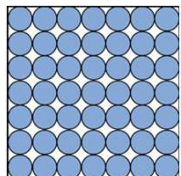
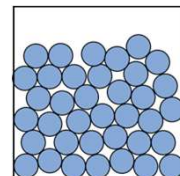
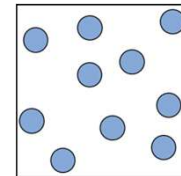


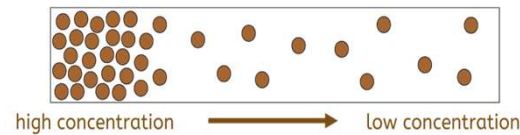
# Particles, substances and mixtures

## The particle model of matter

	Solid	Liquid	Gas
Diagram			
Arrangement	ordered and all touching	random and all touching	random and not touching
Movement	vibrate in fixed positions	move and slide over each other	move around quickly in random directions
Attraction between particles	strong	weak	very weak

## Diffusion

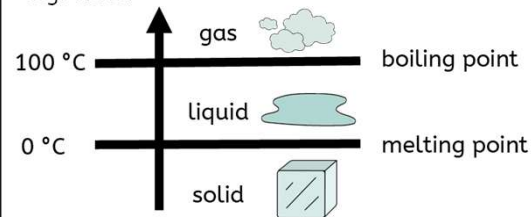
Diffusion is the random movement of particles from an area of high concentration to an area of low concentration. Particles of substances in the liquid and gas states can diffuse because their particles can move freely.



## Melting and boiling points

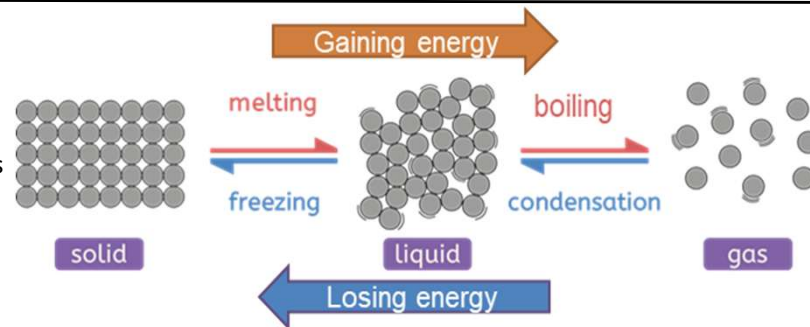
**melting point:** the temperature at which a substance changes from a solid to a liquid

**boiling point:** the temperature at which a substance changes from a liquid to a gas, e.g. water



## Change of state

A change of state is a physical change because no new substances are made, and the change is reversible. Only the amount of energy the particles have changes, which affects the arrangement and movement of the particles. Temperature stays constant during a change of state.



## Explaining the properties of solids

Property	Reason
Fixed shape and cannot flow	Strong forces of attraction between the particles keep them in fixed positions.
Cannot be compressed (squashed)	Particles are all touching and have no space to move into.

## Explaining the properties of liquids

Property	Reason
Takes shape of container and can flow	Weak forces of attraction between the particles, so they can move around each other.
Cannot be compressed (squashed)	Particles are all touching and have no space to move into.

## Explaining the properties of gases

Property	Reason
Takes shape of container and can flow	Very weak forces of attraction between the particles, allowing them to move and spread out.
Can be compressed (squashed)	Particles are not touching and have space to move into.

## Gas pressure

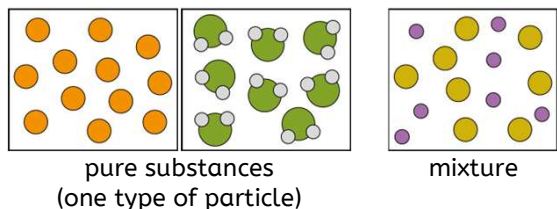
When gas particles collide with the walls of their container, this creates a constant force on the walls of the container. This causes pressure. The faster the particles move, the higher the gas pressure. The gas pressure inside containers can be increased by adding more particles or increasing the temperature. The more frequent the collisions, the higher the gas pressure.



# Particles, substances and mixtures

## Pure substances and mixtures

A **pure substance** is one that contains only one substance, e.g. pure iron contains only iron particles. A **mixture** contains two or more substances that are not joined together and can be physically separated.

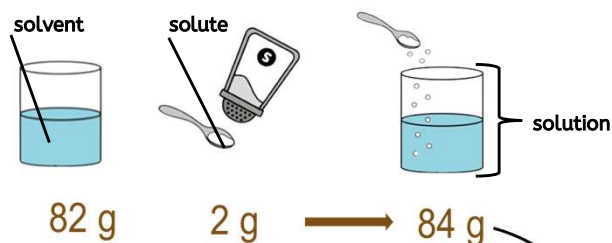


## Solutions and solubility

A **solute** can be dissolved in a **solvent**. The mixture created is called a **solution**. When no more solute can dissolve in the solution, it is a **saturated** solution. If a solid dissolves in a solvent, it is **soluble**. If it does not dissolve in a solvent, it is **insoluble**. **Solubility** is a measure of how much solute can dissolve in a solvent. The higher the temperature of the solvent, the greater the mass of the solute that can be dissolved.

Solubility is different for different solutes. The solubility of a solute will change depending on the solvent used.

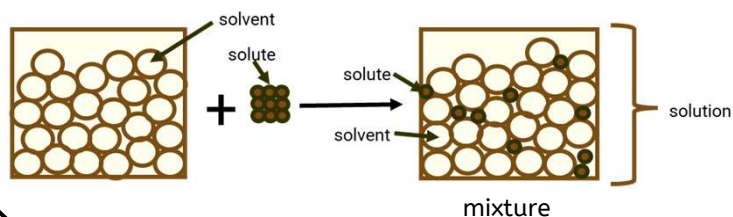
During **dissolving**, the solute particles are separated and fit between the solvent particles to make a solution.



### Conservation of mass

When a solution is formed, **the mass of the solvent + the mass of the solute = the mass of the solution**.

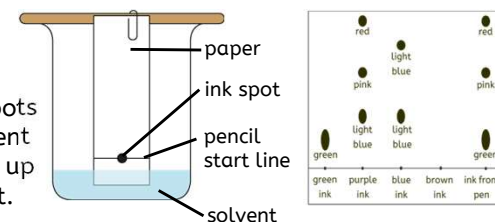
Mass remains constant because the number of particles is the same before dissolving as it is after.



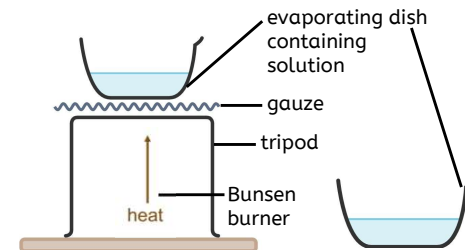
## Separating mixtures

We can separate mixtures in different ways depending on their properties:

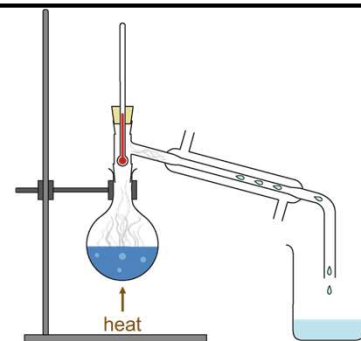
**Chromatography** is a separation technique that separates mixtures containing more than one solute based on their solubilities in a solvent. It works because some of the coloured substances dissolve better than others, so they travel further up the paper. A pencil line is drawn, and spots of ink or dye are placed on it. There is a container of solvent (e.g. water or ethanol). As the solvent continues to travel up the paper, the different coloured substances spread apart. A **chromatogram**, the results of chromatography experiment.



**Evaporation and crystallisation** can be used to separate a soluble solid from a solution. For example, copper sulphate is soluble in water – its crystals dissolve in water to form a copper sulphate solution. During evaporation, the water evaporates away, leaving solid copper sulphate crystals behind. Crystallisation produces larger solid crystals.

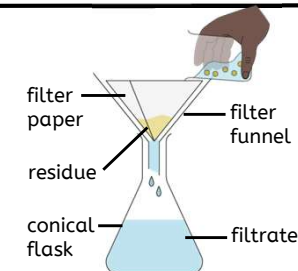


**Distillation** is a separation technique used to separate a mixture of liquids. The basis for separation in distillation is the difference in the boiling points of the components. For example, water can be separated from an ink and water solution because water has a much lower boiling point than ink. When the solution is heated, water evaporates. It is then cooled and condensed into a separate container. The ink does not evaporate, so it stays behind.



**Filtration** can be used to separate a liquid from an insoluble solid. The filter paper used in filtration is 'selectively permeable', meaning that it has holes in it that allow the movement of only some substances through whilst preventing the movement of others. The insoluble solid is unable to pass through the small holes of the filter paper. When a mixture of sand and water is filtered:

- The sand stays behind in the filter paper (it becomes the **residue**).
- The water passes through the filter paper (it becomes the **filtrate**).

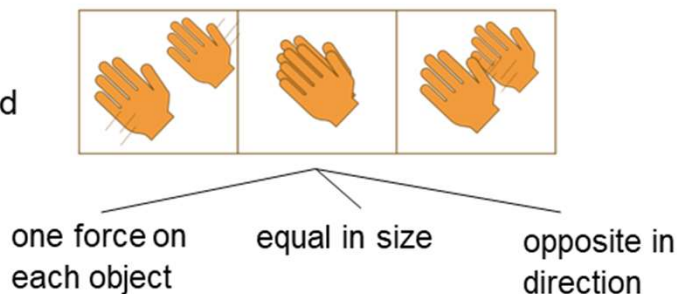


# 7.02: Fundamentals in physics

## Forces and their interactions

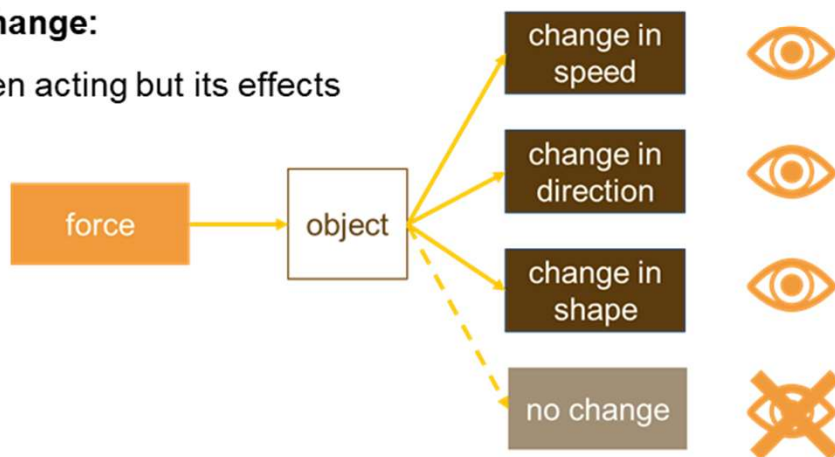
### Interaction:

When two objects influence each other and cause a pair of forces to arise.



### Forces can cause change:

A force cannot be seen acting but its effects often can.



### Forces can be contact or non-contact:

Contact forces arise between two touching objects.

