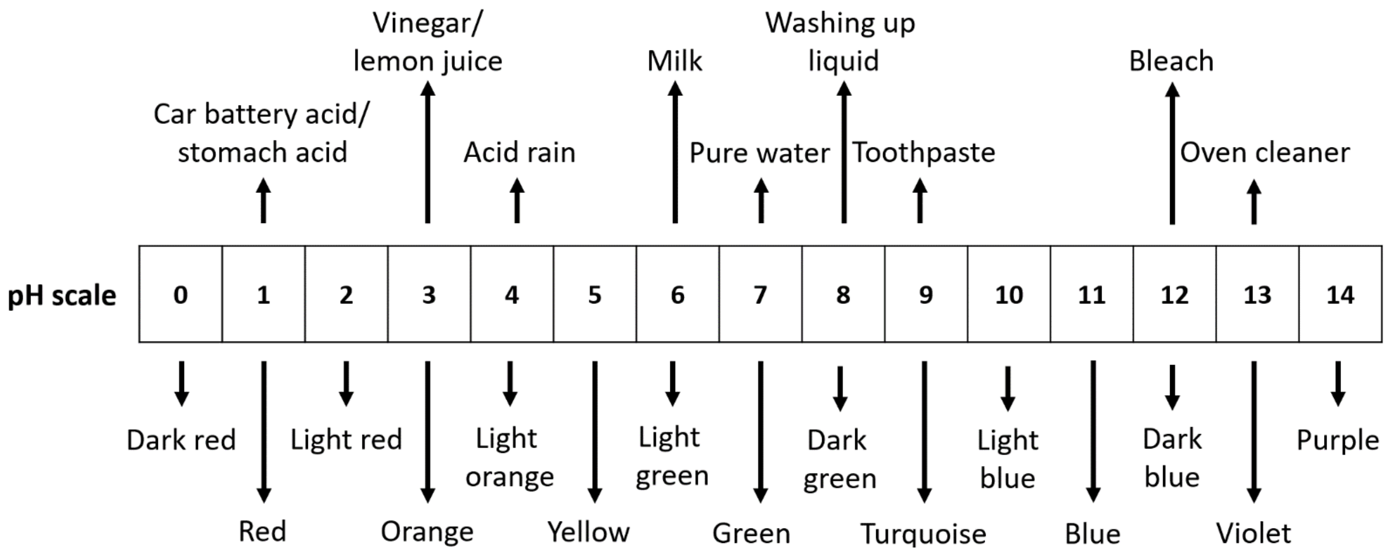
Q7. State two examples of common alkalis.

....

The pH scale and indicators

We can use **indicators** to tell us whether a substance is acidic or alkaline. Some different indicators are described in the table below.

Name of indicator	Description
Blue litmus paper	Blue litmus paper turns red when in contact with an acid.
Red litmus paper	Red litmus paper turns blue when in contact with an alkali.
Phenolphthalein	Phenolphthalein remains colourless unless in contact with an alkali (when it will turn pink).
Red cabbage	Turns to a range of colours, depending on the pH of the substance. In an acid, it turns a pink/red colour. It is purple if in a neutral substance and turns blue or green when added to an alkaline substance.
Methyl orange	Is red in acids and yellow in alkaline solutions.
Universal indicator	Made from a mixture of dyes and changes colour gradually based on the pH. Colours for each pH level (and examples of substances that have those pHs) are in the diagram below.



Remember than any substance with a pH of less than 7 is **acidic** and any substance with a pH of more than 7 is **alkaline**. If a substance (such as pure water) has a pH of 7 then it is **neutral**.

An electronic **pH meter** can also be used to measure the pH of a substance. This has the advantage of not having to interpret a colour as it gives a number to the pH value instead.

Q1. The following statements are either true or false. State which are true and which are false.

a) A substance with a pH of 4 is alkaline.

b) If blue litmus paper were placed in lemon juice, it would turn red.

c) If red litmus paper were placed in stomach acid, it would turn blue.

d) If phenolphthalein were placed in vinegar, it would turn pink.

e) Universal indicator would turn green when placed in pure water.

f) Methyl orange would turn red in milk.

Q2. State two examples of common acids.

Q3. State two examples of common alkalis.

Q4. State the pH of a substance that is neutral and give an example of a neutral substance.

Q5. Describe an advantage of using an electronic pH meter.

Q6. Universal indicator turns orange when placed into a substance.

a) State what the pH of the substance might be.

b) Suggest what the substance might be.

c) The substance is now neutralised. What colour will the universal indicator turn?

Q7. State an example of a substance that would turn universal indicator red.

Acids and metals

If we place a metal into an acid, a **chemical reaction** can occur. One sign of the chemical reaction occurring would be a temperature rise. If the reaction is more vigorous, then effervescence (fizzing) in the acid could be observed or even flames.

The more reactive the metal, the more vigorous the reaction will be. The **reactivity series** (in the diagram to the right) shows the order of reactivity of metals.

		Reactivity
Potassium	K	Most reactive
Sodium	Na	
Lithium	Li	
Calcium	Ca	
Magnesium	Mg	
Aluminium	Al	
Carbon	C	
Zinc	Zn	
Iron	Fe	
Hydrogen	H	
Copper	Cu	
Gold	Au	Least reactive

When a metal reacts with an acid it creates a chemical compound called a **salt** and hydrogen gas. This can be summarised in a general word question as:

metal + acid → salt + hydrogen

Hydrochloric acid will form metal chloride compounds. Two examples of this are below:

iron + hydrochloric acid → iron chloride + hydrogen

magnesium + hydrochloric acid → magnesium chloride + hydrogen

Note that magnesium would have a much more vigorous reaction with hydrochloric acid as it is higher in the reactivity series.

Sulfuric acid will form metal sulfate compounds. For example:

zinc + sulfuric acid → zinc sulfate + hydrogen

aluminium + sulfuric acid → aluminium sulfate + hydrogen

Again, note that aluminium will have a more vigorous reaction as it is more reactive.

Nitric acid will form metal nitrate compounds. For example:

iron + nitric acid → iron nitrate + hydrogen

calcium + nitric acid → calcium nitrate + hydrogen

In all of the reactions above, hydrogen gas is formed. This is because all the acids contain hydrogen and the metals involved are more reactive than hydrogen. The metals therefore **displace** the hydrogen. If copper or gold were to be placed in an acid, there would therefore be no reaction. This is because copper and gold are less reactive than hydrogen. For example, there would be no reaction with gold and nitric acid:

gold + nitric acid → gold + nitric acid

Q1. Complete the general word equation for the reaction between a metal and an acid.

metal + acid → .... + ...

Q2. Magnesium reacts with some hydrochloric acid.

a) Complete the word equation for the reaction.

magnesium + hydrochloric acid → .... + ...

b) State how the temperature of the products would compare to the temperature of the reactants.

....

c) Other than a temperature change, state another way that we could tell a chemical reaction has taken place.

....

d) Describe why there would be no reaction between gold and hydrochloric acid.

....

....

e) Some calcium now reacts with the hydrochloric acid. State and explain how the reaction would compare to that of magnesium and hydrochloric acid.

....

....

f) Complete the word equation for the reaction between calcium and hydrochloric acid.

calcium + hydrochloric acid → .... + ...

Q3. Complete the word equations for all the reactions below

a) calcium + sulfuric acid → .... + ...

b) zinc + hydrochloric acid → .... + ...

c) aluminium + nitric acid → .... + ...

d) iron + sulfuric acid → .... + ...

e) magnesium + nitric acid → .... + ...

f) aluminium + hydrochloric acid → .... + ...

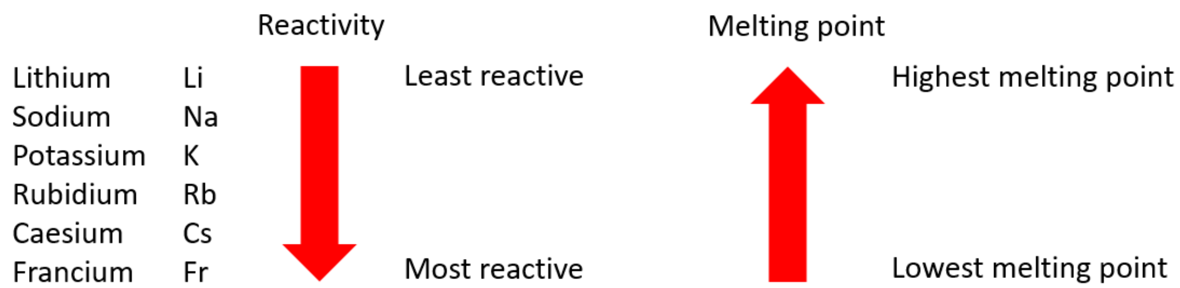
g) copper + sulfuric acid → .... + ...

h) zinc + nitric acid → .... + ...

Alkali metals

The first group (column) of elements in the periodic table is known as the **alkali metals**. As the alkali metals are all in the same group, they all have similar properties. For example, all the alkali metals have low melting points and are so soft that they can be cut with a knife. They also have low densities and are all very reactive. Alkali metals are stored in oil so that air and water are kept away from them.

As you go down group 1, the **reactivity** of the elements goes up and the melting points go down. This is shown in the diagram below.



The alkali metals react strongly with water. It can be quite dangerous to do this, though, and safety precautions need to be taken. If you observe a demonstration of this, it will be behind a safety screen and only small amounts of an alkali metal will be used.

When an alkali metal is added to water it forms a metal hydroxide and hydrogen. These metal hydroxides are **alkaline** (which is why they are called alkali metals). Alkaline solutions have a pH greater than 7. The reaction can be summarised in the general word equation below:

alkali metal + water → metal hydroxide + hydrogen

These reactions become more fierce as you go down group 1. If lithium is added to water, then it fizzes in the water. The fizzing is from the release of hydrogen gas. The word equation for this reaction is:

lithium + water → lithium hydroxide + hydrogen

If potassium is added to water, the reaction is stronger as potassium is more reactive than lithium. The reaction increases the temperature so much that the hydrogen gas released ignites. The word equation for this reaction is:

potassium + water → potassium hydroxide + hydrogen

Elements further down group 1 would have an even stronger reaction. For example, that of caesium:

caesium + water → caesium hydroxide + hydrogen

Q1. The following statements are either true or false. State which are true and which are false.

a) The reactivity of the alkali metals goes up as you go up group 1.

....

b) The melting points of the alkali metals goes up as you go up group 1.

....

c) The alkali metals react strongly with water.

....

d) The alkali metals all have high melting points.

....

e) Alkaline solutions have a pH greater than 7.

....

f) Alkali metals are usually stored in oil.

....

Q2. Complete the general word equation for the reaction between an acid and a metal oxide.

alkali metal + water → .... + ...

Q3. Sodium undergoes a reaction with water.

a) Complete the word equation for the reaction between sodium and water.

sodium + water → .... + ...

b) State an alkali metal which will have a stronger reaction with water.

....

Q4. Complete the word equations for all the reactions below

a) lithium + water → .... + ...

b) rubidium + water → .... + ...

c) potassium + water → .... + ...

Q5. A teacher decides to do a demonstration of the reaction between sodium and water. State any safety precautions that the teacher is likely to take.

....

....

Neutralisation

A **base** is a substance that **neutralises** an acid. An acid has a pH of less than 7 – if an acid is neutralised then the pH will be raised to 7. Neutralisation is a chemical reaction. Two ways of telling a chemical reaction has taken place is that there is a temperature rise during neutralisation and there may be some effervescence.

Metal oxides and metal hydroxides are bases. Some of these are soluble – a soluble base is called an **alkali**. If an acid is neutralised by a metal oxide or metal hydroxide, then a chemical compound called a **salt** and water is formed. This is summarised in the two general word equations below:

acid + metal oxide → salt + water

acid + metal hydroxide → salt + water

Hydrochloric acid will form metal chloride compounds. For example:

hydrochloric acid + iron oxide → iron chloride + water

hydrochloric acid + sodium hydroxide → sodium chloride + water

Sulfuric acid will form metal sulfate compounds. For example:

sulfuric acid + zinc oxide → zinc sulfate + water

sulfuric acid + potassium hydroxide → potassium sulfate + water

Nitric acid will form metal nitrate compounds. For example:

nitric acid + calcium oxide → calcium nitrate + water

nitric acid + magnesium hydroxide → magnesium nitrate + water

Metal carbonates are also bases and can neutralise acids, the products of this reaction are a salt, carbon dioxide and water. The general equation for this reaction is:

acid + metal carbonate → salt + carbon dioxide + water

Two specific examples of this are:

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

nitric acid + sodium carbonate → sodium nitrate + carbon dioxide + water

To tell when a neutralisation reaction is complete, it is best to not use universal indicator as there is a gradual colour change between the different pH levels. Instead, it is better to use an indicator that has a more sudden colour change. For example, litmus paper, phenolphthalein or methyl orange could be used.

Q1. Complete the general word equation for the reaction between an acid and a metal oxide.

acid + metal oxide → .... + ...

Q2. Complete the general word equation for the reaction between an acid and a metal hydroxide.

acid + metal hydroxide → .... + ...

Q3. Complete the general word equation for the reaction between an acid and a metal carbonate.

acid + metal carbonate → .... + ... + ...

Q4. Describe what a base is.

....

....

Q5. Describe what an alkali is.

....

....

Q6. State what pH an acid must have.

....

Q7. Complete the word equations for all the reactions below

a) hydrochloric acid + zinc oxide → .... + ...

b) nitric acid + calcium hydroxide → .... + ...

c) sulfuric acid + calcium carbonate → .... + ... + ...

d) nitric acid + zinc carbonate → .... + ... + ...

e) sulfuric acid + iron oxide → .... + ...

f) hydrochloric acid + magnesium oxide → .... + ...

g) sulfuric acid + sodium hydroxide → .... + ...

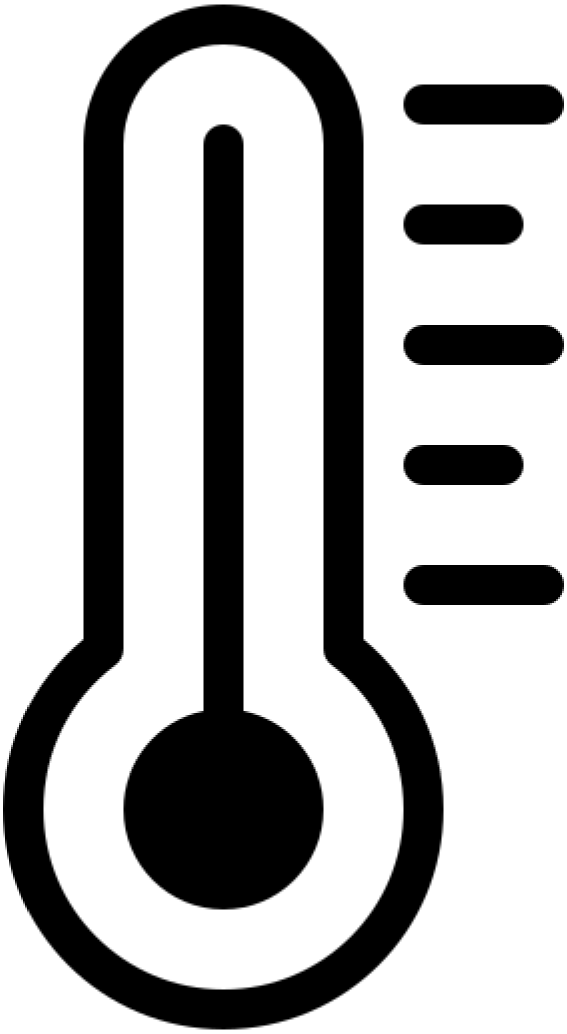
h) hydrochloric acid + potassium hydroxide → .... + ...

Q8. Describe why universal indicator shouldn't be used when being able to tell when a neutralisation reaction is complete.

....

....

Energy



changes

Exothermic and endothermic reactions

Chemical reactions that transfer energy to the surroundings are called **exothermic reactions**. Usually this energy transfer is by heating and so there will be a rise in temperature.

The most obvious example of an exothermic reaction is that of **combustion**. Burning of a fuel like petrol is one example of combustion. This will increase the temperature of the surroundings. The general word equation for combustion is:

fuel + oxygen → carbon dioxide + water

Hi-Res Images of Chemical Elements, CC BY 3.0, via Wikimedia Commons

Other examples of exothermic reactions are **neutralisation** and many **oxidation** reactions. Again, the temperature of the surroundings will increase.

We've seen before that the general word equations for neutralisation are:

acid + metal oxide → salt + water

acid + metal hydroxide → salt + water

acid + metal carbonate → salt + carbon dioxide + water

We've also seen that the general chemical equation for a metal undergoing oxidation is:

metal + oxygen → metal oxide

While exothermic reactions transfer energy to the surroundings, **endothermic reactions** take in energy from the surroundings. This results in a fall in temperature.

One example of an endothermic reaction is **thermal decomposition**. Thermal decomposition is when a compound is heated and breaks down into smaller and simpler products.

Both exothermic and endothermic reactions have everyday applications. Exothermic reactions are used in hand warmers and self-heating cans of hot drinks.

Endothermic reactions are used in "instant cold" packs used to treat sports injuries. These packs usually consist of two bags (with one inside the other). One contains water and one contains a different compound. When the inner bag is squeezed and bursts, water combines with this compound and an endothermic reaction occurs. The "instant cold" pack then decreases in temperature.

Q1. Describe what is meant by an exothermic reaction.

....

....

Q2. State two examples of exothermic reactions.

....

Q3. Describe what is meant by an endothermic reaction.

....

....

Q4. State an example of an endothermic reaction.

....

Q5. The following statements are either true or false. State which are true and which are false.

a) Oxidation is an example of an endothermic reaction.

....

b) Thermal decomposition is an example of an endothermic reaction.

....

c) Neutralisation is an example of an exothermic reaction.

....

Q6. Complete the general word equation for the reaction between an acid and a metal hydroxide.

acid + metal hydroxide → .... + ...

Q7. State whether the reaction in question 6 is exothermic or endothermic.

....

Q8. Copper carbonate undergoes thermal decomposition to form copper oxide and carbon dioxide.

a) State the reactant in this reaction.

....

b) State the products of this reaction.

....

c) Complete the chemical equation.

$CuCO_3 \rightarrow CuO +$ ....

d) State whether this reaction is exothermic or endothermic.

....

Rates of reaction

The phrase "rate of reaction" means how quickly a chemical reaction takes place. The rate of reaction depends on the frequency of **successful collisions** between reacting particles.

The rate of reaction depends on:

- **The temperature of the reactants**. Higher temperatures cause particles to move more quickly. This increases the frequency of collisions and the energy of those collisions, thus increasing the rate of reaction.
- **The concentration or pressure of reactants.** In a more concentrated solution, there are more particles within the same volume. Similarly, a gas at higher pressure has more particles in the same volume. In both cases, more particles lead to a higher rate of collisions, increasing the rate of reaction.
- **The surface area.** For solid reactants, breaking them into smaller pieces increases their surface area to volume ratio. This allows more collisions to occur on the surface of the solid, increasing the rate of reaction.
- **The use of a catalyst.** A catalyst is a substance that increases the rate of reaction without being used up in the process. It works by providing an alternative pathway with a lower activation energy for the reaction, therefore increasing the rate at which collisions result in a reaction.

The rate of reaction can be measured with a few different methods. These include:

- **Measuring the change in mass**. For reactions that produce a gas, the rate can be measured by the loss of mass. One example of this is the reaction between magnesium and hydrochloric acid to form magnesium chloride and hydrogen gas. The hydrogen gas would escape and so the mass measured on the balance would decrease.
- **Measuring the volume of gas produced**. If a reaction produces a gas, the rate can also be measured by capturing the gas in a gas syringe and measuring the volume of gas produced over time.
- **Observing precipitation**. Precipitation is the formation of a solid in a solution during a chemical reaction. The rate of reaction can be measured by observing the time it takes for the precipitate to form. This can be done visually or using a light sensor to detect when a certain level of cloudiness is reached in the solution. One example of this is the reaction between sodium thiosulfate and hydrochloric acid. This reaction forms a yellow sulfur precipitate. The reaction can take place in a conical flask placed above a piece of paper with a black cross drawn on it. The time can then be measured for the black cross to no longer be visible.
- **Monitoring colour change**. Some reactions involve a change in colour. The rate of reaction can be measured by timing how long it takes for the colour change to occur.

Q1. The following statements are either true or false. State which are true and which are false.

a) Particles at a higher temperature move more quickly.

....

b) A catalyst is used up during a chemical reaction.

....

c) The rate of reaction depends on the frequency of successful collisions.

....

d) Breaking a solid up into smaller pieces decreases the surface area to volume ratio.

....

e) A gas at a higher pressure has more particles in the same volume.

....

Q2. Explain why increasing the temperature of reactants increases the rate of reaction.

....

....

Q3. Sodium thiosulfate is reacting with hydrochloric acid. A yellow sulfur precipitate is formed.

a) State what effect increasing the concentration of hydrochloric acid would have on the reaction. Explain the reasons why.

....

....

b) Describe an experiment that could investigate how the rate of reaction depends on the temperature of hydrochloric acid.

....

....

....

....

Q4. Magnesium is added to hydrochloric acid.

a) State whether magnesium powder or large pieces of magnesium would have a higher rate of reaction Explain the reasons why.

....

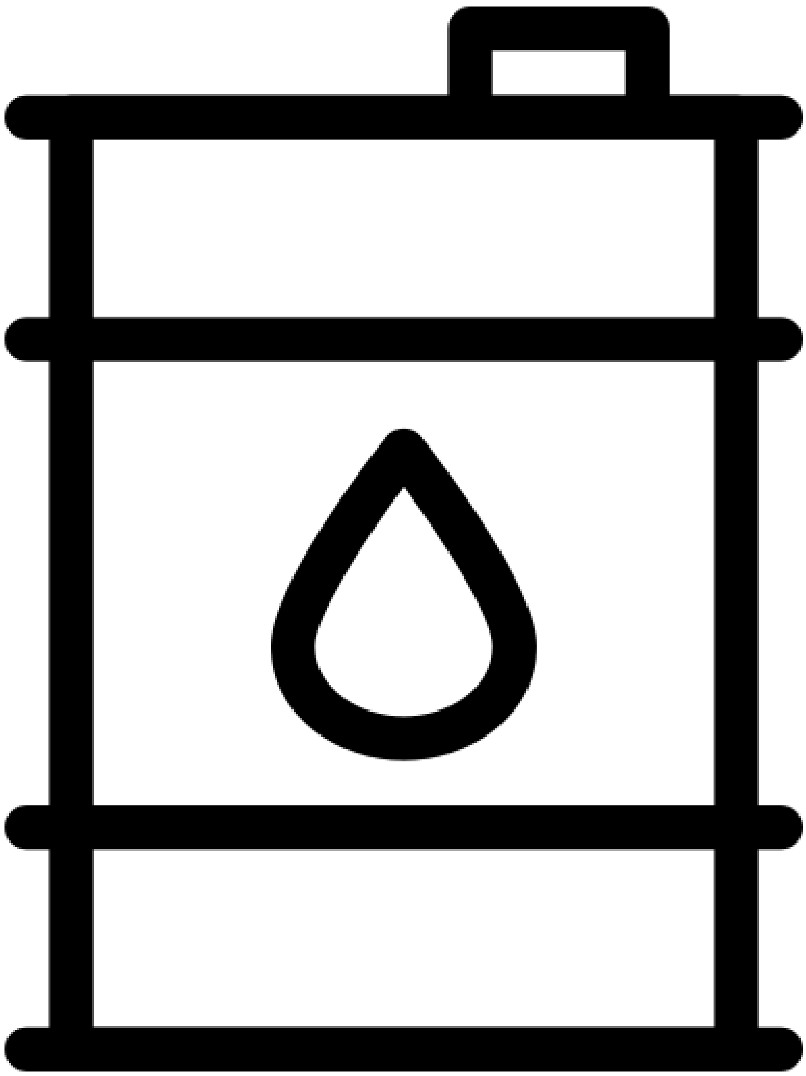
....

b) Describe how we could experimentally verify which of magnesium powder or large pieces of magnesium would have a higher rate of reaction.

....

....

Materials



Metal extraction

Many metals are found in the Earth in rocks called **ores**. To get the metals we need, we have to extract them from these ores. To understand which method we need to use for different metals, we need to recap the **reactivity series**.

Metals have different levels of reactivity. Some are very reactive, like potassium and sodium, while others are not very reactive, like gold and silver. The reactivity series (shown below) is a list that shows metals from most reactive to least reactive.

If a metal is less reactive than carbon, then a **displacement reaction** can be used to extract a metal from a metal ore. Metals like zinc, iron and copper tend to react with oxygen to form metal oxide compounds in ores. A reaction that separates a metal from a metal oxide is called a **reduction reaction**.

For example, to extract iron, the iron ore is heated with carbon (in the form of coke) in a blast furnace. The carbon reacts with the oxygen in the iron oxide to form carbon dioxide and leave behind pure iron:

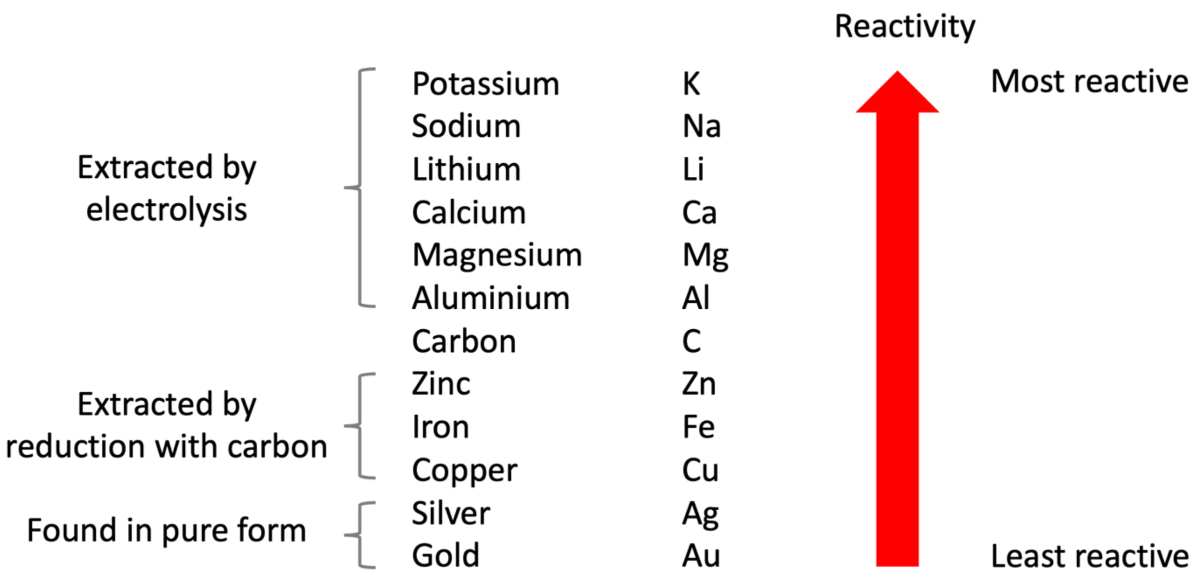
iron oxide + carbon → iron + carbon dioxide

Another example would be separating copper from copper oxide:

copper oxide + carbon → copper + carbon dioxide

If a metal is more reactive than carbon, then carbon would not displace the metal. **Electrolysis** would need to be used to extract the metal from the ore.

As gold and silver are very unreactive, they can be found as a pure metal. Gold and silver therefore don't need to be extracted from ores by chemical reactions.



Q1. The following statements are either true or false. State which are true and which are false.

a) Gold can be found as a pure metal.

....

b) Zinc is more reactive than carbon.

....

c) Iron can be extracted from its ore by heating with carbon.

....

d) Aluminium can be extracted from its ore by heating with carbon.

....

e) Magnesium can be extracted from its ore by electrolysis.

....

f) Carbon would not displace calcium from calcium oxide.

....

Q2. Complete the word equation for the displacement reaction between carbon and iron oxide

carbon + iron oxide → .... + ...

Q3. Complete the word equation for the displacement reaction between carbon and zinc oxide.

carbon + zinc oxide → .... + ...

Q4. Copper is extracted from copper oxide using carbon. Write down a word equation for this reaction.

....

Q5. Describe why the below reaction is not possible.

magnesium oxide + carbon → magnesium + carbon dioxide

....

....

Q6. Explain why carbon is used to extract metals like iron and copper but not aluminium.

....

....

....

....

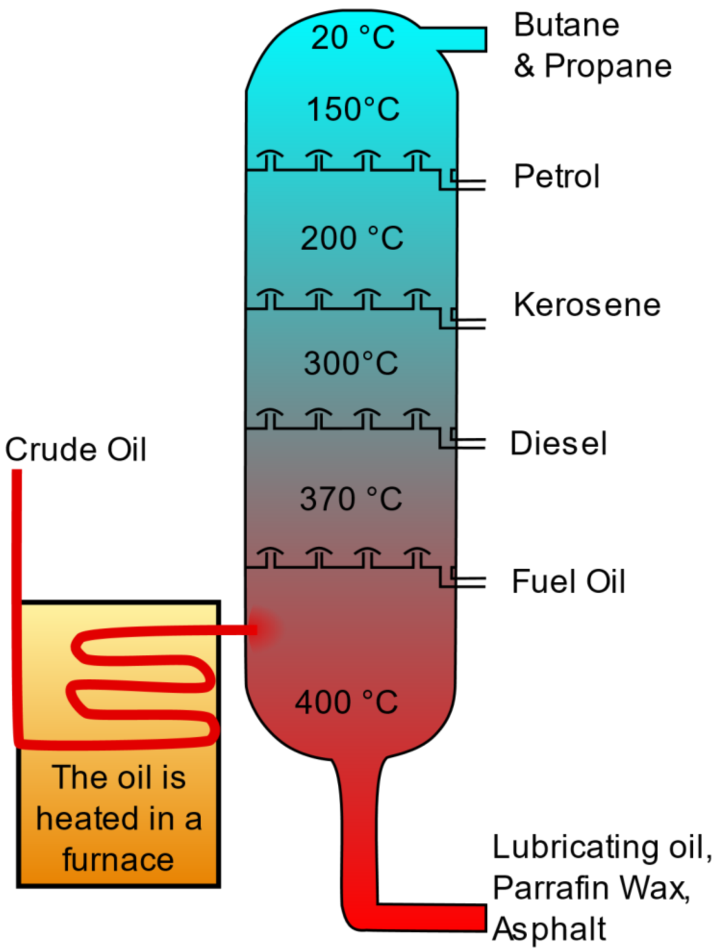
Crude oil

Crude oil is a liquid found deep under the Earth's surface. It is made from the remains of organisms like algae and plankton. These remains were deposited on the sea floor and were covered by sediments. Over millions of years, heat and pressure turned these remains into crude oil.

Crude oil is a mixture of many different substances. These are mostly **hydrocarbons**, which are compounds made of hydrogen and carbon. To use crude oil, we need to separate it into different parts. This is done using a process called **fractional distillation**. In a refinery, crude oil is heated until it turns into a gas. The gas then enters a tall tower called a fractionating column, which is hotter at the bottom and cooler at the top.

As the gas rises up the column, different substances cool down and turn back into liquids at different temperatures. This is because they have different boiling points.

The liquids are collected at various levels of the column. Each level collects a different fraction of the crude oil, such as petrol, kerosene, and diesel. This is why the process is called fractional distillation.



