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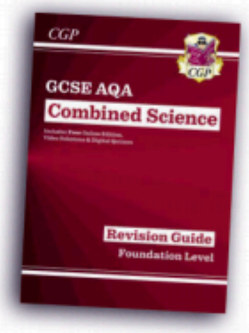
Revision Guide

Foundation Level

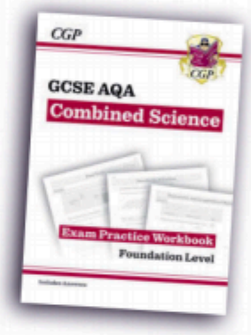
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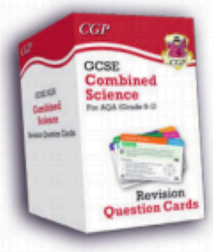
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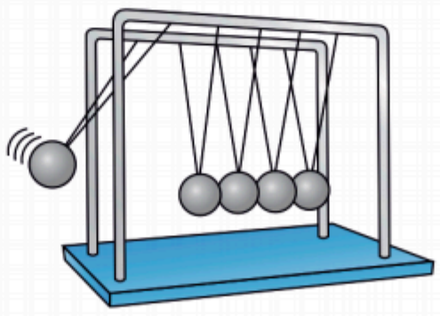
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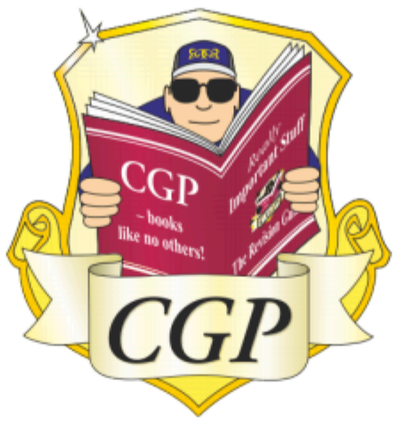
☐ One of these things



(It's a Science experiment and stress relief at the same time.)

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P.S. Science won't really make your brain explode. Probably.



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Revision Guide

Foundation Level

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A QR code next to a tip box question takes you to a **video** that talks you through solving the question. You can access **all** the videos by scanning this code here.

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Published by CGP.
From original material by Richard Parsons.

Editors: Emma Clayton, Mary Falkner, Katie Fernandez, Emily Garrett, Rob Hayman, Paul Jordin, Duncan Lindsay, Luke Molloy, Sarah Pattison, Joe Shaw and George Wright.

Contributor: Paddy Gannon.

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Printed by Elanders Ltd, Newcastle upon Tyne.
Clipart from Corel®
Illustrations by: Sandy Gardner Artist, email sandy@sandygardner.co.uk

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The Scientific Method

This section isn't about how to 'do' science — but it does show you the way most scientists work.

Science is All About Testing Hypotheses

Scientists make an observation.

1) Scientists OBSERVE (look at) something they don't understand, e.g. an illness.
2) They come up with a possible explanation for what they've observed.
3) This explanation is called a HYPOTHESIS.



Hundreds of years ago, we thought demons caused illness.

They test their hypothesis.

4) Next, they test whether the hypothesis is right or not.
5) They do this by making a PREDICTION — a statement based on the hypothesis that can be tested.
6) They then TEST this prediction by carrying out experiments.
7) If their prediction is right, this is EVIDENCE that their hypothesis might be right too.

Other scientists test the hypothesis too.

8) Other scientists check the evidence — for example, they check that the experiment was carried out in a sensible way. This is called PEER-REVIEW.
9) Scientists then share their results, e.g. in scientific papers.
10) Other scientists carry out more experiments to test the hypothesis.
11) Sometimes these scientists will find more evidence that the hypothesis is RIGHT.
12) Sometimes they'll find evidence that shows the hypothesis is WRONG.



Then we thought it was caused by 'bad blood' (and treated it with leeches).

The hypothesis is accepted or rejected.

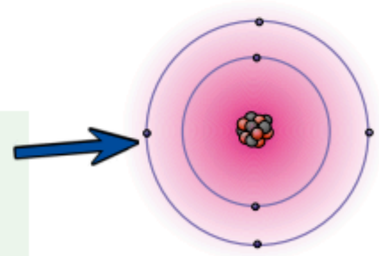
13) If all the evidence that's been found supports the hypothesis, it becomes an ACCEPTED THEORY and goes into textbooks for people to learn.
14) If the evidence shows that the hypothesis is wrong, scientists must:
    - Change the hypothesis, OR
    - Come up with a new hypothesis.



Now we know that illnesses that can be spread between people are due to microorganisms.

Theories Can Involve Different Types of Models

1) A model is a simple way of describing or showing what's going on in real life.
2) Models can be used to explain ideas and make predictions. For example:
    - The Bohr model of an atom is a simple picture of what an atom looks like.
    - It can be used to explain trends in the periodic table. (See p.107 for more.)



3) All models have limits — a single model can't explain everything about an idea.

I'm off to the zoo to test my hippo-thesis...

You can see just how much testing has to be done before something gets accepted as a theory. If scientists aren't busy testing their own hypothesis, then they're busy testing someone else's. Or just playing with their models.

Communication & Issues Created by Science

Scientific developments can be great, but they can sometimes raise more questions than they answer...

It's Important to Tell People About Scientific Discoveries

1) Scientific discoveries can make a big difference to people's lives.
2) So scientists need to tell the world about their discoveries.
3) They might need to tell people to change their habits, e.g. stop smoking to protect against lung cancer.
4) They might also need to tell people about new technologies. For example:

The discovery of molecules called fullerenes has led to a new technology that delivers medicine to body cells. Doctors and patients might need to be given information about this technology.

Scientific Evidence can be Presented in a Biased Way

1) Reports about scientific discoveries in the media (e.g. newspapers or television) can be misleading.
2) The data might be presented in a way that's not quite right — or it might be oversimplified.
3) This means that people may not properly understand what the scientists found out.
4) People who want to make a point can also sometimes present data in a biased way (in a way that's unfair or ignores one side of the argument). For example:

- A scientist may talk a lot about one particular relationship in the data (and not mention others).
- A newspaper article might describe data supporting an idea without giving any evidence against it.

Scientific Developments are Great, but they can Raise Issues

1) Scientific developments include new technologies and new advice.
2) These developments can create issues. For example:

Economic (money) issues: Society can't always afford to do things scientists recommend, like spend money on green energy sources.

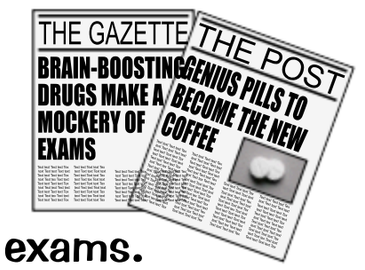
Social (people) issues: Decisions based on scientific evidence affect people — e.g. should alcohol be banned (to prevent health problems)?

Personal issues: Some decisions will affect individuals — e.g. people may be upset if a wind farm is built next to their house.

Environmental issues: Human activity often affects the environment — e.g. some people think that genetically modified crops (see p.78) could cause environmental problems.

Science Can't Answer Every Question — Especially Ethical Ones

1) At the moment scientists don't agree on some things — like what the universe is made of.
2) This is because there isn't enough data to support the scientists' hypotheses.
3) But eventually, we probably will be able to answer these questions once and for all.
4) Experiments can't tell us whether something is ethically right or wrong.
For example, whether it's right for people to use new drugs to help them do better in exams.
5) The best we can do is make a decision that most people are more or less happy to live by.



Tea to milk or milk to tea? — Totally unanswerable by science...

Science can't tell you whether or not you should do something. That's for you and society to decide. But there are tons of questions science might be able to answer, like where life came from and where my superhero socks are.

Working Scientifically

Risk

By reading this page you are agreeing to the risk of a paper cut...

Nothing is Completely Risk-Free

1) A hazard is something that could cause harm.
2) All hazards have a risk attached to them — this is the chance that the hazard will cause harm.
3) New technology can bring new risks. E.g. scientists are creating technology to capture and store carbon dioxide. But if the carbon dioxide leaked out it could damage soil or water supplies. These risks need to be considered alongside the benefits of the technology, e.g. lower greenhouse gas emissions.
4) To make a decision about activities that involve hazards, we need to think about:
   - the chance of the hazard causing harm,
   - how bad the outcome (consequences) would be if it did.

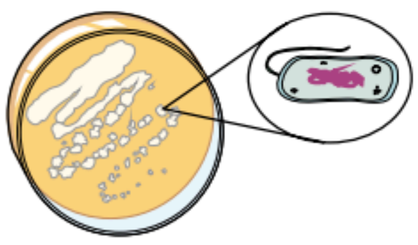
People Make Their Own Decisions About Risk

1) Not all risks have the same consequences. For example, if you chop veg with a sharp knife you risk cutting your finger, but if you go scuba-diving you risk death.
2) Most people are happier to accept a risk if the consequences don't last long and aren't serious.
3) People tend to think familiar activities are low-risk. They tend to think unfamiliar activities are high-risk. But this isn't always true. For example:
   - Cycling on roads is often high-risk. But it's a familiar activity, so many people are happy to do it.
   - Air travel is actually pretty safe, but a lot of people think it is high-risk.
4) The best way to estimate the size of a risk is to look at data. E.g. you could estimate the risk of a driver crashing by recording how many people in a group of 100 000 drivers crashed their cars over a year.

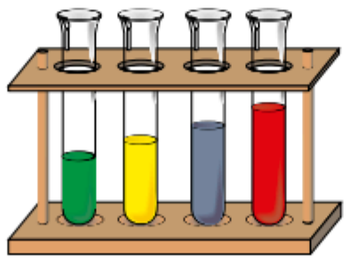
Investigations Can Have Hazards

1) Hazards from science experiments include things like:

microorganisms (e.g. bacteria)



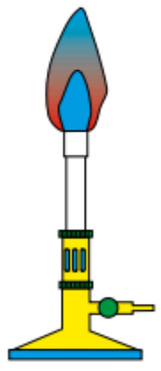
chemicals



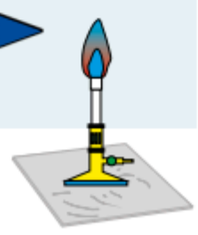
electricity



fire



2) When you plan an investigation you need to make sure that it's safe.
3) You should identify all the hazards that you might come across.
4) Then you should think of ways of reducing the risks. For example:
   - If you're working with sulfuric acid, always wear gloves and safety goggles. This will reduce the risk of the acid burning your skin and eyes.
   - If you're using a Bunsen burner, stand it on a heat proof mat. This will reduce the risk of starting a fire.



There's more on safety in experiments on page 235.

Not revising — an unacceptable exam hazard...

The world is a dangerous place. You need to look out for hazards and find ways to reduce their risks.

Designing Investigations

Dig out your lab coat and dust down your safety goggles... it's investigation time.
Investigations include lab experiments and studies done in the real world.

Investigations Produce Evidence to Support or Disprove a Hypothesis

1) Scientists observe things and come up with hypotheses to explain them (see p.1).
You need to be able to do the same. For example:

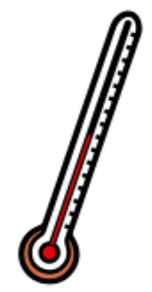
> Observation: People have big feet and spots. Hypothesis: Having big feet causes spots.

2) To find out if your hypothesis is right, you need to do an investigation to gather evidence.
3) To do this, you need to use your hypothesis to make a prediction — something you think will happen that you can test. E.g. people who have bigger feet will have more spots.
4) Investigations are used to see if there are patterns or relationships between two variables (see below).

To Make an Investigation a Fair Test You Have to Control the Variables

1) In a lab experiment you usually change one thing (a variable) and measure how it affects another thing (another variable).

> EXAMPLE: you might change the concentration of a reactant and measure how it affects the temperature change of the reaction.



2) Everything else that could affect the results needs to stay the same.
Then you know that the thing you're changing is the only thing that's affecting the results.

> EXAMPLE continued: you need to keep the volume of the reactants the same. If you don't, you won't know if any change in the temperature is caused by the change in concentration, or the change in volume.

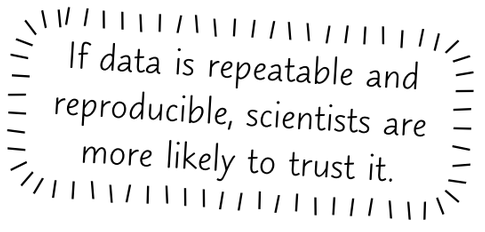
3) The variable that you CHANGE is called the INDEPENDENT variable.
4) The variable you MEASURE is called the DEPENDENT variable.
5) The variables that you KEEP THE SAME are called CONTROL variables.
6) Because you can't always control all the variables, you often need to use a CONTROL EXPERIMENT.

> EXAMPLE continued:
> Independent = concentration
> Dependent = temperature
> Control = volume of reactants, pH, etc.

7) This is an experiment that's kept under the same conditions as the rest of the investigation, but doesn't have anything done to it. This is so that you can see what happens when you don't change anything.

Evidence Needs to be Repeatable, Reproducible and Valid

1) REPEATABLE means that if the same person does the experiment again, they'll get similar results.
To check your results are repeatable, repeat the readings at least three times.
Then check the repeat results are all similar.
2) REPRODUCIBLE means that if someone else does the experiment, the results will still be similar.
To make sure your results are reproducible, get another person to do the experiment too.
3) VALID results come from experiments that were designed to be a fair test.
They're also repeatable and reproducible.



This is no high street survey — it's a designer investigation...

You need to be able to plan your own investigations. You should also be able to look at someone else's plan and decide whether anything needs to be changed to make it better. Those examiners are pretty demanding.

Collecting Data

Ah ha — now it's time to get your hands mucky and collect some data.

The Bigger the Sample Size the Better

1) Sample size is how many things you test in an investigation, e.g. 500 people or 20 types of metal.
2) The bigger the sample size the better — to reduce the chance of any weird results.
3) But scientists have to be realistic when choosing how big their sample should be.
E.g. if you were studying how lifestyle affects weight it'd be great to study everyone in the UK (a huge sample), but it'd take ages and cost loads.
4) When you choose a sample, you need to make sure you've got a range of different people.
5) For example, both men and women with a range of different ages.

Your Data Should be Accurate and Precise

1) ACCURATE results are results that are really close to the true answer.
2) The accuracy of your results usually depends on your method.
You need to make sure you're measuring the right thing.
3) You also need to make sure you don't miss anything that should be included in the measurements. For example:

If you're measuring the volume of gas released by a reaction, make sure you collect all the gas.

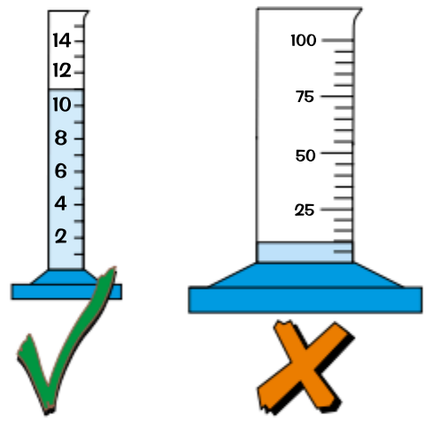
4) PRECISE results are ones where the data is all really close to the mean (average) of your repeated results.

Repeat	Data set 1	Data set 2
1	12	11
2	14	17
3	13	14
Mean	13	14

Data set 1 is more precise than data set 2 — the results are all close to the mean (not spread out).

Your Equipment has to be Right for the Job

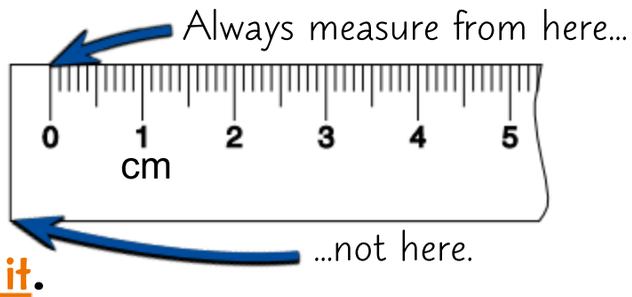
1) The measuring equipment you use has to be able to accurately measure the chemicals you're using. E.g. if you need to measure out 11 cm^3 of a liquid, use a measuring cylinder that can measure to 1 cm^3 — not 5 or 10 cm^3.
2) You also need to set up the equipment properly. For example, make sure your mass balance is set to zero before you start weighing things.



You Need to Look out for Errors and Anomalous Results

1) The results of your experiment will always vary a bit because of RANDOM ERRORS — for example, mistakes you might make while measuring.
2) You can reduce the effect of random errors by taking repeat readings and finding the mean. This will make your results more precise.
3) If a measurement is wrong by the same amount every time, it's called a SYSTEMATIC ERROR.
For example:

If you measure from the very end of your ruler instead of from the 0 cm mark every time, all your measurements would be a bit small.



4) If you know you've made a systematic error, you might be able to correct it.
For example, by adding a bit on to all your measurements.
5) Sometimes you get a result that doesn't fit in with the rest. This is called an ANOMALOUS RESULT.
6) You should try to work out what happened. If you do (e.g. you find out you measured something wrong) you can ignore it when processing your results (see next page).

The bigger the better — what's true for cakes is true for samples...

Make sure you take lots of care when collecting data — there's plenty to watch out for, as you can see.

Processing and Presenting Data

Processing your data means doing calculations with it so it's more useful. Then you get to draw pretty graphs...

Data Needs to be Organised

1) Tables are useful for organising data.
2) When you draw a table use a ruler.
3) Make sure each column has a heading (including the units).

Test tube	Repeat 1 (cm^3)	Repeat 2 (cm^3)
A	28	37
B	47	51

You Might Have to Find the Mean, the Range, the Median or the Mode

1) When you've done repeats of an experiment you should always calculate the mean (a type of average).
2) You might also need to calculate the range (how spread out the data is).

EXAMPLE

The results of an experiment to find the volume of gas produced in a reaction are shown in the table below. Calculate the mean volume and the range.

Volume of gas produced (cm^3)		
Repeat 1	Repeat 2	Repeat 3
28	37	32

1) To calculate the mean, add together all the data values. Then divide by the total number of values in the sample. $(28 + 37 + 32) \div 3 = 32\ cm^3$
2) To calculate the range, subtract the smallest number from the largest number. $37 - 28 = 9\ cm^3$

3) To find the median, put all your data in order from smallest to largest. The median is the middle value.
4) The number that appears most often is the mode.

If you have an even number of values, the median is halfway between the middle two values.

E.g. if you have the data set: 1 2 1 1 3 4 2
The median is: 1 1 1 2 2 3 4. The mode is 1 because 1 appears most often.

5) When calculating any of these values, always ignore any anomalous results.

Round to the Lowest Number of Significant Figures

1) The first significant figure of a number is the first digit that's not zero.
2) The second and third significant figures come straight after (even if they're zeros).
3) In any calculation, you should round the answer to the lowest number of significant figures (s.f.) given.
4) If your calculation has more than one step, only round the final answer.

1st significant figure
0.0307
2nd 3rd

EXAMPLE

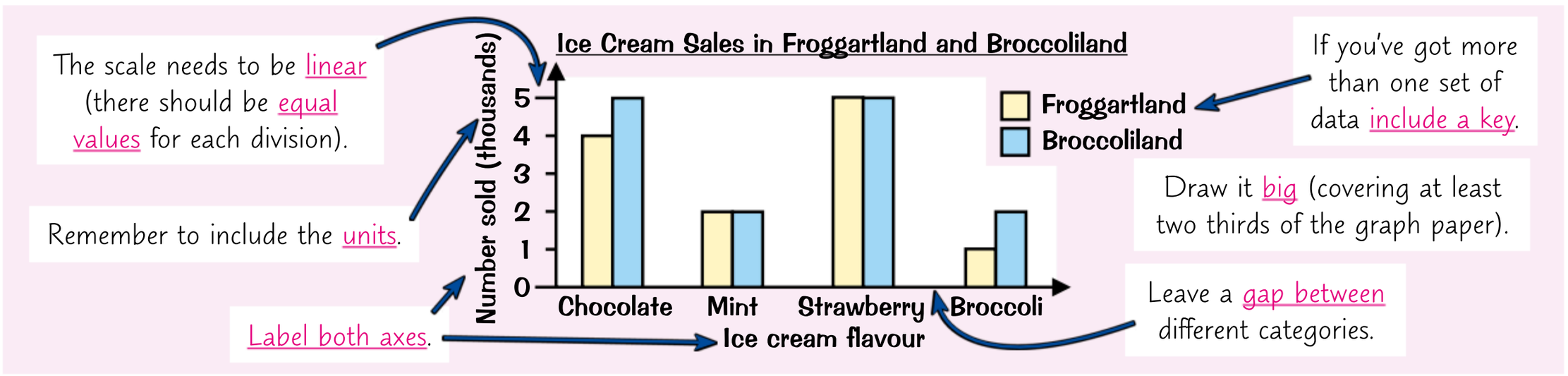
The mass of a solid is 0.24 g and its volume is 0.715 cm^3. Calculate the density of the solid.

Density = 0.24 g ÷ 0.715 cm^3 = 0.33566... = 0.34 g/cm^3 (2 s.f.)

0.24: 2 s.f. 0.715: 3 s.f. Final answer should be rounded to 2 s.f.

If Your Data Comes in Categories, Present It in a Bar Chart

If the independent variable comes in clear categories (e.g. blood group, types of metal) or can be counted exactly (e.g. number of protons) you should use a bar chart to display the data. Here's what to do:



Working Scientifically

If Your Data is Continuous, Plot a Graph

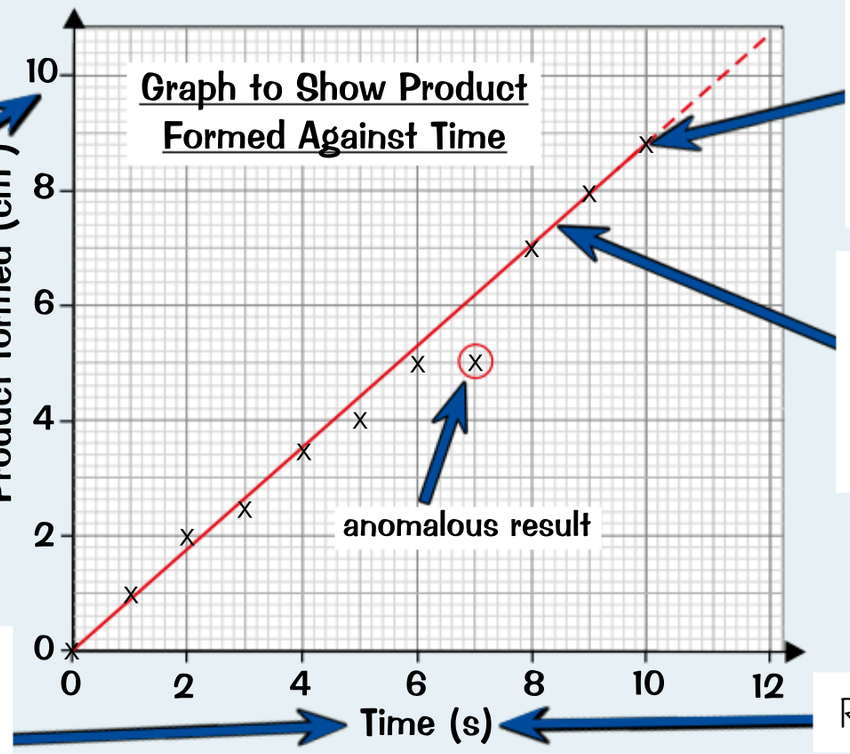
If both variables can have any value within a range (e.g. length, volume) use a graph to display the data.

Here are the rules for plotting points on a graph:

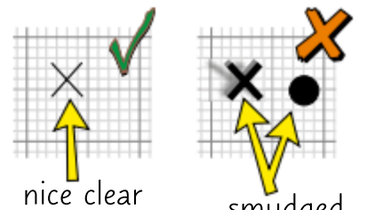
Use the biggest data values you've got to draw a sensible scale on your axes.

The dependent variable goes on the y-axis (the vertical one).

The independent variable goes on the x-axis (the horizontal one).



To plot points, use a sharp pencil and make neat little crosses (don't do blobs).



To draw a line (or curve) of best fit, draw a line through, or as near to, as many points as possible. Ignore any anomalous results. Don't join the crosses up.

Draw it big (covering at least two thirds of the graph paper).

Remember to include the units.

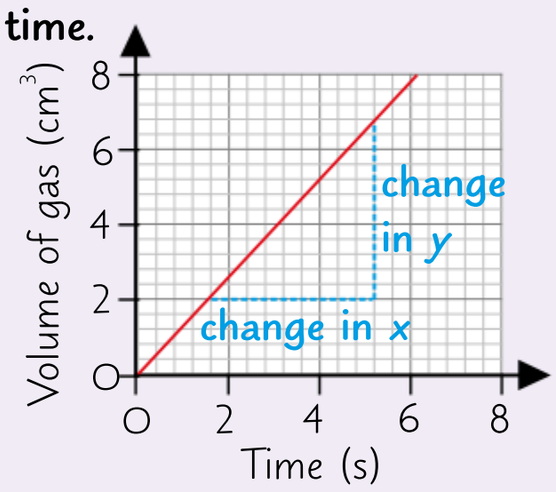
You Can Calculate the Rate of a Reaction from the Gradient of a Graph

1) This is the formula you need to calculate the gradient (slope) of a graph:
2) You can use it to work out the rate of a reaction (how quickly the reaction happens).

$$\text{gradient} = \frac{\text{change in } y}{\text{change in } x}$$

EXAMPLE

The graph shows the volume of gas produced in a reaction against time. Calculate the rate of reaction.



1) To calculate the gradient, pick two points on the line that are easy to read. They should also be a good distance apart.
2) Draw a line down from the higher point. Then draw a line across from the other, to make a triangle.
3) The line drawn down the side of the triangle is the change in y. The line across the bottom is the change in x.
4) Read the x and y values of the points off the graph and work out the change in y and the change in x:

Change in $y = 6.8 - 2.0 = 4.8$ cm³ Change in $x = 5.2 - 1.6 = 3.6$ s

5) Then put these numbers in the formula above to find the rate of the reaction:

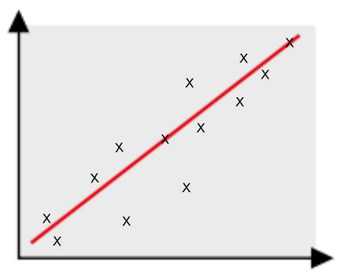
$$\text{Rate} = \text{gradient} = \frac{\text{change in } y}{\text{change in } x} = \frac{4.8 \text{ cm}^3}{3.6 \text{ s}} = 1.3 \text{ cm}^3/\text{s}$$

The units are (units of y)/(units of x). cm³/s can also be written as $\text{cm}^3\ \text{s}^{-1}$.

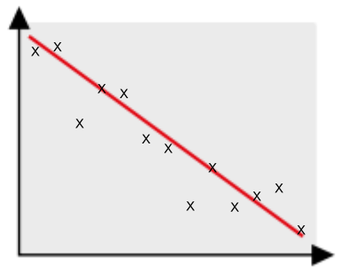
To calculate a rate, the graph must have time on the x-axis.

Graphs Show the Relationship Between Two Variables

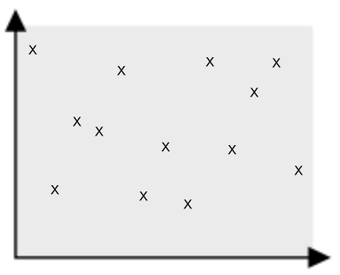
1) You can get three types of correlation (relationship) between variables:
2) A correlation doesn't mean the change in one variable is causing the change in the other (see page 9).



POSITIVE correlation: as one variable increases the other increases.



INVERSE (negative) correlation: as one variable increases the other decreases.



NO correlation: no relationship between the two variables.

I love eating apples — I call it core elation...

Science is all about finding relationships between things. And I don't mean that scientists gather together in corners to discuss whether or not Devini and Sebastian might be a couple... though they probably do that too.

Units

Graphs and maths skills are all very well, but the numbers don't mean much if you can't get the units right.

S.I. Units Are Used All Round the World

1) All scientists use the same units to measure their data.
2) These are standard units, called S.I. units.
3) Here are some S.I. units you might see:

Quantity	S.I. Base Unit
mass	kilogram, kg
length	metre, m
time	second, s
temperature	kelvin, K

Different Units Help you to Write Large and Small Quantities

1) Quantities come in a huge range of sizes.
2) To make the size of numbers easier to handle, larger or smaller units are used.
3) Larger and smaller units are written as the S.I. base unit with a little word in front (a prefix). Here are some examples of prefixes and what they mean:

Kilogram is an exception. It's an S.I. unit with the prefix already on it.

prefix	mega (M)	kilo (k)	deci (d)	centi (c)	milli (m)	micro (μ)
how it compares to the base unit	1 000 000 times bigger	1000 times bigger	10 times smaller	100 times smaller	1000 times smaller	1 000 000 times smaller

E.g. 1 kilometre is 1000 metres.

E.g. there are 1000 millimetres in 1 metre.

You Need to be Able to Convert Between Units

You need to know how to convert (change) one unit into another. Here are some useful conversions:

DIVIDE to go from a smaller unit to a bigger unit.

Mass can have units of kg and g.

kg ⇄ g (× 1000 / ÷ 1000)

Energy can have units of kJ and J.

kJ ⇄ J (× 1000 / ÷ 1000)

Length can have lots of units, including m, mm, and μm.

m ⇄ mm ⇄ μm (× 1000 / ÷ 1000)

MULTIPLY to go from a bigger unit to a smaller unit.

EXAMPLE

A car has travelled 0.015 kilometres. How many metres has it travelled?

1 km = 1000 m. So to convert from km (a bigger unit) to m (a smaller unit) you need to multiply by 1000.

0.015 km × 1000 = 15 m

Always make sure the values you put into an equation or formula have the right units.

You Can Rearrange Equations

1) Equations show relationships between variables. For example, speed = $\frac{\text{distance}}{\text{time}}$.
2) The subject of an equation is the variable by itself on one side of the equals sign. So speed is the subject in the equation above.
3) To change the subject of an equation do the same thing to both sides of the equation until you've got the subject you want. E.g. you can make distance the subject of the equation above:

1) Multiply both sides by time: $\text{speed} = \frac{\text{distance}}{\text{time}} \rightarrow \text{speed} \times \text{time} = \frac{\text{distance} \times \text{time}}{\text{time}}$
2) Time is now on the top and the bottom of the fraction, so it cancels out: $\text{speed} \times \text{time} = \frac{\text{distance} \times \cancel{\text{time}}}{\cancel{\text{time}}}$
3) This leaves distance by itself. So it's the subject: speed × time = distance

I wasn't sure I liked units, but now I'm converted...

If you're moving from a smaller unit to a larger unit (e.g. g to kg) the number should get smaller, and vice versa.

Drawing Conclusions

Congratulations — you've made it to the final step of an investigation — drawing conclusions.

You Can Only Conclude What the Data Shows and NO MORE

1) To come to a conclusion, look at your data and say what pattern you see.

EXAMPLE: The table on the right shows the heights of pea plant seedlings grown for three weeks with different fertilisers.

Fertiliser	Mean growth / mm
A	13.5
B	19.5
No fertiliser	5.5

CONCLUSION: Pea plant seedlings grow taller over a three week period with fertiliser B than with fertiliser A.

2) It's important that the conclusion matches the data it's based on — it shouldn't go any further.

EXAMPLE continued: You can't conclude that any other type of plant grows taller with fertiliser B than with fertiliser A — the results could be totally different.

3) You also need to be able to use your results to justify your conclusion (i.e. back it up).

EXAMPLE continued: The pea plants grow 6 mm more on average with fertiliser B than with fertiliser A.

4) When writing a conclusion you need to say whether or not the data supports the original hypothesis:

EXAMPLE continued: The hypothesis might have been that adding different types of fertiliser would affect the growth of pea plants by different amounts. If so, the data supports the hypothesis.

Correlation DOES NOT Mean Cause

1) If two things are correlated, there's a relationship between them — see page 7.
2) But a correlation doesn't always mean that a change in one variable is causing the change in the other.
3) There are three possible reasons for a correlation:

1 CHANCE

The results happened by chance. Other scientists wouldn't get a correlation if they carried out the same investigation.

2 LINKED BY A 3rd VARIABLE

There's another factor involved.

E.g. there's a correlation between water temperature and shark attacks. They're linked by a third variable — the number of people swimming (more people swim when the water's hotter, which means you get more shark attacks).



3 CAUSE

Sometimes a change in one variable does cause a change in the other. You can only conclude this when you've controlled all the variables that could be affecting the result.

I conclude that this page is a bit dull...

In the exams you could be given a conclusion and asked whether some data supports it — so make sure you understand how far conclusions can go. And remember, correlation does not mean cause.

Uncertainties and Evaluations

Hurrah! The end of another investigation. Well, now you have to work out all the things you did wrong.

Uncertainty is the Amount of Error Your Measurements Might Have

1) Measurements you make will have some uncertainty in them (i.e. they won't be completely perfect).
2) This can be due to random errors (see page 5). It can also be due to limits in what your measuring equipment can measure.
3) This means that the mean of your results will have some uncertainty to it.
4) You can calculate the uncertainty of a mean result using this equation:
5) The less precise your results are, the higher the uncertainty will be.
6) Uncertainties are shown using the '±' symbol.

The range is the largest value minus the smallest value (p.6).

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

EXAMPLE

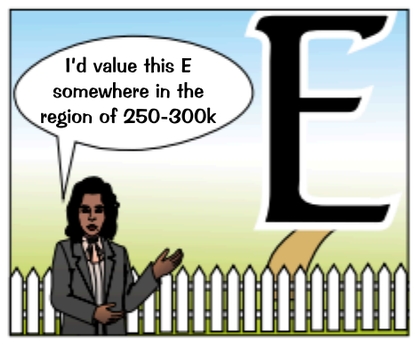
The table below shows the results of an experiment to find the speed of a trolley. Calculate the uncertainty of the mean.

Repeat	1	2	3	mean
Speed (m/s)	2.02	1.98	2.00	2.00

1) First work out the range:
Range = 2.02 – 1.98
= 0.04 m/s

2) Use the range to find the uncertainty:
Uncertainty = range ÷ 2 = 0.04 ÷ 2 = 0.02 m/s So, uncertainty of the mean = 2.00 ± 0.02 m/s

Evaluations — Describe How it Could be Improved



In an evaluation you look back over the whole investigation.

1) You should comment on the method — was it valid?
Did you control all the other variables to make it a fair test?
2) Comment on the quality of the results — was there enough evidence to reach a valid conclusion?
Were the results repeatable, reproducible, accurate and precise?
3) Were there any anomalous results? If there were none then say so.
If there were any, try to explain them — were they caused by errors in measurement?
4) You should comment on the level of uncertainty in your results too.
5) Thinking about these things lets you say how confident you are that your conclusion is right.
6) Then you can suggest any changes to the method that would improve the quality of the results, so you could have more confidence in your conclusion.
7) For example, taking measurements at narrower intervals could give you a more accurate result. E.g.

- Say you do an experiment to find the temperature at which an enzyme works best.
- You take measurements at 30 °C, 40 °C and 50 °C.
  The results show that the enzyme works best at 40 °C.
- To get a more accurate result, you could repeat the experiment and take more measurements around 40 °C. You might then find that the enzyme actually works best at 42 °C.

8) You could also make more predictions based on your conclusion.
You could then carry out further experiments to test the new predictions.

Evaluation — next time, I'll make sure I don't burn the lab down...

So there you have it — Working Scientifically. Make sure you know this stuff like the back of your hand. It's not just in the lab that you'll need to know how to work scientifically. You can be asked about it in the exams as well.

Cells

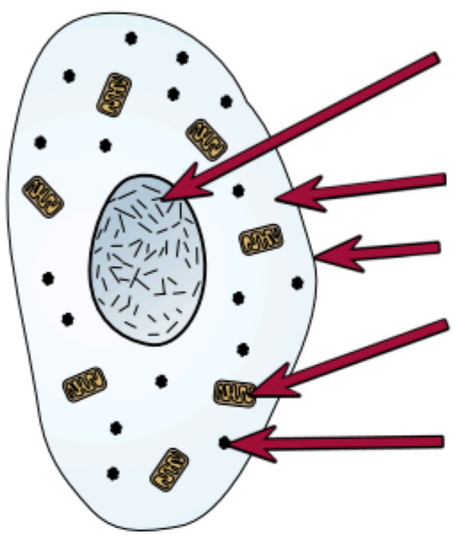
Cells are the building blocks of every organism on the planet.

Cells can be Prokaryotic or Eukaryotic

1) All living things are made of cells.
2) Eukaryotic cells are complex. All animal and plant cells are eukaryotic.
3) Prokaryotic cells are smaller and simpler. Bacteria are prokaryotic cells.

Plant and Animal Cells have Similarities and Differences

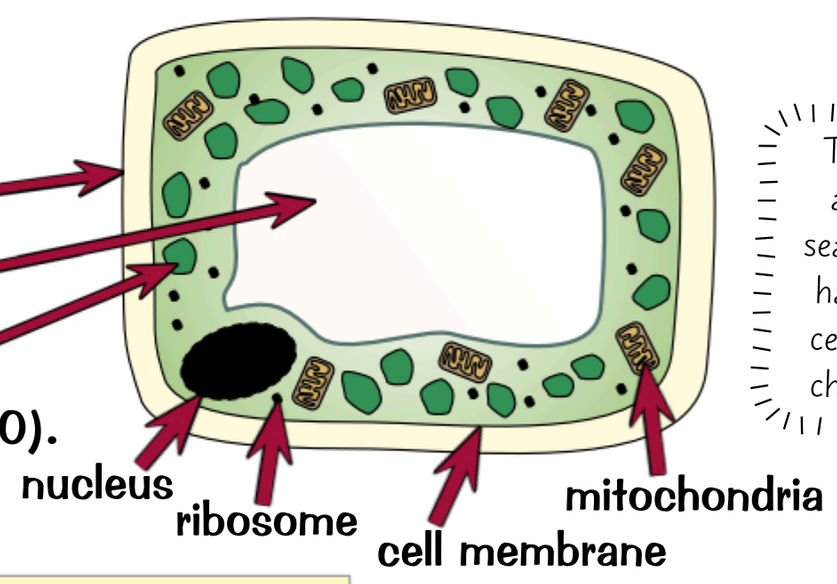
The different parts of a cell are called subcellular structures.
Most animal cells have these subcellular structures:



1) Nucleus — contains genetic material (see page 66).
The genetic material controls what the cell does.
2) Cytoplasm — where most of the chemical reactions happen.
3) Cell membrane — controls what goes in and out of the cell.
4) Mitochondria — where most aerobic respiration happens (see page 54).
Respiration transfers energy that the cell needs to work.
5) Ribosomes — these are where proteins are made in the cell.

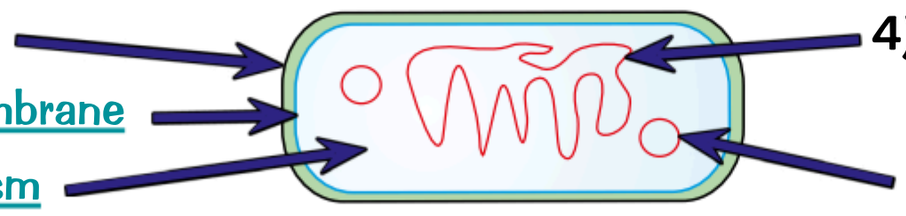
Plant cells usually have all the bits that animal cells have.
They also have:

1) A cell wall — made of cellulose.
It supports the cell and strengthens it.
2) A permanent vacuole — contains cell sap.
3) Chloroplasts — where photosynthesis happens.
Photosynthesis makes food for the plant (see page 50).



The cells of algae (e.g. seaweed) also have a rigid cell wall and chloroplasts.

Bacterial Cells Have These Subcellular Structures:



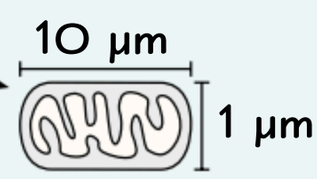
1) Cell wall
2) Cell membrane
3) Cytoplasm
4) A single loop of DNA.
Bacteria don't have a 'true' nucleus.
5) Plasmids — small rings of extra DNA.

You Can Estimate the Area of a Subcellular Structure

If you want to estimate the area of a subcellular structure, you should treat it like a regular shape:

EXAMPLE

Estimate the area of this mitochondrion:



1) The shape of the mitochondrion is close to a rectangle.
2) The area of a rectangle is found by the formula: length × width

So the area of the mitochondrion is roughly 10 μm × 1 μm = 10 μm^2

Cell structures — become an estate agent...

In the exam, you might see the sizes of cells written in standard form — see the next page for more about this.

Q1 Give two differences in structure between bacterial cells and animal cells. [2 marks]

Microscopy

Microscopes are pretty important for biology. So here are a couple of pages all about them...

Microscopes Magnify Things (Make Them Look Bigger)

1) The ways we can use microscopes have developed over the years.
This is because technology and knowledge have improved.
2) Light microscopes can be used to look at cells.
They let us see large subcellular structures (like the nucleus).

See the next page for how to use a light microscope.

3) Electron microscopes have a higher resolution than light microscopes — they show things in more detail.
4) Electron microscopes also have a higher magnification than light microscopes.
They can let us see really small things like ribosomes and plasmids.
5) Electron microscopes were invented after light microscopes.
They helped scientists understand more about subcellular structures.

Magnification is How Many Times Bigger the Image is than the Real Thing

You can work out the magnification of an image using this formula:

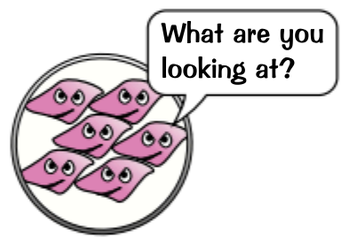
$$\text{magnification} = \frac{\text{image size}}{\text{real size}}$$

Image size and real size should have the same units.

EXAMPLE

The width of a cell is 0.02 mm. The width of its image under a microscope is 8 mm. What magnification was used to view the cell?

magnification = 8 mm ÷ 0.02 mm = × 400



You Can Write Numbers in Standard Form

Standard form is useful for writing very big or very small numbers in a simpler way.

EXAMPLE

Write 0.0025 mm in standard form.

1) The first number needs to be between 1 and 10 so the decimal point needs to move after the '2'.
2) Count how many places the decimal point has moved — this is the power of 10.
3) The power of 10 is positive if the decimal point is moved to the left. It's negative if the decimal point has moved to the right. Here, the decimal point has moved right, so it needs a minus sign.

0.0025 → 2.5
1 2 3

The decimal point has moved 3 places = 10^3

2.5×10^{-3}

Your resolution to revise should be increasing right now...

Keep an eye on the units for that equation — if they're not the same, it just won't work.

Q1 A cheek cell is viewed under a microscope with × 40 magnification. The image of the cell is 2.4 mm wide. Calculate the real width of the cheek cell. Give your answer in μm. [2 marks]

Q1 Video Solution

More on Microscopy

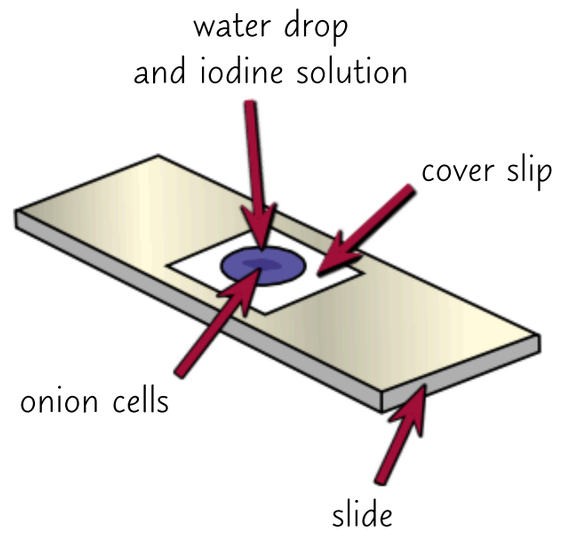
PRACTICAL

So you know what microscopes do... now you need to know how to use one.

You Need to Prepare Your Slide

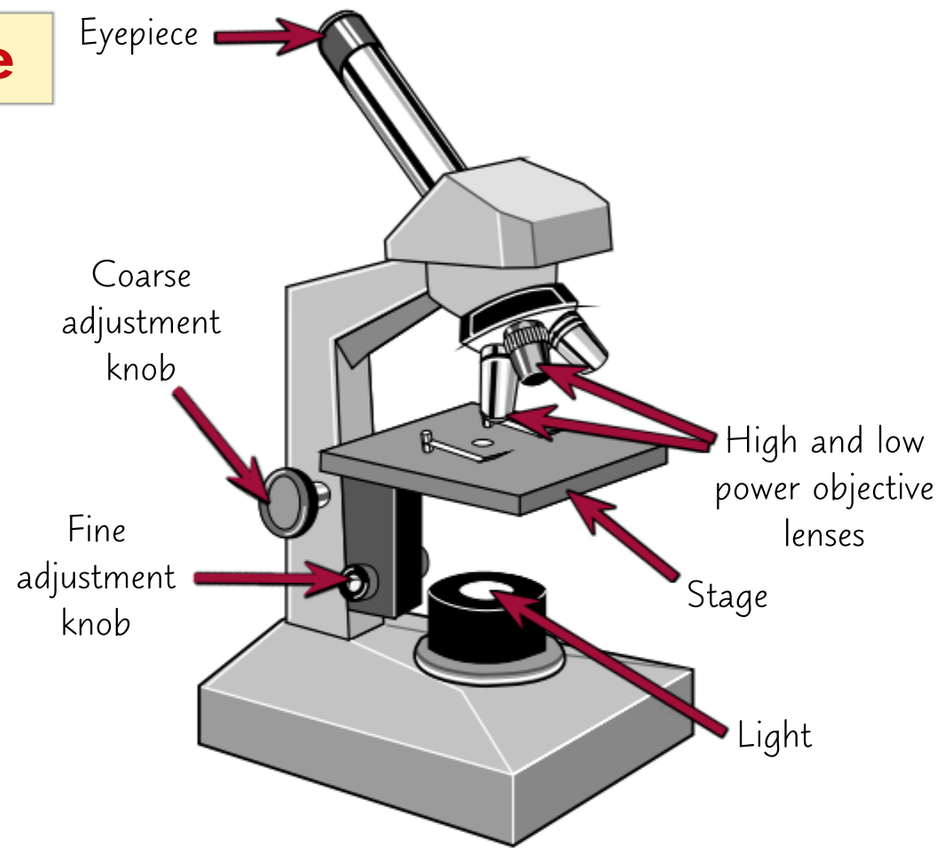
Lots of different animal and plant cells can be looked at under a light microscope.

1) Add a drop of water to the middle of a clean slide.
2) Cut up an onion and take off one layer.
3) Use tweezers to peel off some epidermal tissue (the clear 'skin') from the bottom of the layer.
4) Using the tweezers, place the skin into the water on the slide.
5) Add a drop of iodine solution. Iodine solution is a stain. Stains can make different parts of a cell easier to see.
6) Place a cover slip on top. Try not to get any air bubbles under it.



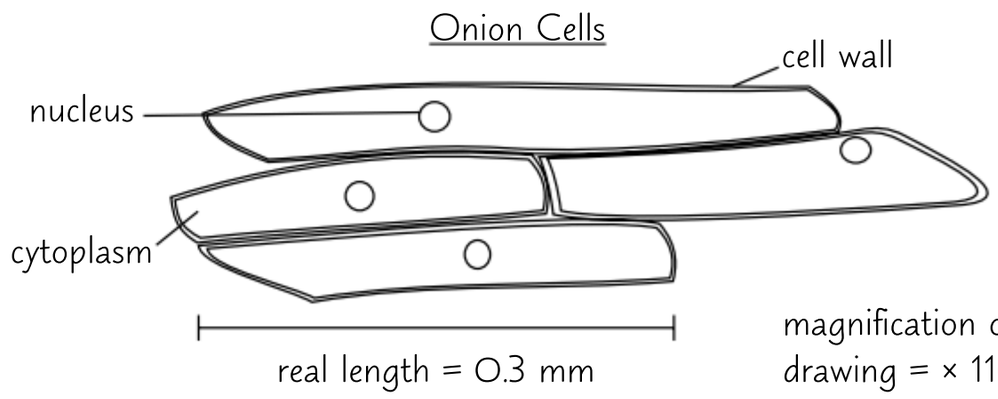
Use a Light Microscope to Look at Your Slide

1) Clip the slide onto the stage.
2) Select the objective lens with the lowest magnification.
3) Use the coarse adjustment knob to move the stage up to just below the objective lens.
4) Look down the eyepiece. Move the stage downwards until the image is roughly in focus.
5) Move the fine adjustment knob, until you get a clear image of what's on the slide.
6) If you want a bigger image, use an objective lens with a higher magnification and refocus.



Draw Your Observations Neatly with a Pencil

1) You should use a pencil with a sharp point to draw what you see under the microscope.
2) Use smooth lines to draw the outlines of the main features (e.g. nucleus, chloroplasts).
3) Don't do any shading or colouring in.
4) Label the features with straight lines. Make sure the lines don't cross over each other.
5) The drawing should take up at least half the space available.
6) Include a title and a scale.
7) Write down the magnification that it was observed under.



You can measure the real size of the cells using a ruler that fits onto your microscope (see p.234).

A light microscope is better than a heavy one...

If you can use a microscope, you're halfway to ruling the world. That's what I like to think, anyway.

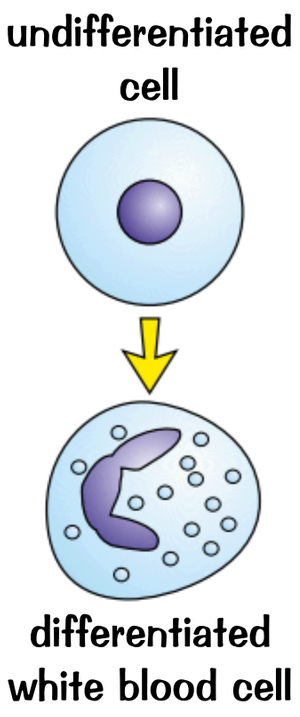
Q1 Why might you add stain to the sample on a microscope slide? [1 mark]

Cell Differentiation and Specialisation

Cells don't all look the same. They have different structures to carry out their different functions.

Specialised Cells are Cells that Carry Out a Specific Function

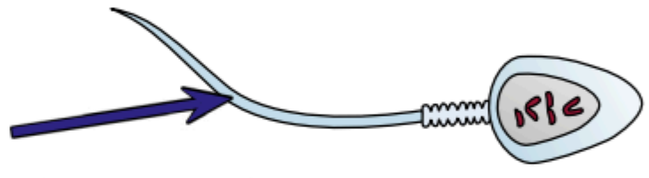
1) The process by which cells change to become specialised is called differentiation.
2) As cells change, they develop different subcellular structures.
They turn into different types of cells. This allows them to carry out specific functions.
3) Most differentiation occurs as an organism develops.
4) Most animal cells can only differentiate at an early stage of the animal's life.
5) But lots of plant cells can differentiate for the whole of the plant's life.
6) The cells that differentiate in adult animals are mainly used for repairing and replacing cells.
7) Some cells are undifferentiated — they are called stem cells.
There's more about them on page 16.



There Are Many Examples of Specialised Cells...

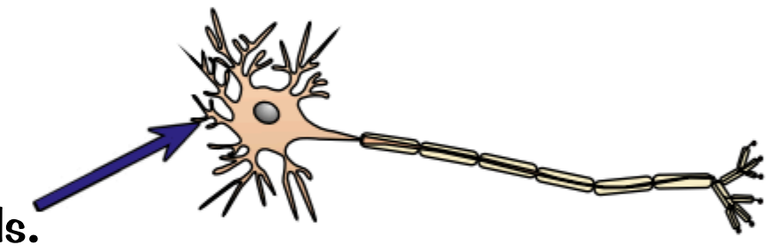
SPERM CELLS take the MALE DNA to the EGG

1) A sperm cell has a tail to help it swim to the egg.
2) It has a lot of mitochondria (see p.11). These provide energy for swimming.



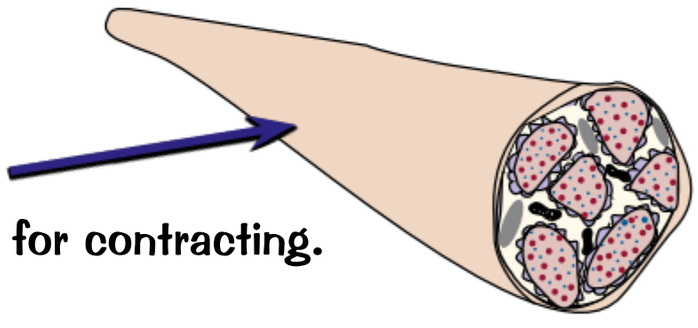
NERVE CELLS carry ELECTRICAL SIGNALS around the BODY

1) Nerve cells are long to cover more distance in the body.
2) They have branches at the end to connect to other nerve cells.



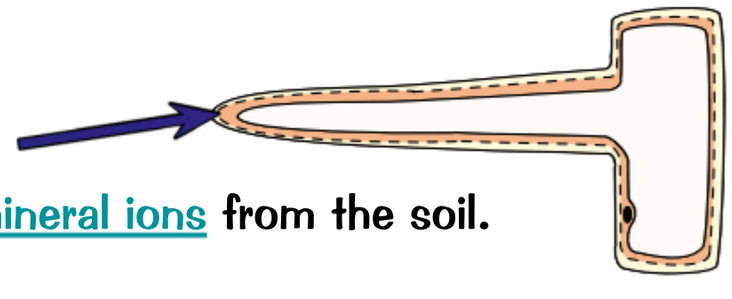
MUSCLE CELLS CONTRACT (SHORTEN)

1) Muscle cells are long so they have space to contract.
2) They have lots of mitochondria. These provide energy for contracting.



ROOT HAIR CELLS absorb WATER and MINERALS

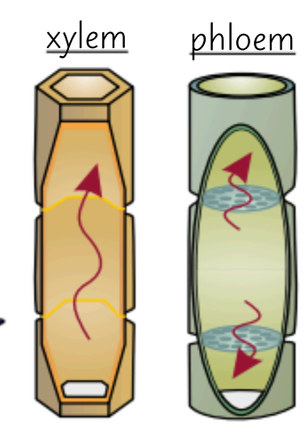
1) Root hair cells grow into long "hairs" that stick out into the soil.
2) This gives the plant a big surface area for absorbing water and mineral ions from the soil.



PHLOEM CELLS transport FOOD and XYLEM CELLS transport WATER

1) Phloem and xylem cells form phloem and xylem tubes.
2) To form the tubes, the cells are long and joined end to end.
3) Xylem cells are hollow and phloem cells have very few subcellular structures.
So there's lots of space inside the cells for stuff to flow through them.

There's more about phloem and xylem on page 39.



Tadpoles and tent pegs — cells are masters of disguise...

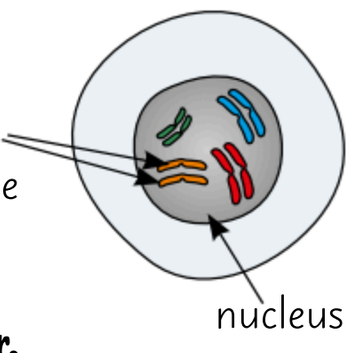
You need to know how the cells on this page are specialised to carry out their functions. Lucky you.

Q1 Describe how a root hair cell is specialised for its function. [2 marks]

Chromosomes and Mitosis

In order to survive and grow, our cells have got to be able to divide. And that means our DNA as well...

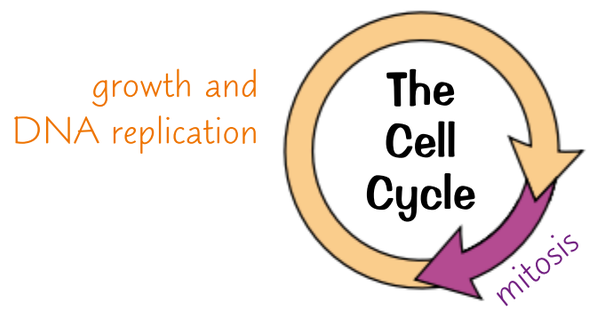
Chromosomes Contain Genetic Information

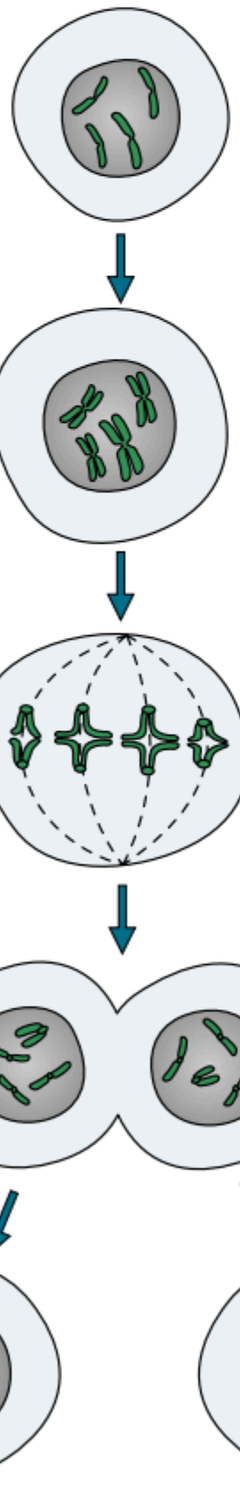


1) The nucleus of a cell contains chromosomes.
2) Chromosomes are coiled up lengths of DNA molecules.
3) Each chromosome carries a large number of genes.
4) Different genes control the development of different characteristics, e.g. hair colour.
5) Body cells normally have two copies of each chromosome.
6) There are 23 pairs of chromosomes in a human cell.

The Cell Cycle Makes New Cells

1) Body cells in multicellular organisms (e.g. like you, me or a plant) divide to make new cells. This is part of a series of stages called the cell cycle.
2) The stage of the cell cycle when the cell divides is called mitosis.
3) Multicellular organisms use mitosis to grow and develop.
4) You need to know about these main stages of the cell cycle:





Growth & DNA Replication

Before it divides:

1) The cell grows and increases the amount of subcellular structures such as ribosomes and mitochondria (see page 11).
2) The DNA is replicated (copied) — so there's one copy for each new cell.
3) The DNA forms X-shaped chromosomes. Each 'arm' of the chromosome is an exact copy of the other.

The left arm has the same DNA as the right arm of the chromosome.



Mitosis

The cell is now ready for dividing...

4) The chromosomes line up at the centre of the cell.
5) The two arms of each chromosome are pulled apart to opposite ends of the cell.
6) This divides the nucleus.
7) Each set of chromosomes become the nucleus of a new cell.
8) The cytoplasm and cell membrane divide.

9) The cell has now produced two new cells.
   - They both contain the same DNA — they're identical.
   - They're also identical to the original cell.

A cell's favourite computer game — divide and conquer...

Mitosis can seem tricky at first. But don't worry — just go through it slowly, one step at a time.

Q1 video solution

Q1 A student looks at cells in the tip of a plant root under a microscope. She counts 11 cells that are undergoing mitosis and 62 cells that are not.

a) Calculate the percentage of cells that are undergoing mitosis. [1 mark]

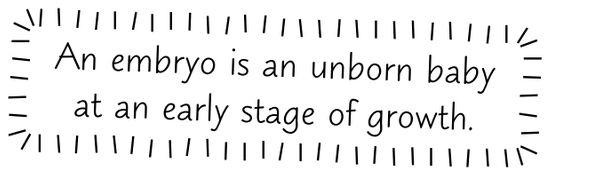
b) Suggest how the student can tell whether a cell is undergoing mitosis or not. [1 mark]

Stem Cells

Stem cell research is pretty exciting... but not everyone agrees it should be done.

Stem Cells can Differentiate into Different Types of Cells

1) Cells differentiate (change) to become specialised for their job (see p.14).
2) Undifferentiated cells are called stem cells.
3) Stem cells can produce lots more undifferentiated cells and differentiate into different types of cell.
4) Stem cells found in early human embryos are called embryonic stem cells.
5) Embryonic stem cells can turn into any kind of cell at all.
6) Adults also have stem cells. They're only in certain places in the body, like bone marrow (a tissue inside bones).
7) Adult stem cells can only produce certain types of specialised cell, e.g. blood cells.
8) Stem cells from embryos and bone marrow can be cloned (copied) in a lab. The cloned cells can be used in medicine or research.





Stem Cells May Be Able to Cure Many Diseases

1) Embryonic stem cells could be used to replace faulty cells in sick people.

E.g. you could make nerve cells for people with paralysis (where they can't move part of the body due to an injury to their spine) or insulin-producing cells for people with diabetes (see page 62).

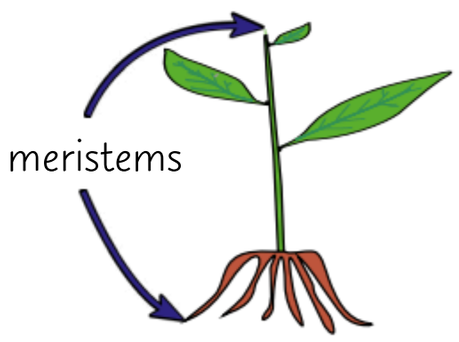
2) It's possible to make an embryo that has the same genes as a patient. This is called therapeutic cloning.
3) This means that the stem cells from the embryo wouldn't be rejected by the patient's body.
4) However, there are risks involved in using stem cells in medicine. For example, the stem cells could be infected with a virus. The virus could be passed on to a patient and make them sicker.

Some People Are Against Stem Cell Research

1) Some people feel embryos shouldn't be used for research because each one could be a human life.
2) Others think that curing patients who are suffering is more important than the rights of embryos.
3) They argue that the embryos used in the research are usually unwanted ones from fertility clinics. If they weren't used for research, would probably just be destroyed.
4) Some people feel that scientists should be finding other sources of stem cells.

Stem Cells Can Produce Identical Plants

1) Plants have tissues called meristems. Meristems are where growth occurs — in the tips of roots and shoots.
2) The meristems contain stem cells that can differentiate into any type of plant cell. They can do this all through the plant's entire life.



3) These stem cells can be used to make clones (identical copies) of plants quickly and cheaply. Clones can be made of:

- rare species (to prevent them being wiped out).
- crop plants that have features that are useful for farmers, e.g. plants aren't killed by a disease.

But florists cell stems, and nobody complains about that...

Stem cells are pretty clever. Make sure you know the uses of stem cells and the arguments about using them.

Q1 How can stem cells be used to preserve rare plant species? [2 marks]

Diffusion

Particles move about, and after a bit they end up evenly spaced. It's not rocket science...

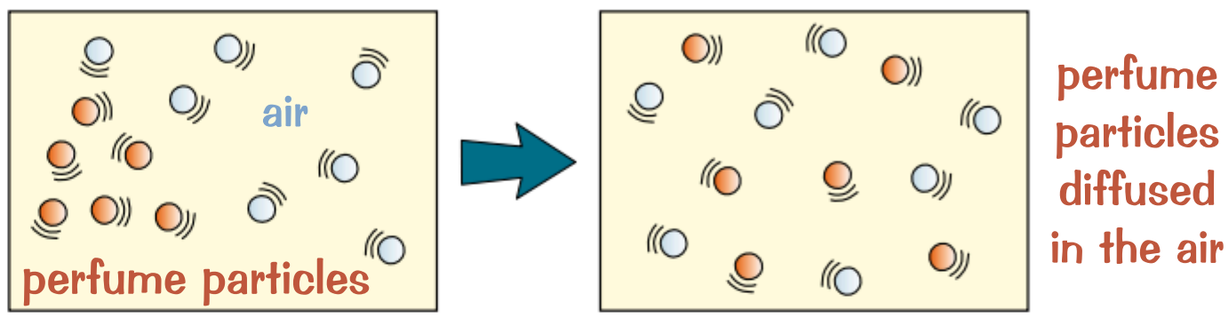
Don't Be Put Off by the Fancy Word

1) "Diffusion" is the movement of particles from where there are lots of them to where there are fewer of them.
2) You have to learn this fancy way of saying it:

DIFFUSION is the SPREADING OUT of particles from an area of HIGHER CONCENTRATION to an area of LOWER CONCENTRATION.



3) Diffusion happens in solutions and gases. For example, the smell of perfume diffuses through the air in a room:



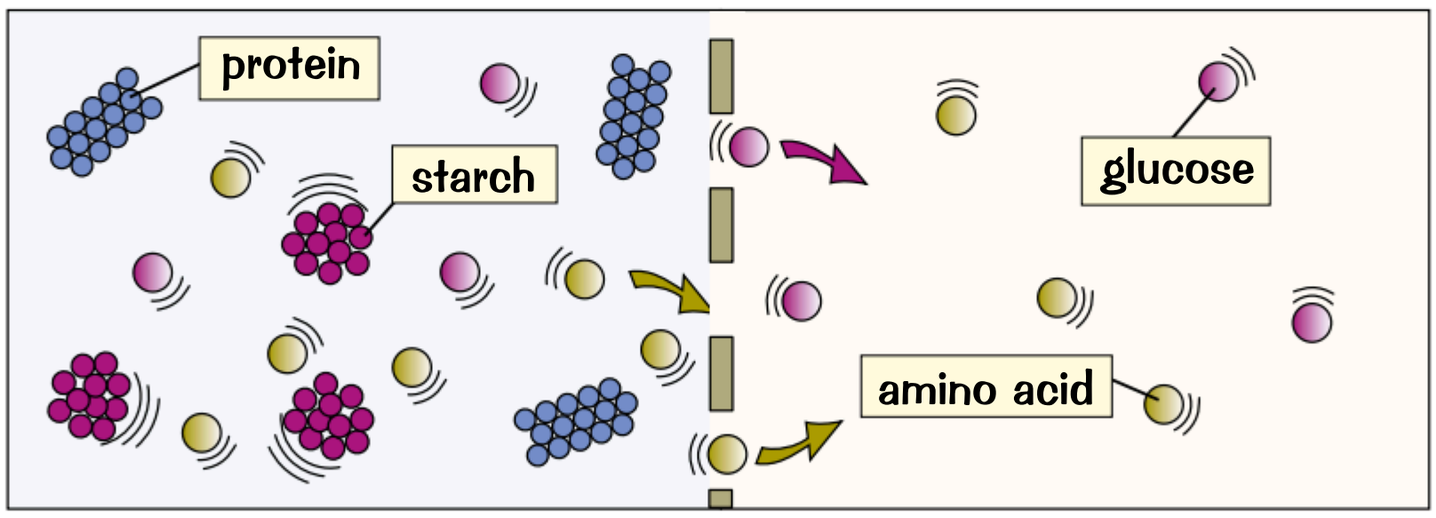
4) The difference in concentration is called the concentration gradient. The bigger the difference in concentration, the faster the diffusion rate.
5) A higher temperature will also give a faster diffusion rate. This is because the particles have more energy, so move around faster.

Cell Membranes Are Kind of Clever...

1) Cell membranes let stuff diffuse in and out of the cell.
2) Only very small molecules can fit through cell membranes, e.g. oxygen, glucose, amino acids and water.

Oxygen is needed for aerobic respiration — see page 54.

3) Big molecules like starch and proteins can't fit through the membrane:



4) Molecules flow through the membrane from where there's a higher concentration (a lot of them) to where there's a lower concentration (not such a lot of them).
5) They actually move both ways — but if there are a lot more particles on one side of the membrane, there's a net (overall) movement from that side.
6) The larger the surface area of the membrane, the faster the diffusion rate. This is because more particles can pass through at the same time.

Revision by diffusion — you wish...

Wouldn't it be great if all the ideas in this book would just slowly drift across into your mind...

Q1 A student adds a drop of ink to a glass of cold water.
a) What will the student observe to happen to the drop of ink. Explain your answer. [2 marks]
b) How might the observation differ if the ink was added to a glass of warm water? [1 mark]

Q2 Explain how the surface area of a membrane affects the rate of diffusion. [2 marks]

Q1 Video Solution

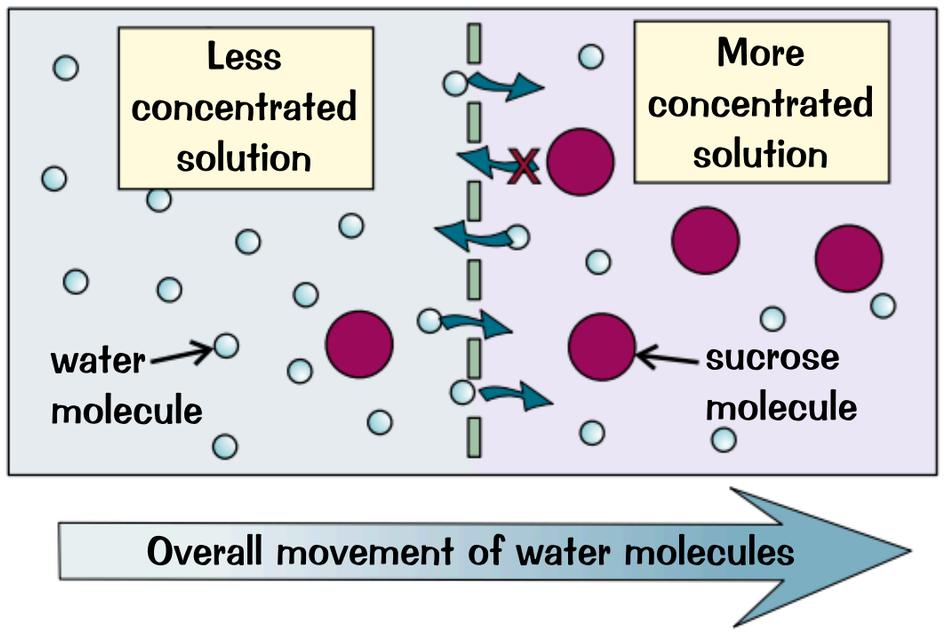
Osmosis

If you've got your head round diffusion, osmosis will be a breeze. If not, have another read of the previous page.

Osmosis is the Movement of Water Molecules

OSMOSIS is the movement of water molecules across a partially permeable membrane from a less concentrated solution to a more concentrated solution.

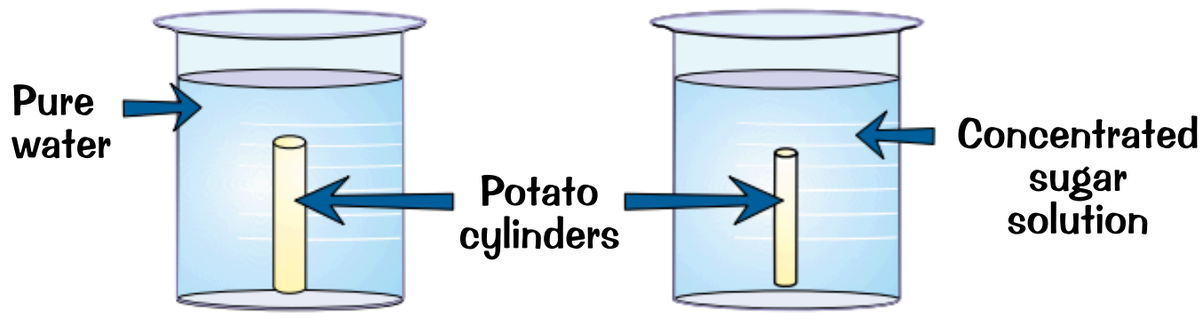
1) A partially permeable membrane is just one with very small holes in it.
2) Tiny molecules (like water) can pass through it, but bigger molecules (e.g. sucrose) can't.
3) Water molecules actually pass both ways through the membrane during osmosis.
4) But overall, the water molecules move from the less concentrated solution (where there are lots of water molecules) to the more concentrated solution (where there are fewer water molecules).
5) This means the more concentrated solution gets more dilute.
6) The water acts like it's trying to "even up" the concentration either side of the membrane.



You can Observe the Effect of Sugar Solutions on Plant Tissue

PRACTICAL

1) First, cut up a potato into cylinders with the same length and width.
2) Then get two beakers — one with pure water and another with a very concentrated sugar solution (e.g. 1 mol/dm^3).
3) You can also have a few other beakers with less concentrated sugar solutions (e.g. 0.2 mol/dm^3, 0.4 mol/dm^3, etc.)
4) Measure the mass of each potato cylinder, then put one in each beaker.
5) Leave the potato cylinders for twenty four hours.
6) Then take them out and dry them with a paper towel.
7) Measure their masses again.
8) If the mass has increased, water has moved into the potato cells.
   If the mass has decreased, water has moved out of the potato cells.
9) You can calculate the percentage change in mass for each potato cylinder — see p.241.
   This means you can compare the effects of each sugar solution.
10) The only thing you should change in this experiment is the concentration of the sugar solution.
    Everything else (e.g. volume of solution, temperature, time, type of sugar used) should stay the same.



You could also do this experiment using different concentrations of salt solution. You should see similar results.

And to all you cold-hearted potato murderers...

Just remember, osmosis is really just a fancy word for the diffusion of water molecules. It's simple really.

Q1 Explain what will happen to the mass of a piece of potato added to a concentrated salt solution. [2 marks]

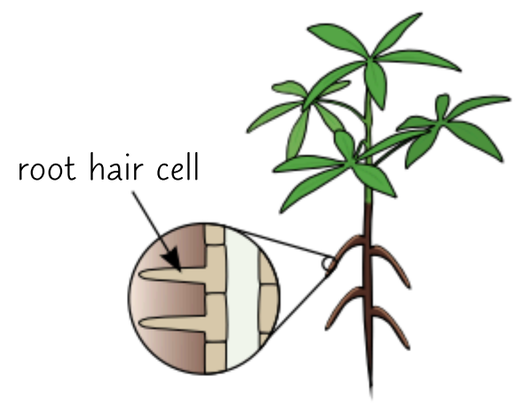
Q1 Video Solution

Active Transport

Sometimes substances need to be absorbed from a lower concentration to a higher concentration — against the concentration gradient. This process is called ACTIVE TRANSPORT.

Root Hairs Take In Minerals and Water

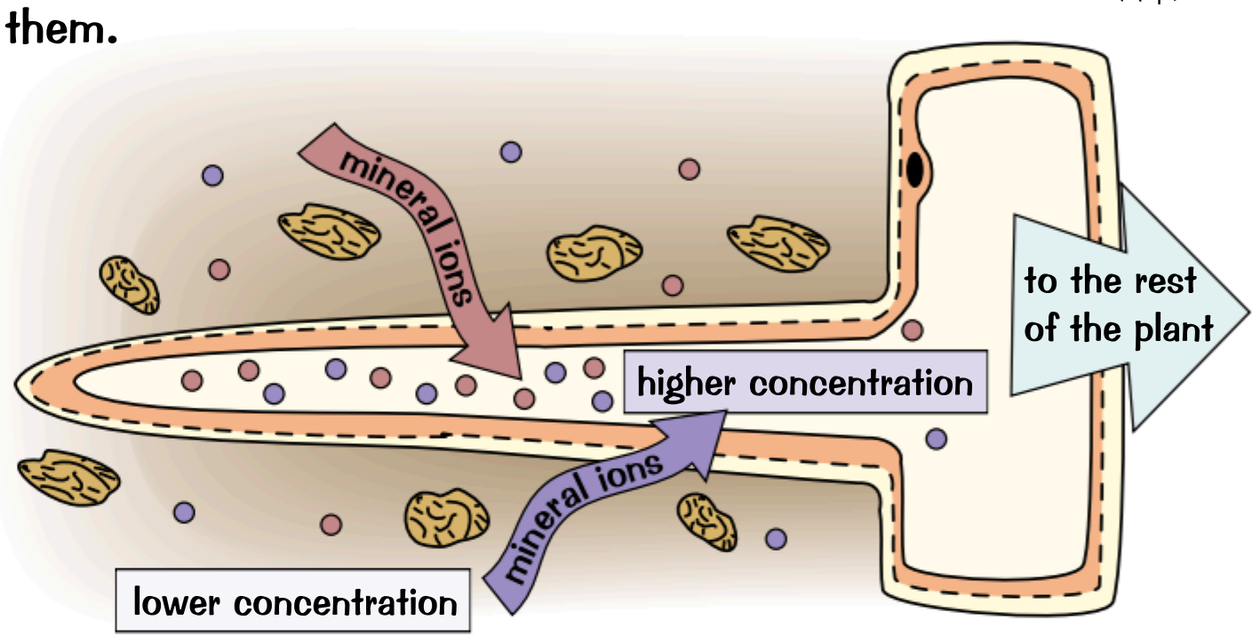
1) Plant roots are covered in millions of root hair cells.
2) These cells stick out into the soil.
3) The "hairs" give the roots a large surface area.
4) This is useful for absorbing water and mineral ions from the soil.
5) Plants need mineral ions for healthy growth.



Root Hairs Take in Minerals Using Active Transport

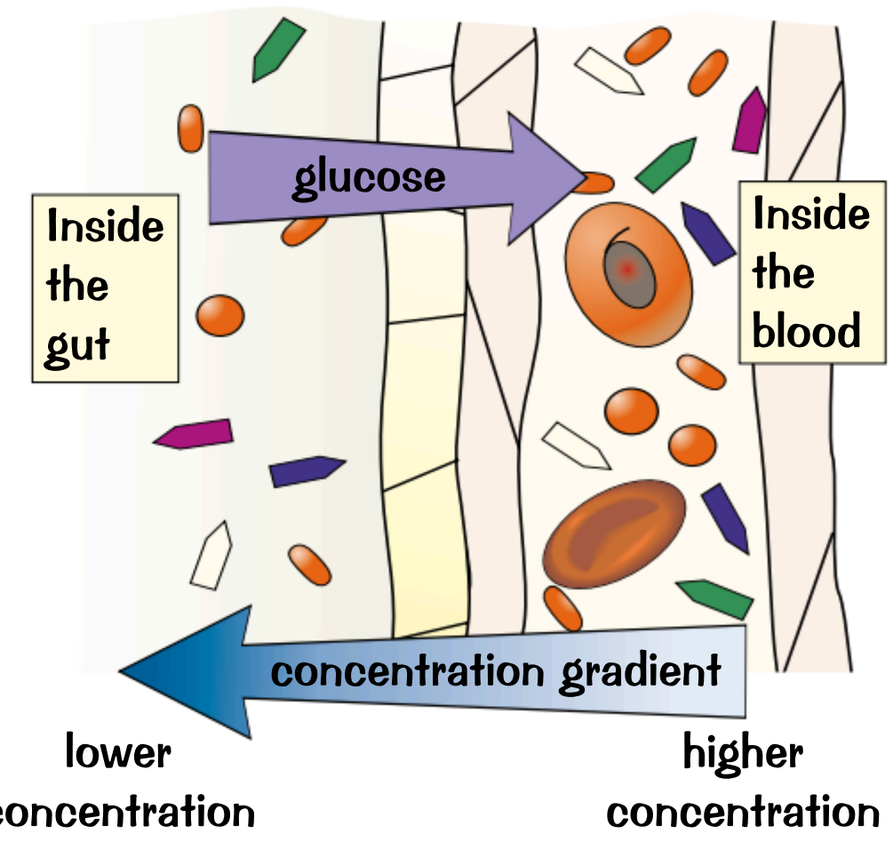
1) The concentration of minerals is usually higher in the root hair cells than in the soil around them.
2) So the root hair cells can't use diffusion to take up minerals from the soil.
3) They use active transport instead.
4) Active transport allows the plant to absorb minerals from a very dilute solution in the soil — it moves the minerals against the concentration gradient.
5) But active transport needs ENERGY from respiration to make it work.

Water is taken into root hair cells by osmosis (see page 18).



We Need Active Transport to Stop Us Starving

1) The body needs to absorb nutrients (e.g. glucose and amino acids) from food to survive.
2) The nutrients have to move from the gut into the blood.
3) When there's a higher concentration of nutrients in the gut, they diffuse into the blood.
4) Sometimes there's a lower concentration of nutrients in the gut than there is in the blood.
5) The body uses active transport to move the nutrients (like glucose) from a lower concentration in the gut to a higher concentration in the blood.
6) This means glucose can be taken into the blood against the concentration gradient. The glucose is then transported to cells, where it's used for respiration (see p.53).



Active transport — get on yer bike...

An important difference between active transport and diffusion is that active transport uses energy.

Q1 What is the purpose of active transport in the gut? [1 mark]

Exchanging Substances

How easily stuff moves between an organism and its environment depends on its surface area to volume ratio.

Organisms Exchange Substances with their Environment

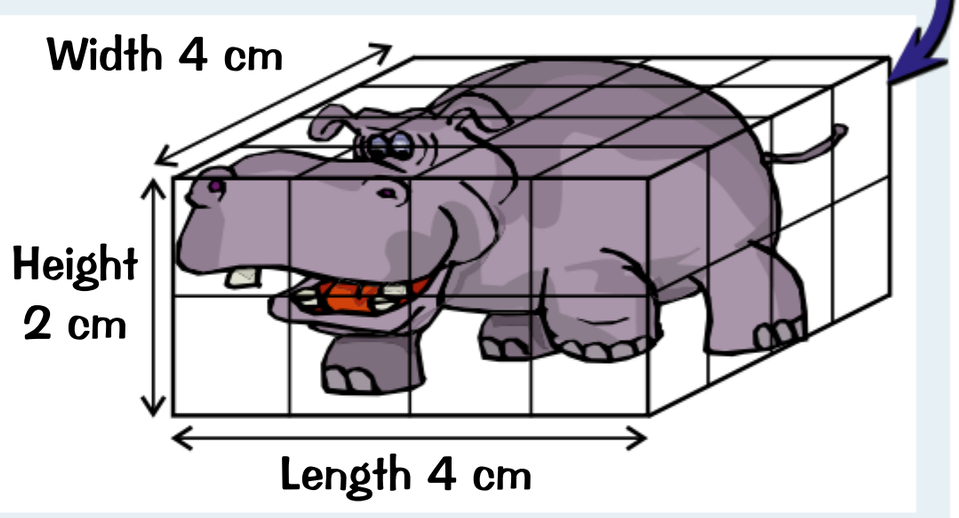
1) Cells can use diffusion to take in substances from the environment, such as oxygen.
2) They also use diffusion to get rid of waste products, such as:
   - Carbon dioxide (from respiration).
   - Urea (from the breakdown of proteins) — urea diffuses from cells into the blood plasma (see p.32). It is then removed from the body by the kidneys.
3) How easy it is for an organism to exchange (swap) substances with its environment depends on the organism's surface area to volume ratio.

You Can Calculate an Organism's Surface Area to Volume Ratio

1) A ratio shows how big one value is compared to another.
2) So a surface area to volume ratio shows how big a shape's surface is compared to its volume.
3) E.g. a 2 cm × 4 cm × 4 cm block can be used to estimate the surface area to volume ratio of this hippo:

SURFACE AREA

- The area of a square or rectangle is found by the equation: LENGTH × WIDTH.
- So the hippo's total surface area is:
  (4 × 4) × 2 (top and bottom surfaces)
  + (4 × 2) × 4 (four sides)
  = 64 cm^2.



VOLUME

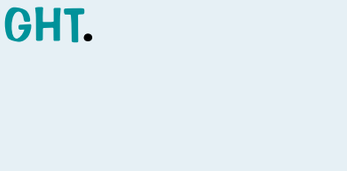
- The volume of a block is found by the equation: LENGTH × WIDTH × HEIGHT.
- So the hippo's volume is 4 × 4 × 2 = 32 cm^3.

SURFACE AREA TO VOLUME RATIO

- The surface area to volume ratio (SA : V) of the hippo can be written as 64 : 32.
- To get the ratio so that volume is equal to one, divide both sides of the ratio by the volume.

64 ÷ 32 = 2 32 ÷ 32 = 1 So the SA : V of the hippo is 2 : 1.

4) A 1 cm × 1 cm × 1 cm block can be used to estimate the surface area to volume ratio of a mouse.
   It's found that the SA : V of the mouse is 6 : 1.
5) The larger the organism, the smaller its surface area is compared to its volume.



Example: The surface area of the mouse is six times its volume.
The surface area of the hippo is only two times its volume.
So the hippo has a smaller surface area compared to its volume.

6) The smaller its surface area compared to its volume, the harder it is for an organism to exchange substances with its environment.

Not that I think you should put animals in boxes...

A large surface area is a key way that organisms' exchange surfaces are made more effective.

Q1 A bacterial cell can be represented by a 2 μm × 2 μm × 1 μm block.
Calculate the cell's surface area to volume ratio. [3 marks]

Q1 Video Solution

More on Exchanging Substances

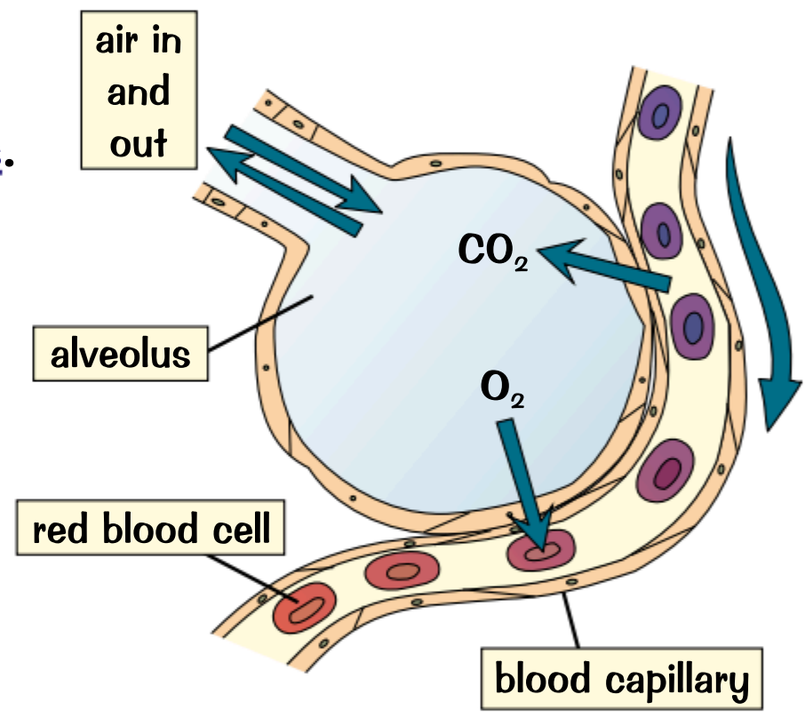
The human body has special surfaces for diffusion to make sure that we can take in enough substances.

Multicellular Organisms Need Exchange Surfaces

1) Single-celled organisms have a large surface area compared to their volume.
2) So, they can exchange all the substances they need across their surface (the cell membrane).
3) Multicellular organisms (such as animals) have a smaller surface area compared to their volume.
4) They can't normally exchange enough substances across their outside surface alone.
5) Instead, multicellular organisms have specialised exchange surfaces — (see below and the next page for some examples).
6) They also have transport systems that carry substances to and from their exchange surfaces.
7) The exchange surfaces are ADAPTED to allow enough of different substances to pass through:
   - They have a thin membrane (so substances only have a short distance to diffuse).
   - They have a large surface area (so lots of a substance can diffuse at once).
   - Exchange surfaces in animals have lots of blood vessels (so stuff can get into and out of the blood quickly).
   - Gas exchange surfaces in animals (e.g. alveoli) are ventilated too — air moves in and out.

Gas Exchange Happens in the Lungs

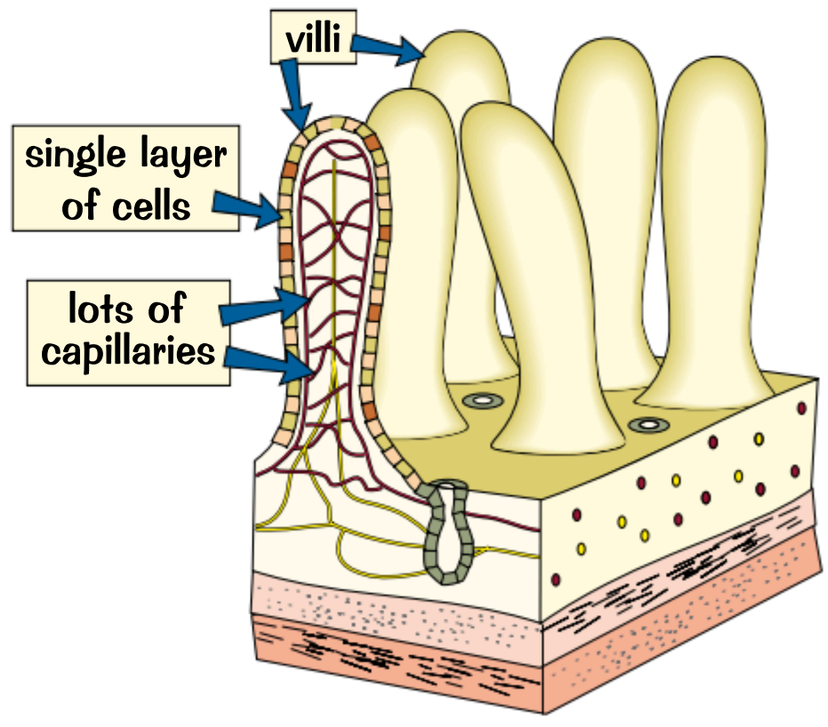
1) Oxygen (O_2) and carbon dioxide (CO_2) are exchanged in the lungs.
2) The lungs contain millions of little air sacs called alveoli. This is where gas exchange happens.
3) The alveoli are specialised for the diffusion of oxygen and carbon dioxide. They have:
   - A large surface area.
   - Very thin walls (so gases don't have far to diffuse).
   - A good blood supply.



The Villi Provide a Really Big Surface Area

1) The inside of the small intestine is covered in millions of villi.
2) They increase the surface area so that digested food is absorbed more quickly into the blood.
3) They have:
   - a single layer of surface cells,
   - a very good blood supply.

The digested food moves into the blood by diffusion and by active transport (see page 19).



Al Veoli — the Italian gas man...

Thankfully, our bodies are well adapted for efficient diffusion of substances. But the array of life's snazzy exchange surfaces doesn't stop here, oh no — just take a look at what's coming up on the next page...

Q1 Give one way in which alveoli are adapted for gas exchange. [1 mark]

Q2 Coeliac disease causes inflammation of the small intestine, which can damage the villi. Suggest why a person with coeliac disease might have low levels of iron in their blood. [2 marks]

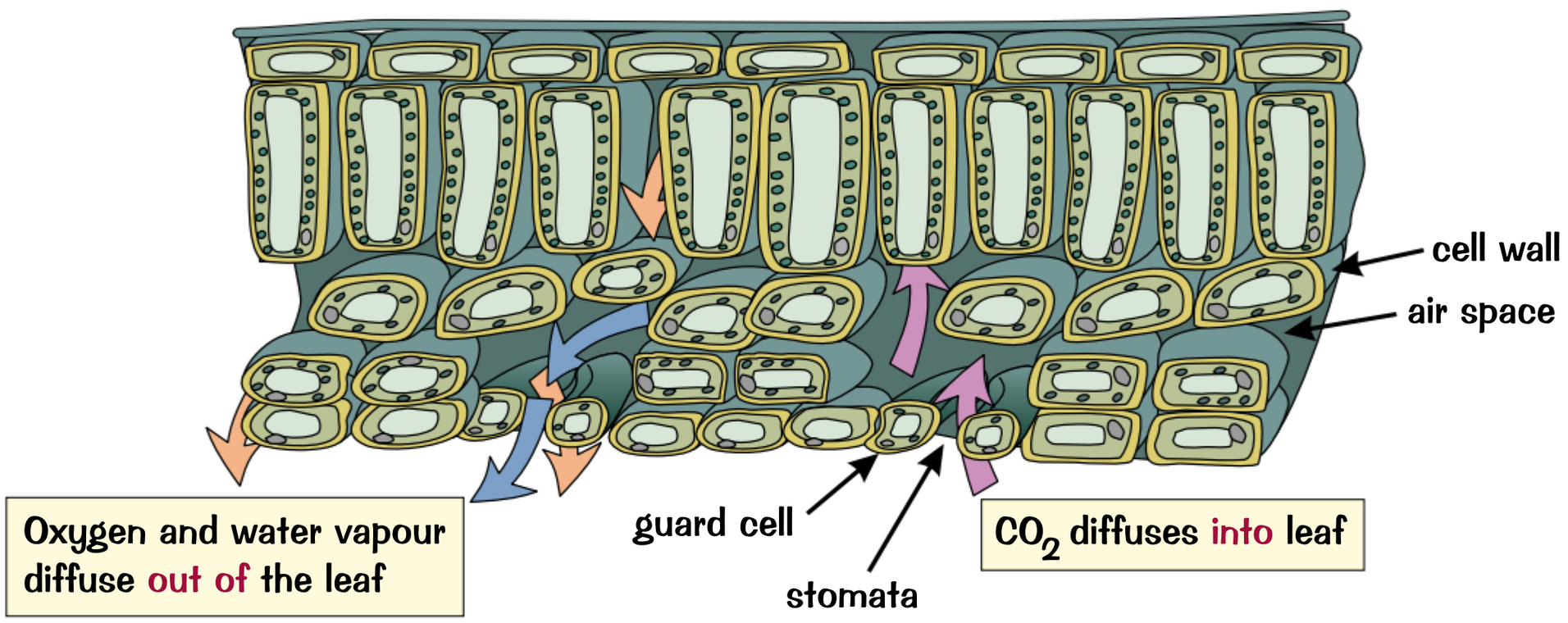
Q2 Video Solution

More on Exchanging Substances

More stuff on exchange surfaces for diffusion now — only this time they're in plants and fish. Whoopee...