Non-contact forces can act between two objects at a distance.

contact	thrust, friction, air resistance, water resistance, normal contact, upthrust
non-contact	gravity force, magnetic force

## Free-body force diagrams



upthrust force on boat by water



gravity force on boat by Earth

One object

Arrows to show size and direction of forces

Labelled forces:

- What kind of force is acting?
- What is the force acting on?
- What exerts the force?

## Deforming forces



Two pushing forces cause compression: the object contracts.



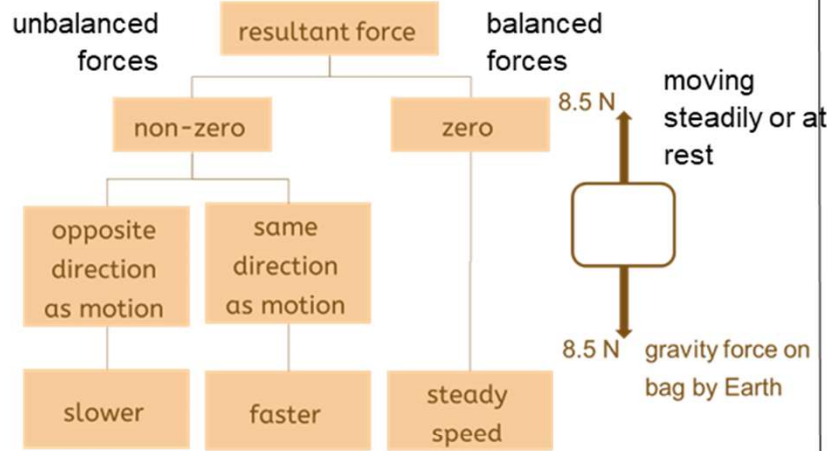
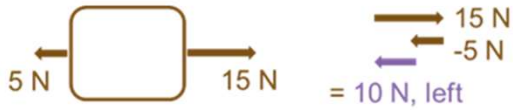
Two pulling forces cause tension: the object extends.

# 7.02: Fundamentals in physics

## Combining forces

### More than one force acting:

- Their effects are combined
- As if a single force is acting: the resultant force

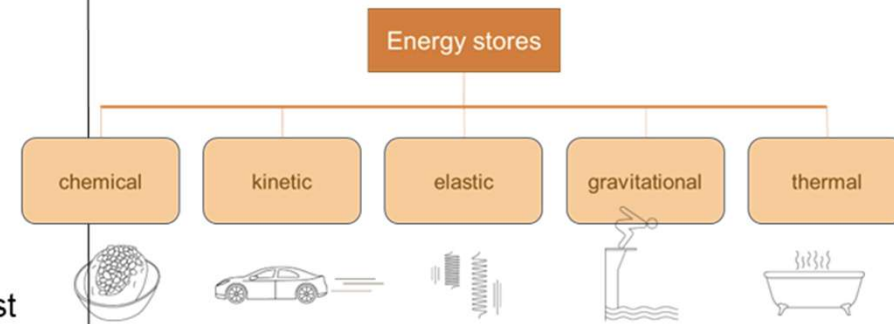


## Energy stores and pathways

### What energy does:

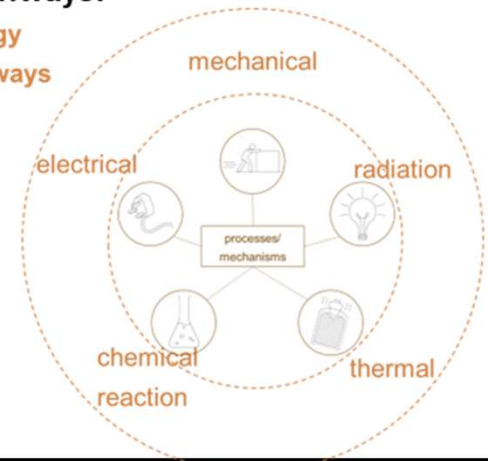
- Flows between objects in a system
- Stays the same when it transfers
- Cannot be used up

### Energy is transferred between stores:



### Energy is transferred because of processes, by pathways:

#### Energy pathways



## Friction force

- **What?** One of three frictional forces. They act to resist motion.
- **Where?** Acts between solid surfaces, along the surfaces.
- **When?** An object is sliding or trying to. When starting to slide, the applied force must be larger than the limiting friction: so, an unbalanced force acts.
- **How?** Opposite direction to the motion, or the applied force.
- **Why?** Surfaces are uneven, so the 'catching' between them must be overcome.

	Useful	Nuisance
Walking	✓	
Machines		✓
Driving	✓	
Wear and tear		✓



catching;



surfaces parted: no catching

lubricant

# 7.02: Fundamentals in physics

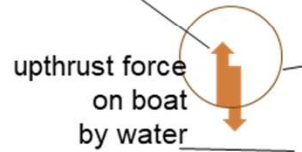
## Modelling forces

Forces are modelled because:

- forces cannot be seen acting
- there are many forces acting at a time
- their size and direction have important effects on situations, so need to be shown.

Arrows (length represents size, direction of forces)

Dot or rectangle shows simplified object



Labels describe type of force, object acted on and objects exerting force on it.

## Investigating forces

### Scientific methods:

- With or without hypothesis
- Manipulating variables or not

Statement to answer an enquiry question.

comparative term

Smoother surfaces cause less friction to act on objects sliding over them.

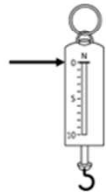
present tense

the effect which can be tested

'group' being tested (IV)

### Planning to collect high-quality data:

- Measuring with skill
- Preparing the data table
- Repeatable data



Check force-meter is on zero with no force.

headings describe variable

IV	Surface	Force to start sliding (N)			DV in columns
		1	2	3	
↓	Glass	1.4	1.5	1.7	repeated
	Metal	1.5	1.6	1.7	
	Polished wood	2.0	2.3	2.2	
	Plastic	2.9	3.0	2.9	
	Paper	4.5	3.8	4.0	



### Peer review: ★★★

Peers (people of a similar level of knowledge) test the results for quality.

- Repeatability: Same group, same results
- Reproducibility: Different group, same results

## Observing by measurement

### Using a scale

- set of lines at equal increments
- Labelled with numbers and units



### Measuring instruments

- Include rulers, balances, clocks and thermometers.
- Force is measured using a force-meter.



### Quantities: and their units

Base quantities: length (m), mass (kg), time (s) and temperature (K).

Derived quantities include force (N).

# Cells and organisation

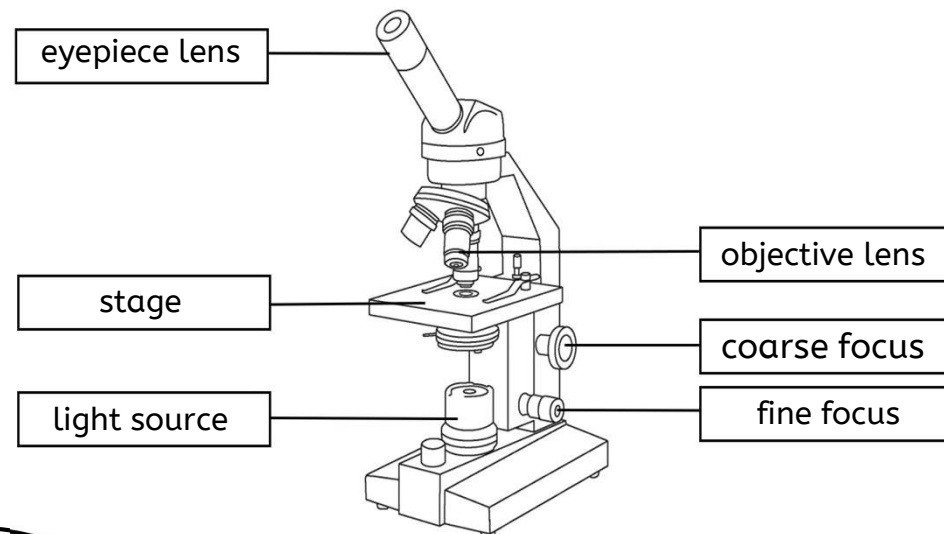
## The seven common processes of living organisms

Process	Definition
Movement	Moving itself or its parts to change position or location.
Reproduction	Producing offspring of the same kind.
Sensitivity	Sensing and responding to changes in their surroundings.
Growth	Increasing in size and repairing parts that are damaged.
Respiration	Using oxygen and glucose (a sugar) to provide energy.
Excretion	Removal of waste substances that are no longer needed.
Nutrition	Using food or other nutrients like water to stay alive.

## Levels of organisation

Levels of organisation	
<div style="display: flex; justify-content: space-around; align-items: center;"> <div style="border: 1px solid black; padding: 2px 5px;">cell</div> <span>→</span> <div style="border: 1px solid black; padding: 2px 5px;">tissue</div> <span>→</span> <div style="border: 1px solid black; padding: 2px 5px;">organ</div> <span>→</span> <div style="border: 1px solid black; padding: 2px 5px;">organ system</div> </div>	
cell	The smallest living building block of organisms.
tissue	A group of similar cells that work together to perform a specific function.
organ	A structure made up of different types of tissues that work together to carry out a specific function.
organ system	A group of organs that work together to perform a common function.

## The parts of the microscope

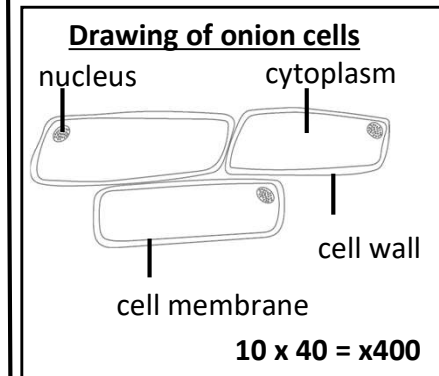


Total magnification = eyepiece x objective

## Using a microscope

1. Turn the **objective lens** to the **lowest magnification**.
2. Secure the slide on the **stage** using the clips.
3. Move the **stage** up to the **objective lens** by turning the **coarse focus**.
4. Look down the **eyepiece lens** and move the stage away by turning the **coarse focus**.
5. To make the image sharper and clearer, turn the **fine focus**.
6. Rotate the **objective lens** to get a higher magnification.

## Rules for scientific drawings of cells

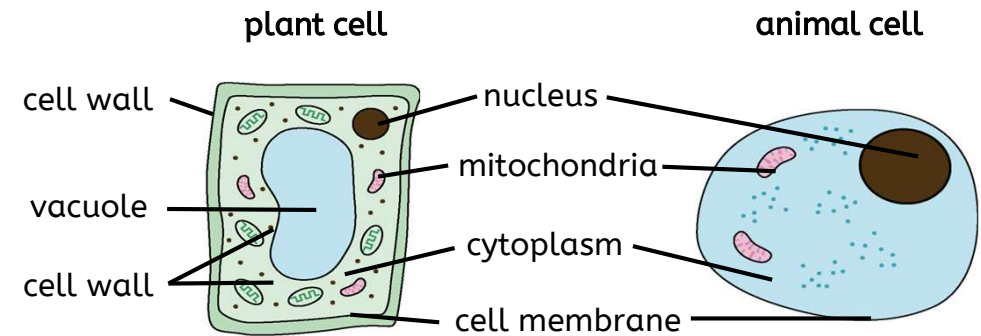


- smooth continuous lines
- large, with the same proportions
- stippling
- a few cells
- title and label
- total magnification

# Cells and organisation

## Cell organelles and their functions

nucleus	Contains the genome which controls the cell's activities.
cytoplasm	Where the chemical reactions of the cell take place.
mitochondria	Where energy is released in respiration.
cell membrane	Controls which substances enter or leave the cell.
vacuole	Stores a watery sap.
cell wall	Strengthen and support the cell.
chloroplasts	Where light is trapped for photosynthesis to happen.