Crude_Oil_Distillation-fr.svg, CC BY-SA 3.0 via Wikimedia Commons

Some of the main uses of these products are:

- **Petrol**: Used as fuel for cars.
- **Diesel**: Is a fuel for trucks, buses, and some cars.
- **Kerosene**: Used as fuel for jet engines and heaters.
- **Fuel Oil**: Used in ships and large industrial plants for heating and power generation.
- **Butane and Propane**: Fuel for cooking, heating, and in lighters. Propane is also used as fuel for some engines and portable stoves.
- **Lubricating oils**: Used to reduce friction in engines and machines.

Burning the fuels made from crude oil releases carbon dioxide (CO_2), which is a greenhouse gas that contributes to **global warming**.

Q1. The following statements are either true or false. State which are true and which are false.

a) A fractionating column is hotter at the top than the bottom.

....

b) Butane, petrol and diesel are examples of products that are made from the fractional distillation of crude oil.

....

c) Petrol has a higher boiling point than diesel.

....

d) Burning fuels made from crude oil releases carbon dioxide.

....

e) Carbon dioxide is a greenhouse gas.

....

Q2. State what is meant by a hydrocarbon.

....

Q3. Describe how crude oil is formed.

....

....

Q4. Describe the process of fractional distillation.

....

....

....

....

Q5. State three products that can be made from crude oil and describe their uses.

....

....

....

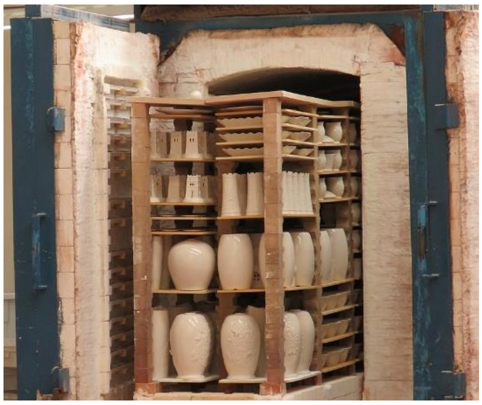
....

Q6. Describe why fuels produced from crude oil would be described as non-renewable resources.

....

....

Ceramics, polymers and composites


Lomita, CC BY-SA 4.0 , via Wikimedia Commons

Ceramics are made by heating certain materials to high temperatures in a **kiln**. This process changes the properties of the starting material and makes them hard, but brittle. For example, clay can be heated in a kiln (shown in the image) to form pottery, bricks or tiles.

Because ceramics like pottery are brittle, they will break if dropped. Ceramics are also resistant to high temperatures. This is why they are used in cookware.

Polymers are long chains of molecules made by joining many small molecules (monomers) together. There are two main types of polymers: natural and synthetic. Natural polymers include things like rubber and silk, while synthetic polymers are made by humans and include plastics like polythene and polyvinyl chloride (PVC).

Polymers can be flexible or rigid, are usually lightweight and can be moulded into different shapes. This makes them useful for applications such as in plastic bags or plastic bottles and containers for storing food and drinks.

Another property of polymers is that they are electrical and thermal insulators. An application of this is that PVC is used as an electrical insulator around wires. Polymers are also very unreactive. This is advantageous in applications like water bottles so that they don't react with their contents. It does mean that they do not break down quickly after being used, though. This can pose an environmental challenge.

Composites are made by combining two or more different materials to create a new material with improved properties. Each material in a composite keeps its own properties, but together they make the composite stronger, lighter, or more durable. Examples of composites include:

- **Fibreglass** is made from glass fibres and plastic. This combination results in a material that is lightweight like plastic but retains the strength of glass. Fibreglass is commonly used to make boat and car bodies.
- **Concrete** is made from cement, sand, and gravel and results in a material that can withstand high compressive forces. Concrete is therefore used as a building material in bridges, roads and buildings.
- **Carbon fibre** is made from a combination of carbon fibres and polymers and is a strong and lightweight material. It is used in high end sports cars, bicycles and other sports equipment.

Q1. The following statements are either true or false. State which are true and which are false.

a) Polymers are good conductors of electricity.

....

b) Ceramics are brittle.

....

c) Concrete is an example of a composite.

....

d) Polymers are usually very reactive.

....

e) Carbon fibre is a strong and lightweight material.

....

Q2. State an application of fibreglass.

....

Q3. State an application of carbon fibre.

....

Q4. State an application of PVC.

....

Q5. Describe how ceramics are made.

....

....

Q6. Describe why ceramics are suitable for use in cookware.

....

....

Q7. State one example of a polymer and a use for that polymer.

....

....

Q8. Describe the difference between a polymer and a monomer.

....

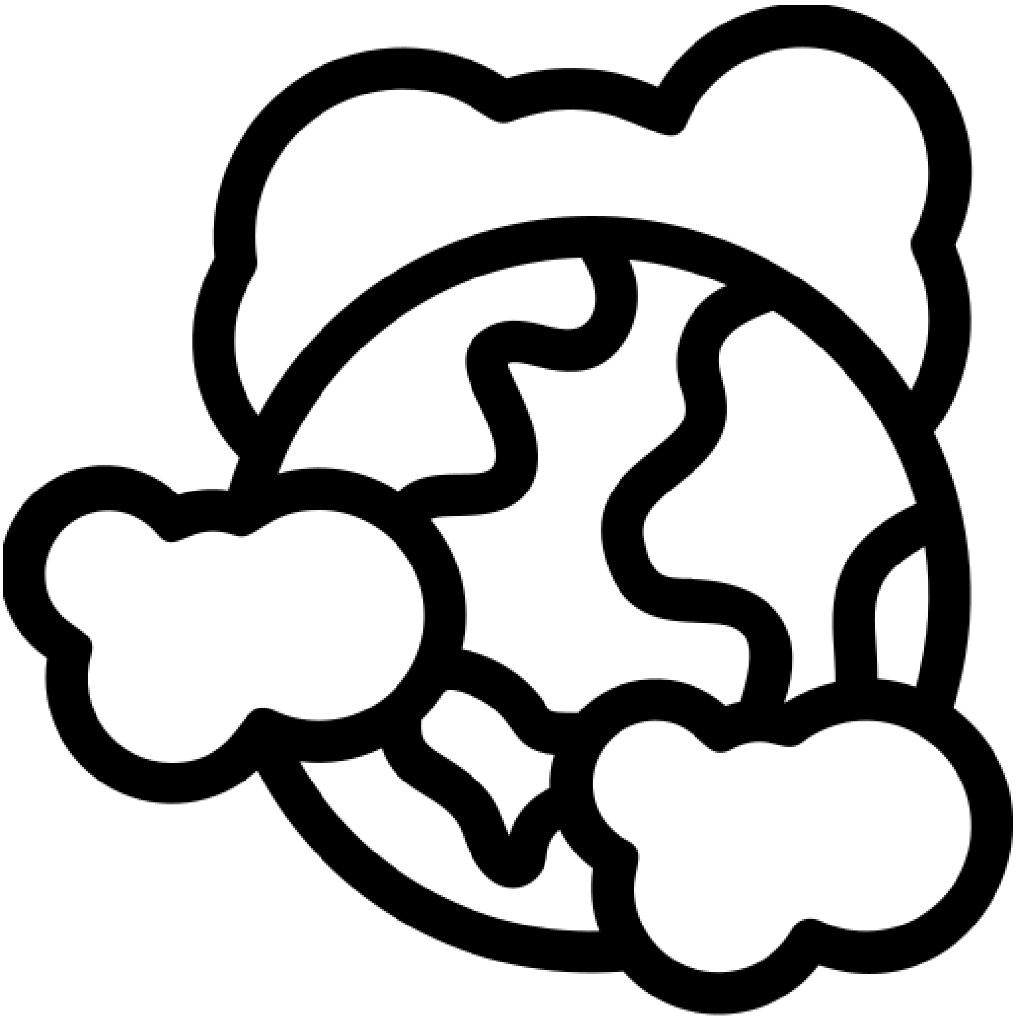
....

Q9. State one composite material and describe what it is made from.

....

....

Earth and the



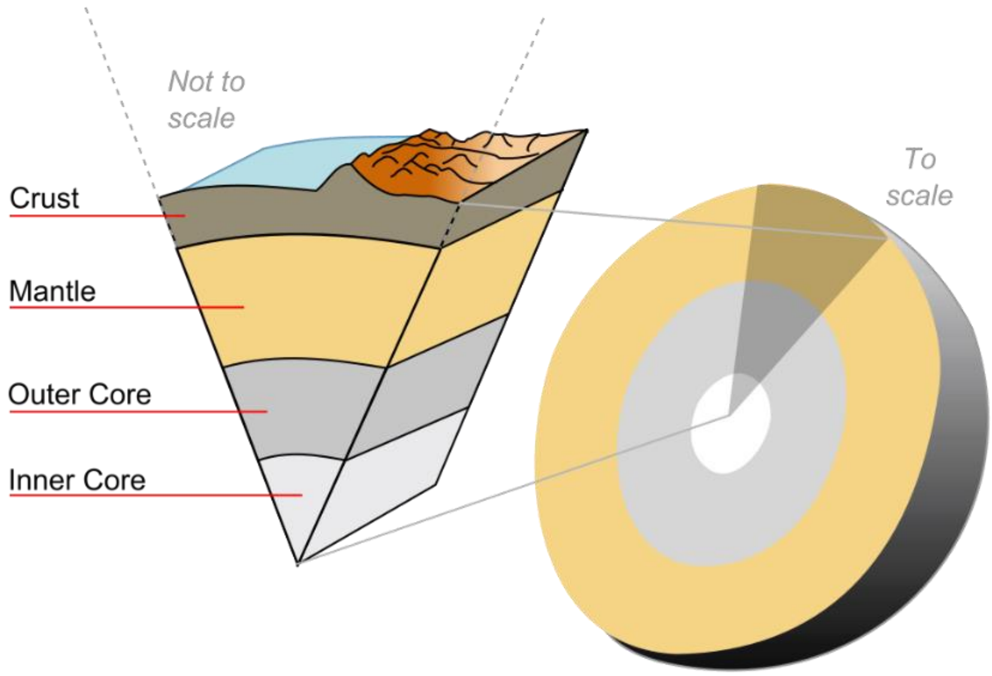
atmosphere

Composition of the Earth

The Earth is roughly spherical and consists of four layers:

1. The **crust** (at the surface of the Earth). The thinnest part of the Earth at 6 to 70 km thick. It is made of rock. The crust is divided into different parts called **tectonic plates**.
2. The **mantle** (below the crust). Around 3000 km thick. It is made of mostly solid rock that flows slowly over time. **Convection currents** in the mantle slowly move the tectonic plates.
3. The **outer core** (below the mantle). A liquid layer that is 2000 km thick. Primarily made of iron and nickel and responsible for the Earth's magnetic field.
4. The **inner core** (at the centre of the Earth). 1400 km radius and the hottest layer of the Earth at 6000 °C. Despite this, the inner core is solid as it experiences more pressure compared to the other layers.

Generally, the temperature of the Earth increases with depth.



Adapted from the public domain image File:Earth-crust-cutaway-english.png by Jeremy Kemp , CC BY-SA 3.0, via Wikimedia Commons

The most abundant elements in the Earth's crust are:

1. Oxygen (46%)
2. Silicon (28%)
3. Aluminium (8%)
4. Iron (6%)

Q1. Name the layer at the centre of the Earth.

....

Q2. State the thickest layer of the Earth, including its thickness.

....

Q3. State the thinnest layer of the Earth, including its thickness.

....

Q4. State the layer of the Earth that is the hottest.

....

Q5. Name all parts of the Earth in order from the outer layer to the inner layer.

....

....

Q6. Name the most abundant element in the Earth's crust.

....

Q7. State what is responsible for the Earth's magnetic field.

....

Q8. Name the different parts that the crust are divided into.

....

Q9. State what convection currents in the mantle lead to.

....

Q10. State what happens to the temperature of the Earth as depth increases.

....

Q11. State what the crust is made of.

....

Q12. State what the outer core is made of.

....

Q13. Describe why the inner core is solid, even though it is a higher temperature than the outer core.

....

....

Q14. State the thickness of the inner core.

....

Q15. State what the mantle is made of.

....

Types of rock and the rock cycle

There are three main types of rock; **sedimentary**, **metamorphic** and **igneous**. Over many years these constantly change from one type to another in the **rock cycle**.

Sedimentary rocks are formed from small rocks and sediment. **Weathering** produces these small rocks and sediment.

Once weathering has occurred, **sediment** is carried by rivers to the sea. Over many years, layers of this sediment build up and pressure compresses the sediment together to form the sedimentary rocks. Two examples of sedimentary rocks are **limestone** and **shale**.

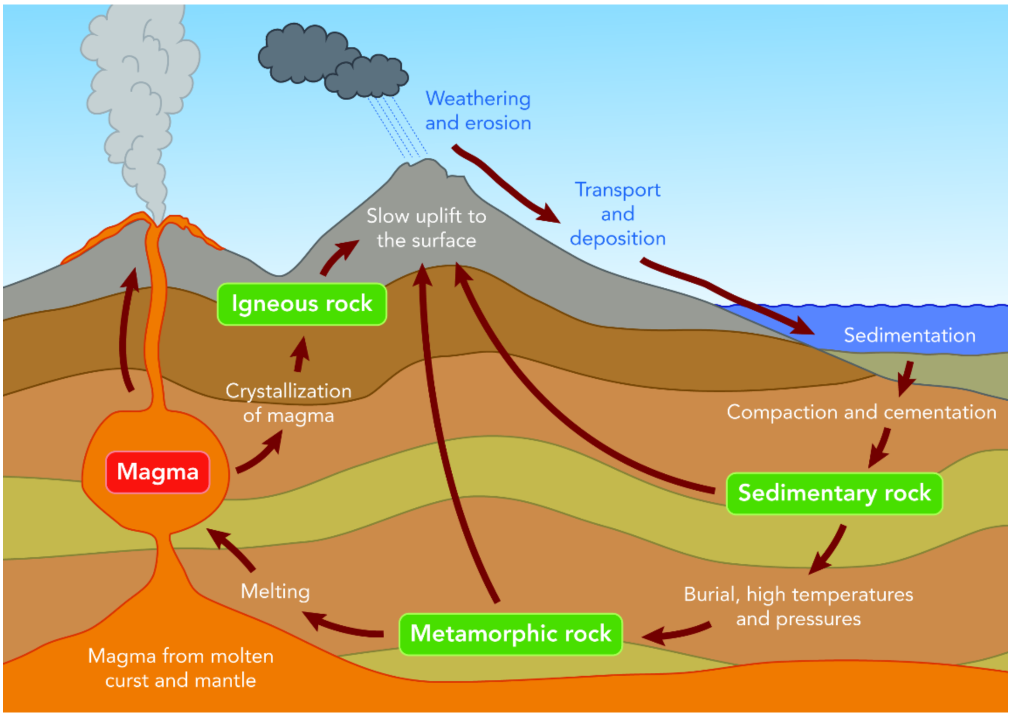
Metamorphic rocks are formed from other types of rocks that experience intense heat and pressure. **Slate** is a metamorphic rock originally made from shale and **marble** is a metamorphic rock made from limestone.

Igneous rocks form when molten rock (called **magma**) cools and solidifies. There are two types of igneous rocks; **intrusive** and **extrusive**.

Extrusive igneous rocks are formed above the Earth's surface. The magma therefore cools and crystallises quickly (leaving small crystals). **Basalt** is an example of an extrusive igneous rock.

Intrusive igneous rocks form when magma cools under the Earth's surface. The temperature under the Earth's surface is higher and so they cool and crystallise slower, forming larger crystals. **Granite** is an example of an intrusive igneous rock.

The diagram below shows these processes in the **rock cycle**.



Q1. State the names of the three different types of rock.

....

Q2. State how sediment is formed.

....

Q3. Describe how sediment forms sedimentary rocks.

....

....

Q4. State one example of a sedimentary rock.

....

Q5. State which rock is formed when limestone experiences intense heat and pressure.

....

Q6. Describe how metamorphic rocks are formed.

....

....

Q7. State one example of a metamorphic rock.

....

Q8. State the name for molten rock.

....

Q9. Describe how igneous rocks are formed.

....

....

Q10. Describe the difference in how intrusive and extrusive igneous rocks are formed.

....

....

Q11. State one example of an igneous rock.

....

Q12. Fossils are only found in sedimentary rocks. Using your knowledge about how metamorphic and igneous rocks are made, explain why this is the case.

....

....

....

Earth's resources

The earth has a **finite** number of resources. Finite means these resources are limited and could run out. As Earth's resources are limited, it's important that humans use them **sustainably**.

This means that we don't overuse the resources that are available to us and that they are available for future generations. This also might mean looking at what alternative resources are available.

Examples of resources we use on Earth are:

- Water
- Land
- Fossil fuels (for example, coal, oil and gas)
- Building materials
- Minerals and ores

To use resources more sustainably, it's important that we **reduce**, **reuse** and **recycle**.

Reducing means cutting back on the amount that we make and therefore limiting the amount of waste created.

Reusing means using the same items again, while recycle means using old resources again and turning them into new materials and objects.

One example of recycling is the recycling of **plastic**. Plastic is made from oil, which is a fossil fuel.

Fossil fuels were formed from the decay of dead plants and animals (like algae and plankton) over millions of years. Because it takes so long for fossil fuels to form, they are considered finite.

It is therefore more sustainable to recycle plastics. It is also cheaper and more energy efficient.

Another example of recycling is the recycling of **aluminium**.

Drinks cans are often made of aluminium. It would take more energy and cost more to extract new aluminium and so the drinks cans are recycled. Used cans can be melted and then turned into new cans. Other metals can be recycled in a similar way.

Q1. Explain what the term “finite” means.

....

....

Q2. State three ways that we can use resources more sustainably.

....

Q3. State three fossil fuels.

....

Q4. Describe how fossil fuels were formed.

....

....

Q5. Explain why fossil fuels are considered to be finite.

....

....

Q6. Describe what recycling means.

....

....

Q7. Describe how aluminium cans can be recycled.

....

....

Q8. State one other material that can be recycled.

....

Q9. State two benefits of recycling.

....

....

Q10. State what plastic is made from.

....

Q11. Describe what using resources sustainably means.

....

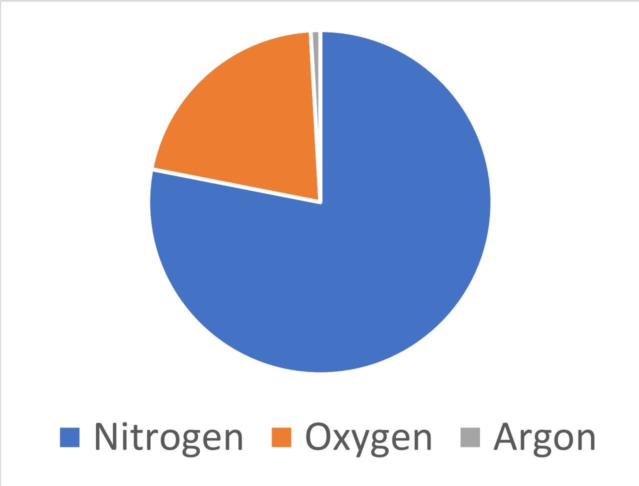
....

Earth's atmosphere

The most abundant gas in Earth's atmosphere is **nitrogen**, which accounts for 78% of the atmosphere.

The next most abundant gases are **oxygen** (at 21%) and **argon** (at 0.9%). These are shown in the pie chart opposite.

Carbon dioxide is also present in the atmosphere (at 0.04%), as well as small amounts of other gases.



The atmosphere of Earth has not always had this composition, though.

Earth was formed around 4.5 billion years ago and there was initially very intense volcanic activity. This volcanic activity led to an atmosphere which consisted of mostly carbon dioxide (and a smaller amount of water vapour). As the Earth cooled, this water vapour condensed to form oceans.

A single celled organism called **cyanobacteria** then arrived on Earth and carried out **photosynthesis**. In photosynthesis, carbon dioxide and water are (in the presence of light) used to produce glucose and oxygen.

Photosynthesis is responsible for producing oxygen on Earth.

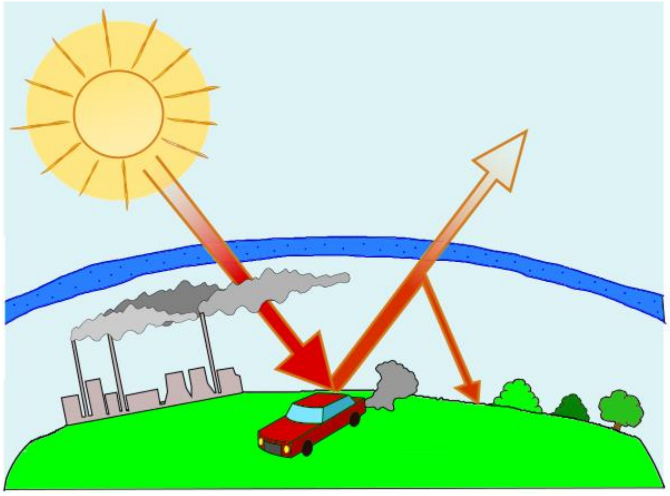
Carbon dioxide is also known as a **greenhouse gas**. Greenhouse gases are responsible for **global warming** (a raising of the average temperature of Earth).

Thermal (infra-red) radiation reaches the Earth from the Sun. The Earth absorbs and re-emits some infra-red radiation, but greenhouse gases reflect some of this back to Earth.

Due to this, the average temperature of the Earth is raised.

Burning **fossil fuels** (like oil, coal or gas) increases the amount of carbon dioxide in the atmosphere.

The global warming caused by this can cause more extreme weather events and lead to melting of the polar ice caps. This can cause flooding of low-lying countries.



Lars Ebbersmeyer, CC BY-SA 4.0, via Wikimedia Commons

Q1. State the three most abundant gases in the Earth's atmosphere.

....

Q2. State the percentage of Nitrogen in the Earth's atmosphere.

....

Q3. State the percentage of Oxygen in the Earth's atmosphere.

....

Q4. Describe the differences in the Earth's early atmosphere and the atmosphere now.

....

....

Q5. Describe the role of cyanobacteria in changing the composition of Earth's atmosphere.

....

....

Q6. State what global warming is.

....

Q7. Describe how greenhouse gases lead to global warming.

....

....

Q8. State what burning fossil fuels does to the levels of carbon dioxide in the atmosphere.

....

Q9. Name the three fossil fuels.

....

Q10. State two effects of global warming.

....

....

Q11. Venus has an atmosphere that mostly consists of carbon dioxide. Describe the effect that this has on Venus' average temperature.

....

....

Q12. Describe the effect that deforestation has on the carbon dioxide levels on Earth. Explain why planting more trees would be beneficial in reducing levels of global warming.

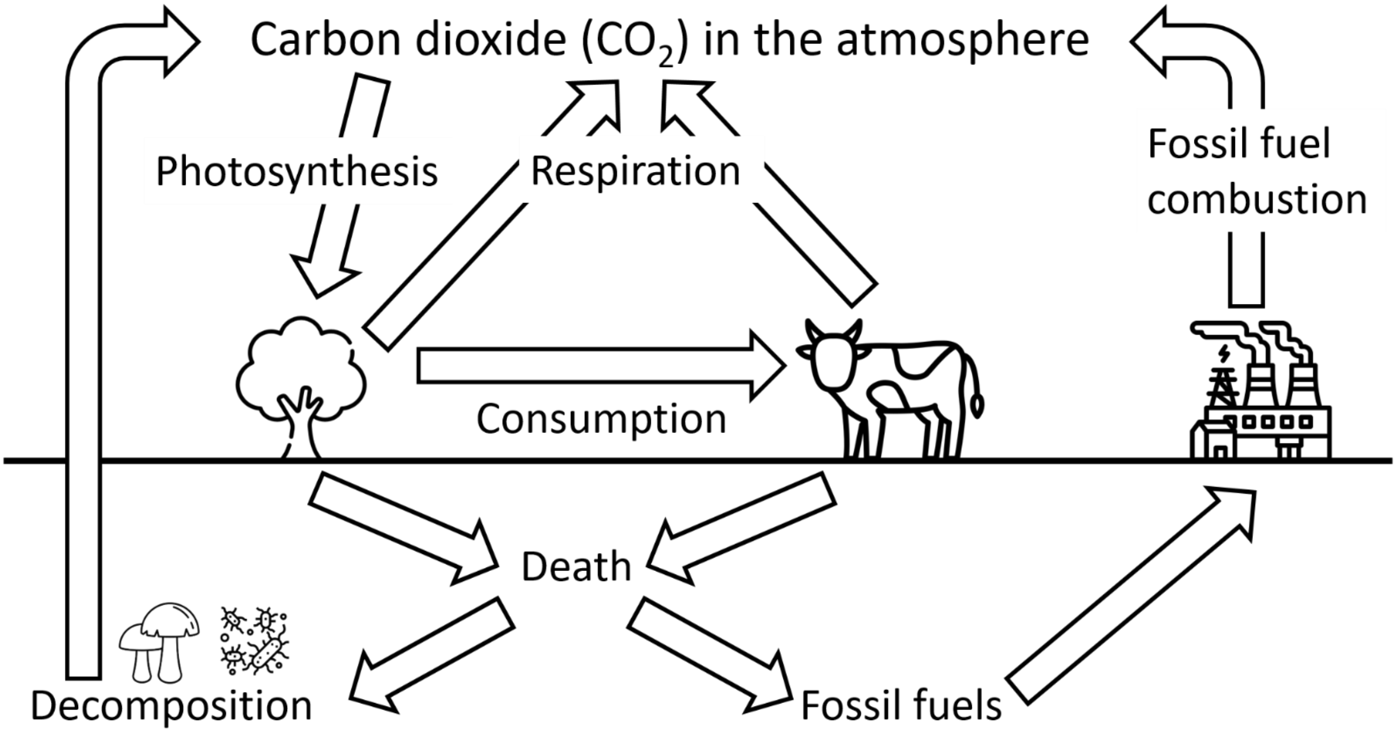
....

....

....

Carbon cycle

The **carbon cycle** describes the continuous movement of carbon into and out of the atmosphere, animals, plants and the ground. The diagram below shows this cycle.



Carbon in the atmosphere is in the form of **carbon dioxide**. Carbon dioxide is removed from the atmosphere by **photosynthesis**. Photosynthesis is a chemical process carried out by **plants**. Glucose and oxygen are made from carbon dioxide and water (under the presence of light).

While plants take carbon dioxide out of the atmosphere through photosynthesis, they also put some back into the atmosphere through **respiration**. Overall, though, plants remove more carbon dioxide from the atmosphere than they put back into it.

Animals also release carbon dioxide through respiration.

Carbon dioxide is also released into the atmosphere by **decomposition** of the remains of plants and animals. Decomposers (**bacteria** and **fungi**) break down dead organisms into simpler substances.

When conditions do not allow for decomposition, the remains of plants and animals also produce **fossil fuels**. This is a slow process that takes millions of years. Humans burn fossil fuels (like coal, oil and gas) in power plants and vehicles. This process releases carbon dioxide, which is a greenhouse gas. Greenhouse gases contribute to **global warming**.

Q1. Describe what the carbon cycle is.

……

……

Q2. State the name of the process that removes carbon dioxide from the atmosphere.

……

Q3. State three processes that release carbon dioxide into the atmosphere.

……

Q4. Name two decomposers.

……

Q5. Describe what decomposers do.

……

Q6. State what fossil fuels are formed from.

……

Q7. Name three fossil fuels.

……

Q8. State what burning fossil fuels does to the levels of carbon dioxide in the atmosphere.

……

Q9. State two uses of burning fossil fuels.

……

Q10. Carbon dioxide is a greenhouse gas. State what having a large amount of greenhouse gases in the atmosphere leads to.

……

Q11. Describe the effect that planting more trees would have on the levels of carbon dioxide in the atmosphere.

……

……

Q12. Describe what photosynthesis is.

……

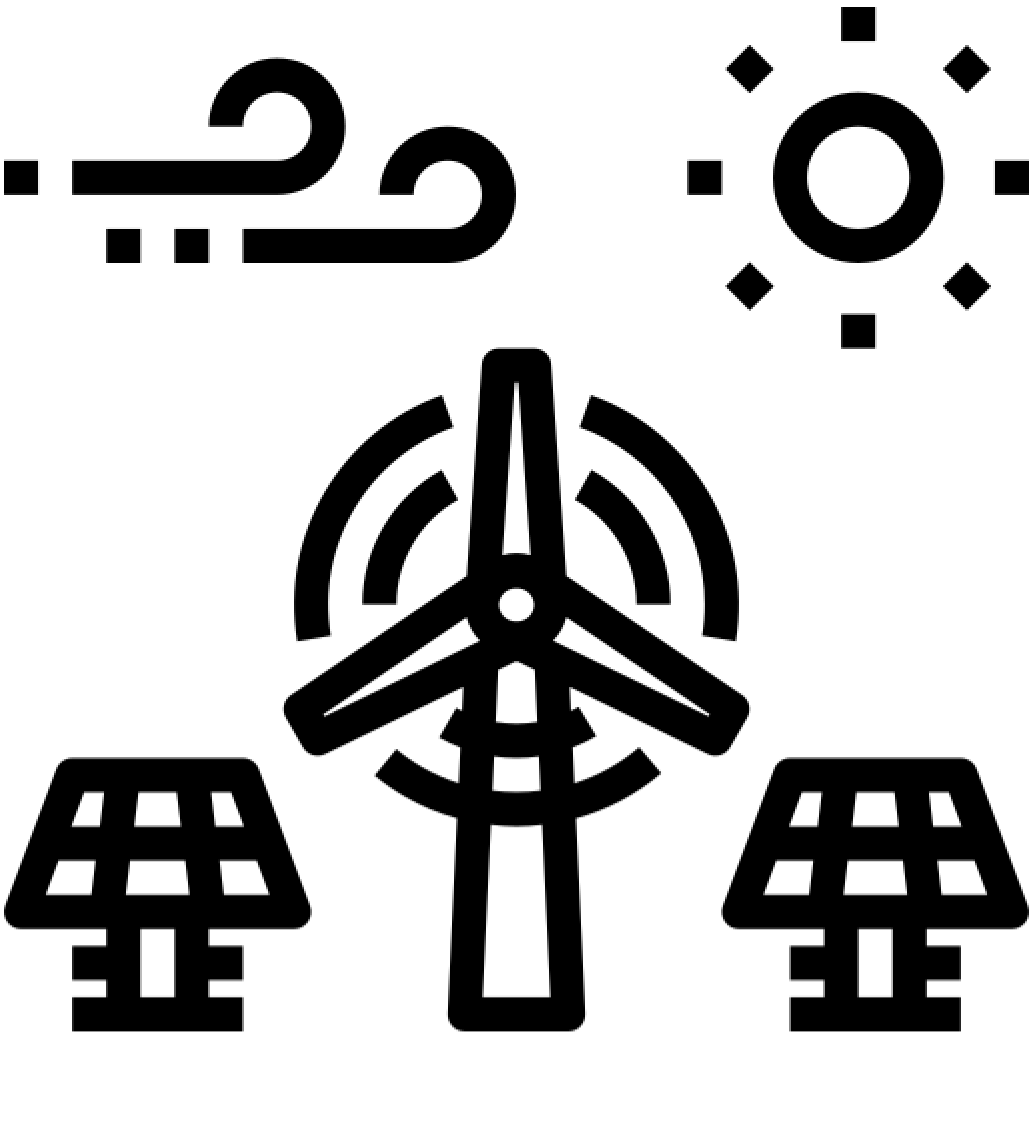
……

Q13. Humans are increasingly looking at reducing the amount of fossil fuels burnt. Describe the effect that this would have on the carbon dioxide levels in the atmosphere and the effect this would have on global warming.