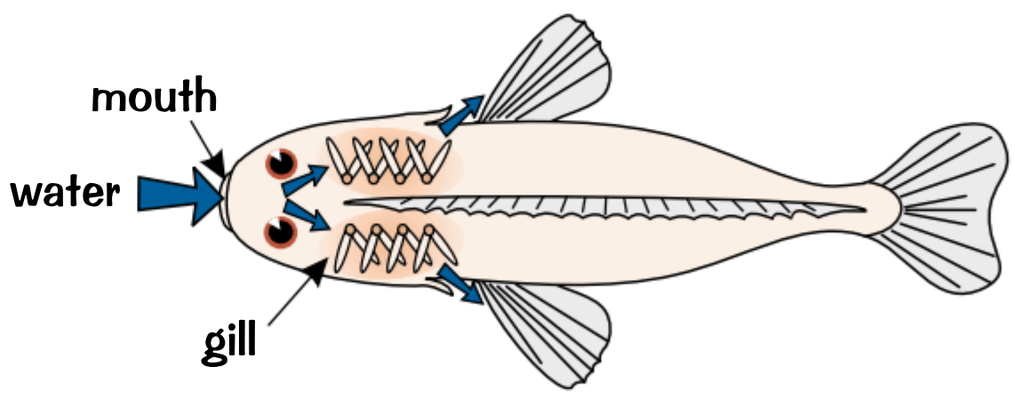
The Structure of Leaves Lets Gases Diffuse In and Out of Cells

1) Plant leaves need to take in carbon dioxide for photosynthesis, and get rid of oxygen and water vapour.
2) The underneath of the leaf is an exchange surface. It's covered in small holes called stomata.
3) Carbon dioxide diffuses through the stomata into the leaf.
4) Oxygen and water vapour diffuse out through the stomata.
5) The size of the stomata are controlled by guard cells — see page 40.
6) The flattened shape of the leaf increases the area of its exchange surface.
7) The walls of the cells inside the leaf are another exchange surface. Gases diffuse into and out of the cells through these walls.
8) There are air spaces inside the leaf to increase the area of these surfaces.



Gills Have a Large Surface Area for Gas Exchange

1) The gills are the gas exchange surface in fish.
2) Water (containing oxygen) flows into the fish's mouth and passes out through the gills.
3) In the gills, oxygen diffuses from the water into the blood. Carbon dioxide diffuses from the blood into the water.
4) The gills are made up of lots of thin plates. This gives them a large surface area for gases to be exchanged.
5) The plates have lots of blood capillaries. So they have a good blood supply to speed up diffusion.
6) They also have a thin layer of surface cells. So the gases only have to diffuse a short distance.



In, out, in, out, shake that oxygen about...

Multicellular organisms are well adapted for getting the substances they need to their cells. Make sure you learn the adaptations for all the examples on these pages — you need to know them for your exam.

Q1 Give two ways in which a gill is adapted for gas exchange. [2 marks]

Revision Questions for Topic B1

Well, that's Topic B1 done and dusted. Now there's only one way to find out whether you've learnt anything from it. And yes, I'm afraid it involves that whole load of questions staring you in the face.

- Try these questions and tick off each one when you get it right.
- When you're completely happy with a sub-topic, tick it off.

For even more practice, try the Retrieval Quiz for Topic B1 — just scan this QR code!

Topic B1 Quiz

Cells and Microscopy (p.11-13) ☐

1) What type of cell are bacteria — prokaryotic or eukaryotic? ☐
2) Name five subcellular structures that both plant and animal cells have. ☐
3) What three things do plant cells have that animal cells don't? ☐
4) Where is the genetic material found in:
   a) animal cells, ☐
   b) bacterial cells? ☐
5) Which has a higher resolution — a light microscope or an electron microscope? ☐

Differentiation and Division (p.14-15) ☐

6) What is cell differentiation? ☐
7) Give two ways that a sperm cell is adapted for swimming to an egg. ☐
8) Draw a diagram of a nerve cell. Why is it this shape? ☐
9) What are chromosomes? ☐
10) What is the cell cycle? ☐
11) What do multicellular organisms use mitosis for? ☐

Stem Cells (p.16) ☐

12) Give one way that embryonic stem cells could be used to cure diseases. ☐
13) Why might some people be against using human embryos in stem cell research? ☐

Exchanging Substances (p.17-22) ☐

14) What is diffusion? ☐
15) How does temperature affect the rate of diffusion? ☐
16) What type of molecules move by osmosis? ☐
17) Name the process that plants use to take up mineral ions from the soil. ☐
18) Give three ways that exchange surfaces can be adapted for diffusion. ☐
19) Give two ways that the villi in the small intestine are adapted for absorbing digested food. ☐
20) Name the holes in the surface of a leaf that gases diffuse through. ☐

Cell Organisation

Some organisms are made of lots of cells. To get a working organism, these cells need to be organised.

Large Multicellular Organisms are Made Up of Organ Systems

1) Cells are the basic building blocks that make up all living organisms.
2) Specialised cells carry out a particular function (see p.14).
3) These specialised cells form tissues, which form organs, which form organ systems (see below).
4) Large multicellular organisms (e.g. humans) have different systems inside them for exchanging and transporting materials.

Similar Cells Make Up Tissues

1) A tissue is a group of similar cells that work together to carry out a function.
2) E.g. epithelial tissue is a type of tissue made of epithelial cells.
It covers some parts of the human body, e.g. the inside of the gut.

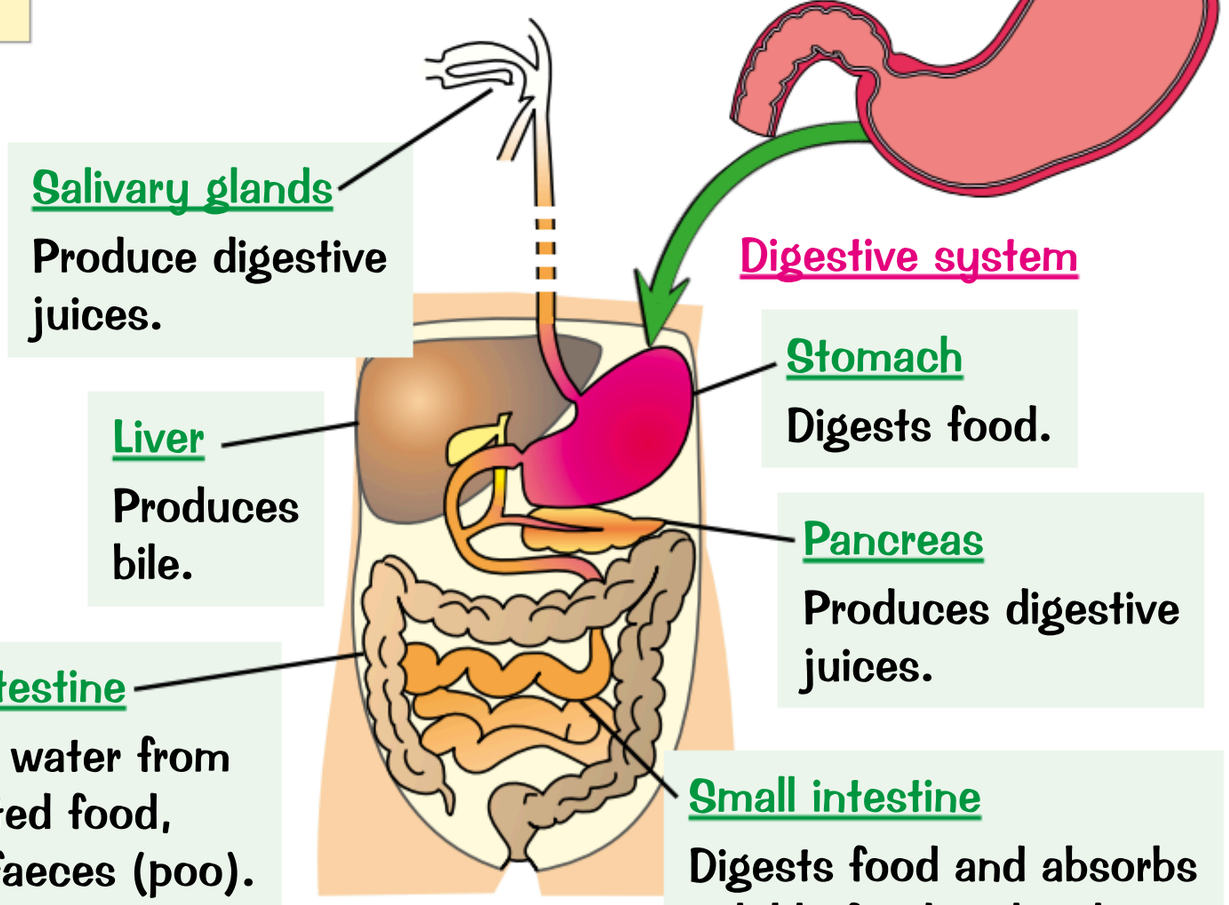
Tissues Make Up Organs

1) An organ is a group of different tissues that work together to perform a certain function.
2) For example, the stomach is an organ.
Epithelial tissue lines the inside and outside of the stomach.

Organs Make Up Organ Systems

1) An organ system is a group of organs working together to perform a function.
2) The digestive system is an organ system found in humans and other mammals.
3) It breaks down and absorbs food.
4) It's made up of these organs:

You need to know where these organs are on a diagram.



5) Organ systems work together to make entire organisms.

Soft and quilted — the best kind of tissues...

So, an organism is made of organ systems, which are groups of organs working together. And organs are made of tissues, which are groups of cells working together. Right. Now just for the thrill of it, here's a practice question.

Q1 The bladder is an organ. Explain what this means. [2 marks]

Enzymes

Chemical reactions are what make you work. And enzymes are what make them work.

Enzymes Are Catalysts

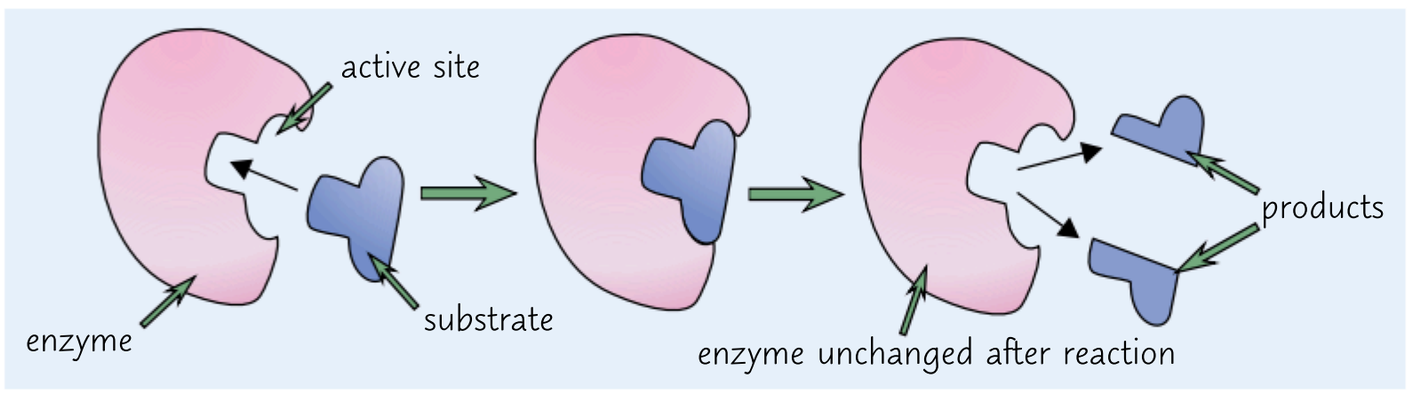
1) Living things have tons of reactions going on inside their cells.
2) These reactions are controlled by enzymes.
3) Enzymes are large proteins.
4) They speed up reactions inside living things by acting as catalysts:

Enzymes are important in metabolism — see page 53.

A CATALYST is a substance which INCREASES the speed of a reaction, without being CHANGED or USED UP in the reaction.

Enzymes Have Special Shapes

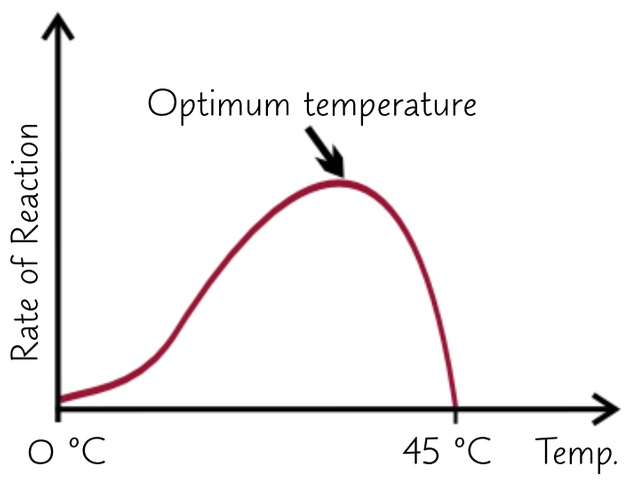
1) Chemical reactions usually involve things either being split apart or joined together.
2) Every enzyme has an active site with a unique shape.
3) The substance involved in the reaction has to fit into the active site for the enzyme to work.
4) So enzymes are really picky — they usually only catalyse one specific reaction.
5) This diagram shows the 'lock and key' model of enzyme action:



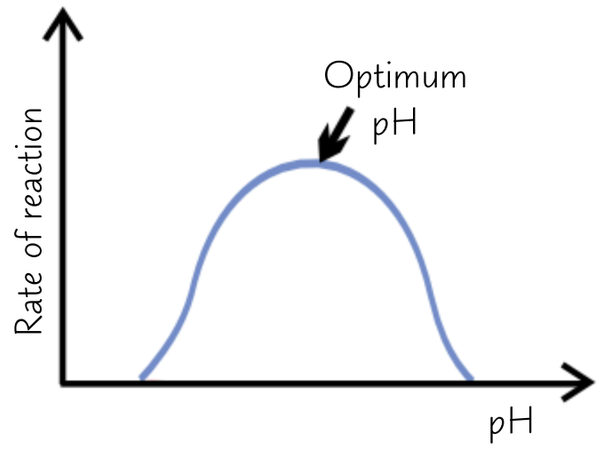
The substance that an enzyme acts on is called the substrate.

This is a useful model but it's a bit simpler than how enzymes actually work.

Enzymes Need the Right Temperature and pH



1) Temperature affects the rate of a reaction involving an enzyme.
2) A higher temperature increases the rate at first.
3) But if it gets too hot, some of the bonds holding the enzyme together break.
4) This changes the shape of the enzyme's active site, so the substrate won't fit any more — the enzyme is denatured.
5) All enzymes have a temperature that they work best at — their optimum temperature.
6) pH can affect the rate of a reaction involving an enzyme.
7) If the pH is too high or too low, it affects the bonds holding the enzyme together.
8) This changes the shape of the active site, and denatures the enzyme.
9) All enzymes have a pH that they work best at — their optimum pH.



If only enzymes could speed up revision...

Make sure you use the special terms like 'active site' and 'denatured' — the examiners will love it.

Q1 Explain why an enzyme is denatured if the pH is too high. [2 marks]

Investigating Enzymatic Reactions

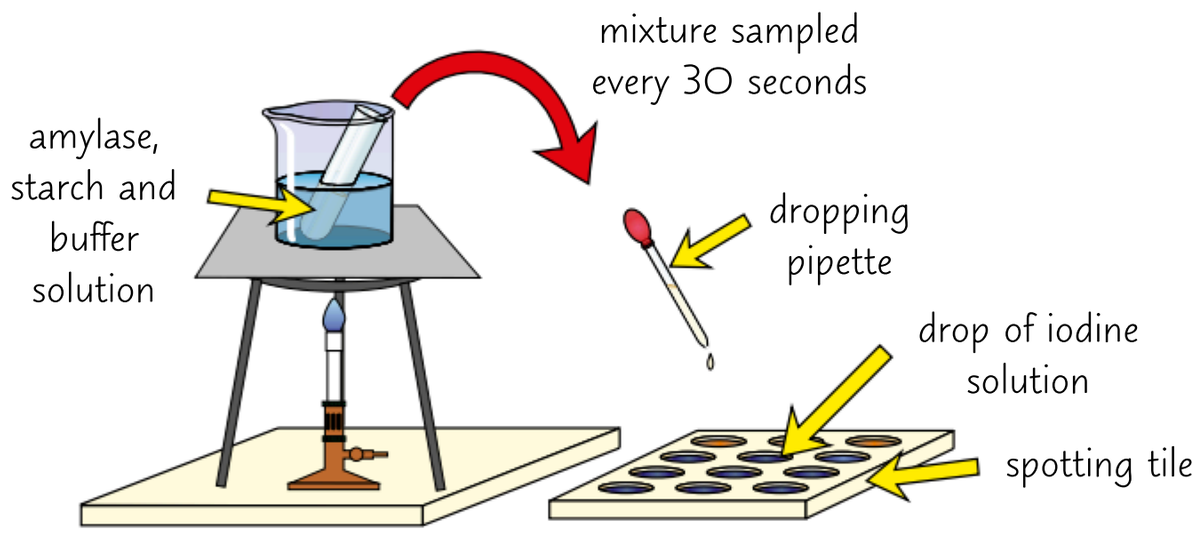
You'll soon know how to investigate the effect of pH on the rate of enzyme activity... I bet you're thrilled.

You Can Investigate the Effect of pH on Enzyme Activity

PRACTICAL

1) The enzyme amylase catalyses the breakdown of starch to sugar.
2) You can detect starch using iodine solution — if starch is present, the iodine solution will change from browny-orange to blue-black.

1) Put a drop of iodine solution into every well of a spotting tile.
2) Set up a water bath at 35 °C.
   (You could use a Bunsen burner and a beaker of water, or an electric water bath.)
3) Add some amylase solution and a buffer solution with a pH of 5 to a boiling tube.
4) Put the boiling tube in the water bath and wait for five minutes.
5) Add some starch solution to the boiling tube, mix, and start a stop clock.
6) Every 30 seconds, take a sample from the boiling tube using a dropping pipette.
7) Put a drop of the sample into a well on the spotting tile.
8) When the iodine solution stays browny-orange, all the starch in the sample has been broken down. Record how long this takes.



9) Repeat the experiment with buffer solutions of different pH values.
10) As the pH changes, the time it takes for the starch to be broken down should also change.
11) Remember to control any variables each time you repeat the experiment. This will make it a fair test. For example, the concentration and volume of the amylase solution should always be the same.

Here's How to Calculate the Rate of Reaction

1) Rate is a measure of how much something changes over time.
2) For the experiment above, you can calculate the rate of reaction using this formula:

$$\text{Rate} = \frac{1000}{\text{time}}$$

EXAMPLE

The time taken for amylase to break down all of the starch in a solution was 90 seconds. Calculate the rate of the reaction. Write your answer in s^{-1}.

Rate of reaction = 1000 ÷ time = 1000 ÷ 90 s
= 11 s^{-1}

s^{-1} just means 'per second'.

Mad scientists — they're experi-mental...

Repeating the experiment at each pH is a great idea — this lets you find a mean value for each pH.

Q1 Calculate the rate of a reaction that finished in 2.5 minutes.
Give your answer in s^{-1}. [2 marks]

Q1 Video Solution

Enzymes and Digestion

The enzymes used in digestion are produced by cells. They're released into the gut to mix with food.

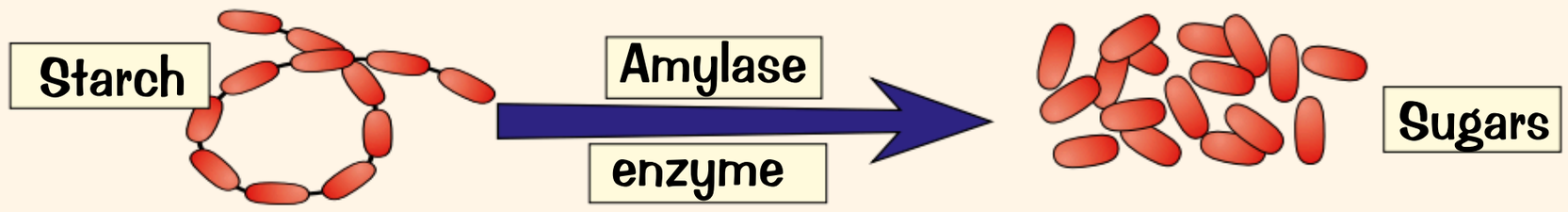
Digestive Enzymes Break Down Big Molecules

1) Starch, proteins and fats are BIG molecules.
2) They're too big to pass through the walls of the digestive system.
3) So digestive enzymes break these BIG molecules down into smaller ones.
4) These smaller, soluble molecules can easily be absorbed into the bloodstream.

CARBOHYDRASES

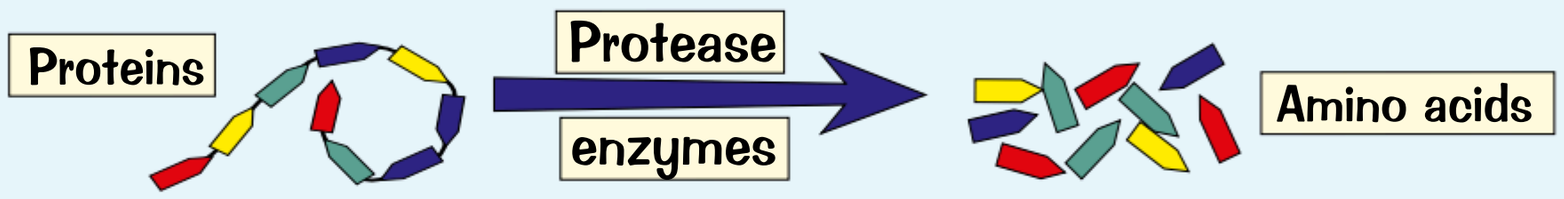
- Amylase is an example of a carbohydrase.
- Amylase is made in the salivary glands, pancreas and small intestine.
- It works in the mouth and small intestine.

Starch is a carbohydrate.



PROTEASES

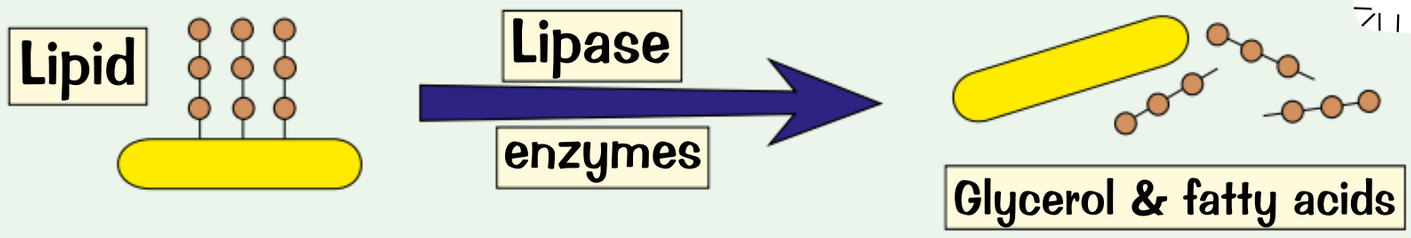
- Proteases are made in the stomach, pancreas and small intestine.
- They work in the stomach and small intestine.



LIPASES

- Lipases are made in the pancreas and small intestine.
- They work in the small intestine.

Lipids are fats and oils.



5) The products of digestion can be used to make new carbohydrates, proteins and lipids.
6) Glucose is a sugar produced by digestion. Some of it is used in respiration (see p.53).

Bile Neutralises the Stomach Acid and Emulsifies Fats

1) Bile is produced in the liver. It's stored in the gall bladder before it's released into the small intestine.
2) Bile is alkaline. It neutralises hydrochloric acid (from the stomach) and makes conditions alkaline.
3) The enzymes in the small intestine work best in these alkaline conditions.
4) Bile also emulsifies fats. Emulsify means that it breaks the fats down into tiny droplets. This gives a bigger surface area of fat for lipase to work on. This makes its digestion faster.

What do you call an acid that's eaten all the pies... **(A fatty acid)**

Make sure you know what amylase, protease and lipase enzymes do, where they're made and where they work.

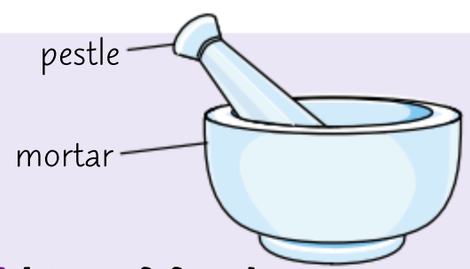
Q1 Describe and explain how bile helps the digestion of fats. [4 marks]

PRACTICAL

Food Tests

Here are some tests you can use to find out what kind of molecules are present in a sample of food.
For each test, you need to prepare a food sample. It's the same each time though — here's what you'd do:

1) Get a piece of food and break it up using a pestle and mortar.
2) Transfer the ground up food to a beaker and add some distilled water.
3) Give the mixture a good stir with a glass rod to dissolve some of the food.
4) Filter the solution using a funnel lined with filter paper. This will get rid of the solid bits of food.



Use the Benedict's Test to Test for Sugars

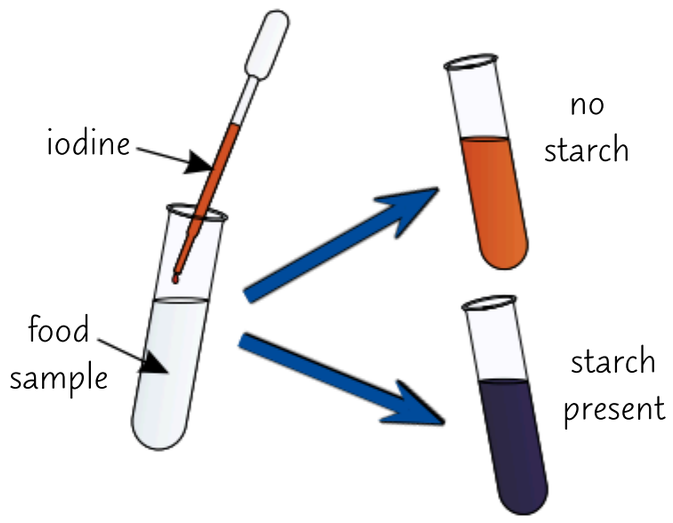
Glucose is a reducing sugar.

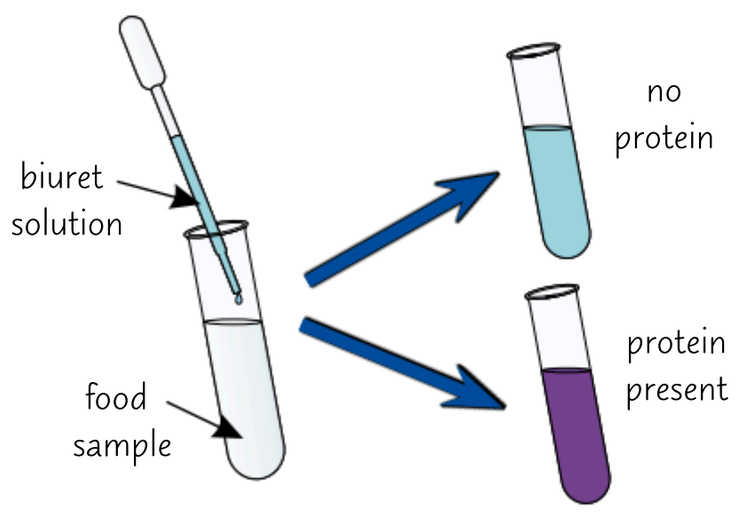
The Benedict's test is used to test for a type of sugar called a reducing sugar. Here's how you do it:

1) Prepare a food sample and transfer 5 cm^3 to a test tube.
2) Prepare a water bath so that it's set to 75 °C.
3) Add some Benedict's solution to the test tube (about 10 drops) using a pipette.
4) Place the test tube in the water bath using a test tube holder. Leave it in there for 5 minutes.
5) If the food sample contains a reducing sugar, the solution in the test tube will change from the normal blue colour to green, yellow or brick-red. The colour change depends on how much sugar is in the food.

Use Iodine Solution to Test for Starch

1) Make a food sample and transfer 5 cm^3 to a test tube.
2) Add a few drops of iodine solution.
Gently shake the tube to mix the contents.
3) If the sample contains starch, the colour of the solution will change from browny-orange to black or blue-black.



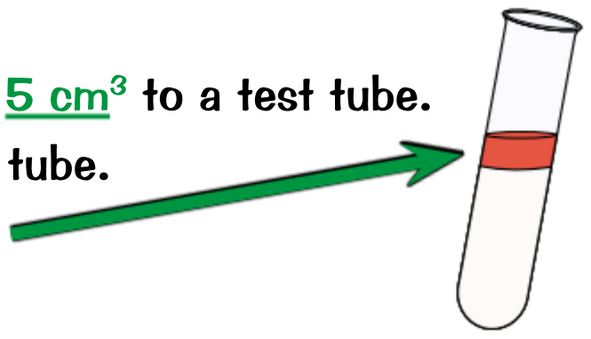


Use the Biuret Test to Test for Proteins

1) Prepare a sample of your food and transfer 2 cm^3 to a test tube.
2) Add 2 cm^3 of biuret solution to the sample.
Mix the contents of the tube by gently shaking it.
3) If the food sample contains protein, the solution will change from blue to purple.

Use the Sudan III Test to Test for Lipids

1) Prepare a food sample using the method above but don't filter it. Transfer 5 cm^3 to a test tube.
2) Add 3 drops of Sudan III stain solution to the test tube. Gently shake the tube.
3) If the sample contains lipids, the mixture will separate out into two layers.
The top layer will be bright red.



All this talk of food is making me hungry...

Make sure you do a risk assessment before starting these tests — there are lots of chemicals to use here.

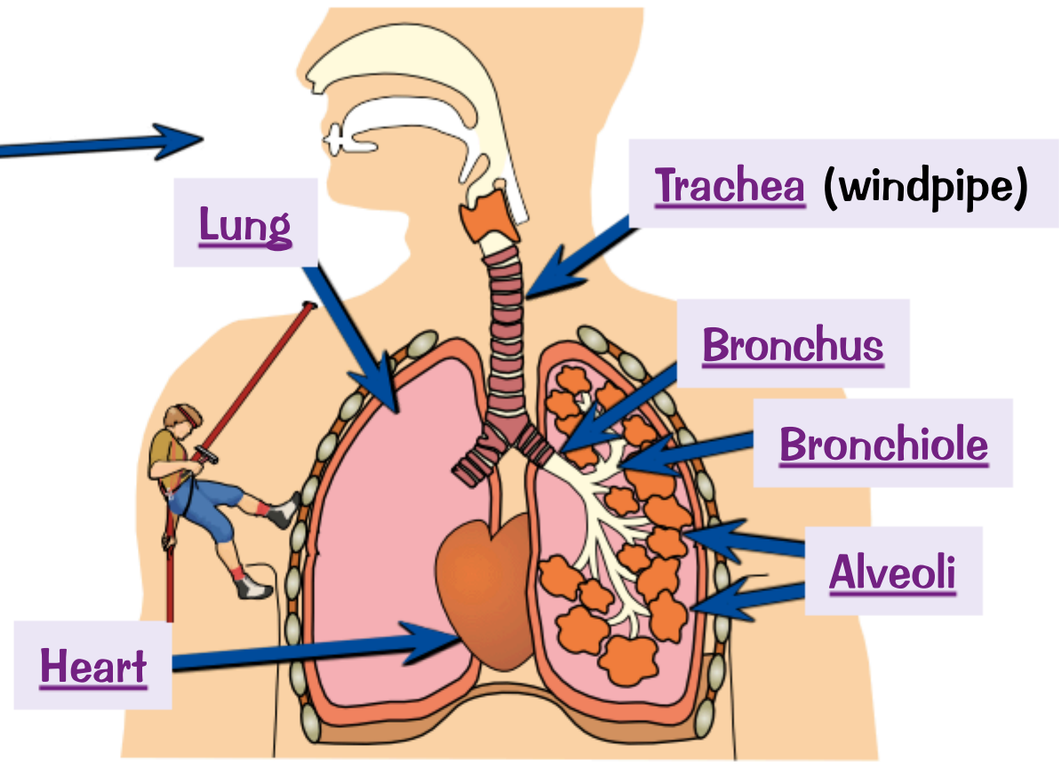
Q1 Name the solution that you would use to test for starch. [1 mark]

The Lungs

You need oxygen to supply your cells for respiration (see p.54). You also need to get rid of carbon dioxide. This all happens in your lungs when you breathe air in and out.

Air Moves In and Out of the Lungs

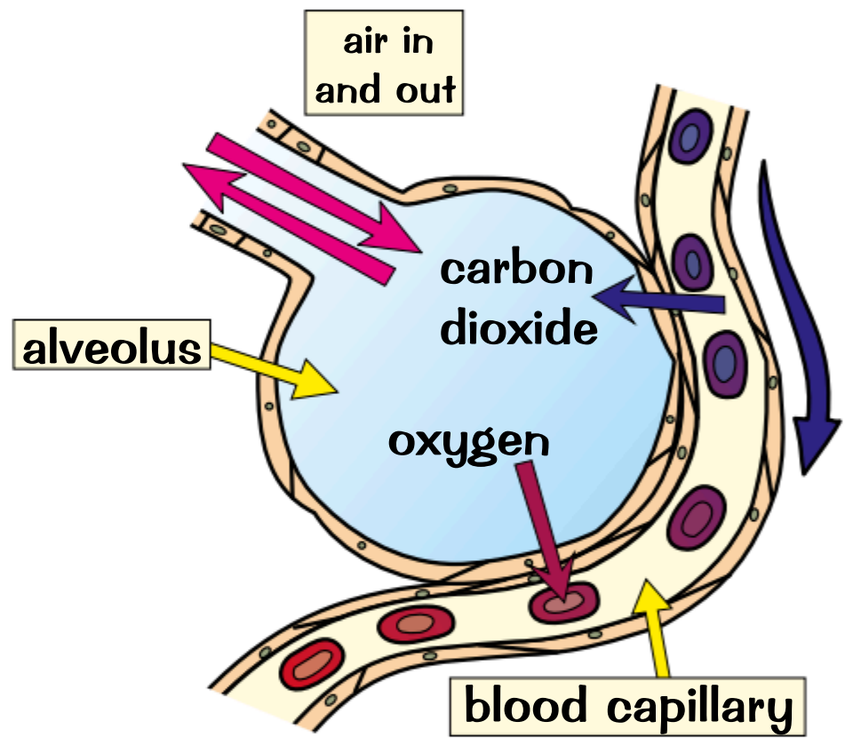
1) This diagram shows the structure of the lungs:
2) The air that you breathe in goes through the trachea.
3) Then it passes through the bronchi, then the bronchioles and ends up in the alveoli (small air sacs).



One bronchus, two bronchi.
One alveolus, many alveoli.

Alveoli Carry Out Gas Exchange

1) Alveoli in the lungs are surrounded by blood capillaries.
2) Blood comes into the lungs through the capillaries. It contains lots of carbon dioxide and very little oxygen.
3) Oxygen diffuses (see p.17) out of the air in the alveolus (where there's a higher concentration) into the blood (where there's a lower concentration).
4) Carbon dioxide diffuses out of the blood (higher concentration) into the air in the alveolus (lower concentration).
5) The blood then leaves the lungs and travels around the body.



You Can Calculate the Breathing Rate

Breathing rate is how fast a person moves air in and out of their lungs. Here's how to calculate it:

EXAMPLE

Bev takes 91 breaths in 7 minutes. Calculate her average breathing rate in breaths per minute.

breaths per minute = number of breaths ÷ number of minutes
= 91 ÷ 7
= 13 breaths per minute

Stop huffing and puffing and just learn it...

Alveoli are really well adapted for carrying out gas exchange — if you need a reminder, flick back to p.21.

Q1 Aaqib jogged around the park for 8 minutes. During his jog he took 304 breaths. Calculate his average breathing rate in breaths per minute. [1 mark]

Q1 Video Solution

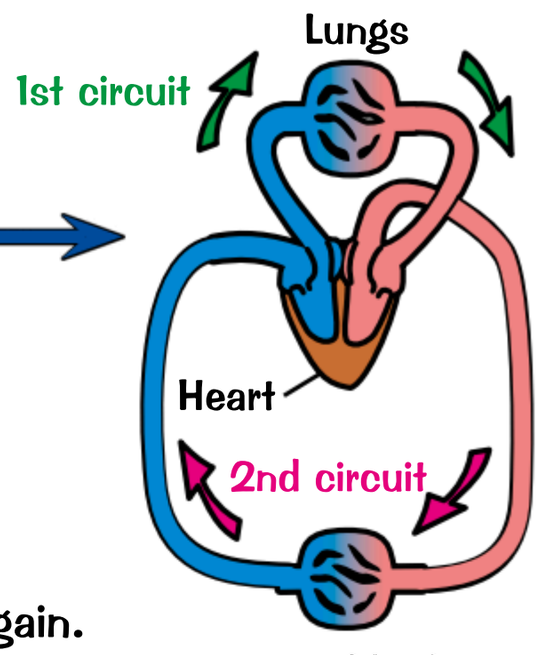
Circulatory System — The Heart

The circulatory system carries food and oxygen to every cell in the body, and waste to where it can be removed.

Humans Have a DOUBLE Circulatory System

The circulatory system is made up of the heart, blood vessels and blood.
A double circulatory system is two circuits joined together:

1) In the first circuit, the heart pumps deoxygenated blood (blood without oxygen) to the lungs. The blood picks up oxygen in the lungs.
2) Oxygenated blood (blood with oxygen) then returns to the heart.
3) In the second circuit, the heart pumps oxygenated blood around all the other organs of the body. This delivers oxygen to the body cells.
4) Deoxygenated blood returns to the heart to be pumped out to the lungs again.



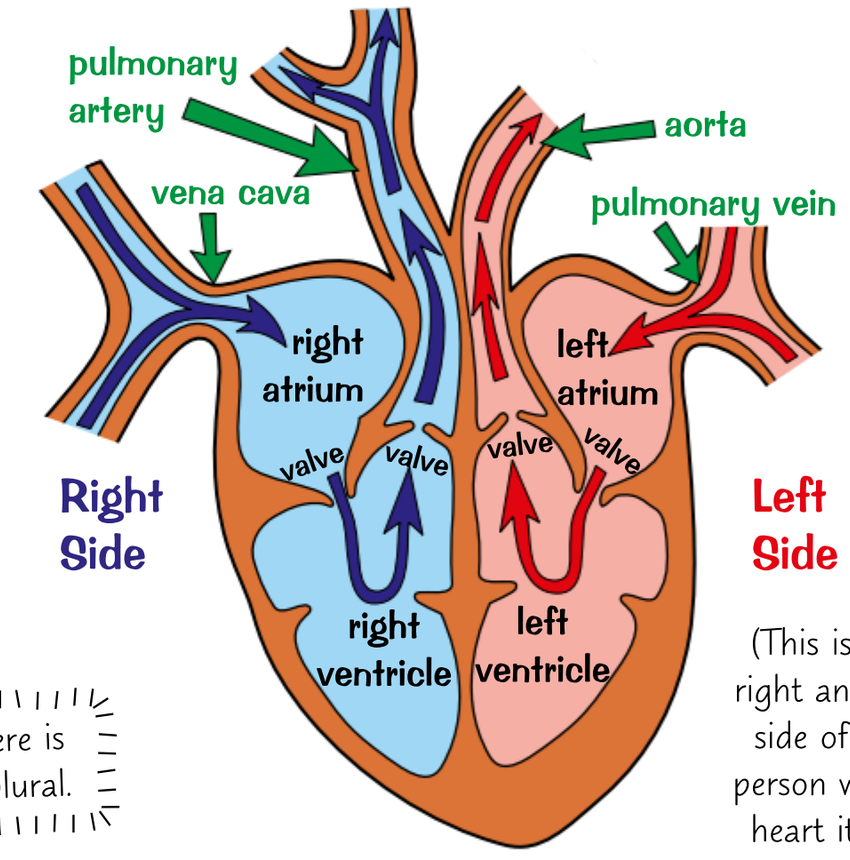
Blue = deoxygenated blood.
Red = oxygenated blood.

The Heart Pumps Blood Around The Body

1) The heart is an organ with four chambers. The walls of the chambers are mostly made of muscle tissue.
2) This muscle tissue is used to pump blood around the body. Here's how:

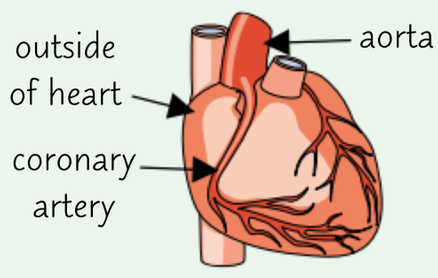
1) Blood flows into the two atria from the vena cava and the pulmonary vein.
2) The atria pump the blood into the ventricles.
3) The ventricles pump the blood out of the heart:
   - Blood from the right ventricle goes through the pulmonary artery to the lungs.
   - Blood from the left ventricle goes through the aorta to the rest of the body.
4) The blood then flows to the organs through arteries, and returns through veins (see next page).
5) The atria fill again — the whole cycle starts over.

Atrium is when there is just one. Atria is plural.



(This is the right and left side of the person whose heart it is.)

3) The valves in the heart stop the blood flowing backwards.
4) The heart also needs its own supply of oxygenated blood.
5) It gets oxygenated blood from arteries called coronary arteries. These branch off the aorta and surround the heart.



The Heart Has a Pacemaker

1) Your resting heart rate is controlled by a group of cells in the right atrium wall.
2) These cells act as a pacemaker — they tell the heart when to pump blood.
3) A pacemaker that doesn't work properly causes an irregular heartbeat.
   An artificial pacemaker (a small electrical device) can be used to keep the heart beating regularly.

Okay — let's get to the heart of the matter...

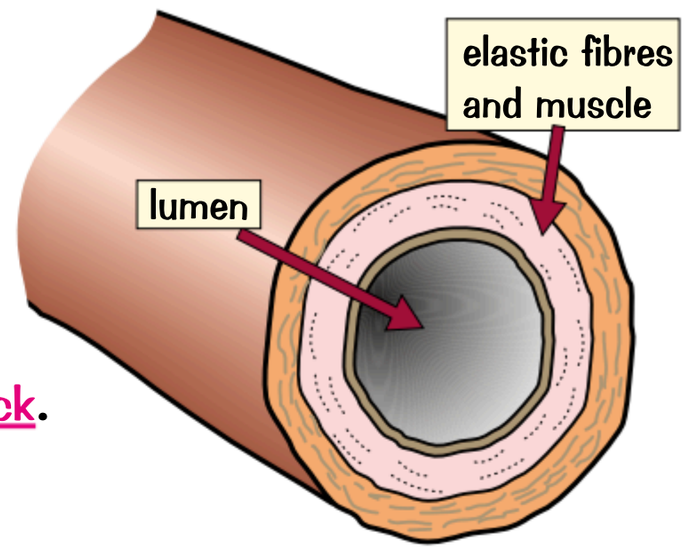
Interesting fact — when doctors use a stethoscope to listen to your heart, it's the valves closing that they hear.

Q1 Which chamber of the heart pumps deoxygenated blood to the lungs? [1 mark]

Circulatory System — Blood Vessels

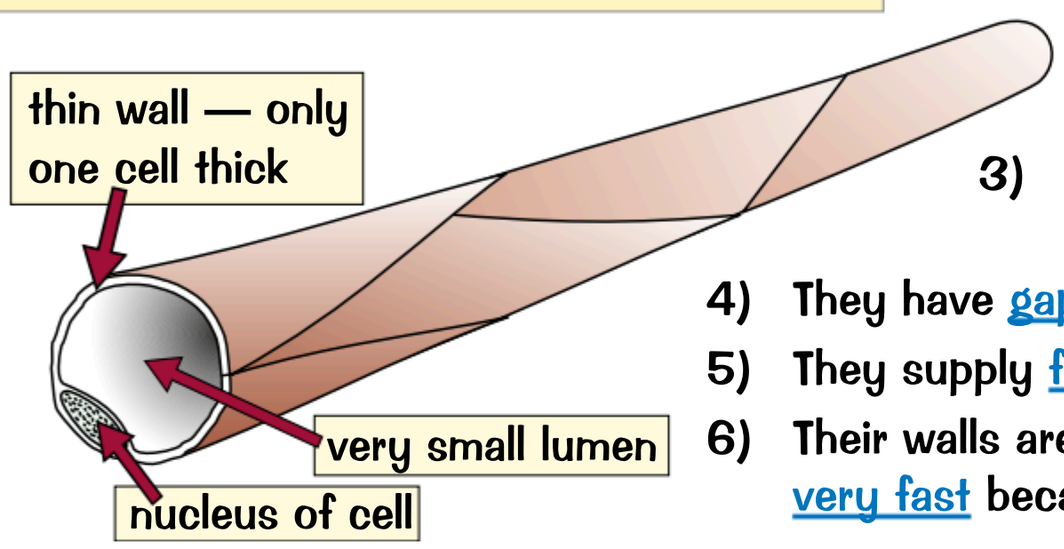
Blood flows around the body in blood vessels. There are three different types — arteries, capillaries and veins.

Arteries Carry Blood Under Pressure



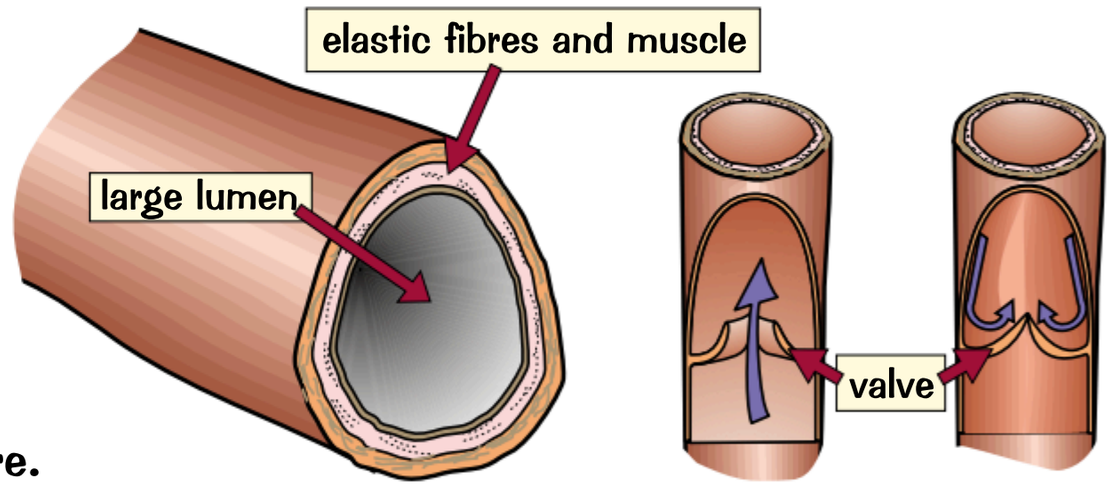
1) Arteries carry blood away from the heart.
2) The heart pumps the blood out at high pressure.
3) So artery walls are strong and elastic.
4) They have thick layers of muscle to make them strong.
5) They also have elastic fibres to allow them to stretch and spring back.
6) The walls are thick compared to the size of the hole down the middle (the "lumen" — silly name!).

Capillaries are Really Small



1) Arteries branch into capillaries.
2) Capillaries are really tiny — too small to see.
3) They carry the blood really close to every cell in the body to exchange substances with them.
4) They have gaps in their walls, so substances can diffuse in and out.
5) They supply food and oxygen, and take away waste like CO_2.
6) Their walls are usually only one cell thick. This means that diffusion is very fast because there is only a short distance for molecules to travel.

Veins Take Blood Back to the Heart



1) Capillaries join up to form veins.
2) The blood is at lower pressure in the veins. This means the walls don't need to be as thick as artery walls.
3) Veins have a bigger lumen than arteries. This helps the blood flow despite the lower pressure.
4) They also have valves. These help keep the blood flowing in the right direction.

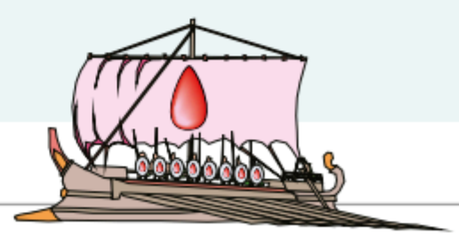
You Can Calculate the Rate of Blood Flow

The rate of blood flow is the amount of blood that passes through a blood vessel in a given time.
Here's how to calculate it:

EXAMPLE

1300 ml of blood passed through an artery in 4 minutes.
Calculate the rate of blood flow through the artery in ml per minute.

rate of blood flow = volume of blood ÷ number of minutes
= 1300 ÷ 4
= 325 ml per minute



Learn this page — don't struggle in vein...

Here's another interesting fact for you — your body contains about 60 000 miles of blood vessels.

Q1 2.175 litres of blood passed through a vein in 8.7 minutes.
Calculate the rate of blood flow through the vein in ml/min. [2 marks]

Q2 Describe how the features of veins help them to carry blood back to the heart. [2 marks]

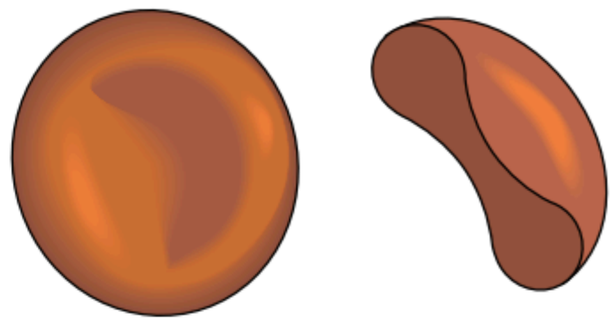
Q1 Video Solution

Circulatory System — Blood

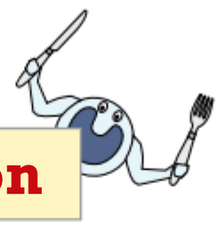
Blood is a tissue (see p.24). One of its jobs is to act as a huge transport system. It has four main parts...

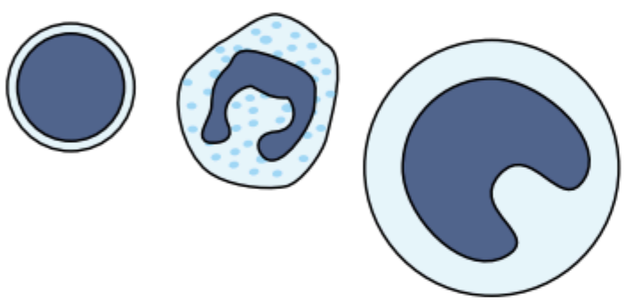
Red Blood Cells Carry Oxygen

1) The job of red blood cells is to carry oxygen from the lungs to all the cells in the body.
2) Their shape gives them a large surface area for absorbing oxygen.
3) They contain a red substance called haemoglobin.
4) Haemoglobin is the stuff that allows red blood cells to carry oxygen.
5) Red blood cells don't have a nucleus — this leaves more space for carrying oxygen.



White Blood Cells Defend Against Infection





1) White blood cells are part of your immune system — see page 46.
2) Some can change shape to gobble up unwelcome microorganisms.
3) Others produce molecules called antibodies and antitoxins to defend against microorganisms.
4) Unlike red blood cells, they do have a nucleus.

Platelets Help Blood Clot

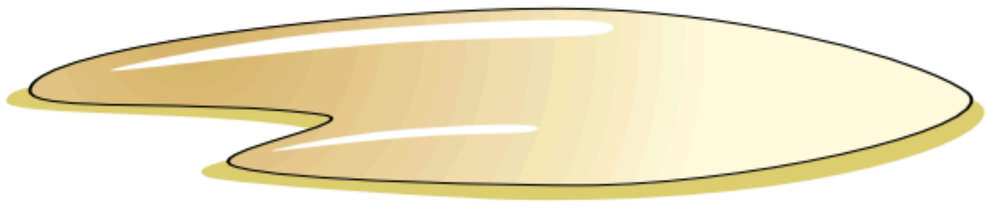
1) These are small fragments of cells. They have no nucleus.
2) They help the blood to clot (clump together) at a wound.
3) This stops all your blood pouring out.
4) It also stops any microorganisms getting in.



Plasma is the Liquid That Carries Everything in Blood

This is a pale straw-coloured liquid. It carries:

1) Red and white blood cells and platelets.
2) Food molecules (like glucose and amino acids).
3) Waste products (like carbon dioxide and urea).
4) Hormones.
5) Proteins.

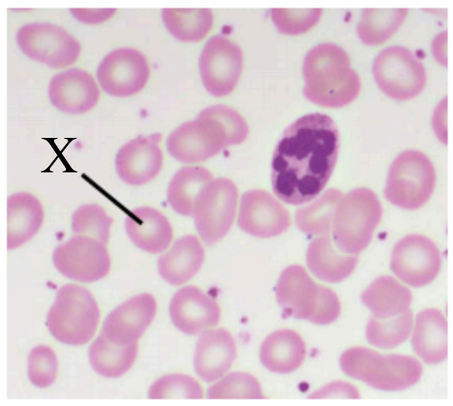


Platelets — ideal for small dinners...

Blood tests can be used to diagnose loads of things — not just disorders of the blood. This is because the blood transports so many chemicals produced by so many organs... and it's easier to take blood than, say, a piece of muscle.

Q1 Describe the purpose of platelets in blood. [1 mark]

Q2 State the function of the cell labelled X in the image on the right. [1 mark]



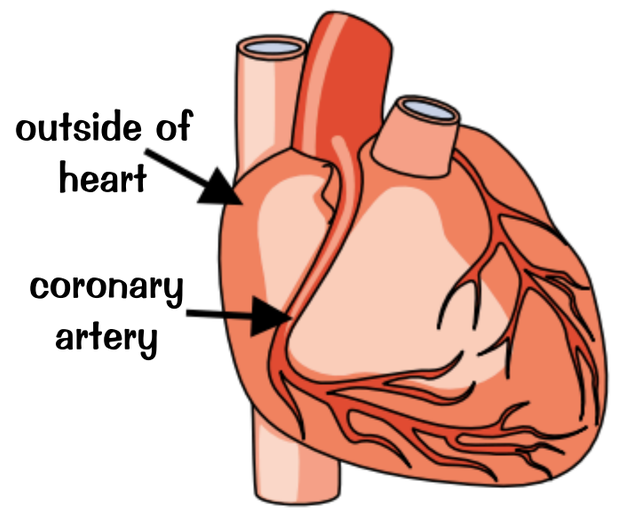
Q2 Video Solution

Cardiovascular Disease

Cardiovascular diseases are diseases of the heart or blood vessels. One example is coronary heart disease.

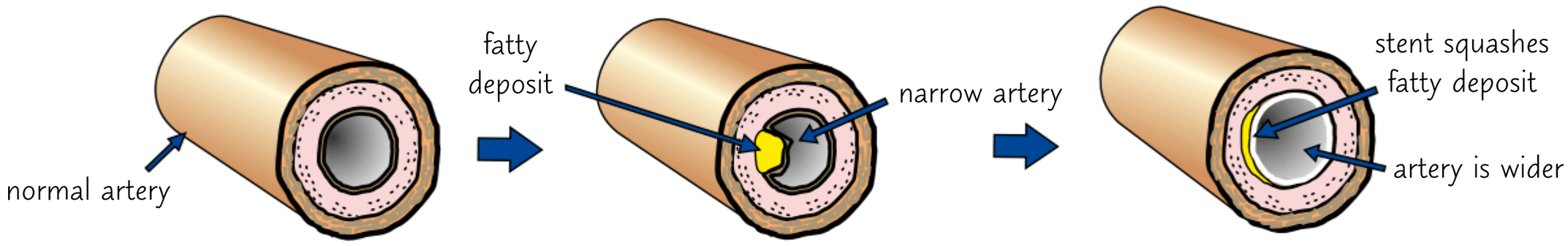
Coronary Heart Disease is a Disease of the Coronary Arteries

1) The coronary arteries supply the heart muscle with blood.
2) Coronary heart disease is when layers of fatty material (called fatty deposits) build up in the coronary arteries. This causes the arteries to become narrow.
3) This reduces the blood flow to the heart muscle.
4) This means less oxygen can get to the heart muscle. This can result in a heart attack.



Stents Keep Coronary Arteries Open

1) Stents are tubes that are put inside coronary arteries by surgery. They keep the arteries open.
2) This allows blood to reach the heart muscles and reduces the risk of a heart attack.



3) Stents are effective for a long time. Recovery time from the surgery is also quite quick.
4) But there are risks. These include having a heart attack during the operation, or getting an infection after surgery. Patients may also develop a blood clot near the stent.

Statins Reduce Cholesterol in the Blood

1) Cholesterol is a lipid that your body needs.
2) However, too much cholesterol can cause fatty deposits to form inside arteries.
3) Statins are drugs that can reduce the amount of cholesterol in the blood.
4) This slows down the rate of fatty deposits forming.

Advantages

1) Statins reduce the risk of strokes, coronary heart disease and heart attacks.
2) Some studies suggest that statins may also help prevent some other diseases.

Disadvantages

1) Statins must be taken regularly over a long time. A person could forget to take them.
2) Statins can cause unwanted side effects, for example, headaches.
3) The effect of statins isn't instant. It takes time for their effect to work.

Unlike stents and statins, using CGP books only has advantages...

Make sure you're aware of the problems as well as the advantages of both stents and statins.

Q1 Suggest two disadvantages of treating patients using stents. [2 marks]

More on Cardiovascular Disease

Here are a few more ways of dealing with problems when things go wrong in the circulatory system.

An Artificial Heart Can Pump Blood Round the Body

1) A heart transplant is when a person's heart is replaced by a donor heart (a heart from someone who has recently died).
2) This can happen if someone has heart failure. Heart failure is when the heart can't pump enough blood.
3) The lungs may also be replaced if they are diseased.
4) If a donor heart isn't available, doctors may fit an artificial heart (a machine that pumps blood around the body).
5) Artificial hearts can be used to keep a person alive until a donor heart is available. Or they can help a person recover by allowing the heart to rest and heal.
6) Sometimes artificial hearts are permanent, so a donor heart isn't needed anymore.
7) Here are some of the advantages and disadvantages of artificial hearts:

Advantage: Artificial hearts are made from metals or plastics. This makes them less likely to be attacked by the body's immune system (see page 46) than a donor heart.



Disadvantages:

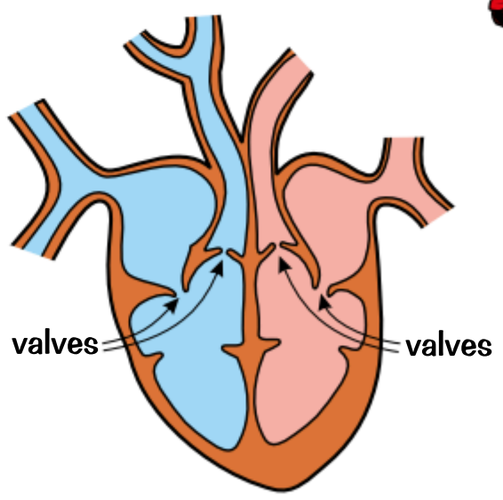
- Surgery to fit an artificial heart can lead to bleeding and infection. (This can also happen with transplant surgery.)
- Artificial hearts don't work as well as healthy natural ones.
- Blood doesn't flow through artificial hearts as smoothly as through a natural heart. This can cause blood clots and lead to strokes.
- The patient has to take drugs to thin their blood. This means they can bleed a lot more than is usual if they have an accident.

Some of the disadvantages of an artificial heart are advantages of a donor heart.

Faulty Heart Valves Can Be Replaced

1) The valves (see p.30) in the heart can be damaged by heart attacks, infection or old age.
2) This may cause the valve to stiffen, so it won't open properly.
3) A valve may also become leaky — blood flows in both directions instead of just forward.
4) This means that blood doesn't flow around the body as well as normal.
5) Damaged valves may be replaced by biological valves — valves from humans or other mammals (e.g. cows or pigs). Or they can be replaced by mechanical valves — these are man-made valves.
6) Replacing a valve is less risky than a heart transplant but there can still be problems with blood clots.





Pity they can't fit me with an artificial brain before the exam...

You should know the advantages and disadvantages of the treatments here.

Q1 Suggest one disadvantage of treating coronary heart disease with an artificial heart. [1 mark]

Health and Disease

First learn the definition of health. Then you can find out the many things that can cause ill health.

Diseases are a Major Cause of Ill Health

1) Health is the state of physical and mental wellbeing.
2) This means that both the body and mind are well.
3) Diseases are often responsible for causing ill health.
4) Diseases can be communicable or non-communicable:

Communicable diseases are sometimes called infectious diseases.

Communicable diseases

1) These are diseases that can spread from person to person or between animals and people.
2) Communicable diseases can be caused by bacteria, viruses, parasites or fungi.
3) Measles and malaria are examples of communicable diseases. See pages 43-45 for more.

Non-communicable diseases

1) These are diseases that cannot spread between people or between animals and people.
2) Coronary heart disease (see page 33) is an example of a non-communicable disease.

Different Types of Disease Can Interact

Sometimes a disease can cause other physical and mental health issues. Here are a few examples:

1) The immune system helps to fight off pathogens (see page 46).
   Some people have problems with their immune system.
   This makes them more likely to suffer from communicable diseases.
2) An immune system reaction (caused by a pathogen) may lead to an allergic reaction, such as a skin rash. Or it may worsen the symptoms of asthma for asthma sufferers.
3) Viruses infect cells in the body. This can lead to some types of cancer.
4) Physical health problems may also lead to mental health problems. For example, a person may become depressed if they can't carry out everyday activities because of ill health.

Pathogen is just the fancy term for a microorganism that can cause disease.

Other Factors Can Also Affect Your Health



1) A poor diet can affect your physical and mental health. A good diet is balanced and provides your body with everything it needs, in the right amounts.
2) Being constantly under lots of stress can lead to poor health.
3) Your life situation can affect your health. This is because it affects how easily you can access medicine or things that prevent you from getting ill.
   E.g. being able to buy condoms to prevent the spread of some sexually transmitted diseases.

If stress can affect your health, why do we have exams...

You really need to get the terms communicable and non-communicable disease into your head. They could come up in the exam and you'd be really sad if you didn't understand the question.

Q1 What is meant by 'health'? [1 mark]

Risk Factors for Non-Communicable Diseases

Non-communicable diseases are linked to risk factors. There are lots of examples of risk factors on this page.

Risk Factors Increase Your Chance of Getting a Disease

1) Risk factors are things that are linked to an increased chance of getting a certain disease.
2) However, risk factors don't mean that someone will definitely get the disease.
3) They can be:
   - part of a person's lifestyle (for example, how much exercise they do),
   - substances in a person's environment (e.g. air pollution),
   - substances in a person's body (e.g. asbestos fibres in the lungs can cause cancer).
4) Many non-communicable diseases are caused by several risk factors that interact with each other.
5) Lifestyle factors can have different effects locally, nationally and globally.

- Globally, non-communicable diseases are more common in developed countries.
  This is because people in developed countries generally earn more and can buy high-fat food.
- Nationally, cardiovascular disease, obesity and Type 2 diabetes are more common in poorer areas.
  This is because people in poorer areas are more likely to smoke, have a poor diet and not exercise.
- Your individual choices affect how common a disease is locally.

Some Risk Factors Can Cause a Disease Directly

1) Some risk factors are able to directly cause a disease. For example:

- Smoking can cause cardiovascular disease, lung disease and lung cancer.
  It damages the walls of arteries and the lining of the lungs.
- Obesity may cause Type 2 diabetes by making the body less sensitive or resistant to (not affected by) insulin (see p.62).
- Drinking too much alcohol can damage the brain and the liver.
- Smoking and drinking alcohol when pregnant can cause health problems for the unborn baby.
- Cancer can be caused by exposure to certain substances or radiation. Things that cause cancer are known as carcinogens. Ionising radiation (e.g. from X-rays) is an example of a carcinogen.

2) Some risk factors don't directly cause a disease.
   BUT there is a correlation (see p.9) between the risk factor and the disease.
3) For example, a lack of exercise and a high fat diet are risk factors for cardiovascular disease, but they can't cause the disease. It's the resulting high cholesterol levels (see p.33) that can cause it.

Non-Communicable Diseases Can Be Costly

1) Tens of millions of people around the world die from non-communicable diseases every year.
   People with these diseases may have a lower quality of life or a shorter lifespan — this is the human cost.
2) The financial cost of researching and treating these diseases is huge.
3) It can also be expensive for individuals if they have to move or adapt their home because of a disease.
   If a person has to give up work or if they die, then their family's income will be reduced.
4) A reduction in the number of people able to work can also affect a country's economy.

Best put down that cake and go for a run...

You might be asked to interpret data about risk factors. See p.9 for a few tips on what you can and can't say.

Q1 Give one type of risk factor that isn't part of a person's lifestyle. [1 mark]

Cancer

The more we understand cancer, the better our chances of avoiding and beating it. Read on to find out more.

Cancer is Caused by Uncontrolled Cell Growth and Division

1) Changes in cells can lead to uncontrolled growth and division. This results in a tumour (a mass of cells).
2) Tumours can be benign or malignant:

1) Benign tumours are masses of abnormal cells.
2) They stay in one place (usually within a membrane).
3) They don't invade other parts of the body.
4) This type isn't normally dangerous, and the tumour isn't cancerous.

1) Malignant tumours spread to other parts of the body.
2) The cells can break off and travel in the bloodstream.
3) The cells get into healthy tissues and form secondary tumours.
4) Malignant tumours are dangerous and can be fatal — they are cancers.

Risk Factors Can Increase the Chance of Some Cancers

1) Scientists have identified lots of risk factors for cancers. For example:

LIFESTYLE FACTORS



- Smoking — Smoking is linked to many types of cancer.
- Obesity — Obesity has also been linked to many different cancers.
- Viral infection — Infection with some viruses can increase the chances of developing certain types of cancer.
- UV exposure — The Sun produces UV radiation. This radiation has been linked to an increased chance of developing skin cancer.



GENETIC FACTORS

- Genes are passed on (inherited) from parent to offspring — see page 67.
- Sometimes you can inherit faulty genes that make you more likely to get cancer.

2) People are now more likely to survive cancer. This is because:
- Treatments have improved.
- Doctors can diagnose cancer earlier.
- More people are being screened (tested) for cancer.
- People know more about the risk factors for cancer.

At least our rubbish summers reduce our UV exposure...

UV radiation can still reach us through the clouds, but we can reduce the risk, e.g. by wearing sun block.

Q1 What are tumours the result of? [1 mark]

Q2 Give three lifestyle factors that can increase the risk of developing cancer. [3 marks]

Plant Cell Organisation

Just like in animals, plant cells are also organised. Here are a few examples of plant tissues and organs.

Plant Cells Are Organised Into Tissues And Organs

For more on photosynthesis, see page 50.

1) Plants are made of organs. These organs work together to make organ systems.
2) For example, stems, roots and leaves are all plant organs.
They work together to transport (carry) substances around the plant.
3) Plant organs are made of tissues. Examples of plant tissues are:
   - Epidermal tissue — this covers the whole plant.
   - Palisade mesophyll tissue — this is the part of the leaf where most photosynthesis happens.
   - Spongy mesophyll tissue — this is the part of the leaf that has big air spaces. This allows gases to diffuse in and out of cells.
   - Xylem and phloem — these transport things like water, mineral ions and food around the roots, stems and leaves (see next page).
   - Meristem tissue — this is found at the growing tips of shoots and roots.



A merry stem.

Leaves Contain Epidermal, Mesophyll, Xylem and Phloem Tissue

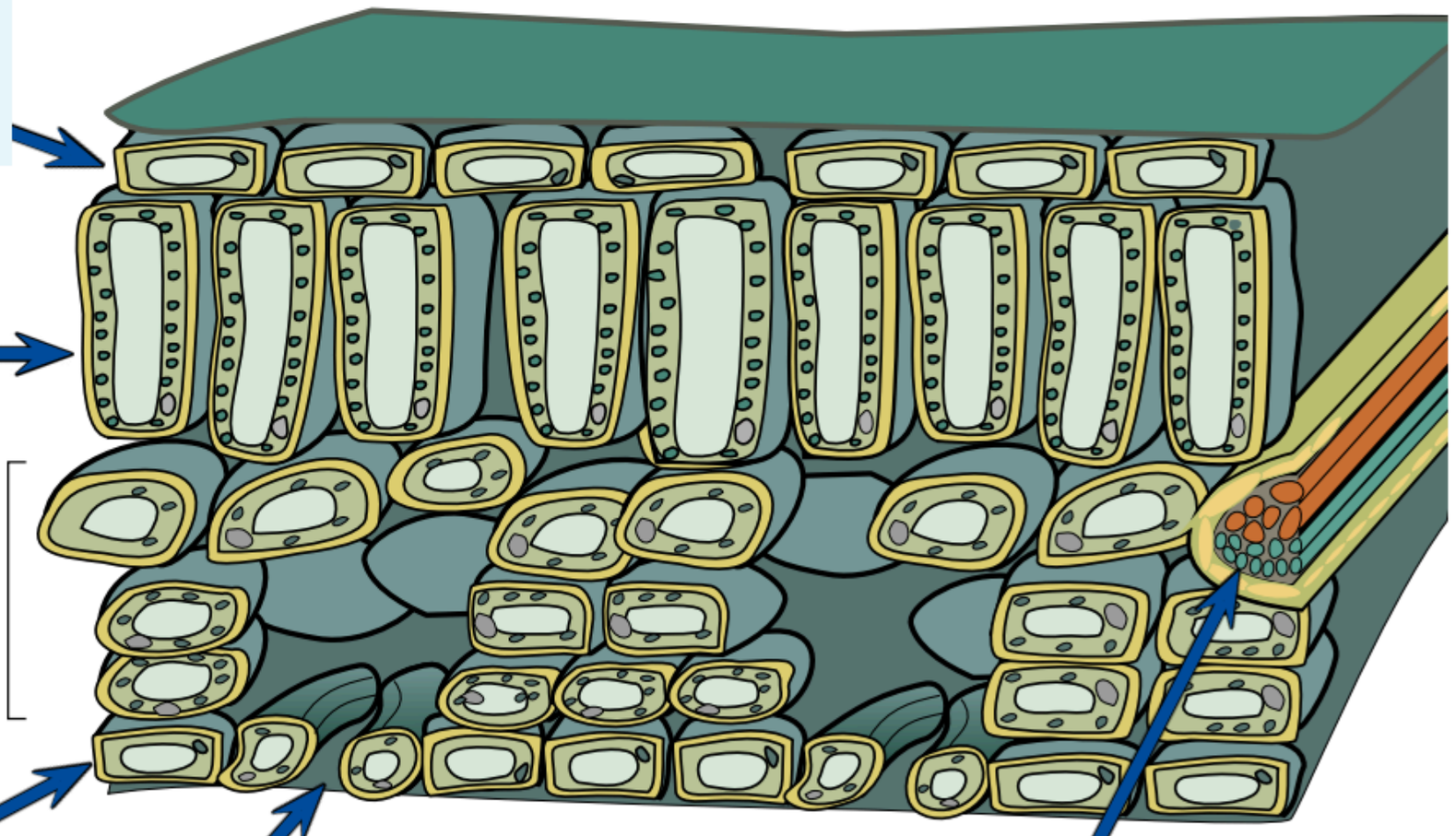
1) The leaf is where photosynthesis and gas exchange happens in a plant.
2) The structures of the tissues in a leaf are related to their function:

Upper epidermis
This layer is transparent (see-through). This lets light through to the palisade layer.

Palisade layer
This has lots of chloroplasts (see page 11). They are near the top of the leaf to get more light.

Spongy mesophyll
This contains air spaces which increase the rate of diffusion of gases.

Lower epidermis



Stomata
These let gases diffuse into and out of the leaf. They are opened and closed in response to the environment. This is controlled by guard cells.

Xylem and phloem
These bring water and nutrients to the leaf and take away glucose produced by photosynthesis. They also support the leaf.

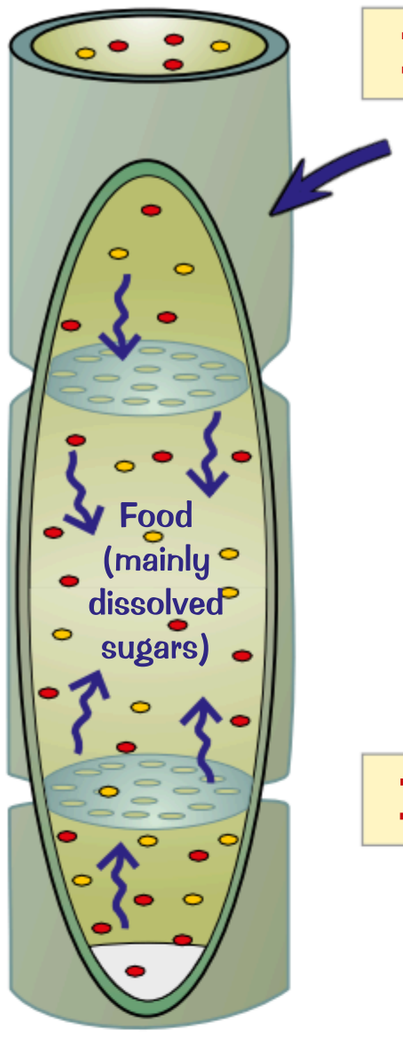
Plant cell organisation — millions of members worldwide...

There are a lot of weird names here, so make sure you spend plenty of time on this page.
Try drawing your own leaf diagram. Label it with the different tissues and describe each type of tissue.

Q1 Where is meristem tissue found in a plant? [1 mark]

Transpiration and Translocation

This page is about how things get moved around a plant so that all the right stuff ends up in the right place.



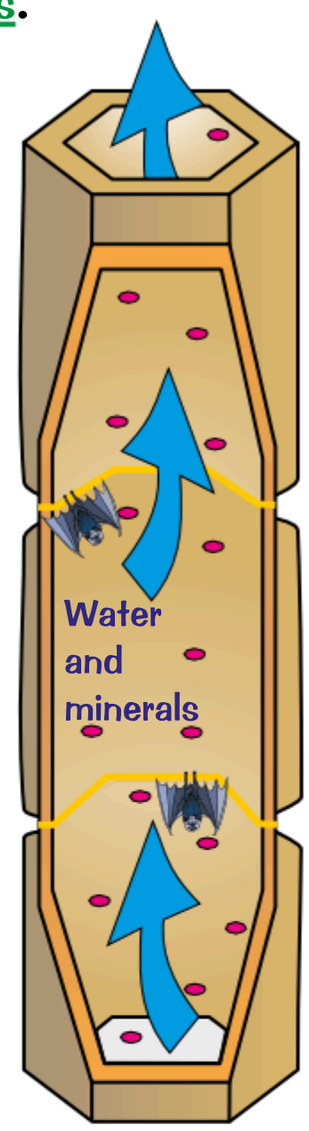
Phloem Tubes Transport Food

1) Phloem tubes are made of elongated (stretched out) living cells.
2) There are end walls between the cells.
These have pores (small holes) to allow cell sap to flow through.
3) Plants make food substances (e.g. dissolved sugars) in their leaves.
4) Phloem tubes transport these food substances around the plant for immediate use or for storage.
5) The transport goes in both directions.
6) This process is called translocation.

Cell sap is a liquid that's made up of the substances being transported and water.

Xylem Tubes Take Water Up

1) Xylem tubes are made of dead cells.
2) The cells are joined together with a hole down the middle.
3) There are no end walls between the cells.
4) The cells are strengthened with a material called lignin.
5) Xylem tubes carry water and mineral ions from the roots to the stem and leaves.
6) The movement of water from the roots, through the xylem and out of the leaves is called the transpiration stream (see below).

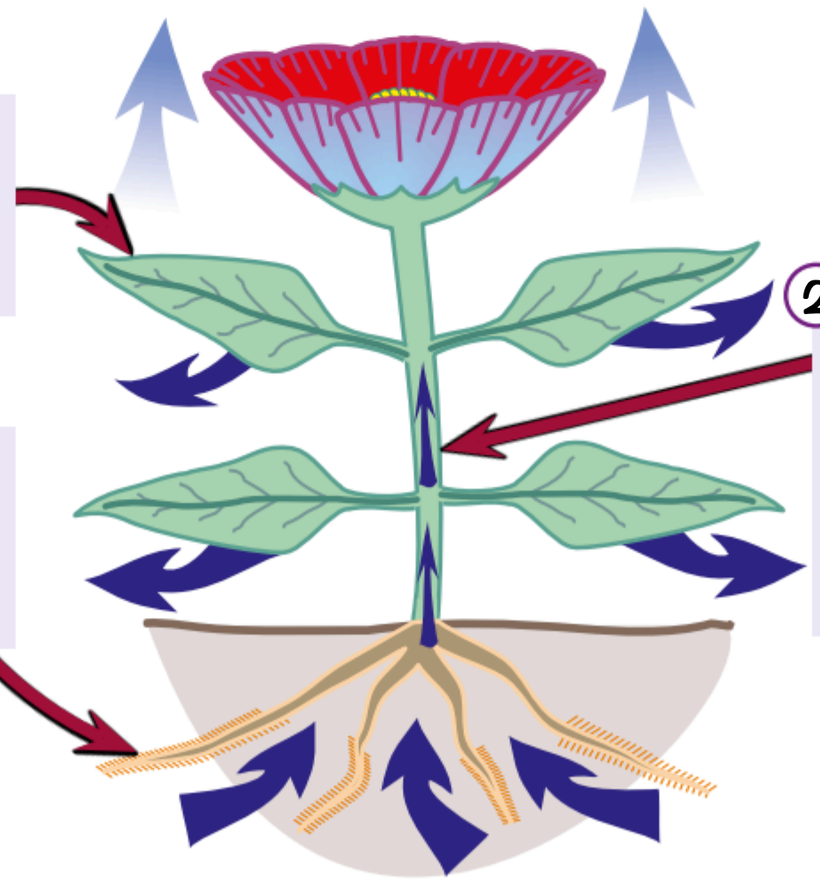


Transpiration is the Loss of Water from the Plant

1) Transpiration is caused by evaporation and diffusion of water from a plant's surface (mainly the leaves).
2) Here's how it happens:

Evaporation is when water turns from a liquid into a gas. See page 17 for more on diffusion.

1 Water evaporates from the leaves and diffuses into the air.



2
- This creates a slight shortage of water in the leaf.
- More water is drawn up from the rest of the plant through the xylem tubes to replace it.

3 This means more water is drawn up from the roots.

Head back to page 19 to see how root hair cells are adapted for taking up water.

3) There's a constant stream of water through the plant. This is called the transpiration stream.

Don't let revision stress you out — just go with the phloem...

Phloem transports substances in both directions, but xylem only transports things upwards — xy to the sky.

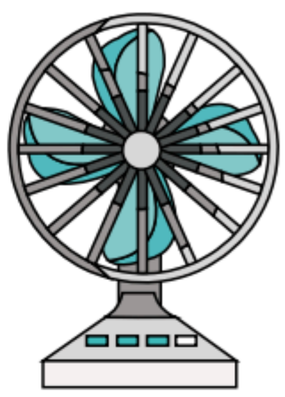
Q1 Describe the structure of xylem. [3 marks]

Transpiration and Stomata

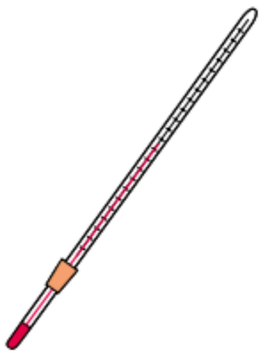
Sorry, more on transpiration. But then it's quickly through stomata and out of the other end of the topic.

Transpiration Rate is Affected by Four Main Things:

1) Air Flow



- The more windy it is, the faster transpiration happens.
- Fast moving air means that water vapour around the leaf is swept away.
- This means there's a higher concentration of water vapour inside the leaf compared to outside. So water will diffuse out of the leaf more quickly.



2) Temperature

- The warmer it is, the faster transpiration happens.
- This is because the water particles have more energy. So they evaporate and diffuse out of the stomata faster.

Many factors affect transpiration rate by affecting the rate of diffusion of water. There's more about diffusion on page 17.

3) Humidity

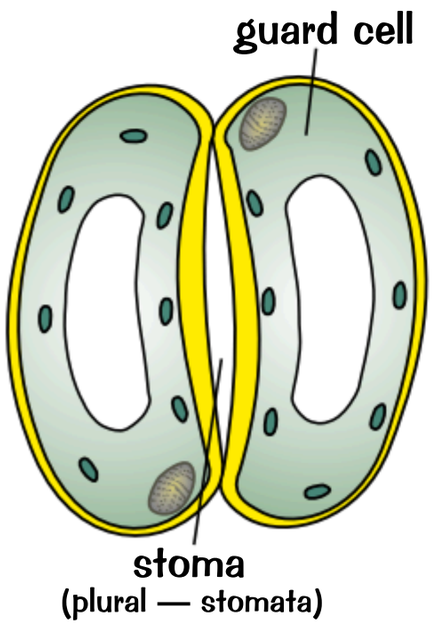
- If the air is humid there's a lot of water in it already.
- This means there isn't much of a difference between the inside and the outside of the leaf.
- This means that diffusion will not happen very fast.
- The drier the air around a leaf, the faster transpiration happens.



4) Light Intensity

- The brighter the light, the greater the transpiration rate.
- Photosynthesis can't happen in the dark, so stomata begin to close as it gets darker.
- When the stomata are closed, very little water can escape.

Guard Cells Control Gas Exchange and Water Loss



1) Stomata are surrounded by guard cells.
2) These change shape to control the size of the stomata.
3) When the plant has lots of water the guard cells fill with it and get fat. This makes the stomata open so gases can be exchanged for photosynthesis.
4) When the plant is short of water, the guard cells lose water and become floppy. This makes the stomata close. This helps stop too much water vapour escaping.
5) There are usually more stomata on the bottoms of leaves than on the tops. This is because the lower surface is cooler — so less water gets lost.

I say stomaaarta, you say stomaaayta...

You can peel off the epidermis of a leaf and count the stomata using a microscope (see p.13).

Q1 Aloe vera plants grow in hot, dry areas. Primroses grow in cool, wet areas. Predict which plant will have fewer stomata per cm^2 on the underside of its leaves. Explain your answer. [2 marks]

Q1 Video Solution

Revision Questions for Topic B2

Well, that's Topic B2 finished. Now it's time for *the* greatest quiz ever.

- Try these questions and tick off each one when you get it right.
- When you're completely happy with a sub-topic, tick it off.

For even more practice, try the Retrieval Quiz for Topic B2 — just scan this QR code!

Topic B2 Quiz

Cell Organisation (p.24) ☑

1) What is a tissue? ☑
2) Explain what is meant by the term 'organ system'. ☑

The Role of Enzymes and Food Tests (p.25-28) ☑

3) Why can enzymes be described as catalysts? ☑
4) Why do enzymes only usually catalyse one reaction? ☑
5) What does it mean when an enzyme has been 'denatured'? ☑
6) Describe how you could investigate the effect of pH on the rate of amylase activity. ☑
7) List the three places where amylase is made in the human body. ☑
8) What is the role of lipases? ☑
9) Where is bile stored? ☑
10) Name the solution that you would use to test for the presence of proteins in a food sample. ☑

The Lungs and Circulatory System (p.29-32) ☑

11) Where does gas exchange happen in the lungs? ☑
12) Name the four chambers of the heart. ☑
13) Why does the heart have valves? ☑
14) How is the resting heart rate controlled in a healthy heart? ☑
15) How are arteries adapted to carry blood away from the heart? ☑
16) Why do red blood cells not have a nucleus? ☑

Diseases and Risk Factors (p.33-37) ☑

17) Give two advantages and two disadvantages of statins. ☑
18) What is the difference between biological and mechanical replacement heart valves? ☑
19) What is a non-communicable disease? ☑
20) Give an example of different types of disease interacting in the body. ☑
21) What is meant by a risk factor for a disease? ☑
22) Which type of tumour is cancerous — benign or malignant? ☑

Plant Cell Organisation and Transport (p.38-40) ☑

23) List the tissues that make up a leaf. ☑
24) Explain how the structure of the palisade layer in a leaf is related to its function. ☑
25) What is the function of phloem tubes? ☑
26) What is transpiration? ☑
27) List the four main things that affect transpiration. ☑
28) Name the type of cell that helps open and close stomata. ☑

Communicable Disease

If you're hoping I'll ease you gently into this new topic... no such luck. Straight on to the baddies of biology.

There Are Several Types of Pathogen

1) Pathogens are microorganisms that enter the body and cause disease.
2) They cause communicable (infectious) diseases.
3) Communicable diseases are diseases that can spread (see p.35).
4) Both plants and animals can be infected by pathogens.
5) There are four main types of pathogens:



bacteria  viruses protists fungi

Pathogens Can Be Spread in Different Ways

Here are a few ways that pathogens can be spread:

1) WATER — Some pathogens can be picked up by drinking or bathing in dirty water.
2) AIR — Pathogens can be carried in the air and can then be breathed in.
Some pathogens are carried in the air in droplets made when you cough or sneeze.
3) DIRECT CONTACT — Some pathogens can be picked up by touching surfaces they're on (e.g. the skin).



The Spread of Disease Can Be Reduced or Prevented

There are things that we can do to reduce or prevent the spread of disease, such as...

1. Being hygienic (clean) — For example, washing your hands before making food can stop you spreading pathogens onto the food and infecting a person who eats it.

2. Destroying vectors — Vectors are organisms that spread disease. Killing them helps to stop the disease from being passed on. Vectors that are insects can be killed using insecticides. Their habitats can also be destroyed so that they can't breed.

3. Isolating infected individuals — If you keep someone who has a communicable disease away from other people, it prevents them from passing it on to anyone else.

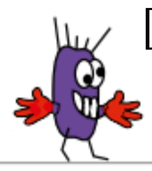
4. Vaccination (see page 47) — Vaccinations make it less likely that people and animals will get a communicable disease and pass it on to others..

Coughs and sneezes spread diseases...

Yuck, lots of nasties out there that can cause disease. Plants need to be worried too, as you'll find out.

Q1 Name two types of pathogen. [2 marks]

Q2 Suggest why it is important for chefs to wash their hands before cooking. [1 mark]

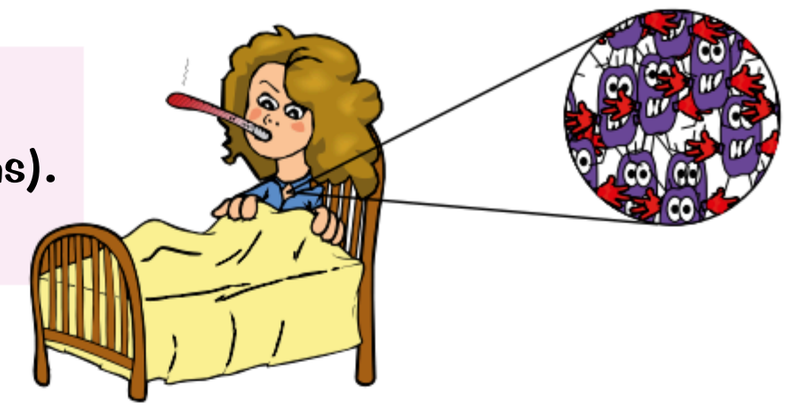


Bacterial Diseases

First up from the pathogen hall of fame are... bacteria.

Bacteria are Very Small Living Cells

1) Bacteria reproduce rapidly inside your body.
2) They can make you feel ill by producing toxins (poisons).
3) Toxins damage your cells and tissues.



Salmonella and Gonorrhoea are Bacterial Diseases

SALMONELLA

1) *Salmonella* is a type of bacteria. It causes food poisoning.
2) Infected people can suffer from fever, stomach cramps, vomiting and diarrhoea. Nice.
3) These symptoms are caused by toxins from the bacteria.
4) You can get *Salmonella* food poisoning by:
   - Eating food that's got *Salmonella* bacteria in it already,
     e.g. eating chicken that caught the disease whilst it was alive.
   - Eating food that has been made where the bacteria is present,
     e.g. in an unclean kitchen or on the hands of the person making the food.
5) In the UK, most poultry (e.g. chickens and turkeys) are given a vaccination against *Salmonella*. This is to control the spread of the disease.



GONORRHOEA

1) Gonorrhoea is caused by bacteria.
2) Gonorrhoea is a sexually transmitted disease (STD).
3) STDs are passed on by sexual contact, e.g. having unprotected sex.
4) A person with gonorrhoea will get pain when they urinate (wee).
   Another symptom is a thick yellow or green discharge (fluid) from the vagina or the penis.
5) Gonorrhoea used to be treated with an antibiotic called penicillin. There are now new strains (types) of gonorrhoea that are resistant to (not killed by) penicillin.
   So this antibiotic doesn't work anymore.
6) To prevent the spread of gonorrhoea:
   - people can be treated with other antibiotics,
   - people should use barrier methods of contraception (see page 65), such as condoms.

I knew that old sandwich was ☠ ...

Once bacteria start reproducing inside your body, they cause lots of problems and make you feel ill.

Q1 Give two symptoms of *Salmonella*. [2 marks]

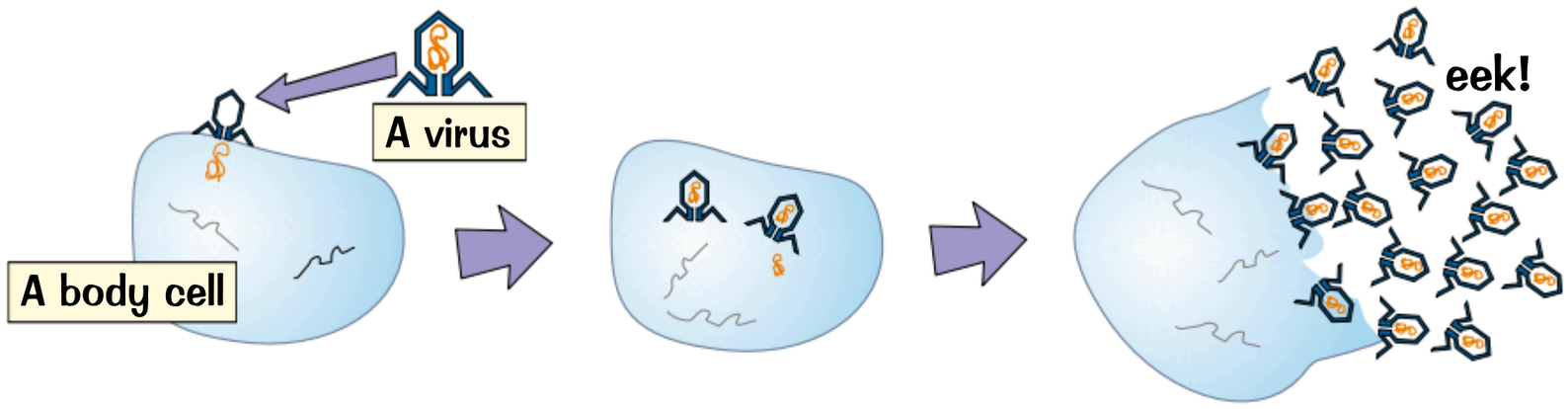
Q2 What has made it harder to treat gonorrhoea? [1 mark]

Viral Diseases

Viruses may be teeny tiny but there are lots of diseases caused by them.

Viruses Are Not Cells — They're Much Smaller

1) Viruses reproduce rapidly inside your body.
2) They live inside your cells.
3) Inside your cells, they make lots of copies of themselves.
4) The cells will usually then burst, releasing all the new viruses.
5) This cell damage is what makes you feel ill.



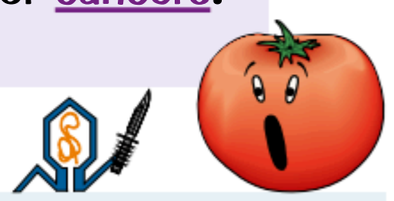
Different Viruses Cause Different Diseases, Such as...

Measles

1) Measles is a viral disease. It is spread by droplets from an infected person's sneeze or cough.
2) People with measles develop a red skin rash. They'll also show signs of a fever (a high temperature).
3) Measles can be very serious. People can die from measles if there are complications (problems).
4) Because of this, most people are vaccinated against measles when they're young.

HIV

1) HIV is a virus spread by sexual contact or by exchanging bodily fluids (e.g. blood). This can happen when people share needles when taking drugs.
2) To start with, HIV causes flu-like symptoms for a few weeks.
3) After that the person doesn't usually have any symptoms for several years.
4) HIV can be controlled with antiretroviral drugs. These stop the virus copying itself in the body.
5) If it's not controlled, the virus attacks the immune cells (see page 46).
6) If the body's immune system is badly damaged, it can't cope with other infections or cancers. At this stage, the virus is known as late stage HIV infection or AIDS.



Tobacco mosaic virus

1) Tobacco mosaic virus (TMV) is a virus that affects many species of plants, e.g. tomatoes.
2) It causes parts of the leaves to become discoloured. This gives them a mosaic pattern.
3) The discoloured leaves have less chlorophyll to absorb light (see p.50).
4) This means less photosynthesis happens in the leaves, so the plant can't make enough food to grow.

I've heard this page has gone viral...

The examiner could grill you on any one of these viral diseases, so make sure you know them all inside out.

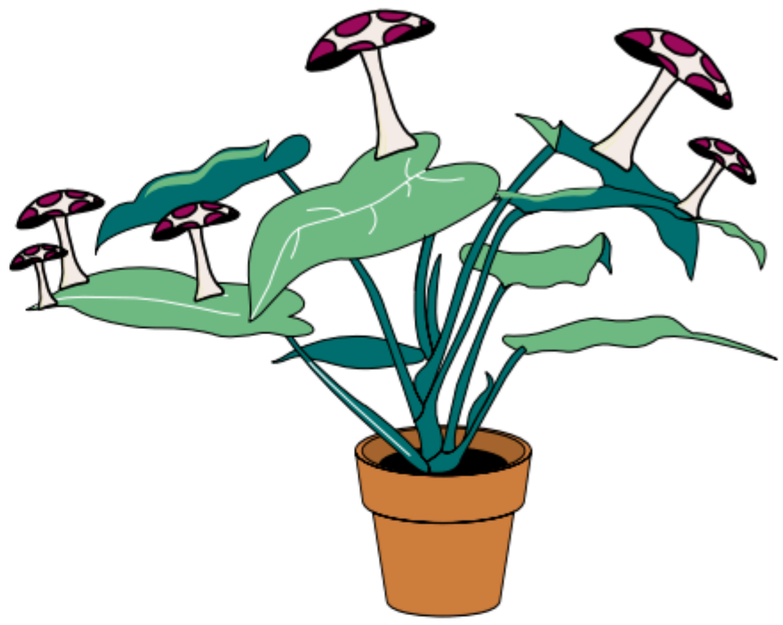
Q1 Give one way that HIV can be spread. [1 mark]

Fungal and Protist Diseases

Sorry — I'm afraid there are some more diseases to learn about here...