Cells are three dimensional (3D).

## The rate of diffusion

The rate of diffusion means how fast diffusion happens. Three factors that can affect the rate of diffusion are **temperature**, the **concentration** of particles and **surface area**.

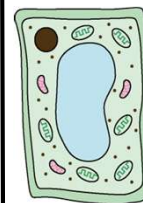
- The higher the temperature, the faster the rate of diffusion.
- The bigger the difference in the concentration of particles, the faster the rate of diffusion.
- The larger the surface area, the faster the rate of diffusion.

## Needs of plants and animals for survival

- Plants need oxygen, water, light, carbon dioxide, minerals, a suitable temperature, and space to grow.
- Animals, including humans, need water, oxygen, nutrients and the right temperature to survive.
- Plants and animals need these to keep all the cells that make them up alive and functioning properly.

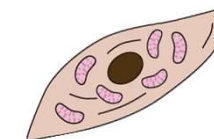
**Oxygen** and **glucose** (a sugar) are needed for **respiration** to take place in cells, to provide energy to keep cells alive. These useful substances enter the cell by **diffusion**. Waste products of respiration are carbon dioxide and water. Waste products leave the cell by diffusion and need to be removed from cells to keep them alive.

## Specialised cells are adapted to carry out a specific function



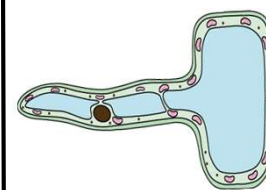
### Palisade cell

**Lots of chloroplasts** that absorb light for photosynthesis. **Column shape** to pack more in the leaf.



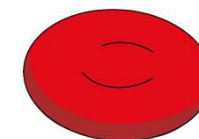
### Muscle cell

**Lots of mitochondria** to release energy for contraction.



### Root hair cell

**A long cell membrane** that provides a large surface area to absorb more water and minerals.



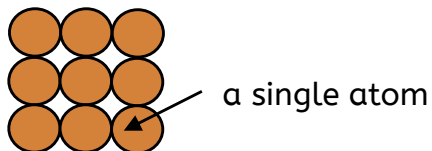
### Red blood cell

**No nucleus** for space to carry more oxygen.

# Chemical changes

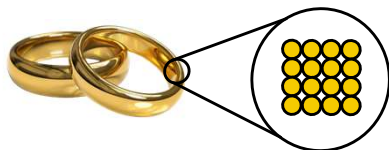
## Atom

The smallest particle of matter, which all things are made of.

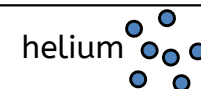


## Element

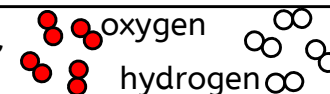
A pure substance that is made of only one type of atom. All atoms of an element are identical, e.g. Gold is an element made up of gold atoms only. The 118 known elements are listed on the periodic table of elements.



The atoms of some elements do not join together, but instead they stay as separate atoms, e.g. helium.



The atoms of other elements join together to make **molecules**, e.g. oxygen and hydrogen.



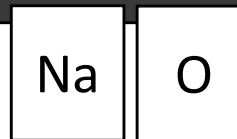
## Properties of elements

Individual atoms do not have the properties of the element. The properties of an element are because of the arrangement and behaviour of the atoms as a group.

Metals	Non-metals
most are shiny	most are dull
most are hard	solid non-metals are soft and easy to cut, <b>except carbon as diamond</b>
most are strong	most are not strong
most are sonorous (makes a ringing sound when hit)	most are not sonorous
malleable (easy to reshape without breaking)	not malleable
most are ductile (can be drawn out into a long wire without breaking)	not ductile
most have very high melting and boiling points	most have very low melting and boiling points
some but not all are magnetic	not magnetic
conduct electricity	non-metals do not conduct electricity, <b>except carbon as graphite</b>
good at conducting heat	poor at conducting heat

## Writing element symbols

The first letter is always written as a capital letter and if there is a second letter, it is always written as a lowercase letter. Element symbols make writing elements easier and allow scientists all over the world to communicate and write about them.



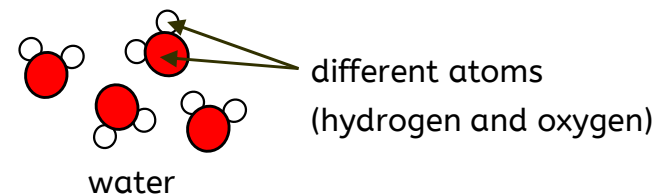
sodium oxygen



# Chemical changes

## Compound

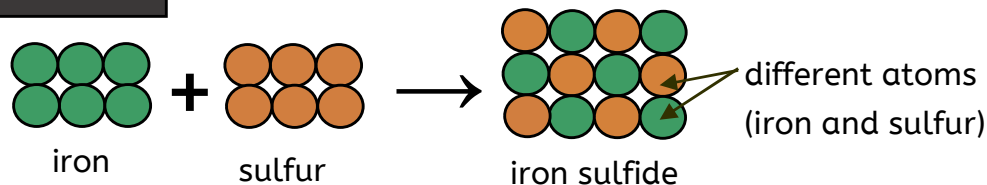
A substance made of two or more different elements chemically joined (bonded) together. A chemical bond is a strong force that holds atoms together in a compound. Lots of energy is needed to break a chemical bond. A compound cannot be easily separated. A compound may have very different properties to those of the elements from which it is made. Water is a compound of hydrogen and oxygen. Each of its molecules contains two hydrogen atoms and one oxygen atom.



## Chemical reactions

When chemicals react, the atoms are rearranged.

For example, iron reacts with sulfur to



make iron sulfide. Iron sulfide, the compound formed in this reaction, has different properties to the elements it is made from.

	iron	sulfur	iron sulfide
Type of substance	element	element	compound
Colour	silvery grey	yellow	black
Is it attracted to a magnet?	yes	no	no

## Conservation of mass

Atoms are not destroyed nor created during chemical reactions, so in any reaction:  
**Total mass of reactants = total mass of products**

## Naming metal and non-metal compounds

The metal element (furthest left on the periodic table) comes first in the name of the compound. The ending for the non-metal is shortened and changed to '-ide'. E.g. iron + sulfur → iron sulfide

## Naming three element compounds containing oxygen

The metal element (furthest left on the periodic table) comes first in the name of the compound. If there are three elements in the compound, and one of them is oxygen, the ending of the non-metal is shortened and changed to '-ate'. E.g. lithium + nitrogen + oxygen → lithium nitrate

## Chemical formulae

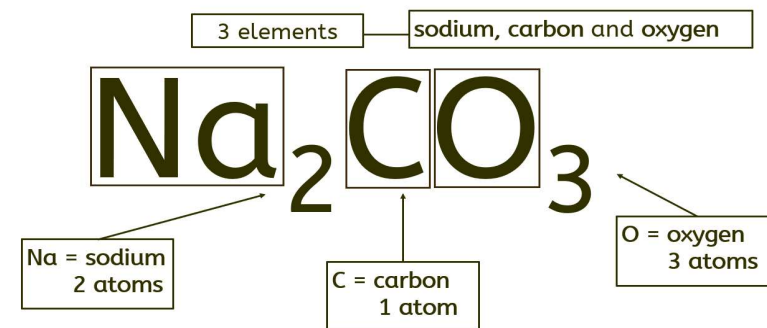
A chemical formula uses chemical symbols and numbers to show how many of each atom is present in a compound.

The small numbers (subscript) go at the bottom.

For example:

CO<sub>2</sub> is correct;

CO2 and CO<sup>2</sup> are wrong.



The formula for sodium carbonate is Na<sub>2</sub>CO<sub>3</sub>. It tells you that sodium carbonate contains two sodium atoms (Na x 2), one carbon atom (C) and three oxygen atoms (O x 3).

# Chemical changes

## Chemical equations

We summarise chemical reactions using equations:

reactants → products

- **Reactants** are shown on the **left** of the arrow;
- **Products** are shown on the **right** of the arrow.

**Do not** write an '=' sign instead of an arrow.

If there is more than one reactant or product, they are separated by a '+' sign. For example:

copper + oxygen → copper oxide

**Reactants:** copper and oxygen  
**Products:** copper oxide

A **word equation** shows the names of each substance involved in a reaction and **must not include any chemical symbols or formulae**.

## Oxidation reactions

In oxidation reactions, a substance gains oxygen. Metals and non-metals can take part in oxidation reactions (be oxidised).

Magnesium reacts with oxygen to form magnesium oxide:  
magnesium + oxygen → magnesium oxide  
 $2\text{Mg(s)} + \text{O}_2\text{(g)} \rightarrow 2\text{MgO(s)}$

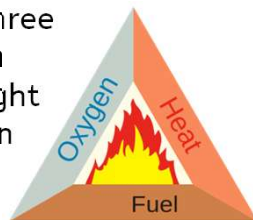
Carbon reacts with oxygen to form carbon dioxide:  
carbon + oxygen → carbon dioxide  
 $\text{C(s)} + \text{O}_2\text{(g)} \rightarrow \text{CO}_2\text{(g)}$

Another example is a combustion reaction, where we burn fuels in oxygen:

**Fuel + oxygen → carbon dioxide + water**

**methane + oxygen → water + carbon dioxide**

- Combustion is another name for burning fuels.
- It is an exothermic reaction.
- The fire triangle shows three components which, when combined, provide the right conditions for combustion to happen.



## Thermal decomposition reactions

This is the breaking down of a substance, using heat, to form two or more products. It is an endothermic reaction. Many metal carbonates take part in thermal decomposition reactions. For example, copper carbonate:

copper carbonate is green; copper oxide is black.  
**copper carbonate → copper oxide + carbon dioxide**  
 $\text{CuCO}_3\text{(s)} \rightarrow \text{CuO(s)} + \text{CO}_2\text{(g)}$

## Exothermic and Endothermic reactions

- **Exothermic** reaction - **transfers** energy to the thermal store of the surroundings. This causes a **rise** in temperature (**positive** temperature change).
- Hand warmers transfer energy to the thermal store of the surroundings by an exothermic oxidation reaction.
- **Endothermic** reaction - **transfers** energy in from the thermal store of the surroundings. This causes a **drop** in temperature (**negative** temperature change).
- Sports injury packs transfer energy from the thermal store of the surroundings by an endothermic reaction.

Temperature data collected from exothermic and endothermic reactions can be improved by:

- Using a **polystyrene** cup as an insulator, as it reduces energy transfers to or from the surroundings.
- Using a **lid** to reduce energy transferred from the surface.
- Using a **digital thermometer**, which is easier to read than a regular thermometer and, if it measures in decimal places, also has better resolution.