……

……

Energy



Energy stores

Energy is not a physical thing that we can see or touch.

Different objects **store** energy in different ways. These are called **energy stores** and are listed below:

Name	Description	Examples
Thermal	Any object with a **temperature** has a thermal energy store. The higher the temperature of an object, the more energy in the thermal energy store.	A hot cup of tea, hot bath water, a hot radiator.
Kinetic	Any object that is **moving** has a kinetic energy store. The faster the movement, the more energy in the kinetic energy store.	A car or train that is moving, somebody walking or running.
Gravitational potential	Objects at a **height above the ground** have a gravitational potential energy store. The larger the height above the ground, the more energy in the gravitational potential energy store.	A book on a high shelf, a bird standing on a high branch of a tree.
Elastic potential	When objects such as a spring or elastic band are **stretched** or **compressed** they store elastic potential energy. The greater the extension or compression, the larger the elastic potential energy store.	A stretched elastic band/spring/hair tie.
Chemical	Different **chemicals** store energy in their chemical energy store.	Food, fuel, batteries.
Nuclear	Energy that is stored in the **nucleus** of an atom is in the nuclear energy store.	Fuel in nuclear power plants. For example, uranium or plutonium.
Magnetic potential	When two **magnets** are held close together, they have a magnetic potential energy store.	Two magnets near each other.
Electrostatic potential	When **charges** are close together, they have an electric potential energy store.	Protons, electrons, any charged particle.

Q1. A helicopter is stationary and hovering above the ground. State the energy store the helicopter has.

....

Q2. The helicopter now starts to move forwards. State another energy store the helicopter now has.

....

Q3. While flying, the engine of the helicopter becomes warm. State the energy store the engine of the helicopter has.

....

Q4. The helicopter uses a fuel called kerosene (similar to petrol). State the energy store that kerosene has.

....

Q5. Somebody is bungee jumping and jumps off a bridge. State what happens to their gravitational potential energy store as they fall.

....

Q6. As the person bungee jumps, they accelerate and get faster. State what happens to their kinetic energy store.

....

Q7. When the person gets to the bottom of their bungee jump, the bungee cord stretches. State what happens to its elastic potential energy store.

....

Q8. A remote-controlled car has a battery that powers it. State the energy store the battery has.

....

Q9. The remote-controlled car accelerates forwards. State the energy store that it now has.

....

Q10. The battery of the remote-controlled car becomes hot as it is being used. State which energy store has increased.

....

Q11. State the energy store that two charged particles close to each other have.

....

Q12. State the energy store that uranium fuel in a nuclear power plant has.

....

Q13. State the energy store that a chocolate bar has.

....

Q14. State the energy store that two magnets near each other have.

....

Energy transfers

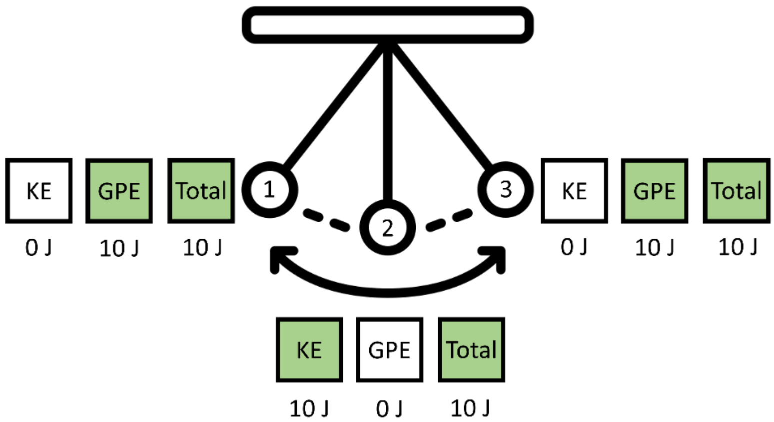
The **principle of conservation of energy** tells us that energy is never created or destroyed; it is only transferred from one energy store to another.

The unit of energy is the **Joule (J)**.

There are four **pathways** for energy to be transferred from one store to another. Energy can be transferred:

1. **Mechanically**. Mechanical work is done on an object when a force is applied over a distance.
2. **Electrically**. Electrical work is done when charges move through a circuit.
3. By **heating**. The transfer of energy from a hotter object to a cooler object.
4. By **radiation**. This includes energy transferred by light (or any electromagnetic wave) and sound.

Note the phrase "work" has been used in some of the pathways. "Work done" is just another way of saying energy transferred from one store to another.



The diagram to the right shows a pendulum swinging from side to side.

In position 1, the pendulum is at its maximum height and it has a gravitational potential energy (GPE) store of 10 J.

As the pendulum falls into position 2, gravity does mechanical work on the pendulum. The pendulum speeds up and becomes lower in height. Its GPE store empties, and its kinetic energy (KE) store fills to 10 J. Note how the overall amount of energy is the same, due to the principle of conservation of energy.

The pendulum then continues swinging to position 3. As it does so, its KE store empties and its GPE store fills back to the original 10 J. The pendulum is stationary at position 3 so it has no KE. It is also at its maximum height, so it has maximum GPE. The total energy is still unchanged.

However, the pendulum will eventually come to a stop. This is primarily due to air resistance. Generally, energy transfers are not 100% **efficient**. Energy is "wasted" by raising the thermal energy store of the surroundings. The temperature of the pendulum and the nearby air will be raised slightly.

Q1. State the principle of conservation of energy.

....

....

Q2. Describe what it means when we say that work is done on an object.

....

....

Q3. State the unit of energy.

....

Q4. A book is on a shelf and has an initial gravitational potential energy store of 30 J. It then falls off the shelf. State how much energy is in the kinetic energy store by the time the book reaches the ground.

....

Q5. In practice, the amount of energy in the kinetic energy store will be less than your answer to Q4. Describe why.

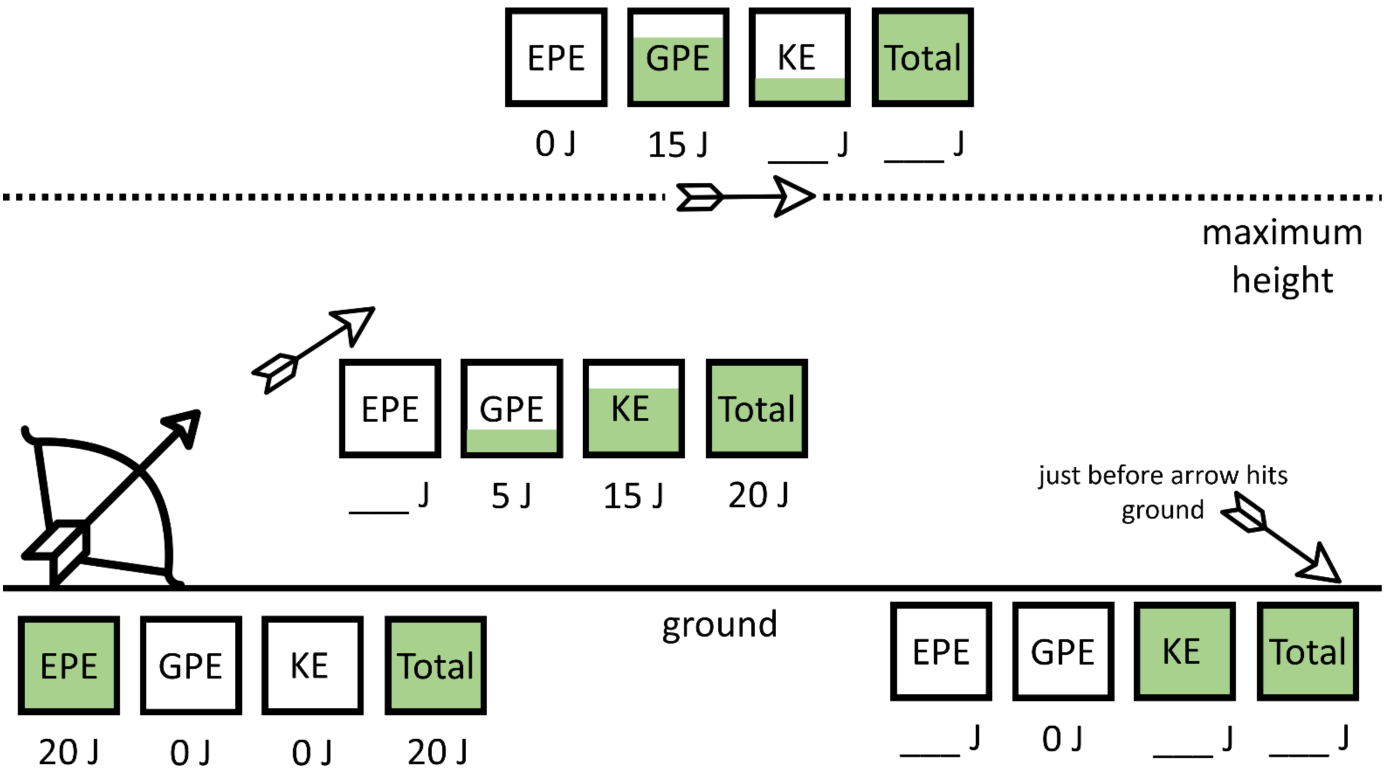
....

....

Q6. State the four pathways for energy transfer.

....

Q7. The diagram below shows the different energy stores involved in firing an arrow from a bow. The before the arrow is released, there is 20 J of energy in the elastic potential energy (EPE) store. Complete the missing energies after the arrow has been fired.



Power

Power is defined as the rate at which energy is transferred. The unit of power is the **Watt (W)**.

There is an equation that relates power, energy and time:

Power = Energy ÷ Time or in symbols **P = E ÷ t**

Remember, the unit of energy is the Joule (J) and the unit of time is the second (s).

We can also rearrange this equation to give:

Energy = Power × Time or in symbols **E = P × t**

Example question 1:

A torch has a power of 5 W and is used for a time of 30 s. Calculate the energy used by the torch.

Step 1. Write down equation: **E = P × t**

Step 2. Insert variables into equation: **= 5 × 30**

Step 3. Calculate answer. Remember units: **= 150 J**

Example question 2:

A toaster uses 20 000 J of energy in a time of 100 s. Calculate the power of the toaster.

Step 1. Write down equation: **P = E ÷ t**

Step 2. Insert variables into equation: **= 20 000 ÷ 100**

Step 3. Calculate answer. Remember units: **= 200 W**

Sometimes power is given in units of **kilowatts (kW)**. One kilowatt is equal to one thousand watts.

To convert from kilowatts to watts you need to multiply the number of kilowatts by one thousand: **kW × 1000 → W**

To convert from watts to kilowatts you need to divide the number of watts by one thousand: **W ÷ 1000 → kW**

Q1. State the equation that links power, energy and time.

....

Q2. State the unit of power.

....

Q3. A lamp uses an energy of 2400 J in a time of 40 s. Calculate the power of the lamp

P = E ÷ t

= 2400 J ÷ 40 s

= ____________ W

Q4. The electric motor in a radio controlled car uses an energy of 4000 J in a time of 200 s. Calculate the power of the electric motor.

__ = __ ÷ __

= ____ __ ÷ ____ __

= ____________ __

Q5. A microwave has a power of 900 W. Calculate how much energy it will use in a time of 15 s.

E = P × t

= ____ __ × ____ __

= ____________ J

Q6. An electric radiator has a power of 2000 W. Calculate how much energy it will use in a time of 90 s.

__ = __ × __

= ____ __ × ____ __

= ____________ __

Q7. State how many watts are in one kilowatt.

....

Q8. Practise converting between watts and kilowatts by filling in each of the blank powers below.

5 kW
= _____ W

1.5 kW
= _____ W

2000 W
= ____ kW

800 W
= ____ kW

0.2 kW
= _____ W

Q9. A washing machine has a power of 2.2 kW. Calculate how much energy it uses in 20 minutes. You will need to convert kilowatts into watts and minutes into seconds.

....

....

Energy resources

We generate electricity through two categories of energy resource: those that are **non-renewable** and those that are **renewable**.

A non-renewable resource is one which cannot be replaced once it has been used. One day, non-renewable resources will run out.

The most common non-renewable resources are the three **fossil fuels** (oil, coal and gas) and **nuclear power**.

As well as being used in power plants, fossil fuels can be used for **transport** and **heating**. For example, petrol and diesel (which are both made from oil) are used in cars. Gas is commonly used in central heating systems, and coal is burnt in some fireplaces.

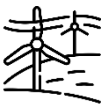
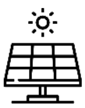
The main advantage of using a non-renewable resource in a power plant is that they all produce a **reliable** output.

However, the main disadvantage is that burning fossil fuels increases the amount of carbon dioxide (CO_2) in the atmosphere. Carbon dioxide is a **greenhouse gas**. Greenhouse gases are responsible for **global warming** (a raising of the average temperature of Earth).

Burning coal and oil also produces **sulphur dioxide** which contributes to **acid rain**.

Nuclear power plants do not have carbon dioxide or sulphur dioxide emissions but they do produce **radioactive waste** which is difficult to dispose of safely. However, they do generate a reliable and large output.

A **renewable** resource will not run out. Three renewable resources are listed below:

<table>
<tr><th>Resource</th><th>Advantage</th><th>Disadvantage</th></tr>
<tr><td>Wind </td><td rowspan="3">No carbon dioxide emissions, so they do not contribute to global warming.
Once built, no fuel costs and so are cheap to run.</td><td>It is not always windy, so the output is unreliable. Noisy & spoils the view.</td></tr>
<tr><td>Hydro-electric </td><td>Requires the flooding of a valley with a dam. This causes a loss of habitat.</td></tr>
<tr><td>Solar </td><td>Only work in direct sunlight, so do not generate electricity at night.</td></tr>
</table>

We are using more renewable resources for generating electricity. In 2022, there was an “energy crisis” due to shortages of oil and gas. This shortage increased the price of electricity. Renewable resources can help reduce our reliance on fossil fuels.

Q1. Describe what a non-renewable resource is.

....

....

Q2. State the three fossil fuels.

....

Q3. Describe what a renewable resource is.

....

....

Q4. State three renewable resources.

....

Q5. The following statements are either true or false. State which are true and which are false.

a) Nuclear power is a renewable resource.

....

b) Wind power has an unreliable output.

....

c) Solar power generates electricity at night.

....

Q6. Describe one disadvantage of burning fossil fuels.

....

....

Q7. Other than their use in power plants, state two uses of fossil fuels.

....

Q8. Describe general advantages of using renewable energy resources.

....

....

Q9. Hydroelectric power involves storing water at a height behind a dam. The water is then allowed to fall. State the initial energy store the water has, and the store it is transferred to as it falls.

....

Q10. State which fossil fuels produce sulphur dioxide emissions. Include what sulphur dioxide emissions lead to.

....

Q11. State the advantage of burning fossil fuels in a power plant.

....

Electricity bills

We've already learnt, on page 8, that one unit of energy is the **Joule (J)**. Two other units of energy are:

1. The **kilojoule (kJ)**. One kilojoule is equal to one thousand joules.
2. The **kilowatt hour (kWh)**. One kilowatt hour is equivalent to an electrical device with a power of 1 kW (equal to 1000 W) being used for a time of one hour. As there are 3600 seconds in one hour, one kilowatt hour is therefore equal to 3 600 000 J of energy.

We use kilowatt hours for electricity bills. This is because electrical devices in the average UK household transfer over 10 billion joules of energy a year. It's more convenient to use kilowatt hours as this brings the numbers down to a more manageable size.

Electrical devices in the average UK household transfer 3000 kWh of energy each year.

To calculate the amount of energy in kWh that a device transfers you need to multiply the power of the device (in kW) by the time that it is used for (in hours):

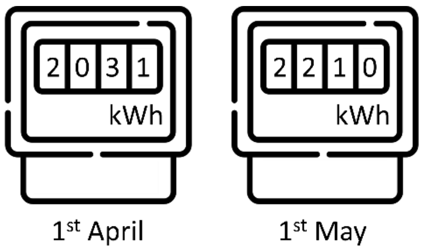
Energy (in kWh) = Power (in kW) × time used (in h)

As of April 2022, the price for each kWh in the UK was 28 p. To calculate the cost of an electricity bill we use the equation:

Total cost (in pence) = Energy transferred (in kWh) × price per kWh (in pence)

Example question:

Using the meter readings to the right, calculate the cost of the monthly electricity bill. The price of each kWh is 28 p.



Step 1. Calculate the total number of kWh used.

To do this, we need to look at the difference in meter readings:

2210 – 2031 = 179 kWh

Step 2. Calculate cost by multiplying total number of kWh by cost per kWh.

179 × 28 = 5012 p

There are 100 p in a pound. To convert from pence to pounds you need to divide the number of pence by one hundred: **p ÷ 100 → £**

In other words, the 5012 p we calculated is equal to £50.12.

Q1. State how many joules are in a kilojoule.

Q2. State how many seconds are in an hour.

Q3. State how many joules are in a kilowatt hour.

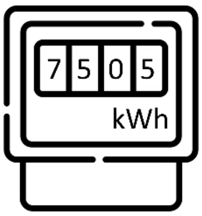
Q4. An electric oven has a power of 2.2 kW and is used for a time of one hour. Calculate how much energy is used in kWh.

Q5. A television has a power of 0.2 kW and is used for a time of 8 hours. Calculate how much energy is used in kWh.

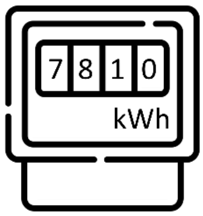
Q6. A hairdryer has a power of 1.8 kW and is used for a time of 30 minutes. Calculate how much energy is used in kWh.

Q7. State the equation that we can use to calculate cost of an electricity bill.

Q8. Using the meter readings to the right, calculate the cost (in pence) of the monthly electricity bill. The price of each kWh is 30 p.



1st November



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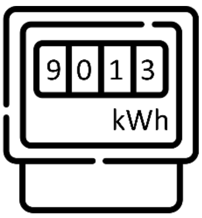

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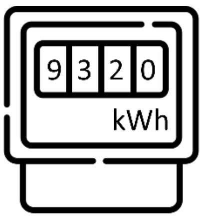
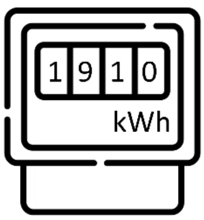


1st July

Q9. Using the meter readings to the left, calculate the cost (in pence) of the monthly electricity bill. The price of each kWh is 25 p.

Q10. Using the meter readings to the right, calculate the cost (in pounds) of the monthly electricity bill. The price of each kWh is 28p.



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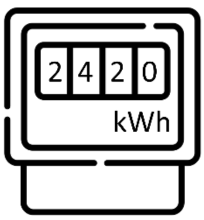


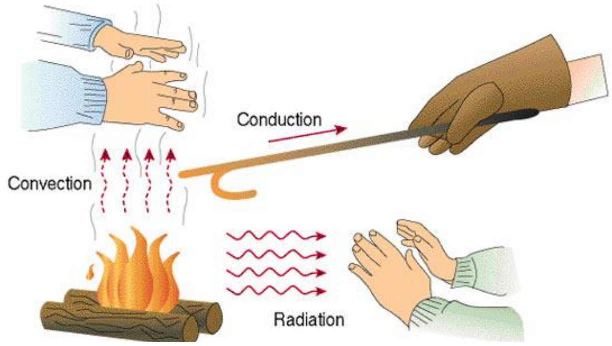
1st April

Thermal energy transfer

There are three ways that thermal energy can be transferred:

1. **Conduction**.
2. **Convection**.
3. **Radiation**.

Thermal energy is transferred from hotter objects to colder objects.



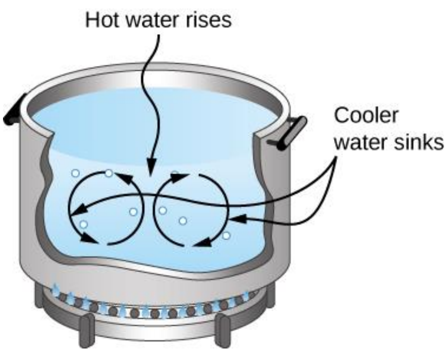
Kmecfiunit, cmglee CC BY-SA 4.0, via Wikimedia Commons

Conduction occurs primarily in solids. As particles in a solid are heated, they vibrate more. These vibrations cause collisions between particles and the vibrations are transferred along the material.

If a material is able to conduct heat well, it is called a **conductor**. Metals are one example of a good conductor.

If a material is not able to conduct heat well, it is called an **insulator**. Plastics are an example of a good insulator. Gases (like air) are very good insulators, as their particles are far apart from each other.

There are no particles in a vacuum. Conduction is not possible through a vacuum.



OpenStax College. ***Located at****: openstax.org/books/college-physics/pages/14-6-convection* ***License****:* CC BY: Attribution.

Convection happens in both liquids and gases. As a liquid or gas is heated, the particles move faster and become more spread out. Due to this they become less dense and therefore rise. Colder liquids or gases are more dense and sink. This is a **convection current**.

This is shown in the image on the left with a pan on a gas stove. The bottom of the pan is hot and so water at the bottom of the pan heats up and rises. Meanwhile, water at the top of the pan cools and sinks.

All objects emit **radiation** in the form of infrared waves. This can be referred to as thermal radiation or infrared radiation. As infrared radiation is an electromagnetic wave, it can even travel through a vacuum. This is how thermal radiation reaches the Earth from the Sun.

Matt black objects absorb the most infrared radiation, while shiny silver surfaces reflect infrared radiation.

Q1. State three ways thermal energy can be transferred.

....

Q2. The following statements are either true or false. State which are true and which are false.

a) Conduction happens mostly in solids.

....

b) Metals are good conductors.

....

c) Convection currents happen only in liquids.

....

d) Thermal energy cannot be transferred through a vacuum.

....

e) Only hot objects emit infrared radiation.

....

f) Thermal energy is transferred from hotter objects to colder objects.

....

Q3. Describe why gases are good insulators.

....

....

Q4. Describe how a convection current forms.

....

....

Q5. Describe how conduction transfers thermal energy.

....

....

Q6. State which colour of object absorbs infrared radiation the best.

....

Q7. Describe what a vacuum is.

....

Q8. Describe what a conductor is.

....

Q9. State which type of thermal energy transfer allows the Earth to be heated by the Sun.

....

Reducing unwanted thermal energy transfers

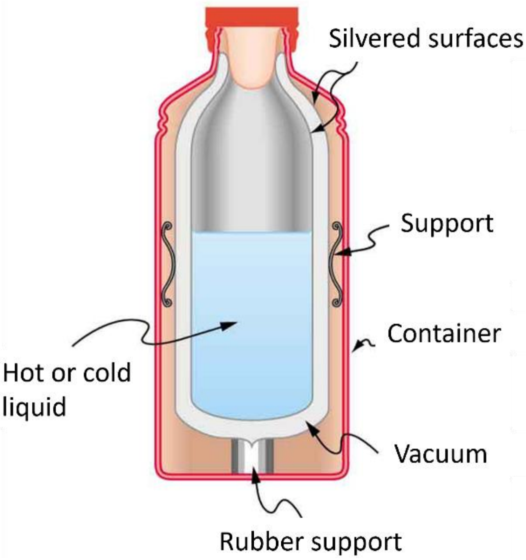
To reduce the size of electricity and fuel bills, it is important to reduce thermal energy losses from a home:

More thermal energy escaping from home ⇨ More energy/fuel needed ⇨ Higher heating costs

In the average home:

- 35% of thermal energy loss is through the walls. This can be reduced with **cavity wall insulation**. A cavity wall is made of two separate walls with a gap in between them. This gap can then be filled with an insulator. This is shown in the diagram to the right.
- 25% of thermal energy loss is through the roof/attic. This can be reduced with **loft insulation**.
- 25% of thermal energy loss is through windows and doors. This can be reduced with **double glazing**, **closing the curtains** and with a **draught excluder** that stop draughts coming in through the bottom of the door.
- 15% of thermal energy loss is through the floor. This can be reduced by improving the insulation in the floor.

Mok9, Public domain, via Wikimedia Commons



OpenStax College. ***Located at:*** *openstax.org/books/college-physics/pages/14-conceptual-questions* ***License****:* CC BY: Attribution.

Vacuum flasks are also designed to limit thermal energy transfers. If a hot liquid is inside a vacuum flask, the following features keep the liquid hot for as long as possible:

- The **silvered surfaces** reflect infrared radiation back into the liquid.
- The **vacuum** does not allow for conduction or convection as there are no particles.
- The plastic lid is an **insulator**, limiting conduction. It also prevents evaporation of liquid.

They also work keep a cold liquid cooler for longer. The silvered surfaces now reflect infrared radiation away from the liquid. The vacuum prevents conduction and convection and the plastic lid also limits conduction.

Q1. State how thermal energy loss can be reduced through the:

a) Walls of a house.

....

b) Roof of a house.

....

c) Door of a house.

....

Q2. Describe why it is important to reduce thermal energy losses from a home.

....

....

Q3. Double glazing is made from two panes of glass, which are separated by a gas. Describe why double installing double glazing will limit thermal energy loss from the windows.

....

....

Q4. State a way, other than double glazing, of reducing thermal energy loss through windows.

....

Q5. Takeaway containers often come in silvered aluminium containers. Describe why this limits thermal energy loss due to radiation.

....

....

Q6. Two metal bottles contain a cold liquid. One of the bottles is coloured black, the other is silver. Explain which one will keep the liquid cooler for longer.

....

....

Q7. The following statements are either true or false. State which are true and which are false.

a) There are no particles in a vacuum.

....

b) Plastic is a good conductor.

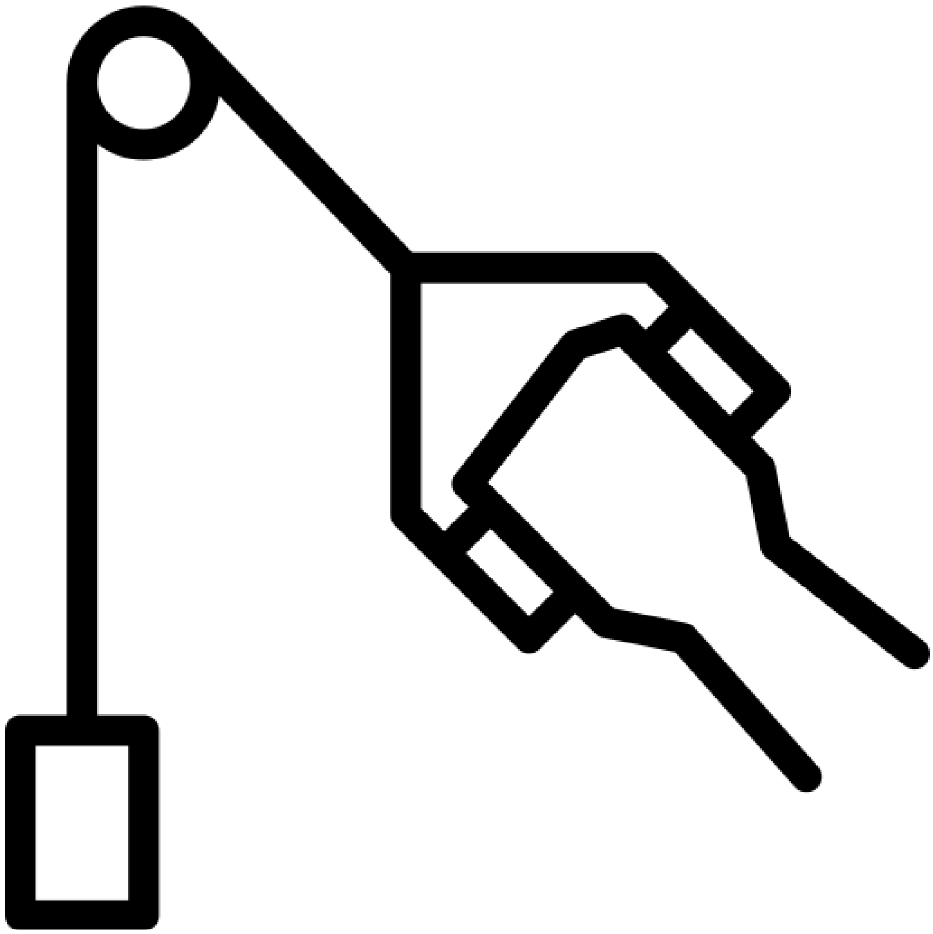
....

Q8. Cavity wall insulation can be made of foam, which contains trapped air bubbles. Explain why this is a good insulator.

....

....

Forces



and motion

Introduction to forces

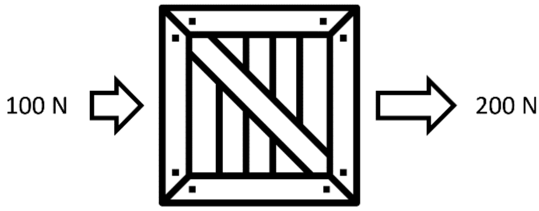
A force is a push, a pull or a twist. Forces change the **speed, direction or shape** of an object.

The unit of a force is the **Newton (N)** and forces are measured using **Newton meters**.

Forces may be represented by **arrows** in diagrams. They are drawn showing the direction the force is acting. The longer the arrow, the larger the size of the force.

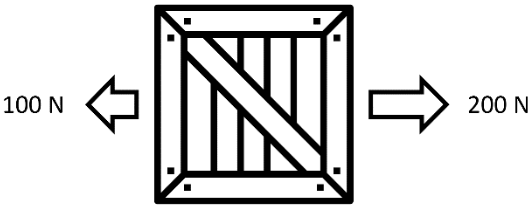
The motion of an object will depend on the **resultant force**. This is calculated by combining the forces, taking their direction into account.

If two forces are in the same direction, then we calculate the resultant force by adding the forces together.



In the example to the right, the 100 N force and the 200 N force are both acting in the same direction (to the right). The resultant force on the crate is therefore equal to 300 N.

It is also important to write the direction the force acts. We would therefore write our final resultant force as 300 N to the right. This means that the crate will **accelerate** to the right.

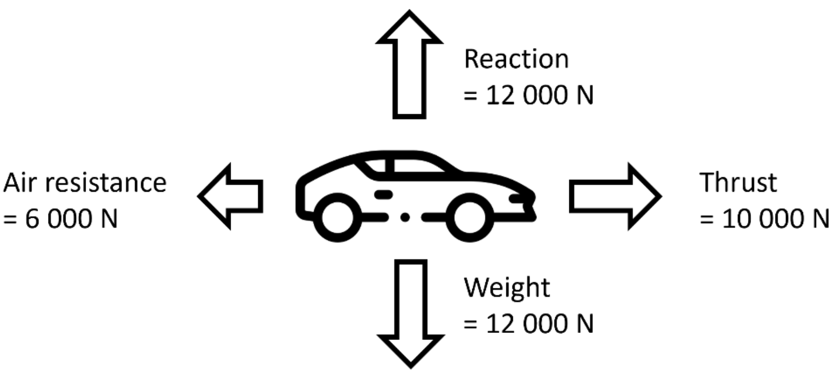


If two forces are in opposite directions, then you subtract one from the other.

In the example to the left, the 100 N force and the 200 N force are acting in opposite directions. Our resultant force would be 100 N to the right.

If there's a resultant force of zero, the object will either remain stationary or remain moving at the same speed. If all individual forces make a resultant force of zero, we say the forces are **balanced**.

For example, the weight and the reaction force on the car below are **balanced**.