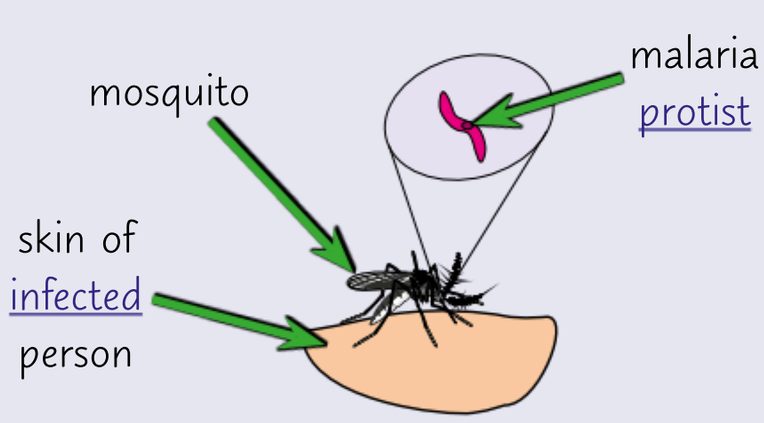
Rose Black Spot is a Fungal Disease

1) Rose black spot is a disease caused by a fungus.
2) The fungus causes purple or black spots on the leaves of rose plants.
3) The leaves can then turn yellow and drop off.
4) This means that less photosynthesis can happen, so the plant doesn't grow very well.
5) It is spread in water or by the wind.
6) Gardeners can treat the disease using fungicides (chemicals that kill fungi).
7) They can also strip the affected leaves off the plant.
8) These leaves then need to be destroyed so that the fungus can't spread to other rose plants.

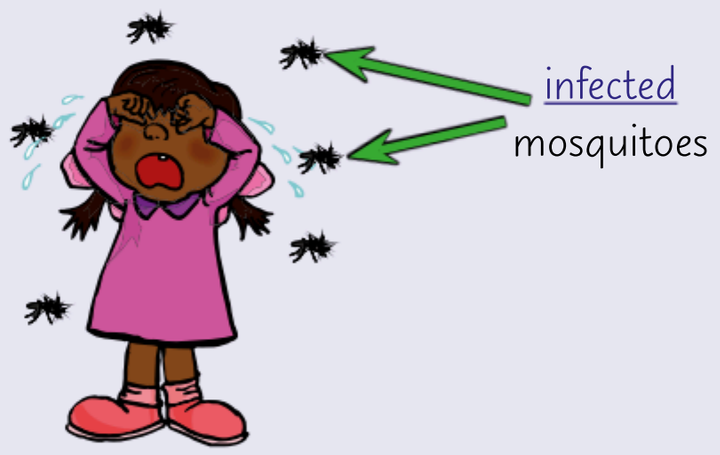


Malaria is a Disease Caused by a Protist

1) Malaria is caused by a protist.
2) Part of the protist's life cycle takes place inside the mosquito.
3) The mosquitoes are vectors. They help spread malaria like this...



- The mosquitoes pick up the protist when they feed on an infected animal.
- The mosquitoes don't get malaria.



- They pass on the protist to other animals (like us) when they bite them.
- These animals get malaria.

4) Malaria causes repeating episodes of fever. People can die from malaria.
5) The spread of malaria can be reduced by stopping the mosquitoes from breeding.
6) People can be protected from mosquito bites using mosquito nets.



Rose black spot — coming to a plant near you...

OK, I promise, that's it. No more diseases to learn about in this topic. You may be sick of them already (joke), but here are some questions to do before you go onto the next page.

Q1 Give two ways rose black spot can be treated so it doesn't spread to other plants. [2 marks]

Q2 What type of pathogen causes malaria? [1 mark]

Fighting Disease

The human body has some pretty neat features when it comes to fighting disease.

Your Body Has a Pretty Good Defence System

The human body has got features that stop a lot of nasties getting inside. For example:

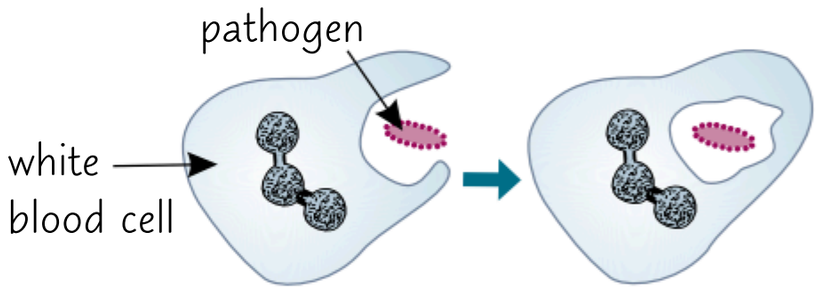
1) The skin — It stops pathogens getting inside you. It also releases substances that kill pathogens.
2) Nose hairs — They trap particles that could contain pathogens.
3) Mucus (snot) — The trachea and bronchi (airways — see page 29) release mucus to trap pathogens.
4) Cilia (hair-like structures) — The trachea and bronchi are lined with cilia. They move the mucus up to the back of the throat where it can be swallowed.
5) Stomach acid — The stomach makes hydrochloric acid. This kills pathogens in the stomach.

Your Immune System Can Attack Pathogens

1) If pathogens do make it into your body, your immune system kicks in to destroy them.
2) The most important part of your immune system is the white blood cells.
3) When they come across an invading pathogen they have three lines of attack:

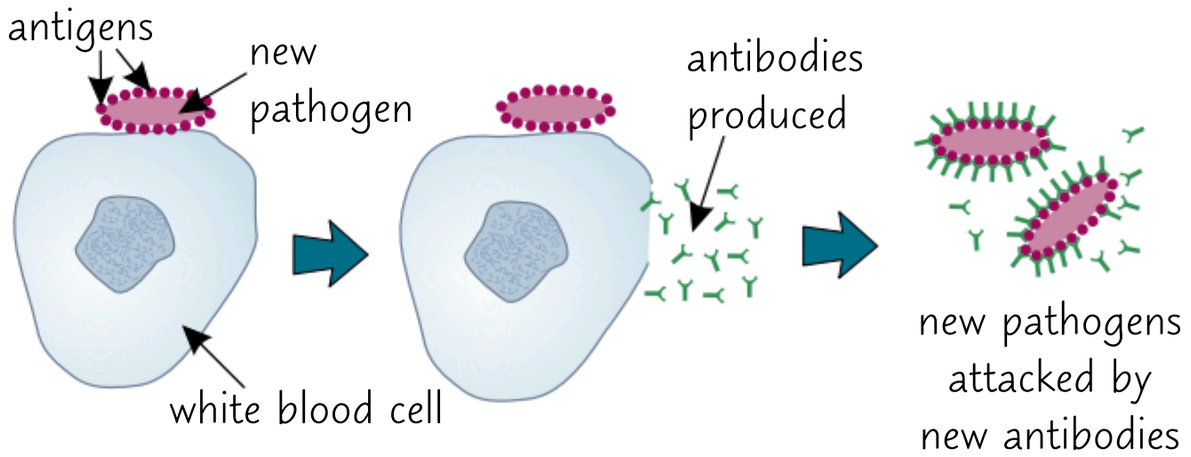
1) PHAGOCYTOSIS

White blood cells can engulf (surround) pathogens and digest them. This is called phagocytosis.



2) PRODUCING ANTIBODIES

1) Every invading pathogen has unique molecules on its surface. These molecules are called antigens.
2) When some types of white blood cell come across a foreign antigen (i.e. one they don't know), they will start to make antibodies.
3) Antibodies lock onto the invading pathogens. The antibodies made are specific to that type of antigen — they won't lock on to any others.



4) The antibodies make sure the pathogens can be found and destroyed by other white blood cells.
5) If the person is infected with the same pathogen again, the white blood cells will rapidly make the antibodies to kill it. This means the person is naturally immune to that pathogen and won't get ill.

3) PRODUCING ANTITOXINS

These stop toxins produced by the invading bacteria from working.

Fight disease — blow your nose with boxing gloves...

So there are three ways that white blood cells kill those pesky pathogens. Make sure you know them all.

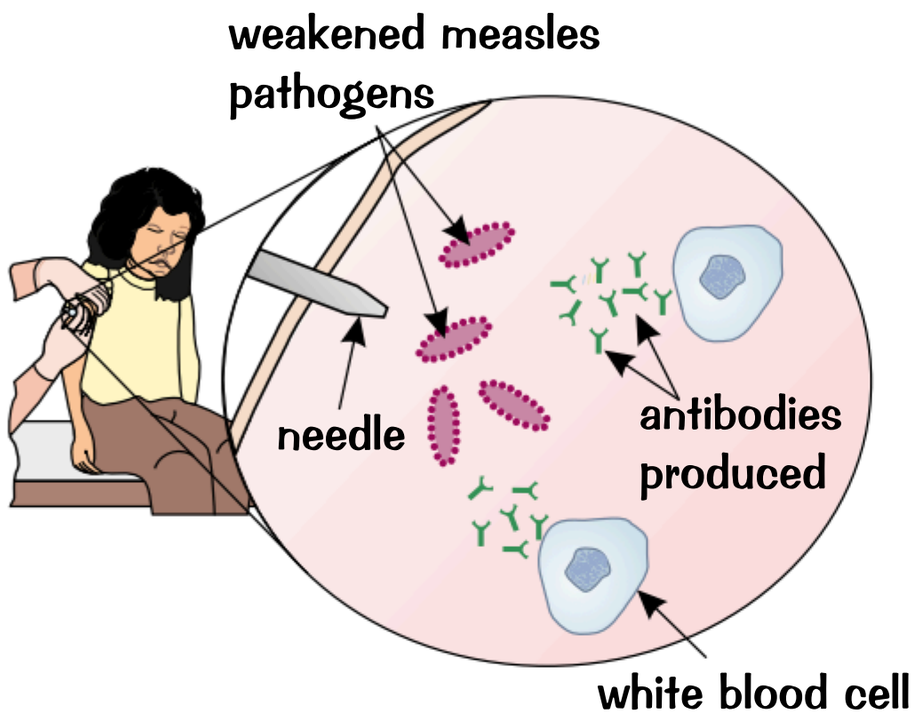
Q1 Explain one way that the bronchi are adapted to defend against the entry of pathogens. [2 marks]

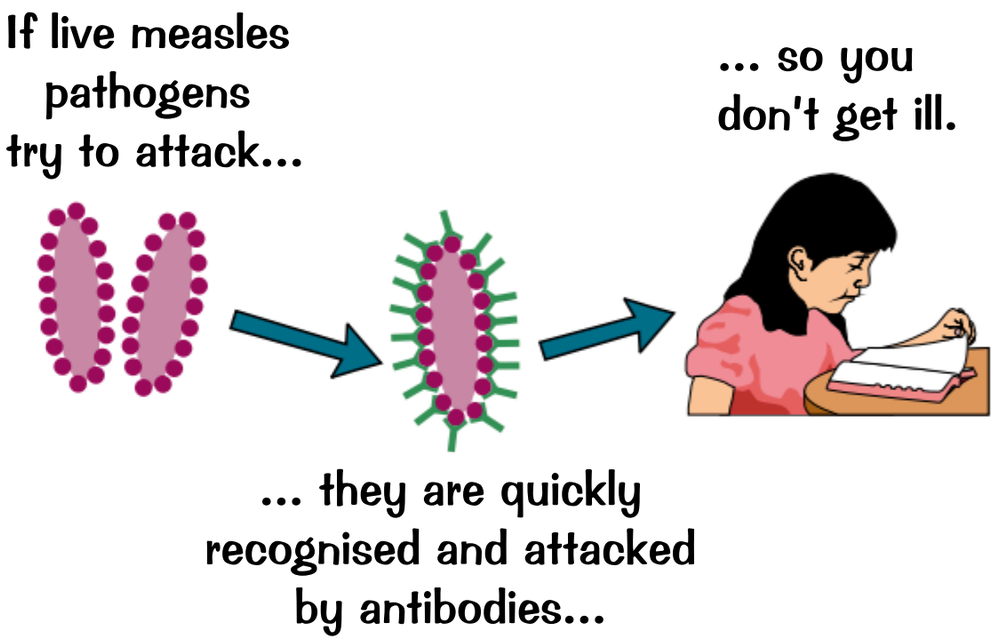
Fighting Disease — Vaccination

Vaccinations mean we don't always have to treat a disease — we can stop the disease in the first place.

Vaccination — Protects from Future Infections

1) Vaccinations involve injecting small amounts of dead or inactive pathogens into the body.
2) These pathogens have antigens on their surface.
3) The antigens cause your white blood cells to produce antibodies to attack the pathogens.
4) If you're infected with the same pathogen later, your white blood cells quickly produce lots of antibodies.
5) These antibodies kill the pathogen so you don't become ill. Cool.
6) For example, children are vaccinated to protect them against the measles virus...





There are Pros and Cons of Vaccination

PROS

1) Vaccines have helped to control lots of communicable diseases that used to be common in the UK, e.g. polio.

2) 1) A big outbreak of a disease is called an epidemic.
2) Epidemics can be prevented if lots of people are vaccinated.
3) That way, even the people who aren't vaccinated are unlikely to catch the disease because there are fewer people able to pass it on.

CONS

1) Vaccines don't always work — sometimes they don't give you immunity.

2) You can sometimes have a bad reaction to a vaccine (e.g. swelling or a fever).

Prevention is better than cure...

Although vaccinations aren't perfect, it's better to have a vaccine than risk catching a nasty disease.

Q1 Basia is vaccinated against flu and Cassian isn't. They are both exposed to a flu virus. Cassian falls ill whereas Basia doesn't. Explain why. [2 marks]

Q1 Video Solution

Fighting Disease — Drugs

Well knock me down with a feather — it looks like there are even more ways of fighting disease.



Some Drugs Get Rid of Symptoms — Others Cure the Problem

1) Some drugs help to get rid of the symptoms of a disease, e.g. painkillers reduce pain.
2) But these drugs don't kill the pathogens that cause the disease.
3) Antibiotics (e.g. penicillin) kill bacteria.
4) Different antibiotics kill different types of bacteria, so it's important to be treated with the right one.
5) The use of antibiotics has greatly reduced the number of deaths from communicable diseases caused by bacteria.
6) Antibiotics don't destroy viruses (e.g. flu viruses).
7) Viruses reproduce using your own body cells.
   This makes it very difficult to develop drugs that destroy the virus without killing the body's cells.

Bacteria Can Become Resistant to Antibiotics

1) Bacteria can mutate (change).
2) Some of these mutations cause the bacteria to become resistant to (not be killed by) an antibiotic.
3) Resistant strains (types) of bacteria, e.g. MRSA, have increased as a result of natural selection (see page 75).

Many Drugs First Came From Plants

1) Plants produce chemicals to defend themselves against pests and pathogens.
2) Some of these chemicals can be used as drugs to treat human diseases or relieve symptoms.
3) A lot of our medicines were found by studying plants used in old-fashioned cures. For example:

ASPIRIN It's used as a painkiller. It was made from a chemical found in willow.

DIGITALIS It's used to treat heart conditions. It was made from a chemical found in foxgloves.



4) Some drugs have come from microorganisms. For example:

PENICILLIN

- Alexander Fleming found that a type of mould (called *Penicillium*) makes a substance that kills bacteria.
- This substance is called penicillin.
- Penicillin is used as an antibiotic.



5) These days, new drugs are made by the pharmaceutical industry (companies that make and sell drugs).
6) The drugs are made by chemists in labs.
7) The process of making the drugs still might start with a chemical taken from a plant.

Ahh...Ahh... Ahhhhh Chooooooooo — urghh, this page is catching...

Once a drug is made it has to be tested. And guess what — you're about to find out more about it...

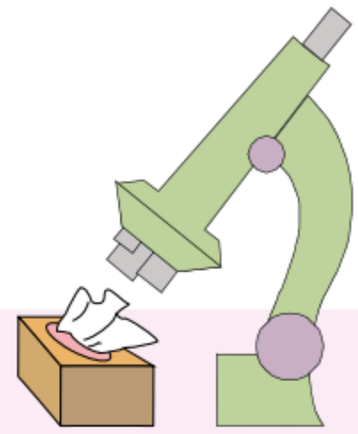
Q1 Which type of pathogen do antibiotics kill? [1 mark]

Developing Drugs

Before drugs can be given to people like you and me, they have to go through a lot of tests.
This is what usually happens...

There Are Different Stages in the Development of New Drugs

1) Once a possible drug has been discovered, it needs to be developed.
2) This involves preclinical and clinical testing.



Preclinical testing:

1) Drugs are first tested on human cells and tissues in the lab.
2) Next the drug is tested on live animals. This is to find out:
   - its efficacy (whether the drug works and has the effect you're looking for),
   - its toxicity (how harmful it is and whether it has any side effects),
   - its dosage (the concentration of the drug that works best and how often it should be taken).

Clinical testing:

1) If the drug passes the tests on animals then it's tested on human volunteers in a clinical trial.
2) First, the drug is tested on healthy volunteers.
3) This is to make sure it doesn't have any harmful side effects when the body is working normally.
4) At the start of the trial, a very low dose of the drug is given. This dose is increased little by little.
5) If these results are good, the drugs can be tested on patients (people with the illness).
6) The optimum dose is found — this is the dose of drug that is the most effective and has few side effects.
7) To test how well the drug works, patients are put into two groups...

Group 1 is given the new drug.



Group 2 is given a placebo (a substance that's like the drug being tested but doesn't do anything).



8) The doctor compares the two groups of patients to see if the drug makes a real difference.
9) Clinical trials are blind — the patient doesn't know whether they're getting the drug or the placebo.
10) In fact, they're often double-blind — neither the patient nor the doctor knows who's taken the drug and who's taken the placebo until all the results have been gathered.
11) The results of these tests aren't published until they've been through peer review. This helps to prevent false claims.

Peer review is when other scientists check the work — see page 1.



Drugs are tested — just like a GCSE student...

There's a lot of information to take in on this page, but just read it through slowly. You might have to go over it a few times to get it stuck in your head. Then you can *test* yourself by having a go at these questions...

Q1 What is meant by the efficacy of a drug? [1 mark]

Q2 Why do clinical trials of a new drug begin with healthy volunteers? [1 mark]

Photosynthesis

First, the photosynthesis equation. Then there are some more bits 'n' bobs you should know...

Photosynthesis Produces Glucose Using Light

1) Photosynthesis uses energy to change carbon dioxide and water into glucose and oxygen.
2) It takes place in chloroplasts in plant cells.
3) Chloroplasts contain chlorophyll that absorbs light.
4) Energy is transferred to the chloroplasts from the environment by light.
5) Photosynthesis is an endothermic reaction.
   This means that energy is transferred from the environment during the reaction.
6) You need to learn the word equation for photosynthesis:

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

7) You also need to know the chemical symbols for the substances involved in photosynthesis:

carbon dioxide: CO_2 water: H_2O glucose: $C_6H_{12}O_6$ oxygen: O_2

Plants Use Glucose in Five Main Ways...

1) For respiration

- This transfers energy from glucose (see p.53).
- This allows the plants to change the rest of the glucose into other useful substances.

2) For making cell walls

Glucose is changed into cellulose for making strong plant cell walls (see p.11).

3) For making amino acids

- Glucose is combined with nitrate ions to make amino acids. Nitrate ions are absorbed from the soil.
- Amino acids are used to make proteins.

4) Stored as oils or fats

Glucose is turned into lipids (fats and oils) for storing in seeds.

5) Stored as starch

- Glucose is turned into starch and stored in roots, stems and leaves.
- Plants can use this starch when photosynthesis isn't happening.
- Starch is insoluble (it can't be dissolved).
- Being insoluble makes starch much better for storing than glucose.
  This is because a cell with lots of glucose in would draw in loads of water and swell up.

I'm working on sunshine — woah oh...

You've just got to learn the whole of this page I'm afraid. It'll help the rest of the topic make sense.

Q1 Name the products of photosynthesis. [2 marks]

The Rate of Photosynthesis

The rate of photosynthesis can be affected by a few different things. Read on for excitement...

The Rate of Photosynthesis is Affected by Light, Temperature and CO_2

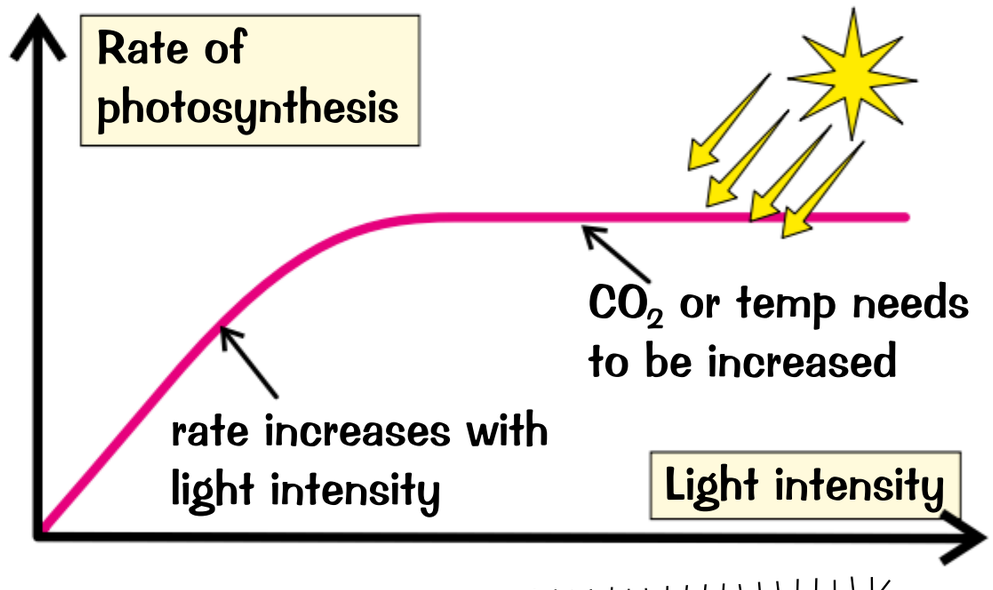
1) The rate of photosynthesis is affected by intensity of light (how bright the light is), concentration of CO_2 and temperature.
2) Any of these things can become the limiting factor of photosynthesis.
3) A limiting factor is something that stops photosynthesis from happening any faster.
4) Chlorophyll can also be a limiting factor of photosynthesis.

- The amount of chlorophyll in a plant can be affected by disease.
- It can also be affected by changes in the environment, such as a lack of nutrients.
- These factors can cause chloroplasts to become damaged or to not make enough chlorophyll.
- This means they can't absorb as much light. The rate of photosynthesis is reduced.

Three Important Graphs for Rate of Photosynthesis

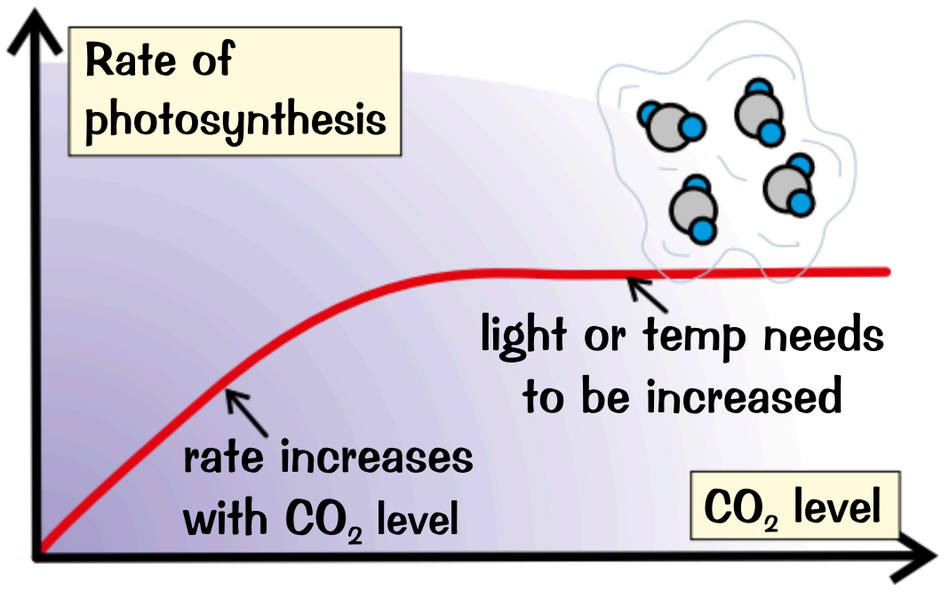
1) Not Enough Light Slows Down the Rate of Photosynthesis

1) At first, the more light there is, the faster photosynthesis happens.
2) This means the rate of photosynthesis depends on the amount of light. Light is the limiting factor.
3) After a certain point the graph flattens out. Here photosynthesis won't go any faster — even if you increase the light intensity.
4) This is because light is no longer the limiting factor. Now it's either the temperature or the amount of carbon dioxide that's the limiting factor.



The amount of light is called light intensity.

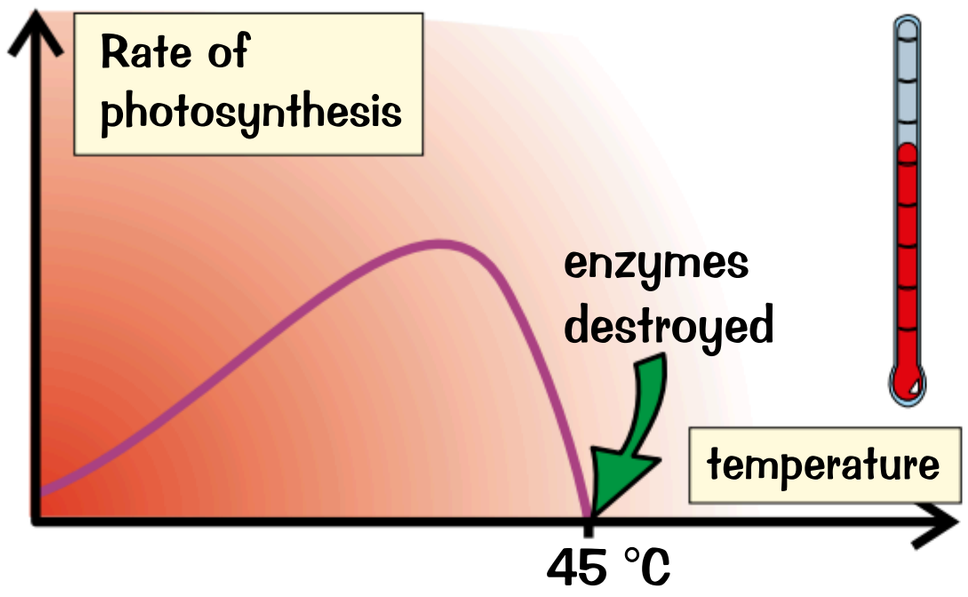
2) Too Little Carbon Dioxide Also Slows it Down



1) The more carbon dioxide (CO_2) there is, the faster photosynthesis happens.
2) This means the amount of CO_2 is the limiting factor.
3) After a certain point, photosynthesis won't go any faster because CO_2 is no longer the limiting factor.
4) If there's plenty of light and carbon dioxide then it must be the temperature that's the limiting factor.

The Rate of Photosynthesis

3) The Temperature has to be Just Right



1) Usually, if the temperature is the limiting factor it's because it's too low.
2) This is because the enzymes (see page 25) needed for photosynthesis work more slowly at low temperatures.
3) But if the plant gets too hot, photosynthesis won't happen at all.
4) This is because the enzymes are damaged if the temperature's too high (over about 45 °C).

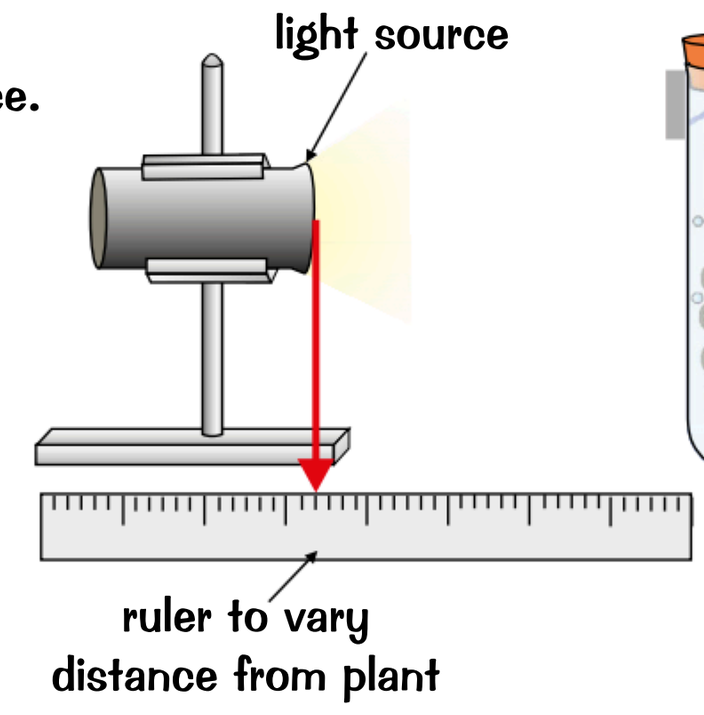
Oxygen Production Shows the Rate of Photosynthesis

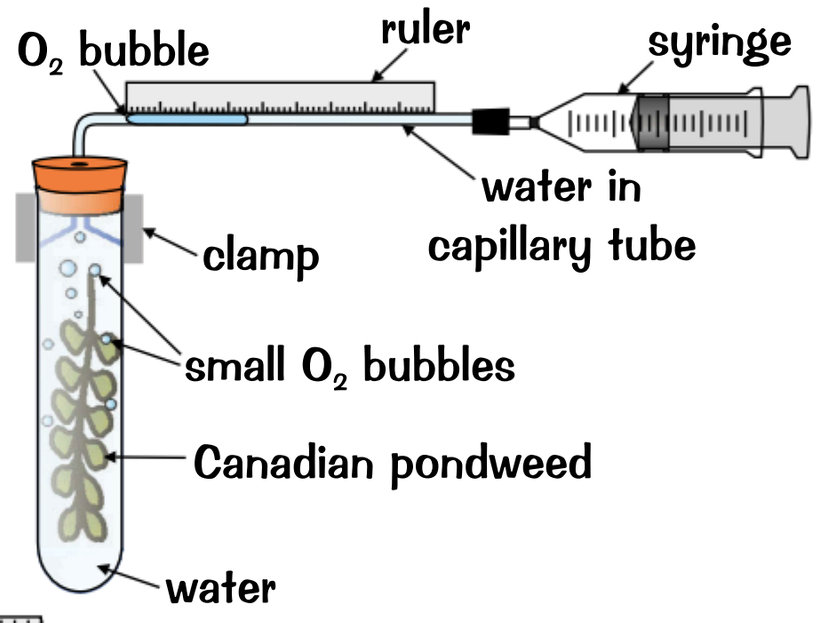
PRACTICAL

Pondweed can be used to measure the effect of light intensity on the rate of photosynthesis.

Here's how the experiment works:

1) A ruler is used to measure a set distance from the pondweed.
2) A light is placed at that distance.
3) The pondweed is left to photosynthesise for a set amount of time.
4) As it photosynthesises, the oxygen released will collect in the capillary tube.
5) At the end of the experiment, the syringe is used to draw the gas bubble in the tube up alongside a ruler.





You can compare the results at different light intensities by giving the rate as the length of the bubble per unit time, e.g. cm/min.

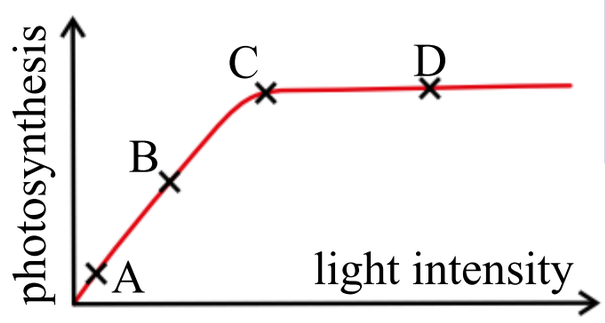
6) The length of the gas bubble is measured.
7) The length of the gas bubble tells you how much oxygen has been produced during that amount of time. This means that the longer the gas bubble, the faster the rate of photosynthesis.
8) For this experiment, any variables that could affect the results should be controlled. E.g. the temperature and the time the pondweed is left to photosynthesise.
9) The experiment is repeated twice with the lamp at the same distance.
10) The mean length of the gas bubble is calculated.
11) Then the whole experiment is repeated with the light source at different distances from the pondweed.

With enough light, photographers can also photosynthesise...

Don't let a few graphs put you off learning everything on these two pages.

Q1 a) The graph on the right shows how light intensity affects the rate of photosynthesis. State at which point (A-D) the light intensity stops being the limiting factor. [1 mark]

b) Suggest what the limiting factor could be at point D. [1 mark]



Q1 Video Solution

Respiration and Metabolism

You need energy to keep your body going. Energy comes from food, and it's transferred by respiration.

Respiration is NOT "Breathing In and Out"

1) All living things respire.
2) Respiration is the process of transferring energy from the breakdown of glucose (a sugar).
3) Respiration goes on in every cell in your body all the time.
4) The energy transferred from respiration is used for all living processes (everything a cell needs to do).

RESPIRATION is the process of TRANSFERRING ENERGY FROM GLUCOSE, which goes on IN EVERY CELL.

5) Respiration is exothermic. This means it transfers energy to the environment.

Respiration Transfers Energy for All Kinds of Things

Here are three examples of how organisms use the energy transferred by respiration:

1) To build up larger molecules from smaller ones (see below).
2) In animals, to move about.
3) In mammals and birds, to keep warm.



Metabolism is ALL the Chemical Reactions in an Organism

1) In a cell there are lots of chemical reactions happening all the time.
2) These reactions are controlled by enzymes.
3) In some of these reactions, larger molecules are made from smaller ones. For example:

There's more about enzymes on page 25.

- Lots of small glucose (sugar) molecules are joined together in reactions to form:
  - starch (a storage molecule in plant cells),
  - glycogen (a storage molecule in animal cells),
  - cellulose (a component of plant cell walls).
- Lipid molecules are each made from one molecule of glycerol and three fatty acids.
- Glucose is combined with nitrate ions to make amino acids. These are then made into proteins.

4) In other reactions, larger molecules are broken down into smaller ones. For example:

- Glucose is broken down in respiration. Respiration transfers energy to power all the reactions in the body that make molecules.
- Excess protein is broken down in a reaction to produce urea. Urea is then excreted in urine.

5) The sum (total) of all of the reactions that happen in a cell or the body is called its metabolism.

Excreted is just a fancy word for 'released from the body'.

Respiration transfers energy — but this page has worn me out...

Isn't it strange to think that each individual living cell in your body is respiring every second of every day.

Q1 Give two examples of how animals use the energy transferred by respiration. [2 marks]

Q2 What is metabolism? [1 mark]

Aerobic and Anaerobic Respiration

There are two types of respiration, don't you know...

Aerobic Respiration Needs Plenty of Oxygen

1) Aerobic respiration is respiration using oxygen.
2) Aerobic respiration goes on all the time in plants and animals.
3) Most of the reactions in aerobic respiration happen inside mitochondria (see page 11).
4) You need to learn the overall word equation for respiration:

glucose + oxygen ⟶ carbon dioxide + water

5) You also need to know the chemical symbols for the substances involved:

glucose: $C_6H_{12}O_6$ oxygen: O_2 carbon dioxide: CO_2 water: H_2O

Anaerobic Respiration is Used if There's Not Enough Oxygen

1) When you do hard exercise, your body sometimes can't supply enough oxygen to your muscles.
2) When this happens, they start doing anaerobic respiration as well as aerobic respiration.
3) Anaerobic respiration is the incomplete breakdown of glucose (the glucose isn't broken down properly).
4) Here's the word equation for anaerobic respiration in muscle cells:

glucose ⟶ lactic acid

5) Anaerobic respiration does not transfer anywhere near as much energy as aerobic respiration.
6) This is because the glucose has not combined with oxygen like it does in aerobic respiration.
7) The posh way of saying this is that the oxidation of glucose is not complete.

Anaerobic Respiration in Plants and Yeast is Slightly Different

1) Plants and yeast cells can respire without oxygen too.
2) Here is the word equation for anaerobic respiration in plants and yeast cells:

glucose ⟶ ethanol + carbon dioxide



3) Anaerobic respiration in yeast cells is called fermentation.
4) In the food and drinks industry, fermentation by yeast is of great value.
5) It's used to make bread. It's the carbon dioxide from fermentation that makes bread rise.
6) It's used to make alcoholic drinks (beer and wine).
   It's the fermentation process that produces alcohol.

I'd like a ham and fermentation sandwich please... yum

Fermentation is a really important process because of its use in making wine and beer, and bread.

Q1 Give the word equation for aerobic respiration. [2 marks]

Q2 What is the process of anaerobic respiration in yeast called? [1 mark]

Exercise

When you exercise, your body responds in different ways to get enough energy to your cells.

When You Exercise You Respire More



1) Muscles need energy from respiration to contract (shorten).
2) When you exercise, some of your muscles contract more often. This means you need more energy.
3) This energy comes from increased respiration.
4) The increase in respiration in your cells means you need to get more oxygen into them. To do this:
   1) Your breathing rate (how fast you breathe) increases.
   2) Your breath volume (how deep the breaths you take are) increases.
   3) Your heart rate (how fast your heart beats) increases.
5) Increasing your breathing rate and breath volume gets oxygen into your blood quicker. Blood containing oxygen is called oxygenated blood.
6) Your heart rate increases to get this oxygenated blood around the body faster.

An unfit person's heart rate goes up a lot more during exercise than a fit person, and they take longer to recover.

Hard Exercise Can Lead to Anaerobic Respiration

1) When you do really hard exercise, your body can't supply oxygen to your muscles quickly enough.
2) This means your muscles start doing anaerobic respiration (see the previous page).
3) This is NOT the best way to transfer energy from glucose. This is because lactic acid builds up in the muscles, which gets painful.
4) Long periods of exercise also cause muscle fatigue. This is when the muscles get tired and stop contracting efficiently.



Anaerobic Respiration Leads to an Oxygen Debt

1) After anaerobic respiration stops, you'll have an "oxygen debt".
2) An oxygen debt is the amount of extra oxygen your body needs after exercise.
3) Your lungs, heart and blood couldn't keep up with the demand for oxygen earlier on. So you have to "repay" the oxygen that you didn't get to your muscles in time.
4) This means you have to keep breathing hard for a while after you stop.
5) This gets more oxygen into your blood, which is transported to the muscle cells.

Oxygen debt — cheap to pay back...

Phew... bet you're exhausted after reading this. Still, it needs learning before you have a pit stop.

Q1 A scientist measured the concentration of lactic acid in her blood after walking for 5 minutes. She also measured the concentration of lactic acid in her blood after running for 5 minutes. Suggest why the concentration of lactic acid in her blood was higher after running than after walking. [3 marks]

Q1 Video Solution

Revision Questions for Topics B3 & B4

It's all over for Topics B3 and B4 folks. I know how much you'll miss them, so here are some questions...

- Try these questions and tick off each one when you get it right.
- When you're completely happy with a sub-topic, tick it off.

For even more practice, try the Retrieval Quizzes for Topics B3 and B4 — just scan the QR codes!

Types of Disease (p.42-45) ☑

Topic B3 Quiz

1) Give one way that pathogens can be spread. ☐
2) How can bacteria make us feel ill? ☐
3) What are the symptoms of gonorrhoea? ☐
4) What type of disease is measles? ☐
5) Why does tobacco mosaic virus affect photosynthesis? ☐
6) What are the vectors for malaria? ☐

Fighting Disease (p.46-49) ☑

7) What does the stomach produce that can kill pathogens? ☐
8) Give three ways that white blood cells can defend against pathogens. ☐
9) Give one pro and one con of vaccination. ☐
10) Why is it difficult to develop drugs that kill viruses? ☐
11) Which plant does the painkiller aspirin come from? ☐
12) Give two things that drugs are tested on in preclinical testing. ☐

Photosynthesis (p.50-52) ☑

Topic B4 Quiz

13) Where in a plant cell does photosynthesis take place? ☐
14) What is an endothermic reaction? ☐
15) What is the word equation for photosynthesis? ☐
16) Why do plants store glucose as starch? ☐
17) What is meant by a 'limiting factor' of photosynthesis? ☐
18) What effect would a low carbon dioxide concentration have on the rate of photosynthesis? ☐
19) Describe how you could measure the effect of light intensity on the rate of photosynthesis. ☐

Respiration and Metabolism (p.53-55) ☑

20) What is respiration? ☐
21) What is an exothermic reaction? ☐
22) Give two molecules that can be made when lots of glucose molecules join together. ☐
23) What is glucose combined with to make amino acids? ☐
24) Give the chemical symbols for carbon dioxide and water. ☐
25) What is produced by anaerobic respiration in muscle cells? ☐
26) What is the word equation for anaerobic respiration in yeast cells? ☐
27) Name two products of the food and drink industry that fermentation is needed for. ☐
28) Give three things that increase to supply the muscles with more oxygenated blood during exercise. ☐

Homeostasis

Homeostasis — a word that strikes fear into the hearts of many GCSE students. But it's really not that bad.

Homeostasis — Keeping Conditions Inside Your Body Steady

1) Homeostasis is the fancy word for keeping the conditions in your body and cells at the right level. This happens in response to changes inside and outside of the body.
2) This is really important because your cells need the right conditions to work properly.
3) This includes having the right conditions for enzymes to work (see p.25).



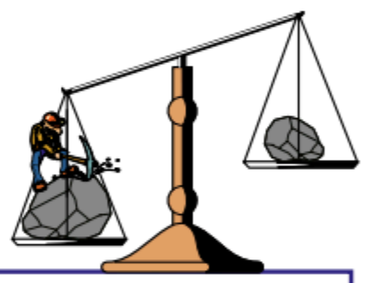
Clive wishes he'd responded to the changes outside.

Your Body Uses Control Systems for Homeostasis

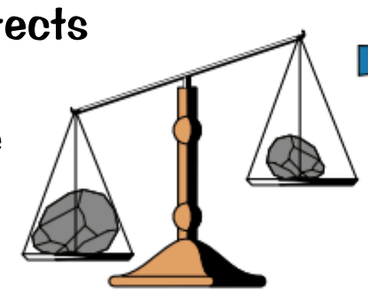
1) You have loads of control systems that keep the conditions in your body steady. For example, they keep your body temperature, blood glucose level and water level steady.
2) These control systems are automatic — you don't have to think about them.
3) They can control conditions in the body using the nervous system or hormones.
4) Control systems are made up of three main parts:
   - receptors,
   - coordination centres (including the brain, spinal cord and pancreas),
   - effectors.
5) When the level of something (e.g. blood glucose) gets too high or too low, its control system brings it back to normal.

If the level is too HIGH, the control system DECREASES the level.
If the level is too LOW, the control system INCREASES the level.

6) Here's how a control system works:



1 If the level of something changes...
- A receptor detects a stimulus (change in the environment).
- It sends information to the coordination centre.



2
- The coordination centre receives and processes the information.
- It then organises a response.



3
- An effector produces a response.
- This returns the level to its optimum (ideal) level.



My sister's not coming out today — she's got homeo-stay-sis...

Homeostasis is really important for keeping processes in your body working. It does this by keeping everything in your body at the right level. Make sure you know what receptors, coordination centres and effectors do.

Q1 Why do the internal conditions of your body need to be kept steady? [1 mark]

Q2 Name the part of a control system that detects stimuli. [1 mark]

The Nervous System

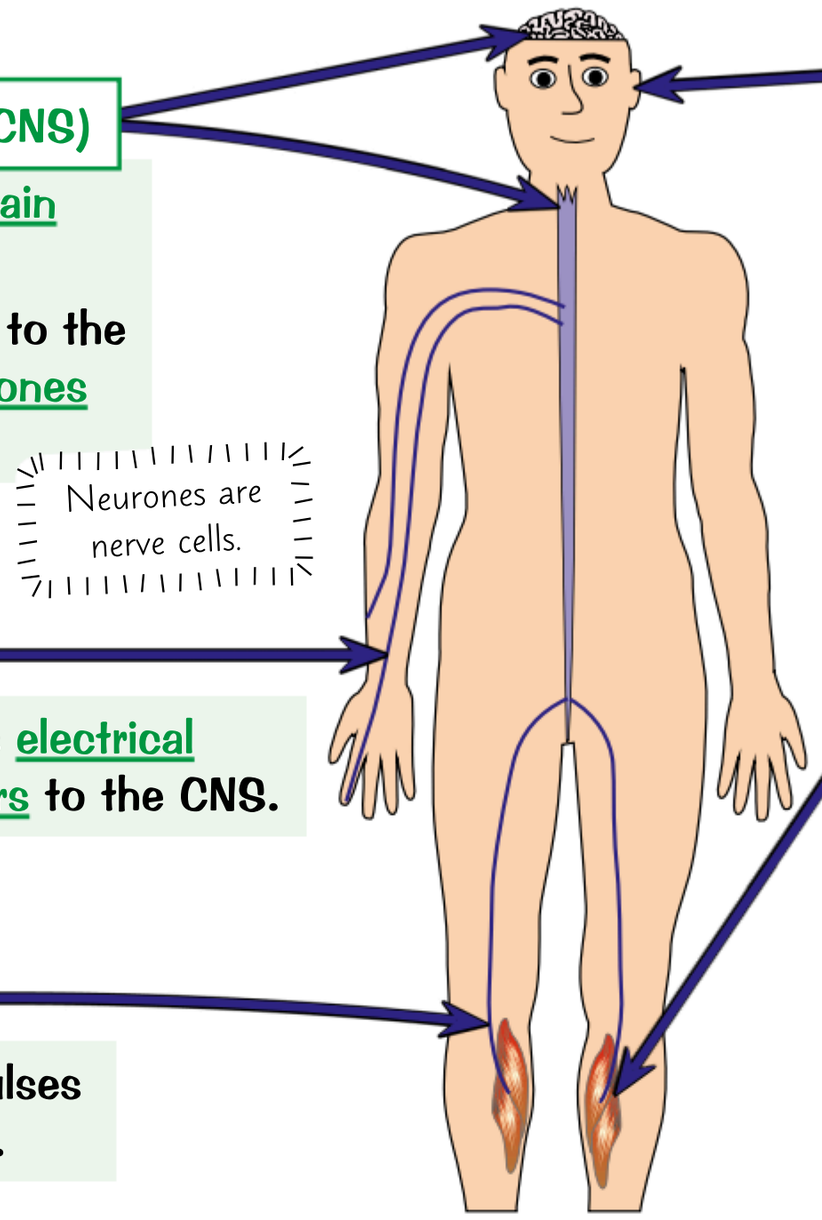
Organisms need to respond to stimuli (changes in the environment). That's where the nervous system comes in.

The Nervous System Detects and Reacts to Stimuli

1) The nervous system means that humans can react to their surroundings and coordinate their behaviour.
2) The nervous system is made up of different parts:

Central Nervous System (CNS)

1) This consists of the brain and spinal cord.
2) The CNS is connected to the body by sensory neurones and motor neurones.



Receptors

1) Receptors are the cells that detect stimuli.
2) Different receptors detect different stimuli.
3) For example, receptors in the ears detect sound.

Sensory Neurones

These carry information as electrical impulses from the receptors to the CNS.

Motor Neurones

These carry electrical impulses from the CNS to effectors.

Effectors

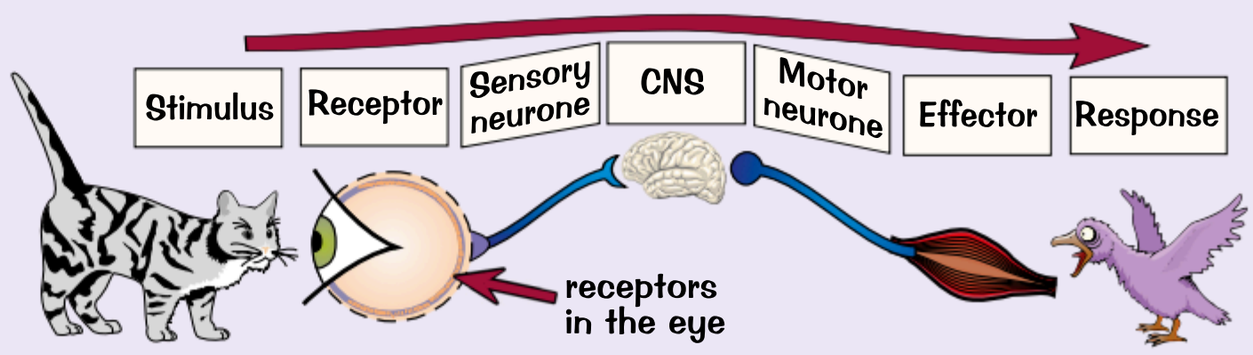
1) Effectors respond to electrical impulses and bring about a change.
2) Muscles and glands are effectors.
3) They respond in different ways — muscles contract and glands release hormones.

The Central Nervous System (CNS) Coordinates the Response

1) The CNS is a coordination centre.
2) It receives information from the receptors and then coordinates a response (decides what to do about it).
3) The response is carried out by effectors.

For example, a small bird is eating some seed...

1) ...when it spots a cat coming towards it (this is the stimulus).
2) The receptors in the bird's eye are stimulated (activated).
3) Sensory neurones carry the information from the receptors to the CNS.
4) The CNS decides what to do about it.
5) The CNS sends information to the muscles in the bird's wings (the effectors) along motor neurones.
6) The muscles contract and the bird flies away to safety.



Don't let the thought of exams play on your nerves...

Make sure you understand how the different parts of the nervous system work together to coordinate a response.

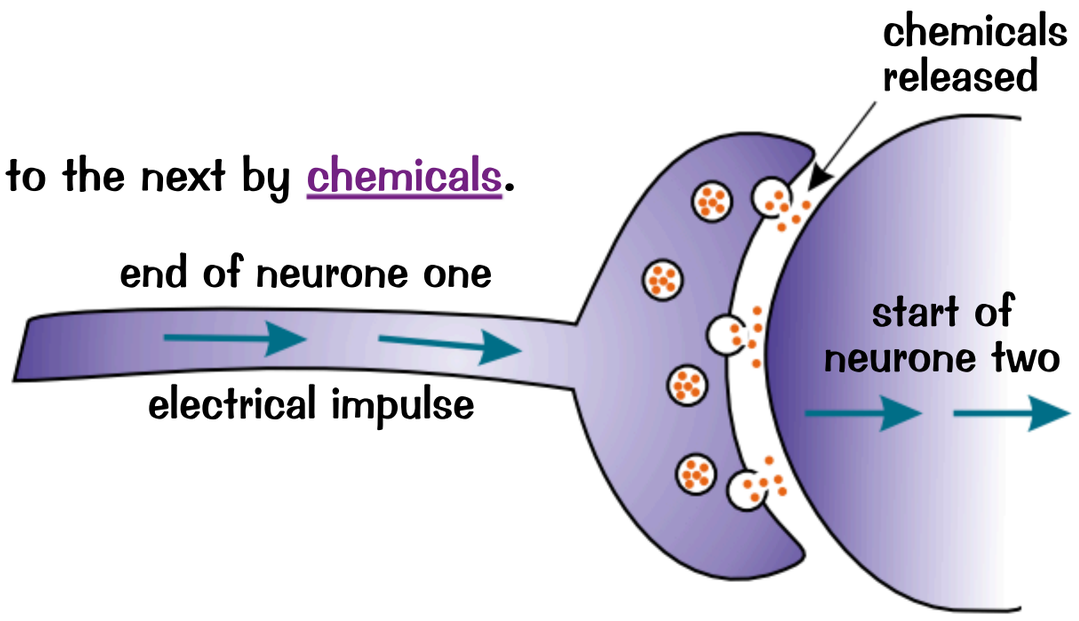
Q1 Name two types of effector. [2 marks]

Synapses and Reflexes

Information is passed between neurones really quickly, especially when there's a reflex involved...

Synapses Connect Neurones

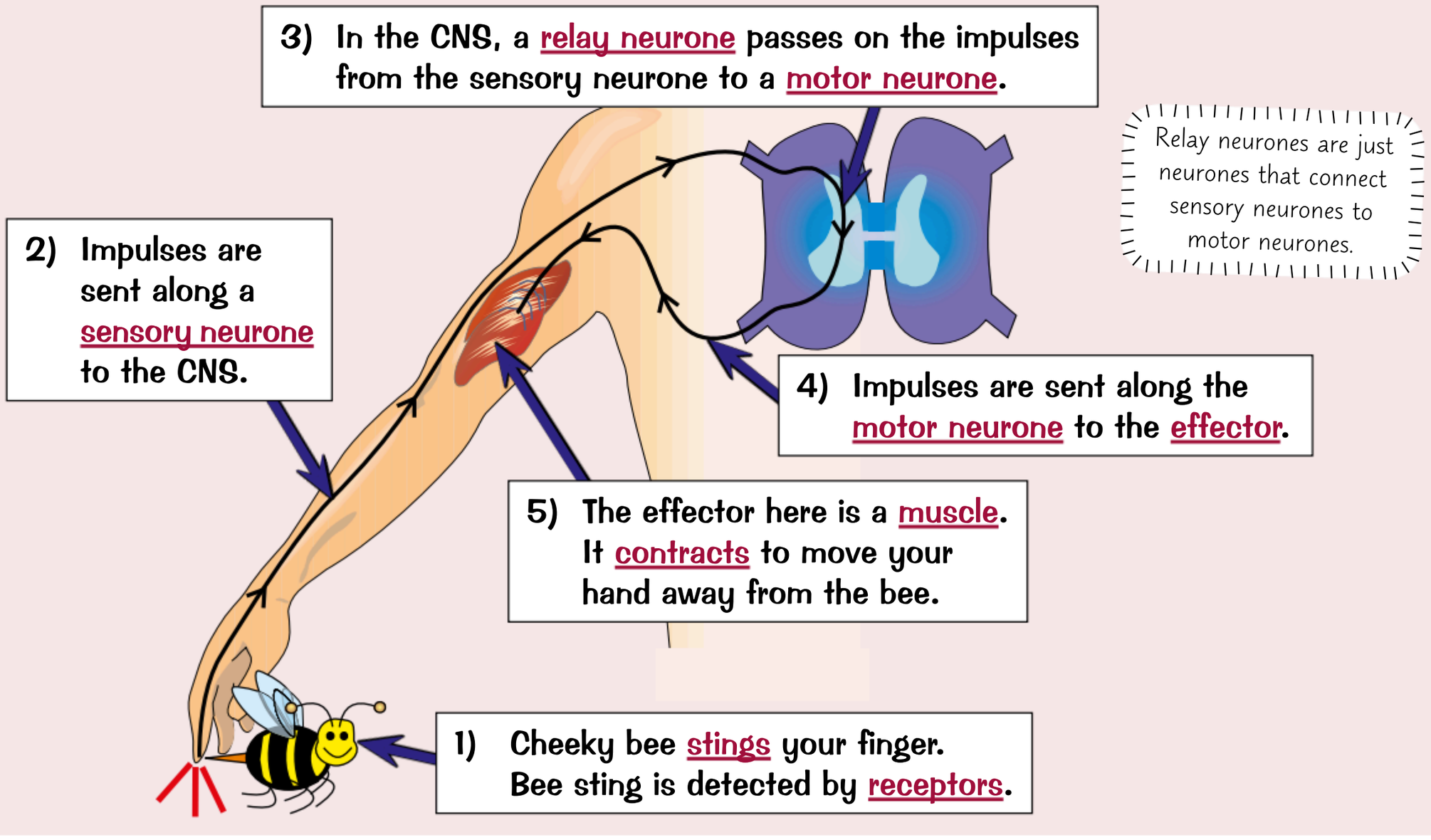
1) A synapse is where two neurones join together.
2) The electrical impulse is passed from one neurone to the next by chemicals.
3) These chemicals move across the gap.
4) The chemicals set off a new electrical impulse in the next neurone.



Reflexes Help Prevent Injury

1) Reflexes are automatic responses — you don't have to think about them.
2) This makes them really quick.
3) They can help stop you getting injured.
4) The passage of information in a reflex (from receptor to effector) is called a reflex arc.
5) The neurones in reflex arcs go through the spinal cord or through an unconscious part of the brain (part of the brain not involved in thinking).
6) Here's an example of how a reflex arc would work if you were stung by a bee:

Reflexes are also called reflex reactions.



Don't get all twitchy — just learn it...

Remember, you don't think about reflexes at all. They're useful for when you need to respond really quickly.

Q1 What is a reflex action? [1 mark]

Q2 A chef touches a hot pan. A reflex reaction causes him to immediately move his hand away.
a) State the effector in this reflex reaction. [1 mark]
b) Describe the pathway of the reflex from stimulus to effector. [4 marks]

Q2 Video Solution

PRACTICAL

Investigating Reaction Time

On your marks... get set... read this page.

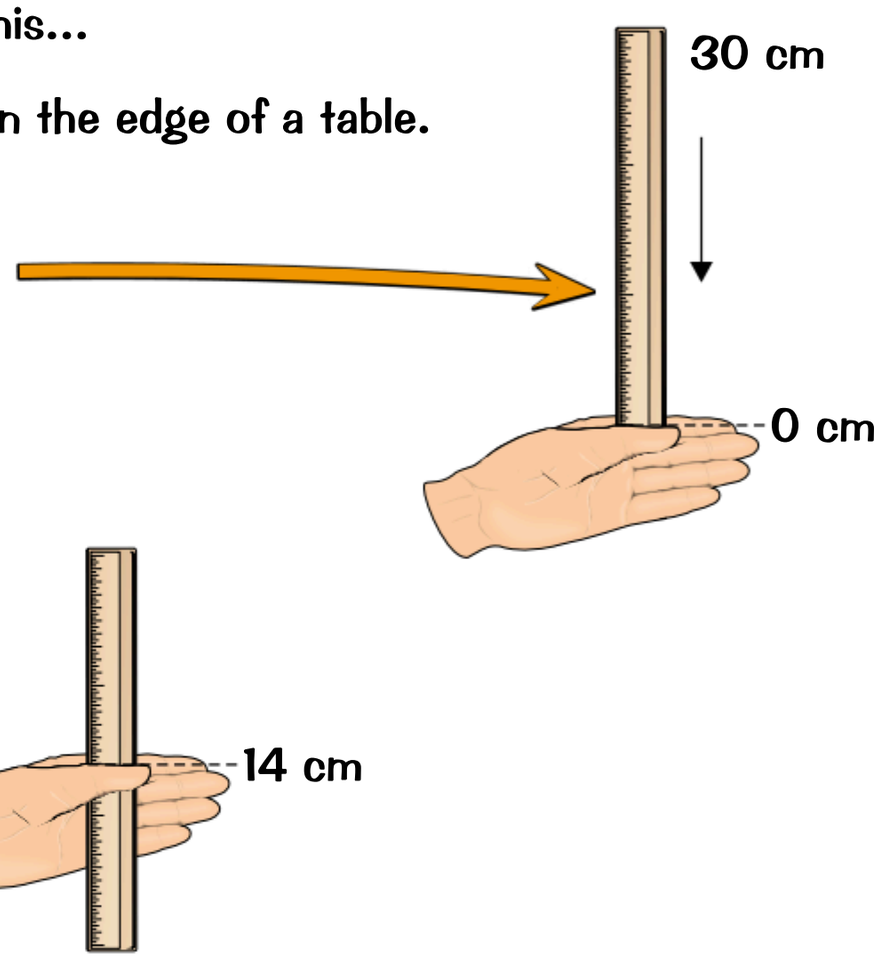
Reaction Time is How Quickly You Respond

1) Reaction time is the time it takes to respond to a stimulus.
2) It's often less than a second. This means it may be measured in milliseconds (ms).
3) It can be affected by factors such as age, gender or drugs.

You Can Measure Reaction Time

Caffeine is a drug. It can speed up a person's reaction time.
The effect of caffeine on reaction time can be measured like this...

1) The person being tested should sit with their arm resting on the edge of a table.
2) Hold a ruler upright between their thumb and forefinger.
Make sure that the zero end of the ruler is level with their thumb and finger. Don't let them grip the ruler.
3) Then let go without giving any warning.
4) The person being tested should try to catch the ruler as quickly as they can.
5) Reaction time is measured by the number on the ruler where it's caught.
   - The number should be read from the top of the person's thumb.
   - The higher the number, the slower their reaction time.



6) Repeat the test several times then calculate the mean distance that the ruler fell.
7) Now give the person being tested a caffeinated drink (e.g. cola).
8) After 10 minutes, repeat steps 1 to 6.
9) You need to control any variables to make sure that this is a fair test.
For example:
   - Use the same person to catch the ruler each time.
   - That person should always use the same hand to catch the ruler.
   - The ruler should always be dropped from the same height.



Ready... Steady...

... Ah, too slow.

Q1 Some students investigated the effect of an energy drink on reaction time. They measured their reaction times using a computer test. They had to click the mouse when the screen changed from red to green. Each student repeated the test five times before having an energy drink, and five times afterwards.

a) The results for one of the students before having the energy drink were as follows:
242 ms, 256 ms, 253 ms, 249 ms, 235 ms. Calculate the mean reaction time. [2 marks]

b) Suggest two variables that the students needed to control during their investigation. [2 marks]

Q1 Video Solution

The Endocrine System

As well as along nerves, information is sent around the body using hormones.

Hormones Are Chemical Messengers Sent in the Blood

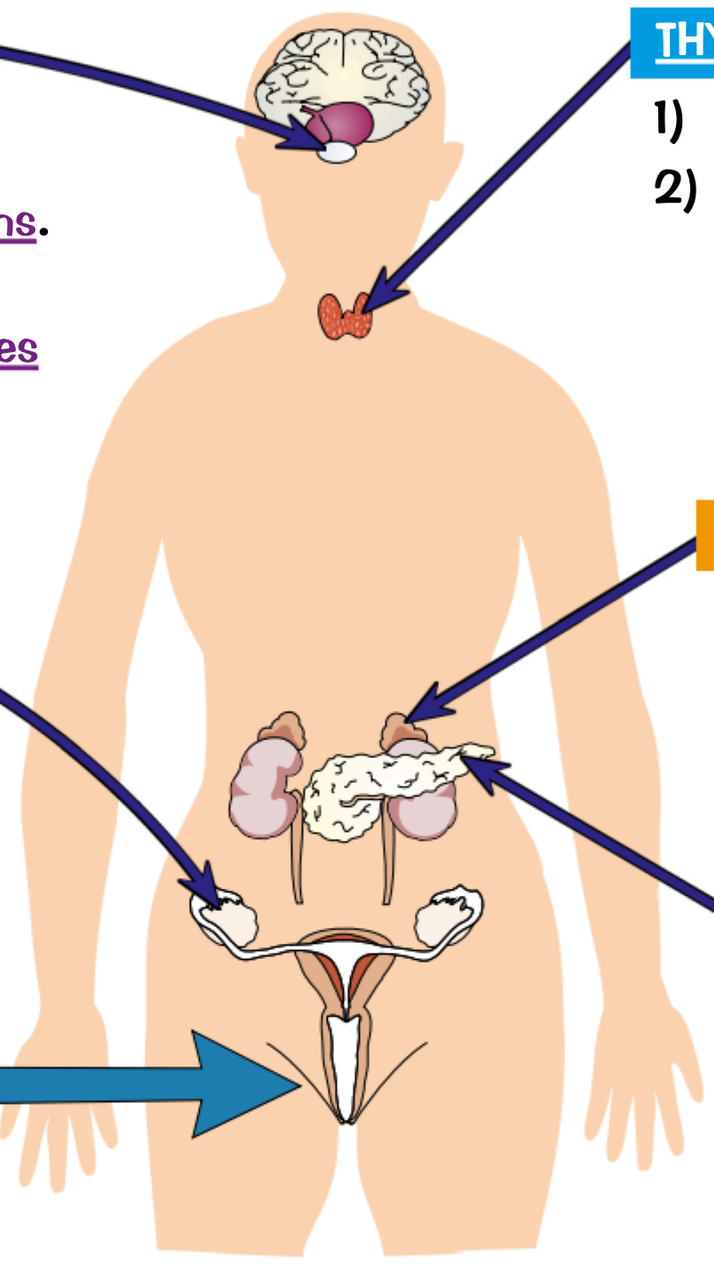
1) Hormones are chemicals released by glands. They're released directly into the blood.
2) These glands are called endocrine glands. They make up your endocrine system.
3) Hormones are carried in the blood to other parts of the body.
4) They only affect particular cells in particular organs (called target organs).
5) Here are some examples of glands:

THE PITUITARY GLAND

1) Sometimes called the 'master gland'.
2) This is because it produces many hormones that regulate body conditions.
3) These hormones act on other glands. They make the glands release hormones that bring about change.

THYROID

1) Produces thyroxine.
2) This is involved in regulating things like the rate of metabolism, heart rate and temperature.



OVARIES — females only

1) Produce oestrogen.
2) This is involved in the menstrual cycle (see page 63).

ADRENAL GLAND

1) Produces adrenaline.
2) This is used to prepare the body for a 'fight or flight' response.

TESTES — males only

1) Produce testosterone.
2) This controls puberty and sperm production in males (see page 63).

THE PANCREAS

1) Produces insulin.
2) This is used to regulate the blood glucose level (see next page).

Hormones and Nerves Have Differences

NERVES:	HORMONES:
Very FAST action.	SLOWER action.
Act for a very SHORT TIME.	Act for a LONG TIME.
Act on a very PRECISE AREA.	Act in a more GENERAL way.



Nerves, hormones — no wonder revision makes me tense...

Hormones control many different organs and cells in the body. They tend to control things that aren't immediately life-threatening (so things like sexual development, blood sugar level, water content, etc.).

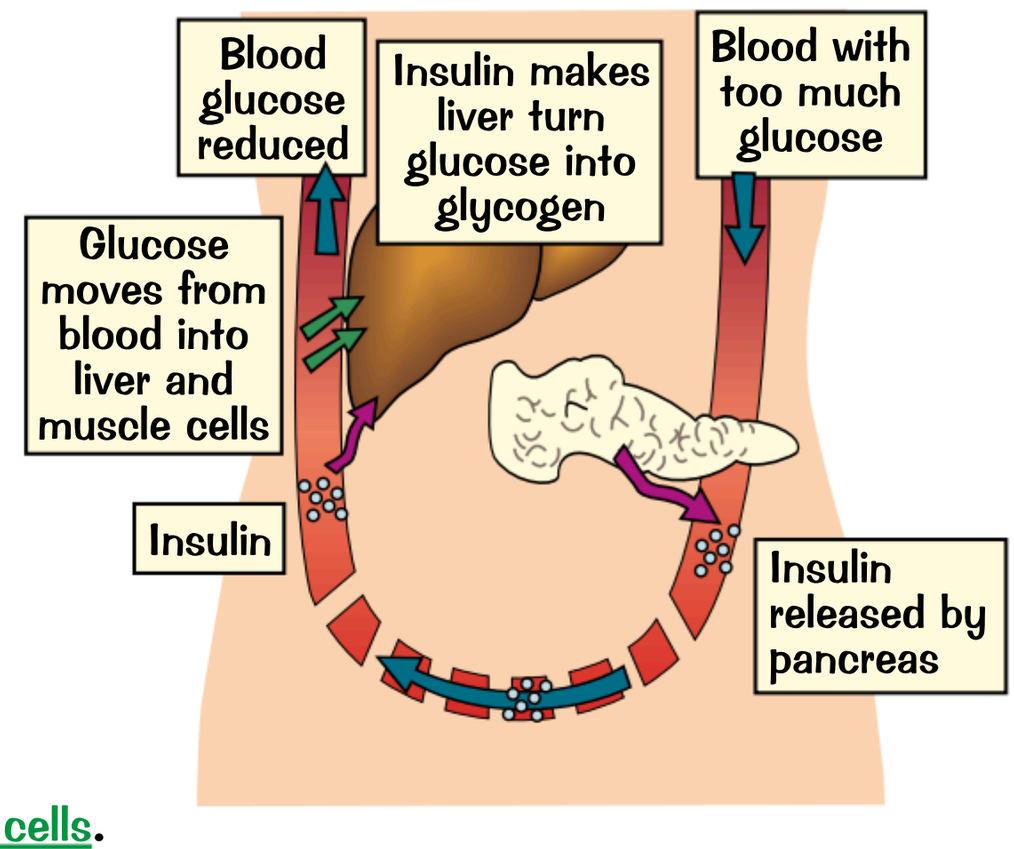
Q1 How do hormones travel from their glands to their target organs? [1 mark]

Controlling Blood Glucose

The amount of glucose in your blood is controlled as part of homeostasis.

Insulin Reduces the Blood Glucose Level

1) Eating carbohydrates puts glucose (a type of sugar) into the blood.
2) Glucose is removed from the blood by cells (which use it for energy).
3) When you exercise, a lot more glucose is removed from the blood.
4) Changes in the blood glucose concentration are monitored and controlled by the pancreas.
5) If blood glucose concentration gets too high, the pancreas releases the hormone insulin.
6) Insulin causes glucose to move into cells (so it removes glucose from the blood).
7) Glucose can be stored as glycogen.
8) Glucose is converted to glycogen in liver and muscle cells.



With Diabetes, You Can't Control Your Blood Sugar Level

There are two types of diabetes:

Type 1 Diabetes

1) Type 1 diabetes is where the pancreas does not produce enough insulin. It may not produce any insulin at all.
2) This means a person's blood glucose level can rise to a level that can kill them.
3) People with Type 1 diabetes need injections of insulin throughout the day.
4) This makes sure that glucose is removed from the blood quickly after the food is digested.

Large amounts of glucose in the blood can damage organs like the heart.

Type 2 Diabetes

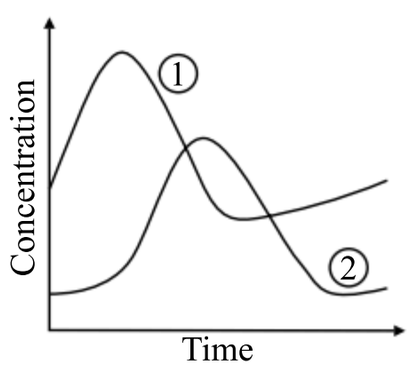
1) Type 2 diabetes is where a person becomes resistant to their own insulin.
2) This means they still produce insulin, but their body's cells don't respond properly to it.
3) This can cause a person's blood sugar level to rise to a dangerous level.
4) Being obese (very overweight) can increase your chance of developing Type 2 diabetes.
5) Type 2 diabetes can be controlled by eating a carbohydrate-controlled diet.
6) This is a diet where the amount of carbohydrates eaten is carefully measured.
7) Type 2 diabetes can also be controlled by taking regular exercise.



And people used to think the pancreas was just a cushion...

In the exam, you might be given a graph showing the effect of insulin on blood glucose level. Don't freak out — just use what you know about graphs (and insulin) to make sense of the data.

Q1 The graph shows the changes in concentration of glucose and insulin in a person's blood over time, after they ate a meal.
Which curve represents insulin? Explain your answer. [2 marks]



Q1 Video Solution

Puberty and the Menstrual Cycle

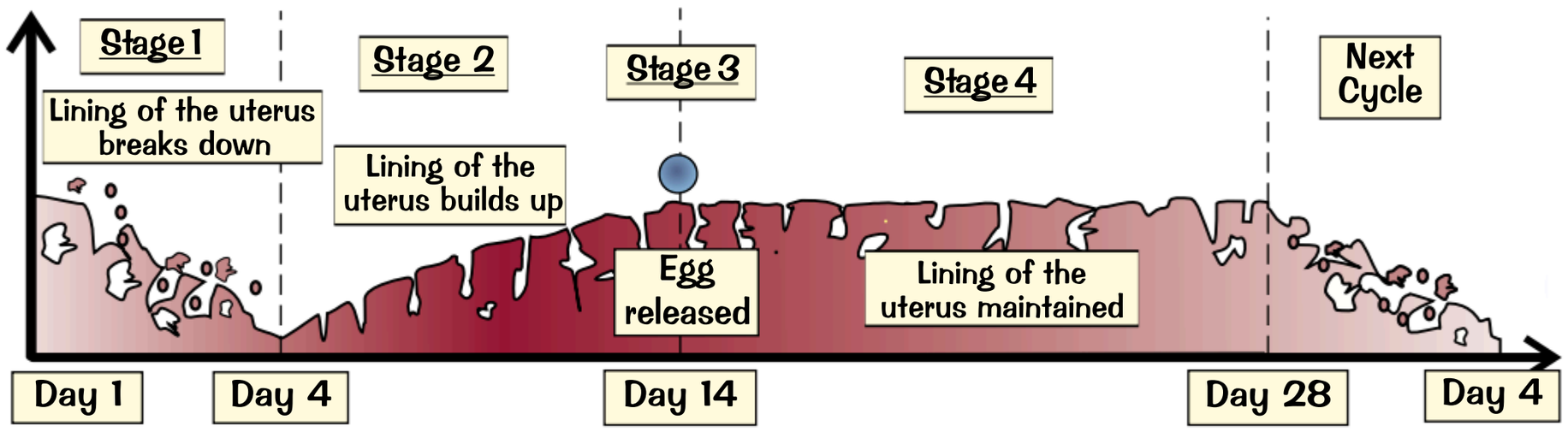
The monthly release of an egg from a woman's ovaries is part of the menstrual cycle.

Hormones Cause Sexual Characteristics To Develop at Puberty

1) At puberty, your body starts releasing sex hormones.
2) These sex hormones trigger secondary sexual characteristics.
For example, the development of facial hair in men and breasts in women.
3) Female sex hormones also cause eggs to mature (develop) in women.
4) In men, the main reproductive hormone is testosterone.
It's produced by the testes. It stimulates sperm production.
5) In women, the main reproductive hormone is oestrogen. It's produced by the ovaries.
Oestrogen is involved in the menstrual cycle.



The Menstrual Cycle Has Four Stages



Stage 1 — Day 1 is when menstruation (bleeding) starts. The uterus lining breaks down for about four days.

Stage 2 — The uterus lining builds up again from day 4 to day 14.
It builds into a thick spongy layer full of blood vessels. It's now ready to receive a fertilised egg.

Stage 3 — An egg develops and is released from the ovary at day 14. This is called ovulation.

Stage 4 — The wall is then maintained (kept the same) for about 14 days until day 28.
If no fertilised egg has landed on the uterus wall by day 28,
the spongy lining starts to break down. The whole cycle starts again.

An egg is released once every 28 days.

The Menstrual Cycle is Controlled by Four Hormones...

HORMONE	WHAT THE HORMONE DOES
FSH (Follicle-Stimulating Hormone)	Causes an egg to mature in one of the ovaries.
LH (Luteinising Hormone)	Causes the release of an egg (ovulation).
Oestrogen	These hormones are involved in the growth and maintenance of the uterus lining.
Progesterone	

Which came first — the chicken or the luteinising hormone...

Learn this page... till you know which hormone does what.

Q1 Name the hormone that causes an egg to mature in the ovary. [1 mark]

Q2 Where is testosterone produced in the male body? [1 mark]

Controlling Fertility

Pregnancy can happen if sperm reaches the egg. Contraception tries to stop this happening.

Hormones Can Be Used to Reduce Fertility

1) Fertility is how easy it is for a woman to get pregnant.
2) Contraceptives are things that prevent pregnancy.
3) Hormones can be used in contraceptives — these are called hormonal contraceptives.

Oral Contraceptives Contain Hormones

1) Oral contraceptives are taken through the mouth as pills.
2) They stop the hormone FSH from being released.
3) This stops eggs maturing.
4) Oral contraceptives are over 99% effective at preventing pregnancy.
5) But they can have bad side effects.
   For example, they can cause headaches and make you feel sick.

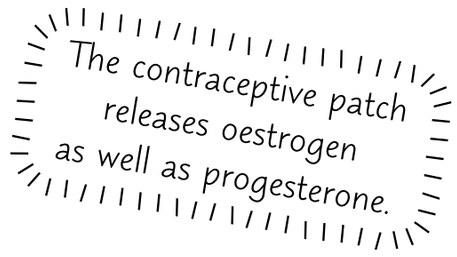


Some Hormonal Contraceptives Release Progesterone

1) Some hormonal contraceptives work by slowly releasing progesterone.
2) This stops eggs from maturing or being released from the ovaries.
3) Examples of contraceptives that work this way are:

Contraceptive patch

1) This is a small patch that is stuck to the skin.
2) It lasts one week.



Contraceptive implant

1) This is inserted under the skin of the arm.
2) An implant can last for three years.

Contraceptive injection

Each dose lasts two to three months.

Some Intrauterine Devices Contain Hormones

1) An intrauterine device (IUD) is a T-shaped device that's inserted into the uterus (womb).
2) It can stop fertilised eggs from implanting in the uterus wall.
3) Some types of IUD release a hormone.

What do you call a fish with no eye — FSH...

Hormones are needed for a woman to get pregnant, but they can also be used to help stop her getting pregnant.

Q1 Name two types of contraception that use hormones. [2 marks]

More on Controlling Fertility

There are even more methods of contraception...

Barriers Stop Egg and Sperm Meeting

1) Non-hormonal contraceptives (types that don't use hormones) stop the sperm from getting to the egg.
2) Barrier methods are one type of non-hormonal contraceptive. For example:

Condom

1) Condoms are worn over the penis during sexual intercourse.
2) Female condoms are worn inside the vagina.
3) Condoms are the only form of contraception that will protect against sexually transmitted diseases.

Diaphragm

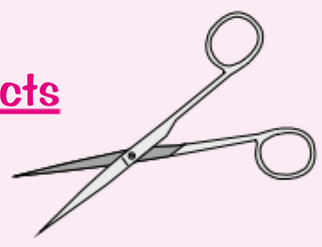
1) A diaphragm is a shallow plastic cup that fits over the entrance to the uterus.
2) It has to be used with spermicide (a chemical that disables or kills the sperm).
3) Spermicide can be used alone as a form of contraception. But when used alone, it is not as effective (it's only about 70-80% effective at preventing pregnancy).



There are Other Ways to Avoid Pregnancy

Sterilisation

1) In females, sterilisation involves cutting or tying the fallopian tubes (tubes that connect the ovaries to the uterus).
2) In males, it involves cutting or tying the sperm ducts (tubes between the testes and the penis).
3) Sterilisation is permanent (lasts for life).



Natural Methods

1) Pregnancy may be avoided by not having sexual intercourse when a woman is at the stage of the menstrual cycle when she is most likely to get pregnant.
2) It's popular with people who think that hormonal and barrier methods are unnatural.
3) But it's not very effective.

Abstinence

1) The only way to be sure that sperm and egg don't meet is to not have intercourse.
2) This is called abstinence.

The winner of best contraceptive ever — just not doing it...

You might be asked to evaluate the different hormonal and non-hormonal methods of contraception in your exam. This means you need to write about both the pros and the cons of each method. Exciting stuff.

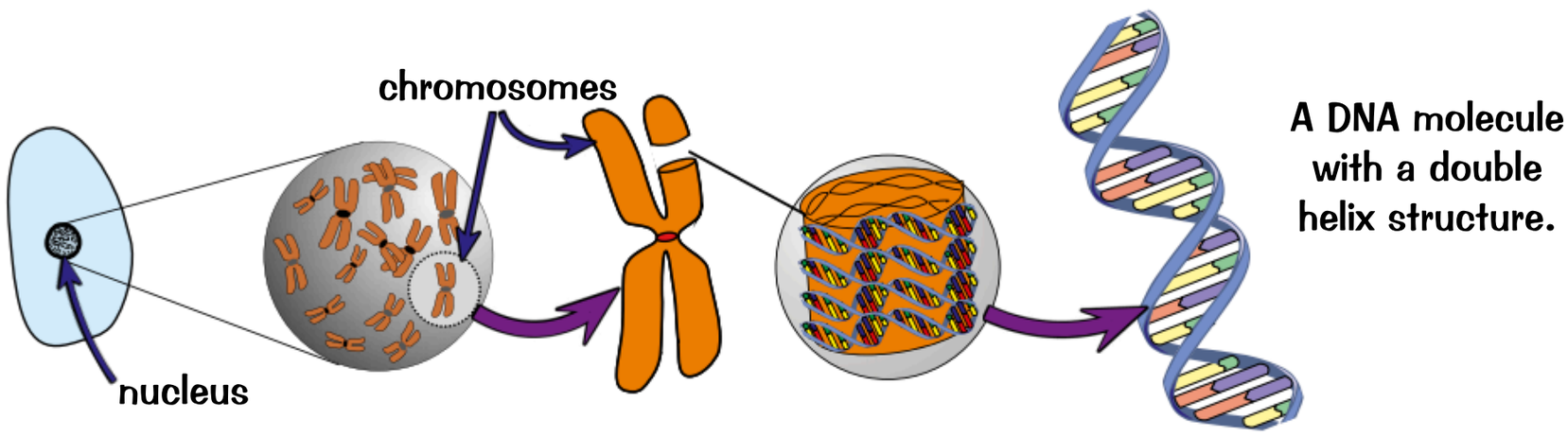
Q1 Explain how barrier methods of contraception work. [1 mark]

DNA

Your DNA is what makes you you. Time to find out what DNA actually is...

Chromosomes Are Really Long Molecules of DNA

1) DNA is the chemical that all of the genetic material in a cell is made up from.
2) It contains all the instructions to put an organism together and make it work.
3) A DNA molecule is made up of two strands of DNA coiled together. They make a double helix (a double-stranded spiral).
4) A DNA strand is a polymer. A polymer is something made up of lots of smaller pieces joined together.
5) DNA is found in the nucleus of animal and plant cells.
6) It's found in really long structures called chromosomes.



A Gene Codes for a Specific Protein

1) A gene is a small section of DNA found on a chromosome.
2) Each gene codes for a particular sequence of amino acids.
3) These amino acids are joined together to make a protein.

Every Organism Has a Genome

1) Genome is just the fancy term for all of the genetic material in an organism.
2) Scientists have worked out the whole human genome.
3) Understanding the human genome is really important for medicine. This is because:
   1) Scientists can find genes in the genome that are linked to different types of disease.
   2) If scientists know which genes are linked to inherited diseases, they can understand them better. This could help us to develop treatments.
   3) Scientists can look at tiny differences in the genomes of different people. This can help them find out about the migration (movement) of certain populations of people around the world over history.



Insert joke about genes and jeans here...

Make sure you've got that info about genes, DNA and chromosomes stuck in your head. It can be tricky stuff.

Q1 What is a gene? [1 mark]

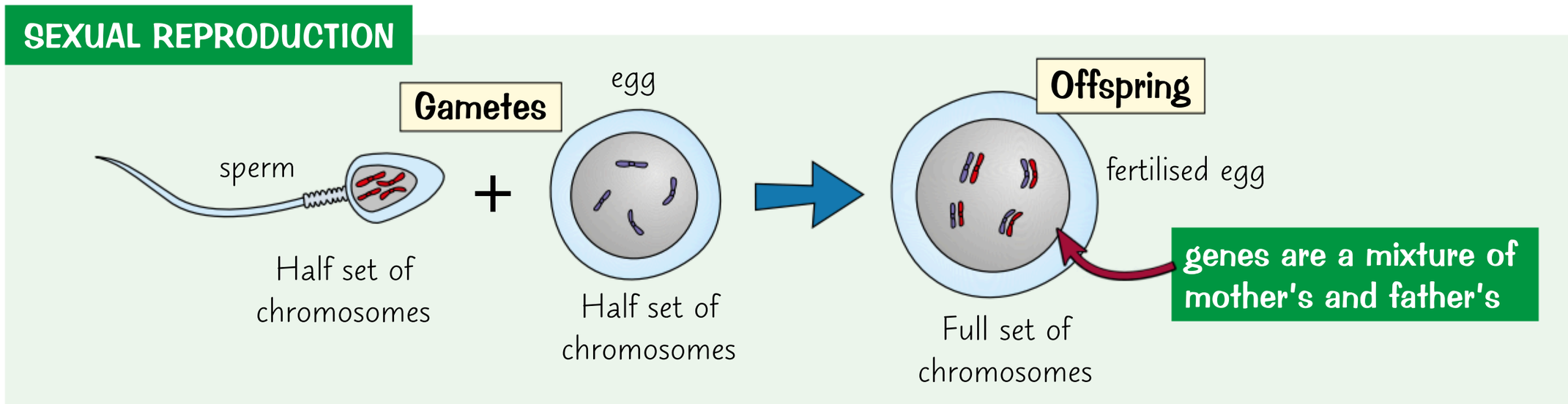
Q2 What is an organism's genome? [1 mark]

Reproduction

Ooo err, reproduction... It can happen in two different ways...

Sexual Reproduction Produces Genetically Different Cells

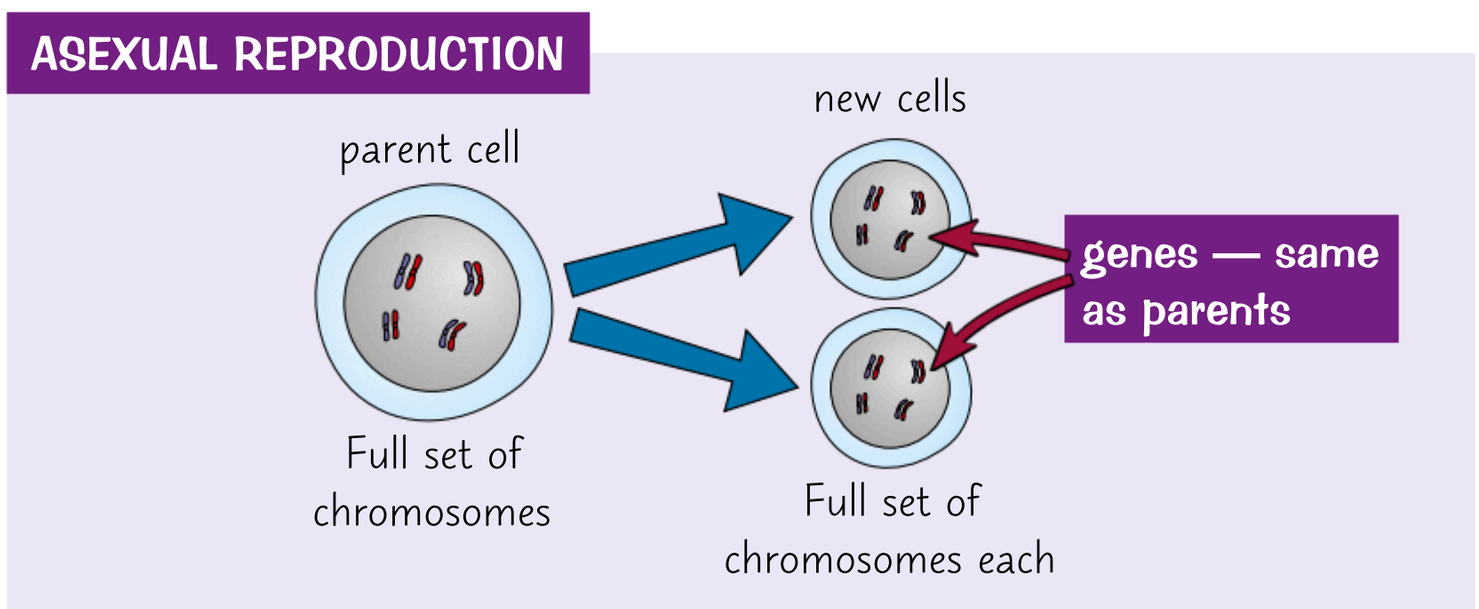
1) Sexual reproduction is where genes from two organisms (a father and a mother) are mixed.
2) The mother and father produce gametes (sex cells). E.g. egg and sperm cells in animals.
3) The gametes are produced by meiosis (see next page).
   Each gamete contains half the number of chromosomes of a normal cell.
4) The egg (from the mother) and the sperm cell (from the father) fuse (join) together.
   This forms a cell with the full number of chromosomes (half from the father, half from the mother).



5) The offspring receives a mixture of genes, so inherits features from both parents.
6) This mixture of genes produces variation in the offspring. Pretty cool, eh.
7) Flowering plants can reproduce in this way too. Their gametes are egg cells and pollen.

Asexual Reproduction Produces Genetically Identical Cells

1) Asexual reproduction happens by mitosis.
2) One parent cell makes a new cell by dividing in two (see page 15).



3) There's no fusion of gametes.
4) So there's no mixing of genes.
5) This means there's no genetic variation in the new cells.
6) Each new cell is genetically identical to the parent cell — it has exactly the same genes.
   The new cell is a clone.

You need to reproduce these facts in the exam...

They might have similar names, but you need to know how sexual and asexual reproduction are different.

Q1 What type of cell division is involved in asexual reproduction? [1 mark]

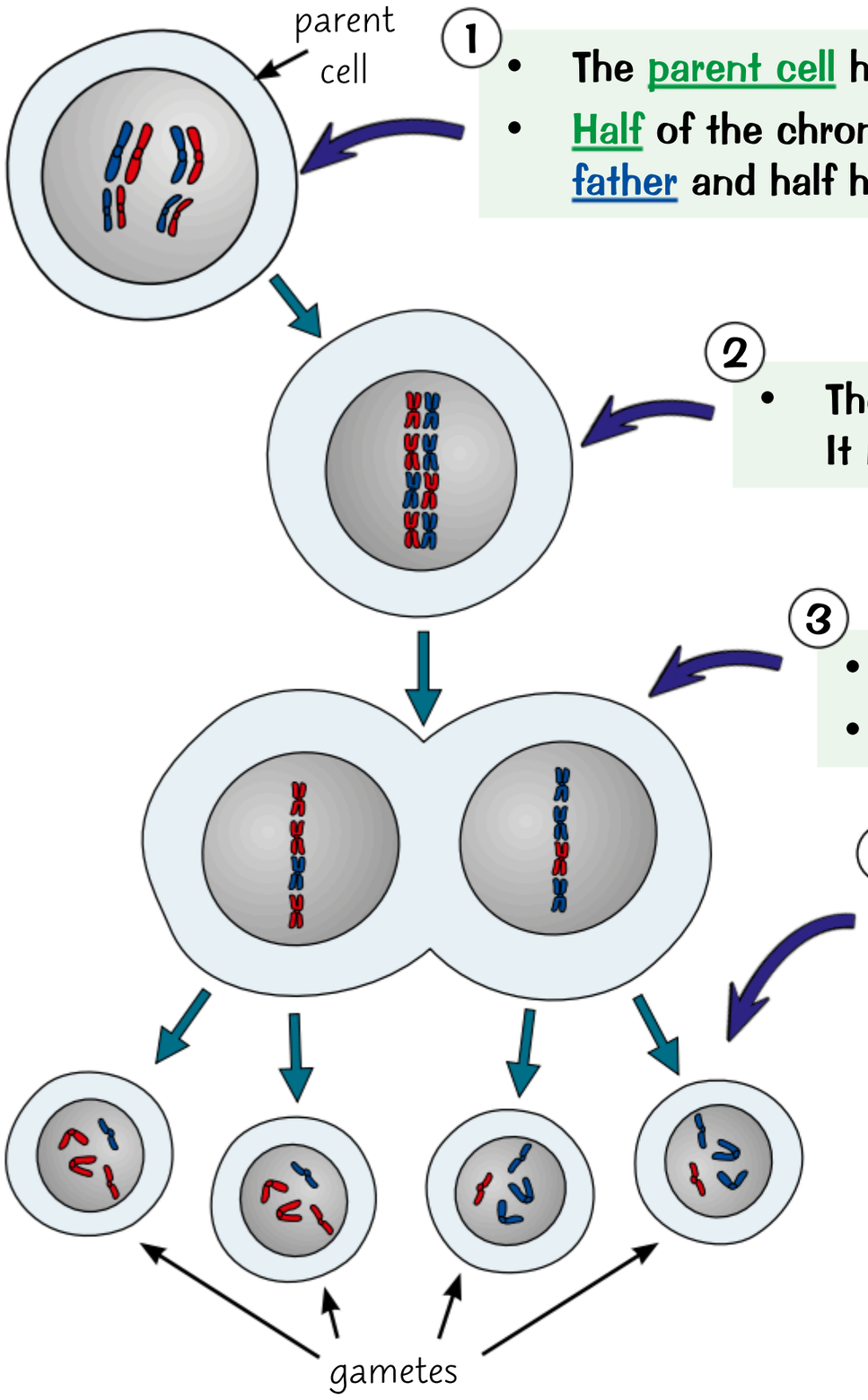
Q2 Suggest why there is variation in the offspring of sexual reproduction. [2 marks]

Meiosis

Ever wondered how sperm and egg cells are made? Well today's your lucky day.

Gametes Are Produced by Meiosis

1) Gametes only have half the number of chromosomes of normal cells.
2) To make gametes, cells divide by meiosis.
3) In humans, meiosis only happens in the reproductive organs (the ovaries in females and testes in males).
4) Here's how meiosis happens:



1
- The parent cell has chromosomes in pairs.
- Half of the chromosomes have come from the organism's father and half have come from the organism's mother.

2
- The DNA in the parent cell is copied. It makes X-shaped chromosomes.

3
- The cell divides.
- Each new cell gets half of the chromosomes.

4
- Each cell divides again.
- The X-shaped chromosomes are pulled apart.
- You end up with four new daughter cells. These are the gametes.
- Each gamete:
  - only has a single set of chromosomes,
  - is genetically different (each has a different mix of the mother's and father's chromosomes).

Gametes Fuse to Make a New Cell

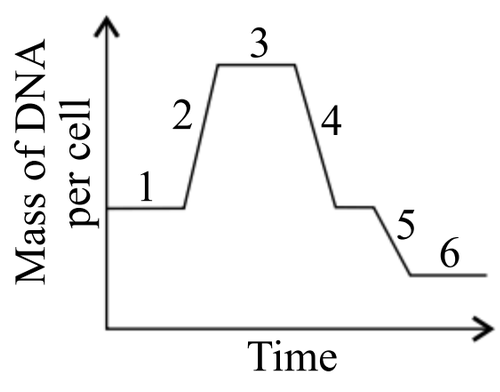
1) During fertilisation, two gametes fuse together (see p.67). This makes a new cell.
2) This new cell has the normal number of chromosomes.
3) The new cell divides by mitosis many times to produce lots of new cells. This forms an embryo.
4) As the embryo develops, these cells differentiate (see page 14). The cells become different types of specialised cell that make up a whole organism.