**State symbols** in chemical formulae provide information about the physical state of the reactants and products.

(s) – solid, (l) – liquid, (g) – gas, and (aq) – aqueous solution (i.e. dissolved in water).

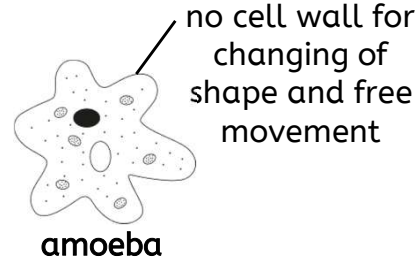
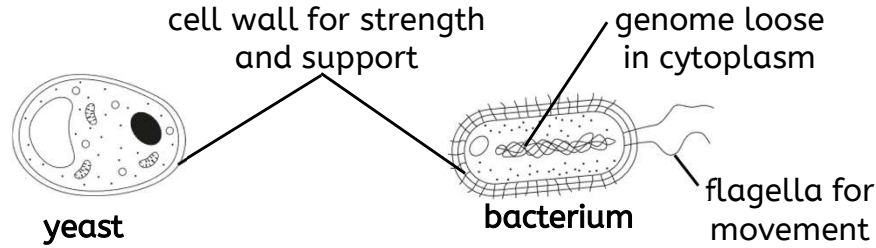
The state symbol comes after the chemical formula and is written in lower case and in brackets. E.g.  $\text{CuCO}_3\text{(s)} \rightarrow \text{CuO(s)} + \text{CO}_2\text{(g)}$



# Organ systems

**Unicellular** organisms are made of only one cell (e.g. bacteria, amoeba and yeast).

- They can carry out the 7 life processes of living organisms, all in one cell.
- Unicellular organisms share common organelles, but they also have adaptations.
- Unicellular organisms can be helpful or harmful.
- Unicellular organisms use diffusion to exchange substances.



- Used in baking
- Used to make alcoholic drinks

- Supports digestion
- Used to make cheese and yoghurt

## Gas exchange system

Air is a mixture of gases, including oxygen and carbon dioxide.

**Multicellular** organisms are made of many cells (e.g. plants and humans).

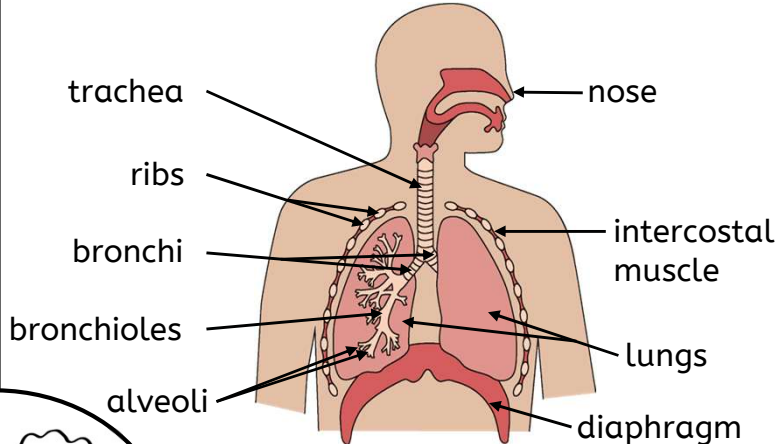
- They are larger and more complex than unicellular organisms.
- They cannot rely on diffusion alone for exchanging substances.
- Multicellular organisms depend on tissues, organs, and organ systems working together to exchange and transport substances to cells of the body, to keep cells alive.
- Organ systems in humans include the **gas exchange system, digestive system, circulatory system, skeletal system and muscular system.**

Breathing involves changes in pressure and volume inside the chest, helped by the movement of intercostal muscles and diaphragm, which causes the movement of the ribcage.

**Vital capacity** is the maximum volume of air exhaled after inhaling fully and can be used to estimate lung volume.

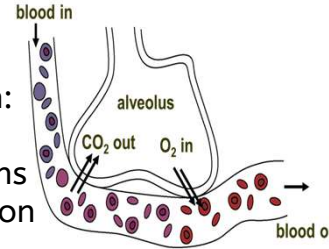
	Inhalation	Exhalation
Intercostal muscles	contract	relax
Ribcage	pulled up and out	released down and in
Diaphragm	contracts and moves downwards	relaxes and moves upwards
Volume in the chest	increases	decreases
Pressure in the chest	decreases	increases
Movement of air	into the lungs	out of the lungs

The human gas exchange system allows for the exchange of oxygen and carbon dioxide between an organism and its environment. Inhaled air contains more oxygen than exhaled air. Exhaled air contains more carbon dioxide than inhaled air. Oxygen moves from the alveoli into cells and then into the blood vessels (capillaries), while carbon dioxide moves in the opposite direction via diffusion.



Alveoli are adapted for efficient diffusion:

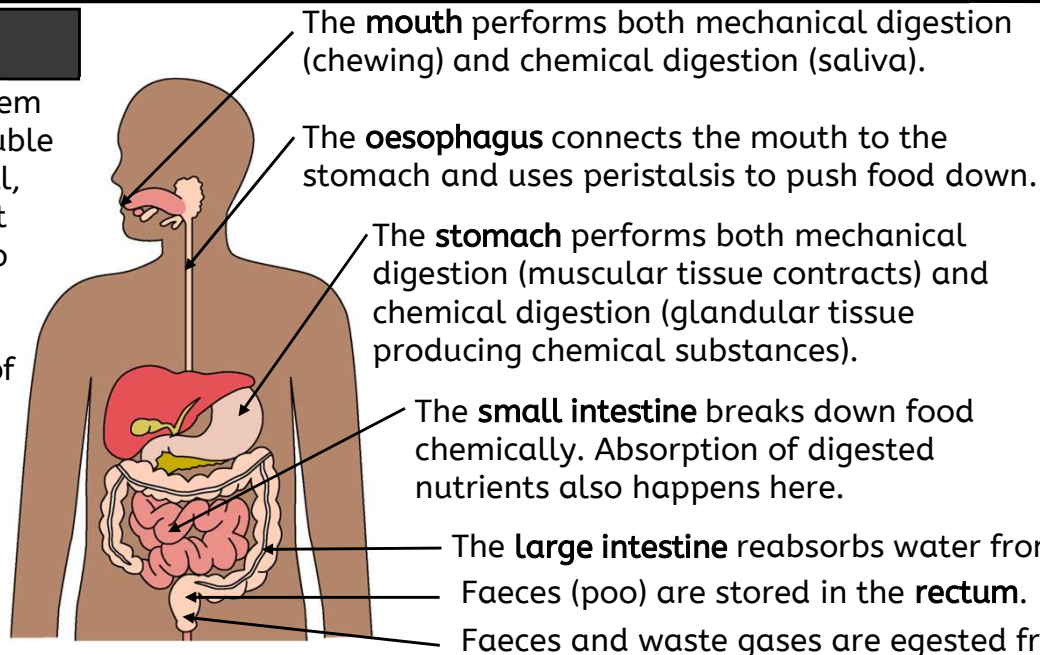
- **good blood supply** maintains the concentration difference
- **large surface area** for faster rate of diffusion
- **thin walls** (one cell thick) to provide a shorter diffusion pathway



# Organ systems

## Digestive system

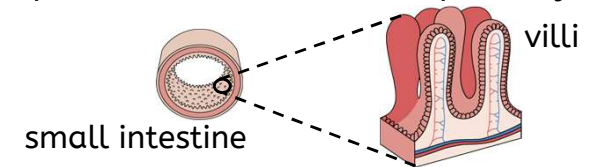
- The human digestive system breaks down large, insoluble food molecules into small, soluble molecules so that they can be absorbed into the blood.
- Mechanical digestion:** the physical breakdown of food into smaller pieces.
- Chemical digestion:** the use of chemical substances to break food down into smaller molecules.



### Adaptations:

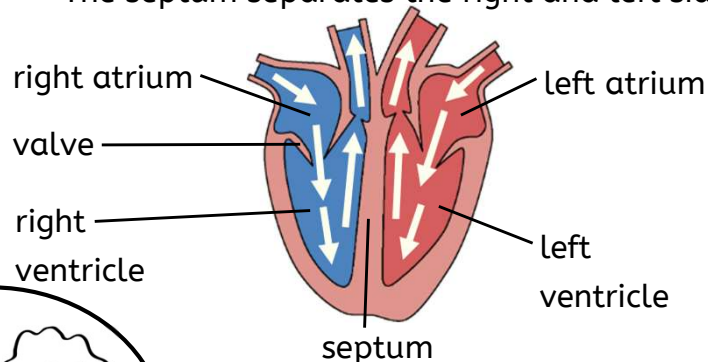
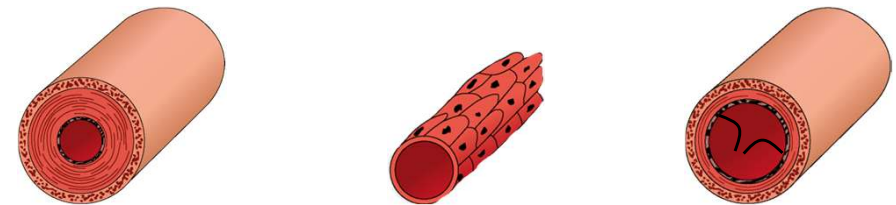
The small intestine is covered in many villi for efficient absorption by diffusion:

- villi provide a **large surface area** for faster rate of diffusion
- villi have **good blood supply** to maintain the concentration difference
- villi have **thin walls** (one cell thick) to provide a shorter diffusion pathway



## Circulatory system

- The circulatory system transports useful molecules and waste around the body. The human circulatory system consists of the heart, blood and blood vessels.
- The heart has four chambers: two atria and two ventricles.
- Valves ensure blood flows in the right direction.
- The septum separates the right and left sides of the heart.



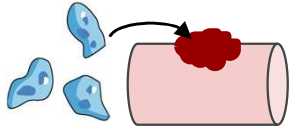
The heart pumps oxygenated blood from the lungs to the body and deoxygenated blood from the body to the lungs (double circulatory system).

Arteries	Capillaries	Veins
<ul style="list-style-type: none"> <li>Blood taken away from heart</li> <li>High pressure blood</li> <li>Thick muscular and elastic walls</li> <li>Small lumen</li> </ul>	<ul style="list-style-type: none"> <li>Exchange substances between blood and cells</li> <li>Very low pressure blood</li> <li>Very thin walls (one cell thick)</li> <li>Very small lumen</li> </ul>	<ul style="list-style-type: none"> <li>Blood brought back to heart</li> <li>Low pressure blood</li> <li>Thin walls</li> <li>Large lumen</li> <li>Valves prevent back flow</li> </ul>

# Organ systems

## Circulatory system (continued)

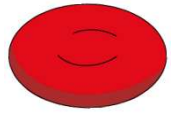
Blood is a fluid that transports substances, useful molecules and waste around the body. Blood helps the body to defend against diseases and to form scabs to heal cuts.