The thrust and the air resistance forces are **unbalanced** and there is a **resultant force** of 4 000 N to the right.

As there's a resultant force, the car will therefore **accelerate** to the right.

Q1. State what we use to measure the size of a force.

Q2. State the unit of a force.

Q3. Two people are competing in a tug of war. Use the force diagram to the right to answer the questions:

a) State whether the forces are balanced.

b) Calculate the resultant force.

Q4. A lorry is travelling on the motorway. Use the force diagram to the right to answer the questions:

a) State whether the forces are balanced.

b) Calculate the resultant force.

c) State what will happen to the lorry.

Q5. An aeroplane is on a flight. Use the force diagram to the right to answer the questions:

a) State whether the forces are balanced.

b) Calculate the resultant force.

c) State what will happen to the aeroplane.

Q6. A force diagram for a boat is shown.

a) State whether the forces are balanced.

b) Calculate the resultant force.

c) State what will happen to the boat.

Types of force

There are two categories of force – those that are **contact** forces and those that are **non-contact** forces.

A **contact force** is one that acts when two objects are physically touching each other. Conversely, a **non-contact** force acts between objects that are not touching each other. Some examples are in the table below:

Name	Description	Examples
Air resistance	Contact force caused when an object travels through air. Air resistance acts against the direction of motion.	A skydiver falling through the air.
Friction	Contact force caused by two objects rubbing together. Friction also acts against the direction of motion.	Friction between somebody's shoes and the ground.
Gravitational	Attractive non-contact force. Any two objects with mass experience gravitational forces towards each other.	The Earth experiences a gravitational force as it orbits around the Sun.
Magnetic	Non-contact force caused by magnetic fields. Can be attractive or repulsive. For more on magnetic forces see page 72.	Two magnets being held near each other.
Normal reaction	This is a contact force that is in opposition to another force. It acts at 90 degrees to the surface of the object.	As we exert our weight on the ground, the ground exerts an equal and opposite reaction force.
Tension	A contact force in a rope or cable being pulled.	A rope that is being pulled.
Thrust	A contact force produced by an engine or rocket.	The forwards force of a car.
Upthrust	Upwards contact force that allows objects to float	A boat floating on water.
Weight	Non-contact force due to gravity.	All objects on Earth have a downwards weight.

Q1. The following statements are either true or false. State which are true and which are false.

a) Friction is a non-contact force.

....

b) Weight is a contact force.

....

c) Thrust is the force that allows objects to float.

....

d) Air resistance acts against the direction of motion.

....

Q2. Describe what a contact force is.

....

....

Q3. State two examples of a contact force.

....

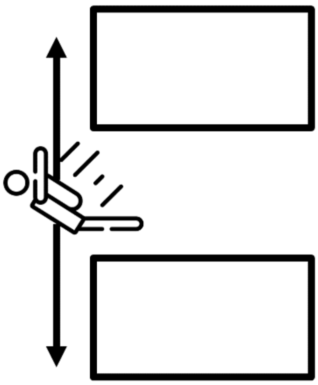
Q4. Describe what a non-contact force is.

....

....

Q5. State two examples of a non-contact force.

....



Q6. The diagram to the left shows a skydiver falling through the air. Label the downwards force and the upwards force.

Q7. The downwards and the upwards force on the skydiver are balanced.

a) Describe what it means to say that two forces are balanced.

....

....

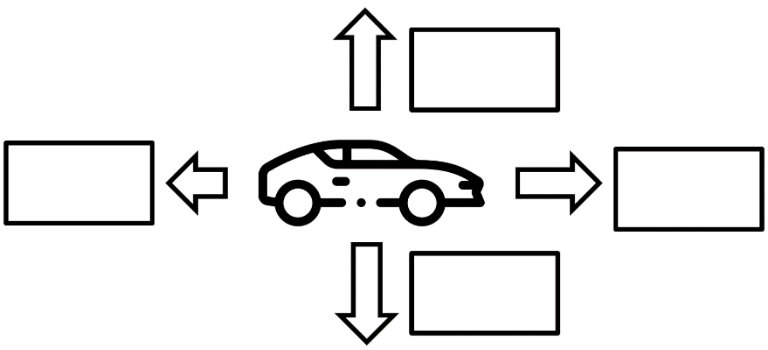
b) State what will happen to the speed of the skydiver.

....

Q8. The diagram to the right shows a car driving along a road. Label the forces.

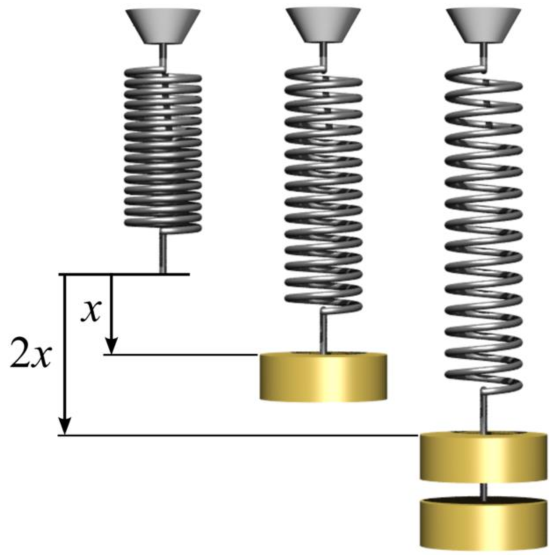
Q9. The forwards force is greater than the backwards force. State what will happen to the speed of the car.

....



Hooke's law

When a force is applied to a spring, the spring **extends** (increases in length) or **compresses** (decreases in length). The extension or compression depends on the size of the force applied.



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The diagram to the right shows a spring with different extensions. In the first diagram there is no mass hung from the spring and so there is no extension.

The second diagram shows a mass hung from the spring, and this gives an extension of x.

This extension is doubled to 2x when two of the same masses are hung from the spring. This is shown in the third diagram.

This is summarised in Hooke's law:

The extension of a spring is directly proportional to the force applied to it.

This also leads to the following equation

Force = Spring constant × Extension which in symbols is **F = k × e**

where F is the **force** with units of **Newtons** (N)

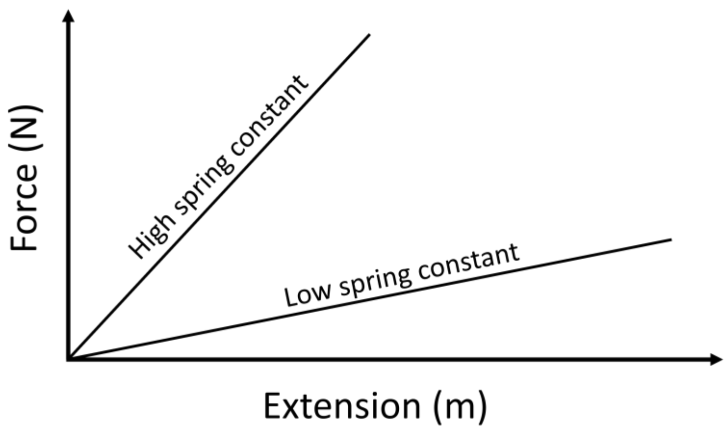
k is the **spring constant** with units of **Newtons per metre** (N/m)

e is the **extension** with units of **metres** (m).

The spring constant is a measure of how much force is needed to extend the spring by one metre.

The higher the spring constant, the more force is needed to stretch the spring by the same amount.

This is shown in the diagram to the right. Note how the force is directly proportional to the extension.



Q1. State the unit of a force. ....

Q2. State the unit of the spring constant. ....

Q3. State the unit of extension. ....

Q4. Describe how the extension of a spring is related to the force applied to it.

....

....

Q5. A spring with a spring constant of 4 N/m is extended by 0.1 m when a force is applied to it. Calculate the force applied to the spring.

Force = Spring constant × Extension
= 4 N/m × 0.1 m
= _____________ N

Q6. A rubber band with a spring constant of 10 N/m is extended by 0.2 m when a force is applied to it. Calculate the force applied to the spring.

Force = Spring constant × Extension
= _____ _____ × _____ __
= _____________ __

Q7. A spring with a spring constant of 20 N/m is compressed by 0.05 m when a force is applied to it. Calculate the force applied to the spring.

Force = ________________ × _______________
= _____ _____ × _____ __
= _____________ __

Q8. The same force is applied to two different springs. Spring X has a high spring constant and Spring Y has a low spring constant. State which spring will have the larger extension.

....

Q9. A rubber band has a spring constant of 60 N/m and is pulled with a force of 15 N. Calculate the extension of the rubber band.

Extension = Force ÷ Spring constant
= _____ __ ÷ _____ _____
= _____________ __

Q10. A spring has a spring constant of 200 N/m and is compressed by 0.04 m when a force is applied to it. Calculate the force applied to the spring.

....

....

Q11. A rubber band has a spring constant of 15 N/m and is pulled with a force of 0.3 N. Calculate the extension of the rubber band.

....

....

Moments

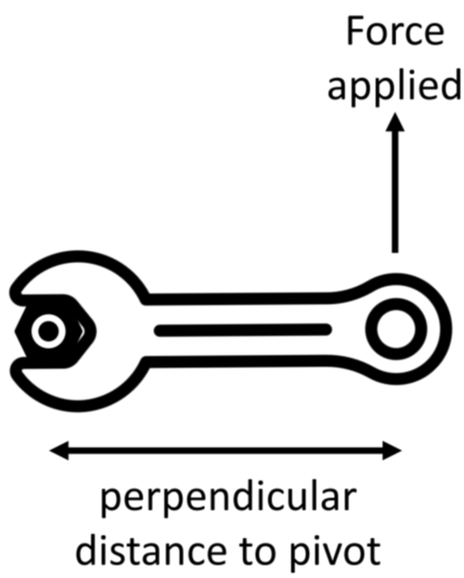
A **moment** is a turning force. The equation to calculate a moment is

Moment = Force × Distance

In this equation, the distance (measured in metres) is the **perpendicular distance to the pivot**.

Forces are measured in **Newtons** (N) and moments are therefore measured in **Newton metres** (Nm).

The diagram to the right shows one example use of a turning force. A spanner is used as a **force-multiplier**. This means that by applying a force at a greater distance, we only need to apply a smaller force to turn the bolt.



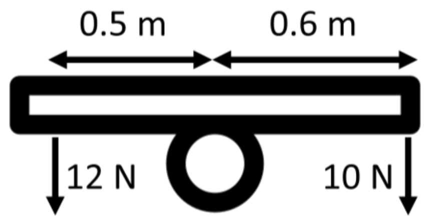
The principle of moments tells us that:

An object is balanced when the sum of the clockwise moments about a point are equal to the sum of the anticlockwise moments about the point.

We can use this when talking about objects being balanced or unbalanced on a seesaw.

Example question:

Using the diagram to the right, state whether the seesaw is balanced or not.



Step 1. Calculate clockwise moments. **Moment = 10 × 0.6 = 6 Nm**

Step 2. Calculate anticlockwise moments. **Moment = 12 × 0.5 = 6 Nm**

Step 3. Conclusion. If the size of the moments is equal; then the seesaw is balanced. **Yes, the seesaw is balanced.**

Q1. State the equation that links a moment, force and perpendicular distance to pivot.

....

Q2. State the units of a moment, force and distance.

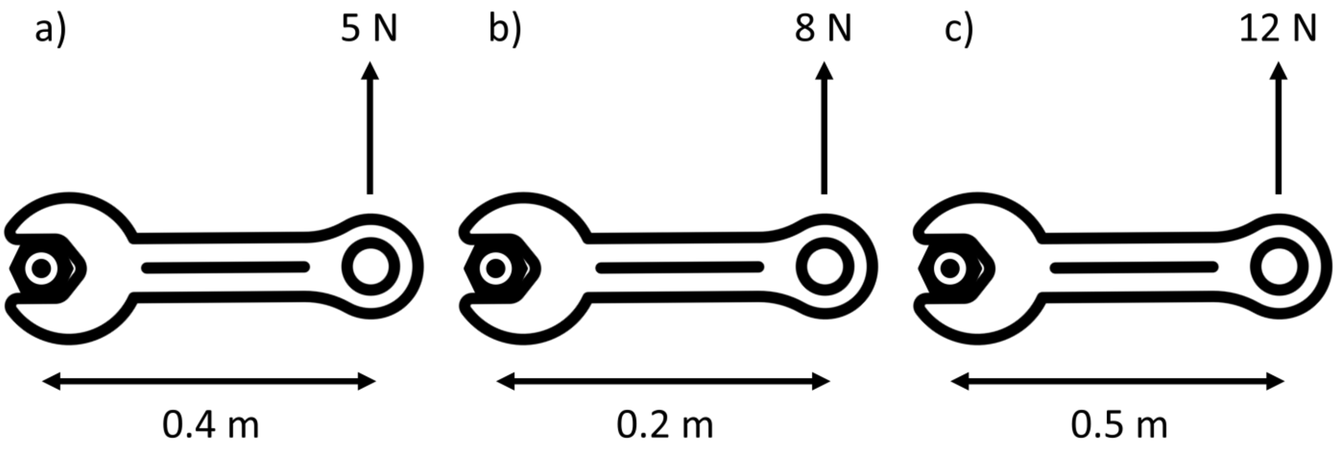
....

Q3. Describe the principle of moments.

....

....

Q4. Using the diagrams below, calculate the moment applied to each of the bolts:



a) ....

b) ....

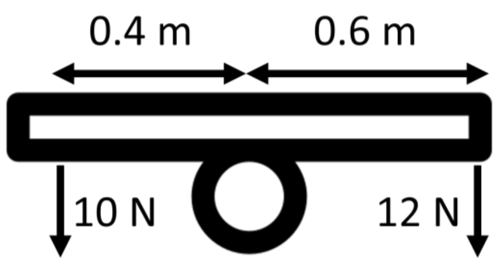
c) ....

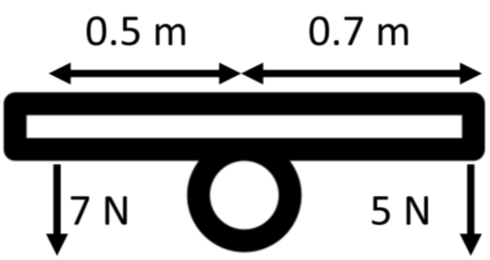
Q5. Using the diagram to the right, state whether the seesaw is balanced or not.

....

....

....





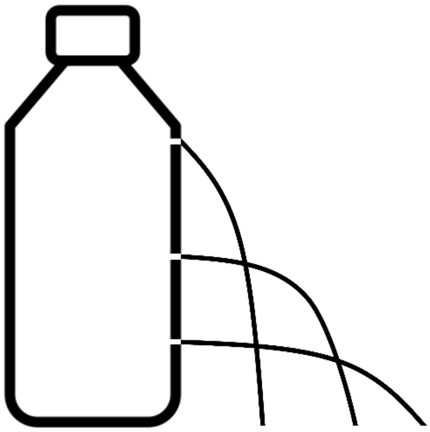
Q6. Using the diagram to the left, state whether the seesaw is balanced or not.

....

....

....

Pressure



Pressure is a measure of how much **force** is applied over a given **area**.

The diagram to the right shows three holes in a bottle full of water.

The hole at the top of the bottle only has a small weight of water above it and so the pressure of the water is comparatively small at this point. Therefore water is only pushed out of the bottle at a relatively low speed.

The hole in the middle of the bottle has more weight of water above it, and therefore experiences a larger pressure. This, in turn, pushes water out of the bottle at a higher speed.

The hole at the bottom of the bottle has the most weight of water above it, and experiences the largest pressure. This explains why water is pushed out of the bottle at the highest speed.

This doesn't only apply to water and liquids, but also to atmospheric pressure. Atmospheric pressure decreases as we increase in height above Earth's surface. This is because as we go further from the Earth's surface there's less weight of air above us.

Pressure can be calculated using the equation:

Pressure = Force ÷ Area

Force is measured in **Newtons**, while **area** is measured in **metres squared** (m^2). The unit of pressure is a **Pascal** (Pa), which is the same as one Newton per metre squared (N/m^2).

Example question:

A force of 500 N is applied over an area of 0.25 m^2. Calculate the pressure.

Step 1. Write down equation: **Pressure = Force ÷ Area**

Step 2. Insert variables into equation: **= 500 N ÷ 0.25 m^2**

Step 3. Calculate answer. Remember units: **= 2000 Pa**

Q1. State the equation that links pressure, force and area.

……

Q2. State the units of pressure, force and area.

……

Q3. Describe what happens to atmospheric pressure as we go higher above the Earth's surface.

……

……

Q4. A full bottle has two holes in it, one higher than the other. State which of the two holes water will come out faster. Explain why.

……

……

Q5. A crate has a weight of 2600 N and the area of the crate's base is 2 m^2. Calculate the pressure the crate exerts on the ground.

Pressure = Force ÷ Area
= 2600 N ÷ 2 m^2
= ____________ Pa

Q6. A book has a weight of 20 N and the area of the book is 0.02 m^2. The book is lying on a table. Calculate the pressure the book exerts on the table.

Pressure = ________ ÷ ________
= _____ N ÷ _____ m^2
= ____________ Pa

Q7. A skip has a weight of 5000 N and the area of the crate's base is 4 m^2. Calculate the pressure the skip exerts on the ground.

Pressure = ________ ÷ ________
= _____ __ ÷ _____ __
= ____________ __

Q8. A person has a weight of 700 N and their shoes have a combined area of 0.04 m^2. Calculate the pressure the person exerts on the ground.

……

……

Q9. Somebody is walking in a wet field. Describe which of a high heel shoe or a trainer will sink into the ground more. Explain why.

……

……

Speed

Speed is a measure of the **distance** an object has moved in a certain **time**. When travelling in a car or an aeroplane, you might have heard of speed being measured in miles per hour (mph) or kilometres per hour (km/h).

In physics, speed is usually measured in **metres per second** (m/s).

If an object is travelling at a constant speed of 30 m/s, that means it travels a distance 30 metres every second. If an object travels at 12 m/s, it travels a distance of 12 metres every second.

The equation to calculate speed is:

Speed = Distance ÷ Time

Example question 1:

A car travels a distance of 400 m in a time of 20 seconds. Calculate the **speed** of the car.

Step 1. Write down equation: **Speed = Distance ÷ Time**

Step 2. Insert variables into equation: **= 400 m ÷ 20 s**

Step 3. Calculate answer. Remember units: **= 20 m/s**

We can also be asked questions to calculate distance or time. We know that if an object travels at 30 m/s, it travels a distance of 30 m/s every second. Therefore in 2 seconds, it would travel 30 × 2 = 60 m. To calculate the distance, we multiply the speed by the time:

Distance = Speed × Time.

Example question 2:

An athlete runs a race at an average speed of 8 m/s. The athlete takes a time of 50 seconds to complete the race. Calculate the **distance** of the race.

Step 1. Write down equation: **Speed = Distance ÷ Time**

Step 2. Insert variables into equation: **8 = Distance ÷ 50**

Step 3. Rearrange equation: **Distance = 8 × 50**

Step 3. Calculate answer. Remember units: **= 400 m**

We can also look at the speed of one object relative to another. For example, take a car that is travelling at 30 m/s and a train is travelling 20 m/s faster than the car.

The train is therefore moving at a speed of 50 m/s, you just add the speeds together to get the speed of the train.

Q1. Describe what speed is.

………

Q2. An object is travelling at a constant speed of 20 m/s. Calculate how far the object travels every second.

………

Q3. An object is travelling at a constant speed of 8 m/s. Calculate how far the objects travel every second.

………

Q4. A car is travelling at a speed of 20 m/s, and a train is travelling 10 m/s faster than the car. State the speed of the train.

………

Q5. State the equation to calculate speed.

………

Q6. A cyclist travels a distance of 120 m in a time of 20 seconds. Calculate the speed of the cyclist.

Speed = Distance ÷ Time
= 120 m ÷ 20 s
= _____________ m/s

Q7. A runner travels a distance of 1500 m in a time of 500 s. Calculate the speed of the runner.

Speed = Distance ÷ Time
= ______ __ ÷ ___ __
= _____________ m/s

Q8. Someone walking their dog travels a distance of 1200 m in a time of 1000 seconds. Calculate the speed of the dog walker.

Speed = _________ ÷ ________
= ______ __ ÷ ___ __
= _____________ ___

Q9. A sound wave travels a distance of 686 m in a time of 2 seconds. Calculate the speed of sound.

………

Q10. Light travels a distance of 4 500 000 000 m in a time of 15 seconds. Calculate the speed of light.

………

Q11. A car travels at a speed of 25 m/s for a time of 400 s. Calculate the distance travelled by the car.

Speed = Distance ÷ Time
25 = Distance ÷ 400
Distance = ___ × ____
= _____________ m

Q12. A motorbike travels at a constant speed of 40 m/s for a time of 20 s. Calculate the distance travelled by the motorbike.

………

Distance-time graphs

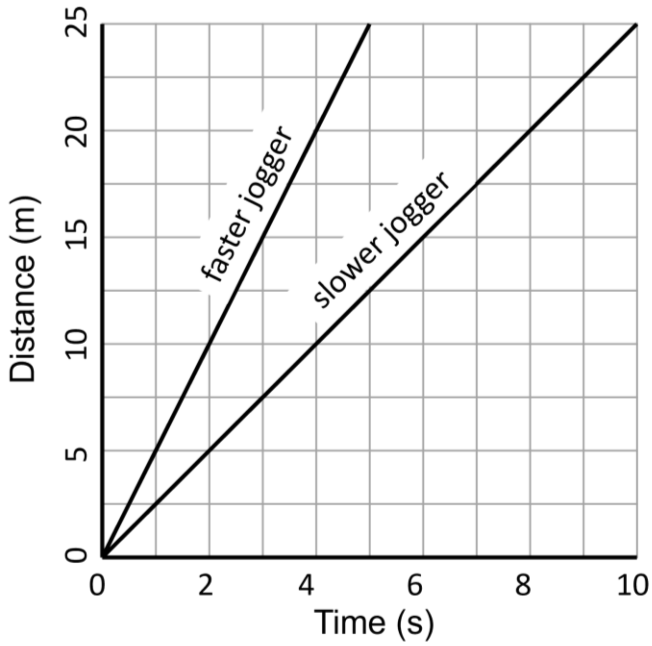
Distance-time graphs are used to represent the journey of an object that is travelling.

The **gradient** (or steepness) of a distance-time graph gives the speed of the object.

An example distance-time graph is shown to the right, where two joggers are shown.

The steeper the gradient of a distance-time graph the greater the speed of the object.

Because of this, we can tell which jogger is travelling at a higher speed.



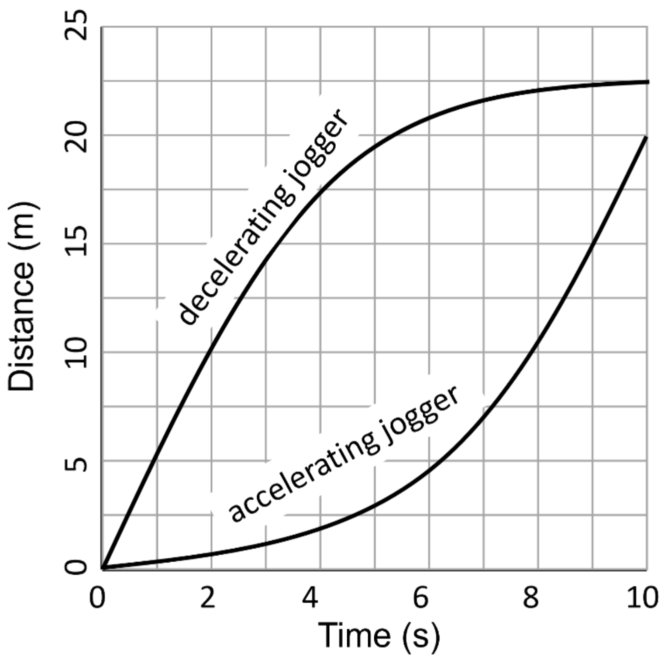
Mathematically, the gradient is calculated by using the equation:

$$\text{gradient} = \frac{\text{change on y axis}}{\text{change on x axis}} = \frac{\Delta y}{\Delta x}$$

For distance-time graphs, Δy is the distance travelled and Δx is the time taken to travel that distance. This makes sense, because we already know the equation to calculate speed is:

Speed = Distance ÷ Time

The faster jogger in the diagram above travels a distance of 25 m in a time of 5 s. We can therefore calculate their speed to be 5 m/s.



The slower jogger travels a distance of 25 m in a time of 10 s. We can therefore calculate their speed to be 2.5 m/s.

The diagram to the left shows two more distance time graphs.

The higher graph shows a jogger that is decelerating. We know the jogger is decelerating because the gradient of the graph is reducing over time.

The lower graph shows a jogger that is accelerating. We know this because the gradient of the graph is increasing over time.

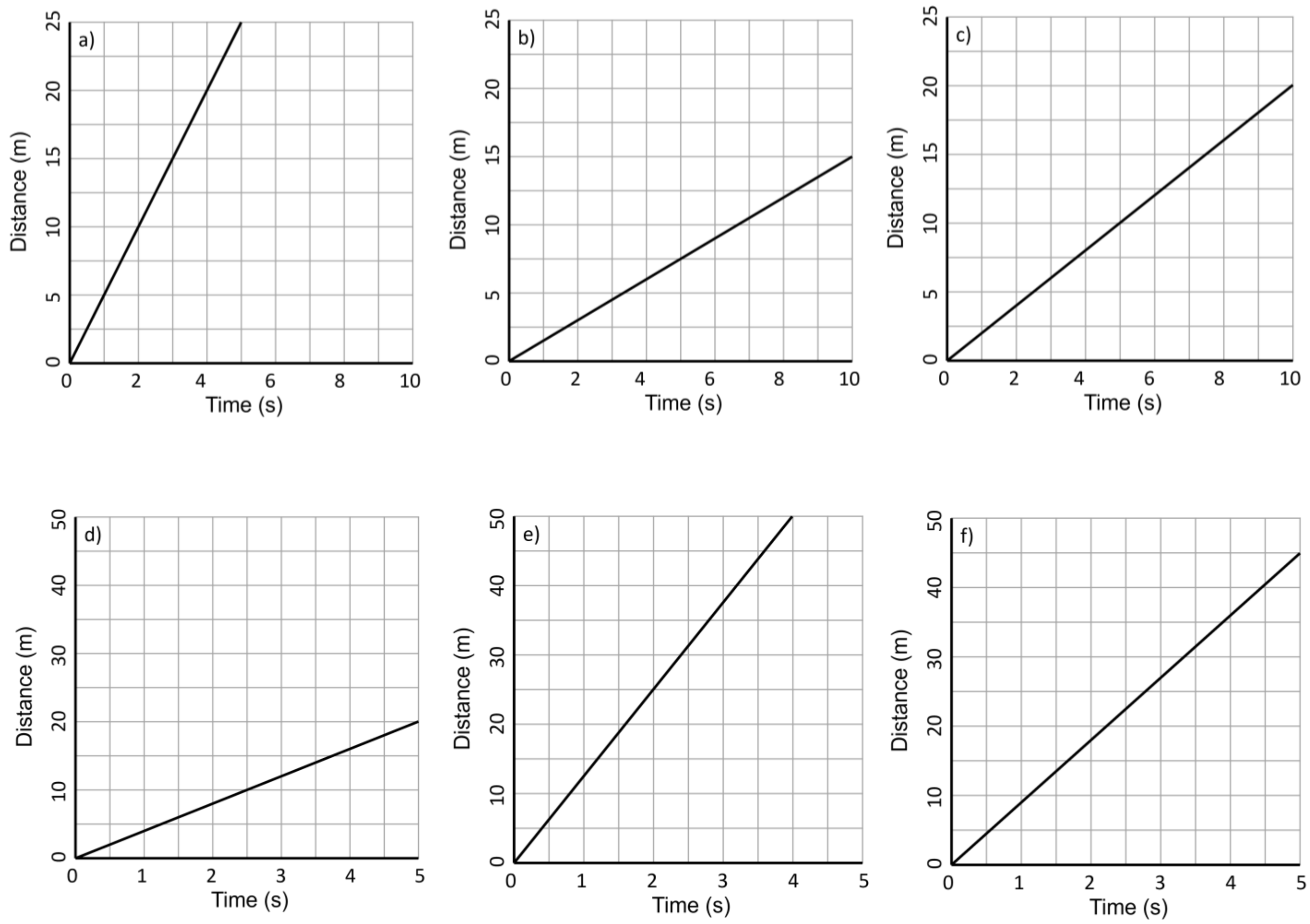
Q1. State what the gradient of a distance-time graph represents.

....

Q2. State the equation for speed.

....

Q3. Using the distance-time graphs below, calculate the speed of each of the objects:



a) ....

b) ....

c) ....

d) ....

e) ....

f) ....

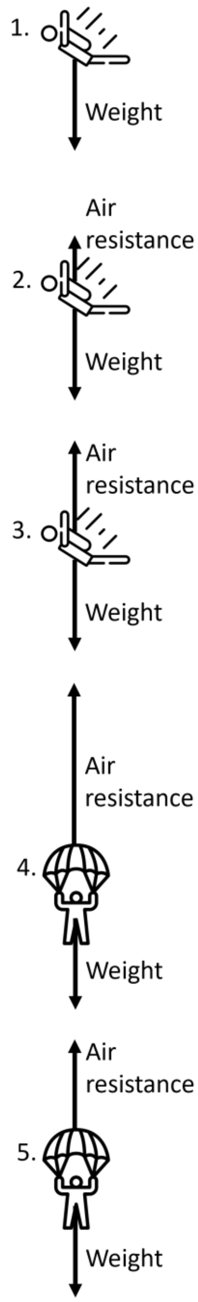
Terminal velocity

When a skydiver jumps out of an aeroplane they **accelerate**. Their acceleration (the rate at which they speed up) is not constant throughout the skydive. We use **Newton's laws** to describe the motion of objects:

Newton's first law: The speed of an object will remain the same unless a resultant force acts on the object. This includes if an object is initially stationary. If there is no resultant force acting on a stationary object, it will remain stationary.

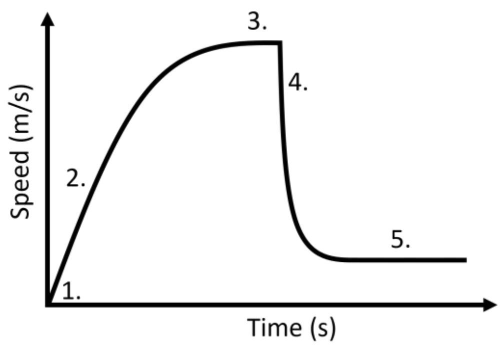
Newton's second law: The acceleration of an object is proportional to the resultant force on the object. The larger the resultant force, the larger the acceleration of the object.

Newton's third law: If object A exerts a force on object B, then object B exerts a force of equal size and opposite direction on object A.



The diagram to the right shows the force diagrams of a skydiver at different stages in their skydive:

1. The skydiver has just jumped out of the aeroplane and hasn't quite started falling yet. The only force acting on the skydiver is their weight. As this is the only force, the skydiver accelerates.
2. As the skydiver increases in speed, the air resistance increases. The **resultant force** downwards decreases, and according to Newton's second law the acceleration downwards must also decrease.
3. Eventually, when the skydiver reaches a certain speed, the air resistance is equal to the weight. As the forces are balanced, there is no **resultant force**. Due to Newton's first law, the speed of the skydiver remains the same. The acceleration is zero. The speed is called the **terminal** (maximum) **velocity**.
4. When the skydiver opens their parachute, they have a much larger **surface area.** This dramatically increases the air resistance and there is a **resultant force** upwards. This means the skydiver decelerates.
5. As the skydiver slows down, the air resistance decreases until it is equal to the weight again. The forces are **balanced** and the skydiver reaches a second (slower) terminal velocity.