An embryo is an unborn baby at an early stage of growth.

Now that I have your undivided attention...

In humans, meiosis only occurs in reproductive organs, for making gametes.

Q1 Human body cells contain 46 chromosomes each. The graph on the right shows how the mass of DNA per cell changed as some cells divided by meiosis in a human ovary. How many chromosomes were present in each cell when they reached stage 6? [1 mark]



Q1 Video Solution

X and Y Chromosomes

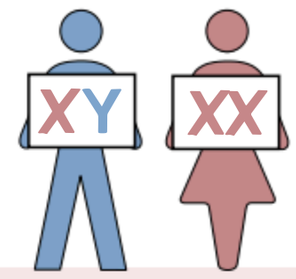
Now for a couple of very important little chromosomes...

Your Chromosomes Control Whether You're Male or Female

1) There are 23 pairs of chromosomes in every human body cell.
2) 22 are matched pairs of chromosomes that just control your characteristics.
3) The 23rd pair are labelled XY or XX.
4) They're the two chromosomes that decide your sex (whether you turn out male or female).

All males have an X and a Y chromosome: XY
The Y chromosome causes male characteristics.

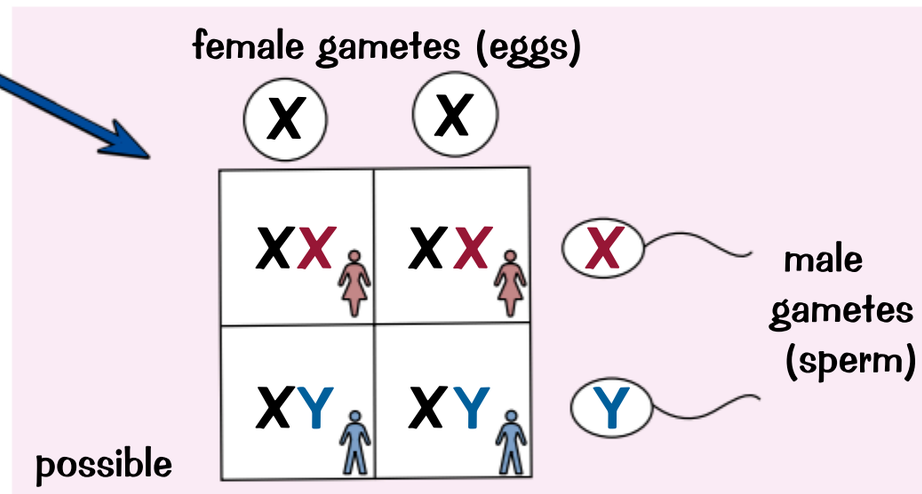
5) Each sperm has either an X or a Y chromosome.
6) All egg cells have a X chromosome.

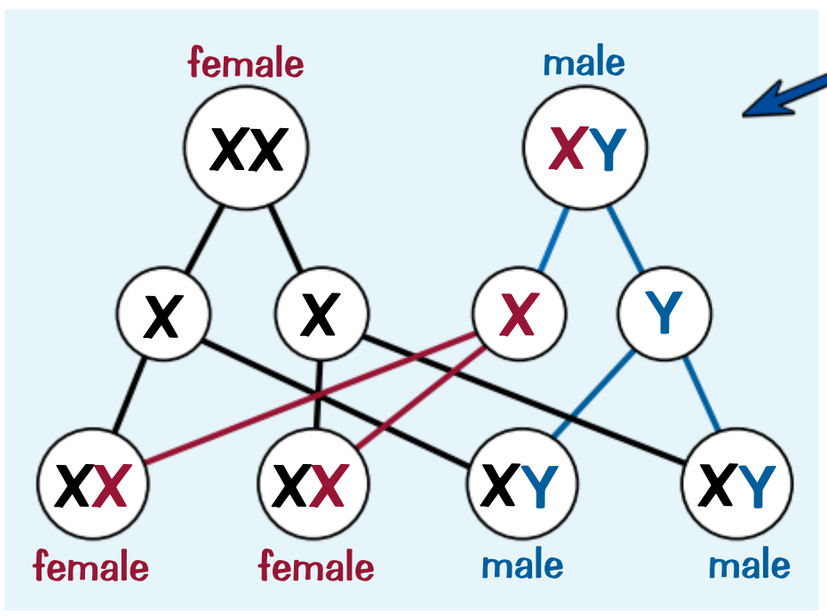


All females have two X chromosomes: XX
The XX combination allows female characteristics to develop.

Genetic Diagrams Show the Possible Gamete Combinations

1) To find the probability (chance) of getting a boy or a girl, you can draw a genetic diagram.
2) This type of genetic diagram is called a Punnett square.
3) Put the possible gametes (eggs or sperm) from one parent down the side.
   Put those from the other parent along the top.
4) Then in each middle square you fill in the letters from the top and side that line up with that square.
5) The pairs of letters in the middle show the possible combinations of the gametes.
6) There are two XX results and two XY results.
7) This means that there's the same probability of getting a boy or a girl — each one has a 1 in 2 chance (which is the same as 50%).





The other type of genetic diagram looks a bit more complicated, but it shows exactly the same thing.

1) At the top are the parents.
2) The middle circles show the possible gametes that are formed. One gamete from the female combines with one gamete from the male (during fertilisation).
3) The criss-cross lines show all the possible ways the X and Y chromosomes could combine.
4) The possible offspring you could get are shown in the bottom circles.

Have you got the Y-factor...

Genetic diagrams only show probabilities. They don't say what will definitely happen. So for each pregnancy, a women has a 50% chance of having a boy or a girl. It doesn't matter how many boys or girls she's had before.

Q1 What combination of sex chromosomes do human females have? [1 mark]

Genetic Diagrams

Genetic diagrams don't always show chromosomes. They might show just a single gene instead.

Different Genes Control Different Characteristics

1) Some characteristics are controlled by a single gene.
   For example, mouse fur colour and red-green colour blindness in humans.
2) However, most characteristics are controlled by several genes.



All Genes Exist in Different Versions Called Alleles

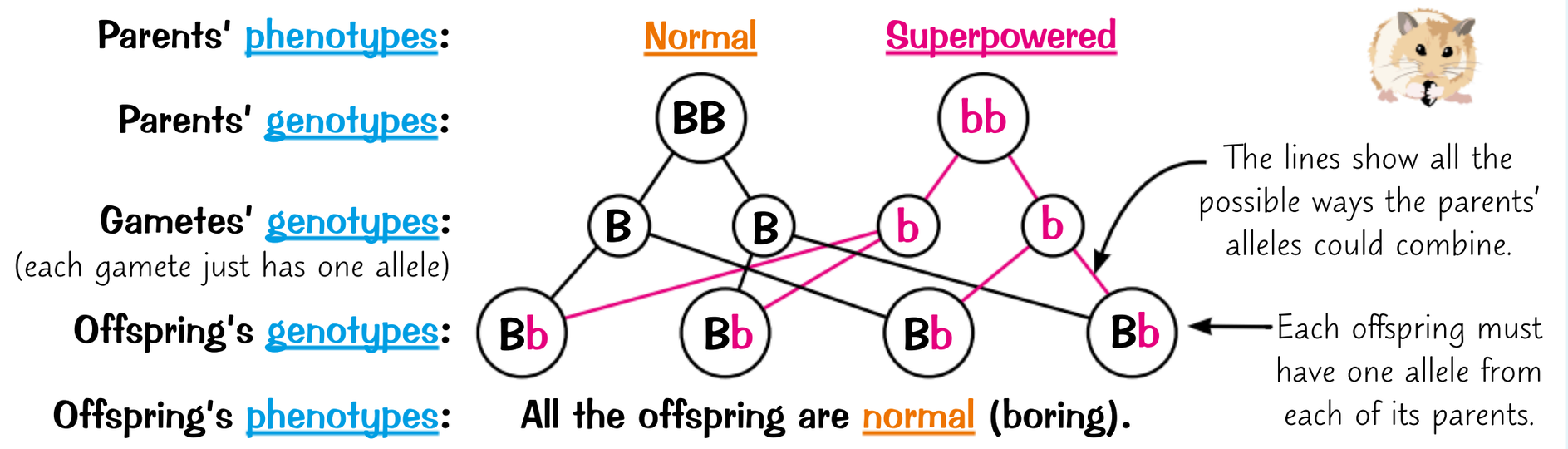
1) You have two alleles of every gene in your body — one on each chromosome in a pair.
2) If the two alleles are the same, then the organism is homozygous for that characteristic.
3) If the two alleles are different, then the organism is heterozygous for that characteristic.
4) Some alleles are dominant (these are shown with a capital letter on genetic diagrams, e.g. 'C').
   Some alleles are recessive (these are shown by a small letter on genetic diagrams, e.g. 'c').
5) For an organism to show a recessive characteristic, both its alleles must be recessive (e.g. cc).
   But to show a dominant characteristic, only one allele needs to be dominant (e.g. either CC or Cc).
6) The mix of alleles you have is called your genotype.
7) Your alleles determine your characteristics. The characteristics you have is called your phenotype.

Genetic Diagrams Can Show How Characteristics are Inherited

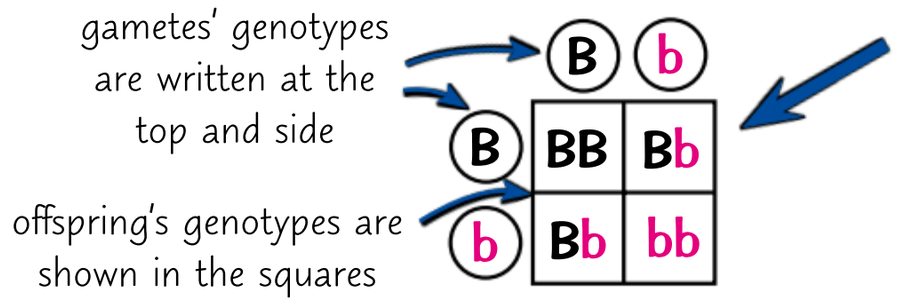
You can use genetic diagrams to show how single genes for characteristics are inherited (passed from parents to offspring). For example:

1) An allele that causes hamsters to have superpowers is recessive ("b").
2) Normal hamsters don't have superpowers due to a dominant allele ("B").
3) Two homozygous hamsters (BB and bb) are crossed (bred together).
   A genetic diagram shows what could happen:

A hamster with the genotype BB or Bb will be normal.
A hamster with the genotype bb will have superpowers.



4) This Punnett square shows a cross between two heterozygous hamsters (Bb and Bb):



- There's a 3 in 4 (75%) chance that offspring will be normal.
- There's a 1 in 4 (25%) chance that offspring will have superpowers.
- This gives a 3 normal : 1 superpowers ratio (3:1).



Your meanotype determines how nice you are to your sibling...

Make sure you understand all the scientific terms on this page. It will help you understand diagrams too.

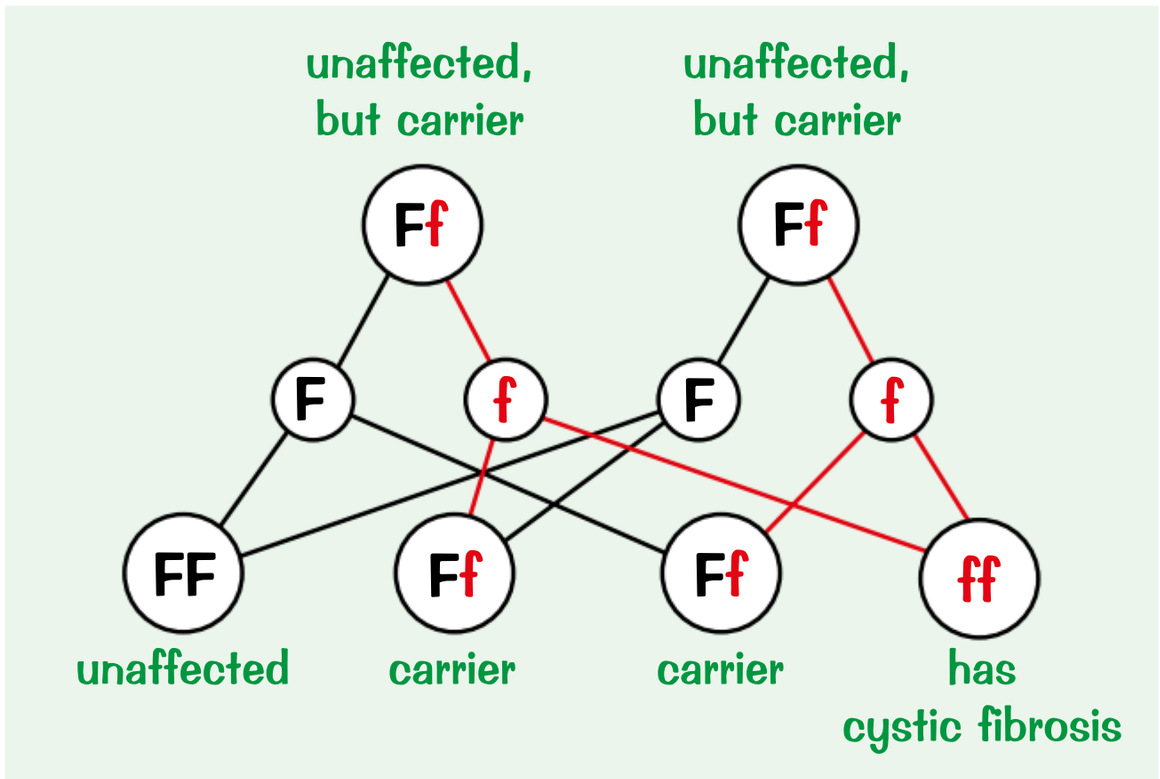
Q1 What is meant by the term genotype? [1 mark]

Inherited Disorders

Inherited disorders are health conditions. They are caused by inheriting faulty alleles.

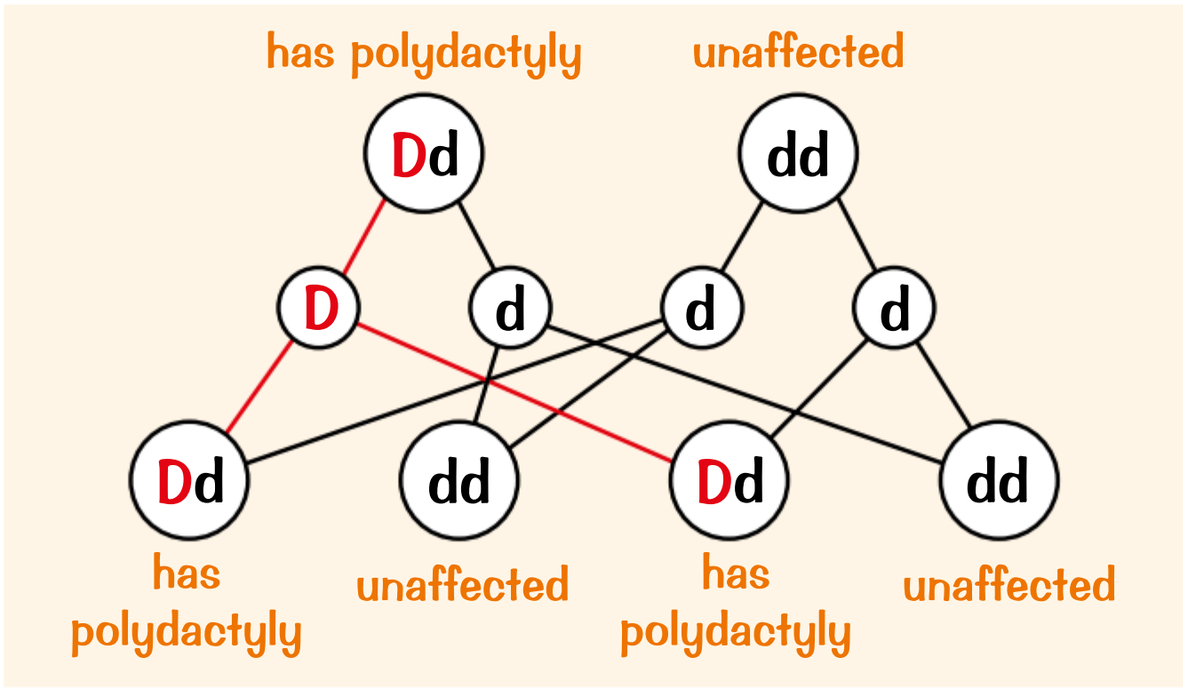
Cystic Fibrosis is Caused by a Recessive Allele

1) Cystic fibrosis is an inherited disorder of cell membranes.
2) The allele which causes cystic fibrosis is a recessive allele, 'f'.
3) Because it's recessive, people with only one copy of the allele won't have the disorder — they're known as carriers.
4) For a child to have the disorder, both parents must be either carriers or have the disorder themselves.
5) As the diagram shows, there's a 1 in 4 chance of a child having the disorder if both parents are carriers.



Polydactyly is Caused by a Dominant Allele

1) Polydactyly is an inherited disorder where a baby's born with extra fingers or toes.
2) The disorder is caused by a dominant allele, 'D'.
3) This means that it can be inherited if just one parent carries the faulty allele.
4) The parent that has the faulty allele will have the disorder too since the allele is dominant.
5) As the diagram shows, there's a 50% chance of a child having the disorder if one parent has one D allele.



Unintentional mooning — caused by faulty genes...

The important bits to take away from this page are that the allele for cystic fibrosis is recessive and the allele for polydactyly is dominant.

Q1 The Punnett square on the right shows the possible inheritance of polydactyly from two parents. Give the probability that their offspring will have polydactyly. [1 mark]

	D	d
D	DD	Dd
d	Dd	dd

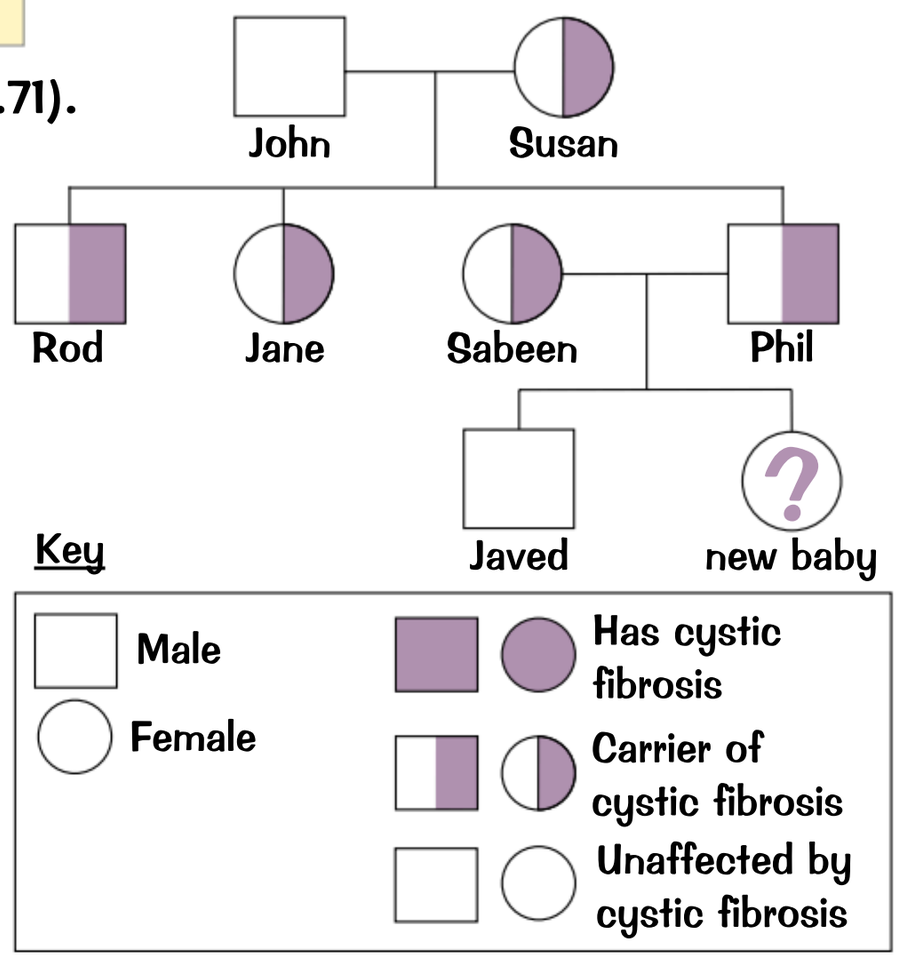
Q1 Video Solution

Family Trees and Embryo Screening

Just when you thought you'd finished with genetic diagrams, these family trees show up...

Family Trees Show the Inheritance of Alleles

1) The diagram on the right is a family tree for cystic fibrosis (p.71).
2) From the family tree, you can tell that the allele for cystic fibrosis isn't dominant. This is because plenty of the family carry the allele but don't have the disorder.
3) There is a 25% chance that the new baby will have the disorder and a 50% chance that it will be a carrier. This is because both of the baby's parents are carriers (Sabeen and Phil are both Ff).
4) The case of the new baby is just the same as in the genetic diagram on page 71. The baby could be unaffected (FF), a carrier (Ff) or have cystic fibrosis (ff).



Embryos Can Be Screened for Inherited Disorders

1) During *in vitro* fertilisation (IVF), embryos are fertilised in a lab and then put in the mother's womb.
2) Before they are put into the mother, scientists can remove a cell from each embryo and look at its genes. This is called embryo screening.
3) Many inherited disorders can be picked up in this way.
4) It's also possible to get DNA from an embryo in the womb and test that for disorders.
5) There are lots of concerns about embryo screening.
6) Some people don't agree with embryonic screening because of the decisions it can lead to.
7) For embryos produced by IVF — after screening, embryos with 'bad' alleles would be destroyed.
8) For embryos in the womb — screening could lead to the decision to stop the pregnancy.
9) Here are some more arguments for and against embryo screening:

Against Embryo Screening

1) It suggests that people with genetic problems are not wanted. This could lead to them being treated unfairly.
2) There may come a point when people want to screen their embryos so they can pick the features they prefer. E.g. they want a certain eye colour or hair colour.
3) Screening is expensive.

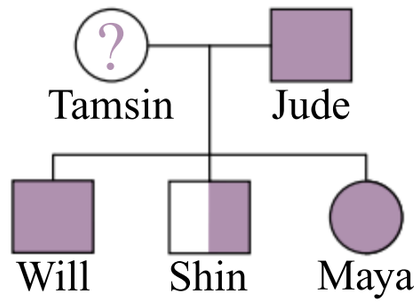
For Embryo Screening

1) It will help to stop people suffering.
2) Treating disorders costs a lot of money.
3) There are laws to stop it going too far. At the moment parents cannot even select the sex of their baby (unless it's for health reasons).

Embryo screening — it's a tricky one...

Arguments about things like embryo screening don't have a simple answer — there are pros and cons to think about.

Q1 Cystic fibrosis is caused by a recessive allele, f. The dominant allele is F. The family tree on the right shows the inheritance of cystic fibrosis. What is Tamsin's genotype? Use the key above to help you. [1 mark]



Q1 Video Solution

Variation

You'll probably have noticed that not all people are identical. There are reasons for this.



Organisms of the Same Species Have Differences

1) Different species look... well... different — my dog definitely doesn't look like a daisy.
2) But even organisms of the same species will usually look at least slightly different.
3) These differences are called the variation within a species.
4) Variation can be huge within a population.
5) Variation can be genetic. This means it's caused by differences in genes that are inherited.
6) Variation can also be environmental. This means it's caused by the conditions in which an organism lives.



- For example, a plant grown on a nice sunny windowsill could grow healthy and green.
- The same plant grown in darkness would grow tall and spindly and its leaves would turn yellow.



7) Most variation in phenotype is caused by a mixture of genes and the environment.

- For example, the maximum height that an animal or plant could grow to is determined by its genes.
- But whether it actually grows that tall depends on its environment (e.g. how much food it gets).

Mutations are Changes to the Genome

1) Sometimes, a gene can mutate.
2) A mutation is a random change in an organism's DNA that can be inherited.
3) Mutations occur continuously.
4) Mutations mean that the gene is changed.
   This produces a genetic variant (a different form of the gene).
5) Most genetic variants have very little or no effect on an organism's phenotype (its characteristics).
6) Some variants have a small effect on the organism's phenotype.
   They alter the individual's characteristics but only slightly. For example:



Well, I suppose it's time for some new jeans.

- Some characteristics (e.g. eye colour) are controlled by more than one gene.
- A mutation in one of the genes may change the eye colour a bit, but the difference might not be huge.

7) Very rarely, variants can have such a big effect that they lead to a new phenotype, e.g. cystic fibrosis.
8) A new phenotype may be useful if the environment that an organism lives in changes.
9) This is because sometimes a new phenotype makes an individual more suited to a new environment.
10) If this happens, the mutation can become common throughout the species relatively quickly.
    This happens by natural selection — see the next page.

My mum's got no trousers — cos I've got her jeans...

So you can't blame all of your faults on your parents — the environment usually plays a role too.

Q1 Explain what is meant by environmental variation. [2 marks]

Evolution

THEORY OF EVOLUTION: All of today's species have evolved from simple life forms that first started to develop over three billion years ago.

Only the Fittest Survive

1) Charles Darwin came up with a really important theory about evolution — it's called evolution by natural selection. It works like this:

- Organisms in a species show wide variation in their characteristics.
- Organisms have to compete for resources in an ecosystem.
- This means organisms with characteristics that make them better adapted to their environment will be better at competing with other organisms.
- These organisms are more likely to survive and reproduce.
- So the genes for the useful characteristics are more likely to be passed on to their offspring.
- Over time, useful characteristics become more common in the population and the species changes. This is evolution.

2) Darwin's theory wasn't perfect. At the time he couldn't explain how new characteristics appeared or were passed on. Nowadays we have evidence to back up Darwin's theory, such as:

- The discovery of genetics — it showed that characteristics are passed on in an organism's genes. It also showed that genetic variants (see page 73) produce the characteristics (phenotypes) that are better adapted to the environment.
- Fossils — by looking at fossils of different ages (the fossil record), scientists could see how changes in organisms developed slowly over time.
- Antibiotic resistance — how bacteria are able to evolve to become resistant to antibiotics also further supports evolution by natural selection (see the next page).

3) This means Darwin's theory of evolution by natural selection is now widely accepted.

Evolution Can Lead to New Species Developing

1) Over a long period of time, the phenotype of organisms can change a lot because of natural selection.
2) Sometimes, the phenotype can change so much that a completely new species is formed.
3) New species develop when populations of the same species change so much that they can't breed with each other to produce fertile offspring.

Extinction is When No Individuals of a Species Are Left

Species become extinct for these reasons:

1) The environment changes too quickly (e.g. their habitat is destroyed).
2) A new predator kills them all (e.g. humans hunting them).
3) A new disease kills them all.
4) They can't compete with another (new) species for food.
5) A catastrophic event happens that kills them all (e.g. a volcanic eruption).

"Natural selection" — sounds like vegan chocolates...

Natural selection's all about the organisms with the best characteristics surviving to pass on their genes.

Q1 The sugary nectar in some orchid flowers is found at the end of a long tube behind the flower. There are moth species with long tongues that can reach the nectar. Explain how natural selection could have led to the moths developing long tongues. [4 marks]

Q1 Video Solution

Antibiotic-Resistant Bacteria

Antibiotic-resistant bacteria are the super villains of the medical world. Trust me on this.

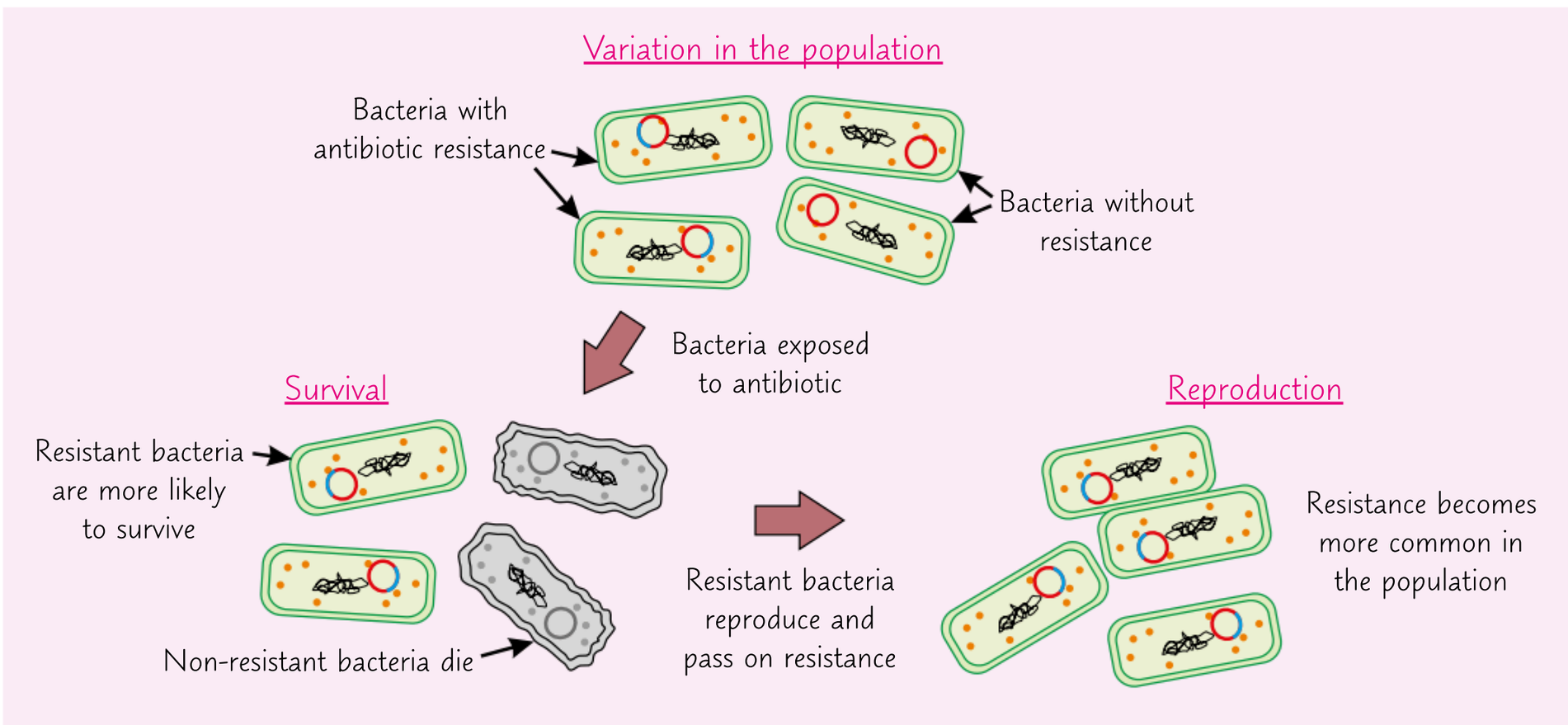
Bacteria can Evolve and Become Antibiotic-Resistant

Antibiotics are drugs that kill bacteria.
Bacteria can become resistant to antibiotics by natural selection.

There's more about natural selection on page 74.

Here's what happens:

1) Bacteria can develop random mutations (changes) in their DNA.
2) These can lead to the bacteria being resistant to (not killed by) a particular antibiotic.
3) These new strains (types) of bacteria are called antibiotic-resistant bacteria.
4) The ability to resist antibiotics is a big advantage for the bacteria.
5) It means that the bacteria are able to survive in a host who's being treated to get rid of an infection.
6) So the antibiotic-resistant bacteria can reproduce many more times.
7) They pass on their gene for antibiotic resistance to their offspring.
8) The gene for antibiotic resistance becomes more common in the population over time — the bacteria have evolved.



9) Because bacteria are so rapid at reproducing, they can evolve quite quickly.
10) The antibiotic-resistant bacteria keep reproducing.
This increases the population size of the antibiotic-resistant strain.

Antibiotic Resistant Bacteria Spread Easily

1) Antibiotic-resistant bacteria are a problem because:
   - There is no effective treatment for the infection.
   - People are not immune to the new strain.
2) This means that the antibiotic-resistant strain is able to easily spread between people.

The spread of resistance — not what I want on my toast...

Understanding natural selection is key to this page really. If you're not sure about it, have a flick back to page 74.

Q1 Give one reason why antibiotic resistant bacteria can be easily spread between people. [1 mark]

More on Antibiotic-Resistant Bacteria

Antibiotic-resistance is getting worse. But there are ways to fight it...

Antibiotic Resistance is Becoming More Common

1) The problem of antibiotic resistance is getting worse because:

- Antibiotics are being overused.
- People aren't using antibiotics correctly.

2) 'Superbugs' (bacteria that are resistant to most known antibiotics) are becoming more common.



E.g. MRSA is a relatively common 'superbug' that's really hard to get rid of.

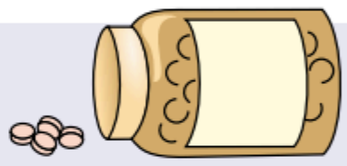
Antibiotics Need to Be Used Sensibly

There are a few things that can be done to avoid antibiotic-resistant bacteria forming:

1) Doctors should only prescribe antibiotics when they really need to.
2) They shouldn't be prescribed for non-serious conditions or infections caused by viruses.

Antibiotics don't kill viruses.

1) You should take all the antibiotics a doctor prescribes for you.
2) Taking the full course makes sure that all the bacteria are destroyed.
3) This means that there are none left to mutate and develop into antibiotic-resistant strains.



The use of antibiotics by farmers should be restricted because:

- In farming, antibiotics can be given to animals to prevent them becoming ill and make them grow faster.
- This can lead to the development of antibiotic-resistant strains of bacteria in the animals.
- The antibiotic-resistant bacteria can then spread to humans.

We Can't Make New Antibiotics Fast Enough

1) Drug companies are working on developing new antibiotics that kill the resistant strains.
2) But there are problems:
   - The rate of development is slow.
   - The process is really expensive.
3) This means that we're unlikely to be able to keep up with the demand for new drugs to fight new antibiotic-resistant strains.

Aaargh, a giant earwig! Run from the attack of the superbug...

The reality of 'superbugs' is even scarier than giant earwigs. Bacteria that are resistant to all our drugs are a worrying thought. It'll be like going back in time to before antibiotics were invented.

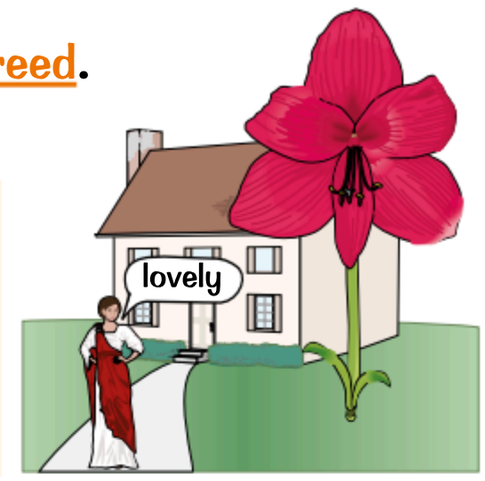
Q1 Explain why it's important that people take the full course of antibiotics they are prescribed. [2 marks]

Selective Breeding

'Selective breeding' sounds like it could be a tricky topic, but it's actually quite simple.

Selective Breeding is Very Simple

1) Selective breeding is when humans choose which plants or animals are going to breed.
2) Organisms are selectively bred to develop features that are useful or attractive.
   For example:
   - Animals that produce more meat or milk.
   - Crops with disease resistance (that are not killed by disease).
   - Dogs with a good, gentle personality.
   - Decorative plants with big or unusual flowers.



3) This is the basic process involved in selective breeding:
   - From your existing plants or animals select the ones which have the feature you're after.
   - Breed them with each other.
   - Select the best of the offspring, and breed them together.
   - Continue this process over several generations. Eventually, all offspring will have the feature you want.

Selective breeding is also known as 'artificial selection'.

4) Selective breeding is nothing new — people have been doing it for thousands of years.
5) This is how we ended up with edible crops from wild plants and domesticated animals like cows and dogs.

Here's an Example:

A farmer might want her cattle to produce more meat.

- Genetic variation means some cattle will have better characteristics for producing meat than others, e.g. a larger size.
- The farmer could select the largest cows and bulls and breed them together.
- She could then select the largest offspring and breed them together.
- After several generations, she would get cows with a very high meat yield.

Selective Breeding Has Disadvantages

There's more on alleles on page 70.

1) The main problem with selective breeding is that it reduces the number of different alleles in a population.
2) This is because the "best" animals or plants are always used for breeding, and they are all closely related — this is known as inbreeding.
3) This means there's more chance of selectively bred organisms having health problems caused by their genes, e.g. they may inherit harmful genetic defects.
4) There can also be serious problems if a new disease appears.
5) This is because it's less likely that individuals in the population will have alleles that make them resistant to the disease.
6) So, if one individual is affected by the disease, the rest are also likely to be affected.



I use the same genes all the time too — they flatter my hips...

Different breeds of dog came from selective breeding. For example, somebody thought 'I really like this small, yappy wolf — I'll breed it with this other one'. After thousands of generations, we got poodles.

Q1 Video Solution

Q1 Explain how you could selectively breed for floppy ears in rabbits. [4 marks]

Q2 What potential issues can selective breeding cause? [3 marks]

Genetic Engineering

As well as selective breeding, humans can also use genetic engineering to control an organism's features.

Genetic Engineering Involves Changing an Organism's DNA

1) Genetic engineering is used to give organisms new and useful characteristics.
2) It involves cutting a gene out of one organism and putting it into another organism's cells.
3) Organisms that have had a new gene inserted are called genetically modified (GM) organisms.

Genetic Engineering is Useful in Agriculture and Medicine

For example, in agriculture:

1) Crops can be genetically engineered — this makes genetically modified (GM) crops.
2) They may be genetically engineered to be resistant to herbicides (chemicals that kill plants). This means that farmers can spray their crops to kill weeds, without affecting the crop itself.
3) Crops can also be genetically engineered to be resistant to insects or disease. Or they can be made to grow bigger and better fruit.
4) These things can increase crop yield (the amount of food produced).



In medicine:

- Bacteria can be genetically engineered to produce human insulin. This can be used to treat diabetes (see p.62).
- Treatments using genetic modification for inherited diseases are being researched.

But There are Some Concerns About Genetic Engineering

There are concerns about using genetic engineering in animals:

1) It can be hard to predict how changing an animal's DNA will affect the animal.
2) Many genetically modified embryos don't survive.
3) Some genetically modified animals also suffer from health problems later in life.



There are also concerns about growing GM crops:

1) Some people say that growing GM crops will affect the number of wild flowers. This could also affect the population of insects.
2) Some people are worried that we might not understand the effects of GM crops on human health.

If only there was a gene to make revision easier...

Genetically modified (GM) organisms could be very useful. But we don't yet know what all the consequences of using them might be — so make sure you know what they can be used for and the arguments against them.

Q1 Give one beneficial feature that GM crops can be engineered to have. [1 mark]

Fossils

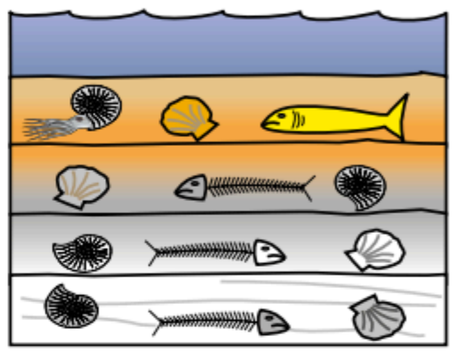
Fossils are great. If they're well-preserved, you can see what really old creatures looked like.

Fossils are the Remains of Plants and Animals

1) Fossils are the remains of organisms from many thousands of years ago. They're found in rocks.
2) They provide the evidence that organisms lived ages ago.
3) Fossils can tell us a lot about how much or how little organisms have changed (evolved) over time.
4) Fossils form in rocks in one of three ways:

1) FROM GRADUAL REPLACEMENT BY MINERALS

(Most fossils happen this way.)



1) Things like teeth, shells and bones don't easily decay.
2) This means they can last a long time when buried.
3) When they do decay, they get replaced by minerals.
4) The minerals form a rock-like substance shaped like the original hard part.

2) FROM CASTS AND IMPRESSIONS

1) Fossils can be formed when an organism is buried in a soft material like clay. The clay hardens around it and the organism decays. The organism leaves a cast of itself. An animal's burrow or a plant's roots can also be preserved as casts.
2) Things like footprints are pressed into soft materials. This leaves an impression when they harden.

3) FROM PRESERVATION IN PLACES WHERE NO DECAY HAPPENS

1) Decay microbes only work if there's oxygen, moisture, warmth and the right pH.
2) In some substances these conditions aren't all present, so decay doesn't happen. For example, there's no oxygen or moisture in amber so decay organisms can't survive.



A preserved organism in amber.

But No One Knows How Life Began

1) Fossils show how much or how little different organisms have changed (evolved) as life has developed on Earth over millions of years.
2) There are lots of hypotheses (see p.1) suggesting how life first came into being. For example:

- Maybe the first life forms appeared in a swamp (or under the sea) here on Earth.
- Or maybe simple carbon molecules were brought here on comets and developed into simple life forms.

But no one really knows.

3) These hypotheses can't be supported or disproved because there's a lack of valid evidence.
4) There's a lack of evidence because many early organisms were soft-bodied. Soft tissue tends to decay away completely. So the fossil record is incomplete (unfinished).
5) Plus, fossils that did form millions of years ago may have been destroyed by geological activity. E.g. the movement of tectonic plates may have crushed fossils already formed in the rock.

Fossils rock my world...

It's a bit mind-boggling really how fossils can still exist even millions of years after the organism died. They really are amazing things, and scientists have learned a whole lot from studying them in detail.

Q1 What are fossils? [2 marks]

Classification

People really seem to like putting things into groups — biologists certainly do anyway...

Classification is Organising Living Organisms into Groups

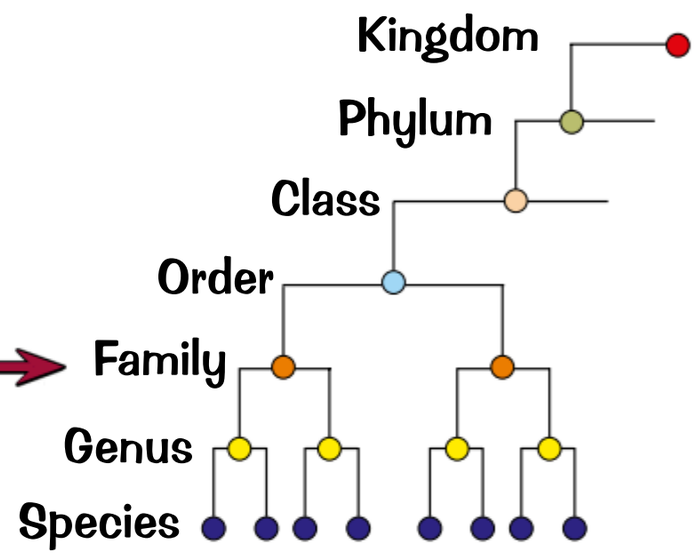
1) In the past, organisms were classified according to characteristics you can see (like number of legs). They were also classified by the structures that make them up (like mitochondria in cells).
2) The more similar two organisms appeared, the more closely related they were thought to be.
3) These characteristics were used to classify organisms in the five kingdom classification system.
4) In this system, living things are divided into five groups called kingdoms. These are:

- Animals — fish, mammals, reptiles, etc.
- Plants — grasses, trees, etc.
- Fungi — mushrooms and toadstools, yeasts, all that mouldy stuff on your loaf of bread (yuck).
- Prokaryotes — all single-celled organisms without a nucleus.
- Protists — eukaryotic single-celled organisms.



There's more on prokaryotes and eukaryotes on p.11.

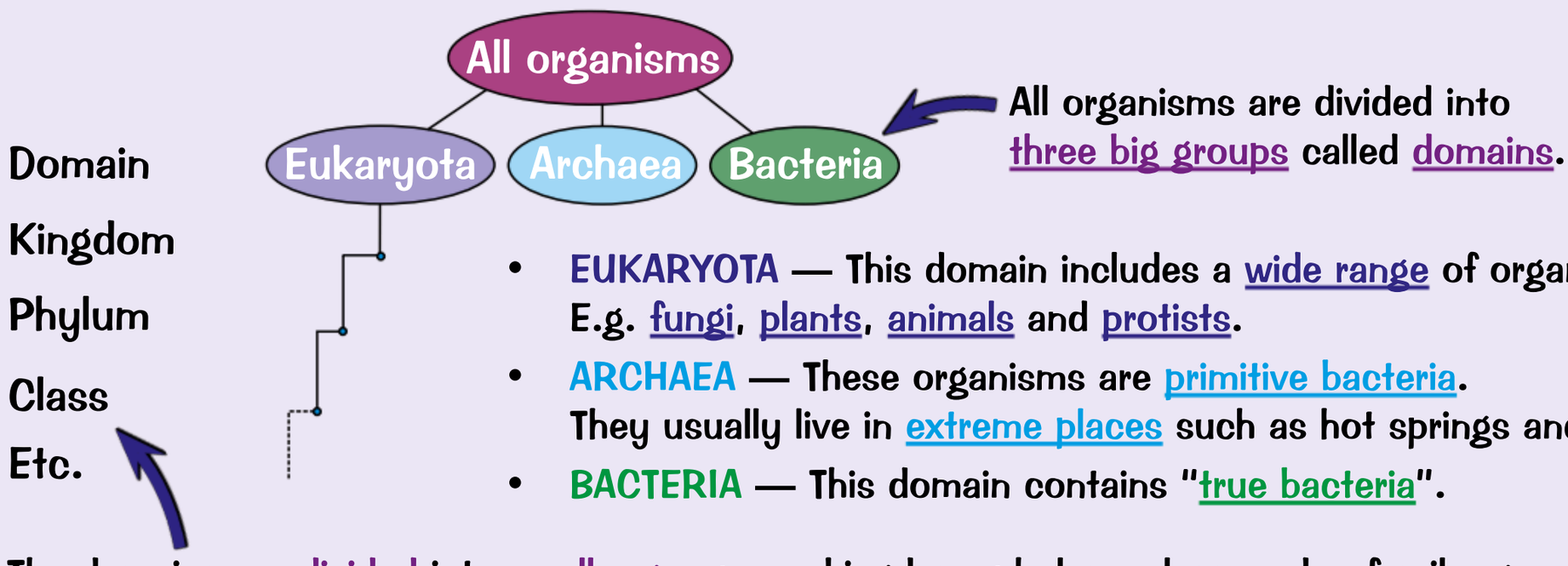
5) The kingdoms are then split into smaller and smaller groups.
6) These groups are phylum, class, order, family, genus and species.
7) The five kingdom classification system was made up by Carl Linnaeus.



Classification Systems Change Over Time

1) Over time, our knowledge of the processes taking place inside organisms has developed.
2) Microscopes have also improved over time. This has allowed us to find out more about the internal structures of organisms.
3) Using this new knowledge, scientists made new models of classification.
4) One of these new models was the three-domain system. It was made up by Carl Woese.
5) He used evidence from analysing chemicals to come up with the system.
6) It showed him that some species were less closely related than first thought.
7) Here's how the three-domain system works:

The three domain classification system:



All organisms are divided into three big groups called domains.

- EUKARYOTA — This domain includes a wide range of organisms. E.g. fungi, plants, animals and protists.
- ARCHAEA — These organisms are primitive bacteria. They usually live in extreme places such as hot springs and salt lakes.
- BACTERIA — This domain contains "true bacteria".

The domains are divided into smaller groups — kingdom, phylum, class, order, family, genus, species.

Classification

Organisms Are Named According to the Binomial System

1) In the binomial system, every organism is given its own two-part Latin name.
2) The first part refers to the genus that the organism belongs to.
   This gives you information on the organism's ancestry (the organisms it's related to).
3) The second part refers to the species.

E.g. humans are known as *Homo sapiens*.

'*Homo*' is the genus... ...and '*sapiens*' is the species.

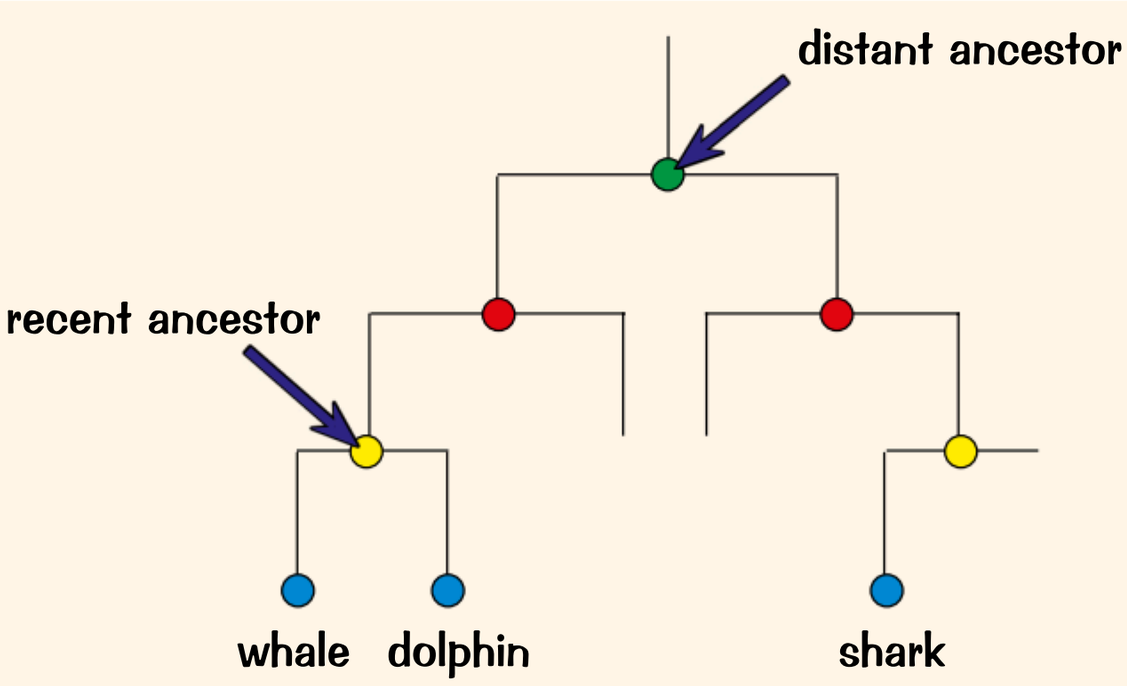
Evolutionary Trees Show Relationships

1) Evolutionary trees show how scientists think different species are related.
2) They show common ancestors and relationships between species.
3) The more recent the common ancestor, the more closely related the two species.
   Also, the more characteristics they are likely to share.
4) Scientists look at lots of different types of data to work out these relationships.
   For example:

- For living organisms, they use current classification data.
- For extinct species, they use information from the fossil record (see page 74).

Extinct species are species that don't exist any more.

5) Here's an example of an evolutionary tree:

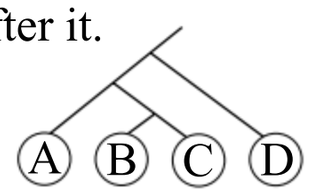


- Whales and dolphins have a recent common ancestor, so they are closely related.
- They're both more distantly related to sharks.

Binomial system — uh oh, sounds like maths...

Sometimes, the genus in a binomial name is abbreviated to a capital letter with a full stop after it.

Q1 The evolutionary tree on the right shows the relationship between four species, A-D.
Which two species shown in the tree are the most closely related? [1 mark]



Q1 Video Solution

Q2 What genus does the Eurasian beaver, *Castor fiber*, belong to? [1 mark]

Revision Questions for Topics B5 & B6

So you've finished Topics B5 and B6 — Hoorah.
Now here's a page full of questions to test your knowledge.

- Try these questions and tick off each one when you get it right.
- When you're completely happy with a sub-topic, tick it off.

For even more practice, try the Retrieval Quizzes for Topics B5 and B6 — just scan the QR codes!

Topic B5 Quiz

Homeostasis and the Nervous System (p.57-60) ☑

1) What is homeostasis? ☑
2) What makes up the central nervous system? ☑
3) What is a synapse? ☑
4) What is the purpose of a reflex action? ☑
5) Name one factor that can affect reaction time. ☑

Hormones in Humans (p.61-65) ☑

6) Give two differences between nervous and hormonal responses. ☑
7) Name the hormone that reduces the blood glucose concentration. ☑
8) What does luteinising hormone (LH) do? ☑
9) What hormone does the contraceptive injection contain? ☑
10) Which of the following is a hormonal contraceptive — condom, implant or diaphragm? ☑

Topic B6 Quiz

DNA, Genes, Reproduction and Meiosis (p.66-68) ☑

11) What is meant by 'double helix'? ☑
12) What do genes code for? ☑
13) What is the name for all of the genetic material in an organism? ☑
14) Name the male and female gametes of animals. ☑
15) State the type of cell division used to make gametes in humans. ☑

Sex Chromosomes, Genetic Diagrams and Inherited Disorders (p.69-72) ☑

16) What is the probability that offspring will have the XX combination of sex chromosomes? ☑
17) What are alleles? ☑
18) Which of these genotypes is heterozygous — FF, Ff or ff? ☑
19) Name one inherited disorder. ☑
20) Give one argument for and one argument against screening embryos for inherited disorders. ☑

Variation, Evolution and Antibiotic-Resistant Bacteria (p.73-76) ☑

21) What is variation? ☑
22) Name the process by which evolution happens. ☑
23) What leads to the formation of antibiotic-resistant strains of bacteria? ☑

Selective Breeding and Genetic Engineering (p.77-78) ☑

24) What is selective breeding? ☑
25) What is genetic engineering? ☑

Fossils and Classification (p.79-81) ☑

26) Give one way that fossils can be formed. ☑
27) What is the smallest group in the Linnaean system of classification? ☑
28) Who proposed the 'three-domain system' of classification? ☑

Competition

Organisms interact with each other and their environment. This is what ecology is all about.

Learn These Words Before You Start

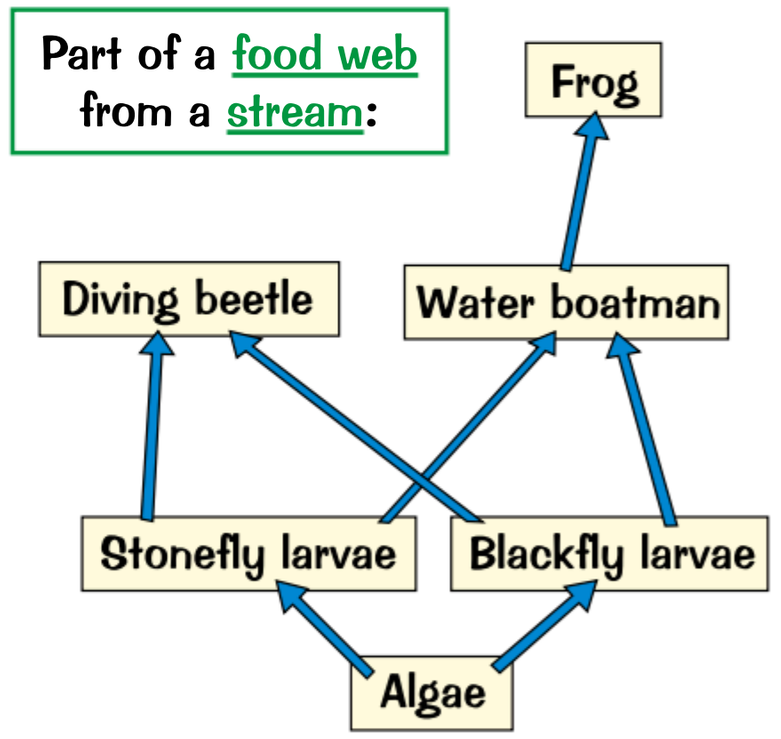
1) Habitat — the place where an organism lives.
2) Population — all the organisms of one species in a habitat.
3) Community — all the populations of different species in a habitat.
4) Ecosystem — the interaction of a community of organisms with the non-living parts of their environment.

Organisms Compete for Resources to Survive

1) Resources are things that organisms need from their environment and other organisms to survive and reproduce:
   - Animals need food, territory (space) and mates.
   - Plants need light, water, space and mineral ions.
2) Organisms compete with other species (and members of their own species) for the same resources.

Organisms in a Community are Interdependent

1) In a community, different species depend on each other for things like food, shelter, pollination and seed dispersal. This is called interdependence.
2) This means that a big change in one part of an ecosystem (e.g. a species being removed) can affect the whole community.
3) The diagram on the right shows part of a food web (a diagram of what eats what) from a stream.
4) If all the stonefly larvae die, then for example:
   - there would be less food for water boatmen, so their population might decrease.
   - the blackfly larvae would not have to compete with the stonefly larvae for food (algae) so their population might increase.



5) In stable communities, all the species and environmental factors are in balance. This means that the population sizes stay about the same.



Everybody needs good neighbours...

Lots of words to learn on this page — but if you do learn them, it'll make your life much easier in the exam.

Q1 Give three resources that plants compete for. [3 marks]

Q2 Look at the food web above. Suggest why the number of water boatmen might increase if all of the diving beetles died. [2 marks]

Q2 Video Solution

Abiotic and Biotic Factors

The environment in which organisms live changes all the time. The things that change are either abiotic (non-living) or biotic (living) factors. These changes can have a big effect on a community...

Abiotic Factors Can Change in an Ecosystem...

1) Abiotic factors are the non-living factors in an environment. For example:
   - Moisture level
   - Light intensity
   - Temperature
   - Carbon dioxide level (for plants)
   - Wind intensity and direction
   - Oxygen level (for animals that live in water)
   - Soil pH and mineral content
2) An increase or decrease in an abiotic factor is a change in the environment.
3) This can affect the size of populations in a community.
4) A change in an abiotic factor that affects one species could also affect the population sizes of other species that depend on them (see previous page). For example:
   - A decrease in the mineral content of the soil could affect the growth of a plant species.
   - This could cause a decrease in the population size of the plant species.
   - A decrease in the plant population could affect any animal species that depend on it for food.

...and So Can Biotic Factors

1) Biotic factors are the living factors in an environment.
2) A change in a biotic factor could affect the population size of some species. This could then affect species that depend on them (see previous page).
3) Biotic factors include:

1. Competition — one species may outcompete another so that numbers are too low to breed.
   - Red and grey squirrels live in the same habitat and eat the same food.
   - Grey squirrels outcompete the red squirrels for food and shelter.
   - So the population of red squirrels is decreasing.



'Outcompete' means they're better at getting the resources they need to survive.

2. New predators (animals that kill other animals)

   A new predator could cause a decrease in the prey population. There's more about predator-prey populations on p.86.

3. Availability of food

   If there is less food available, the population size will decrease.

4. New pathogens (microorganisms that cause disease)

   A new pathogen could quickly decrease the population of an affected species.

Exams — an abiotic factor affecting my environment...

It would be a good idea to learn these two lists of factors. I reckon this is a good time for you to shut the book, scribble them all down and then check how you did. It's the only way they'll get stuck in your brain.

Q1 Give four examples of abiotic factors that could affect a plant species. [4 marks]

Adaptations

Life exists in so many different environments. It's all because of the adaptations that organisms have...

Adaptations Allow Organisms to Survive

1) Organisms, including microorganisms, are adapted to survive in the conditions of their environment.
2) This means they have special features that suit their environment.
3) These features are called adaptations. Adaptations can be:

- Structural — these are features of an organism's body structure — such as shape or colour. For example:

Arctic animals (like the Arctic fox) have white fur so they can't be seen against the snow. This helps them avoid predators and sneak up on prey.



Animals that live in hot places (like camels) have a thin layer of fat and a large surface area compared to their volume. This helps them lose heat.



- Behavioural — these are ways that organisms behave.

E.g. many species (e.g. swallows) migrate (move away) to warmer climates during the winter. So they avoid the problems of living in cold conditions.

- Functional — these are things that go on inside an organism's body. They can be related to processes like metabolism (all the chemical reactions happening in the body).

E.g. desert animals make sure they don't lose too much water. They produce very little sweat and small amounts of concentrated urine (wee without much water in it).

Extremophiles Live in Extreme Places

Some microorganisms (e.g. bacteria) are extremophiles — they're adapted to live in extreme conditions. For example:

- at high temperatures (e.g. in super hot volcanic vents),
- in places with a high salt concentration (e.g. very salty lakes),
- at high pressure (e.g. in deep sea vents).



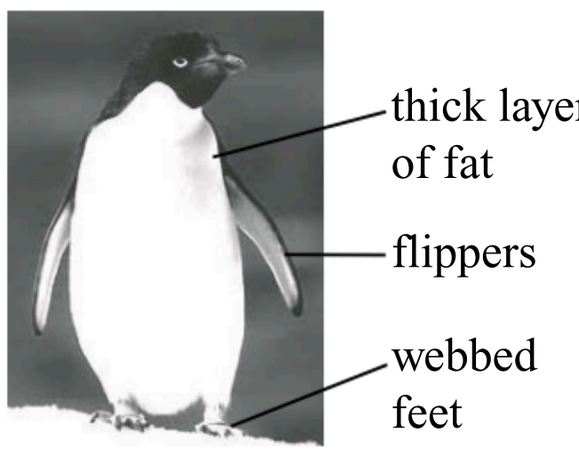
Now I know why my dad refuses to put the heating on...

It's not his fault he's so hairy. If you want to figure out how an organism is adapted to its environment, first think about the conditions it lives in (e.g. temperature). Then look at its features and think how they could be useful.

Q1 The diagram on the right shows a penguin. Some of its adaptations are labelled. Penguins live in the cold, icy environment of the Antarctic. They swim in the sea to hunt for fish to eat. Some penguins huddle together in groups to keep warm.

a) What type of adaptation is being described when penguins 'huddle together'? [1 mark]

b) Use the labels on the diagram to explain one way that the penguin is adapted to its environment. [2 marks]



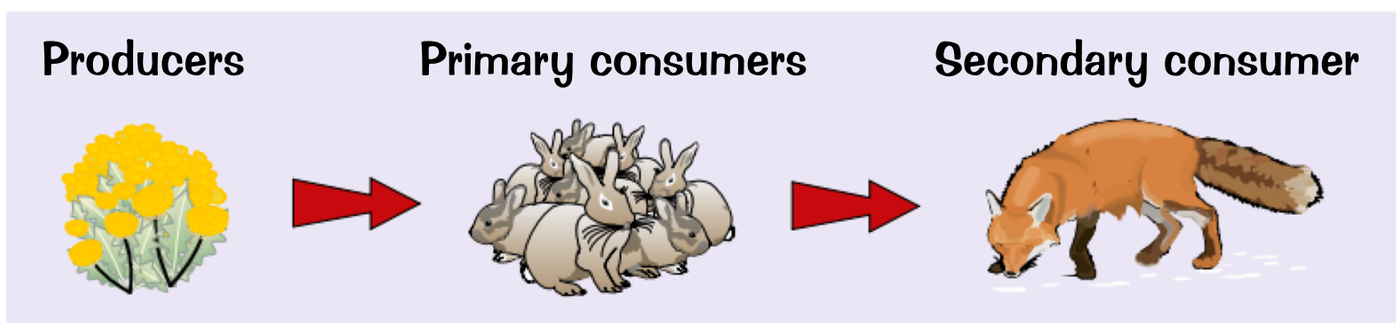
Q1 Video Solution

Food Chains

If you like food, and you like chains, then food chains might just blow your mind. Steady now, here we go...

Food Chains Show What's Eaten by What

1) Food chains always start with a producer.
Producers make (produce) their own food using energy from the Sun.
2) Producers are usually green plants or algae — they make glucose by photosynthesis (see page 50).
3) Some of this glucose is used to make the plant's biomass — its mass of living material.
4) Biomass is passed along a food chain when an organism eats another organism.
5) Consumers are organisms that eat other organisms:
   - Primary consumers eat producers.
   - Secondary consumers eat primary consumers.
   - Tertiary consumers eat secondary consumers.
6) Here's an example of a food chain:

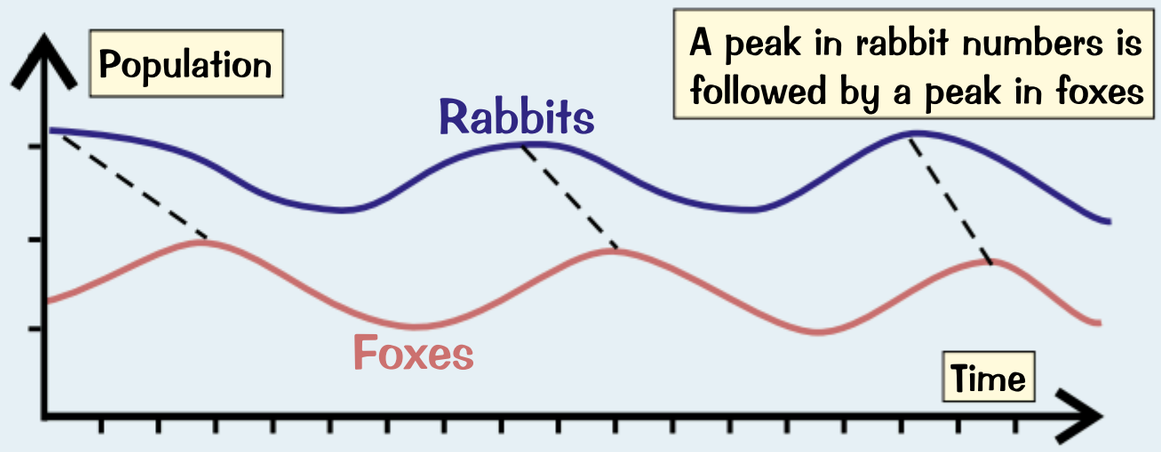


Populations of Prey and Predators Go in Cycles

1) Consumers that hunt and kill other animals are called predators. The animals they eat are called prey.
2) In a stable community, the population size of a species is limited by the amount of food it has.
So the population size of predators is affected by the number of their prey.

1) Foxes are predators. Rabbits are their prey.
2) If the number of rabbits increases, then the number of foxes will increase.
3) This is because there is more food for the foxes.
4) But as the number of foxes increases, then the number of rabbits will decrease.
5) This is because more rabbits will be eaten by the foxes.

For more about a stable community see page 83.



3) It takes a while for one population to respond to changes in the other one.
4) E.g. the number of foxes goes up after the number of rabbits goes up.
This is because it takes time for the foxes to reproduce.



When the TV volume goes up... my revision goes down...

You might think that the start of a food chain always has to be a plant. In most cases it is, but sometimes organisms like algae can be too because they photosynthesise. No wonder algae always looks smug...

Q1 Video Solution

Q1 Look at the following food chain for a particular area: grass → grasshopper → rat → snake

a) Name the producer in the food chain. [1 mark]
b) How many consumers are there in the food chain? [1 mark]
c) Name the primary consumer in the food chain. [1 mark]
d) All the rats in the area are killed.
Explain two effects that this could have on the food chain. [4 marks]

Using Quadrats

PRACTICAL

Studying ecology gives you the chance to rummage around in bushes and get your hands dirty. It's proper fun.

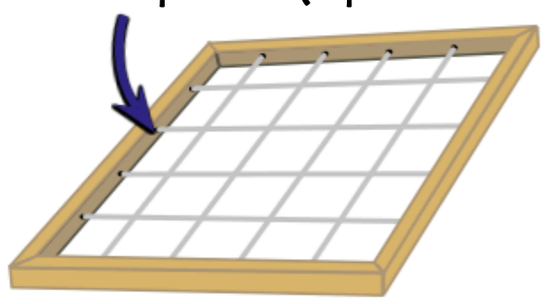
Organisms Live in Different Places Because The Environment Varies

1) The distribution of an organism is where an organism is found.
2) Where an organism is found is affected by biotic and abiotic factors (see page 84).
3) An organism might be more common in one area than another due to differences in factors between the two areas. For example, in a field, you might find daisies are more common in the open than under trees, because there's more light.
4) To study the distribution of an organism you can use quadrats or transects (p.88).

Use Quadrats to Study The Distribution of Small Organisms

Here's how to compare how common an organism is in two different areas — these are called sample areas.

A quadrat (square frame)



1) Place a quadrat on the ground in the first sample area. It needs to be placed at random (see p.240).
2) Count all the organisms you're interested in within the quadrat.
3) Repeat steps 1 and 2 as many times as you can.
4) Work out the mean number of organisms per quadrat within the first sample area.

EXAMPLE

Anna counted the number of daisies in 7 quadrats within her first sample area. She recorded the following results: 18, 20, 22, 23, 23, 23, 25

Here the MEAN is: $\frac{\text{TOTAL number of organisms}}{\text{NUMBER of quadrats}} = \frac{154}{7} = 22$ daisies per quadrat

5) Repeat steps 1 to 4 in the second sample area.
6) Finally compare the two means. E.g. you might find 2 daisies per quadrat in a shady area, and 22 daisies per quadrat (lots more) in a sunny area.

You Can Work Out the Population Size of an Organism

The population size of an organism is sometimes called its abundance.

EXAMPLE

Students used a quadrat with an area of 0.25 m^2 to randomly sample daisies in a field. They found a mean of 10 daisies per quadrat. The field's area was 800 m^2. Estimate the population of daisies in the field.

1) Divide the area of the habitat by the quadrat size. 800 ÷ 0.25 = 3200
2) Multiply this by the mean number of organisms per quadrat. 3200 × 10 = 32 000 daisies in the field

Drat, drat, and double drat — my favourite use of quadrats...

It's key that you make sure you put your quadrat down in a random place before you start counting.

Q1 A field was randomly sampled for tulips using a quadrat with an area of 0.25 m^2. The field had an area of 1200 m^2. A mean of 0.75 tulips was found per quadrat. Estimate the total population of tulips. [2 marks]

Q1 Video Solution

PRACTICAL

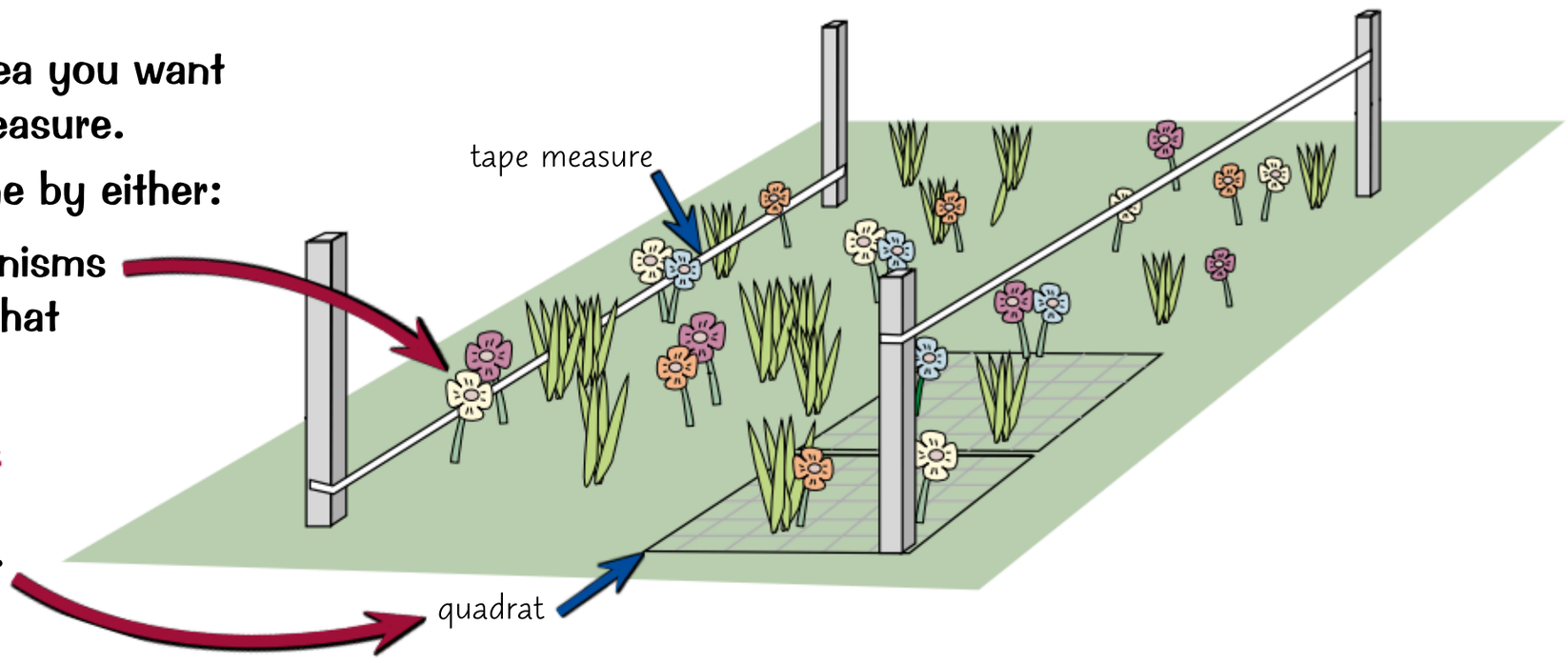
Using Transects

So, now you think you've learnt all about distribution. Well hold on — there's more ecology fun to be had.

Use Transects to Study The Distribution of Organisms Along a Line

You can use lines called transects to help find out how organisms are distributed across an area.
E.g. if an organism becomes more or less common as you move from a hedge towards the middle of a field.
Here's what to do:

1) Mark out a line in the area you want to study using a tape measure.
2) Collect data along the line by either:
   - Counting all the organisms you're interested in that touch the line.
   - Or by using quadrats (see previous page) placed along the line.



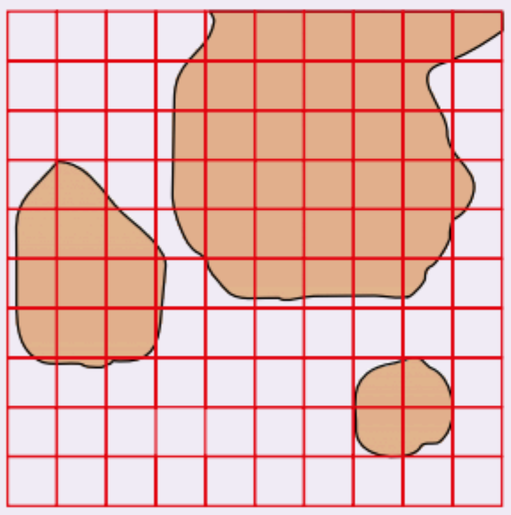
You Can Estimate the Percentage Cover of a Quadrat

1) Sometimes it can be difficult to count all of the organisms in a quadrat (e.g. if they're grass).
2) In this case, you can find the percentage cover instead.
3) This means estimating the percentage area of the quadrat that the organisms cover.
4) You can do this by counting the number of little squares they cover.

EXAMPLE

Some students were measuring the distribution of an organism across a school playing field. They placed quadrats at regular intervals along a transect. Below is a picture of one of the quadrats. Calculate the percentage cover of the organism in this quadrat.

One quadrat



Area covered by organism

1) Count the number of squares covered by the organism. You count a square if it's more than half covered.

   47 squares are covered by the organism.

2) Make this into a percentage:
   - Divide the number of squares covered by the organism by the total number of squares in the quadrat (100).

     (47/100) × 100

   - Multiply the result by 100.

     = 0.47 × 100 = 47%

A slug that's been run over — definitely a widely-spread organism

So if you want to measure the distribution of an organism across an area, you could use a transect. You can use it alone or you can use it with quadrats. Now who's for a game of tennis... I've got my transect up.

Q1 Some students want to measure how the distribution of dandelions changes across a field. Describe a method they could use to do this. [2 marks]

The Water Cycle

Without the water cycle, we wouldn't get enough water to survive.
And I don't just mean there'd be no paddling pools, ice lollies or bubble baths...

The Water Cycle Means Water is Constantly Recycled



1) Energy from the Sun makes water evaporate from the land and sea.
   This turns the water into water vapour.
2) Water also evaporates from plants — this is called transpiration (see p.39).
3) The warm water vapour is carried upwards.
   When it gets higher up, the water vapour cools. It condenses to form clouds.
4) Water falls from the clouds as precipitation (usually rain, but sometimes snow or hail).
   Precipitation provides fresh water for plants and animals:

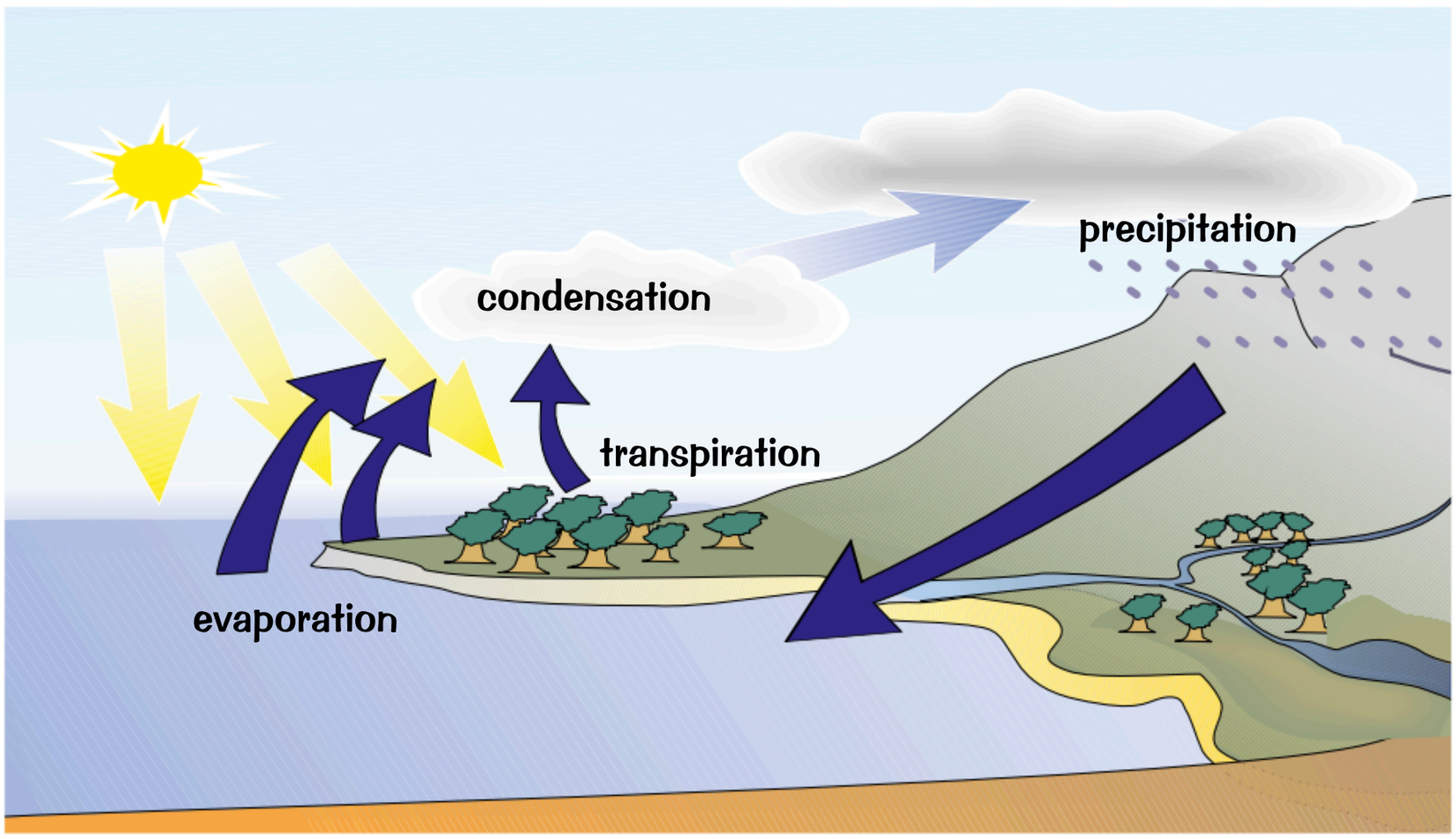
Plants

- Some water is absorbed by the soil. Plants take up the water through their roots.
- Plants need water for things like photosynthesis (p.50).
- Some water becomes part of the plants' tissues. It's passed to animals when plants are eaten.

Animals

- Animals need water for the chemical reactions in their bodies.
- They return water to the soil and atmosphere in their waste (e.g. sweat and urine).

5) Water that doesn't get absorbed by the soil will run off into streams and rivers.
6) The water drains back into the sea. Then it evaporates all over again.



Come on out, it's only a little water cycle, it won't hurt you...

The most important thing to remember is that it's a cycle — there's no beginning or end. Water that falls to the ground as rain will end up back as clouds again. Then fall again... then rise again... and so on.

Q1 a) In the water cycle, how does water move from the land into the air? [1 mark]
b) How does the water cycle benefit plants and animals? [1 mark]

The Carbon Cycle

All the nutrients in our environment get recycled — there's a balance between what goes in and what goes out.

Materials are Recycled by Decay

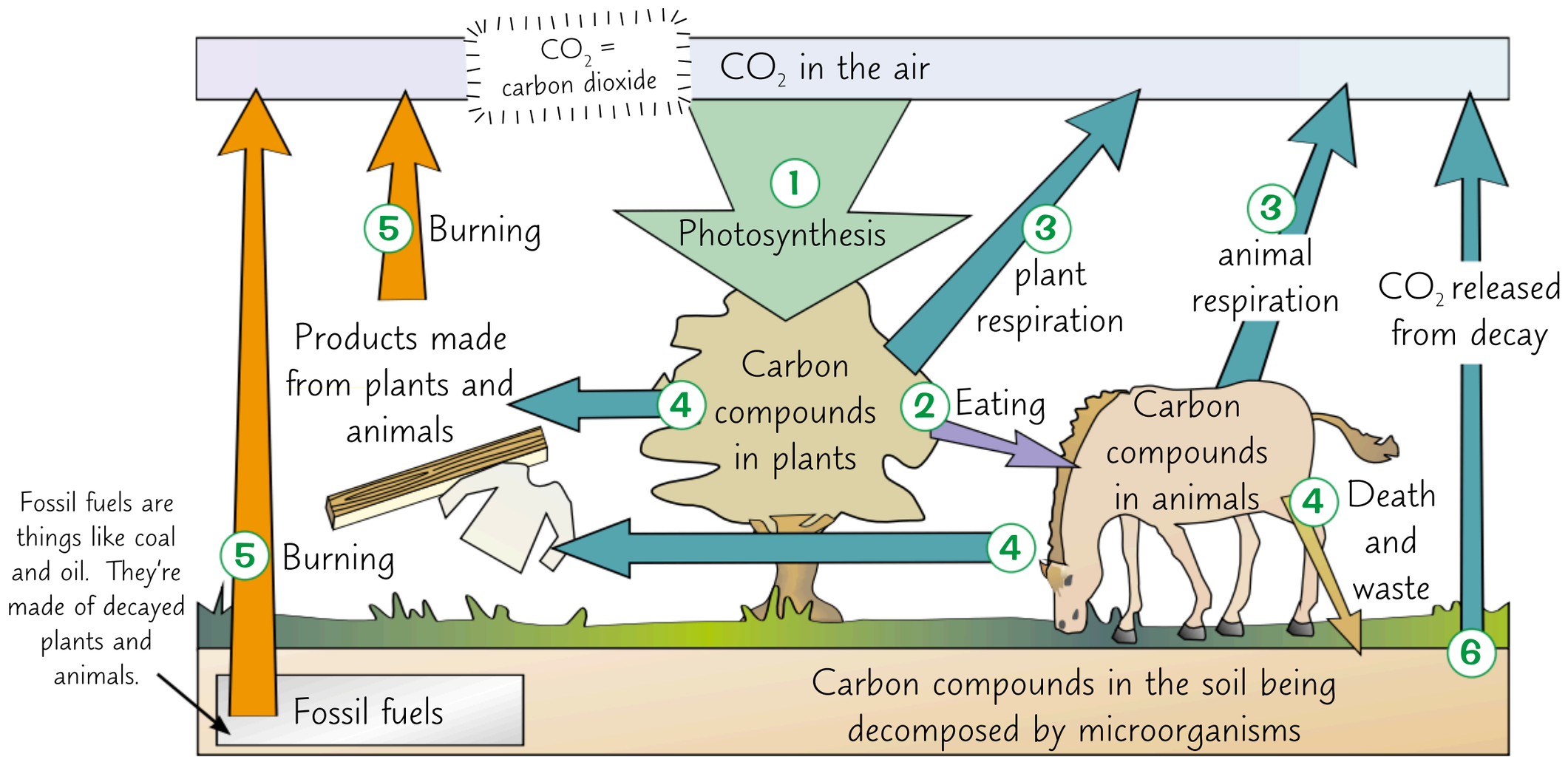


1) Living things are made of materials they take from the world around them.

E.g. plants take up mineral ions from the soil.
These are used to make molecules that make up the plant.
The molecules are passed up the food chain when the plant is eaten.

2) These materials are returned to the environment in waste products, or when dead organisms decay.
3) Materials decay because they're broken down by microorganisms.
4) Decay puts stuff that plants need to grow (e.g. mineral ions) back into the soil — they are recycled.

The Constant Cycling of Carbon is called the Carbon Cycle



1) Plants take in CO_2 from the air during photosynthesis. They use the carbon in CO_2 to make glucose. This glucose is used to make carbon compounds, e.g. carbohydrates. These are used for growth.
2) Eating passes the carbon compounds in plants along to animals in the food chain.
3) Both plant and animal respiration releases CO_2 back into the air.
4) Plants and animals eventually die, or are killed and turned into useful products.
5) Burning plant and animal products (and fossil fuels) releases CO_2 back into the air.
6) Microorganisms break down animal waste and dead organisms.
As they break down the material, they release CO_2 back into the air through respiration.

See p.53-54 for more on respiration.

What goes around comes around...

Carbon is very important for living things — it's the basis for loads of the molecules in our bodies.

Q1 What causes materials to decay? [1 mark]

Q2 Describe how carbon is removed from the atmosphere in the carbon cycle. [1 mark]

Biodiversity and Waste Management

Unfortunately, human activity can negatively affect the planet and its variety of life. Read on for bad news...

Earth's Biodiversity is Important

Biodiversity is the variety of different species of organisms on Earth, or within an ecosystem.

1) Different species depend on each other for different things in an ecosystem (see page 83).
2) Different species can also help keep the conditions in their environment right for each other, e.g. they can help keep the soil at the right pH.
3) So having a high biodiversity can mean that an ecosystem is more stable.
4) For the human species to survive, it's important that a good level of biodiversity is maintained.
5) Lots of human actions are reducing biodiversity (see below and pages 92-93).
6) It's only recently that we've started taking measures to stop biodiversity decreasing.

More People Means Greater Demands on the Environment



1) The population of the world is increasing very quickly.
2) More people need more resources to survive.
3) People are also demanding a higher standard of living.
   This means that more people want luxuries that make life more comfortable, e.g. cars, computers, etc.
4) This means that we use more raw materials and more energy to make things.
5) So resources are being used more quickly than they are being replaced.

We're Also Producing More Waste

1) As we make more things, we produce more waste. This includes waste chemicals.
2) This waste can cause harmful pollution if it's not handled properly.
3) Pollution kills plants and animals. This reduces biodiversity.
4) Pollution can affect:



1) Water
- Sewage and toxic chemicals from industry can pollute lakes, rivers and oceans.
- Fertilisers (and other chemicals) used on land can be washed into water.
- This will affect the plants and animals that rely on these sources of water for survival.

2) Land
- We use toxic chemicals for farming (e.g. pesticides and herbicides).
- We dump a lot of household waste in landfill sites.

3) Air
Smoke and acidic gases can pollute the air if they are released into the atmosphere.



More people = more mess...

Biodiversity's a useful thing, but some of the things that humans do means that it's being reduced every day.

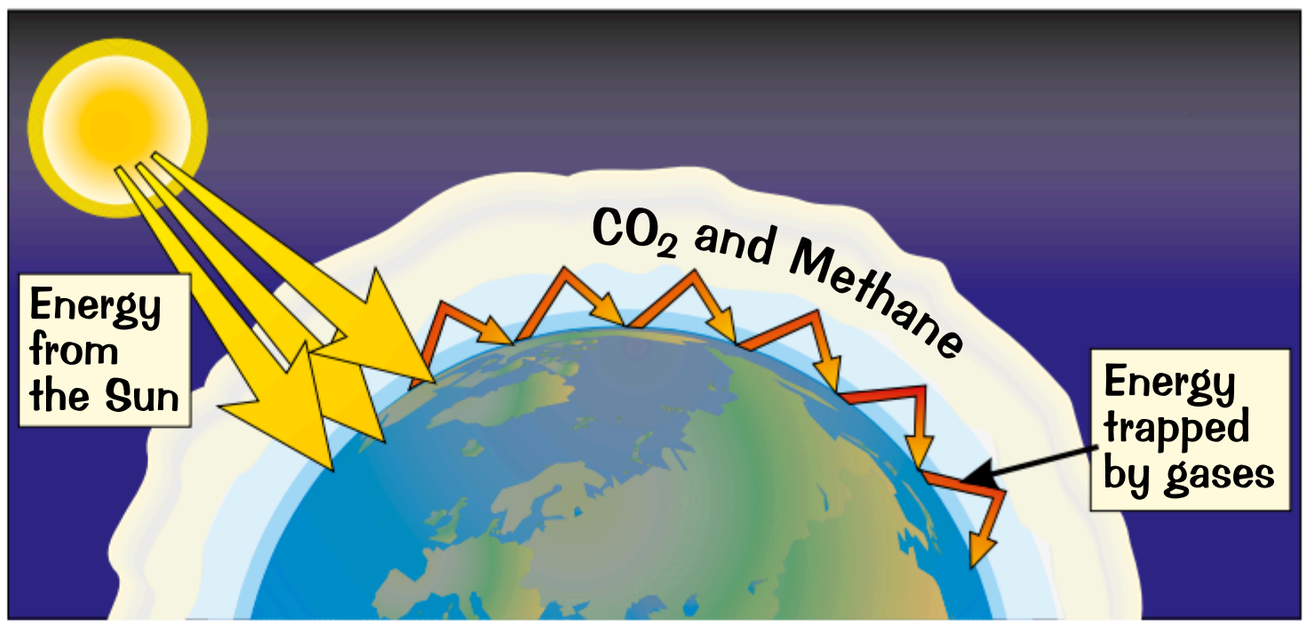
Q1 What is meant by the term 'biodiversity'? [1 mark]

Global Warming

The Earth is getting warmer. Scientists are studying what effects this is having...

Carbon Dioxide and Methane Trap Energy from the Sun

1) Gases in the Earth's atmosphere trap energy from the Sun.
2) These gases mean that not all of the energy is lost into space. This helps to keep the Earth warm.
3) These gases are called greenhouse gases. Without them the Earth would be very cold.
4) But the levels of two greenhouse gases are increasing — carbon dioxide (CO_2) and methane.



5) The increasing levels of greenhouse gases are causing the Earth to heat up — this is global warming.

The Results of Global Warming Could be Pretty Serious

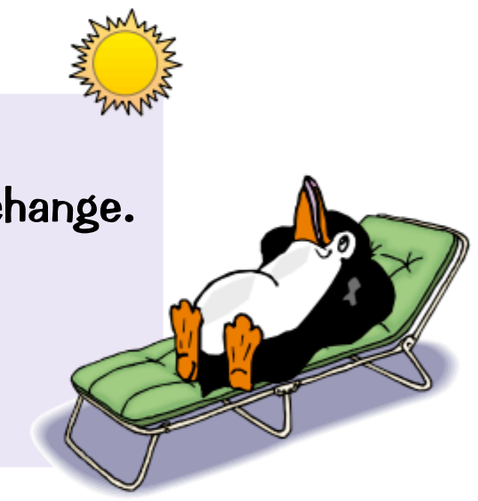
There are several reasons to be worried about global warming. Here are a few:

Flooding

1) Higher temperatures cause seawater to expand and ice to melt. This causes the sea level to rise.
2) Sea level rise leads to flooding of low-lying land.
3) This results in the loss of habitats (where organisms live).

Changes in the distribution of species

1) Global warming is causing changes in rainfall and temperature in many areas.
2) This is causing the distribution (spread) of many animal and plant species to change.
3) E.g. in areas that are becoming warmer:
   - Species that do well in warm conditions are spreading further.
   - Species that need cooler temperatures have a smaller area to live in.



Less biodiversity

1) Some species may not be able to survive a change in the climate.
2) These species might become extinct.
3) This could reduce biodiversity (see p.91).

Changes in migration patterns

1) There have been changes in migration patterns (where animals move to during different seasons).
2) E.g. some birds migrate further north, as more northern areas are getting warmer.

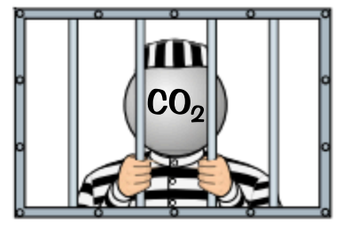
The greenhouse effect — when you start growing into a tomato...

Global warming is rarely out of the news. Most scientists accept that it's happening and that human activity has caused most of the recent warming. However, they don't know exactly what the effects will be.

Q1 Explain how global warming leads to the loss of low-lying habitats. [3 marks]

Deforestation and Land Use

Trees and peat bogs trap carbon dioxide and lock it up. The problems start when it escapes...



Humans Use Lots of Land for Lots of Purposes

1) We use land for things like building, quarrying, farming and dumping waste.
2) This means that there's less land available for other organisms.
3) Sometimes, the way we use land has a bad effect on the environment.

Deforestation Can Cause Many Problems



1) Deforestation is the cutting down of forests. It is done for many reasons, like:
   - To clear land for farming (e.g. cattle or rice crops) to provide more food.
   - To grow crops to make biofuels.
2) This causes big problems when it's done on a large-scale, e.g. cutting down rainforests in tropical areas. These are:

LESS CARBON DIOXIDE TAKEN IN

1) Trees take in carbon dioxide (CO_2) from the atmosphere during photosynthesis (page 50).
2) So cutting down trees means that less carbon dioxide is removed from the atmosphere.
3) Trees 'lock up' some of the carbon in their wood. Removing trees means that less is locked up.

MORE CARBON DIOXIDE RELEASED

1) Carbon dioxide is released when trees are burnt to clear land.
2) Microorganisms feeding on dead wood release carbon dioxide through respiration (p.54).