**Platelets** help with blood clotting for wound healing.



**Plasma** carries the other blood parts, nutrients, waste and carbon dioxide. It is yellow coloured and mostly water.



**Red blood cells** carry oxygen to all the cells of the body.



**White blood cells** help defend against disease.

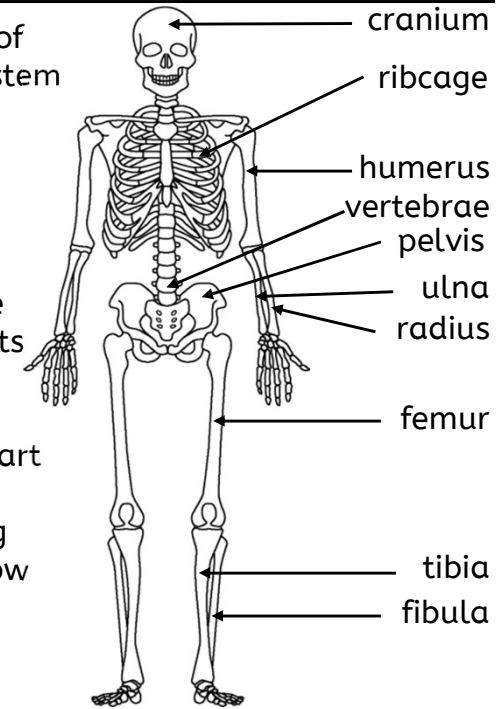
Red blood cells, white blood cells and platelets are made in the **bone marrow** - soft tissue inside large bones protected by the hard part of the bone around it.

### Adaptations of the red blood cells:

- biconcave shape → large surface area for faster oxygen diffusion
- contains haemoglobin → carry oxygen
- no nucleus → space for more haemoglobin → more oxygen

## Skeletal system

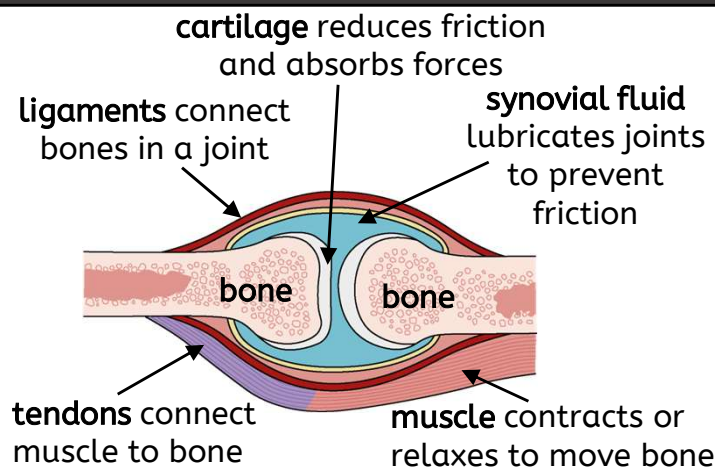
Four functions of the skeletal system are **support, movement, making new blood cells and protection** of organs (e.g. the cranium protects the brain and the ribcage protects the heart and lungs). **Bones** are living tissues that grow and change.



## Joints, muscles and movement

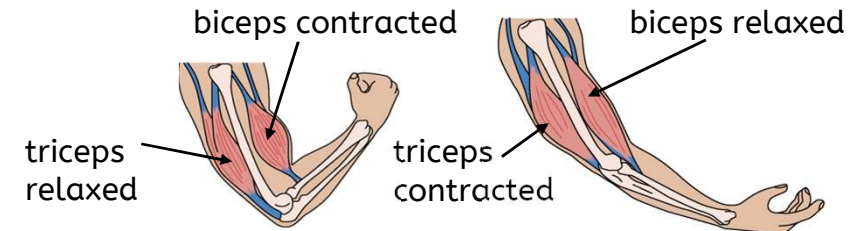
A joint is the point where two or more bones meet in the body. Joints connect bones and allow the body to move and bend. Different joint types allow various movements:

- **hinge joint:** movement backwards and forwards e.g. the knees and elbows
- **ball-and-socket joint:** movement in many directions e.g. the hips and shoulders
- **pivot joint:** twisting movement around a fixed point e.g. the neck
- **fixed joint:** does not allow for any movement e.g. in the cranium



Ageing can lead to joint wear, inflammation and arthritis. Arthritis causes joint pain and affects synovial fluid and cartilage.

- Muscles can **only pull**, they cannot push;
- Muscles work in **antagonistic muscle** pairs. When one muscle contracts to pull the bone in one direction, the other muscle relaxes to allow movement.

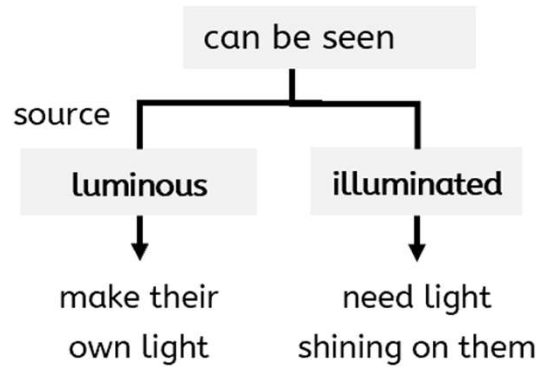


- The way in which muscles and bones work together to exert forces is called **biomechanics**.
- **Muscle strength** varies based on muscle size, age, sex, training, nutrition and injury.

# 7.06: Sound and light

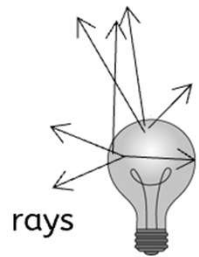


## Describing light



- Light cannot be seen directly as it travels.

## Light travels



- away from source
- from every point
- in all directions
- very fast

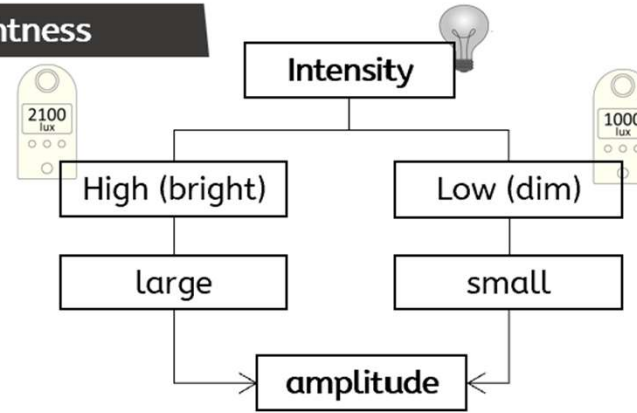
Light is constantly emitted from a source that is 'on'.

Light fills an enclosed space.

Darkness is the absence of light.

Light is the transfer of energy by the radiation pathway to its surroundings so that a region is lit up.

## Brightness

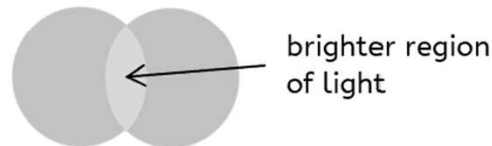


- Some sources transmit more energy away in a given time.

- Light spreads out from a source.
- Brightness decreases with distance.

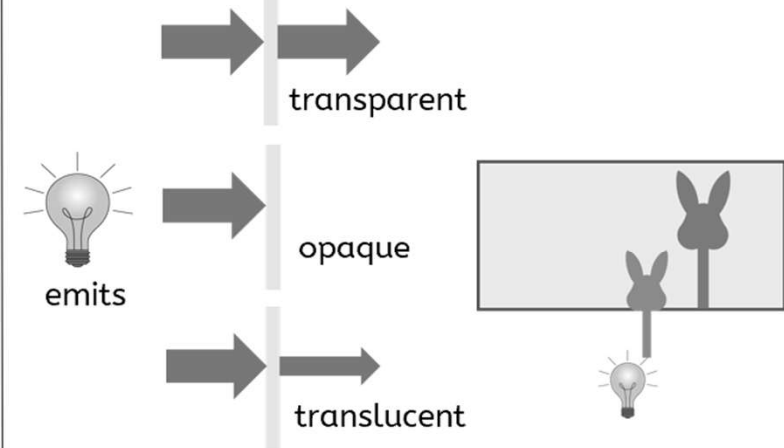
Light meter measures brightness in lux.

- Light from multiple sources falling on a screen is brighter than one.



## Different media

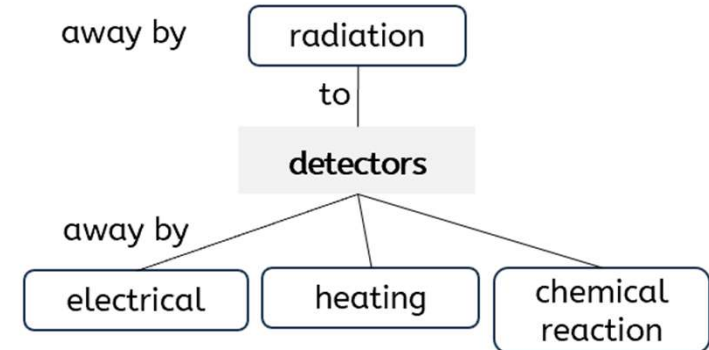
- Light is transmitted through any transparent media, including a vacuum.



- All materials absorb some energy from light.
- Opaque objects transmit nothing (forming shadows)

## Energy pathways

- From a source, light travels ...

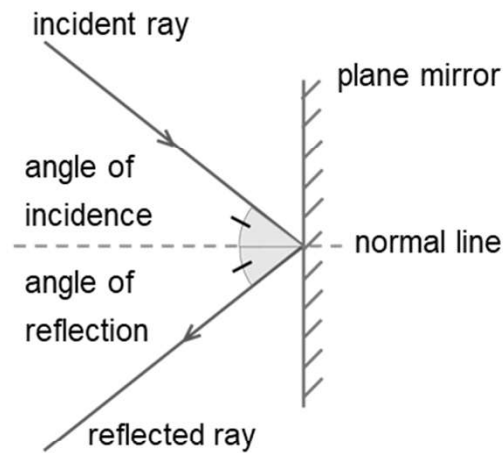


## 7.06: Sound and light

### Light reflecting

- All surfaces reflect light and obey the **law of reflection**.

the angle of incidence = the angle of reflection



specular reflection



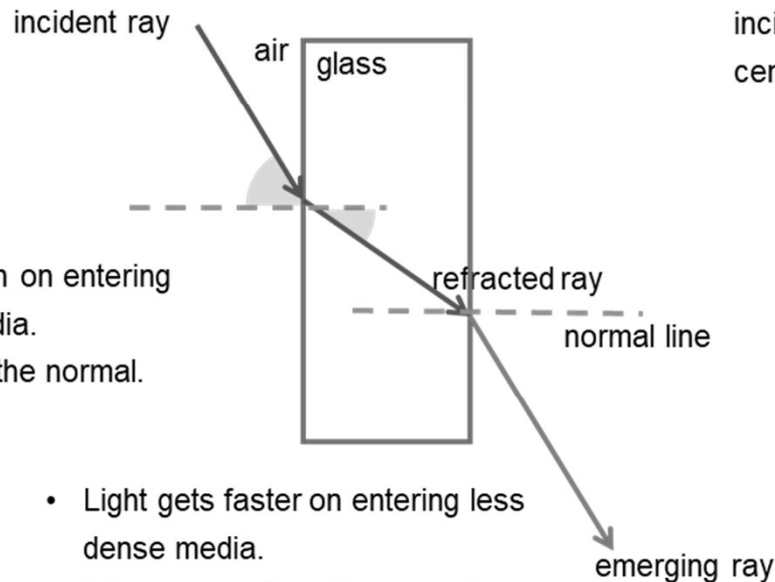
diffuse reflection

- Most surfaces reflect light **diffusely** (scatter it).