These stages are also shown in the graph to the left. Here, the speeds of the skydiver at shown at each stage. Note the terminal velocities at stages 3 and 5.

Q1. State what happens to air resistance as the speed of an object increases.

……

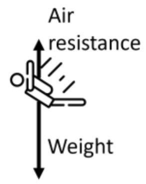
Q2. A car is travelling at a speed of 70 mph on the motorway. All the forces on the car are balanced. State what happens to the speed of the car.

……

Q3. The car now has a resultant force forwards. State what happens to the speed of the car.

……

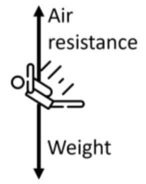
Q4. Using the diagram to the right, state and explain whether the skydiver will be accelerating, decelerating, or falling at a constant speed.



………

………

Q5. Using the diagram to the right, state and explain whether the skydiver will be accelerating, decelerating, or falling at a constant speed.



………

………

Q6. Using the diagram to the right, state and explain whether the skydiver will be accelerating, decelerating, or falling at a constant speed.

………

………

Q7. Explain how a skydiver reaches a terminal velocity.

……

……

……

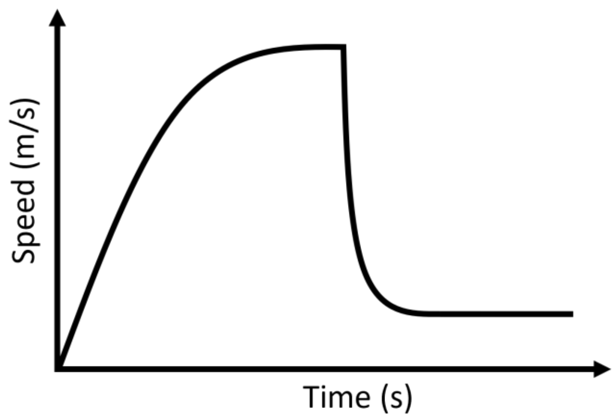
Q8. State and explain what happens to the air resistance on a skydiver straight after they open their parachute.

……

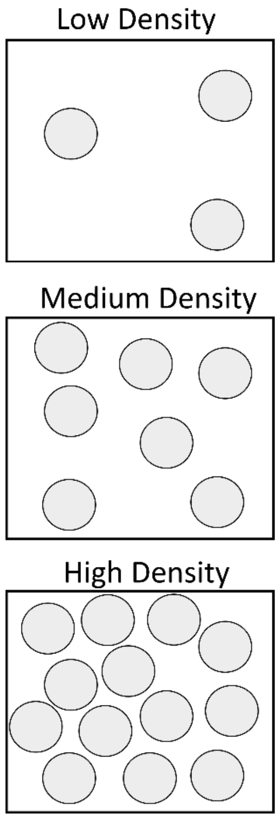
……

Q9. For the questions below, use the speed-time graph of a skydiver to the right.

a) Annotate with an "A" where the skydiver is accelerating.
b) Annotate with a "T" two regions of terminal velocity.
c) Annotate with a "P" the time when the parachute is opened.



Density



Density is a measure of how much **mass** is in a given **volume**.

The diagram to the right shows three gases in the same volume. If we assume that each particle has the same mass, then the top gas must have the least density and the lowest gas must have the highest density.

The density of an object can be calculated using the equation:

Density = Mass ÷ Volume

The **mass** of an object is the amount of matter it contains and is measured in **kilograms** (kg). The **volume** is the amount of space that an object takes up and is measured in **metres cubed** (m^3).

Density has units of **kilograms per metre cubed** (kg/m^3).

Example question 1: Some wood has a mass of 210 kg and a volume of 0.3 m^3. Calculate the density of the wood.

Step 1. Write down equation: **Density = Mass ÷ Volume**

Step 2. Insert variables into equation: **= 210 kg ÷ 0.3 m^3**

Step 3. Calculate answer. Remember units: **= 700 kg/m^3**

The density of water is equal to 1000 kg/m^3. Anything lower than this density will float on water. Therefore the wood that we calculated the density of in the example question will float on water.

Example question 2: The density of granite is 2700 kg/m^3. Some granite has a mass of 5400 kg, calculate the volume of the granite.

Step 1. Write down equation: **Density = Mass ÷ Volume**

Step 2. Insert variables into equation: **2700 kg/m^3 = 5400 kg ÷ Volume**

Step 3. Rearrange equation: **Volume = 5400 kg ÷ 2700 kg/m^3**

Step 3. Calculate answer. Remember units: **= 2 m^3**

Q1. State the equation that links density, mass and volume.

....

Q2. State the units of density, mass and volume.

....

Q3. Water has a density of 1000 kg/m^3 and oil has a density of 800 kg/m^3. State and explain whether the oil will float or sink in the water.

....

....

Q4. A book has a mass of 1 kg and a volume of 0.002 m^3. Calculate the density of the book.

Density = Mass ÷ Volume
= 1 kg ÷ 0.002 m^3
= ____________ kg/m^3

Q5. A gold bar has a mass of 3.8 kg and a volume of 0.0002 m^3. Calculate the density of the gold bar.

Density = ________ ÷ ________
= _____ kg ÷ _____ m^3
= ____________ kg/m^3

Q6. A rock has a mass of 300 kg and a volume of 0.1 m^3. Calculate the density of the rock.

Density = ________ ÷ ________
= _____ __ ÷ _____ __
= _____________ ___

Q7. Steel has a density of 7800 kg/m^3. Calculate the volume of steel that has a mass of 3900 kg.

....

....

Q8. The average human body has a density of 995 kg/m^3.

a) Explain why humans can float on water.

....

b) Calculate the volume of a human body that has a mass of 70 kg.

....

....

Q9. A crate has a mass of 250 kg and a density of 50 kg/m^3. Calculate the volume of the crate.

....

....

Q10. A car has an average density of 280 kg/m^3 and a volume of 4.2 m^3. Calculate the mass of the car.

....

....

Waves

Introduction to waves

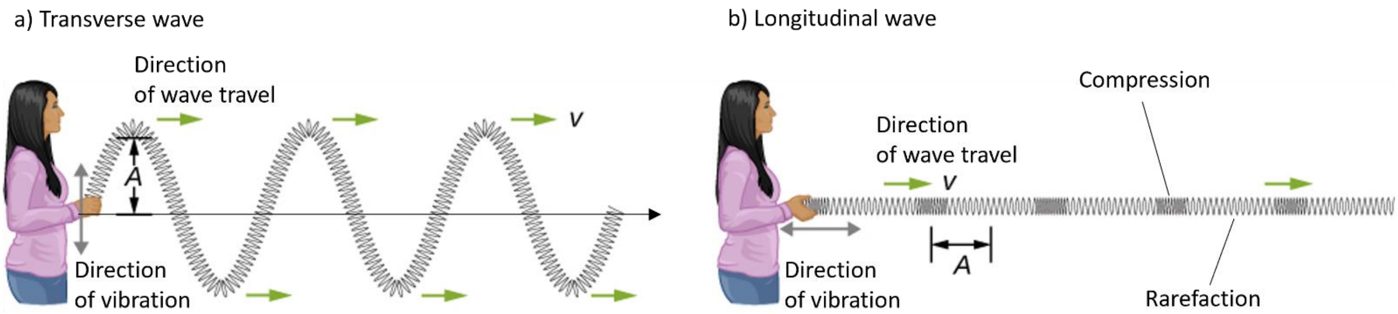
Waves transfer energy from one place to another, without transferring any matter.

There are two types of wave; **longitudinal** and **transverse**.

Both longitudinal and transverse waves are caused by **vibrations**. However, transverse waves are caused by a vibration that is **perpendicular** to the direction of wave travel. Longitudinal waves are caused by a vibration that is **parallel** to the direction of wave travel.

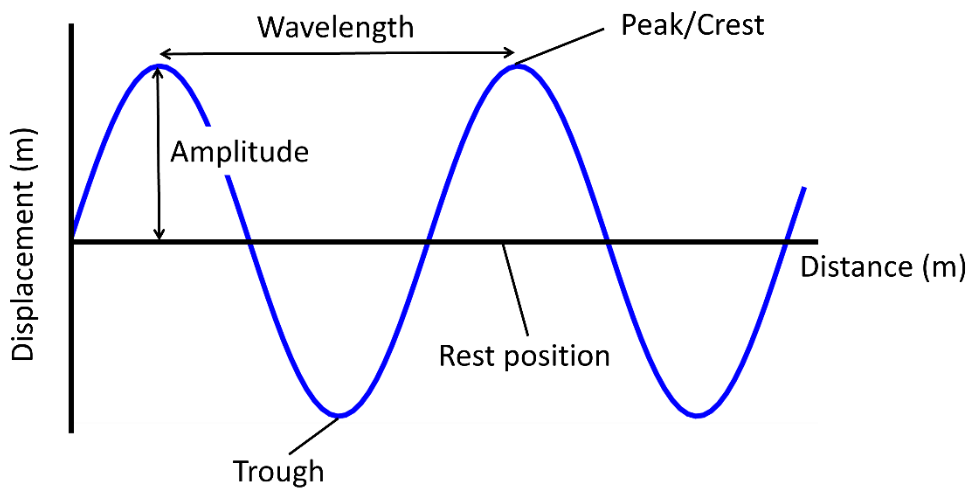
These waves are shown below, where a slinky is being used to demonstrate transverse and longitudinal waves in images a) and b) respectively.

Note two areas are labelled on the longitudinal wave. A **compression** is where particles in the wave are closest together, and a **rarefaction** is where they are furthest apart.



A diagram of a transverse wave is also shown below, including some key terminology:

Displacement	How far a point on the wave is from the rest position.
Wavelength	Distance from peak to peak (or any complete wave cycle).
Amplitude	Maximum displacement of wave.



Q1. The following statements are either true or false. State which are true and which are false.

a) A wave transfers energy from one place to another.

....

b) A wave transfers matter from one place to another.

....

c) Vibrations are the cause of both longitudinal and transverse waves.

....

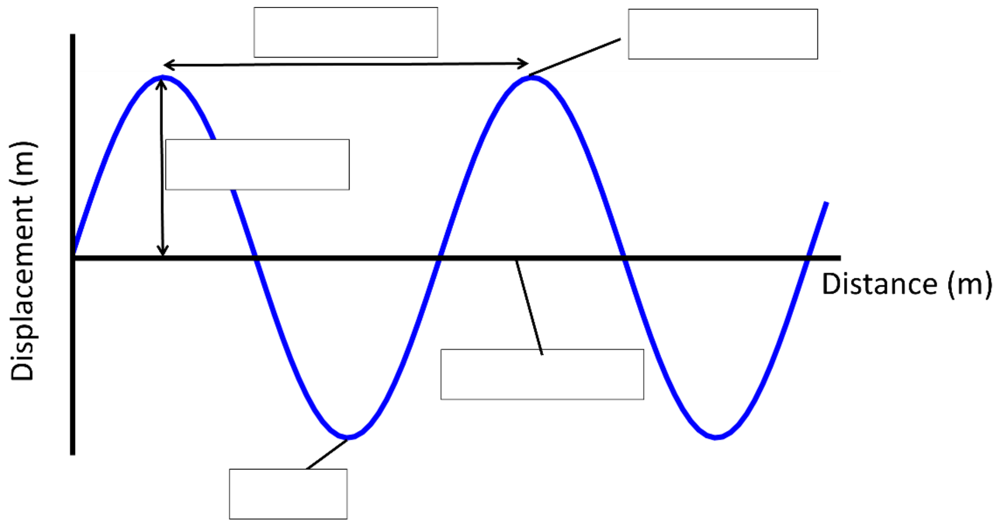
d) In a longitudinal wave, a compression is where particles in the wave are closest together.

....

e) In a transverse wave, the vibration that causes the wave is parallel to the direction of wave travel.

....

Q2. Label the diagram of the transverse wave below.



Q3. Describe what a rarefaction is in a longitudinal wave.

....

....

Q4. Describe a similarity between a longitudinal wave and a transverse wave.

....

....

Q5. Describe the difference between a longitudinal wave and a transverse wave.

....

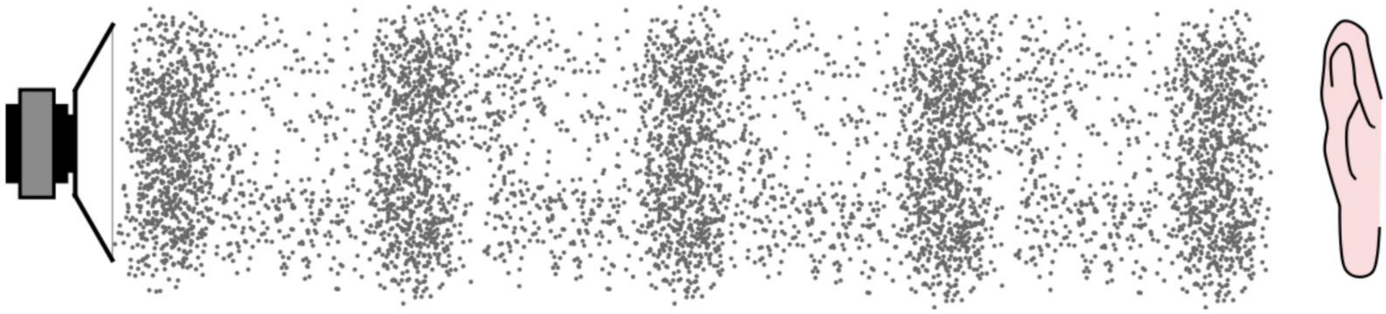
....

....

....

Sound

An object that is **vibrating** makes a sound wave. The object vibrates air particles and these particles collide with other air particles and **transfer energy**. Sound is a **longitudinal** wave. This means the vibrations that cause the sound wave are **parallel** to the direction of wave travel.



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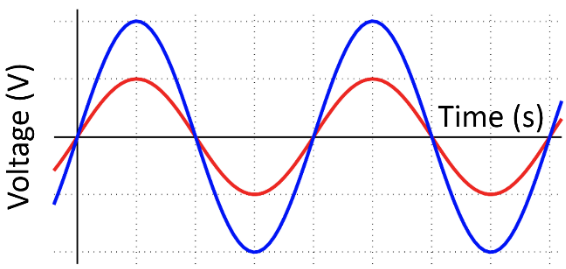
The diagram above shows the cone of a speaker vibrating and forming a sound wave in air. **Compressions** are formed when the air particles are close together. **Rarefactions** are formed where air particles are further apart. The **wavelength** is the distance between one compression and the next (or one rarefaction and the next).

The **frequency** of a sound wave (measured in units of **Hertz**) is related to the **pitch** of a sound wave. The higher the frequency, the higher the pitch. The frequency is a measure of how many sound waves pass a point every second. If 200 sound waves pass a point every second, then the frequency is 200 Hz.

The **amplitude** of a sound wave is related to the **volume**. The larger the amplitude, the louder the sound wave will be.

We can turn a sound wave into an electrical signal by using a **microphone**. The sound wave vibrates a **diaphragm** in the microphone and produces an electrical signal. This electrical signal can be viewed on an **oscilloscope**.



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The diagram to the left shows two example traces from a microphone that would be viewed on an oscilloscope screen. They both have the same frequency, but one has a larger amplitude than the other. The amplitude is related to the volume of the sound wave.

Our ears detect sound waves in a similar way, the sound waves vibrate our **ear drum**. These vibrations are turned into electrical signals which are sent to the brain and interpreted as a sound.

Q1. State what causes a sound wave.

Q2. State the definition of a longitudinal wave.

Q3. The auditory range for humans is any frequency between 20 and 20 000 Hz. State the definition of frequency.

Q4. A sound wave with a frequency above 20 000 Hz is called ultrasound. How many waves pass a point every second for an ultrasound wave with frequency 20 000 Hz?

Q5. Sound waves consist of compressions and rarefactions. Describe the difference between a compression and a rarefaction.

Q6. The following statements are either true or false. State which are true and which are false.

a) The wavelength is the distance between a compression and a rarefaction.

b) The higher the frequency of a sound wave, the louder it is.

c) The lower the amplitude of a sound wave, the quieter it is.

d) A microphone is used to turn a sound wave into an electrical signal.

Q7. A microphone and an oscilloscope is used to produce a trace of a sound wave. On the axes below, draw two traces of sound waves. They should both have the same amplitude, but one should have a higher frequency than the other.

Speed of sound

Sound waves need particles (a **medium**) to travel. Sound cannot travel in a **vacuum** as there are no particles in a vacuum.

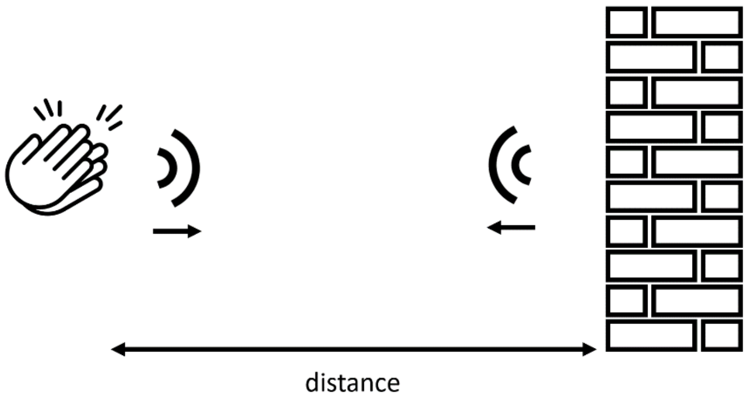
The speed of sound in air is approximately 340 m/s (although this depends on the pressure and temperature of the air).

Sound travels faster in liquids and solids than in air. For example, the speed of sound in water is approximately 1500 m/s and the speed of sound in steel is over 3000 m/s.

This is because the particles in a gas are far apart, while the particles in a liquid or solid are closer together. The vibrations are therefore transferred more quickly.

Usually, sound travels slowest in gases and fastest in solids.

If we wanted to measure the speed of sound in air, we can use an **echo**. An echo is a **reflection** of a sound wave from a surface.



The following method could be used to measure the speed of sound:

1. Stand at least 50 metres from a wall/cliff. To measure this distance use either a measuring tape, or a trundle wheel.

2. Make a loud sound (for example using a clap).

3. Using a **stopwatch**, measure the time for sound to return.

4. Calculate speed by using **Speed = Total distance ÷ Time**.

5. Repeat three times and take average.

Remember the sound wave travels to the wall and back, so the total distance is the distance to the wall multiplied by two.

We could get a more accurate reading for the speed of sound by using a microphone attached to an oscilloscope. The oscilloscope would show a pulse for when the initial sound is made and when the reflected sound returns. This would remove error due to **human reaction time**.

When sound is reflected from a **medium** some sound is **absorbed**. This means that not all of the sound will be **reflected** back.

Q1. The following statements are either true or false. State which are true and which are false.

a) Sound waves can travel through a vacuum.

....

b) Sound usually travels faster through a solid than through air.

....

c) The equation to calculate speed of sound is speed = total distance × time.

....

Q2. Somebody is trying to measure the speed of sound. They stand a distance of 50 metres from a wall and clap. They hear an echo a time of 0.40 seconds later. Calculate the speed of sound.

....

....

....

....

Q3. The answer to question 2 is less than the actual speed of sound. This is because of human reaction time. Explain why human reaction time has led to a speed of sound that is lower than expected.

....

....

....

....

Q4. Rearrange the equation for speed to give an equation for distance.

....

Q5. Human reaction time is usually around 250 ms (0.25 seconds). Calculate how far a sound wave travels in that time. Take the speed of sound to be 340 m/s.

....

....

....

....

Q6. Bats use something called echolocation to locate objects around them. Echolocation works by the bat sending a sound wave outwards and using the echo to estimate how far an object is away from them. One bat detects an echo a time of 0.80 seconds after the sound wave was sent. Calculate how far away the object is from the bat. Take the speed of sound to be 340 m/s.

....

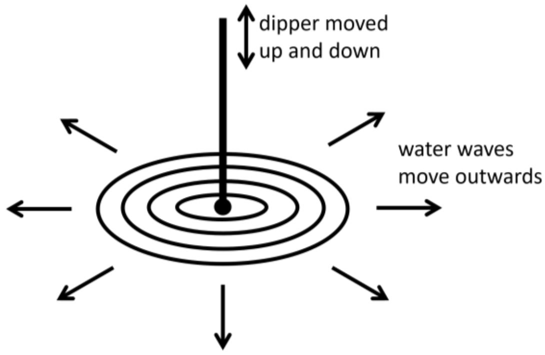
....

....

....

Water waves and superposition

The diagram to the right shows **water waves** being formed in a **ripple tank**. A motor is connected to a **dipper** and makes the dipper vibrate up and down in the water. Each time the dipper does this a water wave is formed.



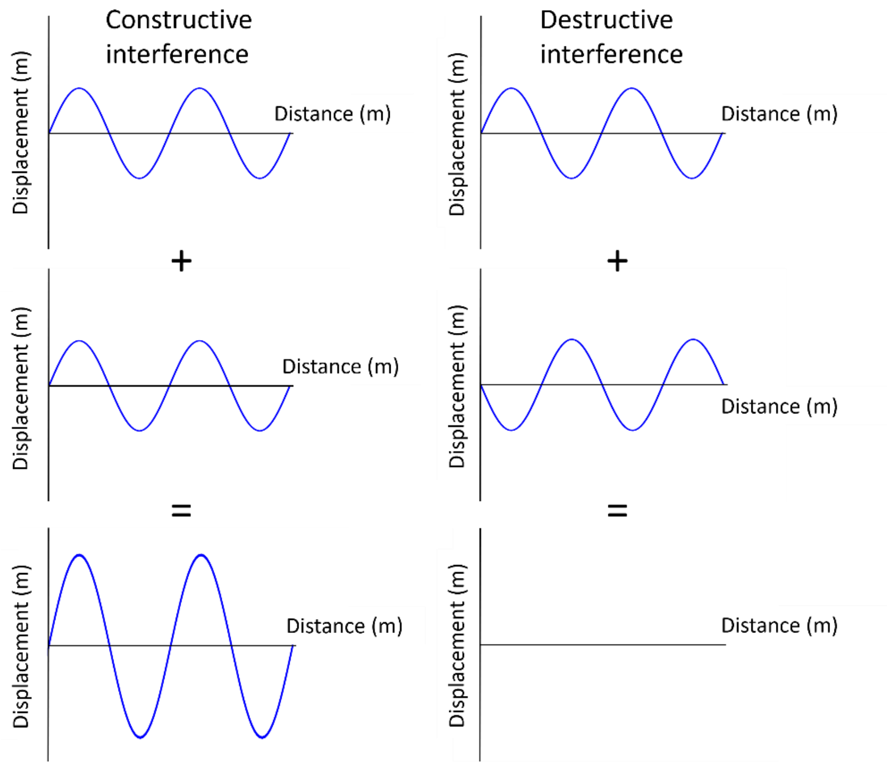
Like all waves, water waves transfer energy without transferring matter.

Water waves are one example of a **transverse** wave. Transverse waves are caused by a vibration that is **perpendicular** to the direction of wave travel. Note how the dipper moves up and down, but the water waves move **perpendicularly** in every direction outwards.

Waves also interact with each other if one wave passes through another. This is called **superposition**. This occurs for both water waves and other types of wave.

We've previously learnt that the displacement of a wave is the distance a particle in the wave has moved from its rest position. When superposition occurs, the displacements of the waves add together.

Two examples of superposition are shown in the diagram below.



When two peaks of a wave arrive at one place at the same time, they add. The amplitude of the combined wave is more than each individual wave. This is shown on the left hand side of the diagram.

When a peak of a wave arrives at one place at the same time as the trough of another wave, they cancel. The amplitude of the combined wave is less than each individual wave. This is shown on the right hand part of the diagram.

More generally, if the displacements of the two waves are the same sign (i.e. both positive) then they add together. If they are opposite signs, they subtract.

Q1. The following statements are either true or false. State which are true and which are false.

a) Water waves are longitudinal.

....

b) Longitudinal waves are caused by a vibration that is perpendicular to the direction of wave travel.

....

c) Water waves transfer energy without transferring matter.

....

d) When two waves overlap, superposition occurs.

....

Q2. State one example of a transverse wave.

....

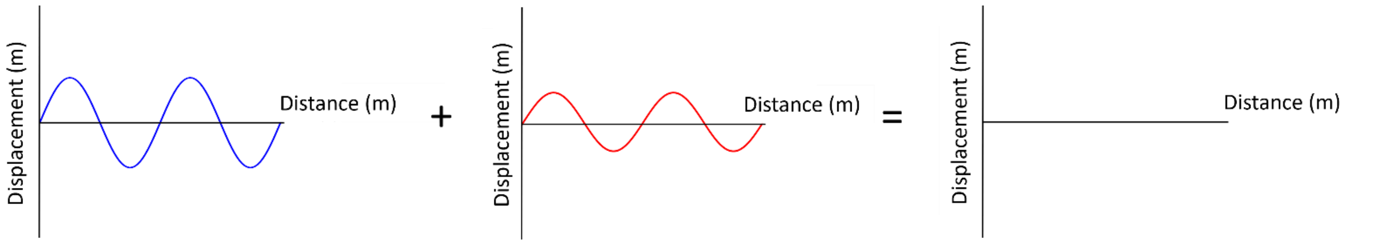
Q3. Describe how transverse waves are formed.

....

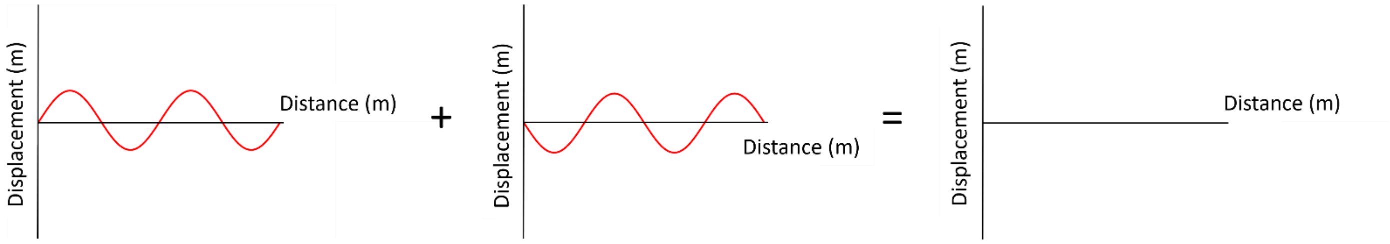
....

....

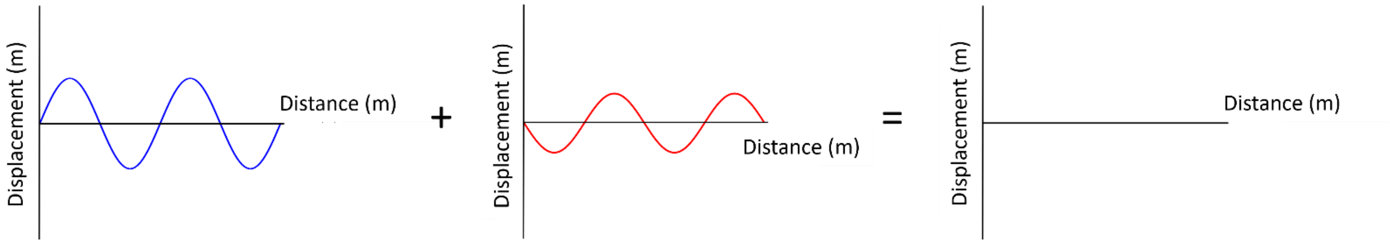
Q4. The two waves below undergo superposition. On the blank axes to the right, draw the combined wave.



Q5. The two waves below undergo superposition. On the blank axes to the right, draw the combined wave.



Q6. The two waves below undergo superposition. On the blank axes to the right, draw the combined wave.

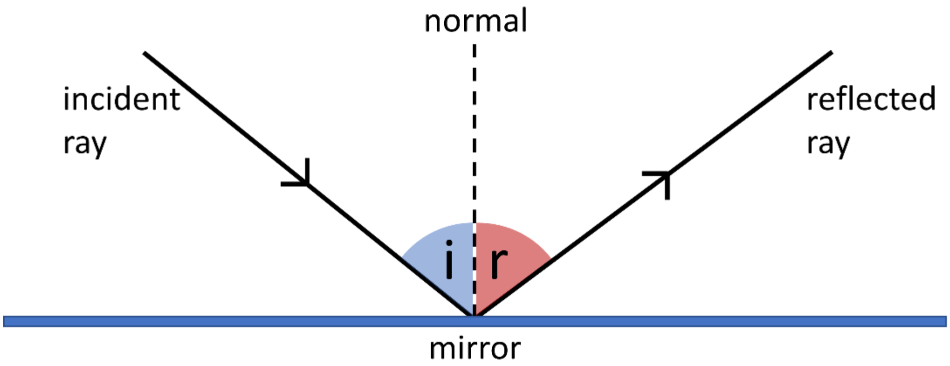


Reflection

We can see ourselves in a mirror because mirrors **reflect** light.

Light is another example of a **transverse** wave and travels at 300 000 000 m/s (the speed of light). Transverse waves are caused by a vibration that is **perpendicular** to the direction of wave travel.

Specular reflections happen when rays of light are reflected from a very smooth surface like a mirror. The diagram below shows **specular** reflection of light from a mirror.



The ray going into the mirror is called the **incident ray**. The **angle of incidence** is the angle that this ray makes to the **normal**. The normal is an imaginary line that we draw at an angle of 90° to the mirror. An arrow shows the direction of the ray.

The **angle of refraction** is also measured between the **reflected ray** and the normal.

This diagram also shows the **law of reflection**. The law of reflection says that:

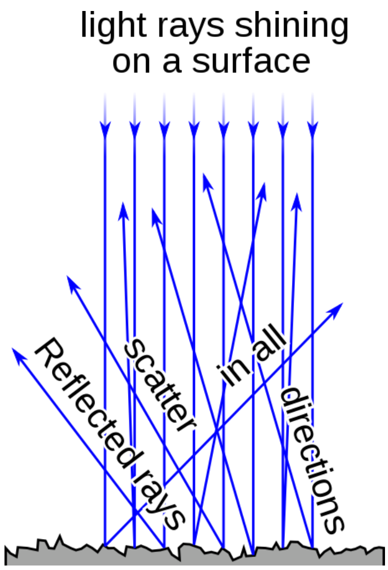
The angle of incidence is equal to the angle of reflection.

This law doesn't only apply to light, but also to other waves. For example, light is part of a family of seven transverse waves in the **electromagnetic spectrum.**

If rays of light are shone onto a surface that isn't smooth, then a **diffuse reflection** happens.

In a diffuse reflection, rays are reflected at many angles. The angle of incidence is still equal to the angle of reflection; it's just the surface isn't smooth and points in different directions.

This is shown in the diagram to the right.



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Q1. The following statements are either true or false. State which are true and which are false.

a) Light is a transverse wave.

....

b) Transverse waves are caused by a vibration that is perpendicular to the direction of wave travel.

....

c) Diffuse reflections happen when rays of light are reflected from a very smooth surface.

....

d) In a diffuse reflection, the angle of incidence is not always equal to the angle of reflection.

....

e) Light is shone onto a mirror. The angle of incidence is measured from the incident ray to the mirror.