More CO_2 in the atmosphere causes global warming (see previous page).

LESS BIODIVERSITY

1) Habitats like forests can contain many species of plants and animals — they have high biodiversity.
2) When forests are destroyed, many species may become extinct (p.74). This reduces biodiversity.

Destroying Peat Bogs Adds More CO_2 to the Atmosphere

1) Bogs are areas of land that are acidic and waterlogged.
2) Plants that live in bogs don't fully decay when they die. The partly-rotted plants build up to form peat.
3) So the carbon in the plants is stored in the peat.
4) Peat bogs can be drained, so the peat can be sold to gardeners as compost.
5) When the peat is drained, microorganisms can break it down. They release CO_2 when they respire.
6) Peat can also be sold as a fuel. CO_2 is released when the peat is burned.
7) Destroying the bogs reduces the area of the habitat.
8) This reduces the number of animals, plants and microorganisms that live there. So it reduces biodiversity.

Don't get bogged down with all these problems...

Removing trees and peat bogs means more carbon dioxide, which means more global warming. Bad times.

Q1 Give two reasons for carrying out deforestation. [2 marks]

Maintaining Ecosystems and Biodiversity

It's really important that biodiversity is maintained...

Programmes Can be Set Up to Protect Ecosystems and Biodiversity

1) Human activities can reduce biodiversity and damage ecosystems.
2) In some areas, programmes to minimise the damage have been set up by concerned citizens and scientists.
3) Here are a few examples:

Breeding programmes

1) Animal species that are at risk of dying out are called endangered species.
2) They can be bred in captivity.
3) This makes sure some individuals will survive if the species dies out in the wild.
4) Individuals can sometimes be released into the wild. This can be to boost a population or replace one that's been wiped out.

Habitat protection

Protecting and regenerating (rebuilding) rare habitats helps to protect the species that live there.

Reintroducing hedgerows and field margins

1) Field margins are areas of land around the edges of fields where wild flowers and grasses are left to grow.
2) Hedges can be planted around fields to form hedgerows.
3) Hedgerows and field margins provide a habitat for lots of types of organisms.
4) This is very useful for fields that only have one type of crop. This is because these fields have very low biodiversity.



Recycling

1) This reduces the amount of waste that gets dumped in landfill sites.
2) This could reduce the amount of land taken over for landfill. So ecosystems can be left alone.

Government programmes

1) Deforestation increases the amount of carbon dioxide in the atmosphere (see previous page).
2) Some governments have made rules to reduce deforestation.
3) They have also made rules to reduce the amount of carbon dioxide released by businesses.
4) This could help to stop global warming increasing (see page 92).

If you go down to the woods today... there might be more bears than before.

Some people might not be keen on some of these programmes (e.g. people who are paid to cut down trees). You've got to learn all the examples above though, even if you don't like them. Sorry.

Q1 Explain how biodiversity can be increased in areas that farm single crops. [2 marks]

Q2 Describe how breeding programmes preserve endangered species. [2 marks]

Revision Questions for Topic B7

That's Topic B7 done with. I bet you're right in the mood for a long list of revision questions now. You're in luck.

- Try these questions and tick off each one when you get it right.
- When you're completely happy with a sub-topic, tick it off.

For even more practice, try the Retrieval Quiz for Topic B7 — just scan this QR code!

Topic B7 Quiz

Competition, Abiotic and Biotic Factors, and Adaptations (p.83-85) ☐

1) Define 'habitat'. ☐
2) What things do animals compete for in an ecosystem? ☐
3) What is meant by a 'stable community'? ☐
4) What are biotic factors? ☐
5) What are functional adaptations? ☐

Food Chains (p.86) ☐

6) What do food chains always start with? ☐
7) Explain what happens to the population size of a predator if the amount of its prey increases. ☐

Quadrats and Transects (p.87-88) ☐

8) Explain how a quadrat can be used to investigate the distribution of clover plants in two areas. ☐
9) Suggest why you might use a transect when investigating the distribution of organisms. ☐

The Water and Carbon Cycles (p.89-90) ☐

10) When water vapour cools and condenses in the atmosphere, what does it change into? ☐
11) How do microorganisms return carbon to the atmosphere? ☐

Human Impacts on the Planet (p.91-94) ☐

12) Suggest why it's important to have high biodiversity in an ecosystem. ☐
13) Name two gases linked to global warming. ☐
14) Give one way global warming could reduce biodiversity. ☐
15) Give two reasons why deforestation increases the amount of carbon dioxide in the atmosphere. ☐
16) Explain why the destruction of peat bogs adds more carbon dioxide to the atmosphere. ☐
17) How can recycling programmes help to protect ecosystems? ☐

Atoms

All substances are made of atoms. They're really tiny — too small to see. Atoms are so tiny that a 50p piece contains about 77 400 000 000 000 000 000 000 of them. Quite a lot then...

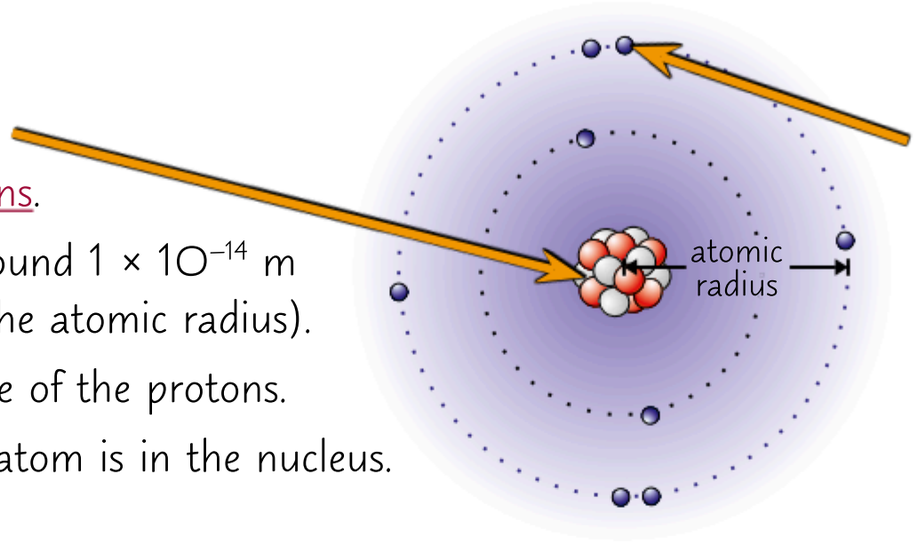
Atoms Contain Protons, Neutrons and Electrons

1) Atoms have a radius of about 0.1 nanometres (that's 1×10^{-10} m). There are a few different modern models of the atom — but chemists tend to like the model below best.

A nanometre (nm) is 0.000000001 m. Shown in standard form, that's 1×10^{-9} m. Standard form is used for showing really large or really small numbers.

Nucleus:

- It's in the middle of the atom.
- It contains protons and neutrons.
- The nucleus has a radius of around 1×10^{-14} m (that's around 1/10 000 of the atomic radius).
- It has a positive charge because of the protons.
- Almost the whole mass of the atom is in the nucleus.



Electrons:

- Move around the nucleus in electron shells (levels).
- They're negatively charged.
- Electrons have almost no mass.

2) You need to know the charges of protons, neutrons and electrons. You also need to know how heavy they are compared to each other (their relative masses).

3) Protons are heavy (compared to electrons) and positively charged.

4) Neutrons are heavy (compared to electrons) and neutral.

5) Electrons are tiny and negatively charged.

Particle	Relative Mass	Relative Charge
Proton	1	+1
Neutron	1	0
Electron	Very small	–1

Atomic Number and Mass Number Describe an Atom

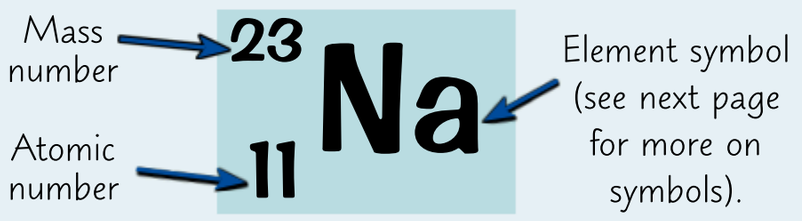
1) The nuclear symbol of an atom tells you its atomic (proton) number and mass number.

atomic number = number of protons

mass number = number of protons + number of neutrons

number of neutrons = mass number – atomic number

Nuclear symbol for sodium.



Number of protons = 11

Number of neutrons = 23 – 11 = 12

Number of electrons = 11

2) Atoms have no charge overall. They're neutral.

3) This is because they have the same number of protons as electrons. So, in an atom...

number of electrons = atomic number

4) The charge on the electrons is the same size as the charge on the protons, but opposite — so they cancel out.

5) In an ion, the number of protons doesn't equal the number of electrons. This means it has an overall charge. For example, an ion with a 2– charge, has two more electrons than protons.

An ion is an atom or group of atoms that has lost or gained electrons.

In a positive ion:

number of electrons = atomic number – charge

In a negative ion:

number of electrons = atomic number + charge

Let's be positive — unless you're an electron of course...

Atoms may be tiny, and the things inside them even smaller, but this stuff is still super important.

Q1 An atom of gallium has an atomic number of 31 and a mass number of 70. Give the number of electrons, protons and neutrons in the atom. [3 marks]

Q1 Video Solution

Elements

An element is a substance made up of atoms that all have the same number of protons in their nucleus.

Elements are Made Up of Atoms With the Same Atomic Number

1) The smallest part of an element that you can have is a single atom of that element.
2) The number of protons in the nucleus decides what type of atom it is.
3) For example, an atom with one proton in its nucleus is hydrogen. An atom with two protons is helium.
4) If a substance only contains atoms with the same number of protons it's called an element.
5) So all the atoms of a particular element have the same number of protons.
And different elements have atoms with different numbers of protons.

There are about 100 different elements

Atoms Can be Represented by Symbols

1) Atoms of each element can be represented by a one or two letter symbol.
2) You'll see these symbols on the periodic table (see page 107).
3) For example: C = carbon O = oxygen Na = sodium Mg = magnesium Fe = iron

Isotopes are the Same Except for Extra Neutrons

1) Isotopes are atoms with the same number of protons but a different number of neutrons.
2) So they have the same atomic number but different mass numbers.

Carbon-12 and carbon-13 are isotopes of carbon.

Carbon-12	$^{12}_{6}C$	6 Protons 6 Electrons 6 Neutrons	Carbon-13	$^{13}_{6}C$	6 Protons 6 Electrons 7 Neutrons

The number of neutrons is the mass number minus the atomic number.

3) If an element has a number of isotopes, you can describe it using relative atomic mass (A_r) instead of mass number. This is an average mass.
4) A_r is worked out from the different masses and abundances (amounts) of each isotope.
5) You can use this formula to work out the relative atomic mass of an element:



You can work out the 'sum of' two or more amounts by adding them together.

$$\text{relative atomic mass } (A_r) = \frac{\text{sum of (isotope abundance} \times \text{isotope mass number)}}{\text{sum of abundances of all the isotopes}}$$

EXAMPLE

Copper has two stable isotopes. Cu-63 has an abundance of 69.2% and Cu-65 has an abundance of 30.8%. Calculate the relative atomic mass of copper to 1 decimal place.

abundance × mass number of Cu-63 — abundance × mass number of Cu-65

$$\text{Relative atomic mass} = \frac{(69.2 \times 63) + (30.8 \times 65)}{69.2 + 30.8} = \frac{4359.6 + 2002}{100} = \frac{6361.6}{100} = 63.616 = 63.6$$

abundance of Cu-63 + abundance of Cu-65

Ah — the symbol for the element of surprise...

Atoms, elements and isotopes — make sure you know what they are and the differences between them.

Q1 What are isotopes? [1 mark]

Q2 Silicon, Si, has three stable isotopes. Si-28 has an abundance of 92.2%, Si-29 has an abundance of 4.7% and Si-30 has an abundance of 3.1%. Calculate silicon's relative atomic mass to 1 decimal place. [2 marks]

Q2 Video Solution

Compounds

It would be great if we only had to deal with elements. But unluckily for you, elements can mix and match to make lots of new substances called compounds. And this makes things a little bit more complicated...

Atoms Join Together to Make Compounds

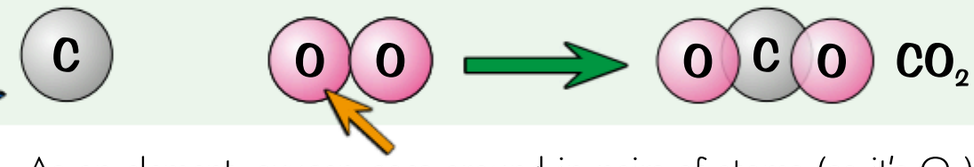
1) During a chemical reaction, at least one new substance is made.
You can usually measure a change in energy such as a temperature change, as well.
2) When two or more elements react, they form compounds.
Compounds are substances that contain atoms of different elements.
3) The atoms of each element are in fixed proportions (amounts) in the compound.
4) The atoms are held together by chemical bonds.
5) The only way to separate a compound into its elements is by using a chemical reaction.

There are different types of compound. For example, ionic compounds (see p.115) and covalent compounds (see p.117).

A Formula Shows What Atoms are in a Compound

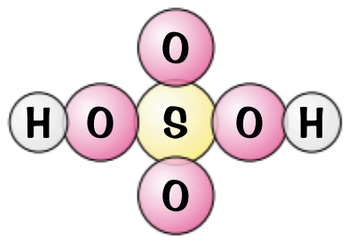
1) Compounds can be represented by formulas.
2) The formulas are made up of element symbols in the same proportions as the elements in the compound.
3) The number of different element symbols tells you how many elements are in the compound.
4) For example, carbon dioxide, CO_2, is a compound made from a reaction between carbon and oxygen.
5) It contains 1 carbon atom and 2 oxygen atoms.

carbon + oxygen → carbon dioxide



As an element, oxygen goes around in pairs of atoms (so it's O_2).

6) Here's another example: the formula of sulfuric acid is H_2SO_4.
So, each molecule contains 2 hydrogen atoms, 1 sulfur atom and 4 oxygen atoms.



7) There might be brackets in a formula, e.g. calcium hydroxide is $Ca(OH)_2$.
8) The little number 2 outside the bracket means there's two of everything inside the brackets.
9) So in $Ca(OH)_2$ there's 1 calcium atom, 2 oxygen atoms and 2 hydrogen atoms.

10) Here are some examples of formulas which might come in handy:

Carbon dioxide — CO_2	Sodium chloride — $NaCl$	Calcium chloride — $CaCl_2$
Ammonia — NH_3	Carbon monoxide — CO	Sodium carbonate — Na_2CO_3
Water — H_2O	Hydrochloric acid — HCl	Sulfuric acid — H_2SO_4

The formula for success — revision, more revision and cake...

Formulas are super important for showing chemical reactions. Make sure you understand how they work — you'll be coming across them quite a bit in the rest of this book.

Q1 How many atoms are in one particle of Na_2CO_3? [1 mark]

Q2 A compound has the formula $Al_2(SO_4)_3$. Name the elements and state how many atoms of each element are represented in its formula. [1 mark]

Q2 Video Solution

Chemical Equations

Chemical equations are really important to chemistry. Pretty much like tomato ketchup is to a bacon butty. Mmm... bacon butties... Sorry, I got distracted. Let's do this.

Chemical Reactions are Shown Using Chemical Equations

1) One way to show a chemical reaction is to write a word equation.
2) Word equations show the names of the chemicals that are reacting and being produced.

Here's an example — methane reacts with oxygen to make carbon dioxide and water:

The chemicals on the left-hand side of the equation are called the reactants (because they react with each other).

methane + oxygen → carbon dioxide + water

The chemicals on the right-hand side are called the products (because they've been produced from the reactants).

Symbol Equations Show the Atoms on Both Sides

1) Chemical reactions can be shown using symbol equations.
2) Symbol equations just show the symbols or formulas of the reactants and products.

magnesium + oxygen → magnesium oxide

$2Mg + O_2 \rightarrow 2MgO$

You'll have spotted that there's a '2' in front of the Mg and the MgO. The reason for this is explained below...

Symbol Equations Need to be Balanced

1) There must always be the same number of atoms on both sides — they can't just disappear.
2) You balance the equation by putting numbers in front of the formulas.
Take this equation for reacting sulfuric acid with sodium hydroxide:

$H_2SO_4 + NaOH \rightarrow Na_2SO_4 + H_2O$

Left-hand side	Right-hand side
H = 3	H = 2
S = 1	S = 1
O = 5	O = 5
Na = 1	Na = 2

3) The formulas are all correct but the numbers of some atoms don't match up on both sides.
4) The more you practise, the quicker you get, but all you do is this:

1) Find an element that doesn't balance and pencil in a number in front of one of the substances to try and sort it out.
2) See where it gets you. The equation may still not be balanced. Don't worry, just pencil in another number and see where that gets you.
3) Keep doing this until the equation is completely balanced.

You can't change formulas like H_2SO_4 to H_2SO_5. You can only put numbers in front of them.

EXAMPLE

In the equation above you'll notice we're short of Na atoms on the LHS (Left-Hand Side).

1) The only thing you can do about that is make it 2NaOH instead of just NaOH:

$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + H_2O$

2) But that now gives too many H atoms and O atoms on the LHS.
So to balance that up you could try putting $2H_2O$ on the RHS (Right-Hand Side):

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

LHS	RHS
H = 4	H = 2
S = 1	S = 1
O = 6	O = 5
Na = 2	Na = 2

3) And suddenly there it is — everything balances. Woohoo.

Revision is all about getting the balance right...

Balancing equations is all about practice. Once you have a few goes you'll see it isn't that scary really.

Q1 Balance the equation: $Fe + Cl_2 \rightarrow FeCl_3$ [1 mark]

Q2 Hydrogen and oxygen molecules are formed in a reaction where water splits apart.
For this reaction: a) State the word equation. b) Give a balanced symbol equation. [3 marks]

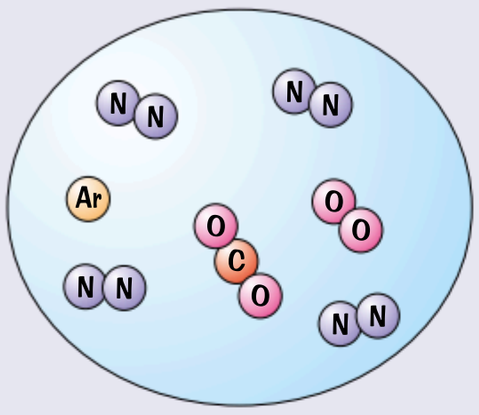
Q2 Video Solution

Mixtures

Mixtures in chemistry are just like mixtures in baking, lots of separate things all mixed together. But most of the time they're considerably less delicious. And you probably shouldn't eat them. Or put them in an oven.

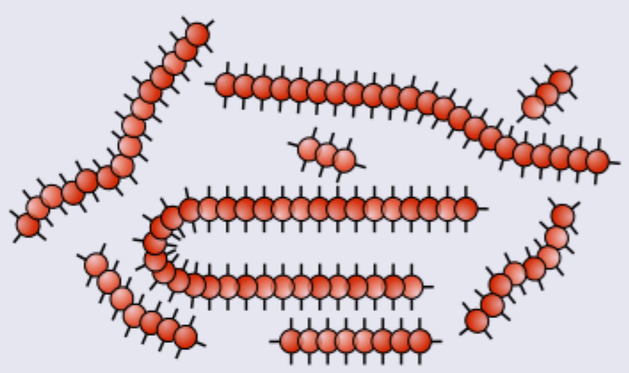
Mixtures are Easily Separated — Not Like Compounds

1) Mixtures contain at least two different elements or compounds.
2) There aren't any chemical bonds between the different parts of a mixture.



Air is a mixture of gases, mainly nitrogen, oxygen, carbon dioxide and argon.
The gases can all be separated out fairly easily.

Crude oil is a mixture of different length hydrocarbon molecules (see p.147).



3) The different parts of a mixture can be separated out by methods such as:
   - filtration (p.102)
   - crystallisation (p.102)
   - simple distillation (p.103)
   - fractional distillation (p.103)
   - chromatography (p.101)

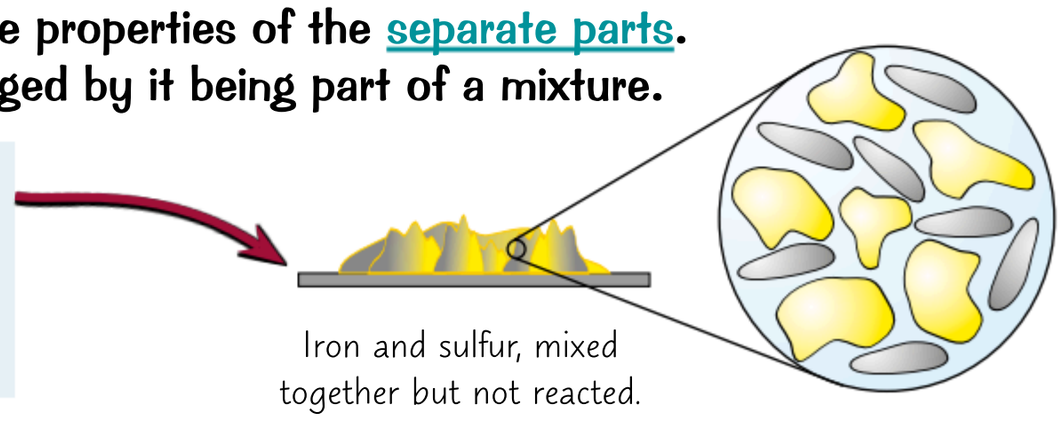


4) The methods are all physical methods.
   This means they don't involve any chemical reactions, and don't form any new substances.

Each Part of a Mixture Keeps Its Own Properties

1) Properties describe what a substance is like and how it behaves, such as hardness or boiling point.
2) The properties of a mixture are just a mixture of the properties of the separate parts.
   The chemical properties of a substance aren't changed by it being part of a mixture.

For example, a mixture of iron powder and sulfur powder will show the properties of both iron and sulfur. It will contain grey magnetic bits of iron and bright yellow bits of sulfur.



Revision and fun are a mixture — easily separated...

Think of mixtures like Pick 'n' Mix sweets. If you add a fizzy cola bottle to your bag of jelly snakes, fried eggs and chocolate mice, it stays as a fizzy cola bottle. You don't get a fizzy, fried jelly mouse or a chocolate cola snake egg.

Q1 Give two methods that can be used to separate mixtures. [2 marks]

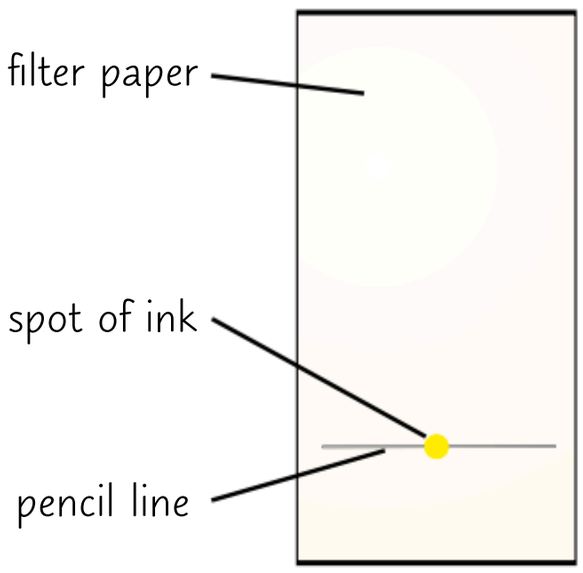
Chromatography

PRACTICAL

Ahh, chromatography. Chemistry mixed with pretty patterns of spots — what more could you want in a page...

You Need to Know How to Do Paper Chromatography

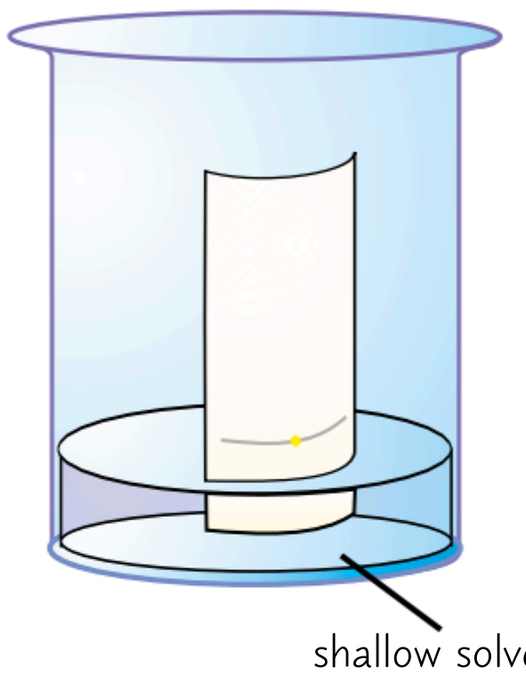
One method of separating substances in a mixture is chromatography.
Chromatography can be used to separate different dyes in an ink. Here's how you can do it:



1) Draw a line near the bottom of a sheet of filter paper. (Use a pencil to do this — pencil marks won't dissolve in the solvent.)
2) Add a spot of the ink to the line.

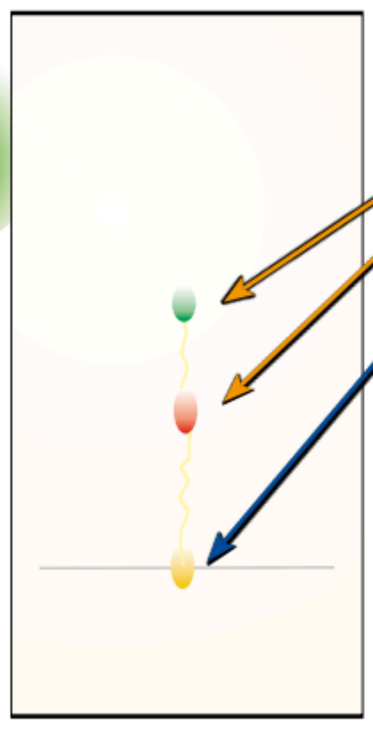
A solvent is a liquid which dissolves another substance.

3) Pour a small amount of solvent into a beaker so it forms a shallow layer.
4) The solvent used depends on what's being tested. Some compounds dissolve well in water, but sometimes other solvents, like ethanol, are needed.
5) Place the sheet in the beaker of solvent. Make sure the ink isn't touching the solvent — you don't want it to dissolve into it.
6) Place a lid on top of the container to stop the solvent evaporating.
7) The solvent seeps up the paper, carrying the ink with it.
8) When the solvent has nearly reached the top of the paper, take the paper out of the beaker and leave it to dry.
9) The end result is a pattern of spots called a chromatogram.



The point the solvent has reached as it moves up the paper is the solvent front.

Chromatography Separates the Parts of a Mixture Into Different Spots



1) During chromatography, each different dye in the ink moves up the paper at a different speed. This separates the dyes.
2) Each dye will form a spot in a different place. So there should be 1 spot for each dye in the ink.
3) If any of the dyes in the ink don't dissolve in the solvent, they'll stay on the pencil line.

All hairdressers have to master Combatography...

Chromatography is actually mighty useful in real life. It's used to test whether athletes have taken drugs. It can also be used to test things from crime scenes. Eeek...

Q1 Give one reason why a dye might stay on the pencil line during chromatography. [1 mark]

PRACTICAL

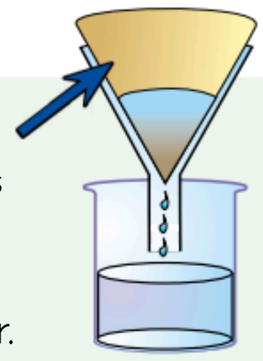
More Separation Techniques

Filtration and crystallisation are methods of separating mixtures. Chemists use these methods all the time to separate solids from liquids, so it's worth making sure you know how to do them.

Filtration Separates Insoluble Solids from Liquids

Filtration can be used to separate an insoluble solid from a liquid reaction mixture (insoluble solids can't be dissolved in the liquid). This can help make substances pure.

1) Put some filter paper in a funnel.
2) Pour the mixture into the filter paper.
3) Make sure the mixture doesn't go above the filter paper.
4) The liquid passes through the paper into the beaker. The solid is left behind in the filter paper.



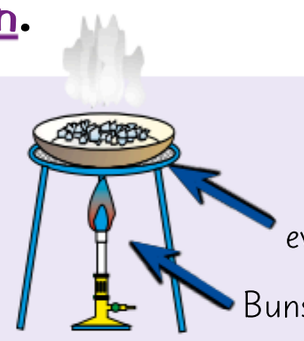
Filter paper folded into a cone shape — the solid is left in the filter paper.

Two Ways to Separate Soluble Solids from Solutions

If a solid can be dissolved we say it's soluble. There are two methods you can use to separate a soluble salt from a solution — evaporation and crystallisation.

Evaporation

1) Slowly heat the solution in an evaporating dish. The solvent will evaporate.
2) Eventually, crystals will start to form.
3) Keep heating until all you have left are dry crystals.



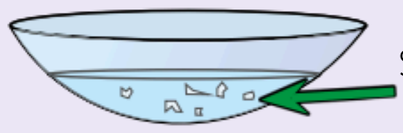
You could also use a water bath, or an electric heater.

Evaporation is a really quick way of separating a soluble salt from a solution. But, you can only use it if the salt doesn't break down when it's heated. Otherwise, you'll have to use crystallisation.

Crystallisation

1) Gently heat the solution in an evaporating dish. Some of the solvent will evaporate.
2) Once some of the solvent has evaporated, or when you see crystals start to form, stop heating. Leave the solution to cool.
3) The salt should start to form crystals.
4) Filter the crystals out of the solution. Leave them in a warm place to dry.

You should also use crystallisation if you want to make nice big crystals of your salt.



Salt crystallising out of solution.

Filtration and Crystallisation can be Used to Separate Rock Salt

1) **Rock salt is a mixture of salt and sand. Salt dissolves in water and sand doesn't.**
2) **This difference in physical properties means we can separate them. Here's what to do...**

1) Grind the mixture to make sure the salt crystals are small, so will dissolve easily.
2) Put the mixture in water and stir. The salt will dissolve, but the sand won't.
3) Filter the mixture. The grains of sand won't fit through the tiny holes in the filter paper, so they collect on the paper instead. The salt passes through the filter paper as it's part of the solution.
4) Use evaporation or crystallisation so that you end up with dry crystals of the salt.

You can heat the mixture to help dissolve the salt.

Revise mixtures — just filter out the important bits...

That's almost all the pages on separating mixtures done, phew... But before you dash on to the next page (I know, it's just so exciting), make sure you know this page to a T. Talking about Tea, I need a cuppa...

Q1 Describe how you could use crystallisation to separate a soluble salt from a solution. [4 marks]

Distillation

Distillation is used to separate mixtures which contain liquids.
There are two types that you should know about — simple and fractional.

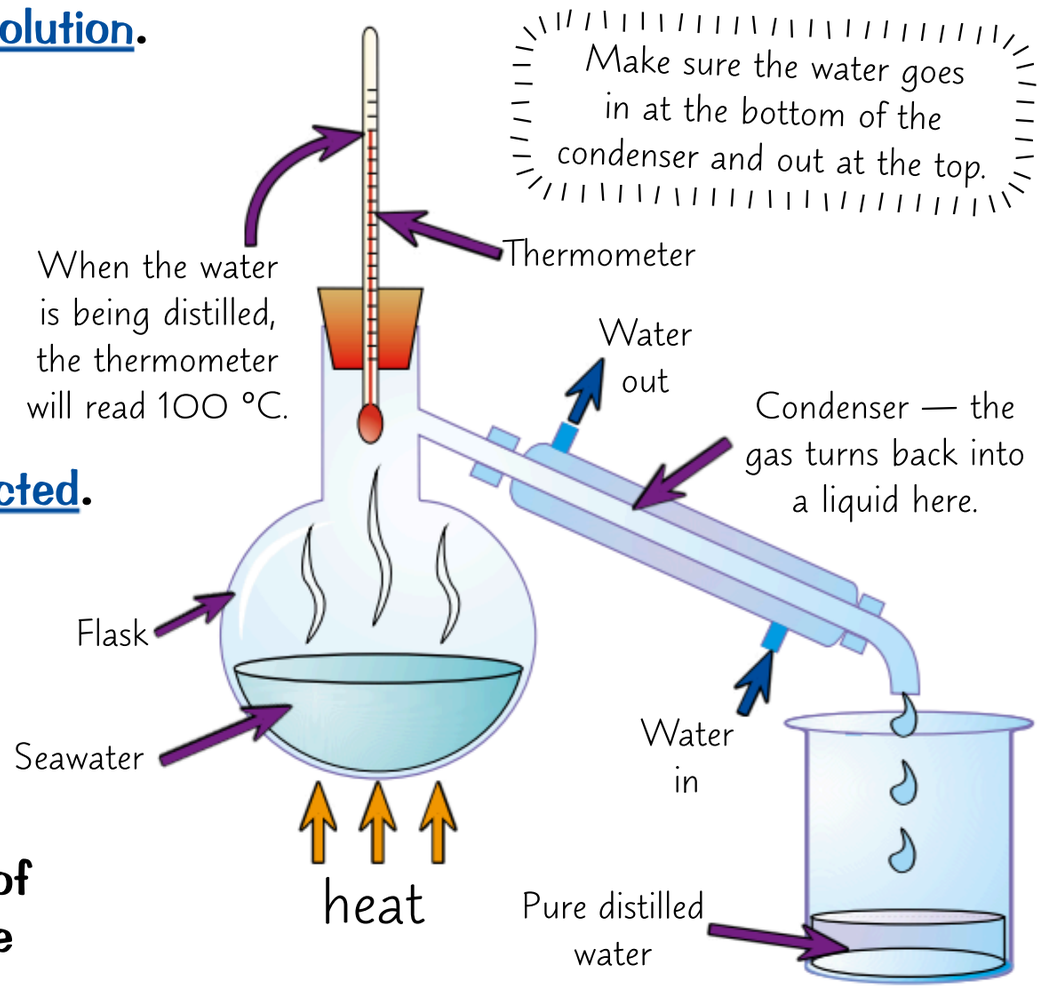
Simple Distillation is Used to Separate Solutions

PRACTICAL

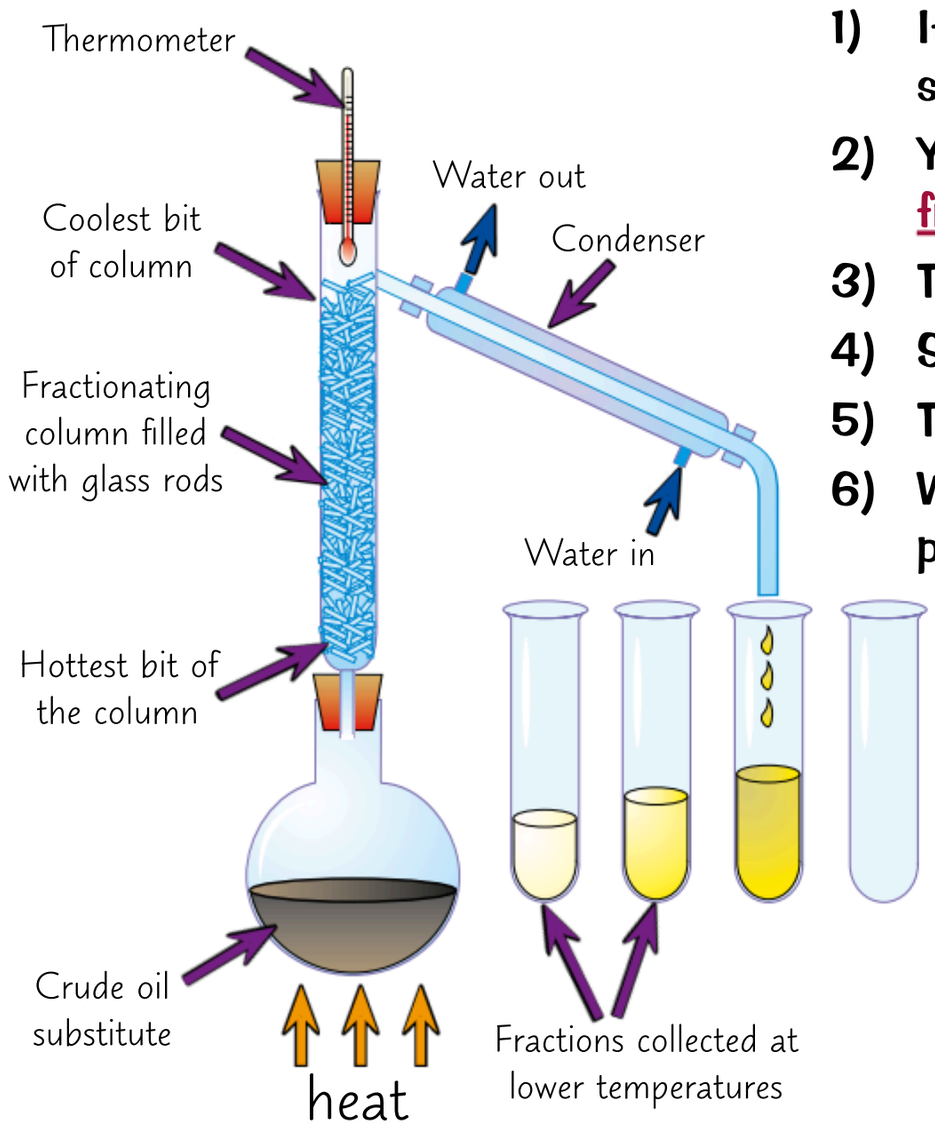
1) Simple distillation is used to separate a liquid from a solution.
2) First, the solution is heated.
3) The part of the solution that has the lowest boiling point evaporates first and turns into a gas.
4) The gas travels into the condenser.
5) In the condenser, the gas is cooled and condenses (turns back into a liquid).
6) The liquid drips out of the condenser and can be collected.
7) The rest of the solution is left behind in the flask.

> You can use simple distillation to get pure water from seawater. The water evaporates. It is then condensed and collected. This leaves the salt behind in the flask.

8) Simple distillation can't be used to separate mixtures of liquids with similar boiling points. So, you need to use another method instead — like fractional distillation...



Fractional Distillation is Used to Separate a Mixture of Liquids



1) If you've got a mixture of liquids you can separate it using fractional distillation.
2) You put your mixture in a flask and stick a fractionating column on top. Then you heat it.
3) The different liquids will have different boiling points.
4) So, they will evaporate at different temperatures.
5) The substance with the lowest boiling point evaporates first.
6) When the temperature on the thermometer matches the boiling point of this substance, it will reach the top of the column.
7) The substance will then enter the condenser, where it cools and condenses.
8) You can collect the liquid as it drips out of the condenser.
9) When the first liquid has been collected, you raise the temperature until the next one reaches the top.

> This experiment can be used to show how fractional distillation of crude oil at a refinery works (see p.148).

Fractionating — sounds a bit too much like maths to me...

You made it to the end of separation techniques. Congratulations. Now all you need to do is learn these techniques. Shouldn't be too tricky. Make sure you scribble all this stuff down — you'd be crazy not to.

Q1 Propan-1-ol, methanol and ethanol have boiling points of 97 °C, 65 °C and 78 °C respectively. A student uses fractional distillation to separate a mixture of these compounds. State which liquid will be collected in the second fraction and explain why. [2 marks]

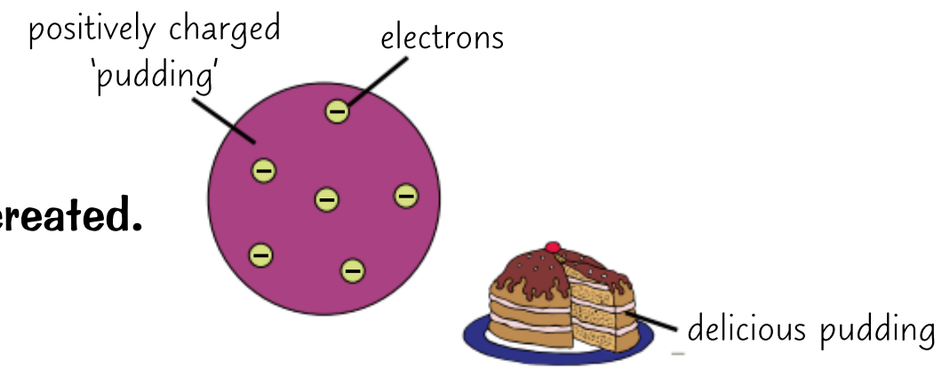
Q1 Video Solution

The History of the Atom

You might have thought you were done with the atom after page 96. Unfortunately pal, you don't get away that easily — there's more you need to learn. Hold on to your hat, you're going on a journey through time...

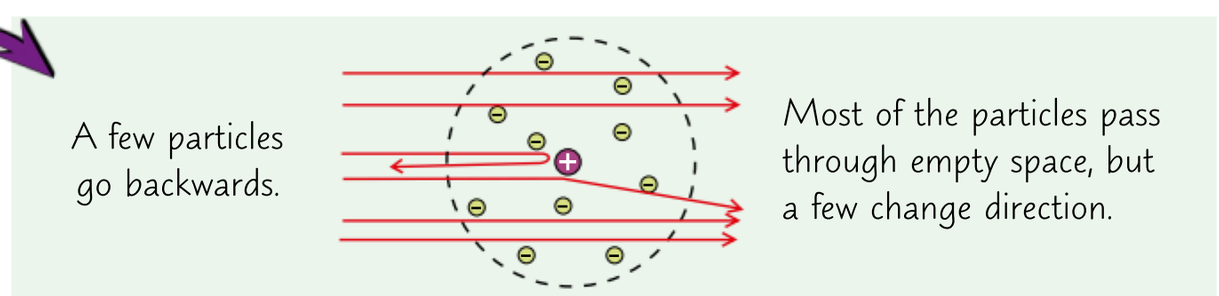
Ideas About What Atoms Look Like Have Changed Over Time

1) Scientists used to think that atoms were solid spheres.
2) They then found atoms contain even smaller, negatively charged particles — electrons.
3) This led to a model called the 'plum pudding model' being created.
4) The plum pudding model showed the atom as a ball of positive charge with electrons scattered in this ball.



Experiments Showed that the Plum Pudding Model Was Wrong

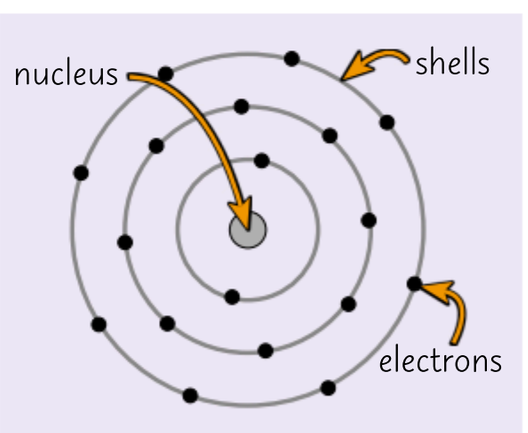
1) Later, scientists carried out alpha particle scattering experiments. They fired positively charged alpha particles at a very thin sheet of gold.
2) From the plum pudding model, they expected most of the particles to go straight through the sheet. They predicted that a few particles would change direction by a small amount.
3) But instead, some particles changed direction more than expected. A small number even went backwards.
4) This meant the plum pudding model couldn't be right.
5) So, scientists came up with the nuclear model of the atom:



- There's a tiny, positively charged nucleus at the centre of the atom.
- Most of the mass is in the nucleus.
- The nucleus is surrounded by a 'cloud' of negative electrons.
- Most of the atom is empty space.

Bohr's Nuclear Model Explains a Lot

1) Niels Bohr changed the nuclear model of the atom.
2) He suggested that the electrons orbit (go around) the nucleus in shells (levels).
3) Each shell is a fixed distance from the nucleus.
4) Bohr's theory was supported by many experiments. Experiments later showed that Bohr's theory was correct.



Later Experiments Found Protons and Neutrons

1) More experiments by scientists showed that the nucleus can be divided into smaller particles. Each particle has the same positive charge. These particles were named protons.
2) Experiments by James Chadwick showed that the nucleus also contained neutral particles — neutrons. This happened about 20 years after scientists agreed that atoms have nuclei.
3) This led to a model of the atom which was pretty close to the one we have today (see page 96).

I wanted to be a model — but I ate too much plum pudding...

In science, other people's work is always being built upon. So we keep learning more about a topic.

Q1 Describe the 'plum pudding' model of the atom. [1 mark]

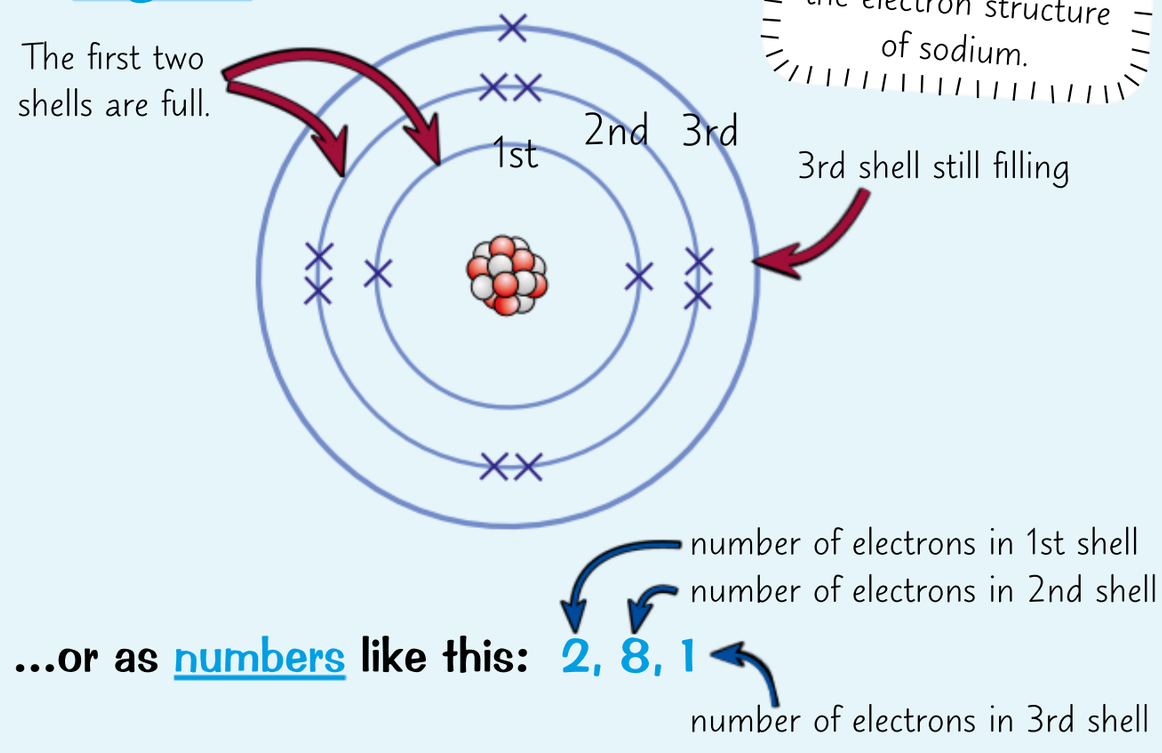
Electronic Structure

Electrons don't just float around the nucleus randomly. They move in areas called shells.
Just don't confuse these with the shells of snails and turtles...

Electron Shell Rules:

1) Electrons always move in shells (sometimes called energy levels).
2) The inner shells are always filled up first. These are the ones closest to the nucleus.
3) Only a certain number of electrons are allowed in each shell:
   1st shell: 2 2nd shell: 8 3rd shell: 8
4) Atoms are a lot more stable when they have full electron shells.
5) In most atoms, the outer shell is not full. These atoms will react to fill it.

Electron structures can be shown as diagrams like this...



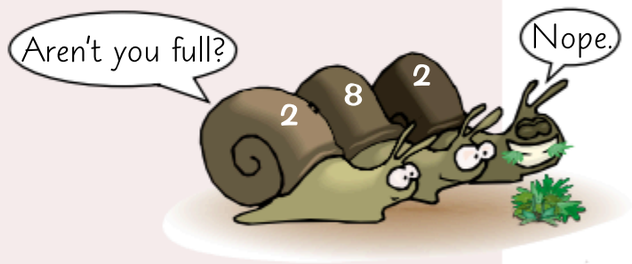
Follow the Rules to Work Out Electronic Structures

You can easily work out the electronic structures for the first 20 elements of the periodic table (things get a bit more complicated after that).

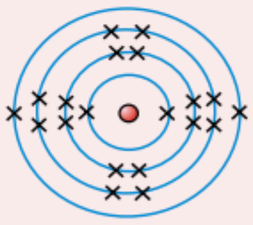
EXAMPLE

What is the electronic structure of magnesium?

1) From the periodic table, you can see that magnesium's atomic number is 12. This means it has 12 protons. So it must have 12 electrons.
2) Follow the 'Electron Shell Rules' above. The first shell can only take 2 electrons. — 2...
3) The second shell can take up to 8 electrons. — 2, 8...
4) So far we have a total of 10 electrons (2 + 8). So the third shell must also be partly filled with 2 electrons. This makes 12 electrons in total (2 + 8 + 2). — So the electronic structure for magnesium must be 2, 8, 2.



Here are some more examples of electronic structures:

H Hydrogen	**He** Helium	**Li** Lithium	**C** Carbon	**Ne** Neon	**Ca** Calcium
					
1	2	2,1	2,4	2,8	2,8,8,2
Atomic no. = 1	Atomic no. = 2	Atomic no. = 3	Atomic no. = 6	Atomic no. = 10	Atomic no. = 20

The electronic structure of the fifth element — it's a bit boron...

Electronic structures may seem a bit complicated at first but once you learn the rules, it's a piece of cake. And just like cake, you'll never regret going back for some more. Better get practising.

Q1 How many electrons are allowed in the first electron shell of an atom? [1 mark]

Q2 Give the electronic structure of argon (atomic number = 18). [1 mark]

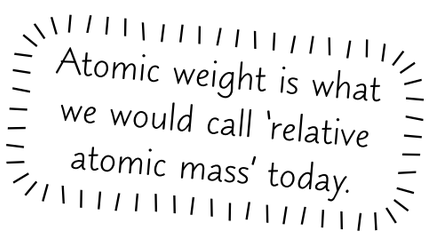
Q2 Video Solution

Development of the Periodic Table

We haven't always known as much about chemistry as we do now. Oh no.
Early chemists looked at patterns in the elements' properties to help them understand chemistry better.

In the Early 1800s Elements Were Arranged By Atomic Weight

1) Until quite recently, scientists hadn't discovered protons, neutrons or electrons. So they had no idea of atomic number.
2) So scientists used atomic weight to arrange the elements into a periodic table.
3) These early periodic tables were not complete.
4) This is because not all of the elements had been found yet.
5) And putting the elements in order of atomic weight meant that some elements were also put in the wrong group (column).



Dmitri Mendeleev Left Gaps and Predicted New Elements

1) In 1869, a scientist called Mendeleev took all of the known elements and arranged them into a table.

Mendeleev's Table of the Elements

H																
Li	Be											B	C	N	O	F
Na	Mg											Al	Si	P	S	Cl
K	Ca	*	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	*	*	As	Se	Br
Rb	Sr	Y	Zr	Nb	Mo	*	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I
Cs	Ba	*	*	Ta	W	*	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi		



2) He ordered them mainly by their atomic weight.
3) Sometimes he switched their positions or left gaps in the table.
4) This was so he could make sure that elements with similar properties stayed in the same groups.
5) Some of the gaps left space for elements that hadn't been found yet.
Mendeleev used the position of the gaps to predict the properties of these elements.
6) New elements have been found since which fit into these gaps.
This shows that Mendeleev's ideas were right.

- Isotopes were discovered a while after Mendeleev made his Table of Elements.
- Isotopes have different masses but share the same properties.
This means they have the same position on the periodic table.
- So, Mendeleev was right to swap some elements around to keep properties together — even if it meant they weren't in order of atomic weight.

The only elements I want on my table are Ba, Co, N...

Ahh more history... This is science at its best, discoveries building upon discoveries — all leading to the point where you have to learn it. Mendeleev would be proud... of himself and you of course.

Q1 How were elements ordered in the early 1800s? [1 mark]

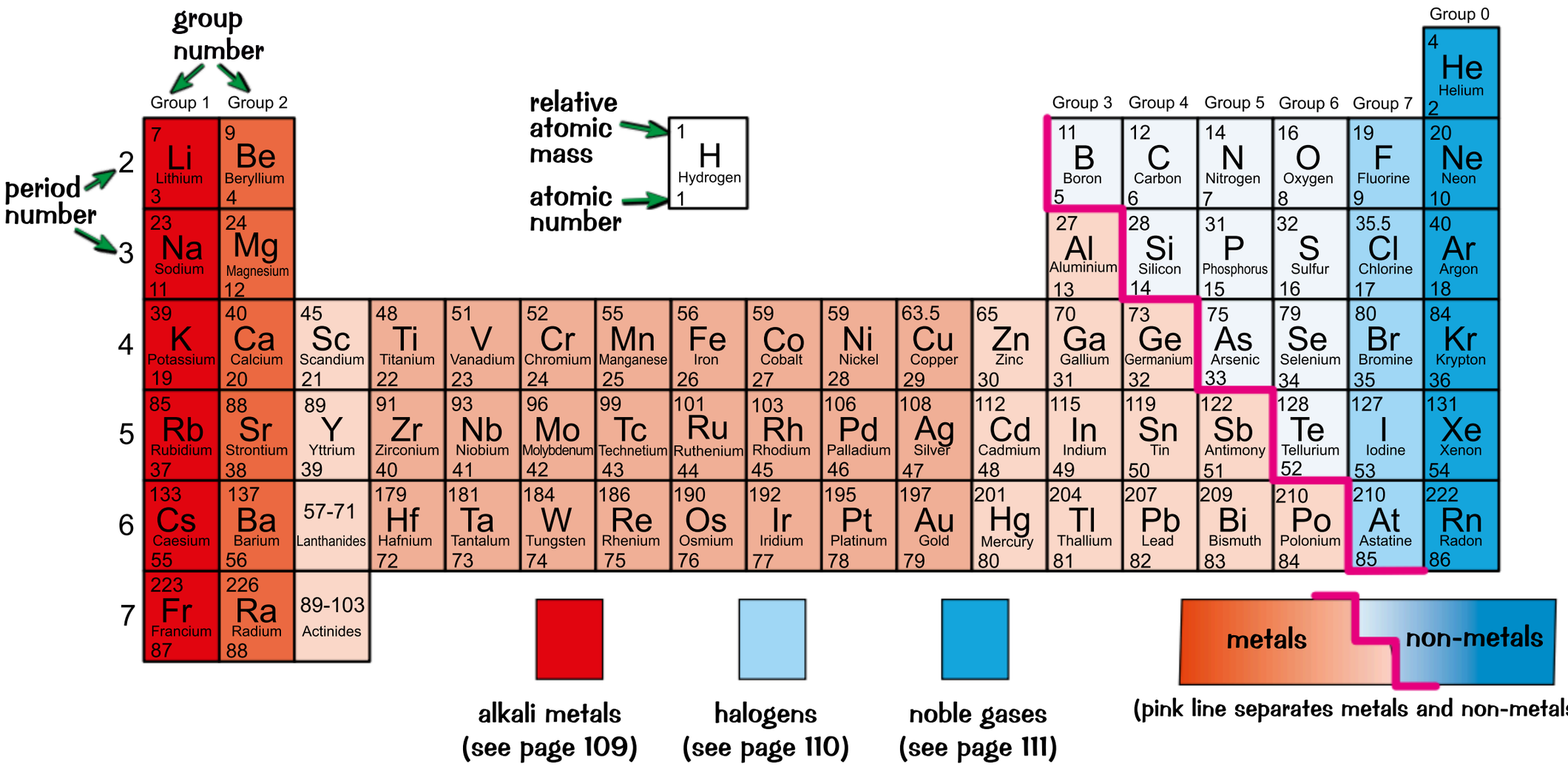
Q2 State two changes that Mendeleev made to early periodic tables. [2 marks]

The Modern Periodic Table

So, as you've seen, it took a while to get to the periodic table that you will soon know and love.
I present to you a chemist's best friend...

The Periodic Table Helps you to See Patterns in Properties

1) There are about 100 elements.
2) In the periodic table the elements are laid out in order of increasing atomic number.
3) There are repeating (periodic) patterns in the properties of the elements.
These periodic properties give the periodic table its name.
4) Metals are found to the left of the periodic table and non-metals are found to the right.



5) Elements with similar properties are arranged to form columns. These columns are called groups.
6) The group number of an element is the same as the number of outer shell electrons it has.
(Except for Group 0 — helium has two electrons in its outer shell and the rest have eight.)
7) So, all the elements in a group have the same number of electrons in their outer shell.
This means that elements in a group react in similar ways.

Example: The Group 1 elements are Li, Na, K, Rb, Cs and Fr.
They all have one electron in their outer shells.
They're all metals and they react in a similar way.

See page 109 for more on Group 1 elements.

8) If you know the properties of one element, you can predict properties of other elements in that group.
9) You can also make predictions about trends in reactivity.
E.g. in Group 1, the elements react more violently as you go down the group.
10) The rows in the periodic table are called periods. Each new period represents another shell of electrons.

I'm in a chemistry band — I play the symbols...

The periodic table is organised into groups and periods. This lets you see patterns in reactivity and properties.
And this means we can make predictions on how reactions will occur. How neat is that?

Q1 How many electrons does beryllium, Be, have in its outer shell? Use a periodic table to help you. [1 mark]

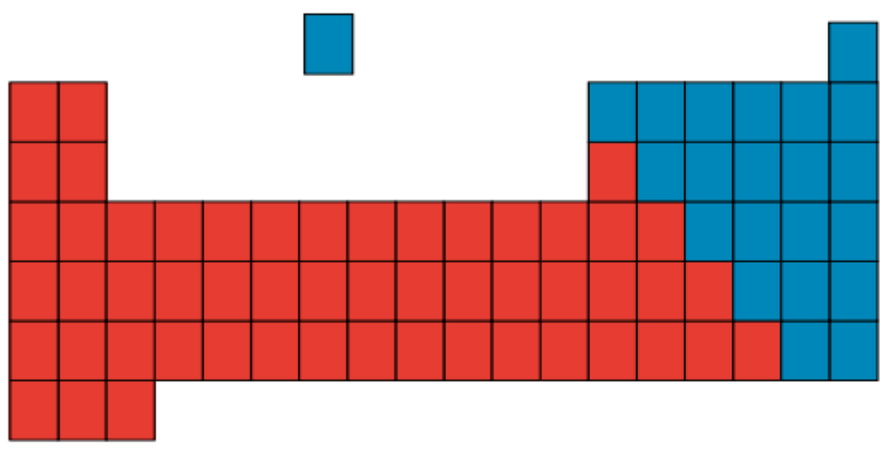
Q2 Chlorine reacts in a similar way to bromine. Suggest a reason why. [1 mark]

Metals and Non-Metals

I am almost dead certain you'll touch something metallic today, that's how important metals are to modern life.

Most Elements are Metals

1) Metals are elements which can form positive ions when they react.
2) They're towards the bottom and to the left of the periodic table.
3) Most elements in the periodic table are metals.
4) Non-metals are at the far right and top of the periodic table.
5) Non-metals don't usually form positive ions when they react.



The red elements are metals.
The blue elements are non-metals.

The Electronic Structure of Atoms Affects How They Will React

1) Atoms are more stable with a full outer shell. So, they react by losing, gaining or sharing electrons.
2) Metal elements are to the left and towards the bottom of the periodic table so they lose electrons quite easily. When this happens, they form positive ions, with a full outer shell.
3) Non-metals are to the right of the periodic table or towards the top, so it's easier for them to share or gain electrons to get a full outer shell.

Metals and Non-Metals Have Different Physical Properties

1) All metals have similar physical properties.

- They're strong (hard to break), but can be bent or hammered into different shapes (malleable).
- They're great at conducting heat and electricity.
- They have high boiling and melting points.



2) Non-metals don't tend to show the same properties as metals.

- They tend to be dull looking.
- They're more brittle. This means they'll break more easily if you try to bend them.
- They're not always solids at room temperature.
- They don't usually conduct electricity.
- They often have a lower density.

You can 'rock out' to metal, you can sway gently to non-metal...

When it comes to properties, metals and non-metals couldn't be much more opposite. Much like me and my sister...

Q1 Iodine usually reacts by forming negative ions. Is iodine a metal or a non-metal? [1 mark]

Q2 State two properties of metals. [2 marks]

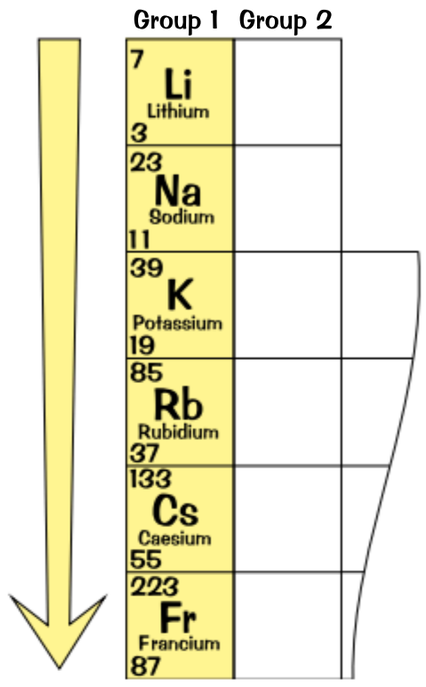
Group 1 Elements

Group 1 elements are known as the alkali metals. As metals go, they're pretty reactive.

The Group 1 Elements are Reactive, Soft Metals

1) The alkali metals are lithium, sodium, potassium, rubidium, caesium and francium.
2) They all have one electron in their outer shell. This makes them very reactive. It also gives them similar properties.
3) The alkali metals are all soft. They all have low density (they're quite light).
4) As you go down Group 1, the properties of the alkali metals change. For example:

- Reactivity increases — the outer electron is more easily lost as it gets further from the nucleus. This is because it's less attracted to the nucleus.
- Melting and boiling points get lower.
- Relative atomic mass goes up.



5) These patterns in the properties are called trends.

Alkali Metals Form Ionic Compounds with Non-Metals

The Group 1 elements easily lose their one outer electron to form a full outer shell. So they form 1+ ions easily.

Reaction with water

1) The reactions are vigorous and produce a metal hydroxide and hydrogen gas:
2) The metal hydroxides are compounds that dissolve in water.
3) The more reactive (lower down in the group) an alkali metal is, the more violent the reaction.
4) Lithium, sodium and potassium float and move around the surface, fizzing furiously.
5) The reaction with potassium gives out enough energy to ignite the hydrogen (set it on fire).

alkali metal + water → metal hydroxide + hydrogen

sodium + water → sodium hydroxide + hydrogen

$2Na_{(s)} + 2H_2O_{(l)} \rightarrow 2NaOH_{(aq)} + H_{2(g)}$

The little letters in brackets after each substance in the reaction show what state the substance is in — see p.121.

Reaction with chlorine

1) Group 1 metals react vigorously when heated in chlorine gas to form white salts called metal chlorides.
2) As you go down the group, the reaction gets more vigorous.

alkali metal + chlorine → metal chloride

sodium + chlorine → sodium chloride

$2Na_{(s)} + Cl_{2(g)} \rightarrow 2NaCl_{(s)}$

Reaction with oxygen

1) Group 1 metals can react with oxygen to form a metal oxide.
2) Different types of oxide will form depending on the Group 1 metal.
3) Group 1 metals are shiny but when they react with oxygen in the air they turn a dull grey (they tarnish). This is because a layer of metal oxide is formed on the surface.

Back to the drawing board with my lithium swimsuit design...

Reactions of alkali metals need safety precautions, but they fizz in water and might explode. Cool.

Q1 Write a word equation for the reaction between lithium and water. [1 mark]

Q2 Why do Group 1 metals have similar properties? [1 mark]

Q1 Video Solution

Group 7 Elements

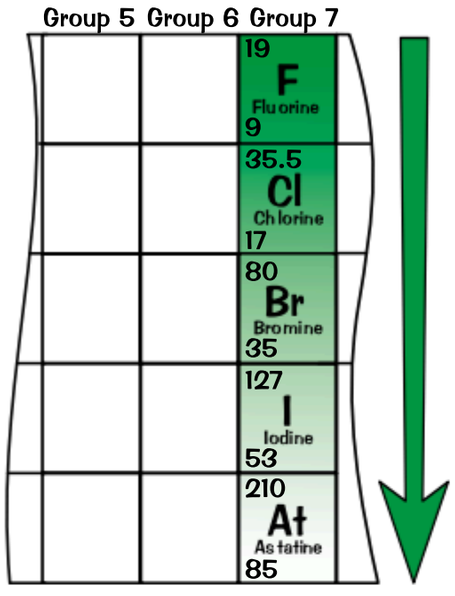
The Group 7 elements are known as the halogens. The whole 'trend thing' happens with the halogens as well.

The Halogens Show Patterns in their Properties

1) The halogens are fluorine, chlorine, bromine, iodine and astatine.

2) As elements, the halogens form molecules that contain two atoms.
For example, chlorine (Cl_2) is a fairly reactive, poisonous green gas.





3) As you go DOWN Group 7, the halogens:

- become less reactive — it's harder to gain an extra electron as the outer shell is further from the nucleus.
- have higher melting and boiling points.
- have higher relative atomic masses.

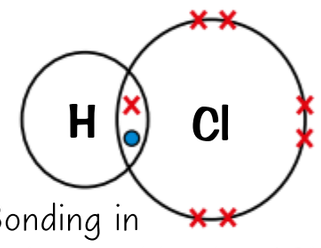
You can use these trends to predict properties of halogens. E.g. iodine will have a higher boiling point than chlorine as it's further down the group.

4) All the Group 7 elements react in similar ways.
This is because they all have seven electrons in their outer shell.

Halogens can Form Molecular Compounds

1) When halogen atoms react with other non-metals, they share electrons and form covalent bonds (see page 116). This is so they can get a full outer shell.

2) These reactions form compounds with simple molecular structures (see p.117).



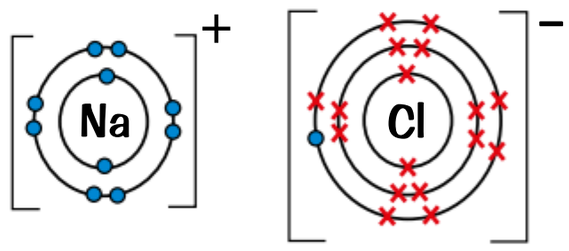
Bonding in hydrogen chloride, HCl.

Halogens Form Ionic Bonds with Metals

1) The halogens form 1– ions called halides:
   - fluoride, F^-
   - bromide, Br^-
   - chloride, Cl^-
   - iodide, I^-

2) Halides form when halogens bond with metals.
For example Na^+Cl^- or $Ca^{2+}Br^-_2$.

3) The compounds (halide salts) that form have ionic structures.



Bonding in sodium chloride, NaCl.

More Reactive Halogens React With Salts of Less Reactive Halogens

1) A reaction can take place between a halogen and the halide salt of a less reactive halogen.

2) These are called displacement reactions.

3) When this happens, the less reactive halogen changes from a halide (1– ion) to a halogen.
The more reactive halogen changes from a halogen into a halide ion and becomes part of the salt.

4) E.g. chlorine is more reactive than bromine.
So if you add chlorine to a solution containing a bromide salt, bromine will be displaced.

$$Cl_{2\,(g)} + 2KBr_{(aq)} \rightarrow Br_{2\,(aq)} + 2KCl_{(aq)}$$
Pale green — Orange

Halogens — one electron short of a full shell...

The halogens get less reactive as you go down the group. So a halogen will only be able to displace another halogen if it's higher up in Group 7. If it's lower down Group 7, no reaction will happen.

Q1 Give the balanced symbol equation for the displacement reaction between bromine and sodium iodide. [1 mark]

Q1 Video Solution

Group 0 Elements

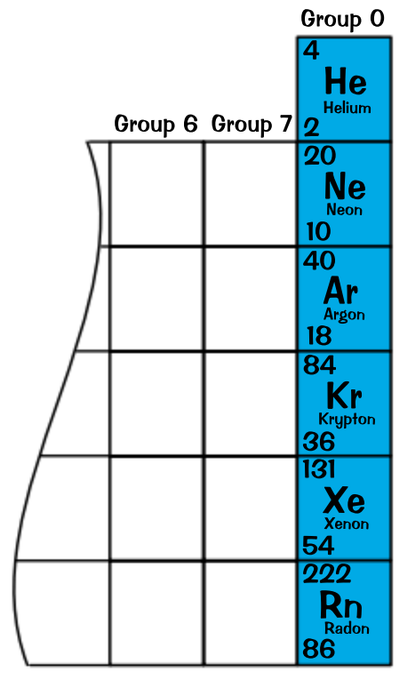
The Group 0 elements are known as noble gases — the most respectable gases you'll ever come across. They don't react with very much and you can't even see them. This makes them, well, a bit dull really.

Group 0 Elements are All Unreactive, Colourless Gases

1) Group 0 elements are called the noble gases.
They include the elements helium, neon and argon (plus a few others).
2) All elements in Group 0 are colourless gases at room temperature.
3) They all have eight outer shell electrons, apart from helium which has two.
This means they have a stable full outer shell.

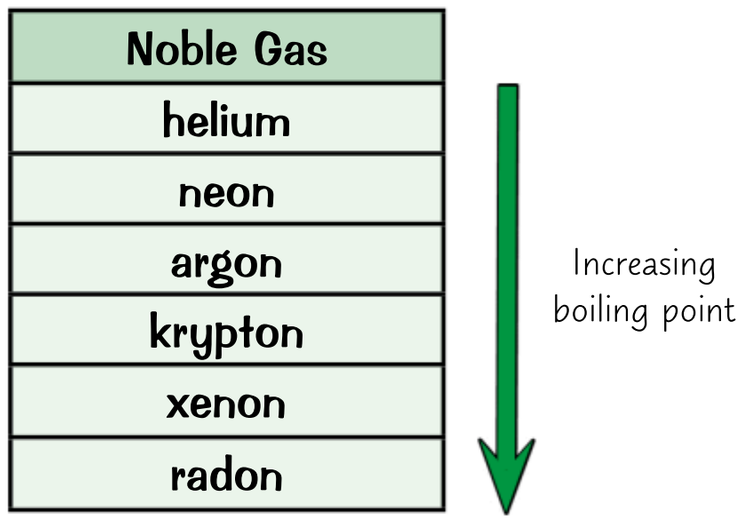
Helium only has electrons in the first shell, which only needs 2 to be filled.

4) This stability makes them very unreactive (inert). This means they don't form molecules easily. So the elements are single atoms.
5) Because noble gases are unreactive, some reactions are carried out in an atmosphere that only contains a noble gas, instead of air.
6) This is done if the reactants could react with things in the air (e.g. oxygen or water) instead of taking part in the reaction you're trying to do. It's also done if the products react with things in the air.



There are Patterns in the Properties of the Noble Gases

1) As you go down Group 0, the relative atomic masses of the elements increase.
2) This means that as you go down the group, the elements have more electrons.
3) More electrons means stronger forces between atoms.
4) The stronger the forces, the higher the boiling point.
So as you go down Group 0, the boiling points increase.
5) If you're given the boiling point of one noble gas you can predict the boiling point for another one.
So make sure you know the pattern.



EXAMPLE

Neon is a gas at 25 °C. Predict what state helium is at this temperature.

Helium has a lower boiling point than neon as it is further up the group.

So, helium must also be a gas at 25 °C.

EXAMPLE

Radon has a boiling point of –62 °C and krypton has a boiling point of –153 °C. Predict the boiling point of xenon.

Xenon comes in between radon and krypton in the group.

So, you can predict that its boiling point would be between their boiling points.

E.g. xenon has a boiling point of –100 °C.

The actual boiling point of xenon is –108 °C — which is between –62 °C and –153 °C. Just as predicted.

Arrrgon — the pirate element...

As noble gases don't really react there isn't too much to learn about them. If you understand why they are unreactive and the trend in boiling points as you go down the group you're sorted.

Q1 Does xenon or neon have the higher boiling point? [1 mark]

Revision Questions for Topic C1

Topic C1 — finished. But hold on there my friend, don't rush on to Topic C2 just yet. There's one more thing for you to do...

- Try these questions and tick off each one when you get it right.
- When you're completely happy with a sub-topic, tick it off.

For even more practice, try the Retrieval Quiz for Topic C1 — just scan this QR code!

Topic C1 Quiz

Atoms, Elements and Compounds (p.96-99) ☐

1) Draw an atom. Label the nucleus and the electrons. ☐
2) What is the charge of a proton? ☐
3) What is the smallest part of an element that you can have? ☐
4) Give the formula for: ☐
   a) Carbon dioxide b) Water
5) Balance these equations: ☐
   a) $Mg + O_2 \rightarrow MgO$ b) $H_2SO_4 + NaOH \rightarrow Na_2SO_4 + H_2O$

Mixtures and Separation (p.100-103) ☐

6) What is a mixture? ☐
7) Are there any chemical bonds between the different parts of a mixture? ☐
8) What method could you use to separate dyes in an ink? ☐
9) What is the name of the pattern formed from carrying out paper chromatography? ☐
10) Which method of separation is useful to separate an insoluble solid from a liquid? ☐
11) Give the name of a method to separate a soluble solid from a solution. ☐
12) Which type of distillation would you use to separate liquids with similar boiling points? ☐

Electronic Structure and the History of the Periodic Table (p.104-107) ☐

13) What did scientists expect to see during the alpha particle scattering experiments? ☐
14) Which scientist first found that the nucleus contains neutrons? ☐
15) How many electrons are allowed in the second electron shell of an atom? ☐
16) What is the electronic structure of sodium? ☐
17) In the early 1800s, how were elements arranged in the periodic table? ☐
18) What does the group number of an element tell you about its electrons? ☐
19) Where are non-metals on the periodic table? ☐

Groups of the Periodic Table (p.108-111) ☐

20) Do metals form positive or negative ions? ☐
21) State two trends as you go down Group 1. ☐
22) How do the boiling points of halogens change as you go down the group? ☐
23) Halogens form ions when they react with metals. What is the charge of the ions? ☐
24) Chlorine is added to a solution containing a bromide salt. ☐
    Will the chlorine displace the bromine in the solution?
25) Why are the Group 0 elements single atoms? ☐
26) How do the boiling points change as you go down Group 0? ☐

Formation of Ions

Ions crop up all over the place in chemistry. You need to know what they are and how they form. Luckily for you, this page has got that covered. So crack on with it.

Ions are Made When Electrons are Transferred

1) Ions are charged particles — for example Cl^- or Mg^{2+}.
2) Ions are formed when atoms gain or lose electrons.
3) They do this to get a full outer shell — like a noble gas.
4) This is because a full outer shell is very stable.
5) Metal atoms lose electrons from their outer shell to form positive ions.
6) Non-metal atoms gain electrons into their outer shell to form negative ions.
7) The number of electrons lost or gained is the same as the charge on the ion.
8) If 2 electrons are lost, the particle now has two more protons than electrons. So the charge is 2+.
9) If 3 electrons are gained, the particle now has three more electrons than protons. So the charge is 3–.

Ions will always have a '+' or '–' sign after the formula. A '+' tells you the ion is positive. A '–' sign tells you the ion is negative.

The noble gases are in Group 0 of the periodic table.

You can Work Out What Ions are Formed by Groups 1 & 2 and 6 & 7

1) Group 1 and 2 elements are metals. They lose electrons to form positive ions.
2) Group 6 and 7 elements are non-metals. They gain electrons to form negative ions.
3) Elements in the same group all have the same number of outer electrons. So they have to lose or gain the same number to get a full outer shell. And this means that they form ions with the same charges.
4) You don't have to remember what ions most elements form. You can just look at the periodic table.

Group 1 elements form ions by losing one electron. They form 1+ ions.

Group 2 elements form ions by losing two electrons. They form 2+ ions.

Group 6 elements form ions by gaining two electrons. They form 2– ions.

Group 7 elements form ions by gaining one electron. They form 1– ions.

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Uut	Fl	Uup	Lv	Uus	Uuo

Noble gases

- A sodium atom (Na) is in Group 1 so it loses 1 electron to form a sodium ion (Na^+).
- A magnesium atom (Mg) is in Group 2 so it loses 2 electrons to form a magnesium ion (Mg^{2+}).
- A chlorine atom (Cl) is in Group 7 so it gains 1 electron to form a chloride ion (Cl^-).
- An oxygen atom (O) is in Group 6 so it gains 2 electrons to form an oxide ion (O^{2-}).

A '+' by itself means the ion has a 1+ charge. A '–' by itself means the ion has a 1– charge.

I've got my ion you...

You need to be able to predict the ions the atoms in Groups 1, 2, 6 and 7 will form. Look at the periodic table above to make sure you know what charged ion each group forms. Keep looking till you've got it sorted.

Q1 Explain why simple ions often have noble gas electronic structures. [2 marks]

Q2 Predict the charges of the ions formed by the following elements:
a) Bromine (Br) b) Calcium (Ca) c) Potassium (K) [3 marks]

Q1 Video Solution

Ionic Bonding

Time to find out how particles bond together to form compounds (bet you can't wait). There are three types of bonding you need to know about — ionic, covalent and metallic. First up, it's ionic bonds.

Ionic Bonding — Transfer of Electrons

1) Metals and non-metals can react together.
2) When this happens, the metal atoms lose electrons to form positively charged ions.
3) The non-metal atoms gain these electrons to form negatively charged ions.
4) These oppositely charged ions are strongly attracted to one another by electrostatic forces.
5) This attraction is called an ionic bond. It holds the ions together to make an ionic compound.

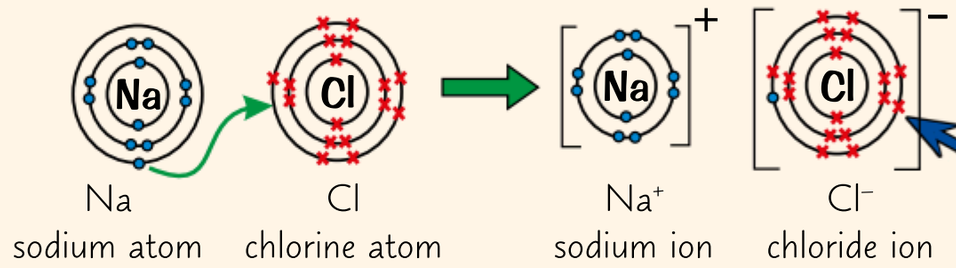
Dot and Cross Diagrams Show How Ionic Compounds are Formed

1) Dot and cross diagrams show how electrons are arranged in an atom or ion.
2) Each electron is represented by a dot or a cross.
3) So these diagrams can show which atom the electrons in an ion originally came from.



Sodium Chloride (NaCl)

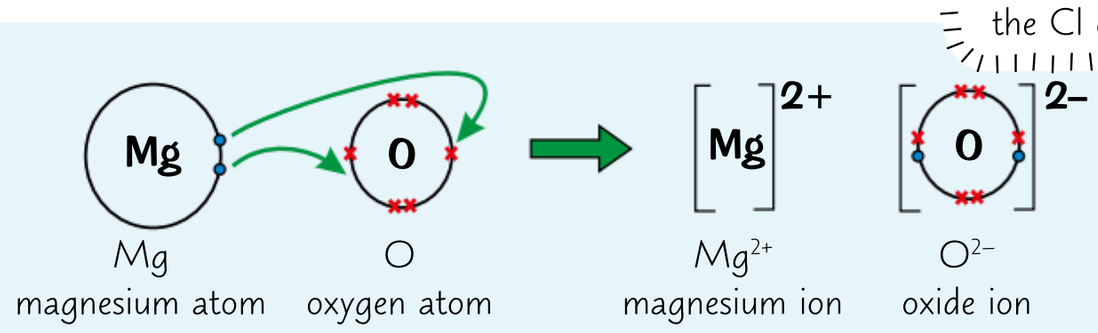
- The sodium (Na) atom loses its outer electron. It forms an Na^+ ion.
- The chlorine (Cl) atom gains the electron. It forms a Cl^- (chloride) ion.



Here, the dots represent the Na electrons and the crosses represent the Cl electrons.

Magnesium Oxide (MgO)

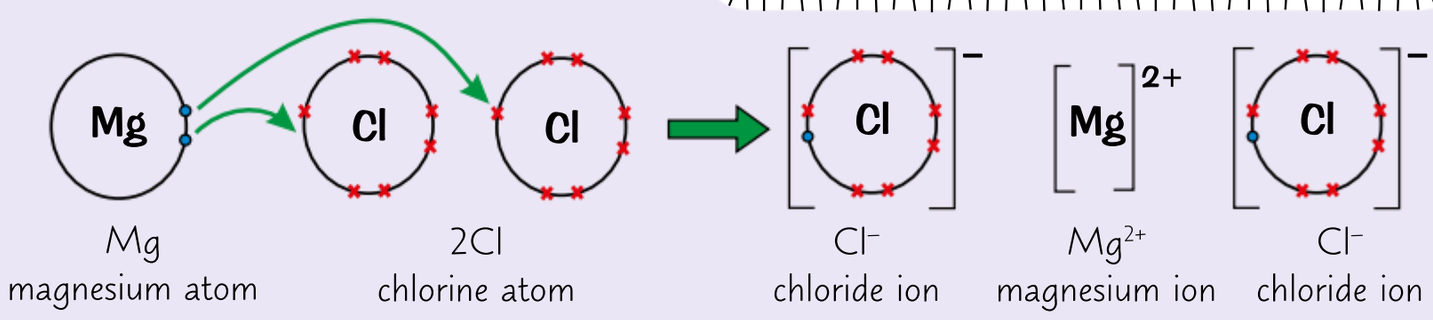
- The magnesium (Mg) atom loses its two outer electrons. It forms an Mg^{2+} ion.
- The oxygen (O) atom gains the electrons. It forms an O^{2-} (oxide) ion.



We've only shown the outer shells of electrons in these two dot and cross diagrams. It makes it easier to see what's going on.

Magnesium Chloride ($MgCl_2$)

- The magnesium (Mg) atom loses its two outer electrons. It forms an Mg^{2+} ion.
- The two chlorine (Cl) atoms gain one electron each. They form two Cl^- (chloride) ions.



4) Dot and cross diagrams are useful for showing how ionic compounds are formed.
5) But they don't show the structure of the compound, the size of the ions or how they're arranged.
6) They also make it look like the electrons that are crosses might be different from the electrons that are dots. Really, they're all the same.

Any old ion, any old ion — any, any, any old ion...

Drawing dot and cross diagrams gets easier with practice. Here are some questions to get you started.

Q1 What type of forces hold the ions together in an ionic compound? [1 mark]

Q2 Draw a dot and cross diagram to show how potassium (a Group 1 metal) and bromine (a Group 7 non-metal) form potassium bromide (KBr). [3 marks]

Q2 Video Solution

Ionic Compounds

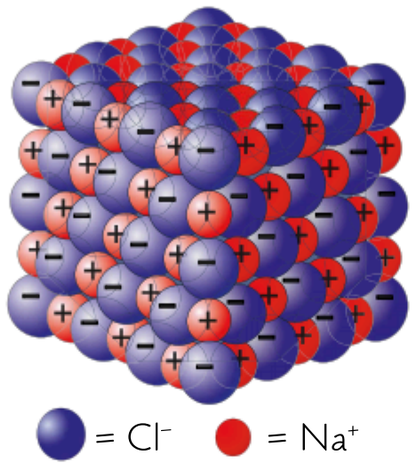
Ionic compounds may sound fancy, but don't be put off. One of the main ionic compounds you need to know about is sodium chloride. And that's just salt. Yep, like you put on your chips. Nothing fancy about that.

Ionic Compounds Have A Giant Ionic Lattice Structure

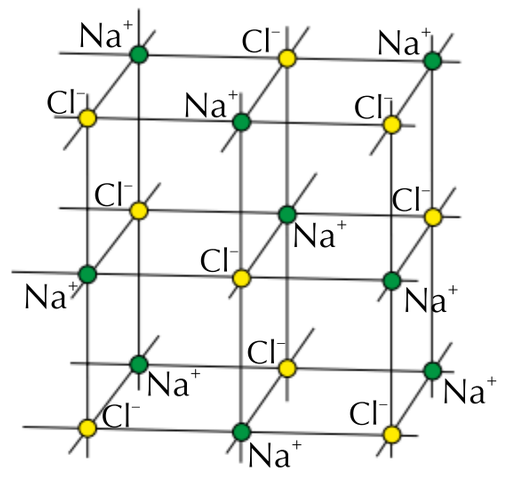
1) In ionic compounds, the ions are arranged in a pattern. This is called a giant ionic lattice.
2) There are strong electrostatic forces of attraction between oppositely charged ions.
3) These forces are called ionic bonds and they act in all directions.

Sodium chloride is a giant ionic lattice. It can be drawn in different ways:

- This is a 3D model. It shows how big the ions are compared to each other.
- It also shows that the ions are ordered in a pattern.
- But it only lets you see the outer layer of the compound.



- This is a ball and stick model. It shows how the ions are arranged.
- But it doesn't show how big the ions are compared to each other.
- And it makes it look like there are gaps between the ions. But there aren't really.



Ionic Compounds All Have Similar Properties



1) They all have high melting points and high boiling points.
   This is because lots of energy is needed to break all the strong ionic bonds.
2) When they're solid, the ions are held in place, so the solid compounds can't conduct electricity.
3) When ionic compounds melt, the ions are free to move and they can conduct electricity.
4) Some ionic compounds dissolve in water. The ions can move in the solution, so they can conduct electricity.

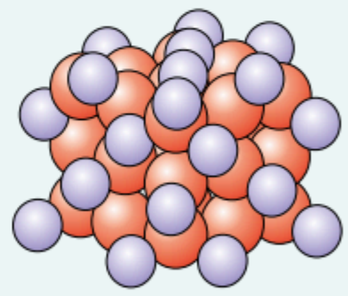
Look at Charges to Find the Empirical Formula of an Ionic Compound

1) For a dot and cross diagram, just count up and write down how many ions there are of each element.
2) For a 3D diagram, use the diagram to work out what ions are in the compound.
3) Then balance the charges of the ions so that the overall charge on the compound is zero.

EXAMPLE

What's the empirical formula of the ionic compound shown on the right?

1) Look at the diagram to work out what ions are in the compound.
   — The compound contains potassium and oxide ions.
2) Work out what charges the ions will form.
   — Potassium is in Group 1 so forms 1+ ions. Oxygen is in Group 6 so forms 2– ions.
3) Balance the charges so the charge of the empirical formula is zero.
   — A potassium ion has a 1+ charge, so two of them are needed to balance the 2– charge of an oxide ion. The empirical formula is K_2O.



The empirical formula shows the smallest ratio of particles.

I'd take this page with a pinch of salt if I were you...

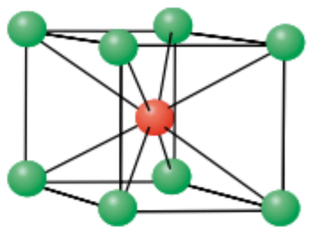
Here's where you can get a little practice explaining the properties of ionic compounds.

Q1 The structure of an ionic compound is shown on the right.

a) Predict, with reasoning, whether the compound has a high or a low melting point. [2 marks]

b) Explain why the compound can conduct electricity when molten. [1 mark]

c) Use the diagram to find the empirical formula of the compound. [3 marks]



Q1 Video Solution

Covalent Bonding

Some elements bond ionically (see page 114) but others form strong covalent bonds.
This is where atoms share electrons with each other so that they've got full outer shells.

Covalent Bonds — Sharing Electrons

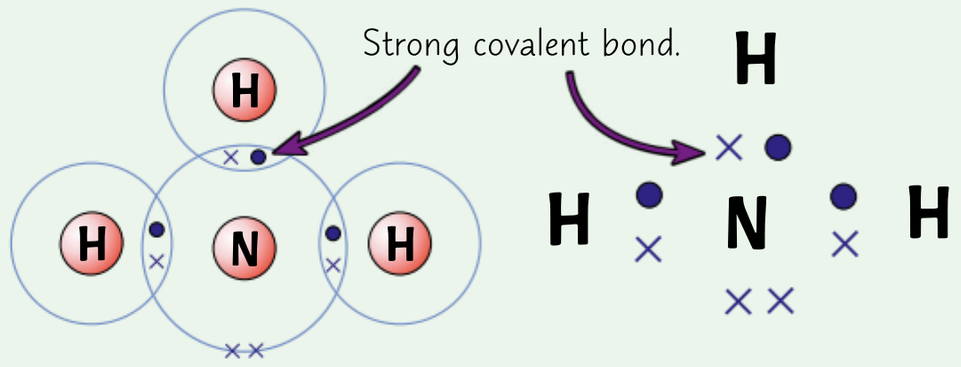
1) When non-metal atoms bond together, they share pairs of electrons to make covalent bonds.
2) Covalent bonds are electrostatic forces and are very strong.
3) Atoms only share electrons in their outer shells.
4) Atoms get one extra shared electron for each single covalent bond that they form.
5) Each atom usually makes enough covalent bonds to fill up its outer shell. This makes them very stable.

There are Different Ways of Drawing Covalent Bonds

Nitrogen has 5 outer electrons. To form ammonia (NH_3) it forms 3 covalent bonds to get the extra 3 electrons it needs for a full outer shell. Here are different ways the bonding can be shown:

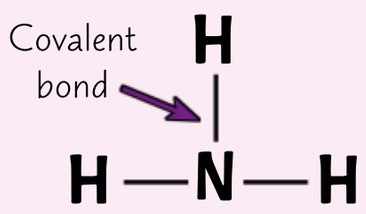
Dot and Cross Diagrams

1) Electrons shown in the overlap between two atoms are shared electrons.
2) Dot and cross diagrams show which atoms the electrons in a covalent bond come from
3) But they don't show how the atoms are arranged, or how big the atoms are compared to each other.



Two different ways of drawing dot and cross diagrams.

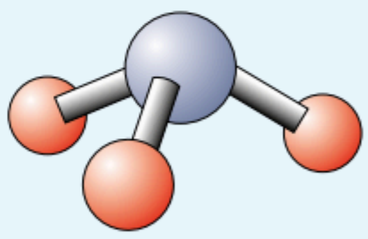
Displayed Formulas



1) Displayed formulas show the covalent bonds as single lines between atoms.
2) If it's a single covalent bond, there'll be one line.
   If it's a double covalent bond, there'll be two lines.
3) They're good for showing how atoms are connected in large molecules.
4) But they don't show the 3D structure of the molecule. They also don't show which atoms the electrons in the covalent bond have come from.

3D Models

1) 3D models show the atoms, the covalent bonds and how they're arranged.
2) But 3D models can be confusing for large molecules.
3) And they don't show where the electrons in the bonds have come from.

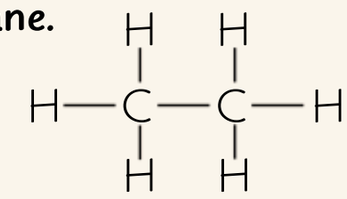


You can find the molecular formula of a simple molecular compound from these diagrams by counting up how many atoms of each element there are.

A molecular formula shows you how many atoms of each element are in a molecule.

EXAMPLE

Find the molecular formula of ethane from the diagram of ethane.



In the diagram, there are two carbon atoms and six hydrogen atoms. So the molecular formula is C_2H_6.

Sharing is caring...

There's a whole page of dot and cross diagrams for other covalent molecules yet to come, but make sure you can draw the different diagrams that can be used to show the bonding in ammonia on this page first.

Q1 Draw a dot and cross diagram to show the bonding in a molecule of ammonia (NH_3). [2 marks]

Q1 Video Solution

Simple Molecular Substances

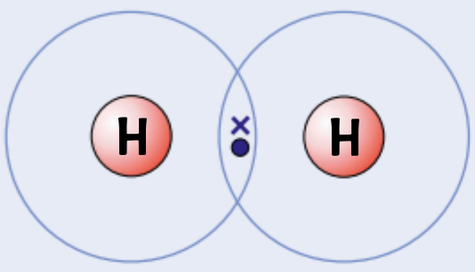
These molecules might be simple, but you've still gotta know about them. I know, the world is a cruel place.

Learn These Examples of Simple Molecular Substances

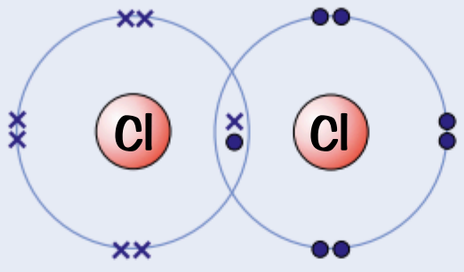
1) Simple molecular substances are made up of molecules that contain a few atoms joined together by covalent bonds.
2) Here are some common examples that you should know...

Make sure you can also draw the dot and cross diagram of ammonia, NH_3, which is on the previous page.