### Light refracting

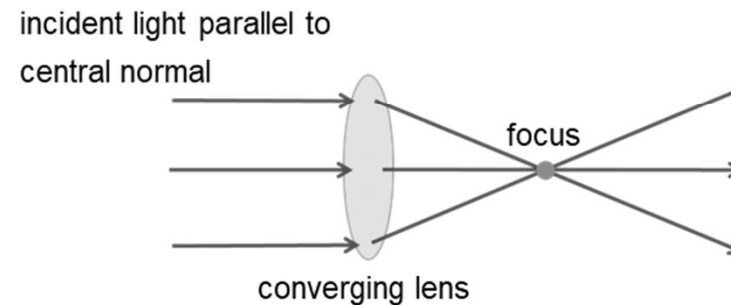
As the angle of incidence increases, there is more refraction.

- Light slows down on entering more dense media.
- It turns towards the normal.



- Light gets faster on entering less dense media.
- It turns away from the normal.

Converging lenses form a focus and Lenses can form a clear image.



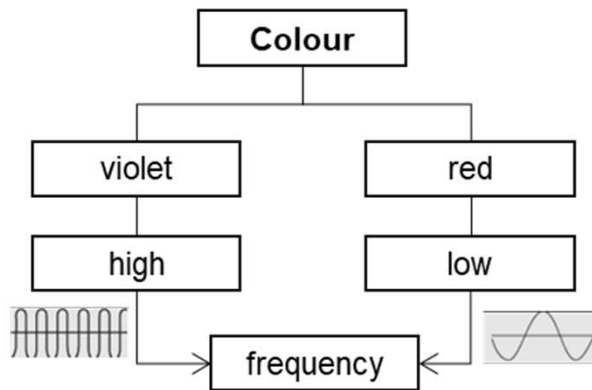
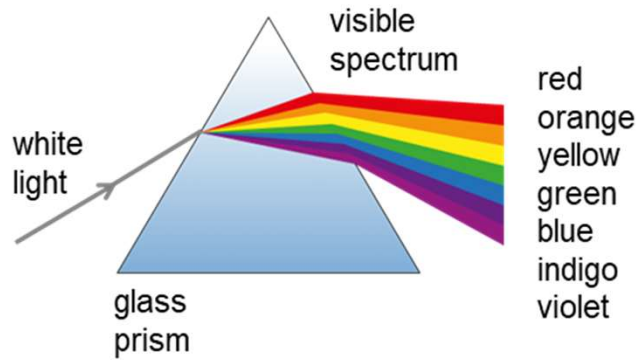
- The focal length is the distance from lens to focus, or lens to image.
- Thicker lenses (more curved) refract more, have a closer focus and longer focal length.



# 7.06: Sound and light

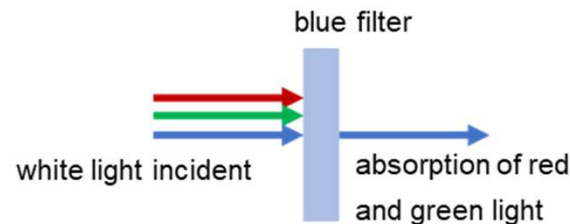
## Coloured light

- Luminous objects emit light of particular colours.
- Most common sources emit white light.



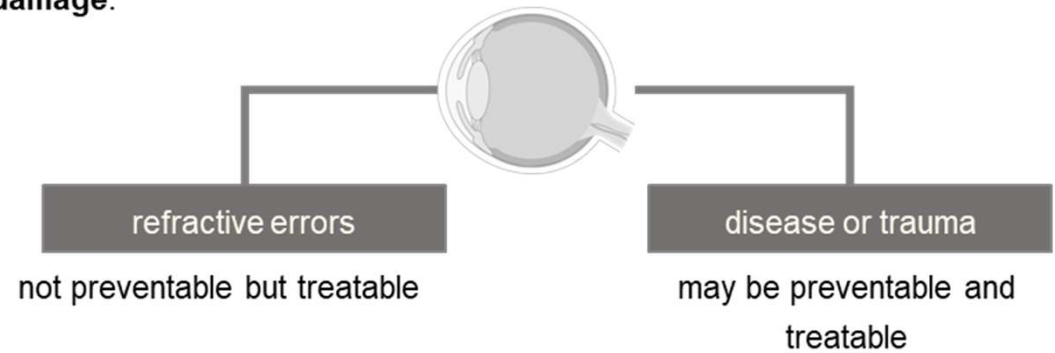
### Coloured filters:

- transparent objects
- transmit own colour
- selectively absorb any other colour of incident light



## Seeing differences

Many problems with our vision are caused by parts of the eye that are not the right **shape** or **size**, that have become **cloudy**, or due to **cell damage**.



**People with low vision** may use:

Long canes, guide dogs, talking books, Braille or other assisted devices.



Light from the Sun can be dangerous:

- Never look directly at the Sun.
- Wear sunglasses in bright sunlight.
- Protect the skin too.



## 7.06: Sound and light

### Images

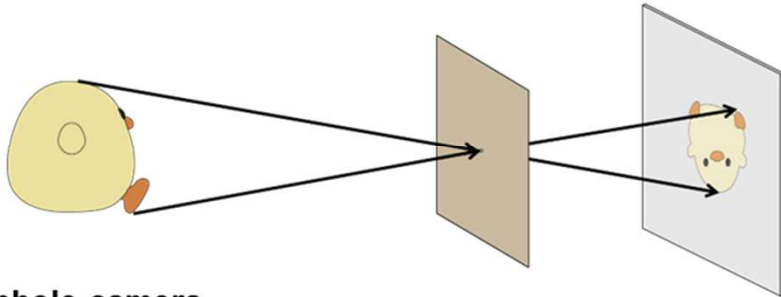


Image is:

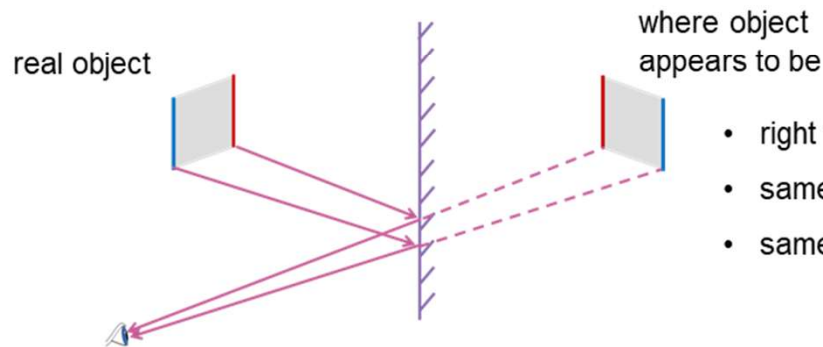
- inverted
- dim
- diminished.

### Pinhole camera

- Some light from each point of the object facing, passes through the pinhole.
- The pinhole only allows a narrow beam through, from each point.
- Light from each point crosses over as it passes through the pinhole.
- Light from every point falls on the screen forming a complete image.

### Mirror image

- Light from every point of real object reflects into eye.
- Brain interprets reflected light as originating from behind mirror.



- right way up
- same size
- same distance

### Images from lenses

- Some light from each point refracts through the lens.
- Light from each point arrives at specific points on the surface forming an image.

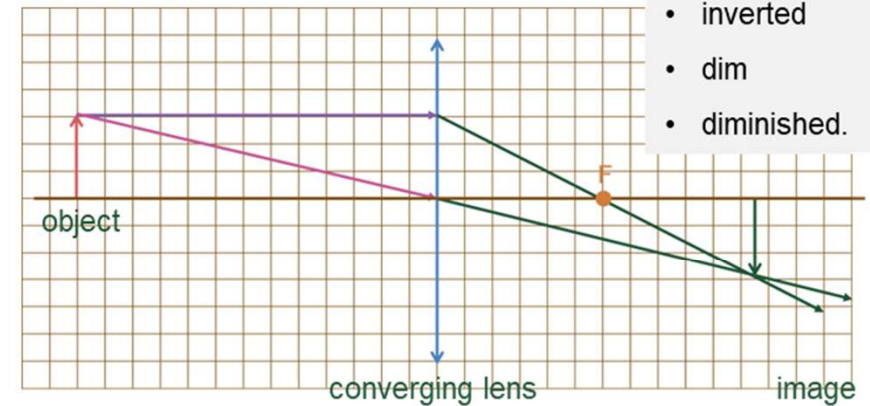


Image is:

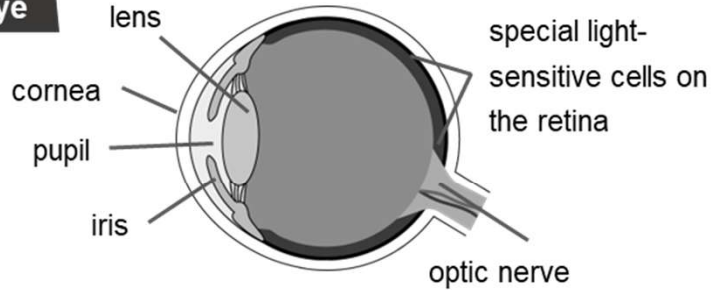
- inverted
- dim
- diminished.

- A partially covered lens still forms an image, but dimmer.