....

f) Only light obeys the law of reflection.

....

Q2. State the speed of light.

....

Q3. State the law of reflection.

....

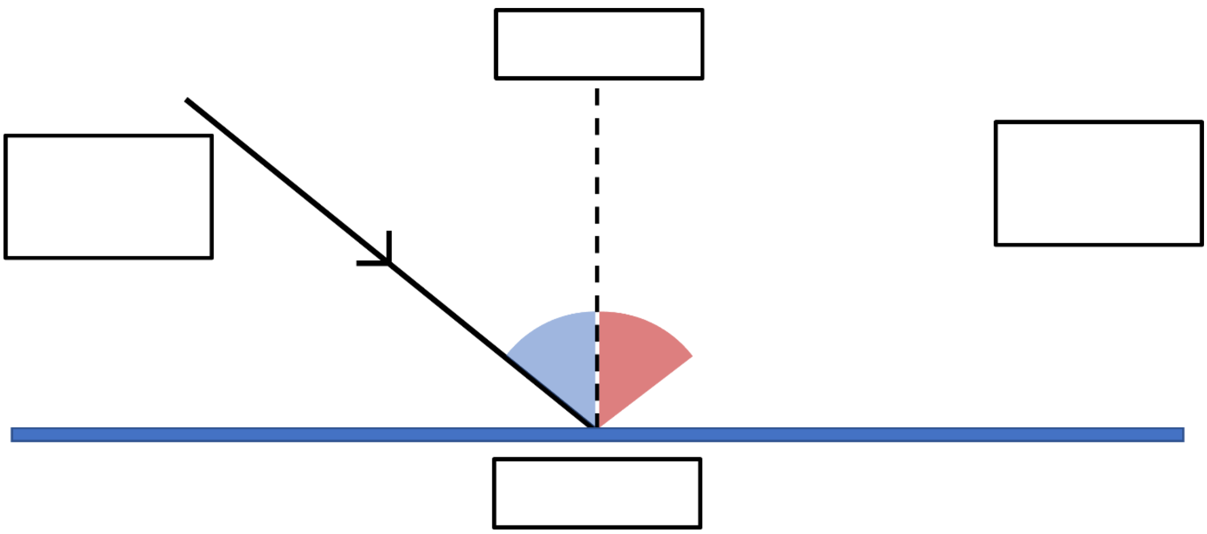
....

Q4. Describe the difference between a specular and a diffuse reflection.

....

....

Q5. The diagram of reflection below is incomplete. Draw the reflected ray and label the diagram completely.



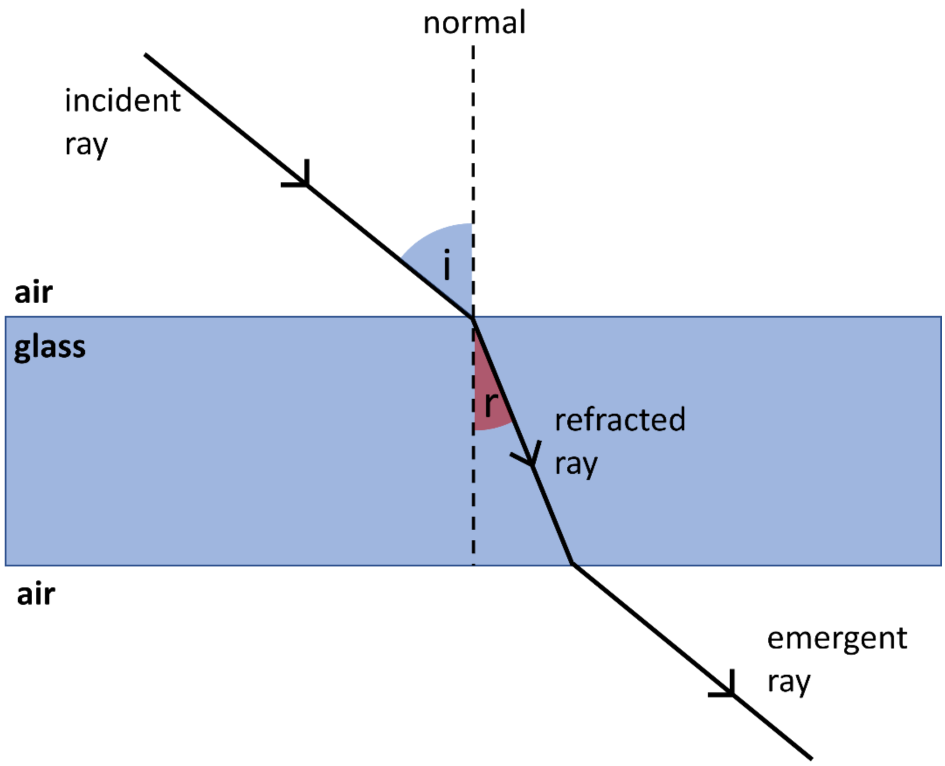
Refraction

The speed of light in a vacuum is 300 000 000 m/s. Nothing can travel faster than this. However, this speed is decreased if the light travels through a different **medium** (material). For example, the speed of light in glass is approximately 200 000 000 m/s. This is because glass has a higher **refractive index** than a vacuum. The higher the refractive index, the slower light travels through the material.

This decrease in velocity also causes two other things:

1. A decrease in wavelength of the light.
2. Unless the angle of incidence is 0°, there will be a change in direction of the light.

The frequency of light is unchanged. The diagram below shows refraction of light from air into a glass block.



As the light passes from air into glass, it slows down as the refractive index of glass is more than the refractive index of air. The light refracts and changes direction, bending towards the normal (an imaginary line at 90° to the glass block). The angle of refraction (labelled r) is less than the angle of incidence (labelled i).

As the light exits the glass block, the opposite happens. Air has a lower refractive index than glass and so speeds up and refracts away from the normal. The ray that exits the block is called the emergent ray. The emergent ray travels in the same direction as the initial incident ray.

If the angle of incidence is 0°, then light continues in the same direction (but more slowly).

Q1. The following statements are either true or false. State which are true and which are false.

a) Light travels at the same speed in a vacuum as it does in glass.

....

b) When light goes from air into a glass block, its wavelength decreases.

....

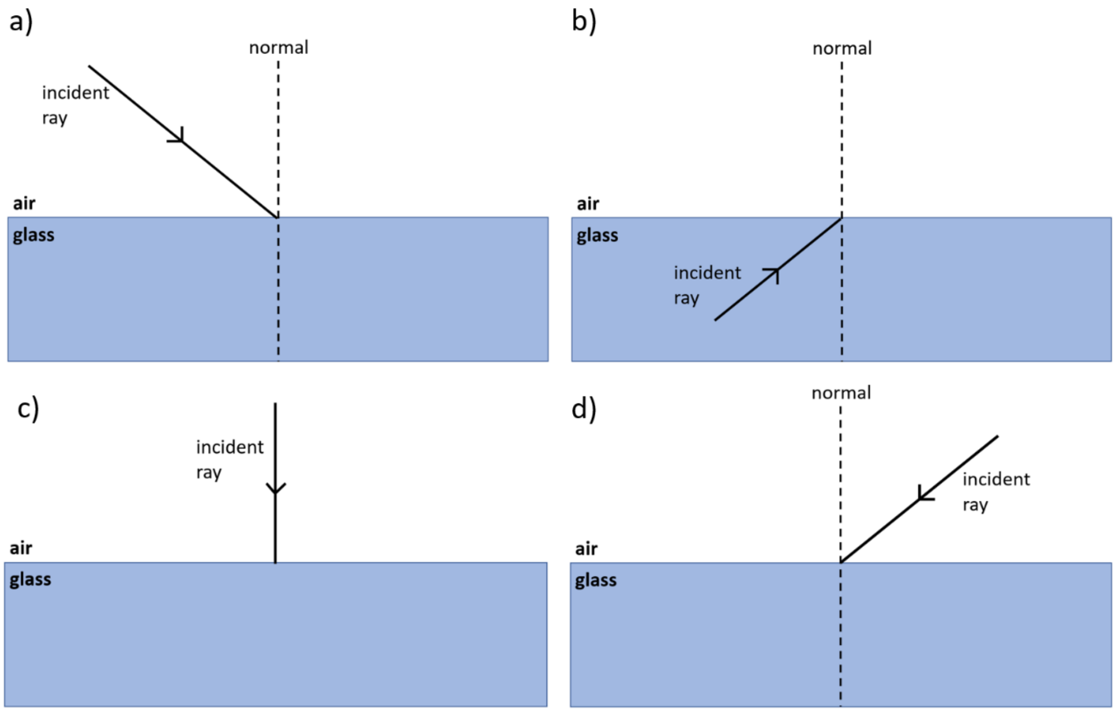
c) When light goes from air into a glass block, the angle of refraction is less than the angle of incidence.

....

d) When light goes from air into a glass block, the frequency of the light of the light remains unchanged.

....

Q2. Complete the diagrams below by drawing the refracted ray. In part c), the incident ray is going in the same direction as the normal.



Q3. The diagram to the right shows the "bent pencil" illusion when a pencil appears to be bent when partially submerged in water. Describe why this illusion happens.

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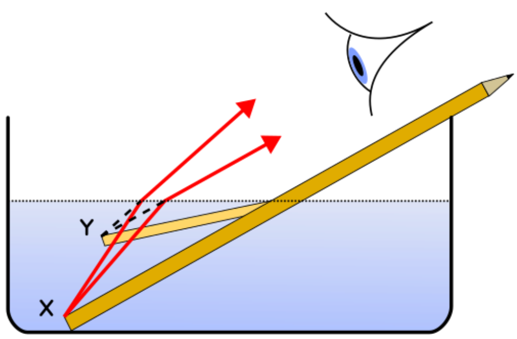
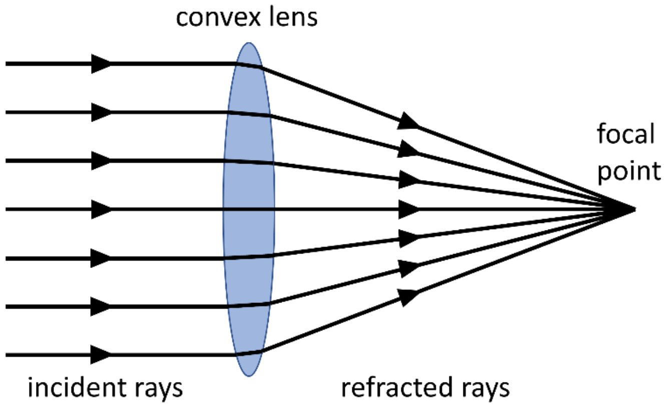
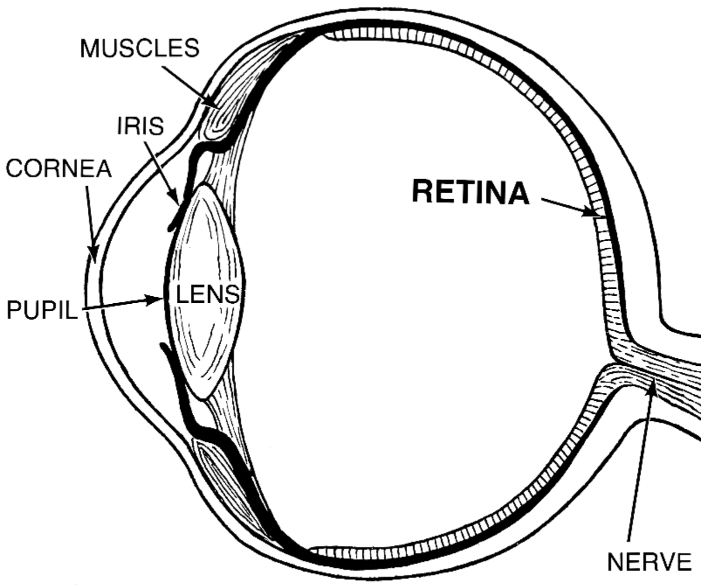


Pencil_in_a_bowl_of_water.png: Theresa Knott derivative work: Gregors (talk) ,CC BY-SA 3.0, via Wikimedia Commons

The human eye

The human eye contains a **convex lens**. A convex lens is wider in the middle than it is at the edges. Because of this, rays of light refract by different amounts depending on where they hit the lens. This causes the light to **converge** (come together) at a **focal point**. This is shown in the diagram to the right.





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Convex lenses are used in objects like:

- Glasses to help people with farsightedness.
- Magnifying glasses.
- Telescopes.

The convex lens inside the eye allows for light to be focused on the back of the eye (called the retina).

A diagram of the human eye is to the left, and descriptions of each of the parts are below.

Cornea	Transparent layer at the front of the eye. Some refraction of light occurs here.
Retina	Contains cells that can detect light and colour. It is sensitive to light that is too bright and can be damaged.
Lens	Refracts light that passes through it. Muscles can change the shape of the lens so it can refract light by different amounts (depending on how far away an object is). The more a lens is curved, the more light will refract.
Iris	Coloured part of the eye around the pupil. Light does not pass through the iris.
Pupil	Dark area in the middle of the eye. Light passes through the pupil. The eye has muscles that can open or close the iris. When it is very bright, the iris will be mostly closed and only a small part of the pupil will be seen. This is to protect the retina from damage. When it is dark, the opposite happens. The iris will be mostly open to allow more light to reach the retina.
Nerve	The nerve carries the signal from the retina to the brain.

Q1. The following statements are either true or false. State which are true and which are false.

a) A lens that is wider in the middle than at the edges is called a convex lens.

....

b) The human eye contains a convex lens.

....

c) The cornea contains cells that can detect light and colour.

....

d) The iris is the coloured part of the eye.

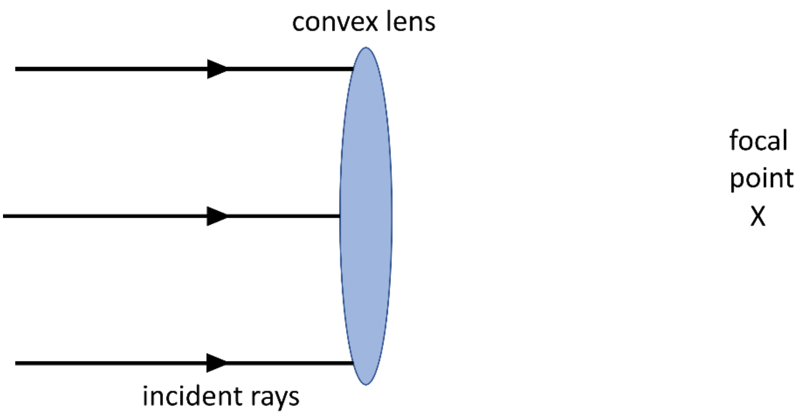
....

Q2. State three uses of convex lenses.

....

....

....



Q3. Complete the ray diagram to the right by showing the path of the rays of light from the lens to the focal point.

Q4. Describe how convex lenses bring rays of light together at a focal point.

....

....

Q5. Describe why the pupil appears larger on someone when it is dark, and smaller when it is very bright.

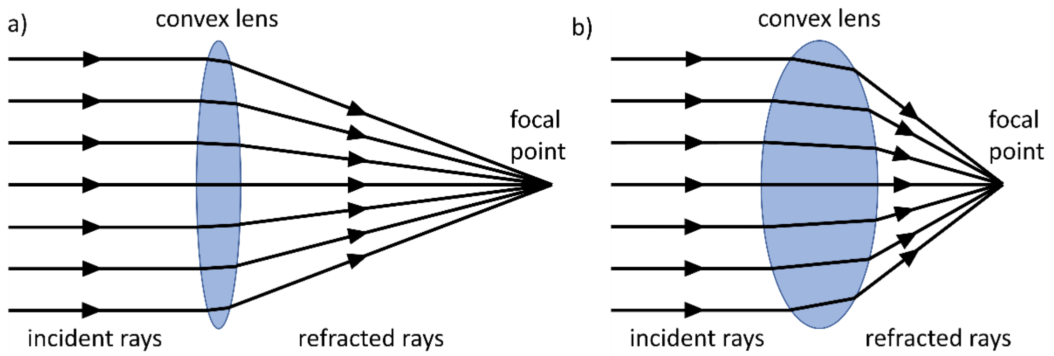
....

....

Q6. Using the diagram below, describe why the focal length (the distance from the lens to the focal point) of lens a) is more than that of lens b).

....

....



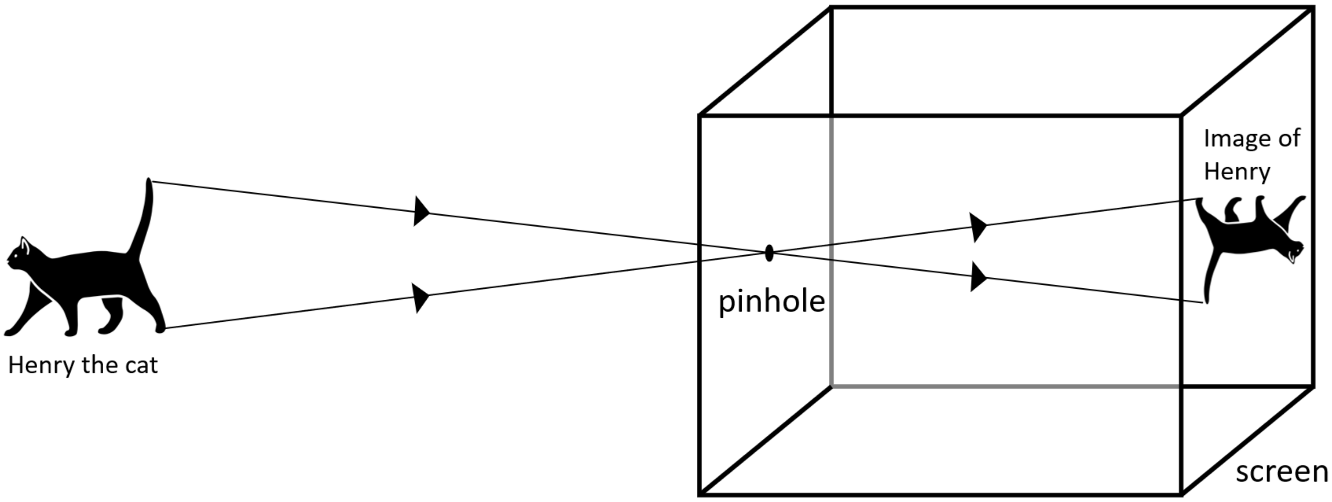
Cameras

A **pinhole camera** is a simple way of making an image of an object.

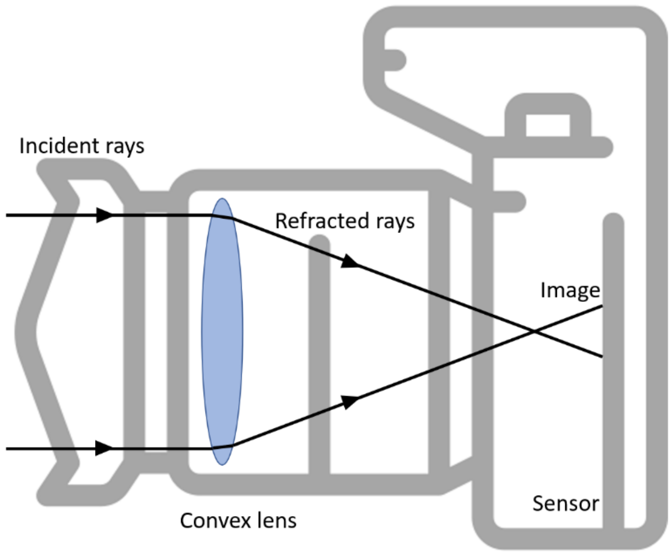
It consists of a box, with a small hole in one end and a "screen" at another. The screen should be made of a thin and **translucent** material like tracing paper. A translucent material is one that allows for some light to pass through it.

A diagram of a pinhole camera is below. Light rays are shown from the top and bottom of an object, but they come from all parts of the object.

Because the light rays from the top of the object are travelling at a different angle to the rays from the bottom of the object, the image is **inverted**. This means the image is upside down.



You can make a pinhole yourself at home by using a shoe box and some tracing paper.



A more modern camera is shown in the diagram to the left.

Like the human eye, it contains a **convex lens**. The convex lens refracts light to a focus.

The camera also has a part of it that is sensitive to light. Instead of being called the retina (as it is in the eye), it is a sensor.

Even much smaller cameras (like the ones in phones) still contain lenses and sensors.

Q1. Describe what an object being translucent means.

....

....

Q2. Describe what an image being "inverted" means.

....

....

Q3. The following statements are either true or false. State which are true and which are false.

a) Both the human eye and a camera contain a convex lens.

....

b) The human eye contains a retina, while the equivalent for a camera is a sensor.

....

c) A pinhole camera contains a convex lens.

....

d) Images formed by a pinhole camera are always the same way up as the object.

....

Q4. Describe what refraction is and how a convex lens refracts light to a focus.

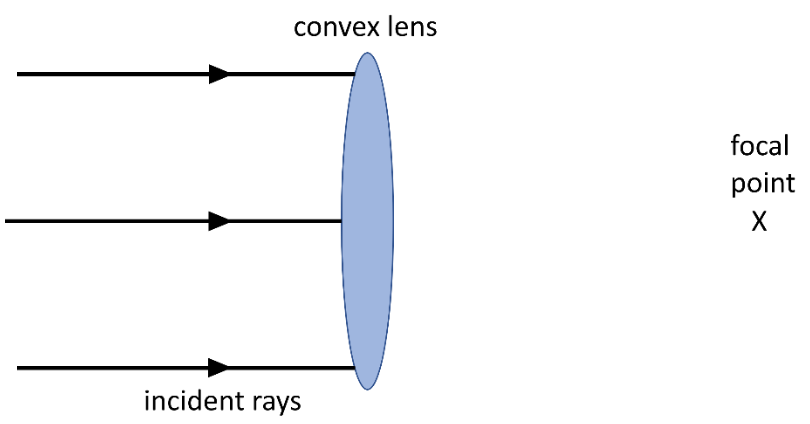
....

....

....

....

Q5. Complete the ray diagram below by showing the path of the rays of light from the lens to the focal point.

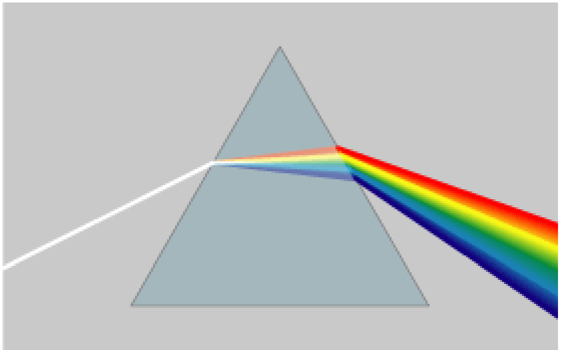


Colours in light

White light is made from different individual colours. We know this because when we pass white light through a prism, the light is split up into seven different colours called a **spectrum**. This splitting of the colours is called **dispersion**. Dispersion is what causes **rainbows**.

The order of the colours (from longest to shortest wavelength) is:

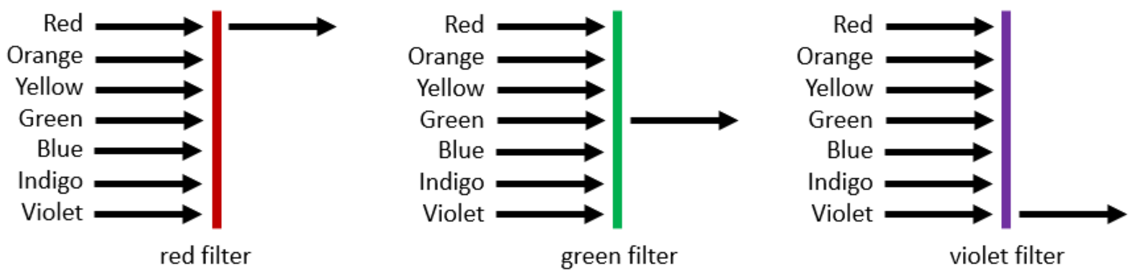
Red — Longest wavelength
Orange
Yellow
Green
Blue
Indigo
Violet — Shortest wavelength



Commonly, people use ROY G. BIV to remember this order. Dispersion happens because the different colours of light experience a different **refractive index** and so **refract** by different amounts.

Violet refracts most as violet experiences the highest refractive index. You can remember this with the phrase "violet bends most violently". Red refracts least as red experiences the lowest refractive index.

A **filter** only allows one colour of light to be transmitted through it. Other colours are absorbed by the filter. The diagram below shows a red filter only letting red light go through it, a green filter only letting green light through it and a violet filter only letting violet light through it.



In a similar way, different objects look coloured because of the light they reflect. A green object looks green because it reflects only green light into our eyes. A red object looks red because it reflects red light into our eyes. A white object reflects all seven colours of light in the spectrum.

Q1. The following statements are either true or false. State which are true and which are false.

a) All colours of light experience the same refractive index when going into a prism.

....

b) Dispersion is caused by refraction.

....

c) Dispersion is what causes rainbows.

....

d) Red light refracts most in a prism.

....

e) Of all the colours, red light has the longest wavelength.

....

Q2. Describe why dispersion happens.

....

....

Q3. State the order of colours in visible light, giving the order from longest to shortest wavelength.

....

....

Q4. State what colour of light is transmitted through an orange filter.

....

Q5. Describe why a blue object looks blue.

....

....

Q6. White light is passed through a yellow filter.

a) State what colour is transmitted through the yellow filter.

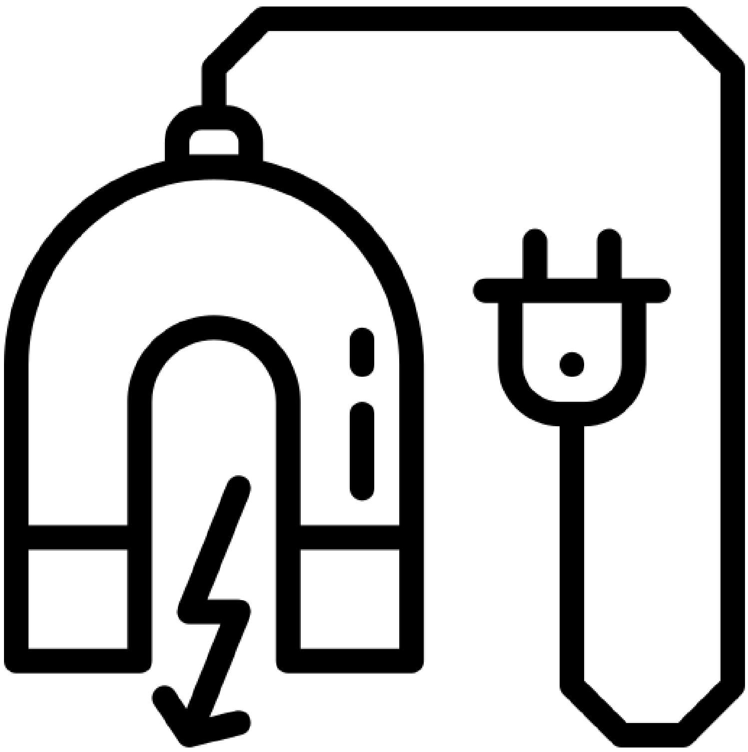
....

b) The light from this filter is then shone onto a blue object. Describe why the object looks black.

....

....

Electricity and



electromagnetism

Introduction to static electricity

All matter is made of **atoms** and **molecules**. In the centre of every atom is the **nucleus**. The nucleus is made of **protons** and **neutrons**. **Electrons** orbit around the nucleus.

Protons are positively charged, while electrons are negatively charged. Neutrons are **neutral** and so have no charge.

Atoms are neutral as they have equal numbers of protons and electrons. If an atom loses an electron then it becomes positively charged. We call an atom that has lost an electron an **ion** and call the process of an atom losing or gaining electrons **ionisation**.

Objects gain a static charge when one object rubs against another. The **friction** between these objects causes one to lose electrons and one to gain electrons.

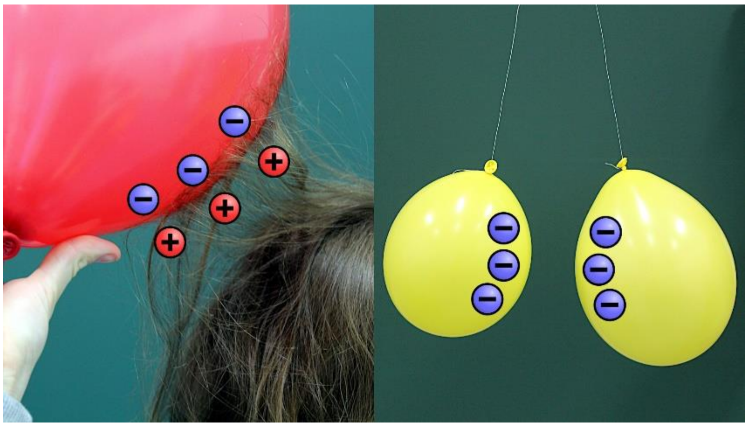
Objects with different charges exert **electrostatic** forces on each other. This force is **non-contact**.

Like charges repel, unlike charges attract.

If somebody rubs a balloon against their hair, the friction transfers electrons from their hair onto the balloon.

If the balloon is removed from their hair, then the balloon will attract the hair. This is because the balloon and the hair have opposite charges.

Similarly, if two negatively charged balloons are placed next to each other then they will repel each other. This is because they have the same charge.



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A Van de Graaff generator works in a similar way and very large charges can build up.

If somebody touches the surface of a Van de Graaff (while insulated from the floor) then the person gains a charge. This includes all of their hairs having the same charge. Because all of their hairs have the same charge, they repel each other and spread out.

Q1. State the two particles that make up the nucleus.

....

Q2. State the name of the particle that orbits around the nucleus. State what charge it has.

....

Q3. State whether electrostatic forces are contact or non-contact. Explain what this means.

....

Q4. State the name of an atom that has lost or gained an electron.

....

Q5. Explain why atoms usually have no overall charge.

....

Q6. Describe how an object gains a static charge.

....

Q7. The following statements are either true or false. State which are true and which are false.

a) A positive charge attracts a negative charge.

....

b) A negative charge attracts a negative charge.

....

c) For an object to become charged, protons are transferred from one object to another.

....

Q8. A balloon is rubbed against someone's jumper. The balloon becomes negatively charged. Describe how the balloon becomes negatively charged. Include in your answer what charge the jumper will become.

....

....

....

Q9. Someone drags their feet while walking across a carpet. Describe why they might get an electric shock if they touch a metal door handle.

....

....

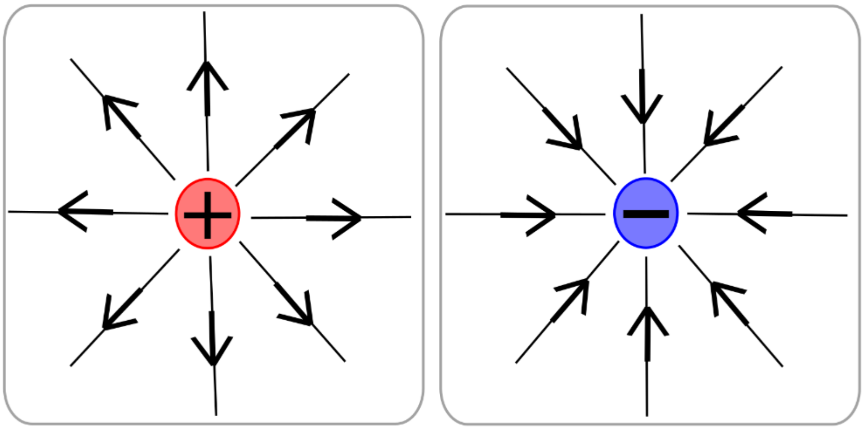
....