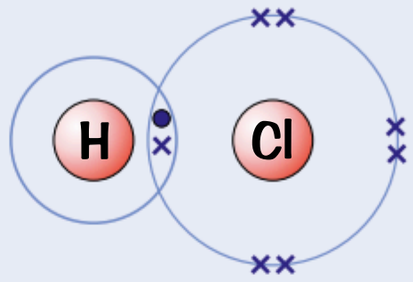
Hydrogen, H_2



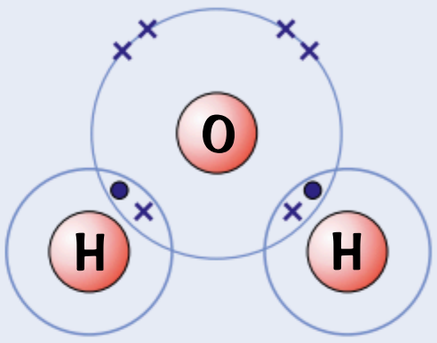
Chlorine, Cl_2



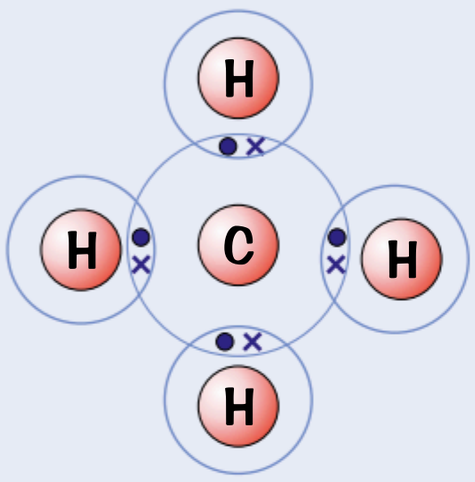
Hydrogen Chloride, HCl



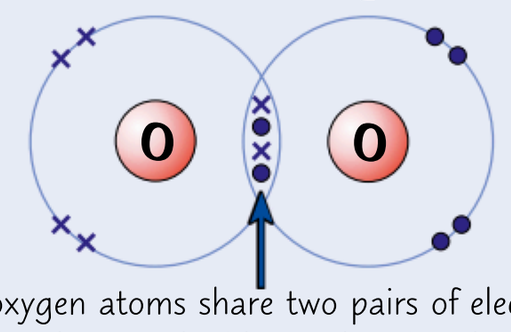
Water, H_2O



Methane, CH_4

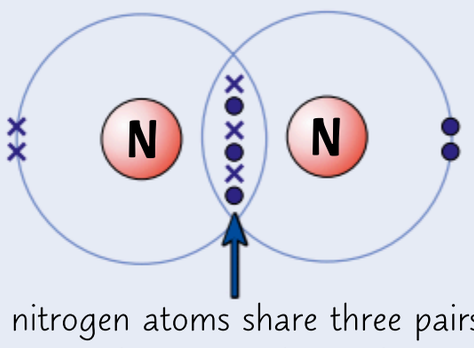


Oxygen, O_2



The oxygen atoms share two pairs of electrons. This is a double covalent bond.

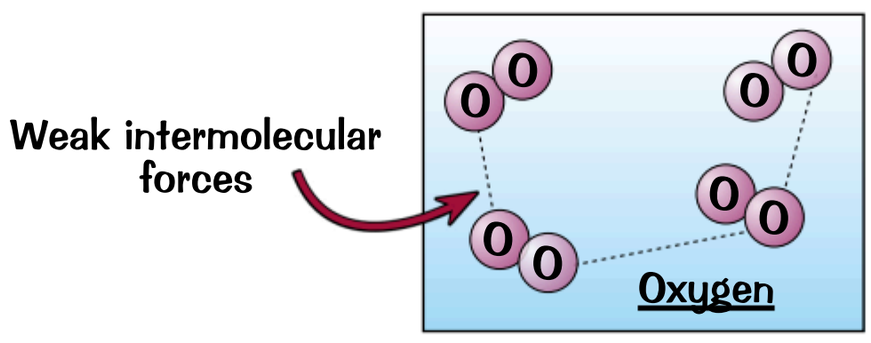
Nitrogen, N_2



The nitrogen atoms share three pairs of electrons. This is a triple covalent bond.

Properties of Simple Molecular Substances

1) Substances containing covalent bonds usually have simple molecular structures, like the examples above.
2) The atoms within the molecules are held together by very strong covalent bonds.
3) But the forces of attraction between these molecules are very weak.



4) To melt or boil a simple molecular compound, you only need to break the weak intermolecular forces and not the covalent bonds.

There's more about melting and boiling on page 122.

5) So the melting and boiling points are very low, because it's easy to break the intermolecular forces.
6) Most molecular substances are gases or liquids at room temperature.
7) As molecules get bigger, the intermolecular forces get stronger. More energy is needed to break the stronger forces, so the melting and boiling points increase.
8) Molecular compounds don't conduct electricity because they aren't charged.



May the intermolecular force be with you...

Never forget that it's the weak forces between molecules that are broken when a simple molecular substance melts.

Q1 Explain why oxygen, O_2, is a gas at room temperature. [1 mark]

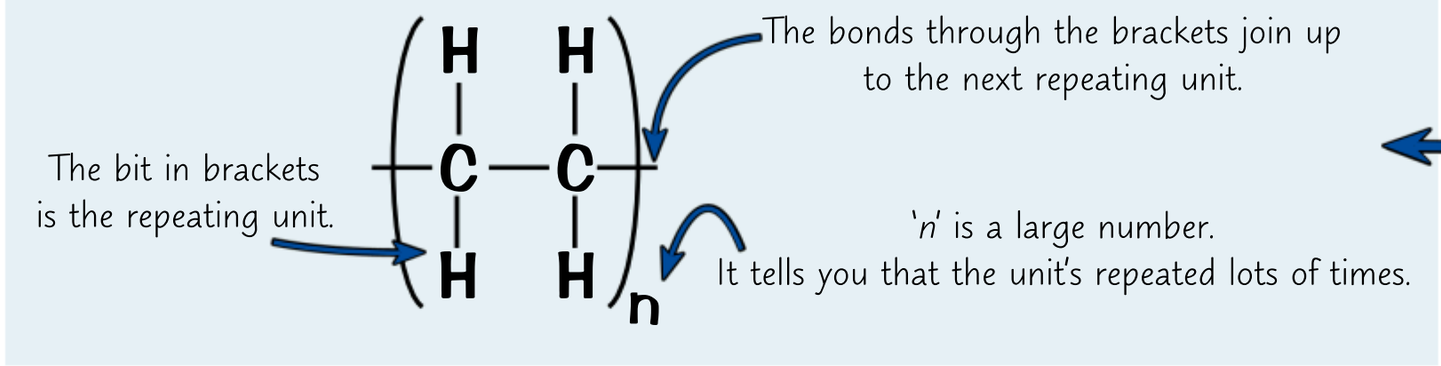
Q2 Explain why nitrogen, N_2, doesn't conduct electricity. [1 mark]

Polymers and Giant Covalent Structures

Wouldn't it be great if the only covalent compounds you needed to know about were simple molecular substances? Well it's not like that. Polymers and giant covalent substances also have covalent bonds.

Polymers Have Very Large Molecules

1) In a polymer, lots of small units are joined together to form a long molecule.
2) All the atoms in a polymer are joined by strong covalent bonds.
3) Instead of drawing out a whole polymer, you can draw a small part of it, called the repeating unit.
4) The polymer is made up of this unit repeated over and over again.



The names of polymers usually have 'poly' followed by something in brackets. E.g. this is poly(ethene).

5) To find the molecular formula of a polymer, write down the molecular formula of the repeating unit. Put brackets around it. Then put an 'n' outside.
6) So for the polymer above, the molecular formula of the polymer is $(C_2H_4)_n$.
7) The intermolecular forces between polymer molecules are larger than between simple covalent molecules. This means more energy is needed to break them. So most polymers are solid at room temperature.
8) The intermolecular forces are still weaker than ionic or covalent bonds. This means they generally have lower melting and boiling points than ionic or giant covalent compounds.

Giant Covalent Structures Include Diamond, Graphite and Silica

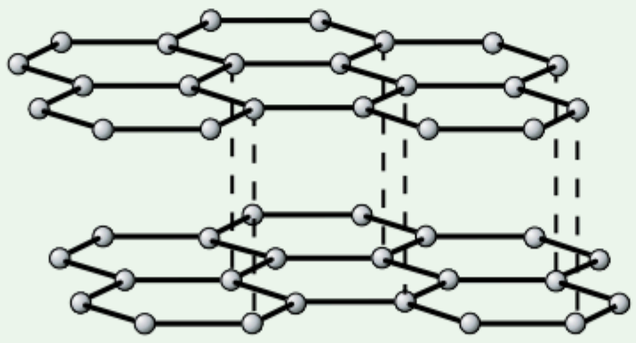
1) In giant covalent structures, all the atoms are bonded to each other by strong covalent bonds.
2) They have very high melting and boiling points.
   This is because lots of energy is needed to break the covalent bonds between the atoms.
3) They don't contain charged particles, so they don't conduct electricity (except for a few weird exceptions such as graphite, see next page).
4) Here are some examples you should know about:

The structures are really much larger than we've shown here. The rest of the substance looks the same, so we've just drawn a section.

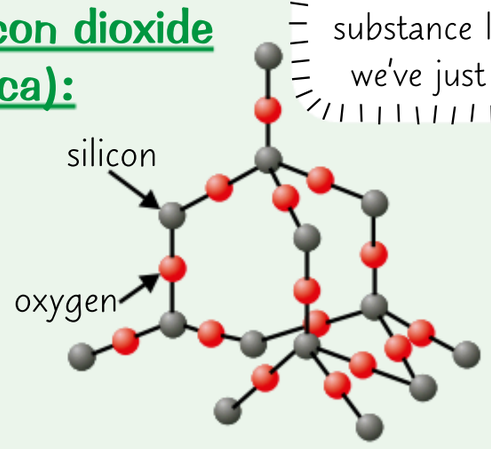
Diamond:



Graphite:



Silicon dioxide (silica):

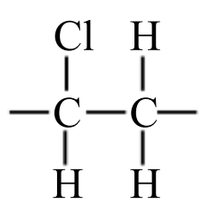


There's more about diamond and graphite on the next page.

Polymers — the intermolecular force is strong in these ones...

To melt or boil a simple molecular substance or a polymer, only the intermolecular forces need to be broken. To melt or boil a giant covalent substance, you have to break very strong covalent bonds.

Q1 The repeating unit of poly(chloroethene) is shown on the right. What's the molecular formula of poly(chloroethene)? [1 mark]



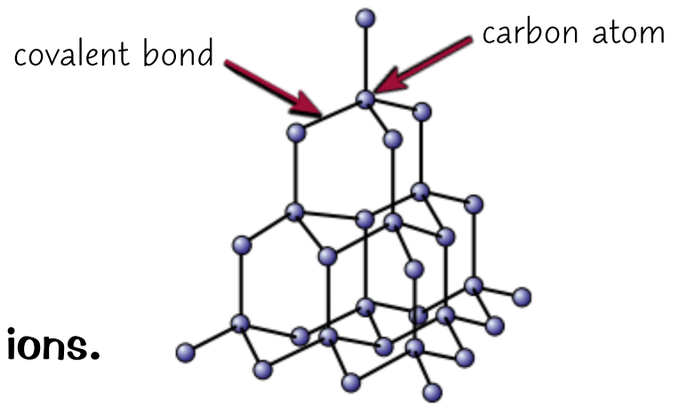
Q2 Explain whether diamond or the polymer poly(ethene) has a higher melting point. [3 marks]

Q1 Video Solution

Structures of Carbon

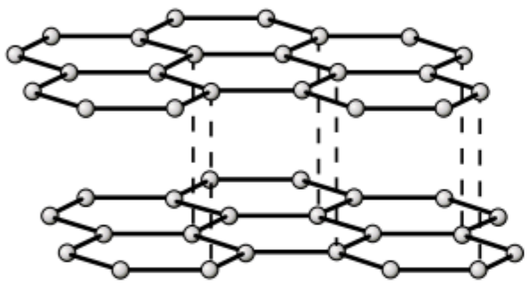
Carbon's a funny old element. Its atoms can arrange themselves into different structures. Here they are...

Diamond is Very Hard



1) In diamond, each carbon atom forms four covalent bonds.
2) This makes diamond really hard.
3) It takes a lot of energy to break the covalent bonds.
So diamond has a very high melting point.
4) Diamond doesn't conduct electricity because it has no free electrons or ions.

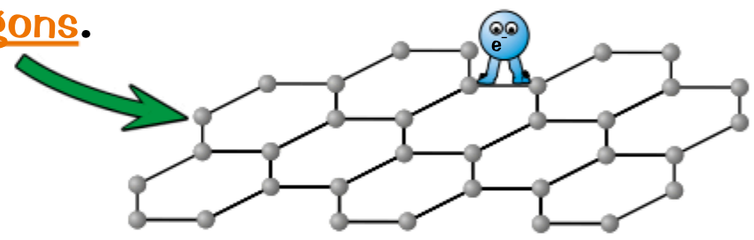
Graphite Contains Layers of Hexagons

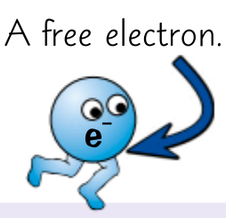


1) Graphite contains layers of carbon atoms. The carbon atoms are arranged in hexagons (rings of six carbon atoms).
2) Each carbon atom forms three covalent bonds.
3) There aren't any covalent bonds between the layers. So the layers can move over each other. This makes graphite soft and slippery.
4) Lots of energy is needed to break the covalent bonds in the layers. So graphite has a high melting point.
5) Each carbon atom has one electron that's free to move (delocalised).
So graphite conducts electricity and thermal energy (heat) — a bit like a metal does (see p.120).

Graphene is One Layer of Graphite

1) Graphene is a sheet of carbon atoms joined together in hexagons.
You can think of it as one layer of graphite.
2) The covalent bonds make it very strong. It's also very light.
3) It can be added to other materials to make composites.
The graphene makes the materials stronger but not much heavier.
4) Graphene contains electrons that are free to move.
So it conducts electricity. This means it could be used in electronics.



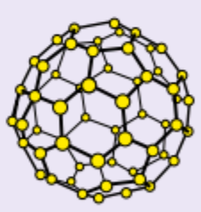


A free electron.

Fullerenes Form Spheres and Tubes

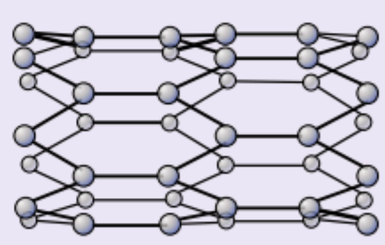
1) Fullerenes are molecules of carbon, shaped like closed tubes or hollow balls.
2) The carbon atoms are mainly arranged in hexagons.
They can also form rings of five carbon atoms or rings of seven carbon atoms.

Buckminsterfullerene (C_{60}) was the first fullerene to be found. It's shaped like a hollow sphere (ball).



3) Fullerenes can be used to deliver drugs into the body. They also make great catalysts (see p.139).

- Fullerenes can form nanotubes — tiny carbon cylinders.
- The ratio between the length and the diameter of nanotubes is very high (they're very long compared to their width).
- Nanotubes have properties that make them useful in electronics. They can also be used to strengthen materials without adding much weight.



Technology that uses very small particles is called nanotechnology.

Graphite — when a bar chart hits a line graph...

Before you go on, make sure you can explain the properties of these forms of carbon. Not fun, but useful.

Q1 Describe the structure and bonding of graphite. [4 marks]

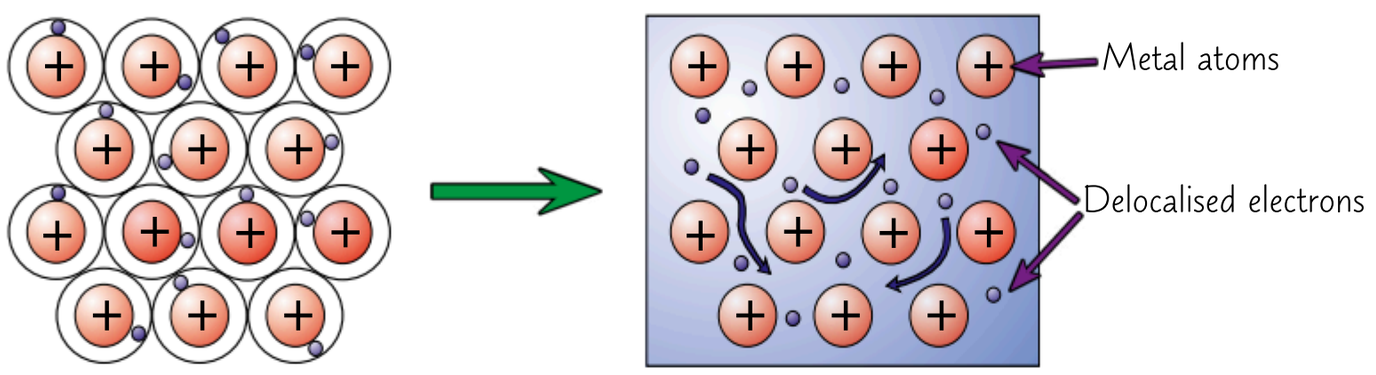
Q1 Video Solution

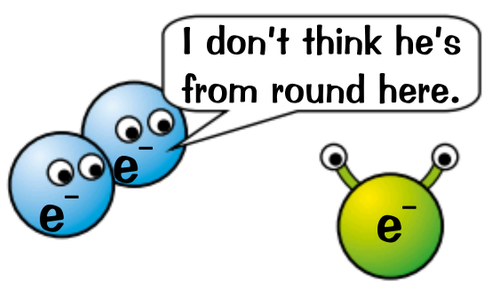
Metallic Bonding

Ever wondered what makes metals tick? Well, whether you have or you haven't, this is still the page for you.

Metallic Bonding Involves Delocalised Electrons

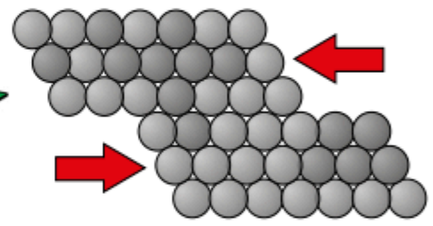
1) Metals are giant structures of atoms.
This means they contain lots and lots of metal atoms bonded together.
2) The electrons in the outer shell of the metal atoms are free to move around (delocalised).
3) There are strong forces of electrostatic attraction between the positive metal ions and the shared negative electrons.
4) These forces of attraction are known as metallic bonds.
They hold the atoms together in a regular pattern.





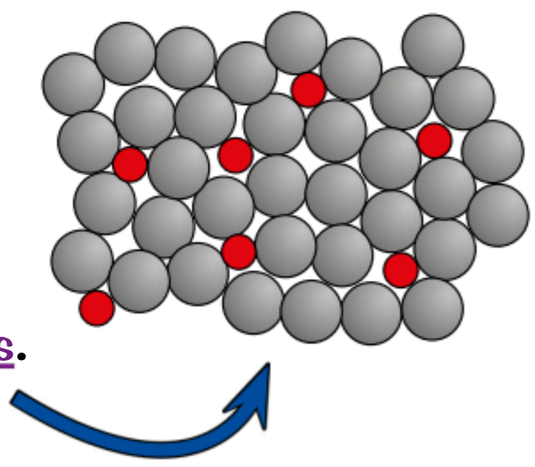
The Bonding in Metals Affects their Properties

1) Metallic bonds are very strong, so lots of energy is needed to break them.
2) This means that most substances with metallic bonds have very high melting and boiling points.
3) They're usually solids at room temperature.
4) The delocalised electrons in the metal are free to move.
5) These electrons can carry electrical charge and thermal (heat) energy through the whole structure.
6) This means metals are good conductors of electricity and heat.
7) The layers of atoms in a metal can slide over each other.
8) Because of this, metals can be bent or formed into different shapes.



Metallic Bonding is Found in Alloys

1) Pure metals are often quite soft.
2) Most of the metals we use are alloys.
An alloy is a mixture of two or more metals or a metal and another element.
3) Mixing another element with a pure metal causes the layers of metal atoms to lose their shape. This is because different elements have different sized atoms.
4) It becomes more difficult for the atoms to slide over each other.
5) This makes alloys harder and so more useful than pure metals.





I saw a metal on the bus once — she was the conductor...

If your knowledge of metals is still feeling a bit delocalised, the questions below will help...

Q1 What is a metallic bond? [2 marks]

Q2 Copper is a metal. What property of copper means it can be used in electrical circuits? [1 mark]

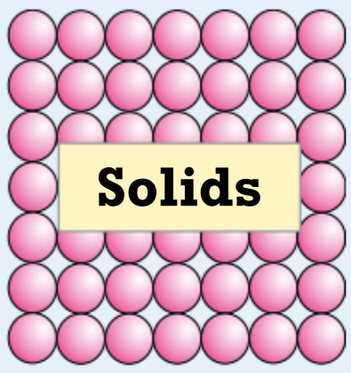
Q3 Suggest why an alloy of copper, rather than pure copper, is used to make hinges for doors. [1 mark]

States of Matter

Better get your thinking hat on, as states of matter really... err.. matter. You'll need to imagine the particles in a substance as little snooker balls. Sounds strange, but it's useful for explaining lots of stuff in chemistry.

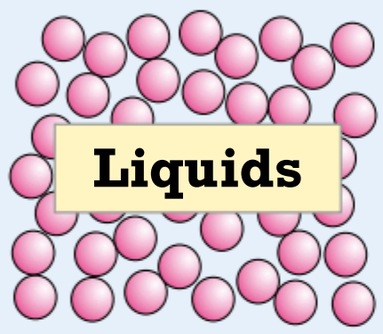
The Three States of Matter — Solid, Liquid and Gas

1) Materials come in three different forms — solid, liquid and gas. These are the three states of matter.
2) Particle theory is a model where each particle is seen as a small, solid sphere (ball).
3) You can use particle theory to show what solids, liquids and gases are like.
It can be used to explain how the particles in solids, liquids and gases behave.

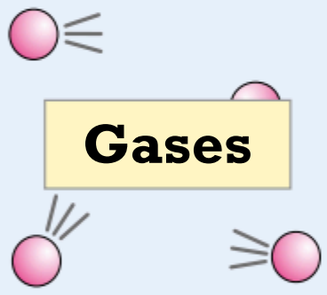


- In solids, there are strong forces of attraction between particles.
- The particles are held close together in fixed positions to form a pattern.
- Solids have a fixed shape and volume.

The particles could be atoms, ions or molecules.



- In liquids, there are weak forces of attraction between the particles.
- They're randomly arranged and free to move past each other, but they tend to stick closely together.
- Liquids have a fixed volume but don't keep a fixed shape. So they flow to fill the bottom of a container.



- In gases, the forces of attraction between the particles are very weak.
- The particles are free to move and are spaced far apart.
- The particles in gases travel in straight lines.
- Gases don't have a fixed shape or volume. They will always fill containers.

If you ever see something described as 'gaseous', it just means that it's a gas.

State Symbols Tell You the State of a Substance in an Equation

1) You saw on page 99 how a chemical reaction can be shown using a symbol equation.
2) Symbol equations can include state symbols next to each substance. They're always shown in brackets, and they're normally subscripts (slightly smaller and below the rest of the letters).
3) They tell you whether each substance is a solid, a liquid, a gas or dissolved in water:

(s) — solid (l) — liquid (g) — gas (aq) — aqueous

'Aqueous' means 'dissolved in water'.

Example: $2HCl_{(aq)} + CaCO_{3(s)} \rightarrow CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$

dissolved in water — solid — dissolved in water — liquid — gas

Phew, what a page — particle-ularly gripping stuff...

It's clever how you can explain the differences between solids, liquids and gases with a page of pink snooker balls.

Q1 Substance A does not have a definite shape or volume. What state is it in? [1 mark]

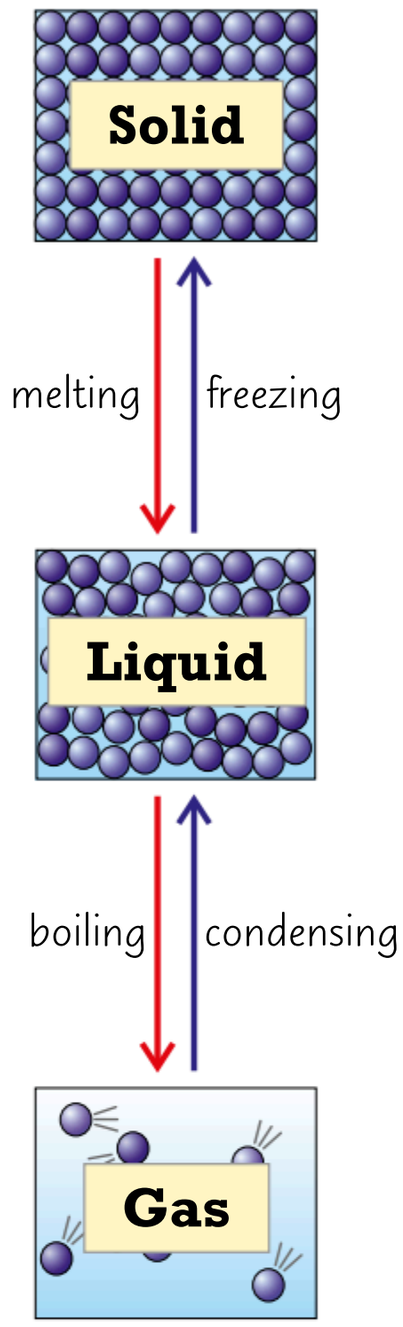
Changing State

This page is like a game show. To start, everyone seems nice and solid, but turn up the heat and it all changes.

Substances Can Change from One State to Another

Solid → Liquid → Gas

- When a solid is heated, its particles gain energy and start to move about.
- Some of the forces between the particles break.
- At a temperature called the melting point, the particles have enough energy to break free from their positions. This is MELTING. The solid turns into a liquid.
- When a liquid is heated, the particles get even more energy.
- The forces holding the liquid together weaken and break.
- At a temperature called the boiling point, the particles have enough energy to break the forces. This is BOILING. The liquid becomes a gas.



Gas → Liquid → Solid

- As a gas cools, the particles have less energy.
- Forces form between the particles.
- At the boiling point, the forces between the particles are strong enough that the gas becomes a liquid. This is CONDENSING.
- When a liquid cools, the particles have less energy, so move around less.
- The forces between the particles become stronger.
- At the melting point, the forces between the particles are so strong that they're held in place. The liquid becomes a solid. This is FREEZING.

1) The amount of energy needed for a substance to change state depends on how strong the forces between particles are.
2) The stronger the forces, the more energy is needed to break them, and so the higher the melting and boiling points of the substance.

You Have to be Able to Predict the State of a Substance

1) You can predict what state a substance is in at a certain temperature.
2) If the temperature's below the melting point of substance, it'll be a solid.
3) If it's above the boiling point, it'll be a gas.
4) If it's in between the two points, then it's a liquid.

The bulk properties such as the melting point of a material depend on how lots of atoms interact together. An atom on its own doesn't have these properties.

EXAMPLE

Which of the substances in the table is a liquid at room temperature (25 °C)?

	melting point	boiling point
oxygen	–219 °C	–183 °C
nitrogen	–210 °C	–196 °C
bromine	–7 °C	59 °C

Oxygen and nitrogen have boiling points below 25 °C, so will both be gases at room temperature.

The answer's bromine. It melts at –7 °C and boils at 59 °C. So, it'll be a liquid at room temperature.

This page has put me in a terrible state...

Learn what all the terms like condensing, boiling, etc. mean. Then you'll sound like a states of matter pro.

Q1 Ethanol melts at –114 °C and boils at 78 °C. Predict the state that ethanol is in at:
a) –150 °C b) 0 °C c) 25 °C d) 100 °C [4 marks]

Q1 Video Solution

Relative Formula Mass

Calculating relative formula mass is important for lots of calculations in chemistry.
It might sound a bit hard to begin with, but it gets easier with practice. We'd better get cracking...

Compounds Have a Relative Formula Mass, M_r

To find the relative formula mass, M_r, of a compound, add together the relative atomic masses of all the atoms in the molecular formula.

The relative atomic mass (A_r) of an element is on the periodic table. See page 97 for more.

EXAMPLES

In the exams, you might be given the relative atomic masses you need in the question.

a) Find the relative formula mass of $MgCl_2$.

1) Look up the relative atomic masses of all the elements in the compound on the periodic table.

2) Add up all the relative atomic masses of the atoms in the compound.

A_r of Mg = 24 A_r of Cl = 35.5

$Mg + (2 \times Cl) = 24 + (2 \times 35.5)$
$= 24 + 71 = 95$

There are two chlorine atoms in $MgCl_2$, so the relative atomic mass of chlorine needs to be multiplied by 2.

M_r of $MgCl_2$ = 95

b) Find the relative formula mass of $Ca(OH)_2$.

1) Look up the relative atomic masses of all the elements in the compound on the periodic table.

2) Add up all the relative atomic masses of the atoms in the compound. The small number 2 after the bracket in the formula $Ca(OH)_2$ means that there's two of everything inside the brackets.

A_r of Ca = 40 A_r of O = 16 A_r of H = 1

$Ca + [(O + H) \times 2] = 40 + [(16 + 1) \times 2]$
$= 40 + 34 = 74$

M_r of $Ca(OH)_2$ = 74

You Can Calculate the Percentage Mass of an Element in a Compound

To work out the percentage mass of an element in a compound, you need to use this formula:

$$\text{Percentage mass of an element in a compound} = \frac{A_r \times \text{number of atoms of that element}}{M_r \text{ of the compound}} \times 100$$

EXAMPLE

Find the percentage mass of sodium (Na) in sodium bromide (NaBr).



1) Look up the relative atomic masses of all the elements in the compound on the periodic table.

A_r of Na = 23 A_r of Br = 80

2) Add up the relative atomic masses of all the atoms in the compound to find the relative formula mass.

M_r of NaBr = 23 + 80
= 103

3) Use the formula to calculate the percentage mass.

$$\text{Percentage mass of sodium} = \frac{A_r \times \text{number of atoms of that element}}{M_r \text{ of the compound}} \times 100$$
$$= \frac{23 \times 1}{103} \times 100$$
$$= 22\%$$

Relative formula = sister + grandad + aunt + cousin...

The best way to get to grips with all this stuff is by practising. Start by having a go at these questions...

Q1 Calculate the relative formula mass (M_r) of: a) H_2O b) LiOH c) H_2SO_4 [3 marks]

Q2 Calculate the percentage composition by mass of potassium in potassium hydroxide (KOH). [2 marks]

Q2 Video Solution

Conservation of Mass

You've probably realised by now that you can't magic stuff out of thin air. It can't magically disappear, either.

In a Chemical Reaction, Mass Always Stays the Same

1) During a chemical reaction no atoms are lost and no atoms are made.
2) This means there are the same number and types of atoms on each side of a reaction equation.
3) Because of this, no mass is lost or gained — we say that mass is conserved (stays the same) in a reaction.

E.g. $2Li + F_2 \rightarrow 2LiF$

In this reaction, there are 2 lithium atoms and 2 fluorine atoms on each side of the equation.

4) You can see that mass stays the same if you add up the relative formula masses of the substances on each side of a balanced symbol equation.
5) The total M_r of all the reactants will be the same as the total M_r of the products.

If you're not sure what the big numbers and the little numbers in reaction equations mean, see p.98 and 99.

EXAMPLE

Show that mass is conserved in this reaction: $2Li + F_2 \rightarrow 2LiF$.
Relative atomic masses (A_r): Li = 7, F = 19

1) Add up the relative formula masses on the left-hand side of the equation.

$2 \times A_r(Li) + 2 \times A_r(F) = (2 \times 7) + (2 \times 19)$
$= 14 + 38$
$= 52$

2) Add up the relative formula masses on the right-hand side of the equation.

$2 \times M_r(LiF) = 2 \times (7 + 19)$
$= 2 \times 26$
$= 52$

The total M_r on the left-hand side of the equation is the same as the total M_r on the right-hand side, so mass is conserved.

You can Calculate the Mass of a Reactant or Product

1) You can use the idea of conservation of mass to work out the mass of a reactant or product in a reaction.
2) You need to know the masses of all the reactants and products except for one.
3) You can work out the total mass of everything on one side of the equation.
4) You can also work out the total mass of everything on the other side of the equation, except for the thing you don't know the mass of.
5) The mass of the thing you don't know is the difference between these two totals.

EXAMPLE

6 g of magnesium completely reacts with 4 g of oxygen in the following reaction:
$2Mg + O_2 \rightarrow 2MgO$
What mass of magnesium oxide is formed?

1) Find the total mass of reactants.

$4 + 6 = 10$ g

2) Magnesium oxide is the only product. So the mass of products you do know is 0 g.

Mass of magnesium oxide = 10 − 0 = 10 g

Not eating your potatoes — that's mash conservation...

Never, ever forget that, in a reaction, the total mass of reactants is the same as the total mass of products.

Q1 Show that mass is conserved in the reaction: $H_2SO_{4(aq)} + 2NaOH_{(aq)} \rightarrow Na_2SO_{4(aq)} + 2H_2O_{(l)}$
$A_r(H) = 1$, $A_r(O) = 16$, $A_r(Na) = 23$, $A_r(S) = 32$ [5 marks]

Q1 Video Solution

More on Conservation of Mass

Even though mass is always (always) conserved in a reaction, sometimes you can carry out an experiment where the mass of the reaction container changes. Time to find out why...

If the Mass Seems to Change, There's Usually a Gas Involved

In some experiments, the mass of an unsealed reaction container might change during a reaction. This usually happens for one of two reasons...

1) If One of the Reactants is a Gas, the Mass Could Go Up

If the mass goes up, it's probably because one of the things that reacts is a gas that's found in air (e.g. oxygen) and all the things that are made are solids, liquids or in solution.

1) Before the reaction, the gas is floating around in the air. It's there, but it's not trapped in the reaction container. This means you can't measure its mass.
2) When the gas reacts, its atoms become part of the product, which is held inside the reaction container.
3) So the total mass of the stuff inside the reaction container goes up.

- When a metal reacts with oxygen in an unsealed container, the mass of the container goes up.
- This is because the mass of the oxygen atoms isn't measured when they're part of the gas, but it is when they're in the metal oxide.

$$\text{metal}_{(s)} + \text{oxygen}_{(g)} \rightarrow \text{metal oxide}_{(s)}$$

Remember from the particle model on page 121 that a gas will spread out to fill any container it's in. So if the reaction container isn't sealed, the gas will escape into the air.

2) If One of the Products is a Gas, the Mass Could Go Down

If the mass goes down, it's probably because one of the products is a gas and all the things that react are solids, liquids or in solution.

1) Before the reaction, all the reactants are held in the reaction container.
2) If the container isn't sealed, then the gas can escape from the reaction container as it's formed.
3) It's no longer trapped in the reaction container, so you can't measure its mass.
4) This means the total mass of the stuff inside the reaction container goes down.



- When a metal carbonate is heated, it can break down to form a metal oxide and carbon dioxide gas.
- When this happens, the mass of the reaction container will go down if it isn't sealed.
- But really, the mass of the metal oxide and the carbon dioxide formed will be the same as the mass of the metal carbonate.

$$\text{metal carbonate}_{(s)} \rightarrow \text{metal oxide}_{(s)} + \text{carbon dioxide}_{(g)}$$

Reactions where substances are heated and break down are called thermal decomposition reactions.

Talking with a pal about grams — it's a mass conversation...

If all this information is escaping from your brain, read the page again and then try these questions...

Q1 During a reaction, the mass in a reaction container increases.
What does this tell you about the states of matter of the products and reactants? [2 marks]

Q2 A scientist carries out the reaction below. She does it in an unsealed reaction container:
$2Na_{(s)} + 2HCl_{(aq)} \rightarrow 2NaCl_{(aq)} + H_{2(g)}$
Predict how the mass of the reaction container will change as the reaction takes place. [1 mark]

Q1 Video Solution

Concentrations of Solutions

Lots of reactions take place between substances that are dissolved in a solution. And sometimes it's useful to find out the mass of a substance that's dissolved in a solution. Hold onto your hats and concentrate...

Concentration is a Measure of How Crowded Things Are

1) The amount of a substance (e.g. the mass) in a certain volume of a solution is called its concentration.
2) The more substance that's dissolved in a certain volume, the more concentrated the solution.

Concentration can be Measured in g/dm^3

1) You can find the concentration of a solution if you know the mass of the substance dissolved and the volume of the solution.
2) The units will be units of mass/units of volume. For example, g/dm^3.
3) Here's how to calculate the concentration of a solution in grams per decimetre cubed (g/dm^3):

$$\text{concentration (in g/dm}^3\text{)} = \frac{\text{mass of dissolved substance (in g)}}{\text{volume of solvent (in dm}^3\text{)}}$$

The thing that dissolves the solid is called a 'solvent'. The solid that dissolves in the solvent is called a 'solute'.

EXAMPLES

a) 30 g of sodium chloride is dissolved in 0.2 dm^3 of water. What's the concentration of this solution in g/dm^3?

Put the numbers into the formula to calculate the concentration.

$$\text{concentration} = \frac{30}{0.2} = 150 \text{ g/dm}^3$$



Gavin wasn't great at concentration.

b) 15 g of salt in 500 cm^3 of water. What's the concentration of this solution in g/dm^3?

1) The units of the volume need to be dm^3 so that the units of concentration are in g/dm^3. So make the units of volume dm^3 by dividing by 1000:

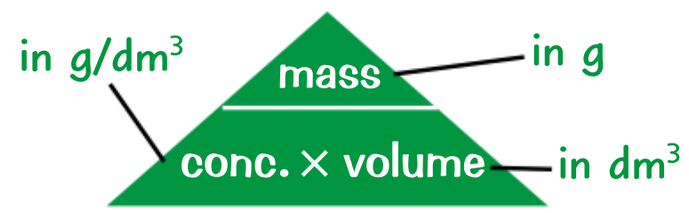
$$500 \div 1000 = 0.5 \text{ dm}^3$$

1 dm^3 = 1000 cm^3

2) Now you've got the mass and the volume in the right units, just stick them in the formula:

$$\text{concentration} = \frac{15}{0.5} = 30 \text{ g/dm}^3$$

4) You can rearrange the equation above to find the mass of substance dissolved in a certain volume of solution if you know its concentration. Here's a formula triangle to help with rearranging the equation:



5) To use the formula triangle, just cover up the thing you want to find with your finger and write down what's left showing.

When you measure something like the mass of a substance or the volume of a solution, there's always some uncertainty to the measurement. You can calculate this uncertainty from a range — see pages 6 and 10 for more.

EXAMPLE

A solution of magnesium chloride has a concentration of 24 g/dm^3. What mass of magnesium chloride is there in 0.40 dm^3 of this solution?

1) You want to find the mass. So cover up 'mass' in the formula triangle. This leaves 'concentration × volume'.

$$\text{mass} = \text{conc.} \times \text{volume}$$

2) Use this equation to calculate the mass:

$$\text{mass} = 24 \times 0.40 = 9.6 \text{ g}$$

CGP Revision Guides — not from concentrate...

Learning that formula could be a useful way to spend a few minutes. As could eating a biscuit.

Q1 Calculate the concentration, in g/dm^3, of a solution that contains 0.6 g of salt in 15 cm^3 of solvent. [2 marks]

Q1 Video Solution

Revision Questions for Topics C2 & C3

Now you've finished Topics C2 and C3, I bet I can guess what you want next. Some questions to test how much of these lovely topics you can remember...

- Try these questions and tick off each one when you get it right.
- When you're completely happy with a sub-topic, tick it off.

For even more practice, try the Retrieval Quizzes for Topics C2 and C3 — just scan the QR codes!

Ions and Ionic Compounds (p.113-115) ☑

1) Do elements from Group 1 form positive or negative ions?
2) What's the charge on the ions formed by Group 7 elements?
3) What type of bond is formed when a metal reacts with a non-metal?
4) Draw dot and cross diagrams to show the formation of:
   a) sodium chloride b) magnesium oxide c) magnesium chloride
5) Give one advantage and one disadvantage of using a ball and stick model to show the structure of an ionic compound.
6) List three properties of ionic compounds.

Covalent Substances (p.116-119) ☑

7) How do covalent bonds form?
8) Draw dot and cross diagrams showing the bonding in a molecule of:
   a) hydrogen (H_2) b) water (H_2O) c) hydrogen chloride (HCl)
9) Explain why simple molecular compounds usually have low melting and boiling points.
10) What type of bonds form between the atoms in a polymer?
11) Give three examples of giant covalent substances.
12) Explain why graphite can conduct electricity.
13) What was the first fullerene to be discovered?

Metallic Bonding (p.120) ☑

14) Explain why substances with metallic structures usually have high melting points.
15) Explain why substances with metallic structures can conduct electricity.
16) What is an alloy?

States of Matter (p.121-122) ☑

17) Name the three states of matter.
18) What is the state symbol of an aqueous substance?
19) What is the name of the temperature at which a liquid becomes a gas?
20) What state will a substance be in if the temperature is above its boiling point?

Topic C2 Quiz

Masses in Reactions (p.123-125) ☑

21) How do you calculate the relative formula mass, M_r of a substance?
22) Why is mass conserved during a reaction?
23) Suggest why the mass of a reaction container might decrease during a reaction.

Concentrations of Solutions (p.126) ☑

24) What is concentration?
25) Give the equation for working out the concentration of a solution in g/dm^3.

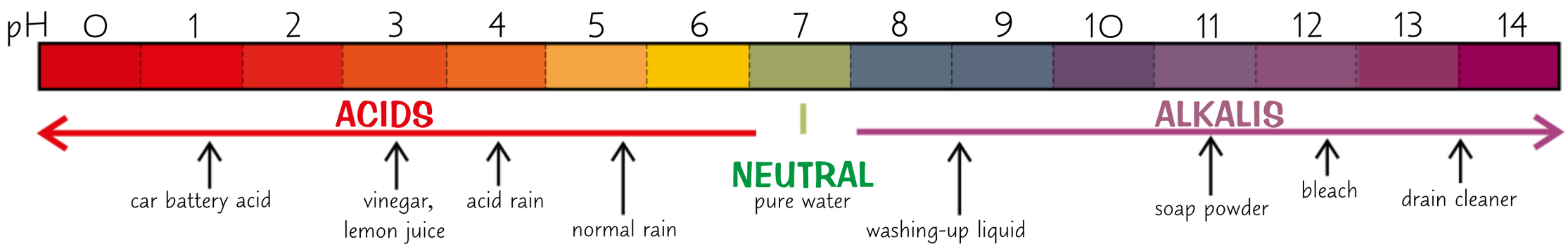
Topic C3 Quiz

Acids and Bases

Testing the pH of a solution means using an indicator — and that means pretty colours...

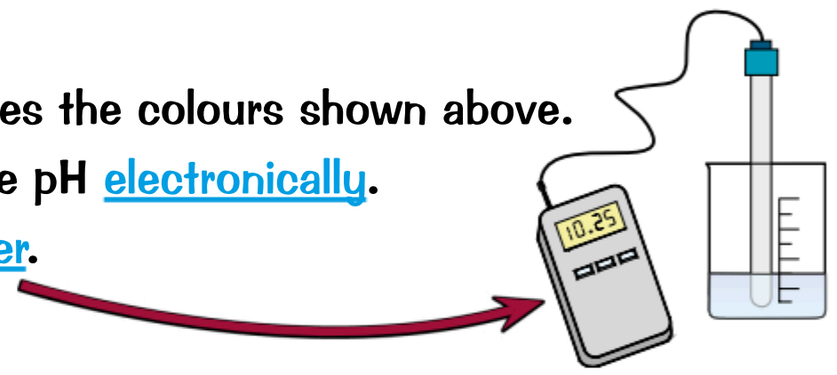
The pH Scale Goes From 0 to 14

1) The pH scale is a measure of how acidic or alkaline a solution is.
2) The lower the pH of a solution, the more acidic it is.
3) The higher the pH of a solution, the more alkaline it is.
4) A neutral substance (e.g. pure water) has pH 7.



You Can Measure the pH of a Solution

1) An indicator is a dye that changes colour depending on whether it's above or below a certain pH.
2) Wide range indicators are substances that gradually change colour as pH changes.
3) They're useful for estimating the pH of a solution.
4) For example, universal indicator is a wide range indicator. It gives the colours shown above.
5) A pH probe attached to a pH meter can also be used to measure pH electronically.
6) The probe is put in the solution and the pH is shown as a number.
This means it's more accurate than an indicator.



Acids and Bases Neutralise Each Other

1) When acids dissolve in water, they form solutions with a pH of less than 7. Acids form H^+ ions in water.
2) Bases have pHs greater than 7.
3) Alkalis are bases that dissolve in water to form solutions with a pH greater than 7.
Alkalis form OH^- ions in water. For example, soluble metal hydroxides are alkalis.



- The reaction between acids and bases is called neutralisation:

$$\text{acid} + \text{base} \rightarrow \text{salt} + \text{water}$$

- Neutralisation between acids and alkalis can be shown using H^+ and OH^- ions like this:

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

- The products of neutralisation reactions have a pH of 7.
This means they're neutral.

Hydrogen (H^+) ions react with hydroxide (OH^-) ions to produce water.

4) You can add an indicator to the acid or alkali you're neutralising. Then gradually add the other substance. The indicator will change colour when the neutralisation reaction is over.
5) If you use Universal indicator, add the substance until the Universal indicator is green.
This is when the pH of the solution is neutral.

This page should have all bases covered...

pHew, you finished the page... So here's an interesting(ish) fact about pH — your skin is slightly acidic (pH 5.5).

Q1 What colour would you expect Universal indicator to turn if you added it to lemon juice? [1 mark]

Q2 The pH of a solution is 8. Is the solution acidic or alkaline? [1 mark]

Reactions of Acids

Remember neutralisation reactions from the previous page? Well, there's more about them coming up...

Metal Oxides and Metal Hydroxides are Bases

1) Metal oxides and metal hydroxides react with acids in neutralisation reactions to form a salt and water.
2) The salt that forms depends upon the acid and the metal ion in the oxide or hydroxide.
3) HCl reacts to form chlorides, H_2SO_4 reacts to form sulfates and HNO_3 reacts to form nitrates.

hydrochloric acid	+	copper oxide	→	copper chloride	+	water
$2HCl$	+	CuO	→	$CuCl_2$	+	H_2O
sulfuric acid	+	potassium hydroxide	→	potassium sulfate	+	water
H_2SO_4	+	$2KOH$	→	K_2SO_4	+	$2H_2O$
nitric acid	+	sodium hydroxide	→	sodium nitrate	+	water
HNO_3	+	$NaOH$	→	$NaNO_3$	+	H_2O

Acids and Metal Carbonates Produce Carbon Dioxide

Metal carbonates are also bases. They react with acids to produce a salt, water and carbon dioxide.

hydrochloric acid	+	sodium carbonate	→	sodium chloride	+	water	+	carbon dioxide
$2HCl$	+	Na_2CO_3	→	$2NaCl$	+	H_2O	+	CO_2
sulfuric acid	+	calcium carbonate	→	calcium sulfate	+	water	+	carbon dioxide
H_2SO_4	+	$CaCO_3$	→	$CaSO_4$	+	H_2O	+	CO_2

You can Make Soluble Salts Using an Insoluble Base

PRACTICAL

1) If you react an acid with an insoluble base or a metal, you can make a soluble salt.
2) First, pick the acid that contains the same negative ion as the salt you want to make.
For example, to make copper chloride, you'd choose hydrochloric acid.
3) Then pick an insoluble base with the same positive ion as the salt you want to make. You could use an insoluble metal oxide, hydroxide, or carbonate.
4) So to make copper chloride, you'd choose copper oxide, copper hydroxide or copper carbonate.
Here's the equation for making copper chloride from hydrochloric acid and copper oxide:

$$CuO_{(s)} + 2HCl_{(aq)} \rightarrow CuCl_{2\,(aq)} + H_2O_{(l)}$$

5) Gently warm the dilute acid using a Bunsen burner, then turn off the Bunsen burner.
6) Add the insoluble base to the acid until no more reacts (you'll see the solid at the bottom of the flask).
7) Filter out the solid that hasn't reacted to get the salt solution (see p.102).
8) To get pure, solid crystals of the salt, you need to crystallise it (see p.102).
9) To do this, gently heat the solution using a water bath or an electric heater.
Some of the water will evaporate. Stop heating the solution and leave it to cool.
10) Crystals of the salt should form, which can be filtered out of the solution and then dried.

AHHHHH so many reactions...

There might be lots of reactions on this page, but I've treated you to a nice practical as well. You're welcome.

Q1 Calcium carbonate is added to hydrochloric acid.
Write the word equation and the balanced symbol equation for the reaction that occurs. [3 marks]

Q1 Video Solution

The Reactivity Series and Extracting Metals

You can place metals in order of reactivity. This can be a lot more useful than it sounds, promise.

The Reactivity Series — How Easily a Metal Reacts

1) The reactivity series lists metals in order of how reactive they are (their reactivity).
2) Metals react to form positive ions.
3) So for metals, their reactivity depends on how easily they lose electrons and form positive ions.
4) The higher up the reactivity series a metal is, the more easily it forms positive ions.

Carbon and hydrogen are non-metals but are often included in the reactivity series.

Potassium	K	Very Reactive
Sodium	Na	
Lithium	Li	
Calcium	Ca	
Magnesium	Mg	Fairly Reactive
Carbon	C	
Zinc	Zn	
Iron	Fe	
Hydrogen	H	Not very Reactive
Copper	Cu	

Metals Often Have to be Separated from their Oxides

1) Lots of common metals, like iron and aluminium, react with oxygen to form oxides.
2) This process is an example of oxidation.
3) These oxides are often the ores that the metals are removed (extracted) from.
4) A reaction that separates a metal from its oxide is called a reduction reaction.

An ore is a type of rock that contains metal compounds. Most metals are found in the earth as ores.

Oxidation = Gain of Oxygen

E.g. magnesium is oxidised to make magnesium oxide.

$2Mg + O_2 \rightarrow 2MgO$

Reduction = Loss of Oxygen

E.g. copper oxide is reduced to copper.

$2CuO + C \rightarrow 2Cu + CO_2$

Some Metals can be Extracted by Reduction with Carbon

1) Some metals can be extracted from their ores using a reaction with carbon.
2) In this reaction, the ore is reduced as oxygen is removed from it. Carbon gains oxygen, so it is oxidised.
3) For example: iron(III) oxide + carbon → iron + carbon dioxide $\quad 2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$

Iron has lost oxygen. Carbon has gained oxygen.

4) The reactivity series can tell you if a metal can be extracted with carbon.

- Metals above carbon in the reactivity series are extracted using electrolysis (p.132). This is expensive as it takes lots of energy to melt the ore and to produce the electricity.
- Electrolysis is also used to extract metals that react with carbon.
- Metals below carbon in the reactivity series can be extracted by reduction using carbon. For example, iron oxide is reduced in a blast furnace to make iron.
- This is because carbon can only take the oxygen away from metals which are less reactive than carbon itself is.

Make sure you can explain how and why different metals are extracted in different ways.

5) Some metals are so unreactive they are found in the earth as the metal itself. For example, gold.

Are you going to revise this page, ore what?

From the metals in the reactivity series above, only zinc, iron and copper can be extracted with carbon.

Q1 Write a balanced equation for the reduction of lead oxide, PbO, by carbon, C. [2 marks]

Q2 A mining company tried to extract calcium from its ore by reduction with carbon. The process did not work. Explain why. [1 mark]

Q1 Video Solution

Reactions of Metals

Metals react to form salts. And you, my friend, need to be able to predict the salt that'll form from a reaction.

Metals React With Acids

1) Some metals react with acids to produce a salt and hydrogen gas.

Acid + Metal → Salt + Hydrogen

HCl reacts to form chloride salts, H_2SO_4 reacts to form sulfate salts.

- hydrochloric acid + magnesium → magnesium chloride + hydrogen — $2HCl + Mg \rightarrow MgCl_2 + H_2$
- sulfuric acid + zinc → zinc sulfate + hydrogen — $H_2SO_4 + Zn \rightarrow ZnSO_4 + H_2$
- hydrochloric acid + iron → iron chloride + hydrogen — $2HCl + Fe \rightarrow FeCl_2 + H_2$

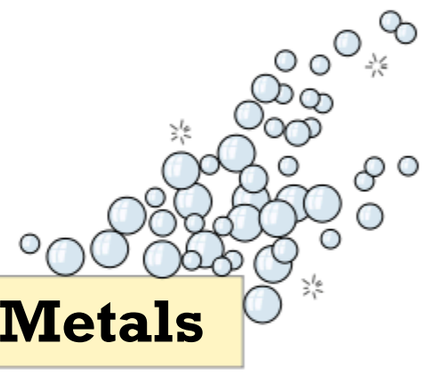
2) Very reactive metals like potassium, sodium, lithium and calcium react explosively with acids.
3) Less reactive metals such as magnesium, zinc and iron react less violently with acids.
4) In general, copper won't react with cold, dilute acids.

Metals Also React with Water

1) Many metals will also react with water.

Metal + Water → Metal Hydroxide + Hydrogen

2) For example, calcium: $Ca_{(s)} + 2H_2O_{(l)} \rightarrow Ca(OH)_{2(aq)} + H_{2(g)}$
3) The metals potassium, sodium, lithium and calcium will all react with water.
4) Less reactive metals like zinc, iron and copper won't react with water.



You Can Work Out a Reactivity Series from the Reactions of Metals

1) If you put metals in order from most reactive to least reactive based on their reactions with either an acid or water, the order you get is the reactivity series (see the previous page).
2) To compare the reactivities of metals, you could watch how quickly bubbles of hydrogen are formed in their reactions with water or acid. The more reactive the metal, the faster the bubbles will form.
3) You can also measure the temperature change of the reaction in a set time period. The more reactive the metal, the greater the temperature change should be.

For these experiments to be fair, the mass and surface area of the metals should be the same each time.

More Reactive Metals can Displace Less Reactive Metals from Salts

1) Displacement reactions involve one metal kicking another one out of a compound. Here's the rule:

A MORE REACTIVE metal will displace a LESS REACTIVE metal from its compound.

2) For example, iron is more reactive than copper.
So if you add solid iron to copper sulfate solution, you get a displacement reaction.
3) The iron kicks the copper out of copper sulfate. You end up with iron sulfate solution and copper solid.

iron + copper sulfate → iron sulfate + copper $Fe_{(s)} + CuSO_{4(aq)} \rightarrow FeSO_{4(aq)} + Cu_{(s)}$

New information displaces old information from my brain...

See, experiments aren't just for fun — they can give you an insight into the relative reactivities of elements.

Q1 Give the balanced equation, including state symbols, for the reaction of sodium and water. [3 marks]

Q1 Video Solution

Electrolysis

Electrolysis uses electricity to cause a reaction. It's actually pretty cool. No, really...

Electrolysis Means 'Splitting Up with Electricity'



1) An electrolyte is just a liquid or solution that can conduct electricity.
For example, an ionic compound that's either dissolved in water, or melted so it's a liquid.
2) An electrode is a solid that is put in the electrolyte and conducts electricity.
3) In electrolysis, an electric current is passed through an electrolyte.
The ions move towards the electrodes, where they react. The compound then breaks down.
4) Positive ions in the electrolyte move towards the cathode (negative electrode). Here, they gain electrons.
5) Negative ions in the electrolyte move towards the anode (positive electrode). Here, they lose electrons.
6) The ions form the uncharged element. The ions are said to be discharged from the electrolyte.
7) A flow of charge is created through the electrolyte as the ions travel to the electrodes.

Electrolysis of Molten Ionic Solids Forms Elements

1) Molten ionic compounds can be electrolysed because the ions can move freely and conduct electricity.
2) Molten ionic liquids are always broken up into their elements.
3) The metal forms at the cathode. The non-metal is formed at the anode.

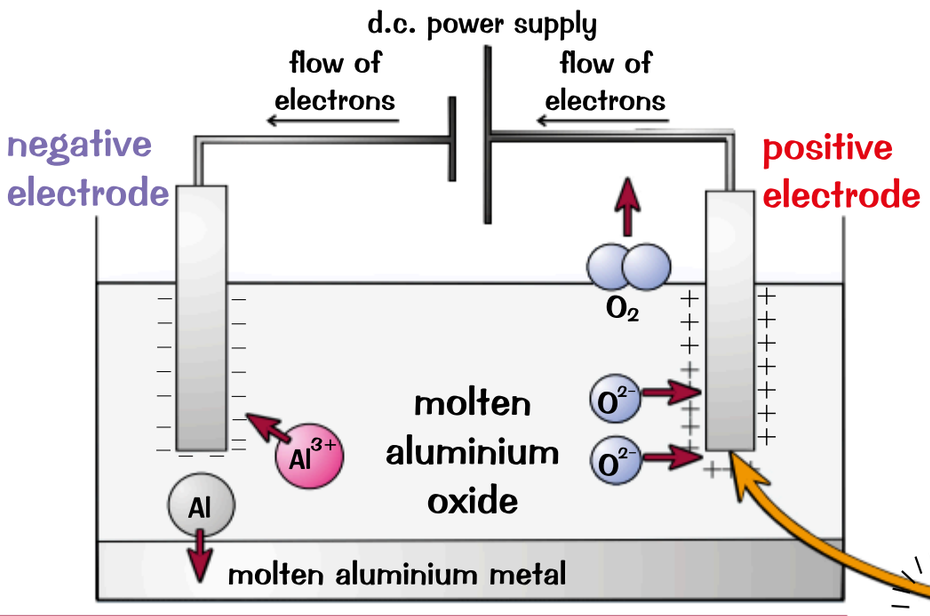
The electrodes should be inert (unreactive) so they don't react with the electrolyte.

When molten lead bromide is electrolysed, lead forms at the cathode and bromine forms at the anode.

Metals can be Extracted From Their Ores Using Electrolysis

1) Aluminium is extracted from an ore that contains aluminium oxide, Al_2O_3.
2) Aluminium oxide has a very high melting point so it's mixed with a substance called cryolite. This lowers the melting point.
3) The positive Al^{3+} ions are attracted to the negative electrode where they form aluminium atoms.
4) The negative O^{2-} ions are attracted to the positive electrode where they react to form O_2 molecules.

1) Metals form positive ions.
2) They're attracted to the negative electrode.
3) Aluminium is produced at the negative electrode.



1) Non-metals form negative ions.
2) They're attracted to the positive electrode.
3) Oxygen is produced at the positive electrode.

The anode is made of graphite (carbon). It can react with oxygen to produce carbon dioxide. This means it needs to be replaced regularly.

Overall Equation:

$$\text{aluminium oxide} \rightarrow \text{aluminium} + \text{oxygen}$$
$$2Al_2O_{3(l)} \rightarrow 4Al_{(l)} + 3O_{2(g)}$$

Faster shopping at the supermarket — use Electrolleys...

When you electrolyse a molten salt, the non-metal forms at the anode and the metal forms at the cathode.

Q1 A student carries out electrolysis on molten calcium chloride. What is produced at:
a) the anode? b) the cathode? [2 marks]

Q1 Video Solution

Electrolysis of Aqueous Solutions

When you electrolyse a salt that's dissolved in water, you also have to think about the ions from the water.

You Can Predict what Forms when a Salt Solution is Electrolysed

1) Water can break down into H^+ and OH^- ions.

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

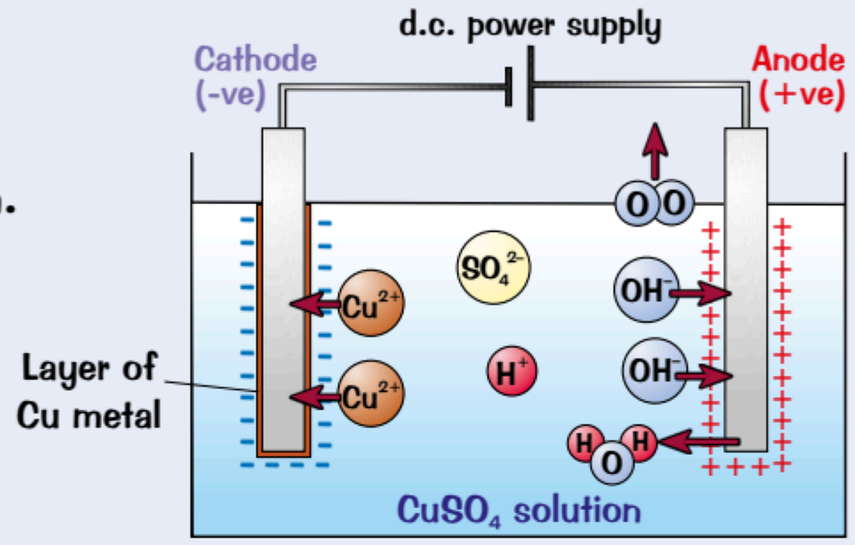
2) So in solutions that contain water, there will be the ions from the ionic compound as well as hydrogen ions (H^+) and hydroxide ions (OH^-) from the water.
3) H^+ ions and metal ions will move to the cathode.
4) If the metal's more reactive than hydrogen, hydrogen gas will form.
5) If the metal is less reactive than hydrogen, a solid layer of the pure metal will form.
6) If the salt contains halide ions (Cl^-, Br^-, I^-), chlorine, bromine or iodine will form at the anode.
7) If no halide ions are present, then the OH^- ions lose electrons and oxygen will form at the anode.

The ⇌ symbol in this reaction shows that it's reversible. For more about reversible reactions see p.144.

A solution of copper(II) sulfate ($CuSO_4$) contains four different ions: Cu^{2+}, SO_4^{2-}, H^+ and OH^-.

At the cathode:

- Copper metal is less reactive than hydrogen.
- So copper metal is produced.



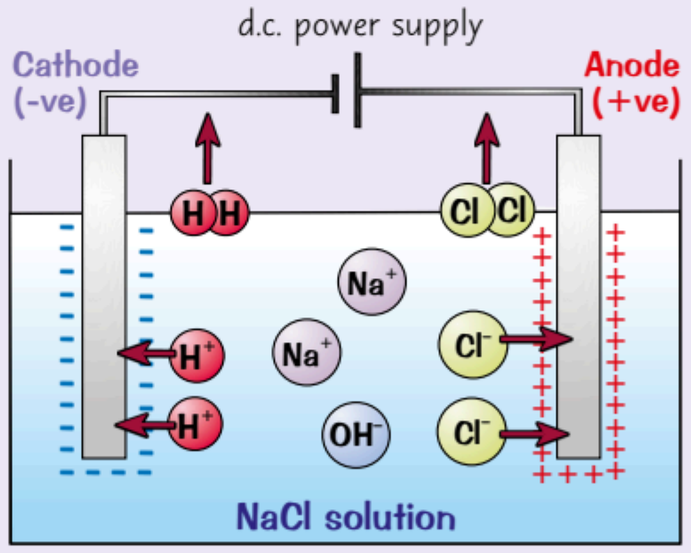
At the anode:

- There aren't any halide ions present.
- So oxygen and water are produced.

A solution of sodium chloride (NaCl) contains four different ions: Na^+, Cl^-, OH^- and H^+.

At the cathode:

- Sodium metal is more reactive than hydrogen.
- So hydrogen gas is produced.



At the anode:

- Chloride ions are in the solution.
- So chlorine gas is produced.

8) You can set up an electrolysis experiment in the lab like the set-up on page 236.

PRACTICAL

9) This will let you collect any gases that form in the reaction.
10) Once the experiment is finished you can test the gases to work out what they are.
    - Chlorine bleaches damp litmus paper, turning it white.
    - Hydrogen makes a "squeaky pop" with a lighted splint.
    - Oxygen will relight a glowing splint.

For more on tests for gases, turn to page 153.

I wrote a poem about my tabby — it was a cat ode...

So it's kinda confusing this electrolysis business — you need to take it slow and make sure you get it.

Q1 An aqueous solution of copper bromide, $CuBr_2$, is electrolysed using inert electrodes.
State what is produced at: a) the anode, b) the cathode. [2 marks]

Q1 Video Solution

Exothermic and Endothermic Reactions

In all chemical reactions, there's a change in energy. This means that when chemicals get together, things either heat up or cool right off. I'll give you a heads up — this page is a good 'un.

Energy is Moved Around in Chemical Reactions

1) Chemicals store a certain amount of energy — and different chemicals store different amounts.
2) Sometimes, the products of a reaction store more energy than the reactants.
This means that the products have taken in energy from the surroundings during the reaction.
3) But if the products store less energy, then the extra energy was transferred (given out) to the surroundings during the reaction.
4) The amount of energy transferred is the difference between the energy of the products and the energy of the reactants.
5) The overall amount of energy doesn't change. This is because energy stays the same (is conserved) in reactions — it can't be made or destroyed, only moved around.
6) This means the amount of energy in the universe always stays the same.

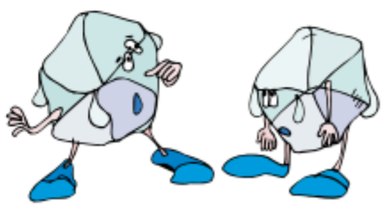
In an Exothermic Reaction, Energy is Given Out

1) An EXOTHERMIC reaction is one which gives out energy to the surroundings.
2) This is shown by a rise in temperature of the surroundings.
3) Examples of exothermic reactions include:
   - Burning fuels — also called COMBUSTION.
   - Neutralisation reactions (acid + alkali).
   - Many oxidation reactions.
4) Exothermic reactions have lots of everyday uses. For example:
   - Some hand warmers use an exothermic reaction to release energy.
   - Self heating cans of hot chocolate and coffee also use exothermic reactions between chemicals in their bases.

In an Endothermic Reaction, Energy is Taken In

1) An ENDOTHERMIC reaction is one which takes in energy from the surroundings.
2) This is shown by a fall in temperature of the surroundings.
3) Examples of endothermic reactions include:
   - The reaction between citric acid and sodium hydrogencarbonate.
   - Thermal decomposition (when a substance breaks down when it's heated).
4) Endothermic reactions also have everyday uses. For example:

Endothermic reactions are used in some sports injury packs. The chemical reaction allows the pack to become instantly cooler without having to put it in the freezer.



Physical processes can also take in or release energy. E.g. freezing is an exothermic process, melting is endothermic.

Right, so burning gives out heat — really...

Remember, "exo-" = exit, "-thermic" = heat, so an exothermic reaction is one that gives out heat — and endothermic means just the opposite. To make sure you really understand these terms, try this question.

Q1 A student has two solutions at the same temperature. She mixes the solutions together and they react. The temperature of the reaction mixture goes up. Is the reaction exothermic or endothermic? [1 mark]

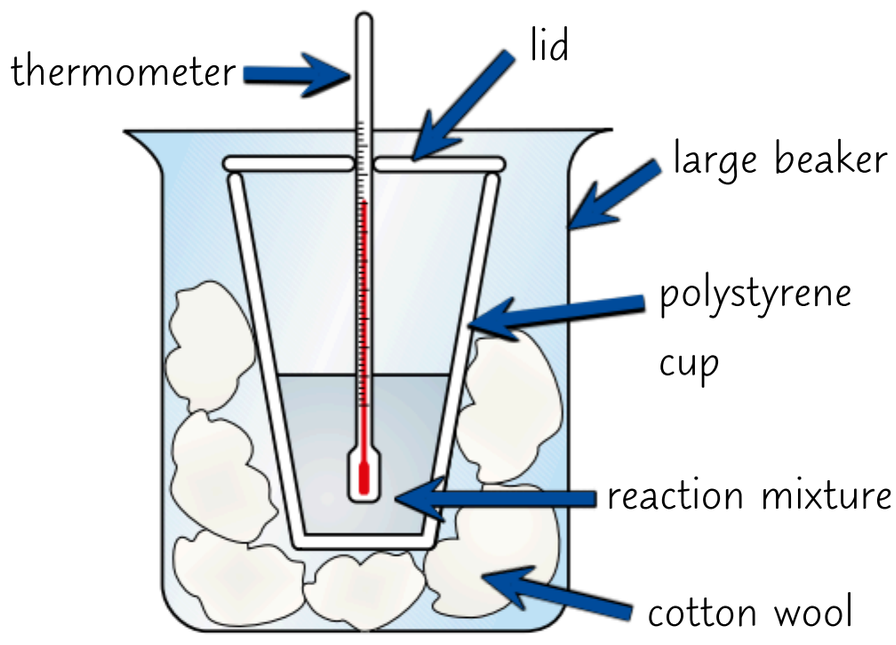
Measuring Energy Changes

PRACTICAL

Sometimes it's not enough to just know if a reaction is endothermic or exothermic.
You may also need to measure how much the temperature changes during a reaction. Fun, fun, fun...

Energy Transfer can be Measured

1) You can use an experiment to investigate the temperature change of a chemical reaction.
2) You can do this by taking the temperature of the reactants and mixing them in a polystyrene cup.
3) If the temperature of the solution rises during the reaction, record the highest temperature that it reaches.
   If the temperature of the solution falls during the reaction, record the lowest temperature that it reaches.
4) To find the temperature change, take away this temperature from the temperature of the reactants.
5) If the temperature goes up, the reaction's exothermic.
   If the temperature goes down, the reaction's endothermic.
6) The biggest problem with temperature measurements is the amount of energy lost to the surroundings.
7) You can reduce this by putting a lid on the polystyrene cup and putting the cup into a beaker of cotton wool.
8) This method works for a number of different reactions.
   For example:
   - neutralisation reactions.
   - reactions between metals and acids.
   - reactions between acids and carbonates.
   - displacement reactions of metals.



The Temperature Change of a Reaction Depends on Different Variables

1) You can also use this method to investigate what effect different variables have on the temperature change — e.g. the mass or concentration of the reactants used.
2) Here's how you could test the effect of acid concentration on the temperature change of a neutralisation reaction between hydrochloric acid (HCl) and sodium hydroxide (NaOH):

- Put 25 cm^3 each of 10 g/dm^3 hydrochloric acid and sodium hydroxide in separate beakers.
- Place the beakers in a water bath set to 25 °C until they are both at the same temperature (25 °C).
- Add the HCl followed by the NaOH to a polystyrene cup with a lid — as in the diagram above.
- Take the temperature of the mixture every 30 seconds, and record the highest temperature.
- Use your results to work out the temperature change of the reaction.
- Repeat these steps using 20 g/dm^3 and then 30 g/dm^3 of hydrochloric acid.
  Then compare your results to see how acid concentration affects the temperature change of the reaction.

Energy transfer — make sure you take it all in...

Fluffy cotton wool doesn't sound very sciencey but it's pretty important. Best check to make sure you know why...

Q1 When measuring the temperature change of a reaction, why is it important to put the polystyrene cup in a beaker of cotton wool and to keep a lid on the cup? [1 mark]

Reaction Profiles

Reaction profiles are handy little diagrams which show you the changes in energy during a reaction.

Activation Energy is Needed to Start a Reaction

1) The activation energy is the minimum amount of energy the reactants need to have to react when they collide with each other.
2) The greater the activation energy, the more energy needed to start the reaction. This energy has to be given, e.g. by heating the reaction mixture.

There's more on activation energy and collision theory on pages 138-139.

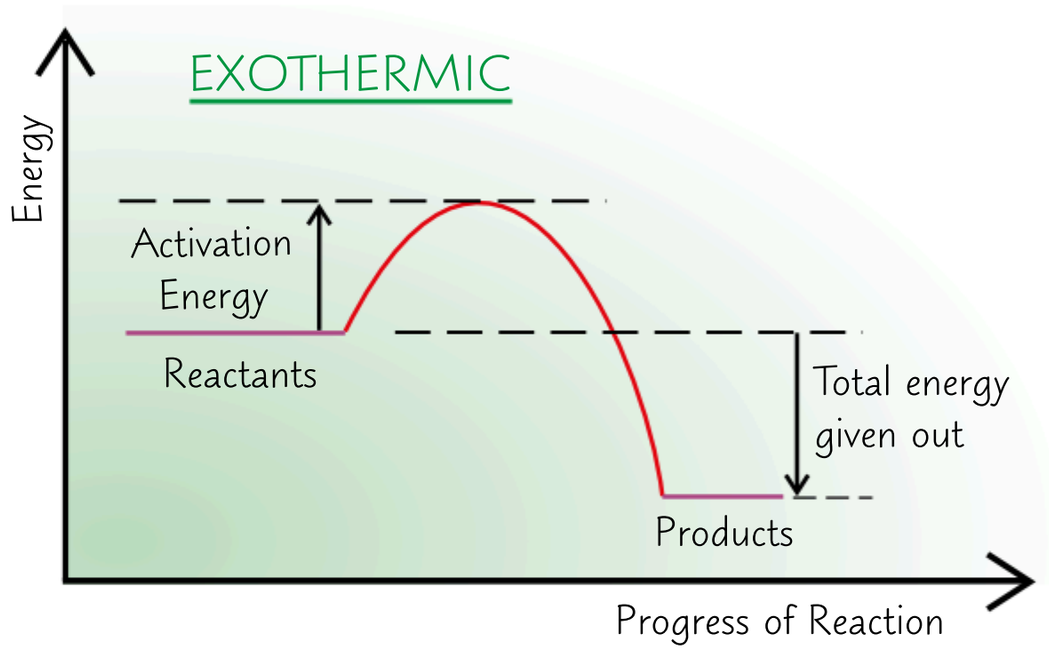
Reaction Profiles Show Energy Changes

Reaction profiles are diagrams that show the difference between the energies of the reactants and products in a reaction, and how the energy changes over the course of the reaction.

Reaction profiles are sometimes called energy level diagrams.

Exothermic Reactions

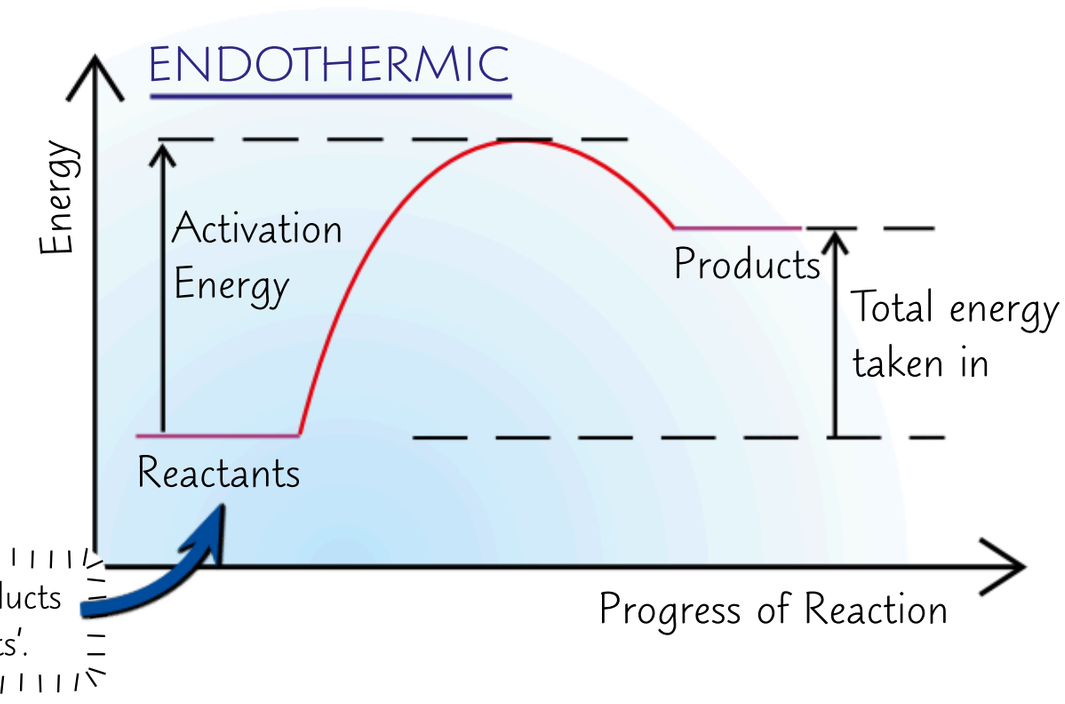
1) The reaction profile on the right shows an exothermic reaction.
2) You can tell because the products are at a lower energy than the reactants.
3) The difference in height between the reactants and the products shows the overall energy change in the reaction (the energy given out).
4) The rise in energy at the start shows the energy needed to start the reaction. This is the activation energy.



Endothermic Reactions

1) In this reaction profile, the products are at a higher energy than the reactants. So the reaction is endothermic.
2) The difference in height shows the overall energy change during the reaction (the energy taken in).
3) The rise in energy at the start is the activation energy.

You can also write the formulas for the reactants and products on the reaction profile instead of 'reactants' and 'products'.



The activation energy needed for me to get out of bed is huge...

Don't get confused by these diagrams. In an exothermic reaction the particles release energy to their surroundings — even though the reaction mixture gets warmer, the particles themselves have lost energy.

Q1 Here is the equation for the exothermic reaction between methane and oxygen:
$CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)}$. Draw a reaction profile for this reaction. [3 marks]

Q1 Video Solution

Revision Questions for Topics C4 & C5

That wraps up Topic C5. It's time to test what you know of Topics C4 and C5.

- Try these questions and tick off each one when you get it right.
- When you're completely happy with a sub-topic, tick it off.

For even more practice, try the Retrieval Quizzes for Topics C4 and C5 — just scan the QR codes!

Topic C4 Quiz

Acids and their Reactions (p.128-129) ☑

1) State whether the following pH values are acidic, alkaline or neutral.
   a) 9 b) 2 c) 7 d) 6
2) Give the general word equation for the reaction between an acid and a base.
3) Name the products that will form when hydrochloric acid reacts with sodium carbonate.

Reactions of Metals (p.130-131) ☑

4) Is zinc more or less reactive than iron?
5) What product forms when magnesium is oxidised by oxygen?
6) State where a metal will be in the reactivity series if it can be extracted from its oxide by reduction with carbon.
7) What is the general word equation for the reaction of a metal with an acid?
8) Complete the equation for the reaction of calcium with water: $Ca + ?H_2O \rightarrow ? + H_2$

Electrolysis (p.132-133) ☑

9) What is an electrolyte?
10) During electrolysis, what are the names for the positive electrode and the negative electrode?
11) Aluminium can be formed by electrolysing aluminium oxide. Which electrode is aluminium formed at?
12) A salt solution contains the ions of a metal that is more reactive than hydrogen. Will hydrogen gas be released if this solution is electrolysed?
13) A salt solution contains halide ions. Will oxygen gas be released if this solution is electrolysed?

Exothermic and Endothermic Reactions (p.134-136) ☑

Topic C5 Quiz

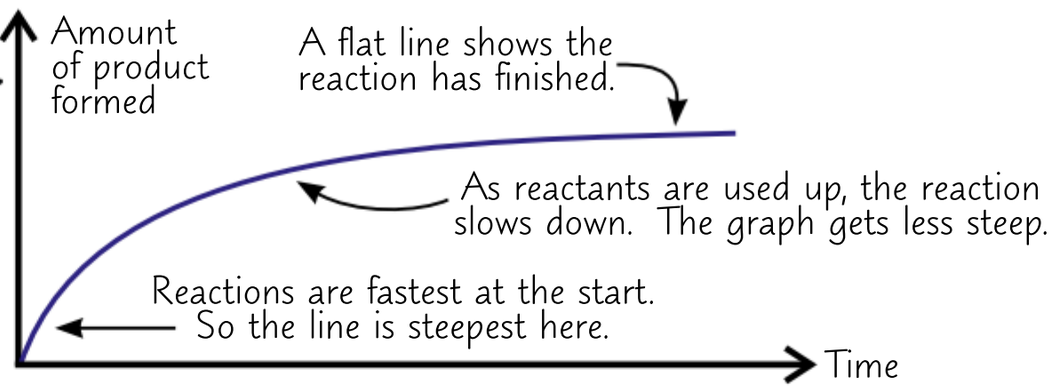
14) In an exothermic reaction is energy transferred to or from the surroundings?
15) Name two different types of reaction which are exothermic.
16) Define what is meant by an endothermic reaction.
17) Draw a diagram of the equipment you would use to measure the temperature change of a reaction.
18) What is the activation energy of a reaction?
19) Sketch an energy level diagram for an endothermic reaction.
20) Is the following statement true or false?
    In an endothermic reaction, the products of the reaction have more energy than the reactants.

Rates of Reaction

Rates of reaction are pretty important. In the chemical industry, the faster you make chemicals, the faster you make money (and the faster everyone gets to go home for tea).

The Speed of a Reaction is Called its Rate

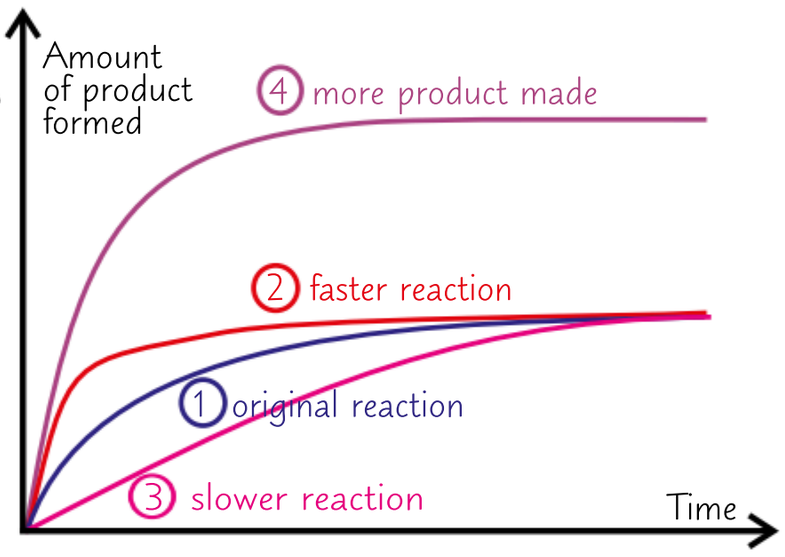
1) The rate of a chemical reaction is how fast the reactants are changed into products.
2) Some reactions are very slow, for example, rusting. Others, like burning, are fast.
3) Graphs can show you how the rate (speed) of a reaction changes.
4) The steeper the line on the graph, the faster the rate of reaction.
5) Over time the line becomes less steep as the reactants are used up.



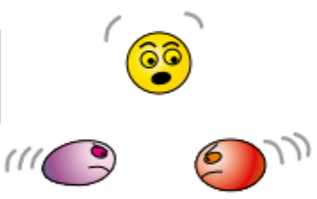
Reaction Rates Can Change when the Reaction Conditions Change

1) Faster reactions have steeper lines to begin with and become flat more quickly.
2) This graph shows how the speed of a particular reaction changes under different conditions.

- Line 1 shows the original reaction.
- Line 2 shows the same reaction taking place faster. It starts more steeply than line 1. It also goes flat sooner.
- Line 3 shows the same reaction taking place more slowly. It isn't as steep at the start as line 1 and goes flat later.
- Lines 1, 2 and 3 all meet at the same level. This shows that they all produce the same amount of product. They just take different times to produce it.
- Line 4 shows more product is formed. This can only happen if there were more reactants at the start.



Particles Must Collide with Enough Energy in Order to React



1) Reaction rates can be explained by an idea called collision theory.
2) Collision theory says that a reaction will only take place when particles collide (crash into each other).
3) The particles also have to have a certain amount of energy when they collide, otherwise they won't react.
4) The minimum (smallest) amount of energy they need is called the activation energy.
5) Collision theory can explain rates of reactions in a bit more detail too...

- The more often the particles collide, the faster the reaction will happen.
- For example, if the reactant particles in a certain reaction collide with enough energy twice as often, the reaction will happen twice as fast.
- The more energy the particles have, the faster the reaction will be.
- This is because there's more chance that they'll have at least the activation energy.

How often the particles collide is sometimes called the 'collision frequency'.



Want a fast reaction? Tickle your teacher. That should do it...

Lots of important stuff to learn here. Make sure you understand the basics of collision theory before you move on. It's simple really — for particles to react they have to collide with each other, with enough energy.

Q1 What is meant by the term activation energy? [1 mark]

Factors Affecting Rates of Reaction

I'd ask you to guess what this page is about, but the title pretty much says it all really. Read on...

The Rate of Reaction Depends on Four Things

1) Temperature.
2) Concentration of a solution (or pressure of a gas).
3) Surface area of a solid.
4) Whether a catalyst is used.

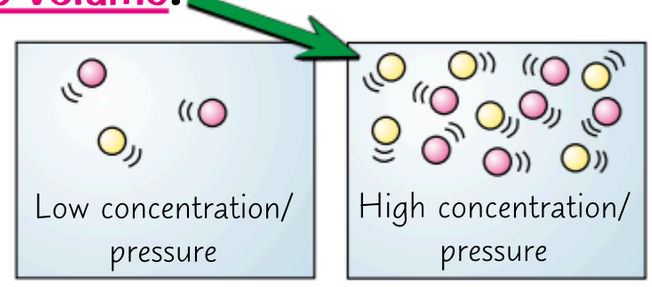
Increasing the Temperature Increases the Rate

1) When temperature increases, the particles move faster.
2) If they move faster, they collide more frequently (often).
3) They also have more energy, so more collisions have enough energy to make the reaction happen.

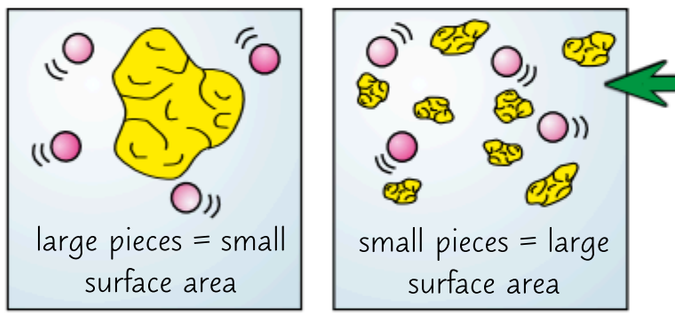
If particles collide twice as often with enough energy to react, the rate of reaction will be twice as fast. If they collide three times as often it'll be three times as fast.

Increasing the Concentration or Pressure Increases the Rate

1) If a solution is more concentrated, it has more particles in the same volume.
2) And when the pressure of a gas is increased, it means the same number of particles are now in a smaller space.
3) So collisions between the reactant particles are more frequent.



Increasing the Surface Area Increases the Rate

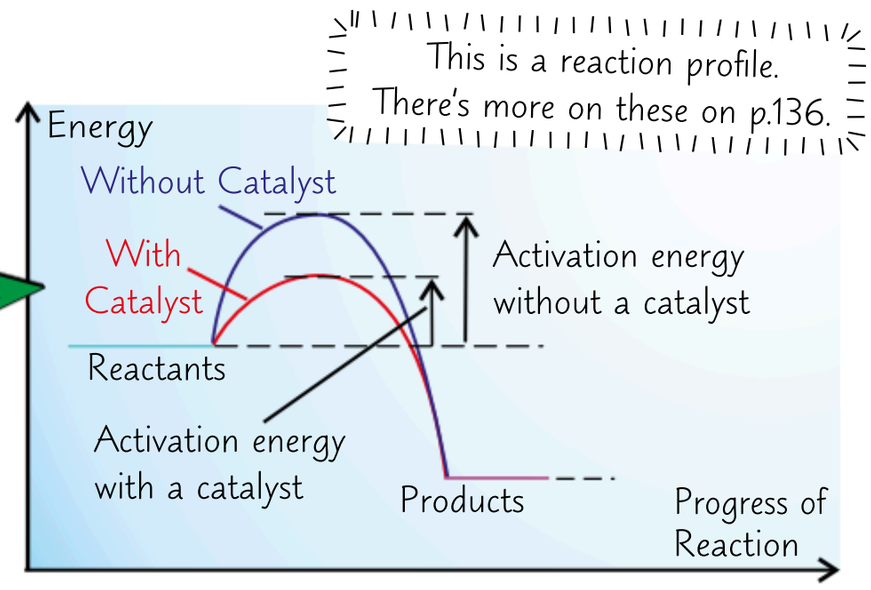


1) If one of the reactants is a solid, then breaking it up into smaller pieces will increase its surface area to volume ratio.
2) This means the same amount of solid has a bigger surface area.
3) So more of the solid's particles are available to particles of the other reactant. And collisions will be more frequent.

Using a Catalyst Increases the Rate

1) A catalyst is a substance that speeds up a reaction. None of it gets used up in the reaction.
2) This means it's not part of the reaction equation.
3) Different catalysts are needed for different reactions.
4) Catalysts work by providing a different pathway for a reaction. The new pathway has a lower activation energy, so less energy is needed for the reaction to happen.
5) Enzymes are biological catalysts — they catalyse reactions in living things.

This is a reaction profile. There's more on these on p.136.



So, the more students in a room, the greater their concentration...?

Write down the 4 factors that affect rate. Check they're right. Write them down again. Check again. Repeat.

Q1 In an experiment, a 2 g strip of magnesium ribbon is reacted with hydrochloric acid. The experiment is then repeated using 2 g of powdered magnesium. Everything else is kept the same. Which experiment would have the fastest rate? Explain your answer. [2 marks]

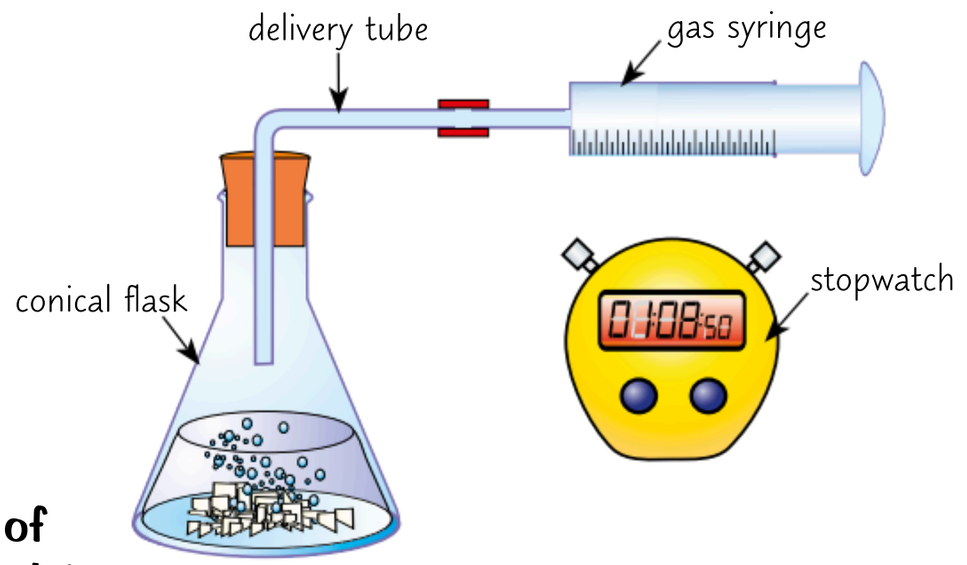
PRACTICAL

Measuring Rates of Reaction

All this talk about reaction rate is fine and dandy, but it's no good if you can't measure it. You can investigate how concentration affects the rate of a reaction by measuring the volume of gas given off in a reaction.

Marble Chips and Hydrochloric Acid React to Produce Carbon Dioxide Gas

1) Measure out a set volume of dilute hydrochloric acid using a measuring cylinder.
2) Carefully pour it into a conical flask.
3) Measure out a set mass of marble chips.
4) Add the marble chips to the flask and quickly attach a delivery tube and gas syringe to the flask. You need to do this quickly before any gas escapes.
5) Start the stopwatch straight away.
6) Gas will start to collect in the gas syringe. Take readings of the volume of gas at regular intervals (e.g. every 10 seconds) and write them into a table.



Gas syringes usually give volumes to the nearest cm^3, so they're quite accurate.
Be careful though — if the reaction is too vigorous, you could blow the plunger out of the syringe.

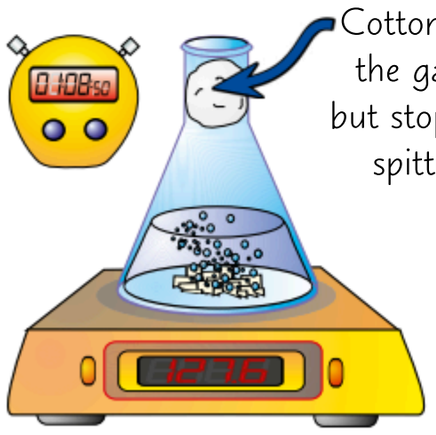
Repeat the Experiment Using Different Concentrations of Acid

1) To investigate the effect of concentration on the rate of reaction, you'll need to repeat the experiment using different concentrations of acid. For example, you might use three different concentrations.
2) To make your experiment a fair test, you should only change the concentration of acid.
3) All the other variables (that's everything else) need to be kept the same. For example, keep the volume of acid, the mass of marble chips and the temperature the same each time.

You Then Need to Interpret Your Results

1) The more gas given off in a set amount of time, the faster the reaction.
2) You can use the results in your table to draw a graph. This makes it easier to see how concentration has affected the rate. (See pages 142 and 143 for more on drawing graphs and calculating rates.)

You Could Also Use a Mass Balance to Measure Amount of Gas Produced



1) As the gas forms and escapes from the container, the mass of the reaction mixture falls.
2) The quicker the reading on the balance drops, the faster the reaction.
3) If you take measurements at regular intervals, you can plot a graph.
4) This is a very accurate method because the mass balance is very accurate.
5) But it does release the gas into the room. That's not good if the gas is toxic (poisonous).

OK, have you got your stopwatch ready...*BANG!* — oh...

Ooh, chemistry in action, nothing beats it. That's why it's one of the best subjects out there. I think so, anyway.

Q1 Name one piece of equipment you could use to measure the volume of gas given off in a reaction. [1 mark]

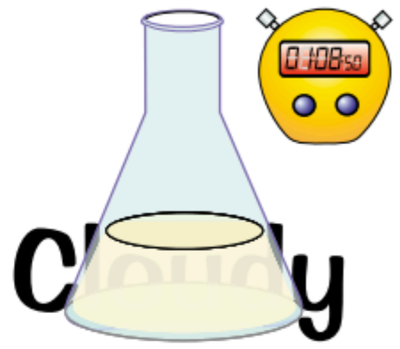
More on Measuring Rates

PRACTICAL

Here's another lovely page on another lovely practical. This practical also looks into what effect concentration has on the rate of a reaction. Get your safety goggles, grab your lab coat and let's go...

You Can Time How Long it Takes For a Solid Product to Form

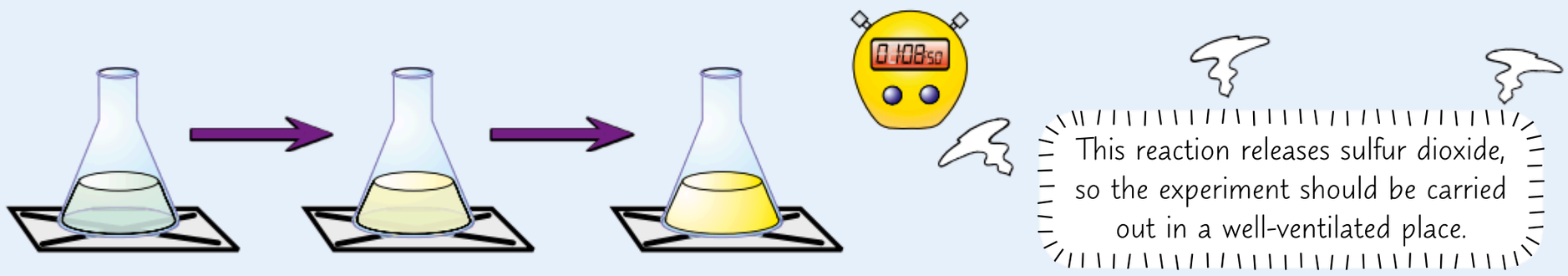
1) Some reactions start with a transparent (see-through) solution and produce a solid product.
2) The solid product (called a precipitate) will make the solution go cloudy. Another way of saying this is to say that its turbidity increases.
3) You can look at a mark through the solution and measure how long it takes for it to disappear. The faster the mark disappears, the quicker the reaction.
4) The results are subjective (there isn't just one right answer). This is because people might not agree over the exact point when the mark 'disappears'.