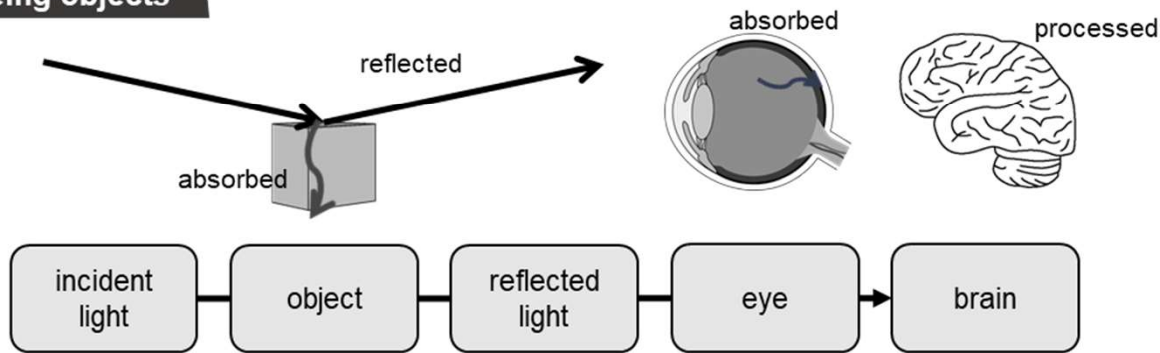
# 7.06: Sound and light

## The human eye



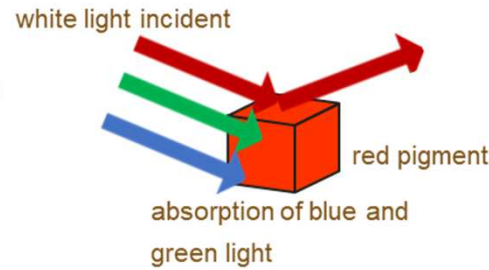
cornea	refracts light before it enters the eye
iris	controls the size of the pupil
pupil	lets light enter the eye
lens	refracts light to form an image
retina	made up of cells that detect light
optic nerve	carries electrical signals to the brain

## Seeing objects

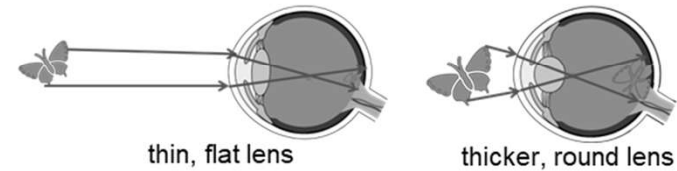


## Seeing coloured objects

- If an opaque object is coloured, it has pigments which absorb specific colours.
- absorbs any colour different not in the pigment
- appears the colour of any scattered light



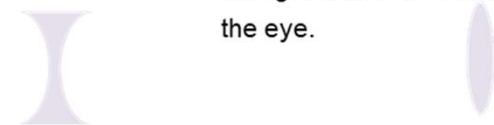
## Seeing at different distances



- The lens shape changes as needed.

## Refraction errors of the eye

- |   |   |
|---|---|
| <p>short-sightedness</p> <ul style="list-style-type: none"> <li>• eye too long or the cornea too extended: focus in front of retina</li> </ul> <p>Glasses to spread out the light before it enters the eye.</p> | <p>long-sightedness</p> <ul style="list-style-type: none"> <li>• eye too short or the cornea too rounded: focus behind the retina</li> </ul> <p>Glasses to converge the light before it enters the eye.</p> |
|---|---|



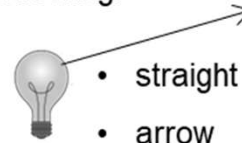
# 7.06: Sound and light

## Scientific models

Representations of reality that can be used to explain observations

### The ray model of light

- Rays are imaginary lines, **drawn to represent** the path light is travelling.
- From an infinite number, **a few** are chosen to be drawn.



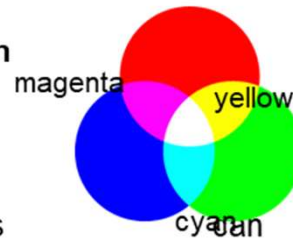
### The 'passive-eye' model of vision

- Objects emit or reflect light into the eye.



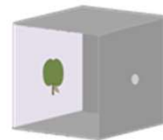
### The 'three primary colours' model of human colour vision

- eye has three types of sensor cell
- detect: red, green and blue, the primary colours of light
- directed at a white screen, combinations of primary colours appear as secondary colours or white (and more)



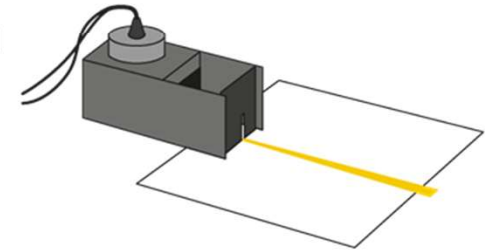
### The pinhole camera as a model for the eye

- Light enters through the pinhole similar to the pupil.
- Light 'crosses over' at the pinhole, similar to the lens.
- Light from the object falls on the screen, similar to the back of the eye.



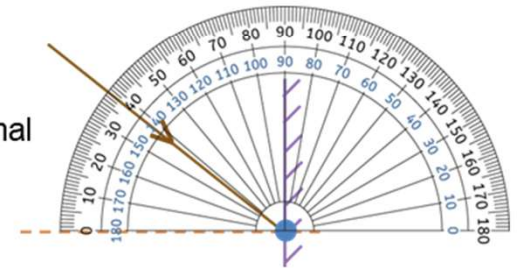
## Using a raybox

- Raybox and comb, connected to a power supply
- Draw crosses (avoiding likely measurement errors).
- Plot and label rays.



## Measuring angles

- centre at vertex
- scale starting at 0° on normal line
- read up from 0°



## Trusted scientific research

### High-quality data

- Well-chosen method
- Appropriate resolution
- Multiple measurements
- Repeatable
- Reproducible
- Appropriate range
- Systematic intervals

### Trustworthy conclusions

Process and display collected data

Describe data from table or chart


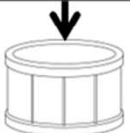
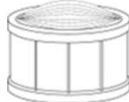
Explain interpreted data

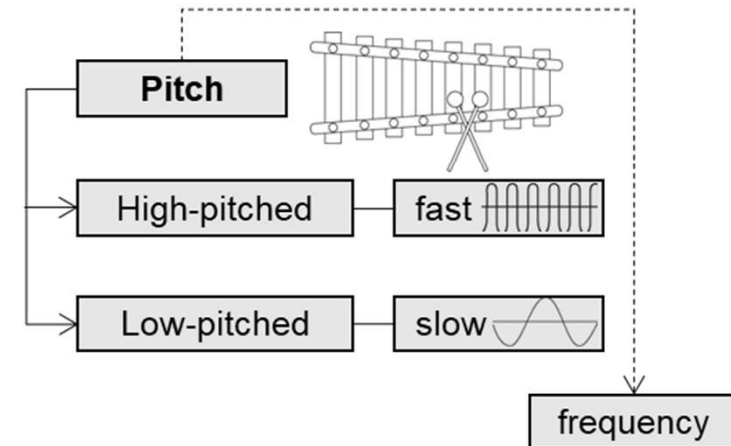
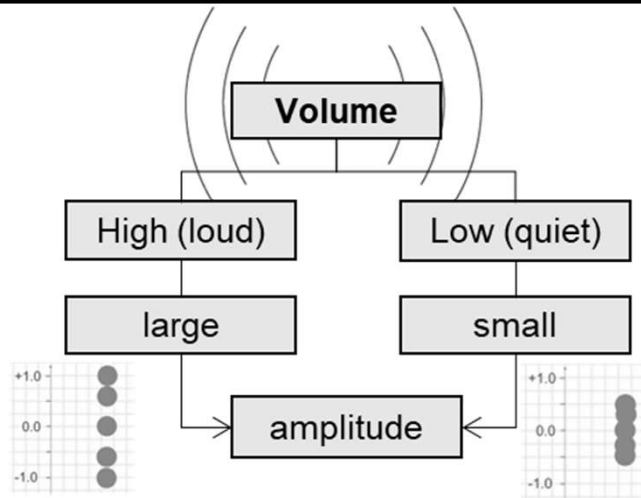


# 7.06: Sound and light

## Describing sound

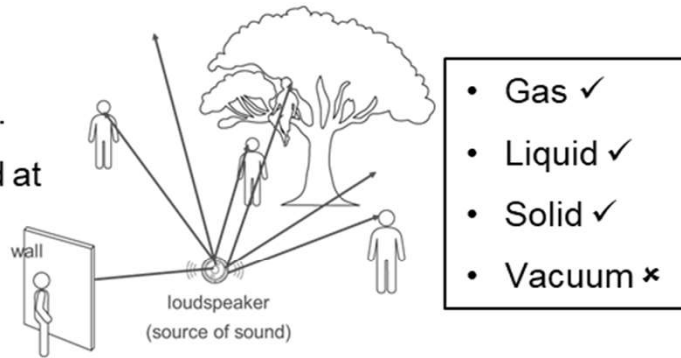
### Sources of sound

		
No sound	Force exerted	Vibrating matter



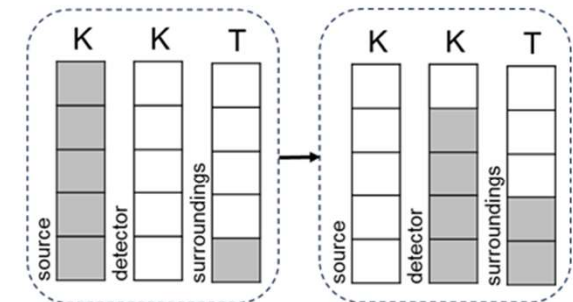
## Vibrations travel through matter

- Travel in **all directions** from a source.
- Can be observed by **detectors** placed at a distance.
- If blocked, a **shadow region** occurs.
- Fastest in solids, slowest in gases.



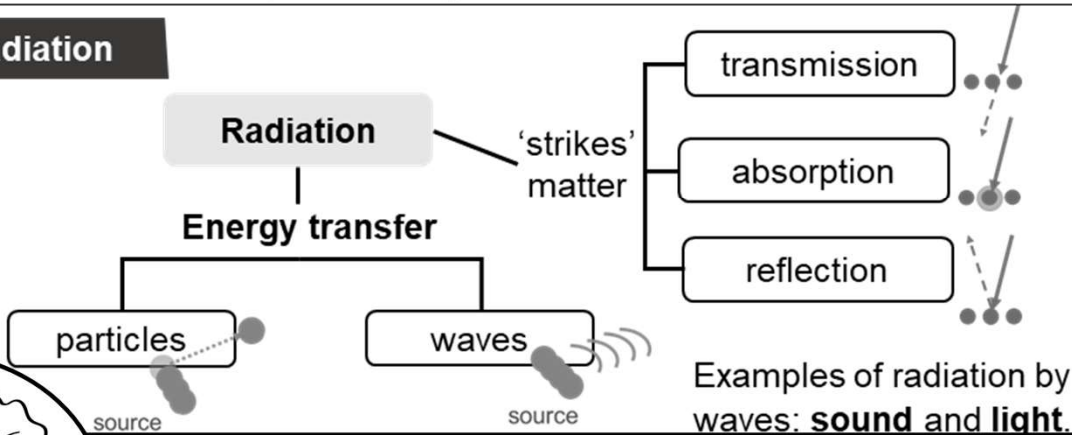
## Energy transfer

- As vibrations travel, the energy store of the source decreases.
- The energy store of the matter increases.
- The kinetic store of any detector increases.
- By the **mechanical** pathway.



- The thermal store of the surroundings also increases.

## Radiation



# 7.06: Sound and light

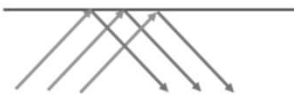
## Vibrations get less with distance



- Energy **spreads out** among more particles.
- Each **particle absorbs** some energy, not passing it all on.
- If **all energy** is absorbed, a shadow region occurs.

## Reflections

smooth surface



rough surface



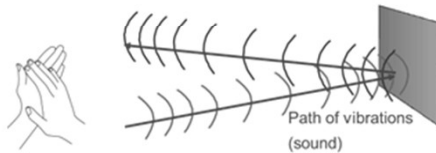
scattering

## Surfaces

- Smooth surfaces can build **noise**.
- Rough surfaces scatter sound so that it spreads out and quietens.
- Noise can be made worse by many reflections interacting, and better by using rough surfaces.