Electric field lines

Electrostatic forces are **non-contact**.

A **contact force** is one that acts when two objects are physically touching each other. Conversely, a **non-contact** force acts between objects that are not touching each other.

Non-contact forces are caused by a **field**. A charged object creates an electric field. The electric field lines for a positive and negative charge are shown in the image to the right.



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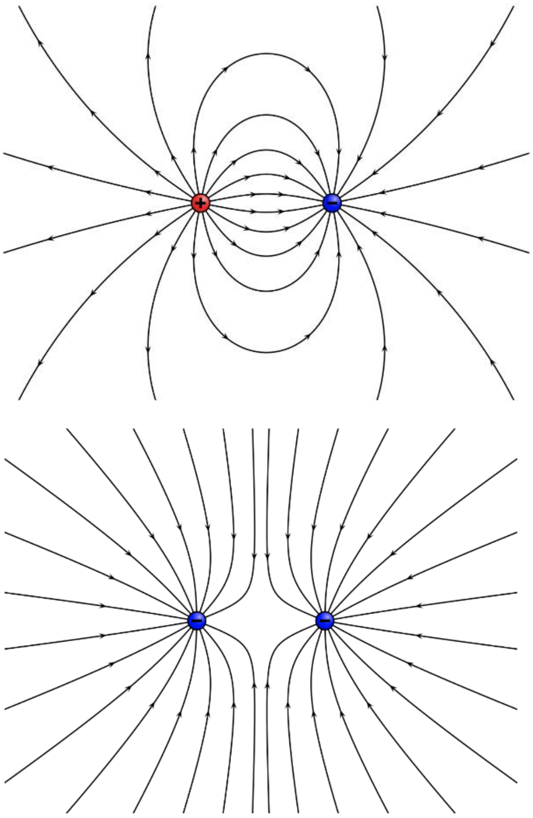
Electric field lines point away from a positive charge and towards a negative charge.

The electric field lines represent the direction of force that a nearby positive charge would experience (and the opposite to the direction of force on a nearby negative charge).

This is because **like charges repel and opposite charges attract**.



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The closer together the field lines, the stronger the electric field. In the diagram above, the further you go away from each charge the weaker the field becomes. We know this because the field lines are further apart.

The top diagram to the left shows the electric field lines when a positive charge is near a negative charge.

The second diagram to the left shows the electric field lines when two negative charges are near each other. If there were two positive charges near each other the pattern would be identical but with the arrows pointing in the opposite direction (away from both positive charges).

In all cases, the electric field lines point away from positive charges and towards negative charges.

Q1. State the direction that electric field lines point.

……

Q2. State the difference between a contact force and a non-contact force.

……

……

Q3. State whether electrostatic forces are contact or non-contact.

……

Q4. State whether like charges repel or attract.

……

Q5. In the space below, sketch the pattern of electric field lines around

a) A positive charge.
b) A negative charge.

Q6. State what the direction of the electric field lines represent.

……

Q7. State what the happens to the strength of the electric field as you go further from a charge.

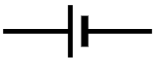
……

Q8. In the space below, sketch the pattern of electric field lines around two positive charges that are near each other.

Circuit symbols

We use **circuit diagrams** to represent electrical circuits. We generally draw circuit diagrams in pencil and use a ruler to draw any connecting wires. **Circuit symbols** are used to represent different electrical components. A list of these circuit symbols are below:

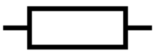
A **connecting wire**. These are used to connect different parts of a circuit together.



A **cell** – provides **potential difference** to the circuit.

A **battery** – made of more than one cell.

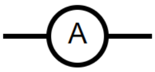
A **lamp** – produces light.



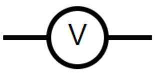
A **resistor** – limits the amount of current in the circuit and is used to vary potential differences.

An o**pen switch**. When a switch is open that part of the circuit is **incomplete**. Current cannot flow through an incomplete circuit.

A **closed switch**. When a switch is closed that part of the circuit is **complete**. Current can flow through a complete circuit.



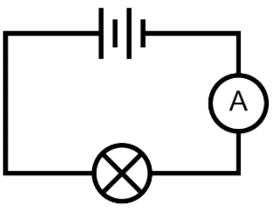
An **ammeter** – measures the **current** in a circuit. Goes in series in the part of the circuit where you want to measure the current.



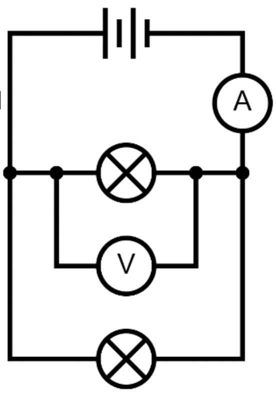
A **voltmeter** – measures the potential difference between two parts of a circuit. Goes in parallel around the component that you want to measure the potential difference across.

The diagrams below show a **series** circuit (on the left) and a **parallel** circuit (on the right). Note how the connecting wires are all straight lines. A series circuit is one where there's only one path for the current to flow. A parallel circuit has more than one path.

Series



Parallel



Q1. State the purpose of an ammeter.

....

Q2. Describe the difference between a series and a parallel circuit.

....

....

Q3. State the difference between a cell and a battery.

....

Q4. The following statements are either true or false. State which are true and which are false.

a) Current can flow through an incomplete circuit.

....

b) Voltmeters go in series with the component you want to measure the potential difference across.

....

Q5. In the space below, draw a series circuit that contains a battery, an open switch and a lamp.

Q6. In the space below, draw a series circuit that contains a cell, an ammeter, a resistor and a lamp. Also include a voltmeter in parallel around the lamp.

Q7. In the space below, draw a circuit that contains a battery and three lamps in parallel. On each path, include a switch so that each lamp can be switched on and off independently.

Current

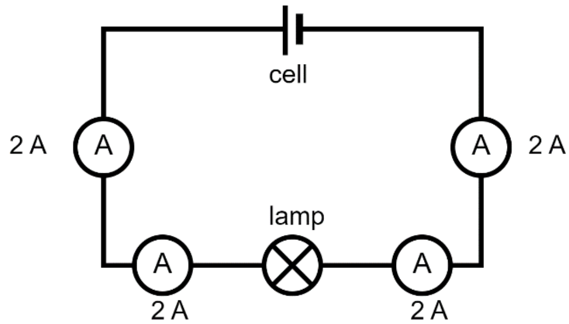
Current flows through an electric circuit. Current is equal to how much **charge** is flowing past a point in the circuit every second. A **complete circuit** is needed for current to flow.

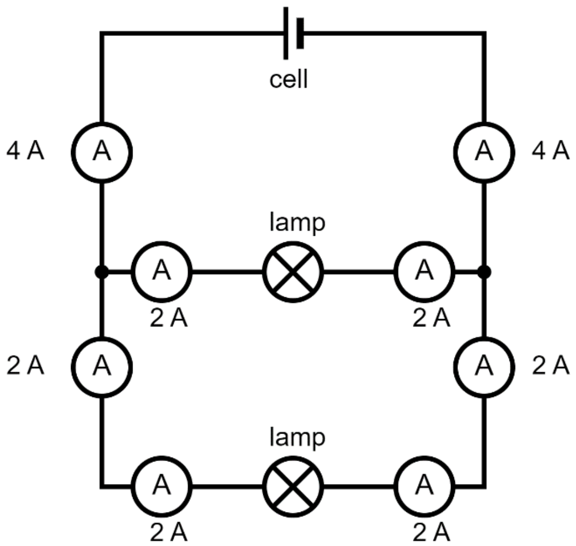
Current is measured in units of **amps** (A). An **ammeter** is used to measure the current at a point in the circuit. The circuit symbol for an ammeter is a circle with an “A” in it.

The charged particles that flow through a circuit are **electrons**. Electrons are **negatively charged** particles.

A **series** circuit only has one path for the current to flow. Therefore, **current is the same everywhere in a series circuit.**

The diagram to the right shows a series circuit with one lamp. The current is 2 A at each point in the circuit.



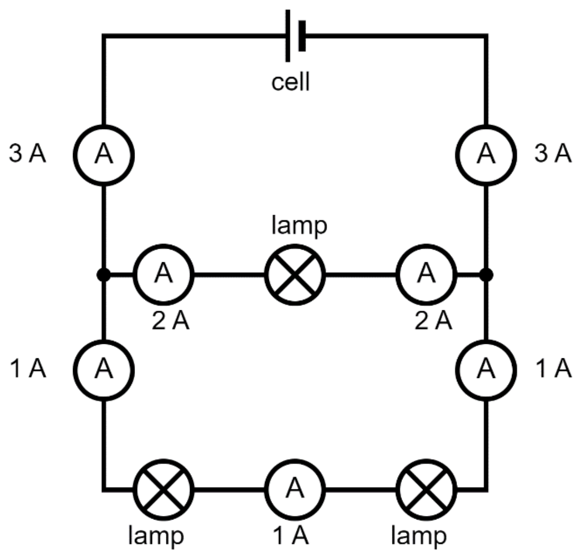


A **parallel** circuit has more than one path for the current to flow. The total current going into a **junction** (that is, where a wire splits or combines) is equal to the total current going out of a junction.

The circuit to the left shows a parallel circuit with each path having an identical lamp. Each branch has the same 2 A of current as before. Before and after each junction, though, the current is 4 A. **Each path draws additional current from the cell**.

To the right is a more complicated circuit diagram. All of the lamps are identical, so there is more **resistance** on one path than the other. The upper path has the same 2 A of current, but the lower path has twice the resistance (because there are two lamps) and so has half the current (at 1 A).

The overall current drawn from the battery is 3 A. **The higher the resistance in a path, the lower the current**.



Q1. The following statements are either true or false. State which are true and which are false.

a) Current is equal to how much charge is flowing past a point in the circuit every second.

....

b) Protons are charged particles that flow through a circuit.

....

c) Current can flow through an incomplete circuit.

....

d) In a series circuit, current is different at different points.

....

Q2. State what we use to measure current in a circuit.

....

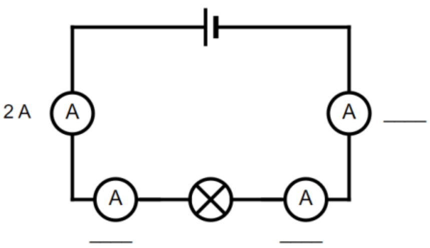
Q3. State the units of current.

....

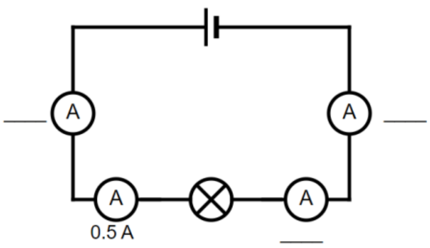
Q4. In the space below, draw the circuit symbols for a cell, a lamp and an ammeter.

Q5. For each of the circuits below:

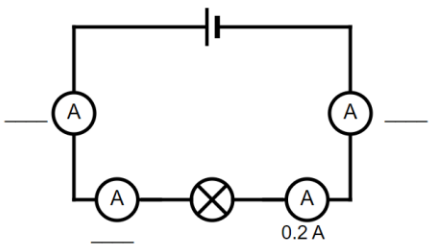
a) Circle whether the circuit is series or parallel.
b) For any ammeters that do not have a current written by them, write the missing current.



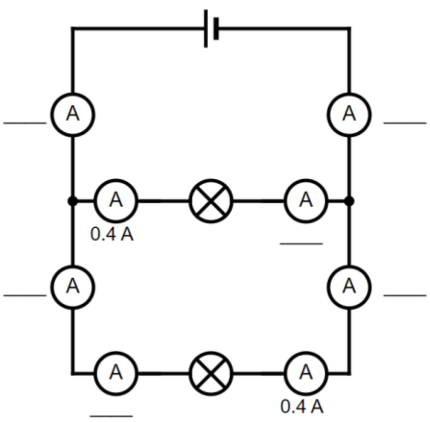
series/parallel



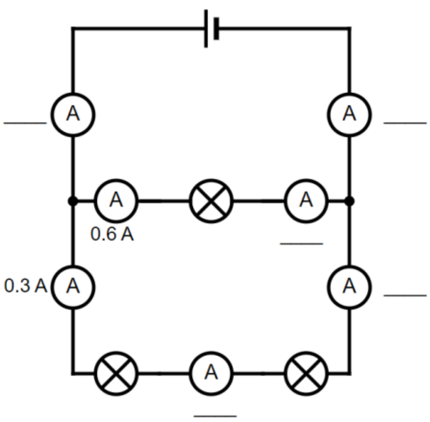
series/parallel



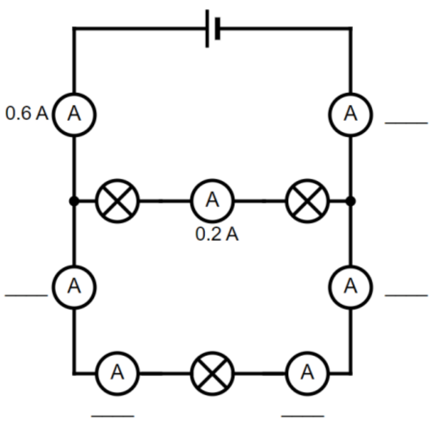
series/parallel



series/parallel



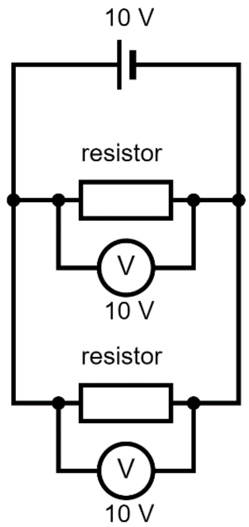
series/parallel



series/parallel

Potential difference

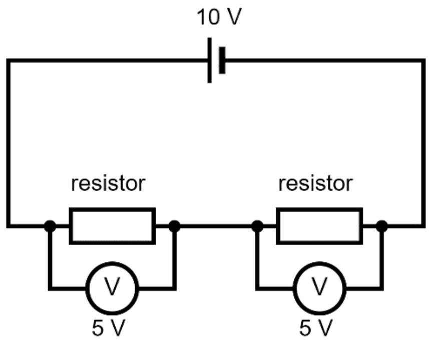
A battery or power supply gives each charge in an electrical circuit **energy**. Electrical components like lamps or resistors use this energy (which gets transferred into different energy stores). **Potential difference** is a measure of the difference in energy that charges have between each two points in a circuit.



Potential difference (commonly referred to as voltage) has units of **volts** (V) and is measured by a **voltmeter** which goes in **parallel** across the component you're measuring the potential difference across. The circuit symbol for a voltmeter is a circle with a "V" in it.

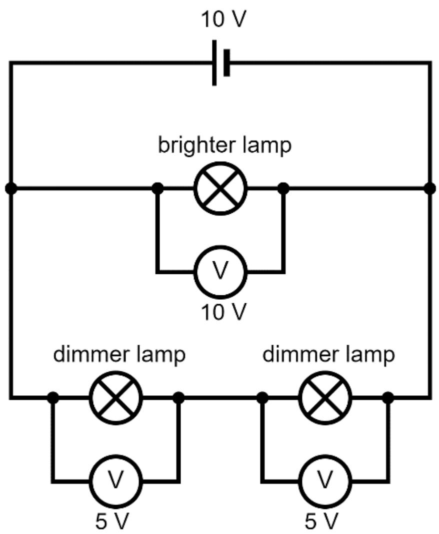
A circuit only experiences a drop in potential difference when the current goes through an electrical component. Therefore, **potential difference across each parallel branch is the same.**

The diagram to the right shows a cell that produces a potential difference of 10 V across it. The two resistors both have 10 V across them.



In a series circuit, potential difference is split across all components.

In the series circuit to the left, there are two identical resistors. Both resistors have a potential difference of 5 V across them (equal to half the potential difference across the cell).



The circuit diagram to the right is slightly more complicated. The total potential difference across each parallel path is 10 V. However, the lower path has two bulbs and so they each have 5 V across them.

Note how the top lamp is brightest. This is because it has a higher potential difference across it.

Lamps in parallel circuits have two main advantages:

- Each lamp receives the full potential difference and so is brighter.
- If there was a switch on each path, each lamp could be turned on and off independently. Remember that a circuit needs to be **complete** for a current to flow.

Lamps also have a **rating**. The lamp rating is the maximum potential difference that is safe to put across a lamp without it breaking.

Q1. The following statements are either true or false. State which are true and which are false.

a) The potential difference across each parallel path is always the same.

b) In a series circuit, potential difference is the same everywhere.

c) The higher the potential difference across a lamp, the brighter the lamp.

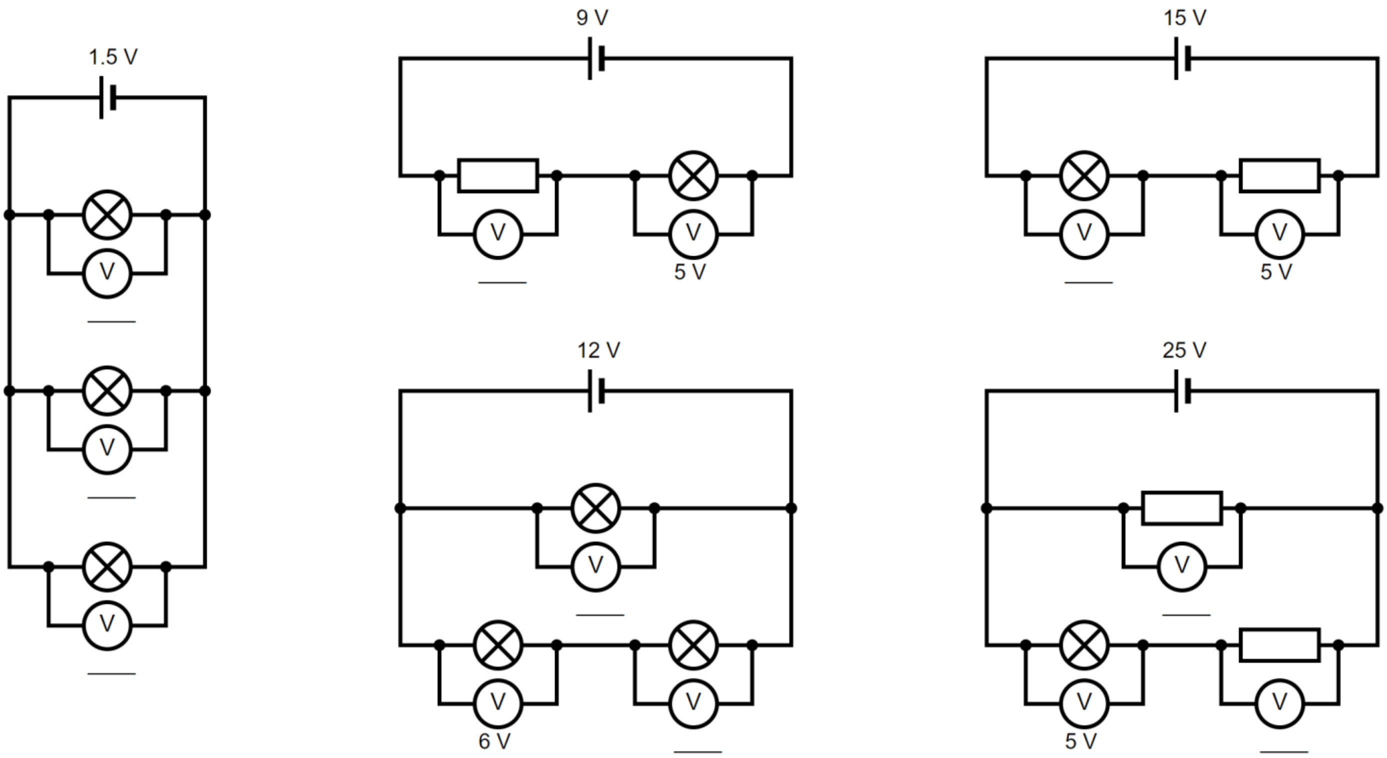
d) The lamp rating is the potential difference the lamp turns on at.

e) Voltmeters go in series in a circuit.

Q2. State an advantage of having lamps in a parallel circuit.

Q3. In the space below, draw the circuit symbols for a resistor and a voltmeter.

Q4. Each of the circuits below have some voltmeters that do not have a potential difference written by them. Fill in the missing potential differences.



Resistance

Resistance is a measure of how hard it is for current to flow through an electrical component. Resistance is measured in **Ohms (Ω)**.

Electrical **conductors** (like metals) have a low resistance, while **insulators** (like plastic) have a high resistance.

There is an equation that relates potential difference, current and resistance:

Potential difference = Current × Resistance or in symbols **V = I × R**

Remember that potential difference has units of volts (V) and current has units of amps (A).

We can also rearrange this equation to give:

Resistance = Potential difference ÷ Current or in symbols **R = V ÷ I**

In words, **resistance is the ratio of potential difference to current**.

Example question 1:

A lamp has a resistance of 20 Ω and a current of 0.5 A flowing through it. Calculate the potential difference across the lamp.

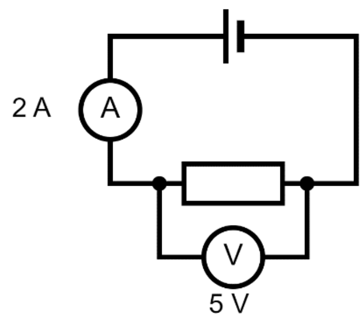
Step 1. Write down equation: **V = I × R**

Step 2. Insert variables into equation: **= 0.5 × 20**

Step 3. Calculate answer. Remember units: **= 10 V**

Example question 2:

Using the information in the circuit diagram to the right, calculate the resistance of the resistor.



Step 1. Write down equation: **R = V ÷ I**

Step 2. Insert variables into equation: **R = 5 ÷ 2**

Step 3. Calculate answer. Remember units: **= 2.5 Ω**

Sometimes resistance is given in units of **kiloohms (kΩ)**. One kiloohm is equal to one thousand Ohms. To convert from kiloohms to Ohms you need to multiply the number of kilowatts by one thousand: **kΩ × 1000 → Ω**. You need to convert to Ohms for calculations.

Q1. State the equation that links potential difference, current and resistance.

....

Q2. State the unit of resistance.

....

Q3. Describe the difference between an electrical conductor and an insulator.

....

Q4. A lamp has a resistance of 15 Ω and a current of 2.0 A flowing through it. Calculate the potential difference across the lamp.

V = I × R

= 2.0 A × 15 Ω

= ____________ V

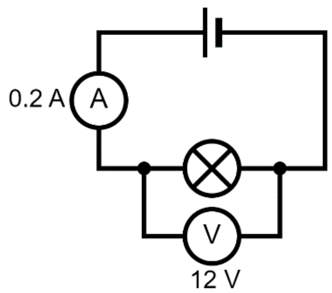
Q5. A resistor has a resistance of 500 Ω and a current of 0.10 A flowing through it. Calculate the potential difference across the resistor.

V = I × R

= _____ __ × _____ __

= ____________ V

Q6. Using the information in the diagram to the right, calculate the resistance of the lamp.



R = V ÷ I

= _____ __ ÷ _____ __

= ____________ Ω

Q7. A resistor has a resistance of 100 Ω and a current of 0.8 A flowing through it. Calculate the potential difference across the resistor.

....

Q8. A light dependent resistor (LDR) has a potential difference of 6 V across it and a current of 0.02 A flowing through it. Calculate the resistance of the LDR.

....

Q9. A thermistor has a resistance of 1.5 kΩ and a current of 0.5 A flowing through it. Calculate the potential difference across the thermistor.

....

Q10. A resistor has a resistance of 2.0 kΩ and a potential difference of 10 V across it. Calculate the current flowing through the resistor.

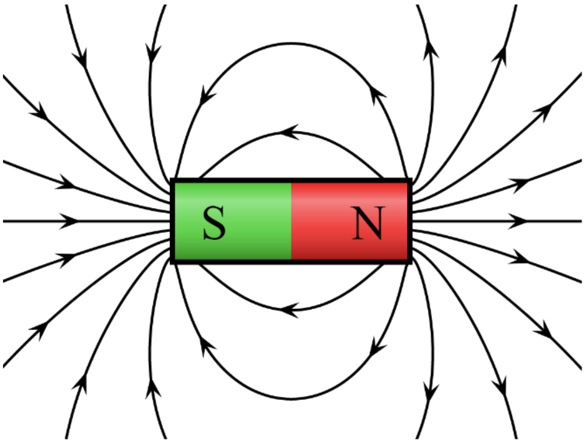
....

Introduction to magnetism

Magnetism is a **non-contact force**.

A **contact force** is one that acts when two objects are physically touching each other. Conversely, a **non-contact** force acts between objects that are not touching each other.

Non-contact forces are caused by a **field**. The magnetic field lines for a bar magnet are shown in the diagram to the right.



By Geek3 - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=10587119

The bar magnet consists of a **north** pole and a **south** pole. The magnetic field lines point away from the North pole and towards the South pole. The field lines give the direction of force on the North pole of another magnet.

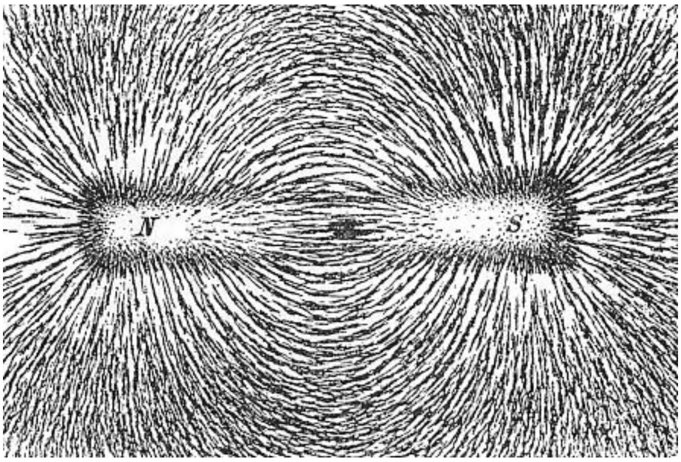
Like poles repel. Unlike poles attract.

The diagram also shows the magnetic field is stronger near the ends (**poles**) of the bar magnet. We can tell this because the magnetic field lines are closer together.

A **permanent magnet** (like a bar magnet) produces its own magnetic field. There are three metals that become magnetic when placed in a magnetic field. These magnetic metals are **iron, nickel and cobalt**. Steel is also a magnetic metal as it contains iron. Metals other than these are not magnetic.

The magnetic metals are attracted by permanent magnets, but never repelled.

A permanent magnet can be **demagnetised** by heating it, hitting it with a hammer or by placing it in a reversed magnetic field.



Newton Henry Black, Harvey N. Davis (1913) Practical Physics, The MacMillan Co., USA, p. 242, fig. 200, Public Domain, https://commons.wikimedia.org/w/index.php?curid=73846

We can visualise the magnetic field around a bar magnet by using **iron filings**. A bar magnet can be put under a piece of paper, with iron filings then sprinkled on top of the paper.

The iron filings arrange themselves in the shape of the field and are most attracted to the regions with the strongest field (the poles). This is shown in the diagram to the left.

Q1. State the direction that magnetic lines point.

....

Q2. State the difference between a contact force and a non-contact force.

....

....

Q3. State whether magnetism is a contact or non-contact force.

....

Q4. In the space below, sketch the magnetic field lines around a bar magnet.

Q5. State the three magnetic metals.

....

Q6. The following statements are either true or false. State which are true and which are false.

a) Cobalt is attracted to a bar magnet.

....

b) A north pole repels another north pole.

....

c) Copper is attracted to a bar magnet.

....

d) A north pole attracts a south pole.

....

e) The closer together the magnetic field lines, the stronger the field.

....

f) Iron is repelled by a bar magnet.

....

g) Magnetic field lines point away from a south pole and towards a north pole.

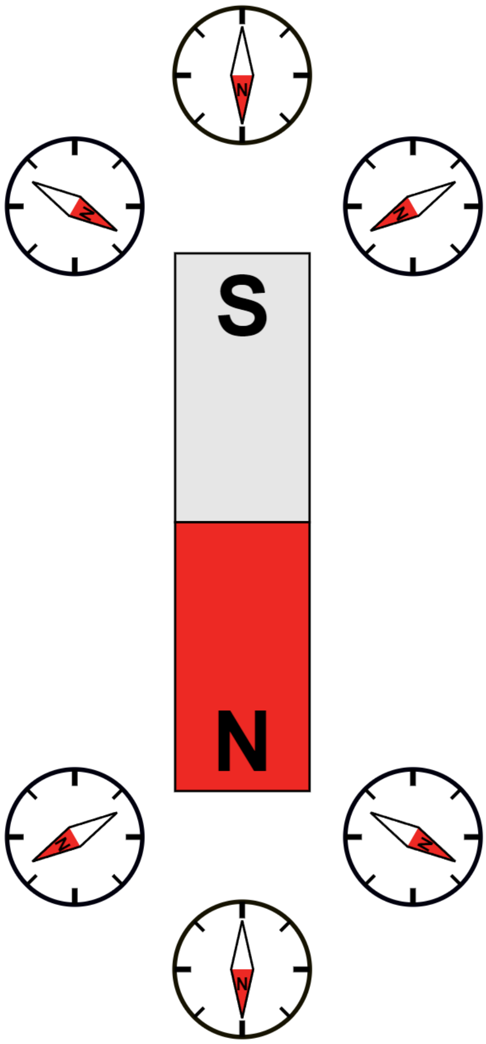
....

Plotting magnetic fields

We already know that we can use **iron filings** to show the magnetic field around a bar magnet. Iron filings don't show the direction of the field, though. If we want to show the direction of a magnetic field then we need to use **plotting compasses**.

A plotting compass is a **small bar magnet** that is free to rotate. The north pole of the small bar magnet in the compass will always point towards magnetic south. The compass points towards magnetic south.

To show the direction of the field, we can place a bar magnet on a piece of paper and place a plotting around near one of its poles. The direction of the compass can then be marked and the compass moved to various other positions. The arrows can then be joined up to show the overall field shape.



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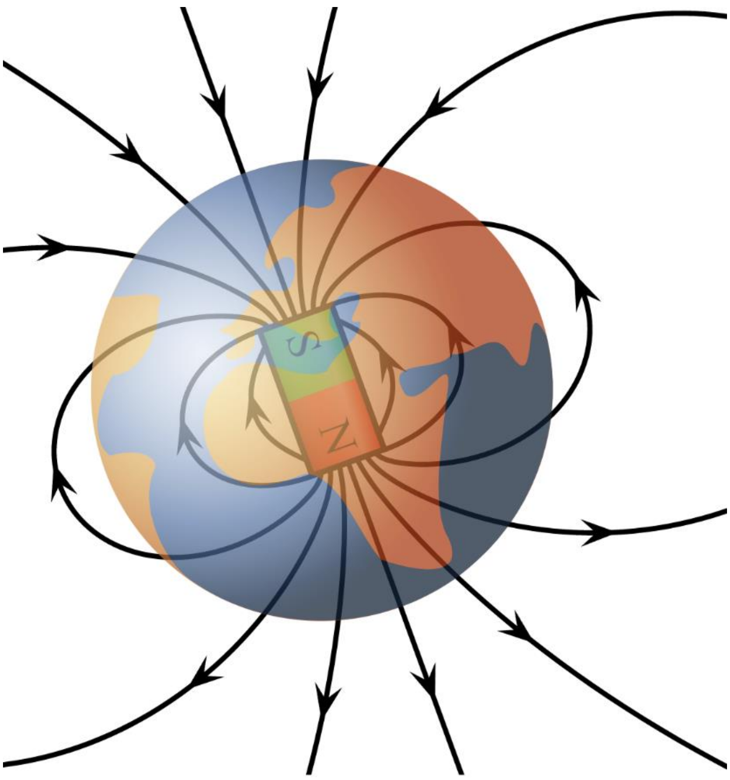


VFPt Earths Magnetic Field Confusion.svg: Geek3 / derivative work: MikeRun, CC BY-SA 3.0 <https://creativecommons.org/licenses/by-sa/3.0>, via Wikimedia Commons

Compasses are also used to help navigate. The Earth's outer core is made of molten iron and nickel and so it has its own magnetic field, in the same shape as that of a bar magnet.