Sodium Thiosulfate and Hydrochloric Acid Produce a Cloudy Precipitate

Sodium thiosulfate and hydrochloric acid are both clear solutions.
They react together to form a yellow precipitate of sulfur.

1) Start by adding a set volume of dilute sodium thiosulfate to a conical flask.
2) Place the flask on a piece of paper with a black cross drawn on it.
3) Add some dilute hydrochloric acid to the flask and start the stopwatch.
4) Watch the black cross disappear through the cloudy sulfur and time how long it takes to go.



5) Repeat the reaction using different concentrations of one of the solutions, e.g. the hydrochloric acid. (Only change the concentration of one reactant at a time though.)
6) Make sure you control all the other variables (keep everything else the same). For example, the volumes of solutions, the temperature and the size of the flask all need to be kept the same.
7) You'll end up with a set of results that show how long it takes for the cross to disappear at different concentrations of acid. Like this:

Concentration of HCl (g/dm^3)	18	36	54	72	90
Time taken for mark to disappear (s)	193	184	178	171	164

8) The higher the concentration, the faster the reaction, so the less time it takes for the mark to disappear.

Vanishing symbols, sulfurous clouds — real witchcraft this is...

You might come across slightly different experiments to measure rates. Or the same methods but different reactions. Either way — DON'T PANIC. If you understand the basics you'll be able to tackle them just fine.

Q1 A scientist carried out an experiment investigating the effect of changing the HCl concentration on the rate of reaction between HCl and Mg. State two factors that she should have kept constant. [2 marks]

Graphs of Reaction Rate Experiments

Experiment time's over. Time to do some work with your results. Much more fun than actually doing the experiment. Maybe. Perhaps not. OK, almost certainly less fun. But it is important, and worth learning...

You Can Draw a Graph of Your Results

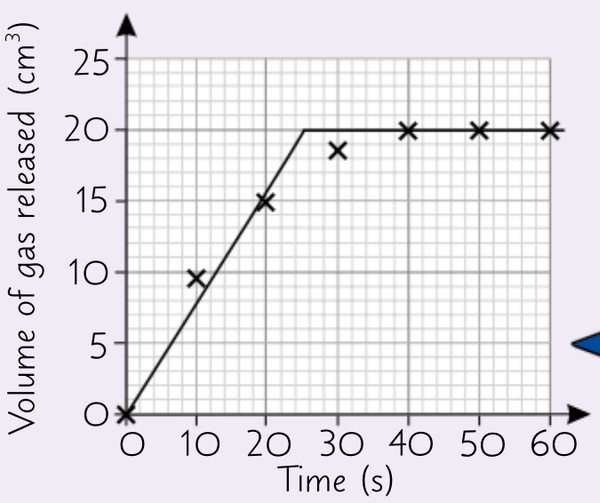
The type of graph you can draw depends on what experiment you did.
Here's how to draw a graph to show the volume of gas given off during a reaction.

EXAMPLE

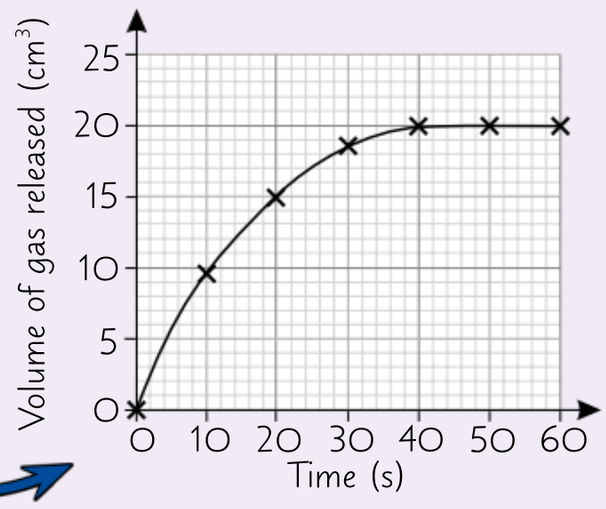
Draw a graph of the results in the table.

Time (s)	0	10	20	30	40	50	60
Volume of gas (cm^3)	0	9.5	15	18.5	20	20	20

1) Put time on the *x*-axis and volume of gas on the *y*-axis. (The *x*-axis goes along the page, the *y*-axis goes up it.)
2) Carefully draw a small cross to show how much gas had been produced at each time interval.



3) Draw a line of best fit through the points. You could do this by drawing a smooth curve of best fit.



4) Or, you could draw two straight lines of best fit, one for the sloped part of the graph and one for the flat part.

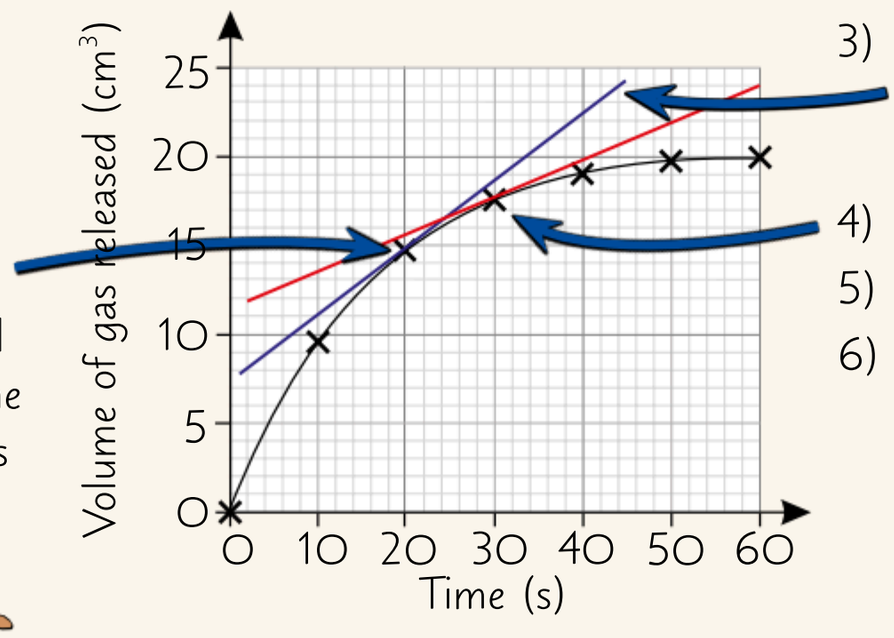
Tangents Help You Compare Reaction Rates at Different Points

If your graph is a curve, it's not always easy to see how the rate changes during a reaction. Tangents can help make this clearer. A tangent is a straight line that touches the curve at one point and doesn't cross it.

EXAMPLE

The graph below shows the volume of gas produced during a chemical reaction.
Is the rate fastest at 20 seconds or 30 seconds?

1) Position a ruler on the graph at a point where you want to know the rate — here it's 20 seconds.
2) Adjust the ruler until the space between the ruler and the curve is equal on both sides of the point.



3) Draw a line along the ruler to make the tangent. Extend the line right across the graph.
4) Do the same thing at 30 seconds.
5) Compare how steep the tangents are.
6) The tangent at 20 seconds (the blue line) is steeper than the tangent at 30 seconds (the red line).

This means that the reaction is faster at 20 seconds.

A tanned gent.



...and that's why I love cows — sorry, I went off on a tangent...

Graphs may look scary, but don't let them put you off. That's what they want. Don't let them win.

Q1 Draw a graph of the results in this table.
Include a curved line of best fit. [3 marks]

Time (s)	0	10	20	30	40	50
Volume of CO_2 (cm^3)	0	18	29	33	34	35

Q1 Video Solution

Working Out Reaction Rates

As well as doing experiments and drawing graphs, you need to be able to do some calculations to work out reaction rates. Don't worry though, they're not too bad. Read on and all will be explained.

Here's How to Work Out the Rate of a Reaction

$$\text{Mean Rate of Reaction} = \frac{\text{Amount of reactant used or amount of product formed}}{\text{Time}}$$

This equation is for mean rate of reaction. So it lets you work out the average rate over an amount of time.

EXAMPLE

A reaction takes 120 seconds. 3.0 g of product are made. Find the mean rate of reaction.

Mean Rate = amount of product formed ÷ time
= 3.0 g ÷ 120 s = 0.025 g/s

Gases can be measured in cm^3, so if the product you measured was a gas the rate could be measured in cm^3/s rather than in g/s.

You Can Calculate the Mean Reaction Rate from a Graph

1) To find the mean rate for the whole reaction, start by working out when the reaction finished. This is when the line goes flat.
2) Then work out how much product was formed (or how much reactant was used up).
3) Then divide this by the total time taken for the reaction to finish.

EXAMPLE

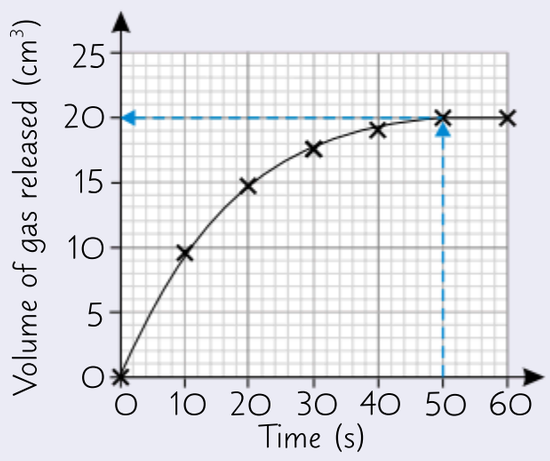
The graph shows the volume of gas released by a reaction, measured at regular intervals. Find the mean rate of the reaction.

1) Work out when the reaction finished.
2) Work out how much product was formed.
3) Divide this by the time taken for the reaction to finish.

The line goes flat at 50 s.

20 cm^3 of gas was formed.

mean rate = 20 cm^3 ÷ 50 s
= 0.40 cm^3/s





4) You can also use the graph to find the mean rate of reaction between two points in time:

EXAMPLE

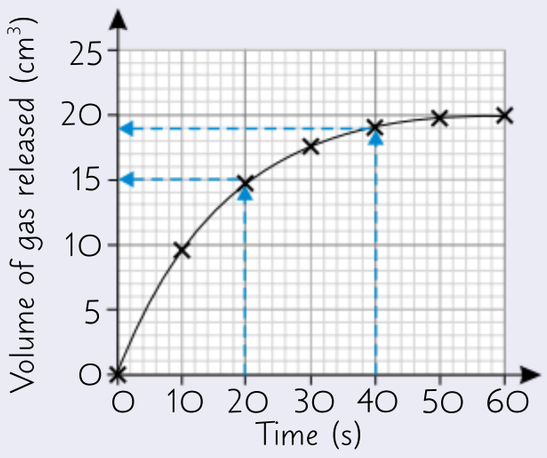
Find the mean rate of reaction between 20 s and 40 s.

1) Work out how much gas was produced between 20 s and 40 s.
2) Work out the time difference between 20 s and 40 s.
3) Divide the amount of gas produced by the time taken.

At 20 s, 15 cm^3 had been produced.
At 40 s, 19 cm^3 had been produced.
Volume released between 20 and 40 s was: 19 cm^3 – 15 cm^3 = 4.0 cm^3

40 s – 20 s = 20 s

mean rate = 4.0 cm^3 ÷ 20 s
= 0.20 cm^3/s



Being asked to calculate reaction rates. That's just mean...

Whether you're calculating the mean rate from just numbers or a graph, you use the formula at the top of the page. Mean rate = amount of reactant used (or product formed) ÷ time. Learn it. It's important.

Q1 A reaction takes 200 s. 6.0 g of reactant are used up.
What is the mean rate of the reaction? [2 marks]

Q1 Video Solution

Reversible Reactions

Reversible reactions are what they sound like — reactions that can be reversed. So they can go backwards.

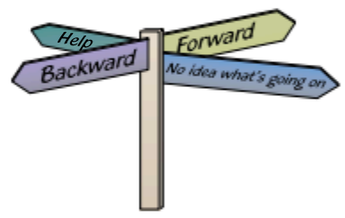
Reversible Reactions Go Both Ways

1) This equation shows a reversible reaction. $A + B \rightleftharpoons C + D$
2) The products (C and D) react to form the reactants (A and B) again.
3) You can tell it's a reversible reaction because of the $\rightleftharpoons$ symbol.
4) The reaction of A and B is called the forward reaction. The reaction of C and D is the backward reaction.

Reversible Reactions Will Reach Equilibrium

1) As the reactants react, their concentrations fall. The forward reaction slows down.
2) As more and more products are made the backward reaction will speed up.
3) After a while the forward reaction and backward reaction will be going at exactly the same rate. The system is at equilibrium.
4) Equilibrium doesn't mean that there are the same amounts of products and reactants. It just means that the amounts of products and reactants aren't changing any more.
5) Equilibrium is only reached if the reaction takes place in a 'closed system'. A closed system just means that none of the reactants or products can escape and nothing else can get in.

Reversible Reactions Have an Overall Direction



1) Once a reaction is at equilibrium, there could be more of the products than reactants. When this happens, we say the reaction is going in the forwards direction.
2) If there are more reactants than products then the reaction is going in the backwards direction.
3) You can change the direction by changing the conditions (the temperature, pressure or concentration).

Ammonium chloride breaks down to form ammonia and hydrogen chloride. The hydrogen chloride can then react with the ammonia to make ammonium chloride again. The reaction equation is:

$$\text{ammonium chloride} \underset{\text{cool}}{\overset{\text{heat}}{\rightleftharpoons}} \text{ammonia} + \text{hydrogen chloride}$$

If you heat this reaction, it will go in the forwards direction. You'll get more ammonia and hydrogen chloride. If you cool it, it will go in the backwards direction. You'll get more ammonium chloride.

Reversible Reactions Can Be Endothermic and Exothermic

1) If the reaction is endothermic (takes in heat) in one direction, it will be exothermic (give out heat) in the other.
2) The amount of energy taken in by the endothermic reaction is the same as the amount given out during the exothermic reaction.

See page 134 for more on endothermic and exothermic reactions.

'Anhydrous' just means 'without water', and 'hydrated' means 'with water'.

$$\underset{\text{(which is blue)}}{\text{hydrated copper sulfate}} \underset{\text{exothermic}}{\overset{\text{endothermic}}{\rightleftharpoons}} \underset{\text{(which is white)}}{\text{anhydrous copper sulfate}} + \text{water}$$

Keep going in the forward direction. Onwards my friend...

Reversible reactions seem tricky but they're OK really. Read the page again until it's all sunk in.

Q1 What does it mean if a reaction is at equilibrium? [1 mark]

Revision Questions for Topic C6

You've almost made it — just one page away from a nice cup of tea...

- Try these questions and tick off each one when you get it right.
- When you're completely happy with a sub-topic, tick it off.

For even more practice, try the Retrieval Quiz for Topic C6 — just scan this QR code!

Topic C6 Quiz

Rates of Reaction (p.138-139)

1) What is meant by the rate of a chemical reaction?
2) On a rate of reaction graph, what does the line getting steeper show?
3) What does a flat line on a graph of amount of products against time show?
4) According to collision theory, what needs to happen for a reaction to take place?
5) What are the four factors that affect the rate of a chemical reaction?
6) Why does increasing the temperature of a reaction mixture increase the rate of a reaction?
7) If a solid is broken up into smaller pieces, what will happen to its surface area to volume ratio?
8) What is a catalyst?
9) How does a catalyst increase the rate of a reaction?

Rate of Reaction Experiments (p.140-143)

10) Describe how you could investigate the effect of increasing hydrochloric acid concentration on the rate of reaction between hydrochloric acid and magnesium.
11) Explain why measuring a mass change during a reaction is an accurate method of measuring rate.
12) Two clear solutions react together and form a precipitate. How could you investigate the rate of this reaction?
13) If you're drawing a graph to show the volume of gas produced over time, what axis should time go on?
14) What is a tangent?
15) How can you use tangents to compare the rates of reaction at two different times in the reaction?
16) Give two possible units for the rate of a chemical reaction.

Reversible Reactions (p.144)

17) What symbol shows that a reaction is reversible?
18) Is this sentence true or false? 'In a reaction at equilibrium, there is the same amount of products as reactants.'
19) What is a closed system?
20) How can you change the direction of a reversible reaction?
21) A reversible reaction is endothermic in the forwards direction. What does this tell you about the reaction in the backwards direction?






Hydrocarbons

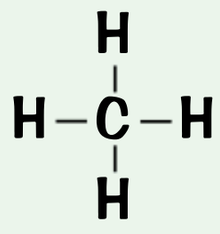
Organic chemistry is about compounds that contain carbon. Hydrocarbons are the simplest organic compounds.

Alkanes Only Have C–C and C–H Single Bonds

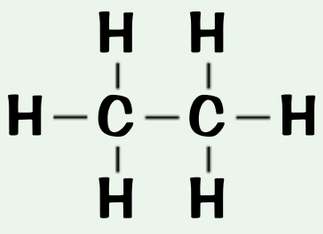
1) Hydrocarbons are compounds formed from carbon and hydrogen atoms only.
2) Alkanes are the simplest type of hydrocarbon. They have the general formula C_nH_{2n+2}.
3) In alkanes, each carbon atom forms four single covalent bonds.
4) The first four alkanes are methane, ethane, propane and butane.

'n' is the number of C atoms in the molecule.

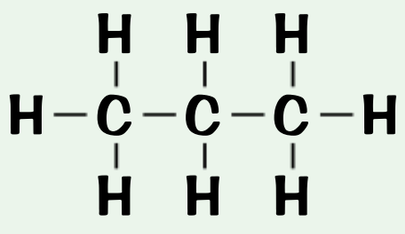
Methane: CH_4



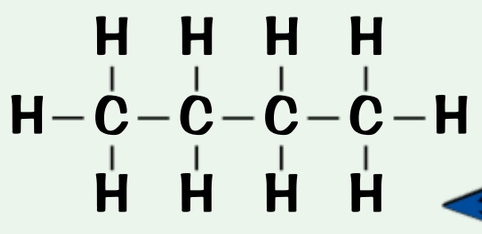
Ethane: C_2H_6



Propane: C_3H_8



Butane: C_4H_{10}



A drawing showing all the atoms and bonds in a molecule is called a displayed formula.

Complete Combustion Occurs When There's Plenty of Oxygen

1) The complete combustion of a hydrocarbon in oxygen releases lots of energy. This makes them useful as fuels.
2) The only waste products are carbon dioxide and water vapour.

hydrocarbon + oxygen → carbon dioxide + water (+ energy)

3) During combustion, both carbon and hydrogen from the hydrocarbon are oxidised. Oxidation is the gain of oxygen.
4) You need to be able to give a balanced symbol equation for the complete combustion of a simple hydrocarbon when you're given its molecular formula. Here's an example:

EXAMPLE

Write a balanced equation for the complete combustion of methane (CH_4).

See p.99 for more on balancing equations.

1) On the left hand side, there's one carbon atom, so only one molecule of CO_2 is needed to balance this.

$CH_4 + ?O_2 \rightarrow CO_2 + ?H_2O$

2) On the left hand side, there are four hydrogen atoms, so two water molecules are needed to balance them.

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

3) There are four oxygen atoms on the right hand side of the equation. Two oxygen molecules are needed on the left to balance them.

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

The name's bond — single covalent bond...

So hydrocarbons only contain two ingredients — carbon and hydrogen. Jamie Oliver would not be happy.

Q1 Write a balanced symbol equation for the complete combustion of ethane, C_2H_6. [2 marks]

Q1 Video Solution

Crude Oil

Crude oil has fuelled modern life — it would be a very different world if we hadn't discovered oil.

Crude Oil is Made Over a Long Period of Time

1) Crude oil is a fossil fuel found in rocks.
2) Fossil fuels are natural substances. They can be used as a source of energy.
3) Crude oil formed mainly from the remains of plankton, as well as other plants and animals. These died millions of years ago and were buried in mud.

Plankton are tiny living plants and animals which float around in oceans and other large bodies of water.

1) Fossil fuels like coal, oil and gas are called non-renewable fuels.
2) This is because they take so long to make that they're being used up much faster than they're being formed.
3) They're finite resources (see p.159) — one day they'll run out.



Crude Oil has Various Important Uses in Modern Life

1) Oil provides the fuel for most modern transport — cars, trains, planes, the lot.
2) Diesel oil, kerosene, heavy fuel oil and LPG (liquefied petroleum gas) all come from crude oil.
3) Petrochemicals are compounds that come from crude oil. The petrochemical industry uses some of the compounds from crude oil as a feedstock to make new compounds for use in things like...
   - polymers (e.g. plastics)
   - solvents
   - lubricants
   - detergents

A feedstock is a raw material used for a chemical process.

4) All the products you get from crude oil are examples of organic compounds. Organic compounds are compounds containing carbon atoms.
5) Most of the organic compounds in crude oil are hydrocarbons (see previous page).
6) You can get a large variety of products from crude oil. This is because carbon atoms can bond together to form different groups called homologous series.
7) These groups contain similar compounds which have many properties in common. Alkanes and alkenes are both examples of different homologous series.



Hydrocarbon Properties Change as the Chain Gets Longer

1) The hydrocarbons in crude oil are a range of different sizes.
2) As the length of the carbon chain changes, the properties of the hydrocarbons change.
3) The shorter the hydrocarbon chain...
   - ...the more runny a hydrocarbon is — that is, the less viscous (gloopy) it is.
   - ...the lower its boiling points will be.
   - ...the more flammable (easier to ignite) the hydrocarbon is.
4) The properties of hydrocarbons affect how they're used for fuels.

I know a good oil joke but it's a bit crude for this page...

Crude oil is dead important. We need it to make lots of important things, like plastics. If we didn't have it, you could have been completing your science exam with a quill and ink instead of a good old plastic pen.

Q1 What is crude oil formed from? [1 mark]

Q2 Crude oil is finite. What does this mean? [1 mark]

Fractional Distillation

Crude oil can be used to make loads of useful things, such as fuels. But you can't just put crude oil in your car. First, the different hydrocarbons have to be separated. That's where fractional distillation comes in.

Fractional Distillation can be Used to Separate Hydrocarbon Fractions

Crude oil is a mixture of lots of different hydrocarbons, most of which are alkanes.
The different compounds in crude oil are separated by fractional distillation.

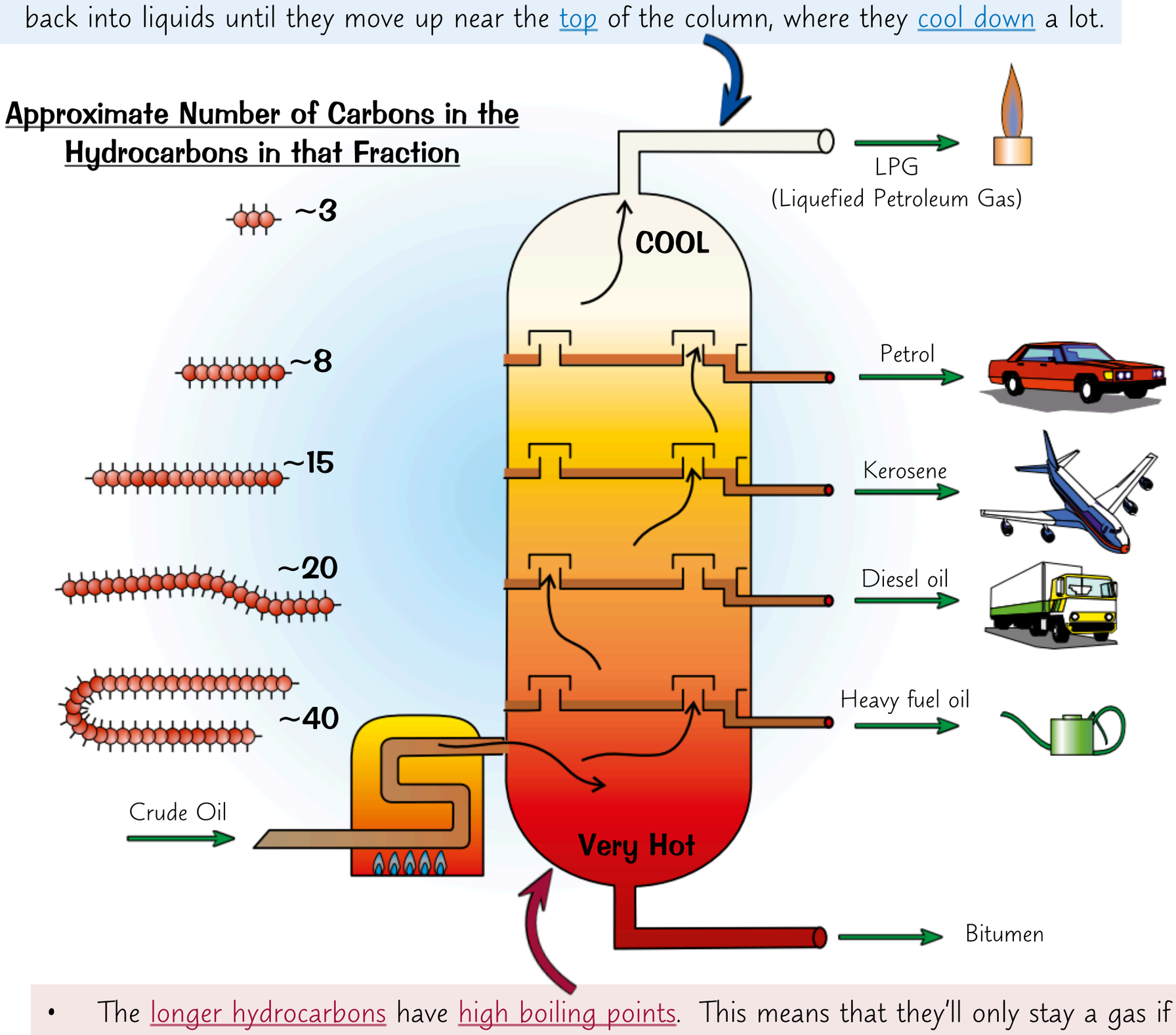
Here's how it works:

1) The oil is heated until most of it has evaporated (turned into gas).
The gases enter a fractionating column (and the liquid bit is drained off).

Hydrocarbons are molecules containing only hydrogen and carbon.

2) In the column it's hot at the bottom and gets cooler as you go up.

- The shorter hydrocarbons have low boiling points.
- This means that they're still gases at low temperatures. So they don't condense and turn back into liquids until they move up near the top of the column, where they cool down a lot.



- The longer hydrocarbons have high boiling points. This means that they'll only stay a gas if it's very hot.
- As they move up the fractionating column, it gets cooler.
So they condense back into liquids and drain out of the column early on, when they're near the bottom.

3) You end up with the crude oil mixture separated into different fractions (parts), e.g. petrol and diesel oil.

4) Each fraction contains a mixture of hydrocarbons. All of the hydrocarbons in one fraction contain a similar number of carbon atoms. This means they'll have similar boiling points.

How much petrol is there in crude oil? Just a fraction...

Make sure you understand how fractional distillation works — it might just save your life... OK, maybe not.

Q1 Petrol drains further up a fractionating column than diesel. Use the diagram of the fractionating column to explain why the boiling point of petrol is lower than that of diesel. [1 mark]

Q1 Video Solution

Cracking

Crude oil fractions from fractional distillation can be split into smaller molecules. This is called cracking. It's super important, otherwise we might not have enough fuel for cars and planes and things.

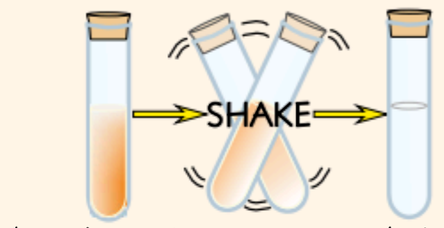
Cracking Means Splitting Up Long-Chain Hydrocarbons

1) There is a high demand for fuels with small molecules.
2) This is because short-chain hydrocarbons tend to be more useful than long-chain hydrocarbons.
3) So, lots of longer alkane molecules are turned into smaller, more useful ones. This is done by a process called cracking.
4) Some of the products of cracking are useful as fuels, e.g. petrol for cars.
5) Cracking also makes alkenes. Alkenes are a lot more reactive than alkanes. They're used as a starting material when making lots of other compounds and can be used to make polymers (see p.118).

Alkenes are a type of hydrocarbon.

Bromine water can be used to test for alkenes:

1) When orange bromine water is added to an alkane, no reaction will happen and it'll stay bright orange.
2) If it's added to an alkene, the bromine reacts with the alkene to make a colourless compound. So the bromine water turns colourless.



There are Different Methods of Cracking

1) Cracking is a thermal decomposition reaction. This means the molecules are broken down by heating them.
2) This can by done by catalytic cracking or by steam cracking.

Catalysts speed up reactions without getting used up (see p.139).

Steam cracking:

1) Long-chain hydrocarbons are heated to turn them into a gas (vapour).
2) The hydrocarbon vapour is mixed with steam.
3) They are then heated to a very high temperature which splits them into smaller molecules.

Catalytic cracking:

1) Long-chain hydrocarbons are heated to turn them into a gas.
2) Then the vapour is passed over a hot powdered aluminium oxide catalyst.
3) The long-chain molecules split apart on the surface of the specks of catalyst.

3) You might be asked to work out the formula of the products or reactants involved in a cracking reaction. You can do this by balancing the number of carbons and hydrogens on each side of the reaction.

EXAMPLE

Decane can be cracked to form octane and one other product. The equation for the cracking of decane, $C_{10}H_{22}$, is shown in the equation below. Complete the equation.

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

1) There needs to be the same number of carbon and hydrogen atoms on each side of the equation.
2) The number of carbon atoms in the missing product equals the number of carbons in $C_{10}H_{22}$ minus the number of carbons in C_8H_{18}. — number of C atoms = 10 – 8 = 2
3) The number of hydrogen atoms in the missing product equals the number of hydrogens in $C_{10}H_{22}$ minus the number of hydrogens in C_8H_{18}. — number of H atoms = 22 – 18 = 4
4) Put these numbers into the formula of the missing product. — $C_{10}H_{22} \rightarrow C_8H_{18} + C_2H_4$

This page is tough — better get cracking...

Cracking's great because it means we use all the long-chain hydrocarbons we otherwise wouldn't need.

Q1 Pentane, C_5H_{12}, can be cracked into ethene and one other hydrocarbon. Give the balanced symbol equation for the cracking reaction. [1 mark]

Q1 Video Solution

Purity and Formulations

In a perfect world, every compound a chemist made would be pure. Unfortunately, in the real world it doesn't always work out like that. Luckily, there are ways to find out how pure a substance is.

Purity Has a Different Meaning in Chemistry to Everyday

1) Usually when you say that a substance is pure you mean that nothing has been added to it. So it's in its natural state. For example: pure milk or beeswax.
2) In chemistry, a pure substance is something that only contains one compound or element all the way through. It's not mixed with anything else.

The Boiling or Melting Point Tells You How Pure a Substance Is

1) A chemically pure substance will melt or boil at a specific temperature.
2) You can test how pure a known substance is by measuring its melting or boiling point. You then compare this value with the melting or boiling point of the pure substance. You can find this in a data book.
3) The closer your measured value is to the actual melting or boiling point, the purer your sample is.
4) Impurities in your sample will lower the melting point.
They may also cause the sample to melt across a wider range of temperatures.
5) Impurities in your sample will increase the boiling point.
They may also cause the sample to boil across a range of temperatures.

Formulations are Mixtures with Exact Amounts of its Parts

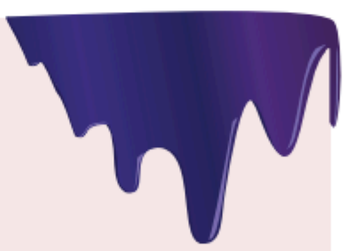
1) Formulations are useful mixtures that have been designed for a particular use.
2) They are made by following a 'formula' (a recipe).
3) Each part of a formulation is measured carefully so that it's there in the right amount.
This makes sure the formulation has the right properties for it to work as it's supposed to.

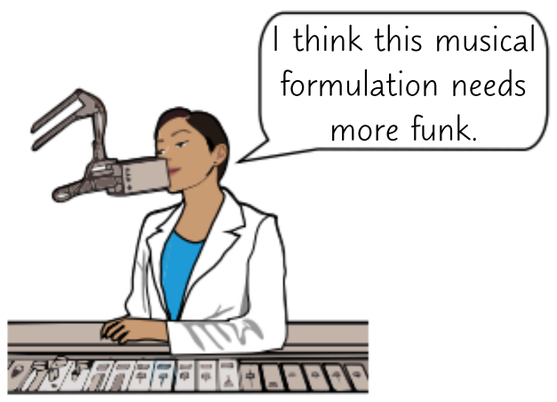
Take a look at p.100 for more on mixtures.

For example, paints are formulations.
They are made up of:

- Pigment — gives the paint colour.
- Solvent — used to dissolve the other parts and change how runny the paint is.
- Binder — holds the pigment in place after it's been painted on.
- Additives — added to change the properties of the paint.

The chemicals used and their amounts can be changed so the paint made is right for the job.





4) In everyday life, formulations can be found in cleaning products, fuels, medicines, cosmetics, fertilisers, metal alloys and even food and drink.

Cake and tea are key to the revision success formula...

Knowing if a product is pure is really important for making things such as medicines or food.
Luckily for us, chemists have lots of different ways to make sure they're making exactly what they want.

Q1 A student makes a sample of aspirin. The melting point of the sample is measured as being between 128-132 °C. The melting point of pure aspirin is 136 °C.
Give two reasons why the melting point measured suggests that the sample is not pure. [2 marks]

Paper Chromatography

You met chromatography on page 101. Now it's time to see how it works. Careful — things might get crazy...

Chromatography uses Two Phases

1) Chromatography is a method used to separate the substances in a mixture.
2) It can then be used to identify the substances.
3) The type of chromatography you need to know about is paper chromatography.
Like all types of chromatography, it has two 'phases'.

- A mobile phase — where the molecules can move.
In paper chromatography, this is a solvent (e.g. water or ethanol).
- A stationary phase — where the molecules can't move. In paper chromatography, this is the paper.

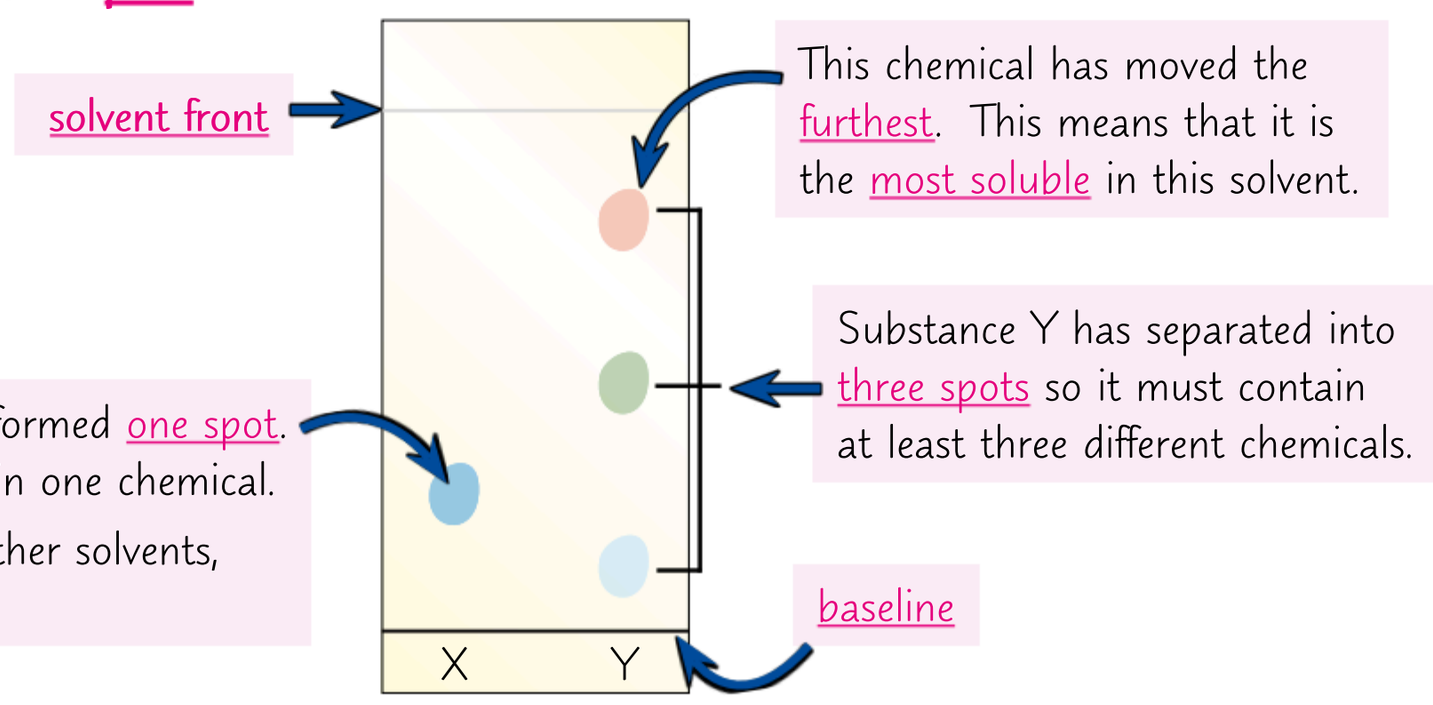
4) During paper chromatography the solvent moves up the paper.
As the solvent moves, it carries the substances in the mixture with it.
5) In a chromatography experiment, the amount of time a chemical spends dissolved in the solvent or stuck on the paper is called its 'distribution'.
6) The more soluble a chemical is, the more time it spends dissolved in the solvent.
This means that the chemical will move further up the paper.
7) Different chemicals may be dissolved in the solvent for different amounts of time.
So the different chemicals will move different distances up the paper.
8) This means they separate into different spots.

The method for carrying out paper chromatography is on page 101.

The Result of Chromatography is Shown on a Chromatogram

PRACTICAL

1) Chromatograms show the result of chromatography experiments.
2) The solvent front is the furthest point reached by the solvent during a chromatography experiment.
3) Chemicals move different distances up the paper. So different spots show different chemicals.
4) The number of spots on a chromatogram is the smallest possible number of chemicals in the mixture.
5) Sometimes more than one chemical may travel the same distance up the paper.
This means that these chemicals will only form one spot between them.
6) If you repeat the experiment with a different solvent, you'll get a different chromatogram.
The spots may have travelled different distances compared to the solvent front.
There might also be a different number of spots on the chromatogram.
7) If you only get one spot in lots of different solvents, there's only one chemical in the substance.
This means the substance is pure.



Chromatography revision — it's a phase you have to get through...

You can't see the chemicals moving between the two phases, but it does happen. You'll just have to trust me.

Q1 What is the purpose of chromatography? [1 mark]

PRACTICAL

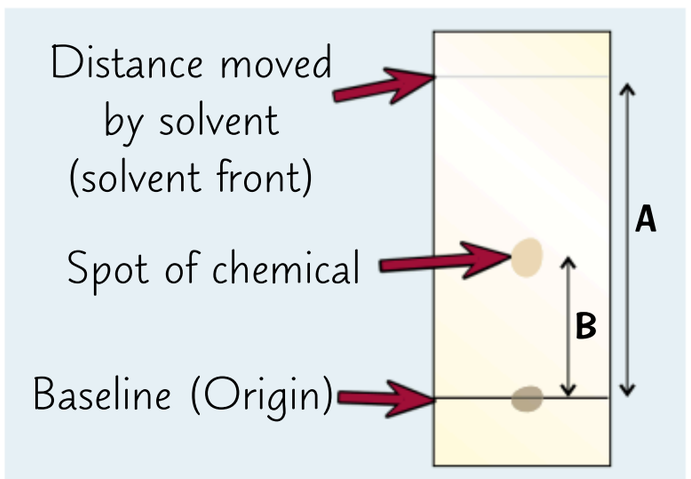
Using Chromatograms

If you were sad the last page on chromatography was finished — fear not. There's more to come on this page.

You can Calculate the R_f Value for Each Chemical

1) An R_f value is the ratio between the distance travelled by the dissolved substance and the distance travelled by the solvent.
2) The further a substance moves through the stationary phase, the larger the R_f value.
3) You can calculate R_f values using the formula:

$$R_f = \frac{\text{distance moved by substance (B)}}{\text{distance moved by solvent (A)}}$$



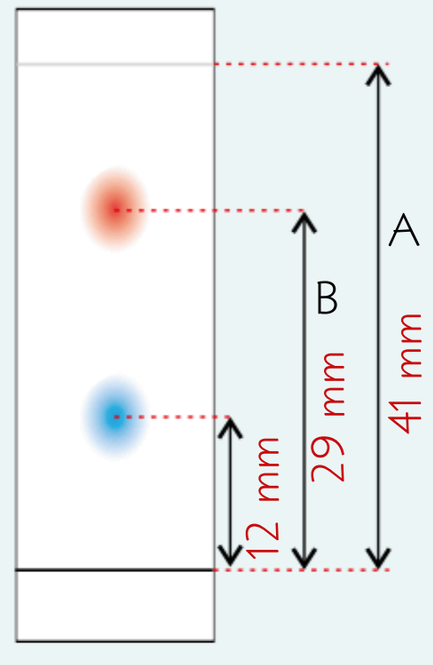
EXAMPLE

A chromatography experiment looking at the colours in a dye produces the chromatogram shown on the right. Calculate the R_f value for the red spot.

1) Measure the distance moved by the red spot (B).
This is the distance from the baseline to the centre of the spot. **29 mm**
2) Measure the distance moved by the solvent (A). **41 mm**
3) Calculate the R_f value.

$$R_f = \frac{\text{distance moved by substance (B)}}{\text{distance moved by solvent (A)}} = \frac{29}{41} = 0.70731... = 0.71$$

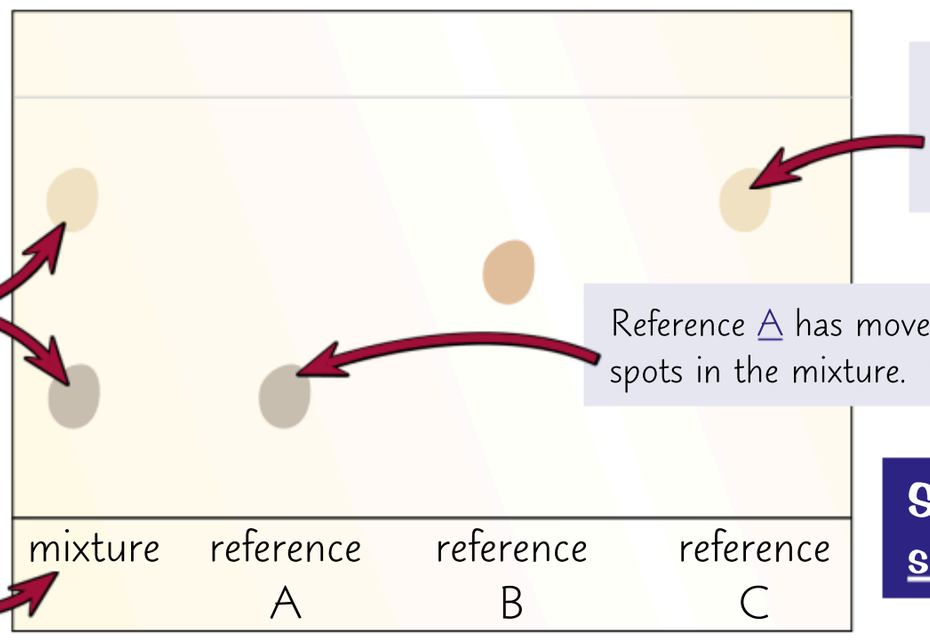
Give your answer to the smallest number of significant figures in the calculation.



4) The R_f value of a chemical will change if you change the solvent.

You Can Identify Substances in Mixtures Using Chromatography

1) You can use chromatography to see if a mixture contains a certain substance.
2) To do this, you run a pure sample of that substance (a reference) next to the mixture.
3) If the R_f value of the reference compound matches one of the spots in the mixture, the substance could be in the mixture. For example:



4) If the R_f values match in one solvent, you can check to see if the chemicals are the same by repeating with a different solvent. If they match again, it's likely that they're the same.

Chromatogram — where chemists post photos of their brunch...

R_f values will always be between 0 and 1, so if your answer's outside this range, check your working again.

Q1 A spot on a chromatogram moved 6.3 cm from the baseline. The solvent front moved 8.4 cm. Calculate the R_f value. [1 mark]

Q1 Video Solution

Tests for Gases

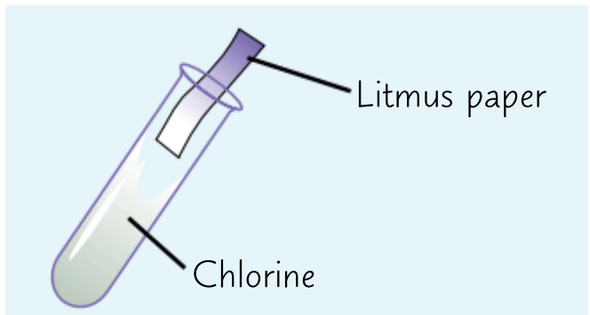
PRACTICAL

Yep, that's right, you need to revise tests for your test. There are a few ways to test for gases, but you only need to know these four. And two of them use fire. Pretty cool.

There are Tests for 4 Common Gases

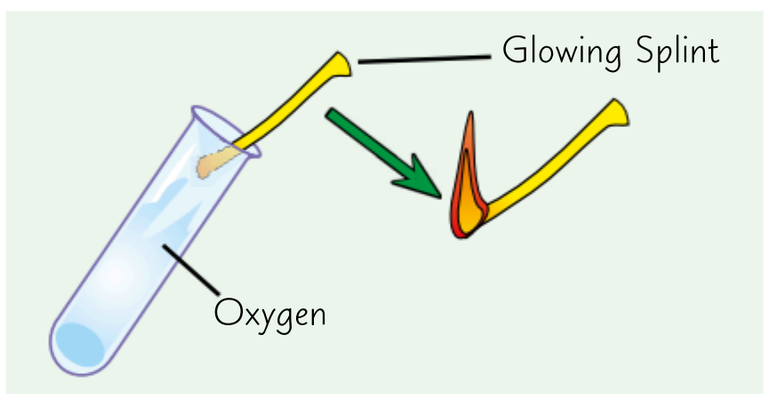
1) Chlorine

Chlorine bleaches damp litmus paper, turning it white.



2) Oxygen

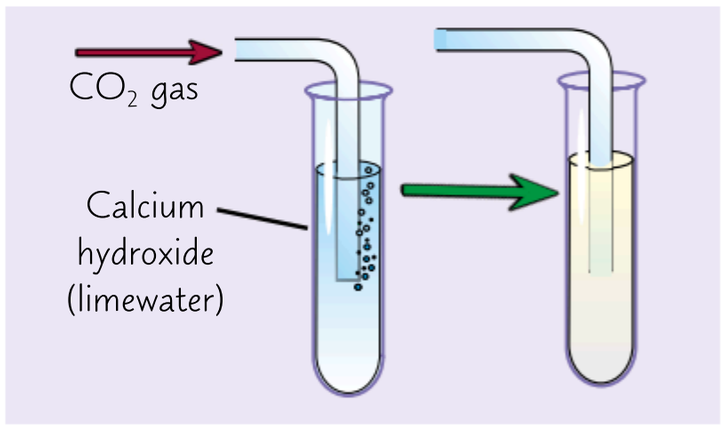
If you put a glowing splint inside a test tube containing oxygen, the oxygen will relight the glowing splint.



3) Carbon Dioxide

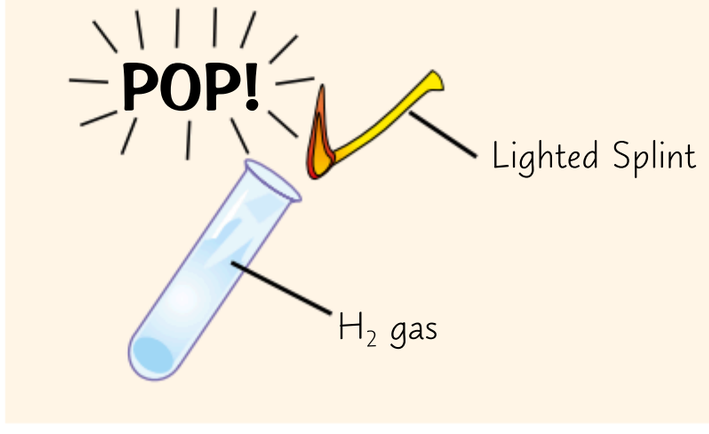
You can test for carbon dioxide by bubbling it through a solution of calcium hydroxide.
If the gas is carbon dioxide, the solution will turn cloudy.
You can also do this test by shaking the gas with the solution.

Calcium hydroxide solution is also called limewater.



4) Hydrogen

If you hold a lit splint at the open end of a test tube containing hydrogen, you'll get a "squeaky pop".





Hopefully this page won't be too testing for you...

Tests for gases are brilliant. You might think it's because you get to do a nice experiment in class, but I like them because you get to write 'squeaky pop' as a real result.

Q1 Hadia collects the gas given off during a reaction and bubbles it through limewater. The limewater goes cloudy. Name the gas produced. [1 mark]

Revision Questions for Topics C7 & C8

Well, that's it for Topics C7 & C8 — I think they were my favourite so far.

- Try these questions and tick off each one when you get it right.
- When you're completely happy with a sub-topic, tick it off.

For even more practice, try the Retrieval Quizzes for Topics C7 and C8 — just scan the QR codes!

Topic C7 Quiz

Topic C8 Quiz

Hydrocarbons and Crude Oil (p.146-147) ☐

1) What two elements do hydrocarbons contain? ☐
2) What is the general formula for alkanes? ☐
3) Draw the displayed formula of butane. ☐
4) What two waste products form from the complete combustion of hydrocarbons? ☐
5) Give three products that can be made from crude oil. ☐

Fractional Distillation and Cracking (p.148-149) ☐

6) Where do the shortest carbon chains condense in a fractional distillation column? ☐
7) Why is cracking used? ☐
8) Give a product of cracking that is used for making polymers. ☐
9) What is used to test for alkenes? ☐

Purity and Formulations (p.150) ☐

10) In chemistry, what does it mean if a substance is pure? ☐
11) Describe how you could use the boiling point of a substance to test whether it is pure. ☐
12) What is a formulation? ☐
13) Why do the different parts of formulation need to be measured exactly? ☐

Paper Chromatography (p.151-152) ☐

14) What are the two phases called in chromatography? ☐
15) A substance only produces one spot on a chromatogram in different solvents. What does this tell you about the purity of the substance? ☐
16) Give the formula for working out the R_f value of a substance. ☐
17) What will happen to the R_f value of a chemical if you change the solvent in the chromatography experiment? ☐

Tests for Gases (p.153) ☐

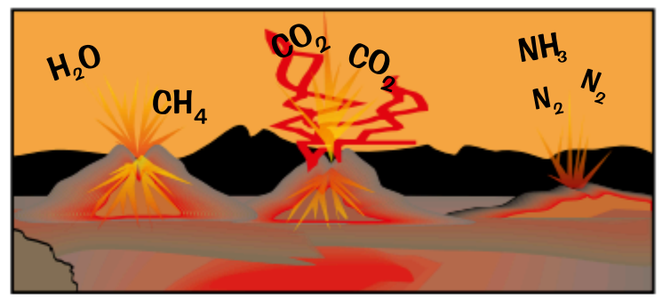
18) What colour does litmus paper turn in the presence of chlorine gas? ☐
19) How can you test if a gas in a test tube is oxygen? ☐

The Evolution of the Atmosphere

Theories for how the Earth's atmosphere evolved have changed a lot over the years. It's hard to gather evidence from such a long time period and from so long ago (4.6 billion years). Here's one idea we've got:

Phase 1 — Volcanoes Gave Out Gases

1) In the first billion years of the Earth's lifetime, its surface was covered in volcanoes.
2) These erupted and released lots of gases. Scientists think these gases formed the early atmosphere.
3) The early atmosphere was probably mostly carbon dioxide. There was little or no oxygen.
4) This is quite like the atmospheres of Mars and Venus today.
5) Volcanoes also released nitrogen (this built up in the atmosphere over time), water vapour and small amounts of methane and ammonia.
6) The oceans formed when the water vapour in the early atmosphere condensed (turned to liquid).



Phase 2 — Oceans, Algae and Green Plants Absorbed Carbon Dioxide

1) Over time, much of the carbon dioxide was removed from the atmosphere.
2) Lots of the carbon dioxide dissolved in the oceans.
3) The dissolved carbon dioxide formed carbonates that precipitated as small, solid particles (sediments).

Precipitation is the formation of an insoluble solid from a solution.

4) When green plants and algae evolved, they took in some carbon dioxide during photosynthesis (see below).

- When sea organisms die, they fall to the seabed and get buried. Over millions of years, they're squashed down. This forms sedimentary rocks (e.g. coal and limestone), oil and gas. The carbon gets trapped within them.
- Things like coal, crude oil and natural gas that are made this way are called 'fossil fuels'.
- Crude oil and natural gas are formed from the remains of plankton that settled on the seabed.
- Coal is made from thick layers of plants that died and then settled on the seabed.
- Limestone is mostly made of calcium carbonate from the shells and skeletons of marine organisms.



Phase 3 — Green Plants and Algae Produced Oxygen

1) Algae evolved about 2.7 billion years ago. Then green plants evolved over the next billion years or so.
2) Green plants and algae produce oxygen in a reaction called photosynthesis:

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

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

3) Over time, oxygen levels built up in the atmosphere. This meant that animals could evolve.
4) The proportions of gases in the atmosphere have been similar for about the last 200 million years. It is made up of about 80% ($^4/_5$) nitrogen, 20% ($^1/_5$) oxygen. There are also small amounts (less than 1%) of other gases (mainly carbon dioxide, noble gases and water vapour).

The atmosphere's evolving — shut the window will you...

We can breathe easy knowing that our atmosphere has developed into a lovely oxygen rich one. Aaaahh.

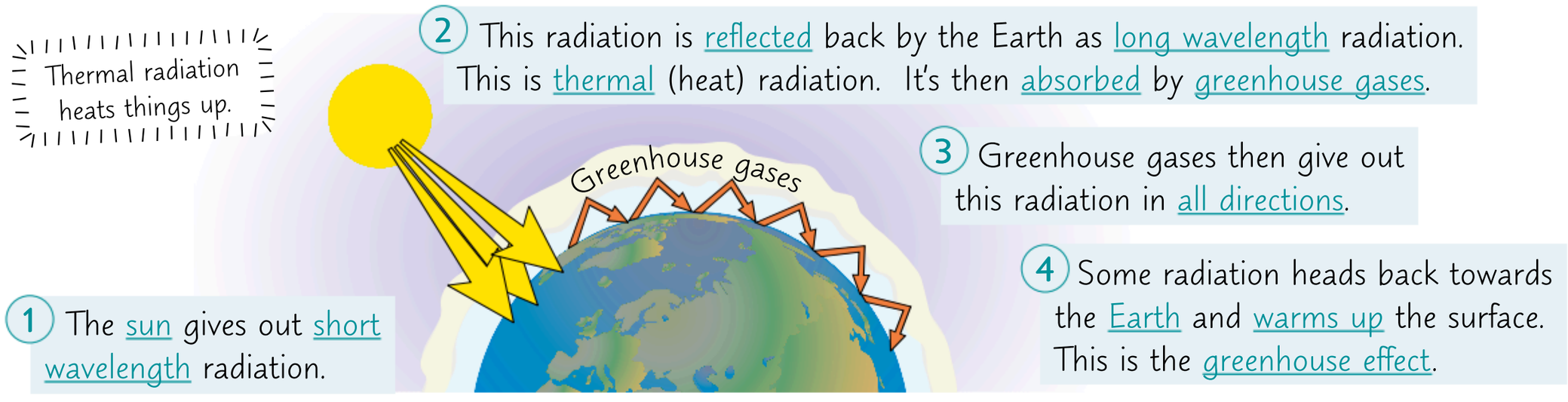
Q1 Describe how sedimentary rocks are formed. [2 marks]

Greenhouse Gases and Climate Change

Greenhouse gases are important but can also cause problems — it's all about keeping a delicate balance.

Carbon Dioxide is a Greenhouse Gas

1) Greenhouse gases include carbon dioxide, methane and water vapour.
2) Greenhouse gases keep the Earth warm enough to support life. Here's how they work:



3) Some forms of human activity increase the amount of greenhouse gases in the atmosphere. For example:

- Deforestation: fewer trees means that less carbon dioxide is taken in for photosynthesis.
- Burning fossil fuels: releases carbon dioxide.
- Agriculture: more farm animals produce more methane when they digest their food.
- Creating waste: more landfill sites and more waste from farming means more carbon dioxide and methane is released when the waste breaks down.

Increasing Carbon Dioxide is Linked to Climate Change

See page 2 for more on science in the media.

1) Recently, the average temperature of the Earth's surface has been going up.
2) Scientists agree that this has been caused by the extra carbon dioxide from human activity.
3) They believe this will lead to climate change.
4) Evidence for this has been peer-reviewed (see page 1). This means that the information is reliable.
5) However, the Earth's climate is very complex. So, it's very hard to make a model that isn't oversimplified.
6) This has led to people forming their own theories and opinions, particularly in the media. These stories aren't based on good evidence — they may be biased or only give some of the information.

If something's biased, it favours one point of view in a way that's not backed up by facts.

Climate Change Could Have Dangerous Consequences

1) Higher global temperatures are causing ice in the Arctic and Antarctic to melt — causing sea levels to rise. If sea levels keep rising, this will lead to more flooding.
2) Changes in rainfall are causing some regions to get too much or too little water.
3) Storms may become more frequent and severe.
4) Changes in temperature and rainfall are having an effect on the production of food in certain places.

Give the climate some privacy — it's changing...

Everyone's talking about climate change these days — make sure you can too, it might pop up in your exam.

Q1 Describe the greenhouse effect and how it affects global temperature. [4 marks]

Q1 Video Solution

Carbon Footprints

Scientists believe that greenhouse gas emissions from human activities are causing climate change.
Knowing what things release lots of carbon dioxide could be useful for stopping climate change from happening.

Carbon Footprints are Tricky to Measure

1) Carbon footprints are a measure of the amount of carbon dioxide and other greenhouse gases released over the full life cycle of something. That can be almost anything:
   - a service (e.g. the school bus).
   - an event (e.g. the Olympics).
   - a product (e.g. a toastie maker).
2) Measuring the total carbon footprint of something can be really hard or even impossible.
3) But a rough calculation can give a good idea of what things release the most greenhouse gases. So, people can then avoid using them in the future.

There are Ways of Reducing Carbon Footprints

1) You can reduce a carbon footprint by reducing the amount of greenhouse gases given out by a process.
2) Here are some things that can be done:
   - Using renewable energy sources (sources that won't run out) or nuclear energy instead of fossil fuels.
   - Using processes that use less energy or produces less waste (decomposing waste releases methane).
   - Governments could tax companies or individuals based on the amount of greenhouse gases they emit. This could encourage people to use processes which use less fuel and are less polluting.
   - Governments can also put a limit on emissions of all greenhouse gases that companies make. They can then sell licences for emissions up to that cap.
   - There's also technology that captures carbon dioxide before it's released into the atmosphere. This carbon dioxide is then stored deep underground.

But Making Reductions is Still Difficult

1) Reducing greenhouse gas emissions isn't simple.
2) Alternative technologies that release less carbon dioxide still need a lot of work.
3) Many governments are worried that making these changes will affect the economies of communities. This could be bad for people's well-being — especially those in developing countries.
4) This makes it hard for countries to agree to reduce emissions.
5) Individuals in developed countries also need to make changes to their lifestyles. But this is tricky when some don't want to and others don't understand why the changes are important or how to make them.

Who has the biggest carbon footprint then? Clowns of course...

Carbon footprints are a game of 'fortunately/unfortunately'. Unfortunately, carbon emissions can lead to global warming. Fortunately, there are steps we can take to cut our carbon dioxide emissions. Unfortunately, not everyone's on board. Fortunately, as time goes on, people are doing more to reduce their emissions. And so on...

Q1 State two things governments can do to try to reduce the greenhouse gas emissions of businesses. [2 marks]

Air Pollution

Increasing carbon dioxide is causing climate change. But carbon dioxide isn't the only gas released when fossil fuels burn — you can also get other nasties like oxides of nitrogen, sulfur dioxide and carbon monoxide.

Combustion of Fossil Fuels Releases Gases and Particles

1) Fossil fuels, such as crude oil and coal, contain hydrocarbons (see page 146).
2) Hydrocarbons can combust (burn in oxygen). There are two types of combustion:

Complete combustion — when there's plenty of oxygen around all of the fuel burns.

Incomplete combustion — when there's not enough oxygen around some of the fuel does not burn.

There's more about complete combustion on p.146.

3) Both types of combustion release carbon dioxide and water vapour into the atmosphere.
4) During incomplete combustion, solid particles (called particulates) of soot (carbon) and unburnt fuel are also released. Carbon monoxide gas is also produced.
5) Particulates in the air and carbon monoxide can cause all sorts of problems:



Particulates

- If particulates are breathed in, they can get stuck in the lungs and cause damage. This can lead to respiratory (breathing) problems.
- They're also bad for the environment — they reflect sunlight back into space. This means that less light reaches the Earth — causing global dimming.

Carbon monoxide

- Carbon monoxide (CO) is really dangerous because it can stop your blood from carrying enough oxygen around the body.
- A lack of oxygen in the blood can lead to fainting, a coma or even death.
- Carbon monoxide doesn't have any colour or smell, so it's very hard to detect. This makes it even more dangerous.

Sulfur Dioxide and Oxides of Nitrogen Can be Released

1) Other pollutants are also released from burning fossil fuels.
2) Sulfur dioxide (SO_2) is released during the combustion of fossil fuels that contain sulfur impurities.
3) Nitrogen oxides form in a reaction between nitrogen and oxygen in the air. This reaction is caused by the heat of the burning fossil fuels.
4) These gases mix with clouds and cause acid rain.
5) Acid rain kills plants. It also damages buildings, statues and metals.
6) Sulfur dioxide and nitrogen oxides also cause respiratory problems if they're breathed in.

You can test for sulfur impurities in a fuel by bubbling the gases from combustion through a solution containing universal indicator. If the fuel contains sulfur, the universal indicator will turn red.

Revision and pollution — the biggest annoyances of modern life...

Burning fossil fuels is definitely useful but it sure does cause a lot of problems. At least this topic is kind of interesting and relevant to everyday life. Just think... you could see this kind of stuff on TV.

Q1 Name two pollutants that could be released during the combustion of hydrocarbons when there is not enough oxygen present. [2 marks]

Finite and Renewable Resources

There are lots of different resources that humans use for things like electricity, heating, travelling, building materials and food. Some of these resources can be replaced, some can't.

Natural Resources Come From the Earth, Sea and Air

1) Natural resources form by themselves — they're not made by humans.
They include anything that comes from the earth, sea or air, e.g. cotton and oil.

2) Some natural products can be replaced or improved by man-made products or processes.

For example, rubber is a natural product that comes from the sap of a tree.
But we can now make polymers (see p.118) to replace some natural rubber to make things like tyres.
Wool is a natural product that comes from animals such as sheep. But scientists have developed synthetic (man-made) fibres that we can use instead of wool to make things like jumpers and blankets.

3) Agriculture (farming) helps to increase our supply of natural resources to provide food, timber, clothing and fuel. It also provides conditions which can make natural resources better for our needs.

E.g. the development of fertilisers means we can increase the amount of crops grown in a given area.

Some Natural Resources will Run Out

1) Renewable resources can be remade at least as fast as we use them.

2) This means that they can be replaced fairly quickly.

For example, timber is a renewable resource. Trees can be planted following a harvest and only take a few years to regrow. Other examples of renewable resources include fresh water and food.

3) Finite (non-renewable) resources are remade very slowly (or not at all).
So we use them up quicker than we can replace them. This means that they'll eventually run out.

4) Finite resources include fossil fuels and nuclear fuels, as well as minerals and metals found in the ground.

5) We can process many finite resources to provide fuels and materials necessary for modern life.

For example, fractional distillation (see p.148) is used to produce usable products such as petrol from crude oil. Metal ores are reduced to produce pure metals (see p.130).

Tables, Charts and Graphs can Tell You About Different Resources

You can interpret information about resources from information that's given to you.

EXAMPLE

The table below shows how long it takes for three resources to form.
The resources are coal, wood and cotton. Work out which resource is coal.

	Time it takes to form
Resource 1	10 years
Resource 2	120-180 days
Resource 3	10^6 years

Wood and cotton are both renewable resources.
Coal is a finite resource.
Finite resources take a very long time to form.
Resource 3 takes a much longer amount of time to form compared to Resources 1 and 2.

Coal is Resource 3.

10^6 is a quick way of showing 1 000 000. This is because $10^6 = 10 \times 10 \times 10 \times 10 \times 10 \times 10 = 1\,000\,000$.

This book is a renewable resource — a gift that keeps on giving...

Unfortunately we can't just run around using every resource we get our hands on — we have to consider the effects of our actions. If you ever start a major mining project think... what would David Attenborough do?

Q1 State the difference between a finite and renewable resource. [2 marks]

Reuse and Recycling

Supplies of many materials used in the modern world are limited. Once they're finished with, it's usually far better to recycle them than to use new finite resources, which will run out.

We Need to Consider the Future When Choosing Resources

1) Sustainable development means thinking about the needs of people today without damaging the lives of people in the future.
2) Using, extracting and processing resources can be unsustainable. This could be because:
   - Some resources are non-renewable — they'll run out one day. For example, the raw materials used to make metals, building materials, many plastics and things made from clay and glass are limited.
   - Extraction processes can use lots of energy and produce lots of waste.
   - Turning resources into useful materials, like glass or bricks, often uses energy made from finite resources.
3) One way to be more sustainable is to use less finite resources. This reduces both the use of that resource and anything needed to produce it.
4) We can do this by reusing and recycling materials when we're finished with them. During recycling, waste is processed so that it can be used to make new products.
5) We can't stop using finite resources completely. But scientists can develop processes that use less and reduce damage to the environment.

Extraction processes separate the materials you want from the other things that they're mixed with.

Recycling Metals is Important

1) Mining and extracting metals takes lots of energy. Most of this energy comes from burning fossil fuels.
2) It's usually better to recycle metals instead of making new metals.

Benefits of recycling:
- It often uses much less energy than the amount needed to make a new metal.
- It helps save some of the finite amount of each metal in the earth.
- It cuts down on the amount of waste getting sent to landfill.

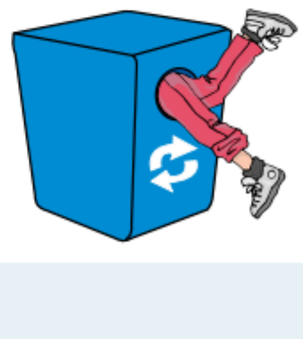
3) Metals can be recycled by melting them and then moulding (recasting) them into the shape of a new product.
4) Sometimes, different metals won't need to be completely separated before recycling. The amount of separation depends on what the final product will be.

For example, waste steel and iron can be kept together. This is because they can both be added to iron in a blast furnace. This means that less iron ore will be needed.

A blast furnace is used to extract iron from its ore at a high temperature using carbon.

Glass can be Reused or Recycled

1) Reusing or recycling glass can help sustainability.
2) This reduces the amount of energy used for making new glass.
3) It also means that less glass is thrown away, so less waste is produced.



- Glass bottles can often be reused without reshaping.
- Some glass products can't be reused so they're recycled for a different use instead.
- The glass is crushed and melted. It's then reshaped to make other glass products like jars.

CGP Jokes — 85% recycled since 1996...

Recycling is really handy — as well as saving limited finite materials it also saves energy.

Q1 Give two positive effects of recycling metals. [2 marks]

Life Cycle Assessments

If a company wants to manufacture a new product, they carry out a life cycle assessment (LCA).

Life Cycle Assessments Show Total Environmental Costs

A life cycle assessment (LCA) looks at every stage of a product's life to assess the impact (effect) it would have on the environment.

1 Getting the Raw Materials:

1) Lots of raw materials need to be extracted (separated from other materials) before we can use them for a product.
2) Extracting raw materials can damage the local environment, e.g. mining metals.
3) Extraction uses lots of energy. This can result in pollution.
4) Raw materials often need to be processed (e.g. by changing their shape and properties) to turn them into useful materials.
5) This often needs large amounts of energy. E.g. extracting metals from ores (see p.130 and 132) or fractional distillation of crude oil (see p.148).



2 Manufacture and Packaging:

1) Making products and their packaging can use a lot of energy and other resources.
2) It can cause lots of pollution too.
3) Chemical reactions are sometimes used to make products. These reactions also produce waste products which need to be got rid of.
4) Some of this waste can be turned into other useful chemicals. This reduces the amount that ends up polluting the environment.



3 Using the Product:

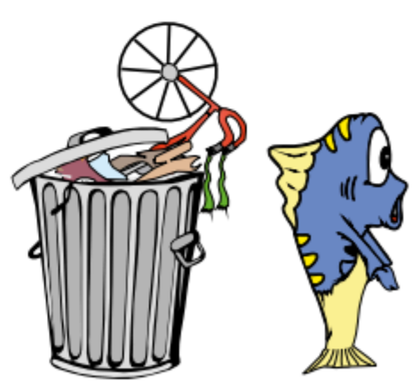
See page 156 for more on greenhouse gases.

1) The use of a product can also damage the environment.
2) For example, burning fuels releases greenhouse gases and other harmful substances. Fertilisers can drain into streams and rivers, causing harm to plants and animals.
3) It's also important to think about how long a product is used for or how many uses it gets. Products that need lots of energy to produce but are used for ages mean less waste in the long run.



4 Product Disposal:

1) Products are often thrown away in landfill sites.
2) This takes up space and pollutes land and water. For example, paint can wash off a product and get into rivers.
3) Energy is used to transport waste to landfill. This can release pollutants into the atmosphere, such as carbon monoxide (see p.158) and carbon dioxide.
4) Products might be incinerated (burnt), which causes air pollution.



Need exercise? Go life-cycling then...

LCAs are great for showing how to improve products, so we can make them less damaging to the environment.

Q1 What are the four stages that need to be looked at when conducting a life cycle assessment? [2 marks]

Using Life Cycle Assessments

You can compare the life cycle assessments of similar products to see which has the smallest effect on the environment. You might want to do this to see which material will affect the environment the least.

You Can Compare Life Cycle Assessments for Plastic and Paper Bags

1) You may be asked to compare life cycle assessment (LCA) information about paper and plastic bags.
2) You can then decide which type of bag is the least harmful to the environment.

Life Cycle Assessment Stage	Plastic Bag	Paper Bag
Raw Materials	Crude oil	Wood
Manufacturing and Packaging	Plastics are made from compounds extracted from crude oil by fractional distillation and processed by cracking and polymerisation. Waste is reduced as the other fractions of crude oil have other uses.	Pulped wood is processed using lots of energy. Lots of waste is made.
Using the Product	Can be reused several times. Can be used for other things as well as shopping. For example, as bin liners.	Usually only used once.
Product Disposal	Recyclable but many types aren't biodegradable. Take up space in landfill and pollute land.	Can be recycled. Biodegradable and non-toxic.

3) LCAs have shown that even though plastic bags aren't usually biodegradable, they may be less harmful to the environment.
4) This is because they take less energy to make and have a longer lifespan than paper bags.

If something's biodegradable, it can be broken down naturally by microorganisms (tiny living things like bacteria).

There are Problems with Life Cycle Assessments

1) It's quite easy to measure things like the use of energy or resources, and the production of some types of waste. So we can give all of these measurements a number in an LCA.
2) But measuring some effects is much harder.

For example, plastic bags that litter the environment don't look very nice. But measuring how unattractive something looks isn't easy. The person measuring it has to use their own judgement.

3) So, producing an LCA can involve the feelings of the person carrying out the assessment as well as facts. So the results could change depending on who does the assessment. This means LCAs can be biased.
4) Selective LCAs only show some of the impacts that a product has on the environment. So these can also be biased because they can be written to purposely support the claims of a company. This would give the company positive advertising.

If something is biased, that means it favours one point of view in a way that isn't backed up by facts.

A bag for life — it's not just for Christmas...

You might have to compare different LCAs for paper and plastic bags. Each bag has good and bad points. So you'll need to pick the bag that affects the environment the least overall.

Q1 Give two reasons why a life cycle assessment may be biased. [2 marks]

Potable Water

We all need safe drinking water. The way that water's made safe depends on local conditions.

Potable Water is Water You Can Drink

1) Potable water is water that's safe for humans to drink. We need it to live.
2) Some water is naturally potable, but most water needs to be treated before it's safe to drink.
3) Potable water isn't pure. Pure water only contains H_2O molecules but potable water can contain lots of other dissolved substances.

See p.150 for more on purity.

4) For water to be safe to drink, it must:
   - not have high levels of dissolved salts,
   - have a pH between 6.5 and 8.5,
   - not have any bad things in it (like bacteria or other microbes).

The Way that Potable Water is Produced Depends on Where You Are

1) Fresh water is water that doesn't have much dissolved in it. Rainwater is a type of fresh water.
2) When it rains, water can either collect as surface water or as ground water.

SURFACE WATER: collects in lakes, rivers and reservoirs (places for storing liquids).
GROUND WATER: collects in rocks that trap water underground.

3) When producing potable water, companies need to choose a suitable source of freshwater. In the UK, the source of fresh water used depends on location.
4) Surface water tends to dry up first. So in warm areas, such as the south-east, most of the water supply comes from ground water. This is because it is underground so doesn't dry up.

Most Fresh Water Needs to be Treated to Make it Safe

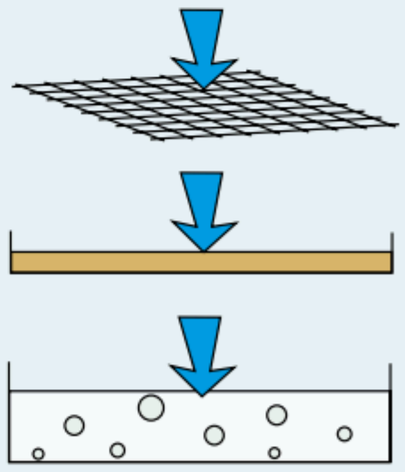
1) Fresh water contains low levels of dissolved substances.
2) It still needs to be treated to make it safe before we use it.
3) This process includes:

Filtration — the water is passed through a wire mesh. This stops large things like twigs from passing through. Next, filter beds are used to filter out any other solid bits.

Sterilisation — the water is sterilised. This means that any harmful bacteria or microbes in the water are killed. This can be done by bubbling chlorine gas through it or by using ozone or ultraviolet light.

Ozone is a gas.

Filter beds are made from grains of sand and gravel. Tiny bits of solid in the water are captured by the grains.



Potable water — nothing to do with gardening...

A lot of the water that we drink comes from rain. Thankfully in the UK, we seem to have an endless supply...

Q1 Describe the steps used to treat fresh water to make it potable. [2 marks]

Q1 Video Solution

Desalination

Some countries have limited supplies of fresh water. They need to use other water sources, like the sea.

Potable Water Can Be Made From Seawater



1) In some very dry countries there's not enough surface or ground water. So instead they use seawater to provide potable water.
2) Seawater contains salts which need to be removed before we can drink it.
3) These salts are removed by a process called desalination.

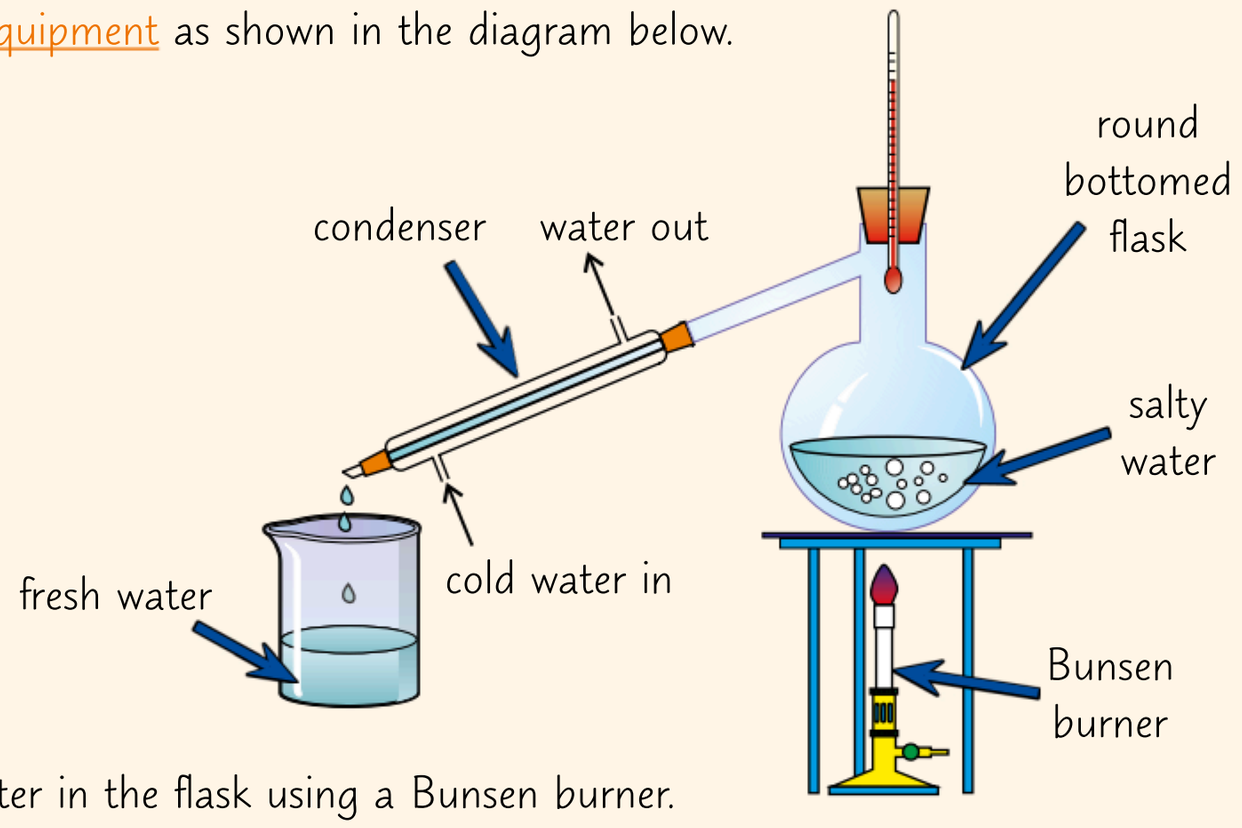
Distillation Can Be Used to Purify Seawater

1) Distillation can be used to remove the salt from seawater (desalination).
2) You can test and purify a sample of water in the lab using distillation:

PRACTICAL

- Use a pH meter to test the pH of a sample of water. If the pH is too high or too low, you'll need to neutralise it (make it neutral). You do this by adding some acid (if the sample's alkaline) or some alkali (if the sample's acidic) until the pH is 7.
- Set up the equipment as shown in the diagram below.

Neutral solutions are neither acidic or alkaline. They have a pH of 7. E.g. pure water is neutral.



- Heat the water in the flask using a Bunsen burner.
- As the water heats up, it becomes a gas (it evaporates). The gas then enters the condenser as steam. Cold water is pumped around the condenser to cool the steam inside of it. This drop in temperature makes the steam condense back into liquid water.
- Collect the water running out of the condenser in a beaker.
- Retest the pH of the water with a pH meter to check it's neutral.
- After the water has been distilled (all of the water has evaporated from the flask), see whether there are any crystals in the round bottomed flask. If there are crystals it means that there were salts in the water before you distilled it.

3) Seawater can also be purified by processes that use thin layers of material called membranes. Membranes have really tiny holes that only let certain things pass through them.
4) One of these processes is called reverse osmosis. The salty water is passed through a membrane. The membrane lets water molecules pass through but traps the salts. This separates them from the water.
5) Both distillation and reverse osmosis need loads of energy to work which makes them really expensive. This is why they're not used when there are other sources of fresh water available.

Revision and distillation — processes that require lots of energy...

...but revision is a practical solution for producing large amounts of success. So make sure you know this page.

Q1 Describe one way that membranes are used to purify seawater. [1 mark]

Waste Water Treatment

Dealing with our waste is really important to make sure that we don't pollute the natural environment. It also means that we can access nice clean water. Super.



Waste Water Comes from Lots of Different Sources

1) We use water for lots of things at home — like having a bath, going to the toilet and doing the washing-up. When you flush this water and other waste matter down the drain, it goes into the sewers forming sewage. The sewage is then carried by the sewers to sewage treatment plants.
2) Agricultural (farming) systems also produce a lot of waste water.
3) Waste water has to be treated before it can be put back into freshwater sources like rivers or lakes. This is to remove any pollutants such as organic matter and harmful microbes (e.g. bacteria and viruses) so that the water doesn't cause health problems.
4) Waste water from industrial processes also has to be collected and treated.
5) Industrial waste water can contain organic matter and harmful chemicals. So it needs further treatment before it's safe to put back into the environment.

Organic matter contains carbon compounds that come from the remains and waste of organisms.

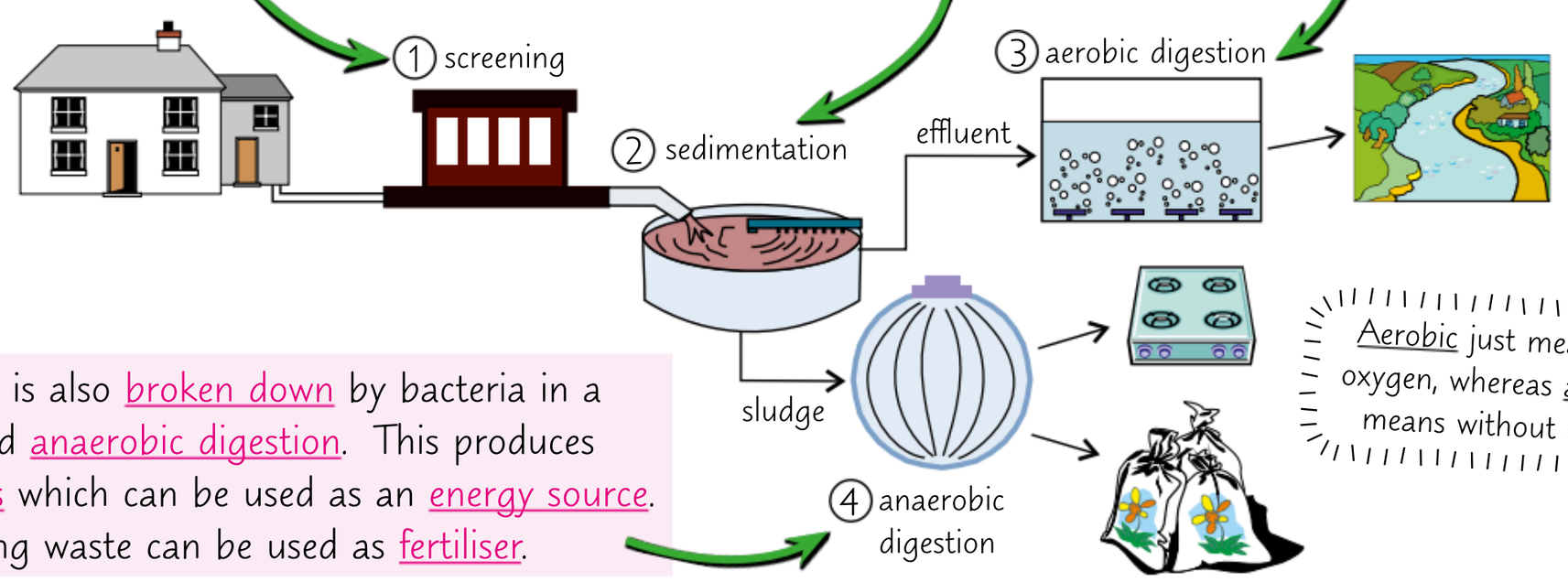
Sewage Treatment Happens in Several Stages

1) Some of the processes involved in treating waste water at sewage treatment plants are shown below.

(1) The sewage is screened to remove any large bits of material (like twigs or plastic bags) and any grit (small bits of stone and sand).

(2) Then it goes through sedimentation. The heavier solids sink to the bottom to produce sludge. The lighter effluent (liquid waste) floats on the top.

(3) The effluent is removed and treated by biological aerobic digestion. This is where bacteria break down any organic matter — including other microbes in the water.



(4) The sludge is also broken down by bacteria in a process called anaerobic digestion. This produces methane gas which can be used as an energy source. The remaining waste can be used as fertiliser.

Aerobic just means with oxygen, whereas anaerobic means without oxygen.

2) Waste water containing toxic substances needs extra stages of treatment. This may include adding chemicals, UV radiation or using membranes.
3) Sewage treatment has more stages than treating fresh water but uses less energy than the desalination of salt water. So it could be used as an option in areas where there's not much fresh water. However, people don't like the idea of drinking water that used to be sewage.

Is it just me, or does this page stink? Phew...

Modern sewage systems have done wonders to make life much less... well... smelly.

Q1 Name and describe the first two stages of waste water treatment at a sewage treatment plant. [2 marks]

Q1 Video Solution

Revision Questions for Topics C9 & C10

That's all for Topics C9 and C10, so here are some questions to finish up with.

- Try these questions and tick off each one when you get it right.
- When you're completely happy with a sub-topic, tick it off.

For even more practice, try the Retrieval Quizzes for Topics C9 and C10 — just scan the QR codes!

Topic C9 Quiz

The Evolution of the Atmosphere (p.155) ☐

1) How did volcanoes help to form the early atmosphere? ☐
2) Name three of the gases that scientists think were present in the early atmosphere. ☐
3) Give one way that the levels of carbon dioxide in the early atmosphere were reduced. ☐
4) Name the gas produced during photosynthesis. ☐
5) What percentage of the Earth's atmosphere today is made up of nitrogen? ☐

Pollution and Climate Change (p.156-158) ☐

6) Name two greenhouse gases. ☐
7) Give two things that humans are doing that are causing a rise in carbon dioxide in the atmosphere. ☐
8) What is a carbon footprint? ☐
9) Give one reason why reducing carbon dioxide emissions can be difficult. ☐
10) Why is carbon monoxide dangerous? ☐
11) Describe how the following air pollutants are produced:
    a) sulfur dioxide b) nitrogen oxides. ☐
12) Describe how acid rain forms. ☐
13) State two problems caused by acid rain. ☐

Chemistry and Sustainability (p.159-162) ☐

Topic C10 Quiz

14) Give two examples of renewable resources. ☐
15) What is sustainable development? ☐
16) What happens to glass when it's recycled into a new product? ☐
17) What do life cycle assessments (LCAs) do? ☐
18) Give one way that paper bags are better for the environment than plastic bags. ☐

Potable Water and Waste Water Treatment (p.163-165) ☐

19) What is potable water? ☐
20) True or False? Ground water collects in rivers and lakes. ☐
21) Name two processes you could use to purify sea water. ☐
22) Name two different sources of waste water. ☐
23) Why is it important to treat waste water before releasing it into the environment? ☐
24) What happens during the screening step of sewage treatment? ☐
25) Name a gas produced by the anaerobic digestion of sewage sludge. ☐

Energy Stores and Systems

Energy is never used up. It's just the way that it's stored that changes.

Energy is Transferred Between Energy Stores

Energy is stored in the different energy stores of an object.

You need to know the following energy stores:

1) KINETIC — anything moving has energy in its kinetic energy store.
2) THERMAL — all objects have energy in this store. The hotter the object, the more energy in the store.
3) CHEMICAL — anything that can release energy by a chemical reaction has energy in this store, e.g. food.
4) GRAVITATIONAL POTENTIAL — any object raised above ground level has energy in this store.
5) ELASTIC POTENTIAL — anything stretched has energy in this store, like springs and rubber bands.
6) ELECTROSTATIC — e.g. two charges that attract or repel each other have energy in this store.
7) MAGNETIC — e.g. two magnets that attract or repel each other have energy in this store.
8) NUCLEAR — the nucleus of an atom releases energy from this store in nuclear reactions (p.199).

You may also see thermal energy stores called internal energy stores.

Energy can be Transferred in Four Ways

MECHANICALLY

1) This happens when a force does work (p.205) on an object.
2) For example, a force pushing an object along the floor.

ELECTRICALLY

1) This happens when a moving charge does work (p.189).
2) For example, when a current flows through a light bulb.



BY HEATING

1) When energy is transferred from a hotter object to a colder object.
2) For example, when a pan of water is heated on a hob.

BY RADIATION

1) This happens when energy is transferred by e.g. sound or light.
2) For example, when energy from the Sun travels to Earth by light.

When a System Changes, Energy is Transferred

1) A system is just the single object or a group of objects that you're interested in.
2) When a system changes, the way energy is stored changes in one of the ways above.
3) Closed systems are systems where no matter (stuff) or energy can enter or leave.
4) When a closed system changes, there is no net (overall) change in the total energy of the system.

For example...

- A cold spoon sealed in a flask of hot soup is a closed system.
- Energy is transferred from the thermal energy store of the soup to the thermal energy store of the spoon by heating.
- But no energy leaves the system. The total energy stays the same.

Transfer this information to your exam knowledge stores...

Energy stores pop up everywhere in physics. Make sure you understand them before you read the next page.

Q1 Name the four ways that energy can be transferred between stores. [4 marks]

Conservation of Energy and Energy Transfers

Repeat after me: energy is NEVER destroyed. Make sure you learn that fact, it's really important.
And then it's time to look at mechanical energy transfers a bit more. They happen when a force does work.

You Need to Know the Conservation of Energy Principle

Energy can be transferred usefully, stored or dissipated, but can never be created or destroyed.

1) This means that whenever a system changes, all the energy is simply moved between stores.
2) It never disappears.
3) This is true for every energy transfer.
4) Even when energy is dissipated (or wasted), it isn't gone.
5) It's just been transferred to an energy store that we didn't want.
6) There's more about wasted energy on p.173.

Energy is usually wasted by heating — see p.170.

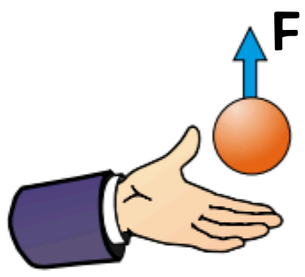
Forces Cause Mechanical Energy Transfers

1) If a force moves an object, then work is done.
2) Work done is the same as energy transferred.
3) So energy is transferred mechanically when a force moves an object.
4) For any given situation, you'll have to describe the changes in how energy is stored.
5) Here are a few examples:

There's more on work done on p.205.

Example 1 — A ball thrown into the air

1) A boy throws a ball upwards. The boy exerts a force on the ball.
2) Energy is transferred mechanically from the chemical energy store of the boy's arm to the kinetic energy stores of the ball and arm.



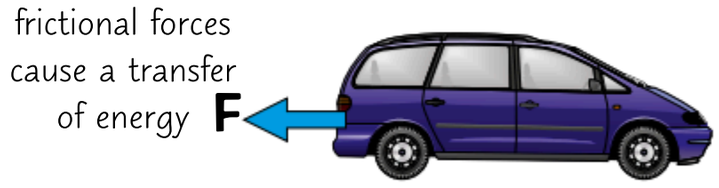
Example 2 — A ball dropped from a height

1) The ball is accelerated by the constant force of gravity.
2) Energy is transferred mechanically from the ball's gravitational potential energy store to its kinetic energy store.



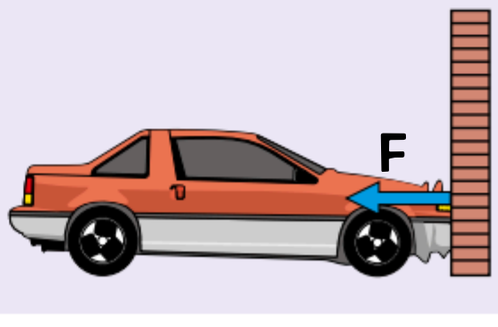
Example 3 — A car slowing down

1) Friction acts between the car's brakes and its wheels.
2) Energy is transferred mechanically from the wheels' kinetic energy stores to the thermal energy store of the surroundings.



Example 4 — A car hitting a wall

1) When the car and the wall touch, there is a normal contact force (p.203) on both of them.
2) Energy is transferred mechanically from the car's kinetic energy store to lots of other energy stores.
3) Some energy is transferred to the elastic potential and thermal energy stores of the wall and the car.
4) Some energy might also be transferred away by sound waves.



All this work, I can feel my energy stores being drained...

The four examples above aren't the only ones you can be asked about. Test yourself with this question.

Q1 Describe the energy transfers that occur when the wind causes a windmill to spin. [3 marks]

Q1 Video Solution

Kinetic and Potential Energy Stores

Now you've got your head around energy stores, it's time to work out how much energy is in them.

Movement Means Energy in an Object's Kinetic Energy Store

1) Energy is transferred to the kinetic energy store when an object speeds up.
2) Energy is transferred away from this store when an object slows down.
3) There's a slightly tricky formula for finding the energy in an object's kinetic energy store:

$$E_k = \tfrac{1}{2}mv^2$$

Kinetic energy (J) — Mass (kg) — (Speed)^2 (m/s)^2

$\frac{1}{2}mv^2$ means $\frac{1}{2} \times m \times v^2$.

EXAMPLE

A car of mass 2500 kg is travelling at 20 m/s. Calculate the energy in its kinetic energy store.

$E_k = \frac{1}{2} \times 2500 \times 20^2 = 500\,000$ J

Raised Objects Store Energy in Gravitational Potential Energy Stores

1) All objects raised above the ground gain energy in their gravitational potential energy (g.p.e.) store.
2) You can find the energy in an object's g.p.e. store using:

$$E_p = mgh$$

g.p.e. (J) — Height (m) — Mass (kg) — Gravitational field strength (N/kg)

Gravitational field strength on Earth is equal to 9.8 N/kg.