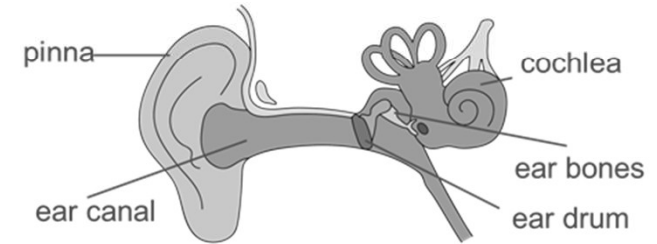
## Echoes

- A reflected sound is an echo.
- Some animals use echoes.



## The ear

## Hearing



## Sound in the ear

- The function:
  - **transfer energy** to the nervous system, as much as possible
  - from the vibrations in the air
  - to the inner ear,
  - so that the brain can perceive and interpret it.
- Energy transfer from the tiny hairs in the cochlea to the nerves is by the **electrical** pathway.

## Differences in hearing

- The **audible range** of human hearing is from about 20 Hz to 20 000 Hz.
- Above this is **ultrasound** and below this is **infrasound**.
- Different animals have different ranges of hearing.
- Exposure to loud sounds and ageing can contribute to hearing differences, e.g. deafness.

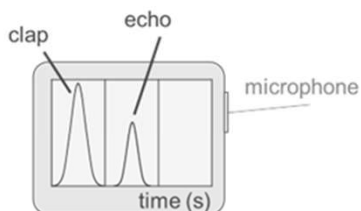


## 7.06: Sound and light

### Using technology to improve data quality

#### Measuring short times

- **Digital** clock reduces systematic error (no scale).
- **Datalogging** equipment:
  - reduces difficulty observing quiet sounds e.g. echoes
  - reduces difficulty judging when sound arrives (measures directly)
  - reduces reflex action delays
  - allows 'zoom in' on time scale.



### Using scientific knowledge

#### Echolocation

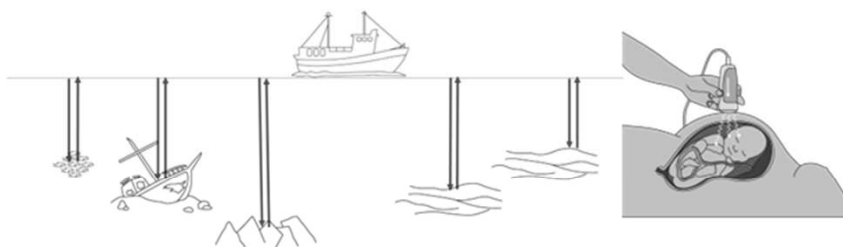
- Finding an object

#### Acoustic imaging

- Deep in the sea
- Inside living organisms (foetal scan)
- Inside solid objects

#### Hearing technology examples

- Hearing aids
- Hearing implants
- Hearing loops



We have more information, of better quality, with much less risk.

Reduce the chance of hearing damage by wearing ear protection and reducing volume of sounds.

### Observing by measurement

#### Quantities: and their units

Base quantities: length (m), mass (kg), time (s), temperature (K).

Derived quantities include force (N), **frequency (Hz)**, **loudness (dB)**.

#### Measuring instruments

- Include rulers, balances, clocks and thermometers.
- Measuring tapes are used to measure distances longer than a few metres.



#### Unit prefixes

- Standard prefixes change a number by multiples of 1 000, e.g. one *kilometre* is equal to 1 000 metres.
- The prefix **milli-** uses a multiple of 0.001, it means one thousandth:
  - one **millisecond** is one thousandth of a second (1 ms is easier to use than 0.001 s).
- A non-standard but common prefix is **centi-**, to mean one hundredth.
  - one centimetre is one hundredth of one metre (1 cm is easier to use than 0.001 m).



# Materials

Everything around us is made of materials. The material is what an object is made of, for example a cup can be made of glass, plastic or paper. Materials can be **natural** (found in nature), or **synthetic** (made by humans). The material that we choose to make an object from depends on its purpose. Understanding materials helps us select the right one for different uses, with the use depending on the property of the material.



glass cup



plastic cup



paper cup

## Ceramics

A ceramic is a non-metallic material that is formed by heating and cooling a soft substance, which transforms it into a hard material.

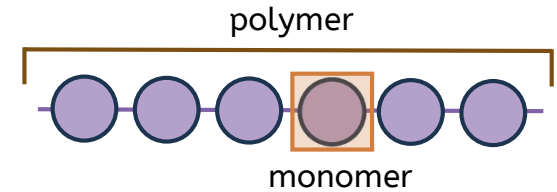
Clay ceramics are made by shaping wet clay while it's soft and then heating it to a high temperature and allowing it to cool, which causes it to harden.

Property	Examples of uses
<b>hard</b>	vases, statues and many other objects
<b>strong when compressed</b>	bricks used for building structures
<b>good electrical insulators</b>	outdoor electrical power-line insulators
<b>non-reactive with water</b>	mugs and dishes
<b>resistant to chemicals</b>	kitchen and bathroom tiles
<b>high melting points</b>	oven baking dishes, jet engine turbine blades

Ceramics are **brittle**, so they cannot be bent, and they shatter or break when hit, dropped, or if too much force is applied.

## Polymers

A polymer is a long chain molecule made of repeating units called monomers.



**Polymerisation** is the joining of monomers to form polymers.

**Natural polymers** occur naturally and are found in plants and animals e.g. cellulose in plant cell walls, starch in potatoes, wool from sheep, chitin that forms exoskeletons.

**Synthetic polymers** are manufactured using chemicals taken from crude oil e.g. polyester and nylon used in clothing, PVC used to make rain gutters, polyethene used for plastic bags.

An increased population increases demand for resources and raw materials. Raw materials, which are natural resources that are used to make other things, are running out e.g. crude oil used to manufacture synthetic polymers. Competition for and the reduction of raw materials like crude oil has ethical, social, economic and political consequences.

Polymers have common properties, like being in the solid state at room temperature.

Property	Examples of uses
<b>good electrical insulators</b>	casing around electrical wires
<b>chemically unreactive</b>	food containers
<b>durable</b>	shopping bags
<b>mouldable</b>	Plastic bottles



# Materials

## Polymers (continued)

Polymers can have very different properties.

- Polymers can have different properties when they are made of different monomers. This is because different monomers have different properties.
- Polymers can also have different properties when they have different length chains lengths. Longer polymer chains have higher melting points and are stronger.

Plastics and polymers can cause environmental and health problems:

- Many polymers take hundreds of years to degrade, accumulating in landfills and oceans.
- Improper disposal and littering of polymer products cause widespread pollution.
- Polymer chemicals may disrupt reproduction in organisms.

Global efforts like the plastic bag charge are being taken to address polymer-related environmental issues.

Polymers can be reused, recycled, incinerated, or sent to landfill. Each method has advantages and disadvantages, e.g. landfill takes up space and releases harmful gases.

## Composite materials

A composite material is a material that is made from two or more different types of material.

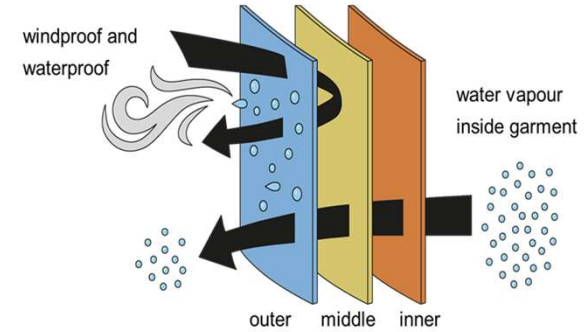
- The materials for a composite material are chosen because they have different properties that combine to make a more useful material with improved properties.
- Each material in a composite keeps its original properties, and the properties of those materials complement one another.

## Composite materials (continued)

The properties of composites make them suitable for specific applications e.g. breathable fabric used for outdoor activities.

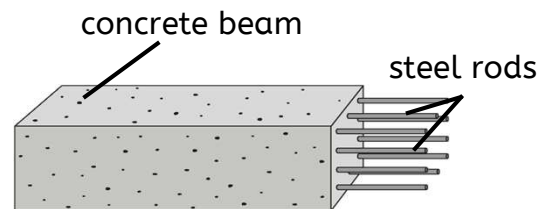
The exact properties and behaviour of a composite material will depend on:

- choice of materials
- the amounts used of each material
- the way each material is structured within the new composite material.



Reinforced concrete is a composite material because it is made from concrete and steel, which are two different materials.

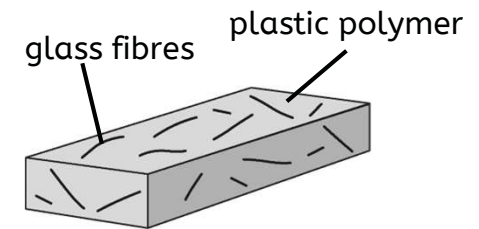
Reinforced concrete is strong in compression and tension. It is used for construction and for building.



material	property
concrete	strong in compression
steel	strong in tension

Fibreglass is a composite material because it is made from glass fibres and a plastic polymer, which are two different materials.

Fibreglass is strong in tension, lightweight and stiff. It is used for making kayaks and car body panels.



material	property
glass fibres	strong in tension and lightweight
plastic polymer	weak in tension and stiff

# Materials

## Scientific methods

Scientists use a scientific method to collect high-quality data to explain observations and answer questions.

A scientist might choose any of the four scientific methods:

- Testing a hypothesis by changing variables e.g. smoother surfaces cause less friction to act on objects sliding over them.
- Testing a hypothesis without changing variables e.g. as age increases, the likelihood of developing arthritis increases.
- Experimenting by changing variables without testing a hypothesis e.g. testing different elements to classify them as metals or non-metals.
- Observing phenomena without changing variables or testing a hypothesis e.g. biologists observing cells or astronomers observing planets.

## Measurement error

Random error is a measurement error that arises unpredictably from the experimental environment and cannot be controlled. As it is unpredictable, random error cannot be removed or corrected.

But the impact of random error can be minimised by taking multiple measurements, ignoring any anomalies and calculating a mean.

## Conclusions

It is important that a conclusion is based on the observed data and trends without making over-generalisations that extend beyond the scope of the experiment. This makes the conclusion more reliable. E.g. when testing polymer strengths, a statement such as “polymer C is always stronger than polymer B” would be an over-generalisation.

## Developing technology through scientific knowledge

Scientific advances have enabled workers in Science, Technology, Engineering, and Mathematics (STEM) fields) to further technology and industry by developing new tools and machines, and by making the production of goods in large quantities possible.

For example, being able to create new composite materials such as fibreglass has led to their use for car body panels, and these are mass produced, made in large quantities, every day.

## Developing scientific knowledge through technology

Technology developments have allowed scientists to learn more about materials.

Technology	What it allows scientists to do
Electron microscope	See the structure of materials down to the level of each atom.
Computer simulations	Simulate how ceramics behave under different conditions.
Three-dimensional (3D) printing machines	Quickly produce prototypes and test new ceramic designs.

Advancements in technology have improved scientific research by providing scientists with many ways of collecting high-quality data and communicating.

- Computer simulations allow scientists to test materials under different conditions.
- Cloud-based platforms (online tools) allow scientists all over the globe to communicate and collaborate.