Confusingly, the geographic North pole of the Earth is near (but not precisely at) its magnetic south pole.

A compass always points to Earth's magnetic south.

Q1. The following statements are either true or false. State which are true and which are false.

a) A compass points towards Earth's magnetic north.

....

b) A compass can be used for navigation.

....

c) The geographic North pole of Earth is near its magnetic south pole.

....

Q2. State what a compass is made of.

....

Q3. State what the outer core of the Earth is made of.

....

Q4. Your answer to question 3 should contain two of the three magnetic metals. State the other magnetic metal.

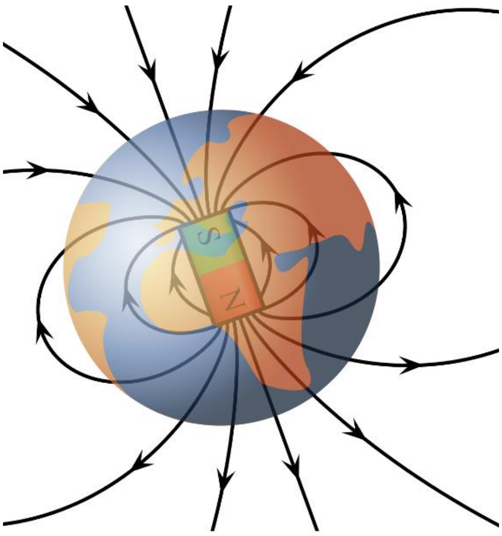
....

Q5. When visualising the magnetic field around a magnet, state a benefit of using a compass over iron filings.

....

Q6. Electronic devices (like a mobile phone) produce a magnetic field. Describe why a compass should not be used near an electronic device.

....



VFPt Earths Magnetic Field Confusion.svg: Geek3 / derivative work: MikeRun, CC BY-SA 3.0 <https://creativecommons.org/licenses/by-sa/3.0>, via Wikimedia Commons

Q7. State where the magnetic field is strongest on the Earth. Explain, using the diagram to the left, how we know this.

....

....

Q8. Explain if we would be able to use compasses to navigate if the Earth didn't have a magnetic field.

....

....

Electromagnetism

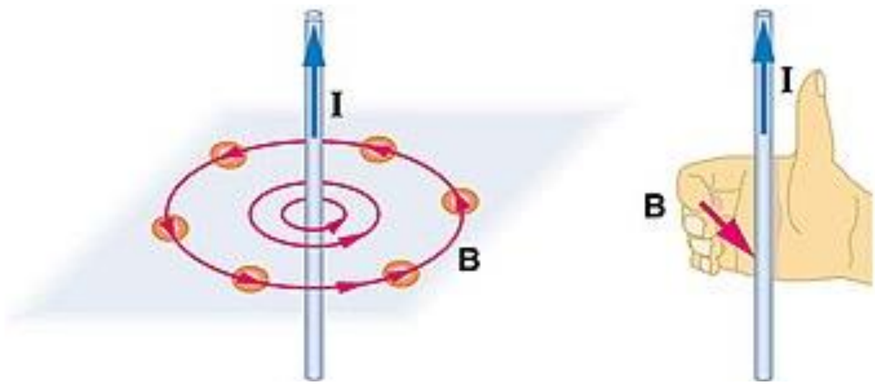
Any time a **current** flows through a wire, a magnetic field is formed around the wire. This is called an **electromagnet**. The magnetic field can be made stronger by increasing the current.

The magnetic field is strongest near to the wire and gets weaker further away.

If the current stops flowing, then the magnetic field also stops.

The field around a current carrying wire is in concentric circles around the wire. The circles are closer together closer to the wire. This shows the magnetic field is strongest nearer the wire. We can see what direction the magnetic field goes in by using the **right hand rule**.

Here, you point the thumb on your right hand along the direction of current. The direction that your fingers point give the direction of the magnetic field. This is shown in the diagram to the right. The current is labelled *I*, and the magnetic field is labelled *B*.



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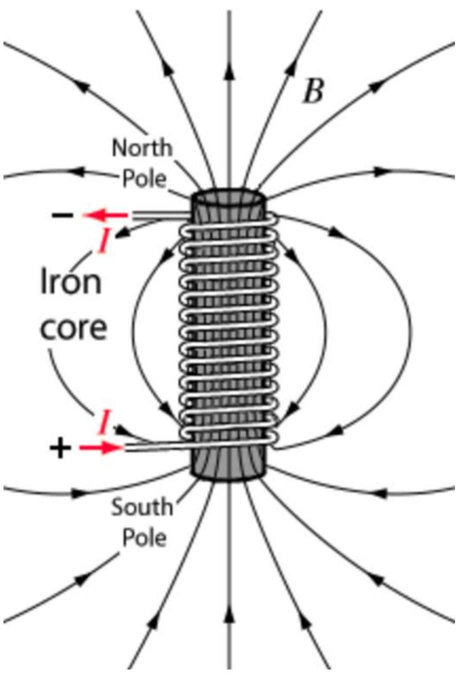
We could also show the direction of the field by using **plotting compasses** in the same way that we used them to show the shape of a magnetic field around a bar magnet.



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A coil of wire is called a **solenoid**. A solenoid creates a magnetic field in the same pattern as a bar magnet. The magnetic field is strongest inside a solenoid. There are three ways to increase the strength of the field produced by a solenoid:

1. Increase the number of turns in the coil.
2. Increase the current.
3. Add an **iron core**.

Iron is an example of a **soft** magnetic material. A soft magnetic material can be easily magnetised and demagnetised. This is an advantage as we want electromagnets to be able to easily turn their magnetism on and off. A **hard** magnetic material is difficult to magnetise and demagnetise. A hard material shouldn't be used in the core of a solenoid as it would retain some magnetism.

Q1. State what has to flow through a wire to create an electromagnet.

....

Q2. Describe what a solenoid is.

....

Q3. State where the magnetic field produced by a solenoid is strongest.

....

Q4. State three ways of making the magnetic field around a solenoid stronger.

....

....

....

Q5. Describe the difference between a soft magnetic material and a hard magnetic material.

....

....

Q6. State one example of a soft magnetic material.

....

Q7. Describe why hard magnetic materials are not placed in a solenoid.

....

....

Q8. State what happens to the strength of the magnetic field as you go further from a current carrying wire.

....

Q9. Describe the shape of a magnetic field around a current carrying wire.

....

Q10. State what the direction of the thumb represents in the right hand rule.

....

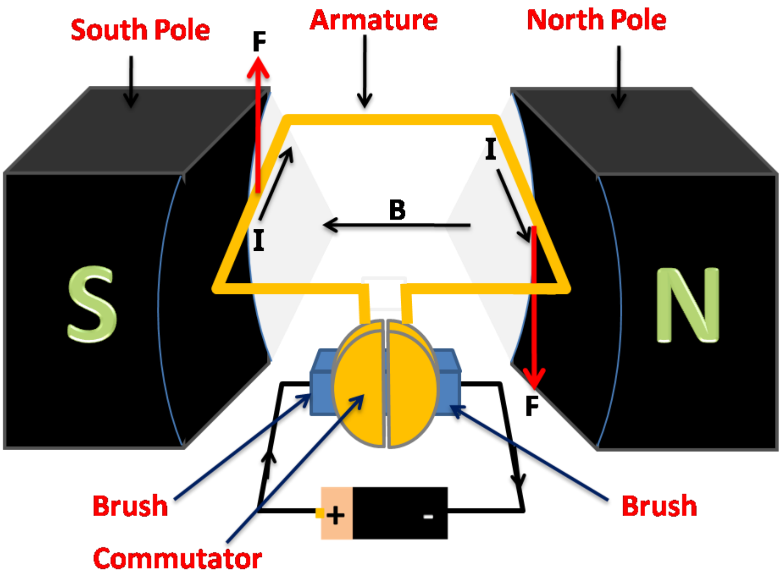
Q11. State what the direction of the fingers represent in the right hand rule.

....

Q12. Other than using the right hand rule, state how we could show the direction of a field around a current carrying wire.

....

Electric motors



K.Venkataramana, CC BY-SA 4.0 <https://creativecommons.org/licenses/by-sa/4.0>, via Wikimedia Commons

The construction of an electric motor is quite simple, it is made of a coil of wire inside a magnetic field. The magnetic field is produced by two permanent magnets.

In the diagram to the right, a battery supplies a **current** to a coil of wire (labelled armature). When a current flows through a wire, it creates a magnetic field. The magnetic field is labelled "B", and the field lines point away from a north pole towards a south pole.

This magnetic field interacts with the permanent magnetic field that surrounds the coil. This interaction produces a **force**.

A coil of wire is used, as the more turns in the coil the greater the strength of the overall magnetic field produced and the greater the force on the coil.

On the left side of the coil in the diagram this interaction of magnetic fields leads to an upwards force. As the current (labelled I) goes around the coil, though, it changes direction. There is therefore a downwards force on the right side of the coil in the diagram. These forces lead to a rotation of the coil.

However, if the coil rotates by 180° then the direction of those forces would reverse. To counter this a **split ring commutator** is used. A split ring commutator reverses the direction of current every half turn. This ensures the motor continues to rotate in the same direction. The **brushes** (made of carbon) rub against the split ring commutator and allow it to rotate.

There are three main ways to make an electric motor rotate faster:

- Increase the current flowing through the coil.
- Increase the number of turns in the coil.
- Increase the strength of the magnetic field.

There are two ways of making an electric motor rotate in the opposite direction. You can either reverse the direction of the current or reverse the direction of the magnetic field produced by the permanent magnets.

Q1. The following statements are either true or false. State which are true and which are false.

a) When a current flows through a wire, it creates a magnetic field.

....

b) Magnetic field lines point away from a south pole towards a north pole.

....

Q2. State the components in an electric motor.

....

....

Q3. Explain why there is a force on the coil in an electric motor.

....

....

Q4. Describe the role of the split ring commutator in an electric motor.

....

....

Q5. State three ways of making an electric motor rotate faster.

....

....

....

Q6. State two ways of making an electric motor rotate in the opposite direction.

....

....

Q7. State what the brushes in an electric motor are made of.

....

Q8. The current supplied to an electric motor is switched off. Explain why the motor stops spinning.

....

....

Q9. The battery powering an electric motor has been used for a long time and the current supplied by the battery is starting to decrease. Explain what happens to the electric motor.

....

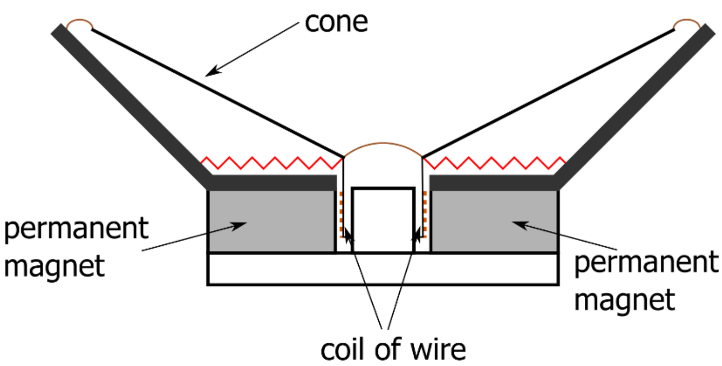
....

Speakers and microphones

A speaker is made from a coil of wire, a permanent magnet and a cone.

A **current** flows into the coil of wire. Any time a current flows through a wire, a **magnetic field** is formed around the wire.

This magnetic field interacts with the field caused by the permanent magnets. This causes a **force** which, in turn, causes the cone to move.



Adapted from: Harkonnen2 - Loudspeakerconstruction.png, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=9540717

If the current changes direction, then the magnetic field caused by the coil changes direction. This causes the force on the coil to be in the opposite direction to before.

A current that constantly changes direction is called an **alternating current**.

If the current constantly changes direction, then so does the direction of the force on the cone. The cone therefore vibrates back and forth, making a sound. The **vibration** of an object is what makes sound.

The **frequency** of the sound made is the same as the frequency of vibration. The faster the vibration of the cone, the higher the frequency of sound made.

There are three ways of making this sound louder:

- Increase the current flowing through the coil.
- Increase the number of turns in the coil.
- Increase the strength of the magnetic field caused by the permanent magnet.

A **microphone** is built in the same way as a speaker but works in the opposite way.

In a microphone, a sound wave comes onto the cone and causes it to vibrate. In a microphone, the cone is sometimes called a **diaphragm**.

This causes the coil of wire to vibrate and the coil moves within the magnetic field of the permanent magnet.

Any time a coil of wire experiences a change in magnetic field (as it would when it moves in a magnetic field) then it causes a current to flow in the coil.

This changing current in the coil could then be passed into a speaker for playing (or the pattern of the changing current could be saved to play later).

Q1. The following statements are either true or false. State which are true and which are false.

a) Any time a current passes through a wire, a magnetic field is formed around the wire.

b) A microphone contains a diaphragm which vibrates when sound reaches it.

c) An alternating current is one that always flows in the same direction.

d) If a coil moves in a magnetic field, a current is made.

e) If the current in the coil in a speaker is decreased, the sound made by the speaker is louder.

Q2. State the names of the three different parts of a speaker.

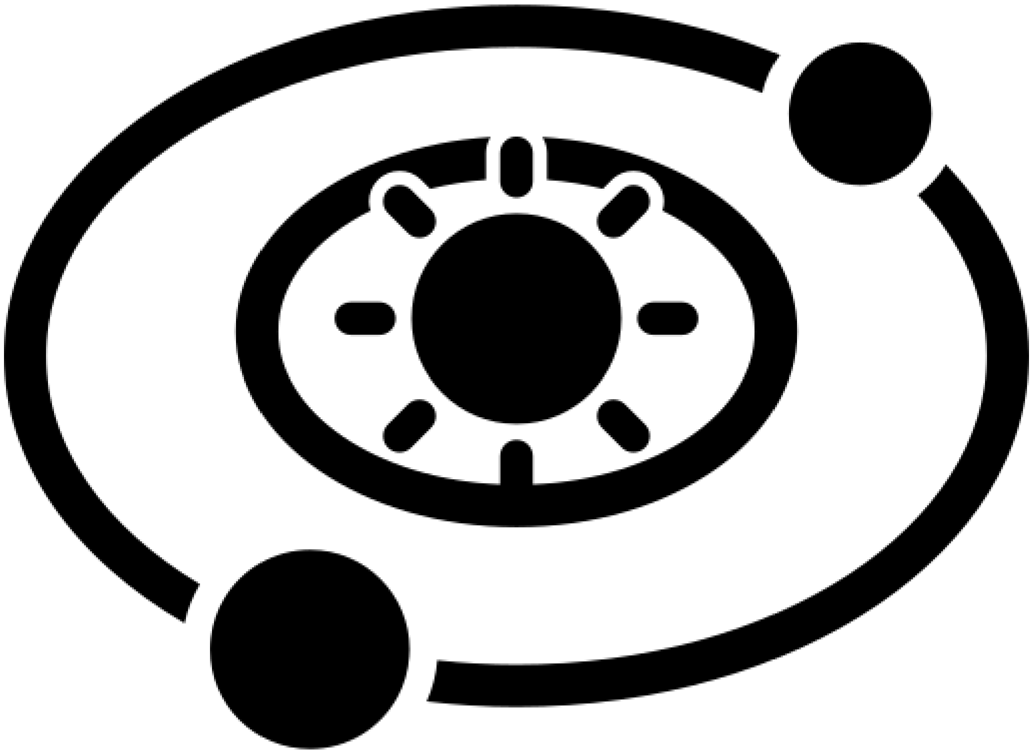
Q3. Describe what an alternating current is.

Q4. Describe how a speaker makes a sound.

Q5. State three ways of making a speaker make a louder sound.

Q6. Describe how a microphone works.

Space



Mass and weight

Weight is a downwards force due to **gravity**. All objects have a force that attracts them towards each other. This force is due to gravity**.** Even you attract other objects to you because of gravity, but you have too little mass for the force to be very strong.

The **gravitational field strength (g)** at the surface of a planet is determined by its mass. The gravitational field strength on the surface of the Earth is **9.8 N/kg**.

The weight of an object can be calculated using the equation:

Weight = Mass x Gravitational field strength

The **mass** of an object is the amount of matter it contains and is measured in kilograms (kg). The mass of an object **stays the same** wherever it is, but its **weight can change** depending on the gravitational field strength.

Example question 1:

The moon has a gravitational field strength of 1.6 N/kg. Calculate the **weight** of a 20 kg mass on the surface of the moon.

Step 1. Write down equation: **Weight = Mass x Gravitational field strength**

Step 2. Insert variables into equation: **= 20 kg × 1.6 N/kg**

Step 3. Calculate answer. Remember units: **= 32 N**

We can also be asked questions to calculate mass or gravitational field strength. To answer these, we need to rearrange the equation.

Example question 2:

The gravitational field strength on Mars is 3.7 N/kg. An object on the surface of Mars has a weight of 0.74 N. Calculate the mass of the object

Step 1. Write down equation: **Weight = Mass x Gravitational field strength**

Step 2. Insert variables into equation: **0.74 N = Mass x 3.7 N/kg**

Step 3. Rearrange equation: **Mass = 0.74 N ÷ 3.7 N/kg**

Step 3. Calculate answer. Remember units: **= 0.2 kg**

Q1. State the equation that links weight, mass and gravitational field strength.

....

Q2. The following statements are either true or false. State which are true and which are false.

a) The mass of an object is the same everywhere.

....

b) The weight of an object is the same everywhere.

....

Q3. A book of mass 0.5 kg is on the surface of Earth. Calculate the weight of the book (the gravitational field strength on Earth is 9.8 N/kg).

Weight = Mass × Gravitational field strength
= 0.5 kg × 9.8 N/kg
= _____________ N

Q4. The Lunar Rover vehicle had a mass of 210 kg. The gravitational field strength on the surface of the Moon is 1.6 N/kg. Calculate the weight of the Lunar Rover Vehicle.

Weight = Mass × Gravitational field strength
= ______ __ × ___ __
= _____________ N

Q5. A rock of mass 2 kg is on the surface of Venus. The gravitational field strength on the surface of Venus is 8.8 N/kg. Calculate the weight of the rock.

Weight = Mass × Gravitational field strength
= ______ __ × ___ __
= _____________ __

Q6. Pluto has a gravitational field strength of 0.5 N/kg. Calculate the weight of an object of mass 4 kg on the surface of pluto.

....

Q7. An object is on the surface of Ceres. The object has a weight of 0.81 N and a mass of 3 kg. Calculate the gravitational field strength on Ceres.

....

Q8. Dr Edmunds is leading a class expedition to Mercury. Dr Edmunds has a mass of 70 kg and a weight of 259 N. Calculate the gravitational field strength on Mercury.

....

Q9. The gravitational field strength at the top of Mount Everest is slightly less than at sea level, and is equal to 9.77 N/kg. Calculate the mass of a water bottle of weight 12 N.

....

Q10. A can of cola has a mass of 330 g and a weight of 2.3 N. Calculate the gravitational field strength.

....

Day, night and seasons

The Earth orbits around the Sun due to **gravity**.

The Earth also spins around an imaginary line called an **axis**. It completes one revolution every 24 hours.

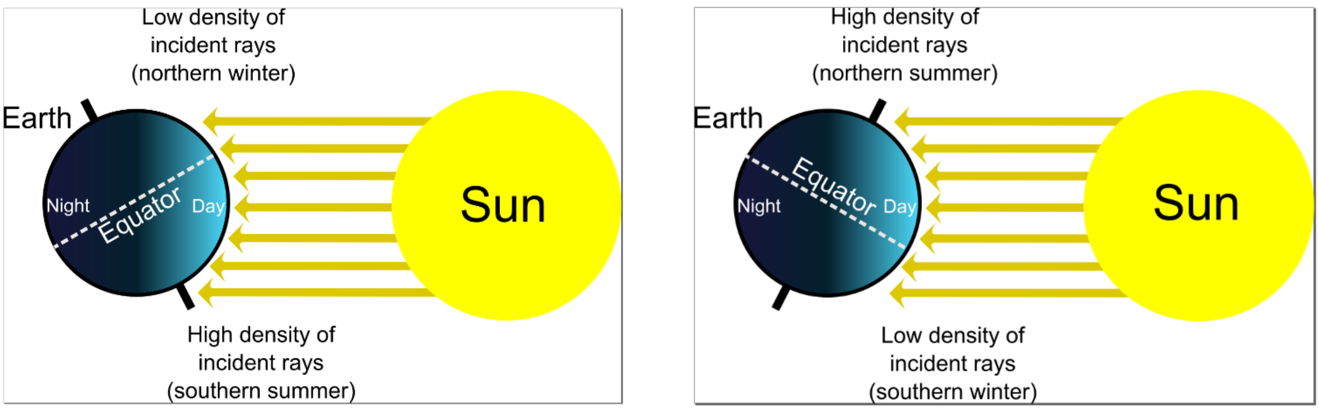
24 hours is the length of a day, and it is this spinning of the Earth around its axis that causes day and night.

When one side of the Earth is facing towards the Sun, it is day-time.

When one side of the Earth is facing away from the Sun, it is night-time.

It takes the Earth 365 days to orbit around the Sun. This is the length of one **year**.

The axis of the earth is tilted 23.5° from vertical. This tilt, combined with the orbit around the Sun, causes the **seasons**.



By Rhcastilhos - Own work, Public Domain, https://commons.wikimedia.org/w/index.php?curid=1577426

An imaginary line called the **equator** divides the Earth into two halves, called **hemispheres**.

When the northern hemisphere is tilted away from the Sun, it experiences a winter. This is because there is a lower intensity of light in the northern hemisphere.

When the northern hemisphere is tilted towards the Sun, it experiences a summer. This is because there is a higher intensity of light in the northern hemisphere.

When it is summer in the northern hemisphere, it is winter in the southern hemisphere (and vice versa).

During the summer, there are long days and short nights. During the winter, there are short days and long nights.

The Sun and other stars appear to move slowly in the sky. This is because the Earth is rotating. On Earth, the Sun appears to rise in the East and sets in the West.

Q1. Describe why the Earth orbits around the Sun.

....

Q2. State the name of the imaginary line the earth spins around.

....

Q3. State the length of a day in hours.

....

Q4. Describe what causes day and night on Earth

....

....

Q5. State how long it takes for the Earth to orbit around the Sun.

....

Q6. State what a hemisphere of the Earth is.

....

Q7. Describe when the northern hemisphere experiences a summer.

....

....

Q8. Describe when the southern hemisphere experiences a winter.

....

....

Q9. Describe how the length of the day compares to the length of the night in winter.

....

....

Q10. Describe why the Sun and other stars appear to move slowly in the sky.

....

....

Q11. State the direction the Sun appears to rise.

....

Q12. State the direction the Sun appears to set.

....

The solar system

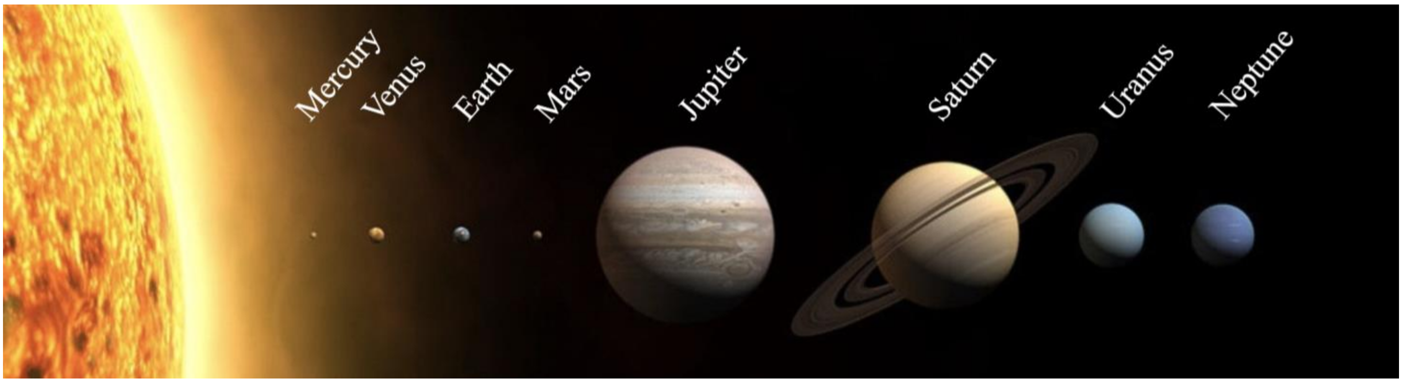
The **solar system** consists of a star (the Sun) and eight **planets**. The Sun contains most of the mass of the solar system. Therefore, **gravitational forces** keep the planets in **orbit** around the Sun. The surface temperature of the Sun is around 6000°C, but this temperature is much greater below the Sun's surface.

There are eight **planets** that orbit around the Sun. In order from closest to furthest from the Sun, they are:

1. **Mercury**. The smallest planet and the one closest to the Sun.
2. **Venus**. There is a carbon dioxide atmosphere on Venus. Carbon dioxide is a greenhouse gas and so Venus is the hottest planet in the solar system.
3. **Earth**. Our own planet and the only known planet that has life.
4. **Mars**. Much colder than the Earth as it is further away from the Sun.
5. **Jupiter**. The largest planet in the solar system. Due to this, it has the largest gravitational field strength (equal to 25 N/kg). It is famous for its Great Red Spot which is a storm that has lasted for over 400 years.
6. **Saturn**. The second largest planet and has rings that are made of ice and rock.
7. **Uranus**. The third largest planet and rotates on its side.
8. **Neptune**. The furthest planet from the Sun and, because of this, has the lowest average temperature.

You might also have heard of **Pluto**. Pluto is a **dwarf planet** and is further away from the Sun than Neptune.

There is a mnemonic that can help you to remember the order of the planets: **M**y **V**ery **E**asy **M**ethod **J**ust **S**peeds **U**p **N**aming (**P**lanets).



The four planets closest to the Sun are called the **terrestrial** (rocky) planets. Jupiter and Saturn are **gas giants**, while Uranus and Neptune are **ice giants**. Generally, the temperature of the planets decrease with distance from the Sun. The exception to this is Venus because of its carbon dioxide atmosphere.

Q1. State how many planets there are in the solar system.

....

Q2. Name the four terrestrial planets.

....

Q3. Name the two gas giants.

....

Q4. Name the two ice giants.

....

Q5. List the planets in the solar system, from nearest to the Sun to furthest from the Sun.

....

....

Q6. Name the planet that has the highest temperature. Explain why it has the highest temperature.

....

....

Q7. Name the object that contains most of the mass in the solar system.

....

Q8. State the force that keeps planets in orbit around the Sun.

....

Q9. Name the planet that has the lowest average surface temperature. Explain why it has the lowest temperature.

....

....

Q10. Name a dwarf planet in the solar system.

....

Q11. State the surface temperature of the Sun.

....

Q12. State the name of the planet that is the second largest in the solar system and has rings made of rock and ice.

....

Q13. Name the planet which has the largest gravitational field strength.

....

Beyond the solar system

The **universe** contains billions of different galaxies. A galaxy contains billions of stars. Our solar system is part of the **Milky Way galaxy**.

The image to the right shows an artist's impression of the Milky Way. We can also capture photographs of parts of it in the night sky.

National Aeronautics and Space Administration, Public domain, via Wikimedia Commons

The universe was formed 13.8 billion years ago in the **Big Bang**. We know this by looking at the light emitted by distant galaxies.

We measure the distance to distance galaxies in **light years**.

The speed of light is 300 000 000 m/s. A light year is the distance travelled by light in a time of one year. This is equal to 9.5×10^{15} m.

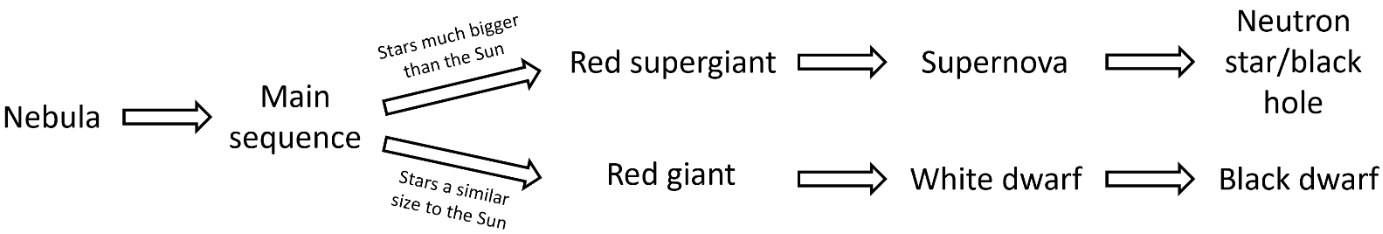
One example of a nearby (in astronomical terms) galaxy is the Andromeda galaxy. The Andromeda galaxy is 2.5 million light years away.

At the centre of the Milky Way galaxy is a **black hole**. A black hole is formed from the death of a very massive star.

Indeed, all stars go through a life cycle. All stars start off as a cloud of dust and gas (mostly hydrogen). This cloud of dust and gas is called a **nebula**. Gravitational attraction pulls this dust and gas together and eventually there is such a large amount of pressure and friction the temperature increases a lot. A **main sequence** star is formed.

When stars run out of hydrogen, they expand. Stars a similar size to our Sun form **red giants** and stars much bigger than our Sun form **red supergiants**.

Red giants leave behind a hot and small **white dwarf** which then cools to form a **black dwarf**. Red supergiants explode dramatically in a **supernova**. The biggest stars then leave behind a **black hole**, while less large stars leave behind a **neutron star**.



Q1. The following statements are either true or false. State which are true and which are false.

a) A galaxy contains around 1000 stars.

....

b) The universe contains billions of galaxies.

....

c) A galaxy is bigger than the universe.

....

d) The universe was formed around 5000 years ago.

....

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

....

Q2. State the name of the galaxy that our solar system is in.

....

Q3. A light year is equal to 9.5×10^{15} m. The nearest star to Earth (other than the Sun) is Proxima Centauri. Proxima Centauri is 4.2 light years away, calculate this distance in metres.

....

....

Q4. State what is in the centre of our galaxy.

....

Q5. Describe what a nebula is.

....

Q6. Describe how a main sequence star is formed from a nebula.

....

....

Q7. A main sequence star runs out of hydrogen and forms a red giant. State the next two stages in the life cycle of this star.

....

Q8. State the name of an explosion of a red supergiant.

....

Q9. Describe when black holes are formed, and when neutron stars are formed.

....

....

Answers

This is the free version of the Science Doctor KS3 Physics workbook. Hundreds of hours have gone into writing this workbook and sharing it freely. Answers are contained in the physical copy on Amazon. To support the work that has gone into this book, please consider buying one on Amazon.