You Can Calculate Energy Transfers Using Conservation of Energy

You can also make calculations when energy is transferred between two stores. For example:

1) You saw on p.168 that a falling object transfers energy from its g.p.e. store to its kinetic energy store.
2) The conservation of energy principle (p.168) says that energy can't be destroyed.
3) So for a falling object when there's no air resistance:

Energy lost from the g.p.e. store = Energy gained in the kinetic energy store

Stretching can Transfer Energy to Elastic Potential Energy Stores

1) Stretching or squashing an object can transfer energy to its elastic potential energy store.
2) The energy in the elastic potential energy store of a stretched spring can be found using:

$$E_e = \tfrac{1}{2}ke^2$$

Elastic potential energy (J) — Spring constant (N/m) — (Extension)^2 (m)^2

3) This equation only works if the limit of proportionality has not been passed (p.206).

Make the most of your potential — jump on your bed...

That's a lot of energy equations. Make sure you're really happy using them before moving on.

Q1 A 2.0 kg object is dropped from a height of 10 m.
Calculate the speed of the object after it has fallen 5.0 m, assuming there is no air resistance.
Give your answer to 2 significant figures. $g = 9.8$ N/kg. [5 marks]

Q1 Video Solution

Energy Transfers by Heating

Heating is just one way of transferring energy, as you saw back on p.167. Also coming up on this page — specific heat capacity. Which is really just a sciencey way of saying how hard it is to heat something up...

Energy can be Transferred by Heating

1) As a material is heated, energy is transferred to its thermal energy store.
2) This causes its temperature to increase.
3) You need to be able to describe the changes in how energy is stored when an object is heated.
4) For example, if you boil water in an electric kettle:
   1) Energy is transferred electrically to the thermal energy store of the kettle's heating element.
   2) Energy is then transferred by heating to the water's thermal energy store.
   3) So the temperature of the water increases.



Different Materials Have Different Specific Heat Capacities

1) Some materials need more energy to increase their temperature than others.
2) These materials also transfer more energy when they cool down again.
3) They can 'store' a lot of energy.
4) The amount of energy stored or released as a material changes temperature depends on the specific heat capacity of the material.
5) This energy can be found using:

$$\Delta E = mc\Delta\theta$$

Change in thermal energy (J) — ΔE
Mass (kg) — m
Specific heat capacity (J/kg°C) — c
Temperature change (°C) — $\Delta\theta$

'Δ' just means change in.

6) Specific heat capacity is the amount of energy needed to raise the temperature of 1 kg of a material by 1 °C.

EXAMPLE

A hot block of metal cools from 55 °C to 25 °C. The block has a mass of 0.50 kg and is made from a material that has a specific heat capacity of 320 J/kg°C. Calculate the energy transferred from the block as it cooled.

1) First, calculate the change in the block's temperature. $55\ °C - 25\ °C = 30\ °C$
2) The numbers are in the correct units. So put them into the equation.
3) The unit for energy is joules (J).

$$\Delta E = mc\Delta\theta$$
$$= 0.50 \times 320 \times 30$$
$$= 4800\ J$$

All those symbols are leaving me a bit hot and bothered...

That equation is pretty nasty looking — make sure you can use it, as it's coming up again on the next page.

Q1 Find the final temperature of 5 kg of water, at an initial temperature of 5 °C, after 50 kJ of energy has been transferred to it. The specific heat capacity of water is 4200 J/kg°C. [3 marks]

Q1 Video Solution

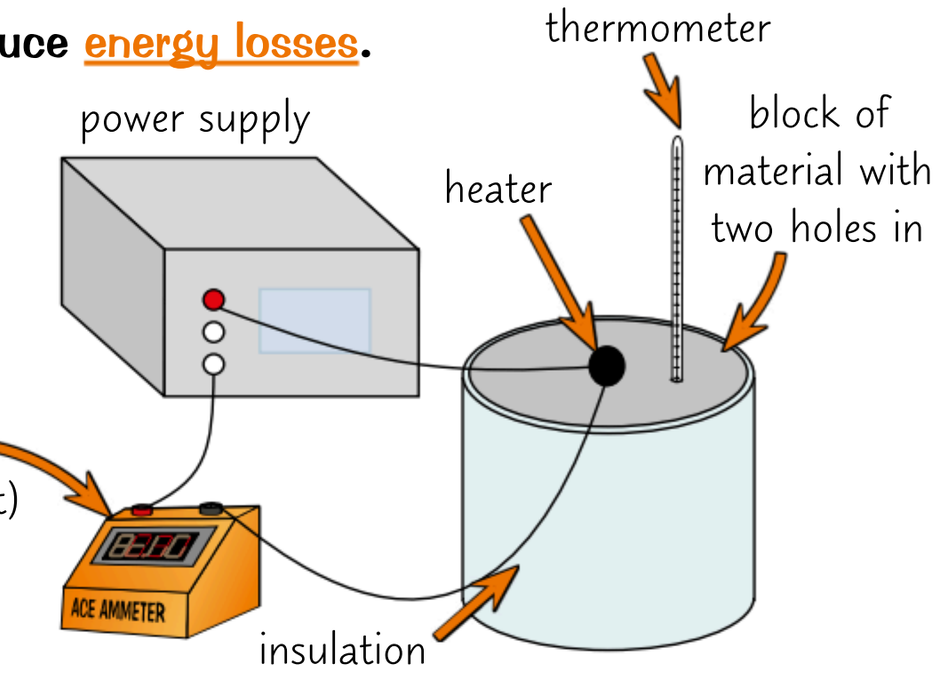
Investigating Specific Heat Capacity

Time for a practical. Woohoo I hear you shout! Maybe not, but you do have to know it I'm afraid.

Investigate the Specific Heat Capacity of a Solid Block

PRACTICAL

1) Measure the mass of the block.
2) Wrap it in an insulating layer (e.g. thick newspaper) to reduce energy losses.
3) Set up the apparatus as shown.
4) Measure the starting temperature of the block.
5) Turn on the power supply and start a stopwatch.
6) Record the potential difference, V, of the power supply and the current, I. They shouldn't change at all.
7) After 10 minutes, take a reading of the block's temperature.
8) Turn off the heater and work out the temperature change.
9) Calculate the power of the heater using $P = VI$ (p.190).



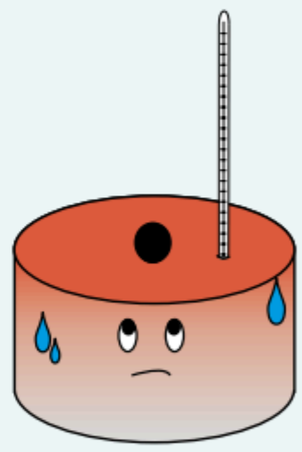
Calculating the Specific Heat Capacity

To calculate the specific heat capacity, you need ideas about work done and energy transferred:

1) When you turn on the power, the current in the circuit does work on the heater.
2) Energy is transferred electrically from the power supply to the heater's thermal energy store.
3) The energy transferred to the heater is given by $E = Pt$ (p.172).
(P is the power of the heater and t is how long the heater is on for.)
4) This energy is then transferred to the material's thermal energy store by heating.
5) So the value of E you calculated in step 3 is equal to the change in thermal energy of the block, ΔE, and you can use it to find the specific heat capacity of the block, c.
6) Rearrange the equation from page 170 to give you $c = \Delta E \div (m \times \Delta\theta)$, and put in your results.
7) The temperature change, $\Delta\theta$, and mass, m, were measured in the experiment.
Use your value of E from step 3 as ΔE.
8) This example shows how to do the calculation:

EXAMPLE

A 1.0 kg block of material is heated using a 10 V power supply.
The starting temperature of the block is 20 °C.
The current through the heater is recorded as 10 A.
After 60 seconds, the final temperature of the block is 26 °C.
Calculate the specific heat capacity of the material of the block.



1) Calculate the power of the heater. $P = V \times I = 10 \times 10 = 100$ W
2) Calculate the energy transferred. $E = P \times t = 100 \times 60 = 6000$ J
3) Find the change in temperature. $\Delta\theta = 26 - 20 = 6$ °C
4) Calculate the specific heat capacity. $c = \Delta E \div (m \times \Delta\theta) = 6000 \div (1.0 \times 6) = 1000$ J/kg °C

10) You can repeat this experiment with different materials to see how their specific heat capacities compare.
11) For a liquid, place the heater and thermometer into an insulated beaker with a known mass of the liquid.
12) Then carry out the rest of the experiment in exactly the same way as above.

I've eaten five sausages — I have a high specific meat capacity...

This is quite a tricky experiment, with lots of steps. Re-read this whole page to get it in your head.

Q1 A student uses an 80 W heater to heat a 2 kg block of metal for 200 s. The temperature of the block increases by 20 °C. Calculate the specific heat capacity of the metal. Assume that all the energy from the heater is transferred to the metal block. [5 marks]

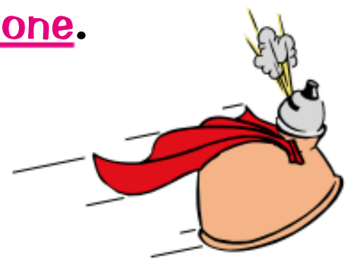
Q1 Video Solution

Power

Punch your fist in the air and repeat after me — '**I HAVE THE POWER**'.

Power is the 'Rate of Doing Work' — How Much Work is Done per Second

1) Power is the rate of energy transfer.
2) You can also say it's the rate of doing work.
3) This just means that power is how fast energy is transferred or how fast work is done.
4) Power is measured in watts.
5) One watt = 1 joule of energy transferred per second.
6) You can calculate power using these equations:



$$\text{Power (W)} \quad P = \frac{E}{t} \quad \begin{matrix}\text{Energy transferred (J)} \\ \text{Time (s)}\end{matrix}$$

$$\text{Power (W)} \quad P = \frac{W}{t} \quad \begin{matrix}\text{Work done (J)} \\ \text{Time (s)}\end{matrix}$$

EXAMPLE

a) It takes 8000 J of work to lift a stuntman to the top of a building. A motor takes 50 s to make the lift. Calculate the power of the motor.

1) The numbers are in the correct units.
2) Put the numbers into the equation for power in terms of work.

a) $P = W \div t$
$= 8000 \div 50$
$= 160$ W



b) A second motor has a power of 200 W. It lifts the stuntman for 30 s. Calculate the energy transferred by the motor.

1) Rearrange the power equation for energy transferred.
2) Put the numbers in.
3) Remember energy is in joules.

b) $P = E \div t$ so $E = P \times t$
$= 200 \times 30$
$= 6000$ J

A Powerful Machine Transfers a Lot of Energy in a Short Space of Time

1) Take two cars that are the same in every way apart from the power of their engines.
2) Both cars race the same distance along a straight race track to a finish line.
3) The car with the more powerful engine will reach the finish line faster than the other car.
4) This is because it will transfer the same amount of energy but over a shorter time.



Watt's power? Power's watts...

You might be tired of hearing this, but energy transferred and work done are the same thing. That's why power can be described using energy or work done, and why those two equations above look so similar.

Q1 A motor transfers 4.8 kJ of energy in 2 minutes. Calculate its power output. [3 marks]

Q1 Video Solution

Reducing Unwanted Energy Transfers

There are a few ways you can reduce the amount of energy running off to a completely useless store.

Energy is Always Wasted in any Energy Transfer

1) When energy is transferred between stores, some energy is transferred to the store you want it in.
2) This energy is usefully transferred.
3) But in any energy transfer, some energy is always dissipated.
4) This means the energy is transferred to useless stores.
5) These useless energy stores are usually thermal energy stores.
6) This energy is often described as 'wasted' energy.

- When you use a mobile phone, energy is transferred from the chemical energy store of the battery.
- Some energy is usefully transferred.
- But some is dissipated to the thermal energy store of the phone.



7) There are a few ways you can reduce the amount of energy wasted.

Lubrication Reduces Frictional Forces



1) Friction acts between all objects that rub together.
2) This causes some energy in the system to be dissipated.
3) Lubricants can be used to reduce the friction between the objects.
4) For example, oil in car engines reduces friction between all of the moving parts.
5) This reduces the amount of dissipated energy.

Insulation Has a Low Thermal Conductivity

1) When part of a material is heated, that part of the material gains energy.
2) This energy is transferred across the material so that the rest of the material gets warmer.
3) For example, if you heated one end of a metal rod, the other end would eventually get warmer. This is known as conduction.
4) Thermal conductivity is a measure of how quickly energy is transferred by conduction through a material.
5) Materials with a high thermal conductivity transfer lots of energy in a short time.
6) Materials with a low thermal conductivity are called thermal insulators.
7) Thermal insulators can reduce unwanted transfers by heating, e.g. in the home.

Insulation is Important for Keeping Buildings Warm



You can keep your home cosy and warm by reducing the rate of cooling.
How quickly a building cools depends on:

1) How thick its walls are. The thicker the walls are, the slower a building will cool.
2) The thermal conductivity of its walls. Building walls from a material with a low thermal conductivity reduces the rate of cooling.
3) How much thermal insulation there is, e.g. loft insulation reduces energy losses through the roof.

Energy can't be created or destroyed — only talked about a lot...

Remember, when energy is wasted it's not destroyed — it still exists, it just isn't stored usefully anymore.

Q1 A builder is designing a house.
Give one way the builder could reduce the rate of cooling of the house. [1 mark]

Efficiency

More! More! Tell me more about energy transfers please! Oh go on then, since you insist...

Energy Transfers Involve Some Wasted Energy

1) You saw on page 173 that some energy is always wasted when energy is transferred.
2) The less energy that is wasted, the more efficient the energy transfer is.
3) The efficiency of an energy transfer is a measure of the amount of energy that ends up in useful energy stores.
4) But as some energy is always wasted, nothing is 100% efficient.

There Are Two Efficiency Equations

1) The efficiency for any energy transfer can be worked out using this equation:

$$\text{Efficiency} = \frac{\text{Useful output energy transfer}}{\text{Total input energy transfer}}$$

This gives efficiency as a decimal, but you can turn it into a percentage — see below.

EXAMPLE

36 000 J of energy is transferred to a television. It transfers 28 800 J of this energy usefully. Calculate the efficiency of the television. Give your answer as a percentage.

1) Put the numbers you're given into the equation.

efficiency = useful output energy transfer ÷ total input energy transfer
= 28 800 ÷ 36 000
= 0.8

2) To change a decimal to a percentage, multiply your answer by 100.

0.8 × 100 = 80, so efficiency = 80%

2) You might not know the energy input and output of a device.
3) But you can use its power input and output to calculate its efficiency:

$$\text{Efficiency} = \frac{\text{Useful power output}}{\text{Total power input}}$$



EXAMPLE

A blender is 70% efficient. It has a total input power of 600 W. Calculate the useful power output.

1) Change the efficiency from a percentage to a decimal. To do this, divide the percentage by 100.

efficiency = 70% ÷ 100 = 0.7

2) Rearrange the equation for useful power output.

useful power output = efficiency × total power input

3) Stick in the numbers and find the useful power output.

useful power output = 0.7 × 600 = 420 W

Don't waste your energy — turn the TV off while you revise...

Make sure you can use and rearrange the equations for efficiency, then have a go at these questions.

Q1 A motor in a remote-controlled car transfers 300 J of energy into the car's energy stores. 225 J are transferred to the car's kinetic energy stores. Calculate the efficiency of the motor. [2 marks]

Q2 A machine has a useful power output of 900 W and a total power input of 1200 W. In a given time, 72 kJ of energy is transferred to the machine. Calculate the amount of energy usefully transferred by the machine in this time. [4 marks]

Q2 Video Solution

Energy Resources and Their Uses

Energy resources are mostly used to generate electricity or for transport and heating.

Non-Renewable Energy Resources Will Run Out One Day



1) Non-renewable energy resources are fossil fuels and nuclear fuel.
2) The three main fossil fuels are coal, oil and (natural) gas.
3) We can't replace non-renewable energy resources as quickly as we're using them.

Renewable Energy Resources Will Never Run Out

1) Renewable energy resources can be replenished (replaced) as quickly as they are being used.
2) The renewable energy resources you need to know are:

1) The Sun (Solar)
2) Wind
3) Water waves
4) Hydro-electricity
5) Bio-fuels
6) Tides
7) Geothermal

Energy Resources can be Used for Transport...

1) Transport uses both renewable and non-renewable energy resources. For example:

NON-RENEWABLE ENERGY RESOURCES

- Petrol or diesel is used in most vehicles. They're both created from oil.
- Coal is used in steam trains to boil water to produce steam.

RENEWABLE ENERGY RESOURCES

Vehicles can run on pure bio-fuels (p.178) or a mix of a bio-fuel and petrol or diesel.

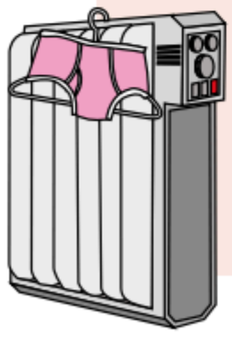
2) Electricity can also be used for transport — e.g. electric cars and some trains.
3) The electricity can be generated using renewable or non-renewable energy resources (p.174-176).

...And for Heating

Energy resources are also needed for heating things, like your home.

NON-RENEWABLE ENERGY RESOURCES

- Natural gas is burnt to heat water in a boiler. This hot water is then pumped into radiators.
- Gas fires burn natural gas to heat rooms.
- Coal is burnt in open fireplaces.
- Electric heaters use electricity which can be generated from non-renewable energy resources.



RENEWABLE ENERGY RESOURCES

- Bio-fuel boilers work in the same way as gas boilers.
- A geothermal heat pump uses geothermal energy resources (p.176) to heat buildings.
- Solar water heaters use the Sun to heat water which is then pumped into radiators in the building.
- Electric heaters can use electricity generated from renewable resources.

I'm pretty sure natural gas is renewable — I make enough of it...

You need to know the difference between the two different types of energy resource, so get cracking.

Q1 Write down whether each of the following is a renewable or non-renewable energy resource.
a) Tidal power b) Natural gas c) Nuclear power d) Bio-fuel [4 marks]

Wind, Solar and Geothermal

Time for the first page on renewable energy resources. You've probably heard about a few of these already.

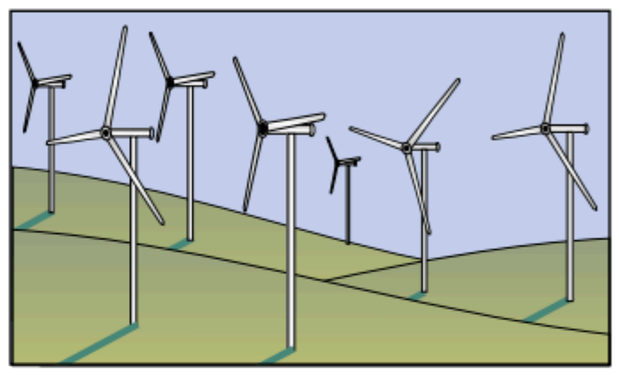
You Need to Be Able to Compare Resources

1) You're about to learn all about the main energy resources.
2) You need to be able to:
   - describe their effects on the environment (e.g. pollution).
   - compare their reliability (whether they can be trusted to provide energy when we need it).
3) So make sure you're paying attention.

No energy resource is 100% reliable as power plants may unexpectedly break or need to be shut down.

Wind Power — Lots of Wind Turbines

1) Wind turbines are usually put up in open spaces.
2) When the wind turns the blades, electricity is produced.
3) They produce no pollution once they're built.
4) And they do no permanent (lasting) damage to the landscape. If you remove the turbines, the area goes back to normal.
5) However, they're not as reliable as other energy resources.
6) They don't produce electricity when the wind stops.
7) Turbines are also stopped if the wind is too strong. This stops them getting damaged.
8) It's also impossible to increase supply when there's extra demand (p.191) for electricity.



Solar Cells — Expensive but No Environmental Damage

1) Solar cells generate electricity directly from sunlight.
2) They create no pollution once they're built.
3) But quite a lot of energy is used to build them.
4) Solar power only generates electricity during the day.
5) In sunny countries solar power is a very reliable source of energy.
6) It's still fairly reliable in cloudy countries like Britain.
7) Like wind, you can't increase the power output when there is extra demand.



Time to recharge.

Geothermal Power — Energy in Underground Thermal Energy Stores

1) Geothermal power uses energy from the thermal energy stores of hot rocks below the Earth's surface.
2) It can be used to generate electricity or to heat buildings.
3) Geothermal power is very reliable because the hot rocks are always hot.
4) Most geothermal power stations only have a small impact on the environment.

People love the idea of wind power — just not in their back yard...

There are pros and cons to all energy resources. Make sure you know them for solar, wind and geothermal.

Q1 Explain why geothermal power is more reliable than wind power. [2 marks]

Hydro-electricity, Waves and Tides

Good old water. Not only can we drink it, we can also use it to generate electricity.

Hydro-electric Power Uses Falling Water

1) Hydro-electric power usually involves building a big dam across a valley.
2) The valley is usually flooded.
3) Water is allowed to flow out through turbines, which generates electricity.
4) There is no pollution when it's running.
5) But there is a big impact on the environment due to the flooding of the valley.
6) Plants rot and release greenhouse gases which lead to global warming (see p.178).
7) Animals and plants also lose their habitats (where they live).
8) There's no problem with reliability in countries that get rain regularly.
9) And it can respond straight away when there's extra demand (p.191) for electricity.

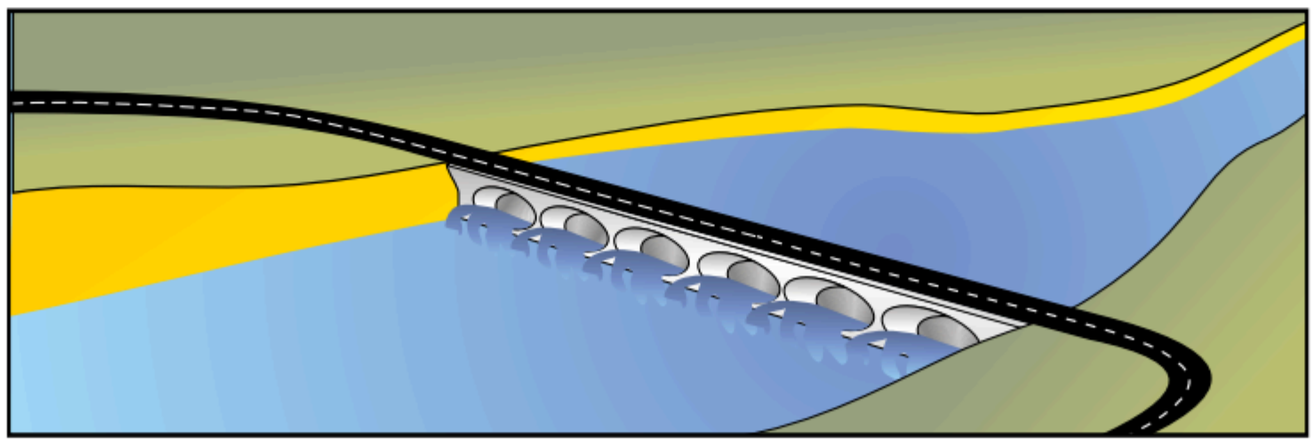
Wave Power — Lots of Little Wave-Powered Turbines



1) Turbines around the coast are turned by water waves and electricity is generated.
2) There is no pollution.
3) But they disturb the seabed and the habitats of animals.
4) They are fairly unreliable, as waves tend to die down when the wind drops.

Tidal Barrages Use the Tides of the Sea

1) Tidal barrages are big dams (with turbines in them) built across rivers.
2) Water passing through the turbines generates electricity.
3) The amount of energy generated changes with the tides.
4) But tidal barrages are very reliable, as we can predict the tides (we know what they're going to do).
5) There is no pollution.
6) But they do change the habitat of the wildlife, e.g. birds and sea creatures.
7) And often fish are killed as they swim through the turbines.



The hydro-electric power you're supplying — it's electrifying...

Learn the differences between all of these water-based resources before having a go at this question.

Q1 Give one negative environmental impact of wave power. [1 mark]

Bio-fuels and Non-renewables

And the energy resources just keep on coming. It's over soon, I promise. Just a few more to go.

Bio-fuels are Made from Plants and Waste

1) Bio-fuels are fuels created from plant products or animal dung.
2) They can be burnt to produce electricity or used to run cars in the same way as fossil fuels.
3) They produce carbon dioxide when they're burnt.
4) But the plants used to make biofuels will have absorbed a lot of carbon dioxide while they were growing.
5) In some places, large areas of forest have been cleared to make room to grow bio-fuels.
6) This leads to lots of animals losing their natural habitats.
7) Crops can be grown throughout the year.
8) Extra bio-fuels can be constantly produced and stored for when they are needed.
9) So bio-fuels are fairly reliable.



Non-Renewables are Reliable...

1) Fossil fuels and nuclear energy are reliable.
2) There's enough fossil and nuclear fuels to meet current demand.
3) We always have some in stock so power plants can respond quickly to changes in demand.
4) However, these fuels are slowly running out.
Some fossil fuels may run out within a hundred years.

...But Create Environmental Problems

1) Coal, oil and gas release CO_2 into the atmosphere when they're burned. All this CO_2 leads to global warming.
2) Burning coal and oil also releases sulfur dioxide, which causes acid rain.
3) Acid rain makes lakes and rivers acidic, which can kill animals and plants. It can also damage trees and soils.
4) Coal mining makes a mess of the landscape.
5) And it destroys the habitats of local animals and plants.
6) Oil spills cause big environmental problems and harm sea creatures.
7) Nuclear power is clean but the nuclear waste is very dangerous and difficult to get rid of.
8) Nuclear power also carries the risk of a big accident that could release a lot of radiation, like the Fukushima disaster in Japan.

Global warming is where greenhouse gases cause the Earth to warm up.



Radiation can be very dangerous to humans — see p.201 for more.

Bio-fuels are great — but don't burn your biology notes just yet...

Make sure you can talk about how bio-fuels and non-renewables affect the environment.

Q1 Give two benefits of using fossil fuels to generate electricity. [2 marks]

Q2 Give three environmental impacts of using oil as an energy resource. [3 marks]

Trends in Energy Resource Use

Over time, the types of energy resources we use change. Read on to find out why.

Currently we Still Need Non-Renewables

1) Our use of electricity increased a lot in the 1900s.
2) This was because the population and the number of things that used electricity increased.
3) But electricity use in the UK has been falling slowly since around the year 2000.
4) This is because we're trying harder to be energy efficient and save energy.
5) At the moment, we use non-renewables for much of our electricity, transport and heating.

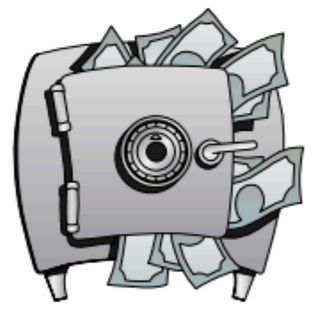
But People Want to use More Renewable Energy Resources

1) We now know that non-renewables are very bad for the environment and will run out one day (p.178).
2) This makes many people want to use renewable energy resources as they are better for the environment.
3) Many people also think it's better to move to renewables before non-renewables run out.
4) Pressure from other countries and the public has meant that governments have begun to introduce targets for using renewable energy resources.
5) This puts pressure on energy providers to build new renewable power plants. If they don't, they may lose business and money in the future.
6) Car companies have also had to change to become more environmentally-friendly.
7) Cars that can run on electricity are already on the market. The electricity can be generated using renewable energy resources.

The Use of Renewables is Limited by Lots of Factors

1) There's a lot of scientific evidence supporting renewables.
2) But scientists can only give advice. They don't have the power to make people, companies or governments change their ways (see p.2).
3) Moving to renewables can be limited by money.

- Building new renewable power plants costs money.
- Some renewable resources are less reliable than other resources, so a mixture of different resources would need to be used.
- This costs even more money.
- Cars that run on electricity are more expensive than petrol cars.



4) Moving to renewables can also be affected by politics, people and ethics (if something is right or wrong).

- The cost of switching to renewable power will have to be paid through energy bills or taxes.
- Governments often don't want to suggest raising taxes as this may make them unpopular.
- Some people don't want to or can't afford to pay. There are arguments about whether it's ethical (right or wrong) to make them pay.
- Many people also don't want to live near to a power plant (like a wind farm or hydro-electric dam).
- And some think it's not ethical to make people put up with new power plants built near to them.

Going green is on-trend this season...

More people want to help the environment, so the energy resources we use are changing. But for lots of reasons, it's not happening very quickly. Make sure you learn the reasons listed on this page.

Q1 Give two reasons why we currently do not use more renewable energy resources in the UK. [2 marks]

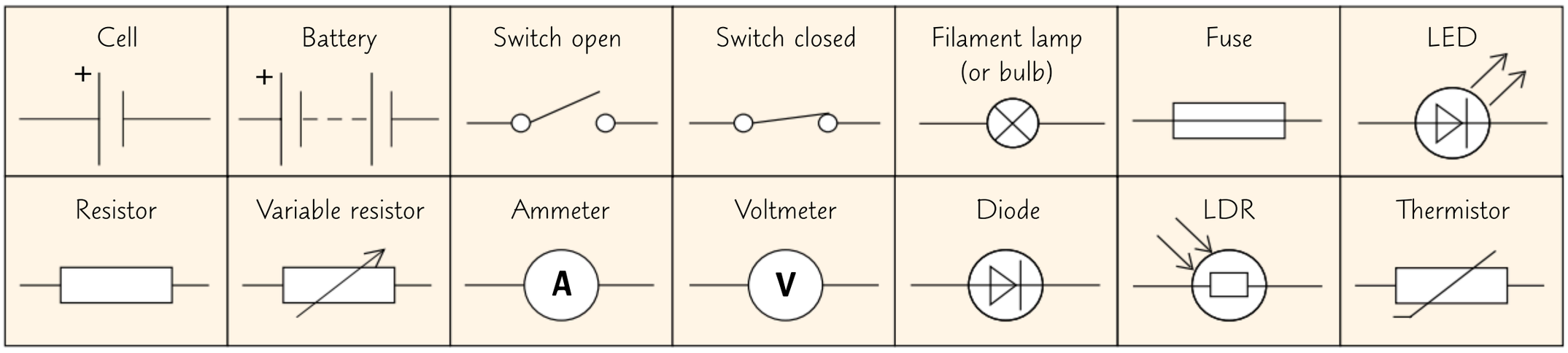
Current and Circuit Symbols

If the word current makes you think of delicious cakes instead of physics, that's all about to change. Learn what it means, as well as some handy symbols to show things like batteries and switches in a circuit.

Learn these Circuit Diagram Symbols

1) You need to be able to understand circuit diagrams and draw them using the correct symbols.
2) These are the symbols you need to know:

The parts in a circuit e.g. bulbs, resistors, etc. are called 'components'.



3) Follow these rules to draw a circuit diagram:

- Make sure all the wires in your circuit are straight lines.
- Make sure that the circuit is closed. This means you can follow a wire from one end of the cell or battery, through any components, to the other end of the cell or battery.

Total Charge Through a Circuit Depends on Current and Time

1) Electric current is a flow of electrical charge.
2) Current is measured in amperes, A.
3) Charge is measured in coulombs, C.
4) Electrical charge will only flow round a complete (closed) circuit if something is providing a potential difference, e.g. a battery.
5) The potential difference is the 'driving force' that pushes charge around the circuit.
6) Resistance is anything that slows down the flow of charge.
7) In a single, closed loop the current is the same everywhere in the circuit (see p.185).
8) The size of the current tells you how fast the charge is flowing. This is known as the rate of flow of charge.
9) Charge flow, current and time are related by this handy equation:



'Potential difference' is sometimes called 'voltage'. Exam questions will use 'potential difference', but you can use either.

Charge flow (C) = Current (A) × Time (s) $\quad Q = It$

EXAMPLE

A battery charger passes a current of 2 A through a cell over a period of 300 seconds. How much charge is transferred to the cell?

Just substitute the values into the equation above and calculate the charge.

$Q = It = 2 \times 300$
$= 600$ C

Remember charge is measured in coulombs.

I think it's about time you took charge...

Learn those symbols. It's no good if you're asked to draw a circuit diagram and you can't tell a resistor from a fuse.

Q1 A student creates a simple circuit containing a battery, a switch and a bulb. She connects them all in a single, closed loop. Draw the circuit diagram for this circuit. [3 marks]

Resistance and $V = IR$

Potential difference, current and resistance are linked by a very important formula. Make sure you learn it.

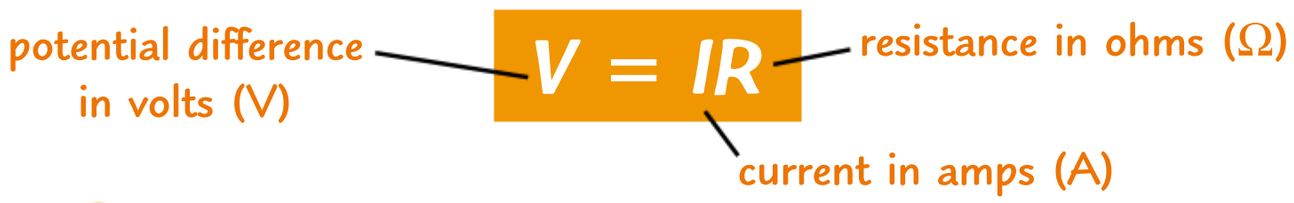
There's a Formula Linking Potential Difference and Current

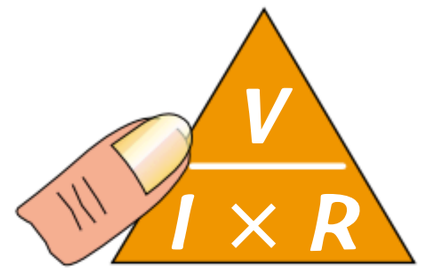
1) The current flowing through a component depends on the potential difference across it and the resistance of the component.

Resistance measures how much the current is slowed down.

The greater the resistance across a component, the smaller the current that flows (for a given potential difference across the component).

2) The formula linking potential difference (pd) and current is:





EXAMPLE

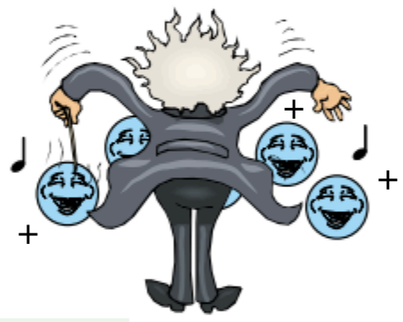
A 4.0 Ω resistor in a circuit has a potential difference of 6.0 V across it. What is the current through the resistor?

1) Cover the I in the formula triangle to find that $I = V \div R$. $I = V \div R$
2) Substitute in the values you have, and work out the current. $I = 6.0 \div 4.0 = 1.5$ A

Ohmic Conductors Have a Constant Resistance

1) $V = IR$ works for components with a fixed resistance. This means the resistance of the component doesn't change with current.
2) These components are called ohmic conductors.
3) Ohmic conductors only have a fixed resistance if their temperature doesn't change.
4) Wires and resistors are examples of ohmic conductors.
5) For an ohmic conductor at a fixed temperature:

The current flowing through it is directly proportional to the potential difference across it.



6) This means that if you multiply the potential difference by a certain amount, the current will be multiplied by the same amount. For example, if the potential difference doubles, the current doubles too.

Some Components Have a Changing Resistance

1) The resistance of some components DOES change with current. For example, a filament lamp or a diode.
2) Filament lamps contain a wire (the filament), which is designed to heat up and 'glow' as the current increases.
3) So as the current increases, the temperature of the filament increases.

A higher current makes a filament glow brighter. So a higher pd means a brighter lamp.

4) Resistance increases with temperature, so the resistance increases with current.
5) For diodes, the resistance depends on the direction of the current.
6) A diode will let current flow in one direction. It has a very high resistance in the opposite direction, which makes it hard for a current to flow that way.

Ohm sweet ohm...

There's loads more coming up on resistance, so make sure you're happy with this page before moving on.

Q1 An appliance is connected to a 230 V source. Calculate the resistance of the appliance if a current of 5.0 A is flowing through it. [3 marks]

Q1 Video Solution

PRACTICAL

Investigating Resistance

Woo, experiments. Here's a simple experiment for investigating resistance.

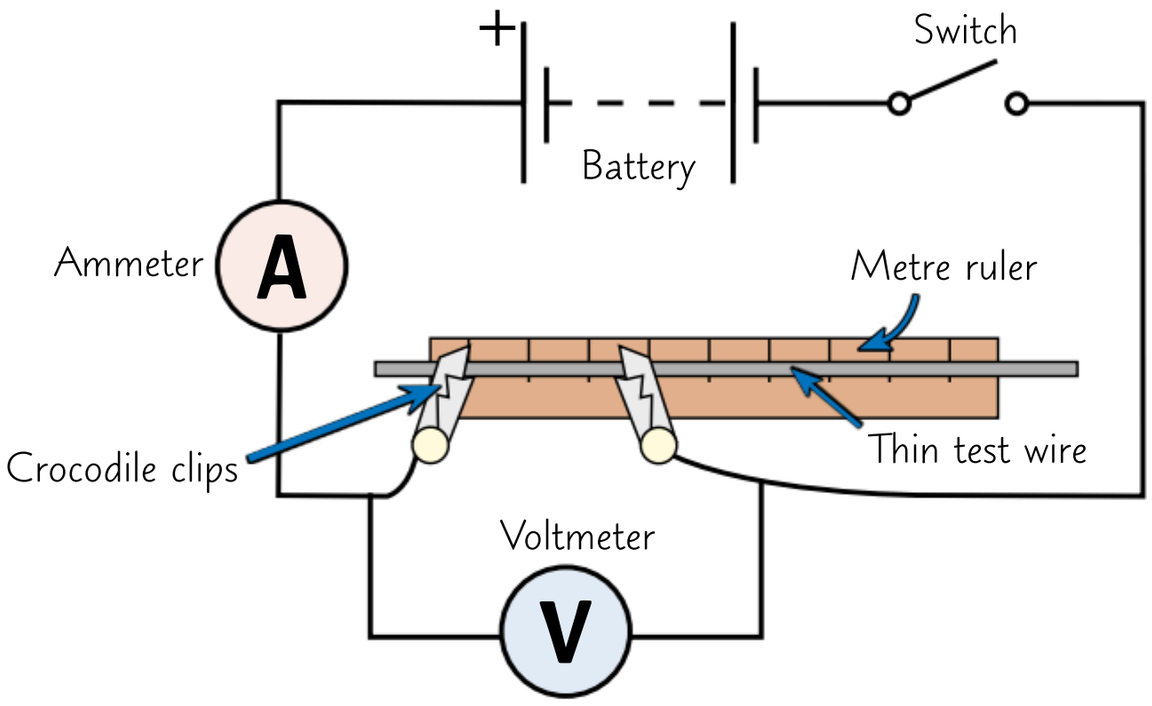
You Can Investigate the Factors Affecting Resistance

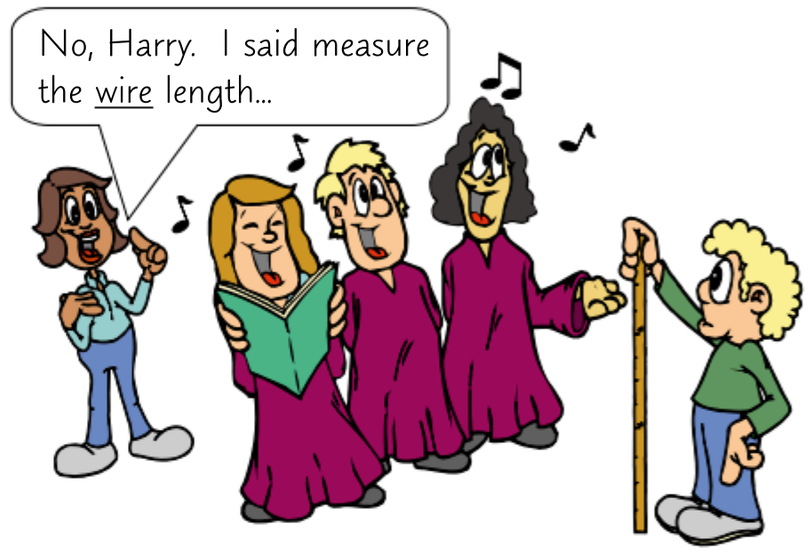
The resistance of a circuit can depend on a number of things, including:

- If components are in series or parallel. See p.185 for more on this.
- The length of wire used in the circuit.

Learn How to Investigate the Effect of Wire Length

You can investigate the effect of wire length using this circuit:



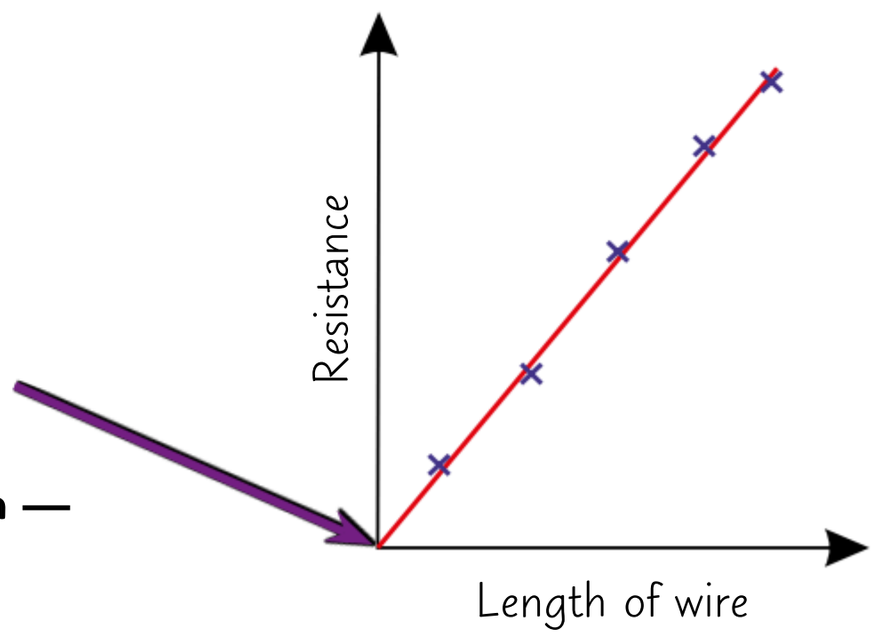


Measure Potential Difference and Current for Different Lengths

1) Attach a crocodile clip to the wire level with 0 cm on the ruler.
2) Attach the second crocodile clip to the wire a short distance from the first clip.
3) Write down the length of the wire between the clips.
4) Close the switch, then record the current through the wire and the pd across it.
5) Use $R = V \div I$ (from the equation $V = IR$ on p.181) to calculate the resistance of the wire.
6) Open the switch and move the second crocodile clip along the wire.
7) Repeat steps 3 to 6 for a range of wire lengths.

Plot a Graph of your Results

1) Plot a graph of resistance against wire length.
2) Draw a line of best fit through your points.
3) Your graph should be a straight line through the origin (where length and resistance are both zero).
4) This means resistance is directly proportional to length — the longer the wire, the greater the resistance.



Measure gymnastics — use a vaultmeter...

Opening the switch between readings lets the circuit cool down. This reduces the error in your measurements.

Q1 A student performs an investigation into the effect of wire length on resistance.
Draw a circuit diagram of a circuit the student could use to carry out this investigation.
Use the symbol for a variable resistor to represent the test wire. [3 marks]

I-V Characteristics

There are three different graphs to learn on this page — you have to know how you get them too.

I-V Characteristics Show How Current Changes With Pd

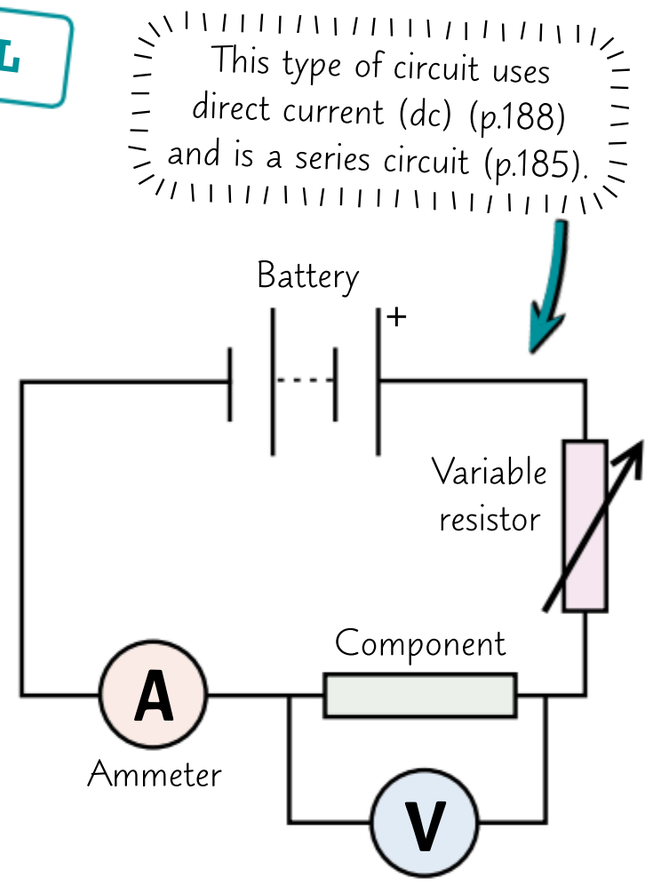
1) An '*I-V* characteristic' is a graph showing how the current (*I*) flowing through a component changes as the potential difference (*V*) across it changes.
2) Components with straight line *I-V* characteristics are called linear components (e.g. a fixed resistor).
3) Components with curved *I-V* characteristics are non-linear components (e.g. a filament lamp or a diode).
4) To find the resistance at any point on the *I-V* characteristic, first read off the values of *I* and *V* at that point. Then use $R = V \div I$ (from $V = IR$ on page 181).

You Can Investigate *I-V* Characteristics

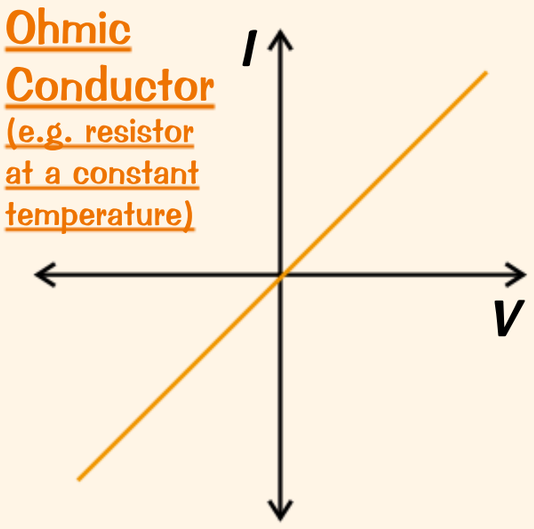
PRACTICAL

You should do this experiment for different components, including a filament lamp, a diode and a resistor at a fixed temperature.

1) Set up the test circuit shown on the right.
2) The variable resistor is used to change the current in the circuit. This changes the potential difference across the component.
3) Now you need to get sets of current and potential difference readings:
   - Set the resistance of the variable resistor.
   - Measure the current through and potential difference across the component.
   - Take measurements at a number of different resistances.
4) Swap over the wires connected to the battery to reverse the direction of the current. The ammeter should now display negative readings.
5) Repeat step 3 to get results for negative values of current.
6) Plot a graph with current on the *y*-axis and potential difference on the *x*-axis.
7) Here are the graphs or '*I-V* characteristics' you should get for different components:

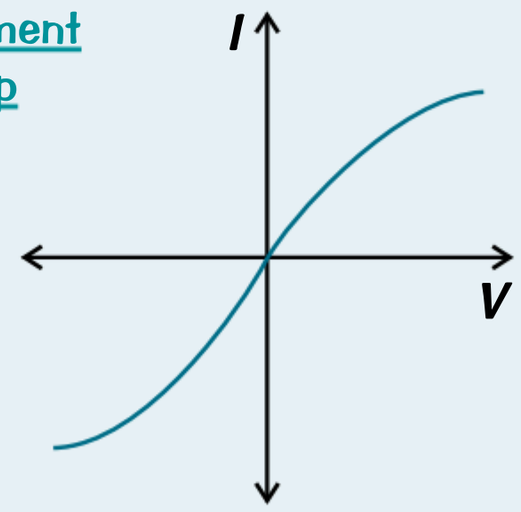


Ohmic Conductor (e.g. resistor at a constant temperature)



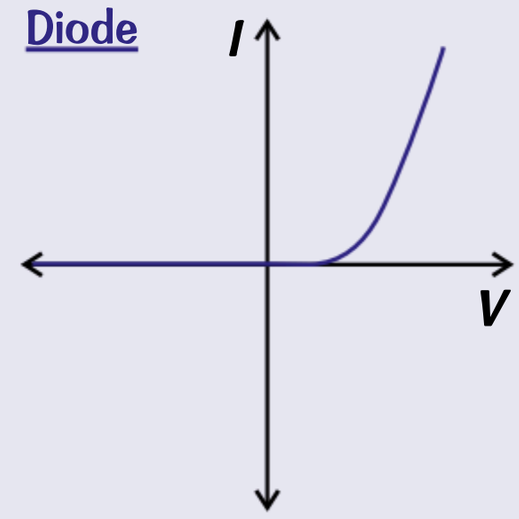
1) Current is directly proportional to potential difference.
2) So you get a straight line.

Filament Lamp



1) Temperature increases as current increases.
2) So resistance increases.
3) This makes it harder for current to flow.
4) So the graph gets less steep.

Diode



1) Current only flows in one direction.
2) The diode has very high resistance in the reverse direction.

In the end you'll have to learn this — resistance is futile...

Draw out those graphs until you're sketching them in your sleep.

Q1 Explain the shape of the filament lamp *I-V* characteristic above, for the quadrant where *I* and *V* are positive. [3 marks]

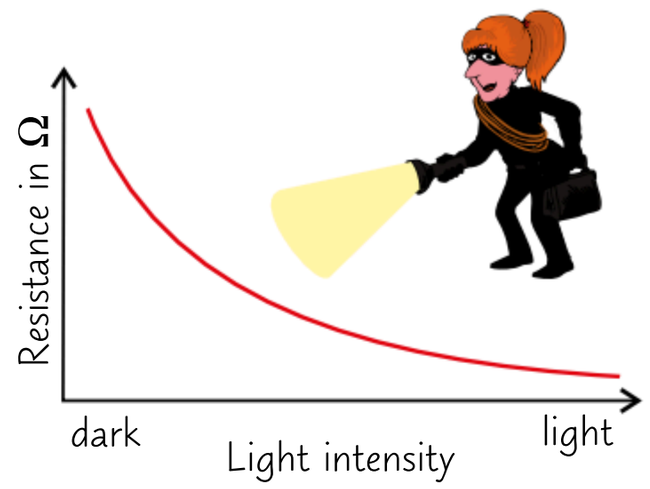
Q1 Video Solution

Circuit Devices

For some components resistance can depend on things like light and temperature, and this can be really handy.

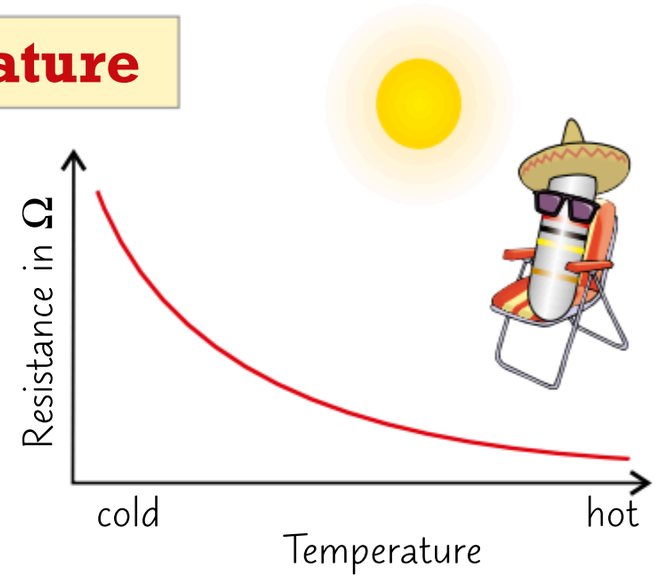
LDR is Short for Light Dependent Resistor

1) The resistance of an LDR changes as the intensity of light changes.
2) In bright light, the resistance is low.
3) In darkness, the resistance is high.
4) LDRs have lots of uses including turning on lights when it gets dark.
5) This can be used in automatic night lights, or outdoor lighting.
6) They're also used in burglar detectors.



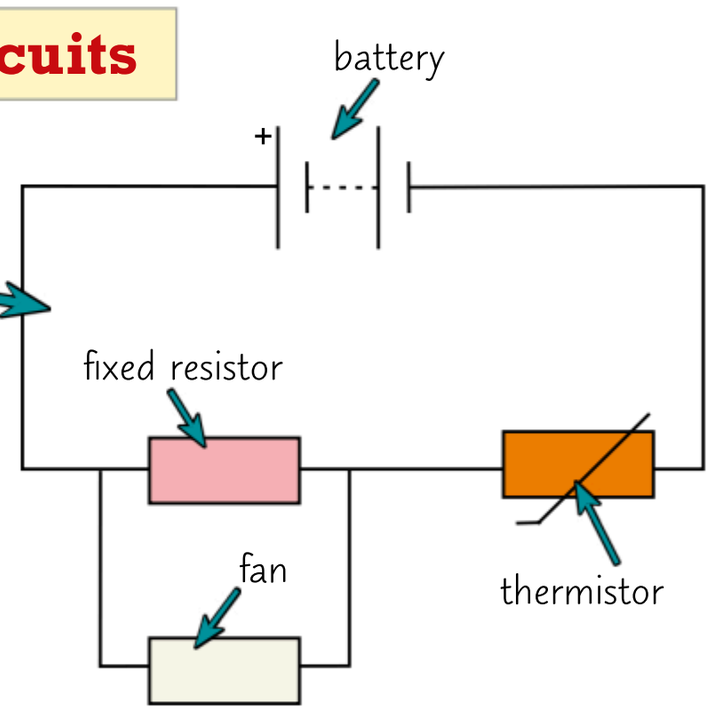
The Resistance of a Thermistor Depends on Temperature

1) A thermistor is a temperature dependent resistor.
2) In hot conditions, the resistance drops.
3) In cool conditions, the resistance goes up.
4) Thermistors are used in car engines and central heating thermostats.
5) Thermostats turn the heating on when it's cool and off when it's warm.



You Can Use LDRs and Thermistors in Sensing Circuits

1) Sensing circuits can be used to automatically change the pd across components depending on changes in the environment.
2) This circuit is a sensing circuit used to control a fan in a room.
3) The potential difference of the power supply is shared out between the thermistor and the fixed resistor (see p.185).
4) How much pd each one gets depends on their resistances.
5) The larger a component's resistance, the more of the pd it takes.
6) This circuit means that the pd across the fan goes up as the room gets hotter. Here's why:



- As the room gets hotter, the resistance of the thermistor decreases.
- The thermistor takes a smaller share of the pd from the power supply.
- So the pd across the fixed resistor rises.
- The pd across the fixed resistor is equal to the pd across the fan (you'll see why on p.186).
- So the pd across the fan rises too, making the fan go faster.

7) If you connected the fan across the thermistor instead, the circuit would do the opposite.
8) The fan would slow down as the room got hotter.

LDRs — Light Dependent Rabbits...

When your heating turns on by itself, you can show off and tell everyone how thermistors made it happen.

Q1 An engineer wants to make a circuit containing a bulb that will get brighter when the surroundings get darker. Draw a diagram of a circuit the engineer could make. You can assume the light from the bulb does not affect any of the circuit components. [3 marks]

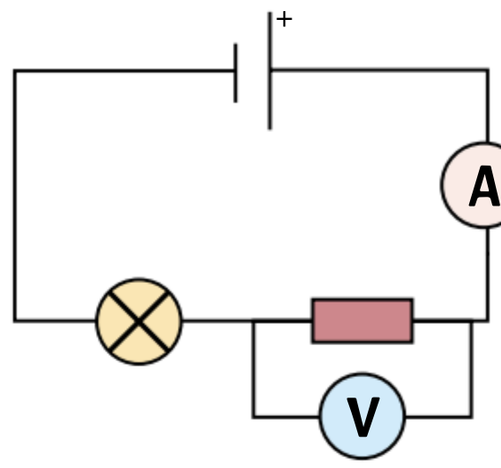
Q1 Video Solution

Series Circuits

There's a difference between connecting components in series and parallel — first up, series.

Series Circuits — All or Nothing

1) In series circuits, the components are all connected in a line between the ends of the power supply.
2) Only voltmeters break this rule. They're always in parallel (see p.186).
3) If you remove one component, the circuit is broken. So all the components stop working.
4) You can use the rules on this page to design series circuits to measure and test all sorts of things.
5) For example the test circuit on p.183 and the sensing circuits on p.184.



Potential Difference is Shared, Current is the Same Everywhere

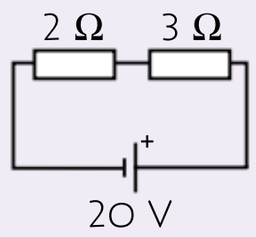
1) In series circuits the total pd of the supply is shared between all of the components.
2) If you add up the pd across each component, you get the pd of the power supply.
3) The bigger a component's resistance, the bigger its share of the total pd.
4) If you connect cells in series, their pds add together to make the total pd across the circuit.
5) In series circuits the same current flows through all components.

Resistance Adds Up

1) In series circuits, the total resistance of two components is found by adding up their resistances.
2) R_{total} is the total resistance of the circuit.
R_1 and R_2 are resistances of the components: → $R_{total} = R_1 + R_2$

EXAMPLE

For the circuit diagram below, calculate the current passing through the circuit.



1) First find the total resistance by adding together the resistance of the two resistors. $R_{total} = 2 + 3 = 5\ \Omega$
2) Then rearrange $V = IR$ for I. $I = V \div R$
3) Substitute in the values you have and calculate the current. $= 20 \div 5$ $= 4\ A$

3) You need to be able to explain why adding resistors in series increases the total resistance of the circuit:

- Adding a resistor in series means the resistors have to share the total pd.
- This means the pd across each resistor is lower, so the current through each resistor is lower ($V = IR$).
- The current is the same everywhere.
- So the total current in the circuit is reduced when a resistor is added.
- This means the total resistance of the circuit has gone up.

Series circuits — they're no laughing matter...

Get those rules straightened out in your head, then have a quick go at this question to test yourself.

Q1 A battery is connected in series with a 4 Ω resistor, a 5 Ω resistor and a 6 Ω resistor. A current of 0.6 A flows through the circuit. Calculate the potential difference of the battery. [3 marks]

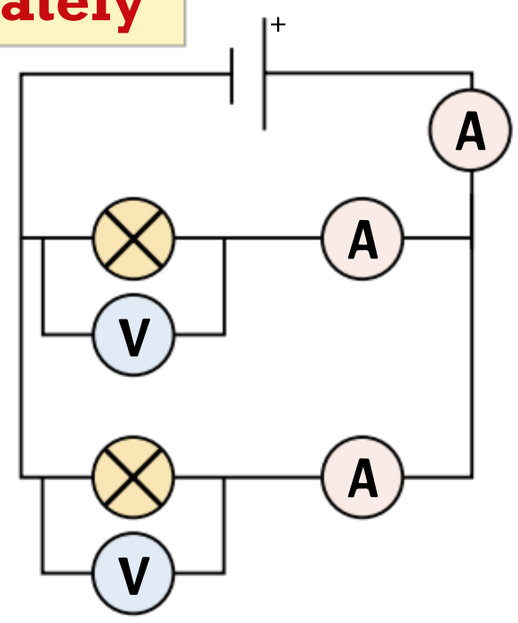
Q1 Video Solution

Parallel Circuits

Parallel circuits are much more sensible than series circuits, so they're much more common in real life.

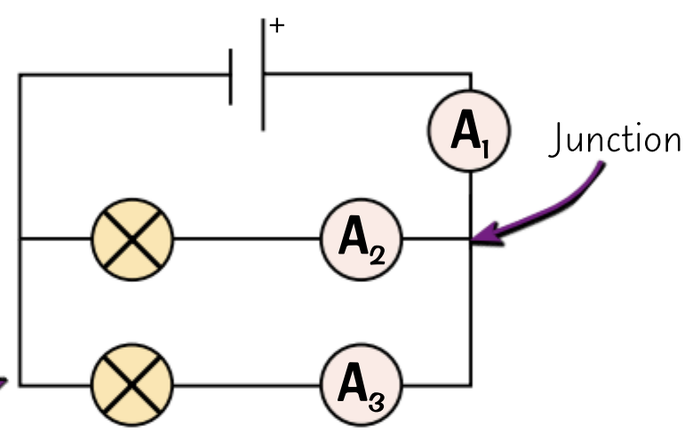
Parallel Circuits — Every Component Connected Separately

1) In parallel circuits, each component is separately connected to the ends of the power supply.
2) Only ammeters break this rule, they're always in series (see p.185).
3) If you take out one of the loops in a parallel circuit, the things in the other loops won't be affected.
4) This means things in parallel can be switched on and off without affecting each other.
5) Everyday circuits often include a mixture of series and parallel parts.



Current is Shared, Potential Difference is the Same Everywhere

1) In parallel circuits all components get the full source pd.
2) So the potential difference is the same across all components.
3) This means that identical bulbs connected in parallel will all be at the same brightness.
4) In parallel circuits the total current in a circuit is equal to the sum of all the currents through the separate components.
5) At junctions, the current either splits or rejoins.
6) The total current going into a junction must equal the total current leaving it. So in this circuit, $A_1 = A_2 + A_3$.



EXAMPLE

Find the pd measured by V_1 and the current measured by A_1. The resistors are identical.

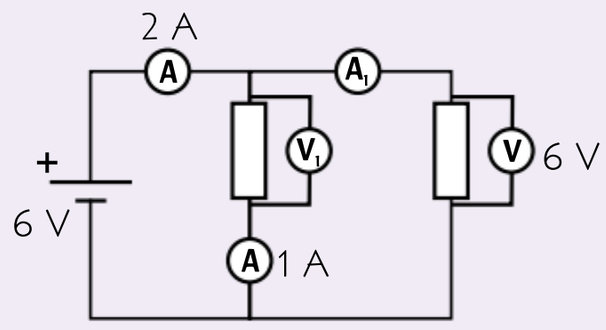
1) The resistors are in parallel, so the pd across each resistor is the same as the cell pd.
2) The current into the first junction is the same as the current out of it.

Cell pd = 6 V

V_1 = 6 V

In: 2 A Out: 1 A + A_1

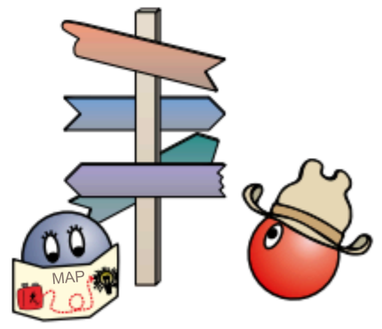
So $A_1 = 2 - 1 = 1$ A



Adding a Resistor in Parallel Reduces the Total Resistance

1) The total resistance of two resistors connected in parallel, is less than the resistance of the smallest of the two resistors.
2) Here's why:

- If you add a resistor in parallel, both resistors still have the same potential difference across them as the power supply.
- This means the 'pushing force' making the current flow is still the same.
- But by adding another loop, the current has more than one direction to go in.
- More current can flow around the circuit, so the total current increases.
- This means the total resistance of the circuit is lower (as $R = V \div I$).



A current shared (between identical components) — is a current halved...

Parallel circuits are a bit more complicated but they crop up a lot, so get learning them.

Q1 A circuit contains three resistors, each connected in parallel with a cell. Explain what happens to the total current and resistance in the circuit when one resistor is removed. [4 marks]

Q1 Video Solution

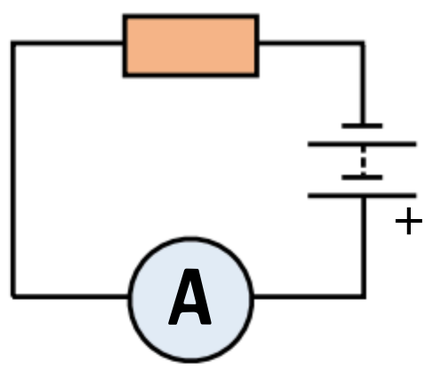
Investigating Circuits

PRACTICAL

You saw on page 182 how the length of the wire affects its resistance. Now it's time to do an experiment to see how adding resistors in series or in parallel can affect the resistance of the whole circuit.

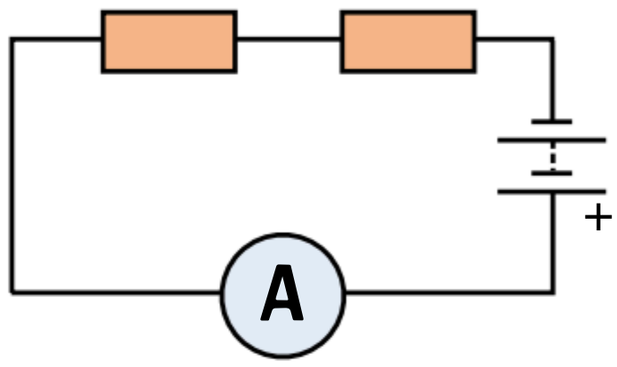
First Set Up the Basic Circuit

1) Find at least four identical resistors.
2) Build the circuit shown on the right.
3) Write down the pd of the battery. This is the pd of the circuit (V).
4) Read the current in the circuit (I) from the ammeter.
5) Calculate the resistance of the circuit using $R = V \div I$.



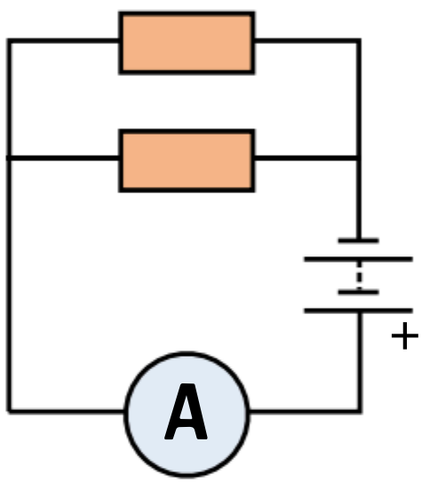
Investigate Adding Resistors in Series...

1) Add another resistor, in series with the first.
2) Measure the current again and calculate resistance again. The pd is the same as the pd of the battery.
3) Repeat steps 1 and 2 until you've added all of your resistors.



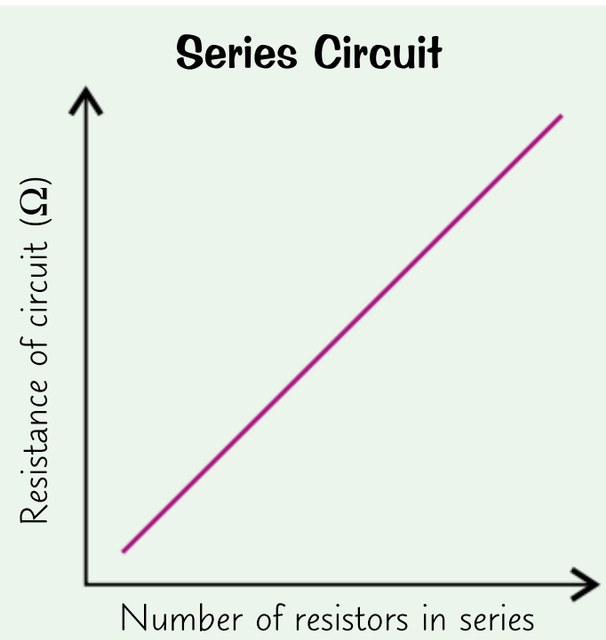
... and in Parallel

1) Build the basic circuit again. You already know its resistance.
2) Use the same equipment so it's a fair test.
3) Add another resistor, in parallel with the first.
4) Measure the total current through the circuit and calculate the overall resistance of the circuit. The pd is still the same as before.
5) Repeat steps 3 and 4 until you've added all of your resistors.

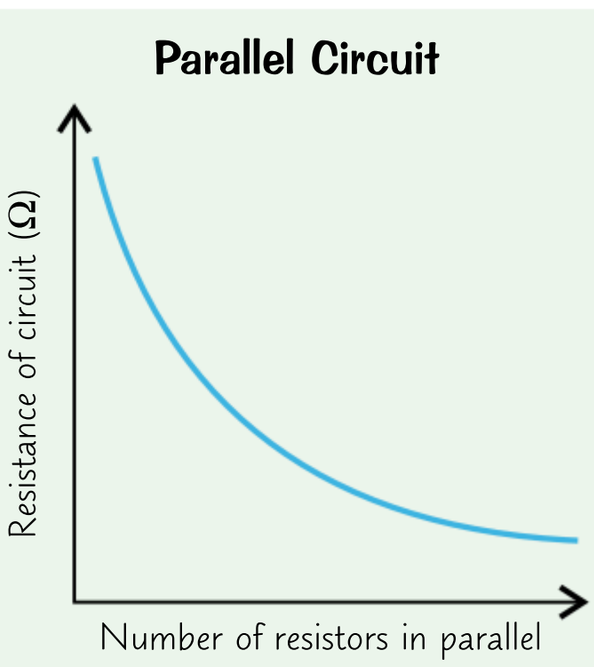


Draw Graphs so you can Compare your Results

1) Plot a graph of the number of resistors in the circuit against the total resistance.
2) You should get graphs that look like this:



Adding resistors in series increases the total resistance of the circuit.



The more resistors you add, the smaller the overall resistance becomes.

I can't resist a good practical...

Make sure you're completely happy building circuits from diagrams — this experiment is good practice.

Q1 A student is investigating how the resistance of a circuit changes as identical resistors are added in parallel. She plans to plot a graph of the total resistance of the circuit against the number of resistors in the circuit. Sketch the graph that you expect her to get. [2 marks]

Electricity in the Home

There are two types of electricity supply — alternating and direct currents. Read on for more about both...

Mains Supply is ac, Battery Supply is dc

1) An alternating potential difference is a potential difference that is constantly changing direction. It produces an alternating current (ac).
2) In an alternating current, the current (flow of charge) is also constantly changing direction.
3) The UK mains supply (the electricity in your home) is an ac supply at around 230 V.
4) The frequency (p.219) of the ac mains supply is 50 Hz (hertz).
5) Direct current (dc) is a current that is always flowing in the same direction.
6) It's created by a direct potential difference.
The direction of a direct potential difference is always the same.

Cells and batteries supply dc.

Most Cables Have Three Separate Wires

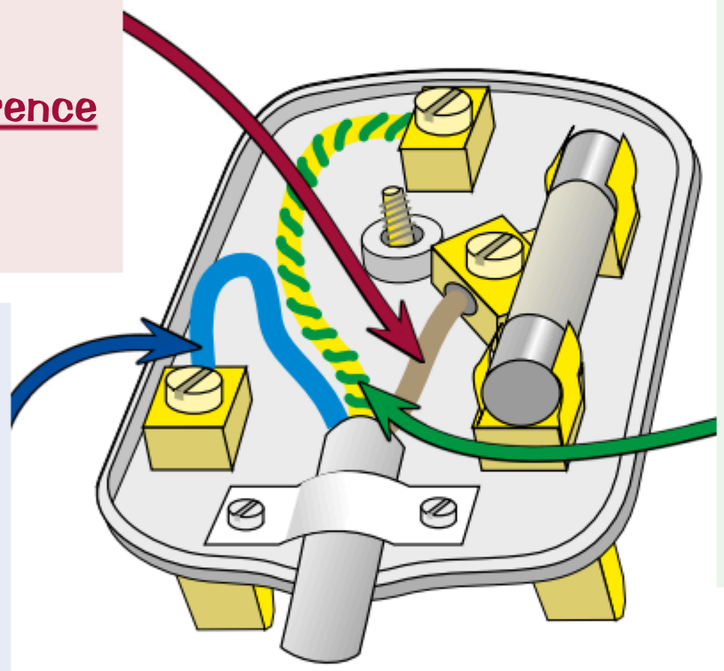
1) Most electrical appliances are connected to the mains supply by three-core cables.
2) They have three wires covered with plastic insulation inside them.
3) They are coloured so that it is easy to tell the different wires apart.

LIVE WIRE — brown.

1) The live wire provides the alternating potential difference from the mains supply.
2) It is at about 230 V.

NEUTRAL WIRE — blue.

1) The neutral wire completes the circuit — when the appliance is operating normally, current flows through the live and neutral wires.
2) It is around 0 V.



EARTH WIRE — green and yellow.

1) The earth wire is a safety wire.
2) It stops the appliance becoming live:
   - It is connected to the metal casing of an appliance.
   - If a fault causes the live wire to touch the casing, the current flows away through the earth wire.
3) It's also at 0 V.

The Live Wire Can Give You an Electric Shock

1) There is a pd between the live wire and your body (which is at 0 V).
2) Touching the live wire can cause a current to flow through your body.
3) This can give you a dangerous electric shock.
4) Even if a switch is turned off (the switch is open), touching the live wire is still dangerous. This is because it still has a pd of 230 V.
5) Any connection between live and earth can be dangerous.
6) The pd could cause a huge current to flow, which could result in a fire.



Why are earth wires green and yellow — when mud is brown..?

Electricity is very useful, but it can also be very dangerous. Make sure you know the risks.

Q1 State the potential difference of: a) the live wire b) the neutral wire c) the earth wire. [3 marks]

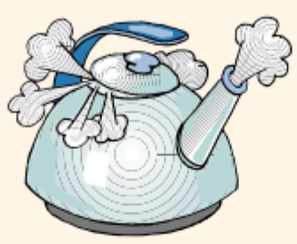
Power of Electrical Appliances

Energy is transferred between stores electrically (like you saw on page 167) by electrical appliances.

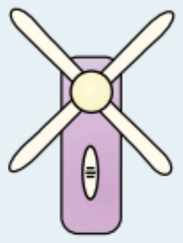
Energy is Transferred from Cells and Other Sources

1) When a charge moves around a circuit, work is done against the resistance of the circuit.
2) Whenever work is done, energy is transferred.
3) When the work is done by a charge, the energy is transferred electrically.
4) Electrical appliances transfer energy to components in the circuit when a current flows.

Kettles transfer energy electrically from the mains supply to the thermal energy store of the heating element inside the kettle.



Energy is transferred electrically from the battery of a handheld fan to the kinetic energy store of the fan's motor.



Energy Transferred Depends on the Power

1) The total energy transferred by an appliance depends on how long the appliance is on for and its power.
2) The power of an appliance is the energy that it transfers per second.
3) So the more energy it transfers in a given time, the higher its power.
4) The amount of energy transferred by electrical work is given by:

This equation should be familiar from page 172.

Energy transferred (J) = Power (W) × Time (s) $\quad E = Pt$

EXAMPLE

A 600 W microwave is used for 5 minutes. How much energy does it transfer?

1) Convert the time into seconds.
2) Substitute the numbers into $E = Pt$ to find the energy transferred.

$t = 5 \times 60 = 300$ s

$E = Pt = 600 \times 300$
$= 180\,000$ J



5) Appliances are often given a power rating. This is the power that they work at.
6) The power rating tells you how much energy is transferred between stores when the appliance is used.
7) An appliance with a higher power will cost more to run for a given time, as it uses more energy.

A 850 W microwave will transfer more energy between stores during 5 minutes than the 600 W microwave in the example above. This means it will cost more to use it for 5 minutes.

Have a break from all this work — or you'll have no energy left...

Get that equation for power stuck into your brain. Then become a powerful physicist by practising it.

Q1 An appliance transfers 6000 J of energy in 30 seconds. Calculate its power. [3 marks]

Q2 Calculate the difference in the amount of energy transferred by a 250 W TV and a 375 W TV when they are both used for two hours. [4 marks]

Q2 Video Solution

More on Power

And we're not done yet. There are even more power equations for you to get your head around. How fun.

Potential Difference is Energy Transferred per Charge Passed

1) As a charge moves around a circuit, energy is transferred to or from it.
2) The energy transferred by a component depends on the potential difference across it and the charge flowing through it.
3) The formula is real simple:

Energy transferred (J) — $E = QV$ — Potential difference (V); Charge flow (C)

EXAMPLE

An electric toothbrush contains a 3.0 V battery.
140 C of charge passes through the toothbrush as it is used.
Calculate the energy transferred.

Just put the charge and pd values in to the equation: $E = QV = 140 \times 3.0 = 420$ J



Power Also Depends on Current and Potential Difference

1) You saw on the previous page that power is energy transferred in a given time.
2) The power of an appliance can also be found using:

Power (W) = Potential difference (V) × Current (A) $\quad P = VI$

3) You can also find the power if you don't know the potential difference, using:

Power (W) — $P = I^2R$ — Resistance (Ω); (Current)^2 $(A)^2$

EXAMPLE

A motor with a power of 1250 W has a resistance of 50 Ω.
Calculate the current flowing through the motor.

Your calculator should have a '√' (square root) button to help with these calculations.

1) First rearrange the formula $P = I^2R$ to make I the subject.
   - Divide both sides by R.
   - Find the square root of both sides.

$P \div R = I^2$ so $I^2 = P \div R$

$I = \sqrt{P \div R}$

2) Now just plug in the numbers.

$I = \sqrt{1250 \div 50} = \sqrt{25}$

$= 5$ A

You have the power — now use your potential...

I'm afraid the best way to learn all of this is to just practise using those equations again and again. Sorry.

Q1 Calculate the energy transferred in a circuit with a pd of 200 V when 10 000 C of charge flows. [2 marks]

Q2 An appliance is connected to a 12 V source. A current of 4.0 A flows through it. Calculate the power of the appliance. [2 marks]

Q3 An appliance has a power of 2300 W and has a current of 10.0 A flowing through it. Calculate the resistance of the appliance. [3 marks]

Q3 Video Solution

The National Grid

Whoever you pay for your electricity, it's the national grid that gets it to you.



Electricity is Distributed via the National Grid

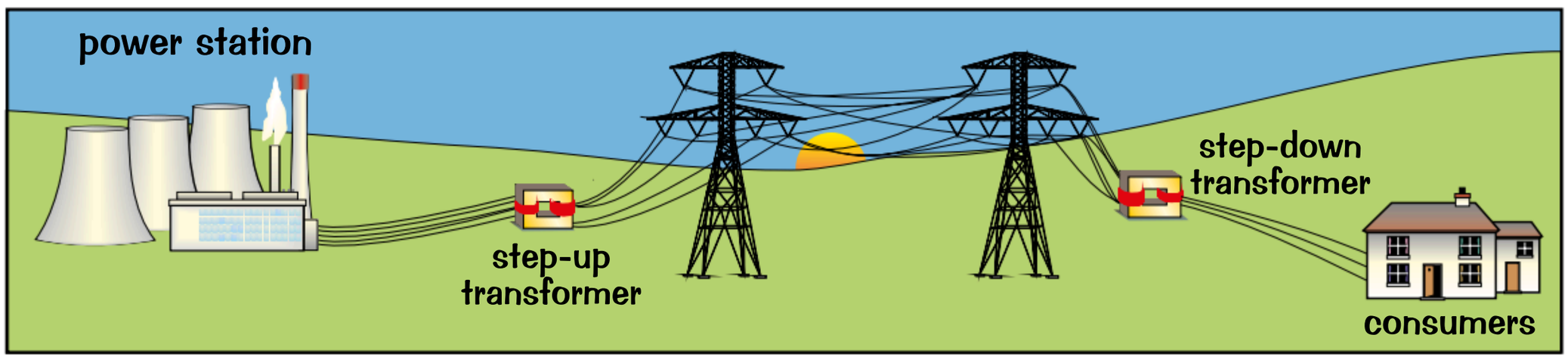
1) The national grid is a giant system of cables and transformers that covers the UK.
2) It transfers electrical power from power stations to consumers (anyone who is using electricity) across the UK.

Electricity Production has to Meet Demand

1) Throughout the day, the amount of electricity used (the demand) changes.
2) Power stations have to produce enough electricity for everyone to have it when they need it.
3) More electricity is used when people get up in the morning, come home from school or work and when it starts to get dark or cold outside.
4) Power stations often run at well below their maximum power output, so that they can increase their power if needed.
5) This means that the national grid can cope with a high demand, even if another station shuts down without warning.

The National Grid Uses a High Pd and a Low Current

1) The national grid transfers loads of energy, so the power has to be very high.
2) To transmit this huge amount of power you need either a high potential difference or a high current.
3) This is because $P = VI$ (from the previous page).
4) A high current means loads of energy is lost to thermal energy stores as the wires heat up.
5) So the national grid transmits electricity at a very high pd.
   For a given power, the higher the pd the lower the current.
6) This reduces the energy lost, making the national grid an efficient way of transferring energy.
7) Step-up transformers are used to increase the pd from power stations to electric cables.
8) Step-down transformers bring the pd back down to safe levels before the electricity gets to homes.



Transformers — NOT robots in disguise...

Transformers can be a little tricky, but it's important that you can explain why they're used in the national grid.

Q1 What is the national grid? [1 mark]

Revision Questions for Topics P1 & P2

And that's Topics P1 and P2 done — here's some lovely revision questions.

- Try these questions and tick off each one when you get it right.
- When you're completely happy with a sub-topic, tick it off.

For even more practice, try the Retrieval Quizzes for Topics P1 and P2 — just scan the QR codes!

Energy Stores and Transfers (p.167-171) ☑

Topic P1 Quiz

1) Write down four energy stores. ☑
2) State the conservation of energy principle. ☑
3) Describe the energy transfers that occur as a ball is dropped. ☑
4) If energy is transferred to an object's kinetic energy store, what happens to its speed? ☑
5) What is the definition of the specific heat capacity of a material? ☑
6) Describe an experiment to find the specific heat capacity of a material. ☑

Power and Efficiency (p.172-174) ☑

7) Define power. Give two equations you could use to calculate power. ☑
8) How can you reduce unwanted energy transfers in a machine with moving parts? ☑
9) True or false? A high thermal conductivity means there is a high rate of energy transfer. ☑
10) What is the efficiency of an energy transfer? Give the equation that relates efficiency to power. ☑

Energy Resources and Trends in their Use (p.175-179) ☑

11) Name four renewable energy resources and four non-renewable energy resources. ☑
12) Give an example of how a renewable energy resource is used in everyday life. ☑
13) Give two ways in which the environment can be damaged when using fossil fuels. ☑
14) Explain why the UK is trying to use more renewable energy resources in the future. ☑

Circuit Basics (p.180-184) ☑

Topic P2 Quiz

15) Draw the circuit diagram symbols for a resistor, a voltmeter, an LED and a diode. ☑
16) State an equation that links current, charge flow and time. Write down the units of each. ☑
17) What is the equation that links potential difference, current and resistance? ☑
18) Describe how you would investigate how the length of a wire affects its resistance. ☑
19) What is an *I*-*V* characteristic? ☑
20) What happens to the resistance of a thermistor as it gets hotter? ☑

Series and Parallel Circuits (p.185-187) ☑

21) True or false? Potential difference is shared between components in a series circuit. ☑
22) How does the overall resistance of a circuit change when a resistor is added in parallel? ☑
23) Describe an experiment to investigate how adding resistors in series and parallel affects the total resistance of the circuit. ☑

Electricity in the Home (p.188) ☑

24) What is the potential difference and the frequency of the UK mains supply? ☑
25) Name and give the colours of the three wires in a three-core cable. ☑

Power and the National Grid (p.189-191) ☑

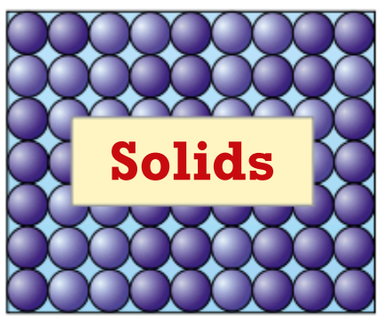
26) Describe the useful energy transfer that occurs for a battery-powered fan. ☑
27) State three equations that can be used to calculate electrical power. ☑
28) How are step-up and step-down transformers used in the national grid? ☑

The Particle Model and Motion in Gases

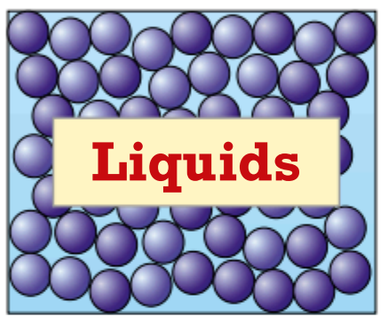
Everything is made up of small particles. The particle model describes how these particles behave.

There are Three States of Matter

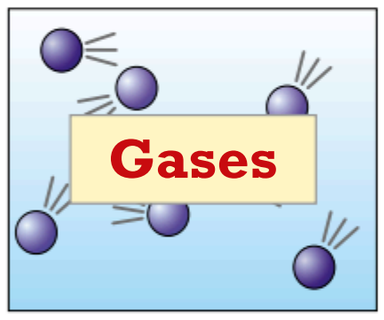
1) The three states of matter are solid (e.g. ice), liquid (e.g. water) and gas (e.g. water vapour).
2) The particle model explains the differences between the states of matter:
   - The particles of a certain material are always the same, no matter what state it is in.
   - But the particles have different amounts of energy in different states.
   - And the forces between particles are different in each state.
   - This means that the particles are arranged (laid out) differently in different states.



1) Particles are held close together by strong forces in a regular, fixed pattern.
2) The particles don't have much energy.
3) So they can only vibrate (jiggle about) around a fixed position.



1) The particles are held close together in an irregular pattern.
2) The particles have more energy than the particles in a solid.
3) They can move past each other in random directions at low speeds.



1) The particles aren't held close together. There are no forces between them.
2) The particles have more energy than in liquids and solids.
3) The particles constantly move around in random directions at a range of speeds.

Gas Particles Bump into Things and Create Pressure

1) Particles in a gas are free to move around.
2) They collide with (bump into) each other and the sides of the container they're in.
3) When they hit something, they apply a force to it. Pressure is the force applied over a given area.

Increasing the Temperature of a Gas Increases its Pressure

1) The temperature of a gas depends on the average energy in the kinetic energy stores of the gas particles.
2) The hotter the gas, the higher the average energy.
3) If particles have more energy in their kinetic stores, they move faster.
4) So the hotter the gas, the faster the particles move on average.
5) Faster particles hit the sides of the container more often. This increases the force on the container.
6) So increasing the temperature of a gas increases its pressure.
7) This only works if the space the gas takes up (the volume) doesn't change.



Don't let the pressure of exams get to you...

Get your head around the particle model before moving on to the rest of the topic.

Q1 Explain why decreasing the temperature of a gas in a fixed container decreases its pressure. [3 marks]

Density of Materials

The density of an object tells you how many of its particles are squished into a given space.



The Particle Model can also Explain Density

1) Density is a measure of how much mass there is in a certain space.
2) You can work out density using:

density (kg/m^3) $\rho = \frac{m}{V}$ mass (kg), volume (m^3)

3) The density of an object depends on what it's made of and how its particles are arranged.
4) A dense material has its particles packed tightly together.
5) So, solids are generally denser than liquids.
6) And liquids are generally denser than gases.

EXAMPLE

A 0.0020 m^3 block of aluminium has a mass of 5.4 kg.
Calculate the density of aluminium.

density = mass ÷ volume
= 5.4 ÷ 0.0020
= 2700 kg/m^3

You Need to be Able to Measure Density in Different Ways

PRACTICAL

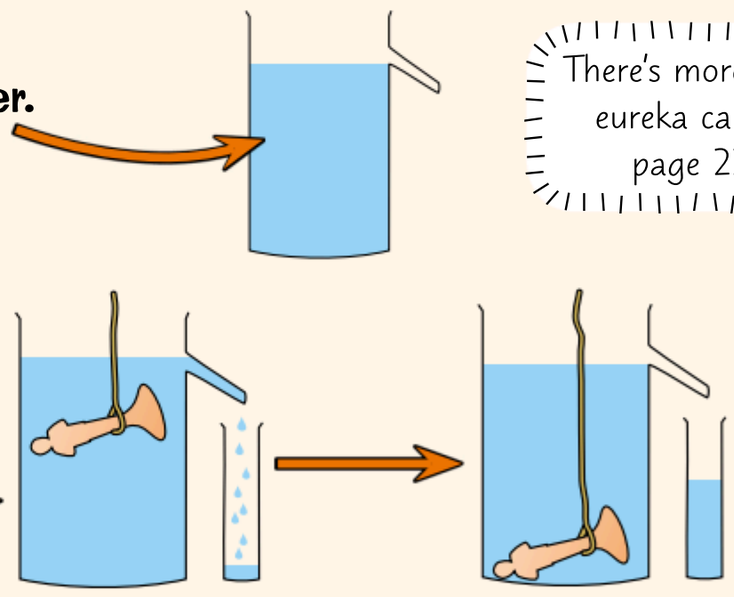
To find the density of a regularly shaped object (e.g. a cuboid)

1) Use a balance to measure its mass (see p.232).
2) Measure its length, width and height with a ruler.
3) Then calculate its volume using the formula for that shape.
4) Use density = mass ÷ volume to find the density.

The volume of a cuboid is equal to length × width × height.

To find the density of an irregularly shaped object (e.g. an awards statue)

1) Use a balance to measure its mass.
2) Fill a eureka can (a can with a spout in its side) with water.
3) Place a measuring cylinder (p.232) under the spout.
4) Place your object into the water.
This will push some of the water out through the spout.
5) Measure the volume of water that has collected in the measuring cylinder.
6) This is equal to the volume of the object.
7) Use the formula above to find the object's density.



There's more about eureka cans on page 233.

To find the density of a liquid

1) Place a measuring cylinder on a balance and zero the balance (p.232).
2) Pour 50 ml of the liquid into the measuring cylinder.
3) Record the liquid's mass shown on the mass balance.
4) Use the formula above to find the density. The volume is 50 cm^3, or 0.00005 m^3.

For both of these experiments, you'll need to know that 1 ml = 1 cm^3 and that 1 cm^3 = 0.000001 m^3.

Who can measure volume — the eureka can can, oh the eureka can can...

Remember, density is all about how close together the particles in a substance are. Nice and simple really.

Q1 A 0.019 kg gemstone is placed into a full eureka can, causing 7.0 cm^3 of water to be pushed out the spout into a measuring cylinder.
Calculate the density of the gemstone in g/cm^3. [3 marks]

Q1 Video Solution

Internal Energy and Changes of State

This page is all about heating things. Take a look at your specific heat capacity notes (p.170) before you start. You need to understand it and be able to use $\Delta E = mc\Delta\theta$ for this topic too I'm afraid.

Internal Energy is the Total Energy Stored by Particles in a System

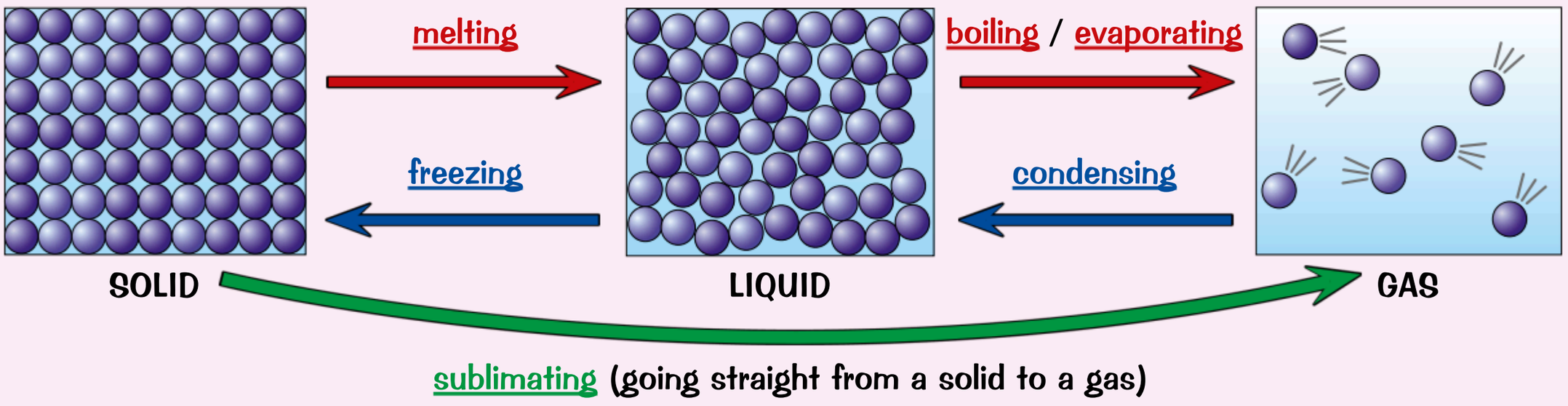
1) The energy stored in a system (p.167) is stored by its particles (atoms and molecules).
2) The particles have energy in their kinetic energy stores.
3) They also have energy in their potential energy stores because of their positions.
4) The internal energy of a system is the total energy that all its particles have in their kinetic and potential energy stores.

Heating Increases Internal Energy

1) Heating a system transfers energy to its particles.
2) This increases the system's internal energy.
3) This leads to a change in temperature or a change of state (e.g. melting or boiling).
4) How much the temperature changes depends on the mass of the system, its specific heat capacity (p.170) and how much energy is transferred to it.
5) You can see this from the equation $\Delta E = mc\Delta\theta$.
6) A change of state happens when the particles have enough energy in their kinetic energy stores to break the bonds holding them together.

Mass Doesn't Change in a Change of State

1) A change of state can happen because of cooling, as well as heating.
2) The changes of state are:



3) A change of state is a physical change (not a chemical change).
4) This means you don't end up with a new material.
5) The particles are just arranged in a different way (p.193).
6) The number of particles stays the same when the state changes.
7) This means the mass is conserved (it doesn't change).
8) If you reverse a change of state, the material will get back all the properties it had before the change.





Breaking Bonds — Blofeld never quite manages it...

I'll say it one more time — have a look back over your specific heat capacity notes. You'll need them, I promise.

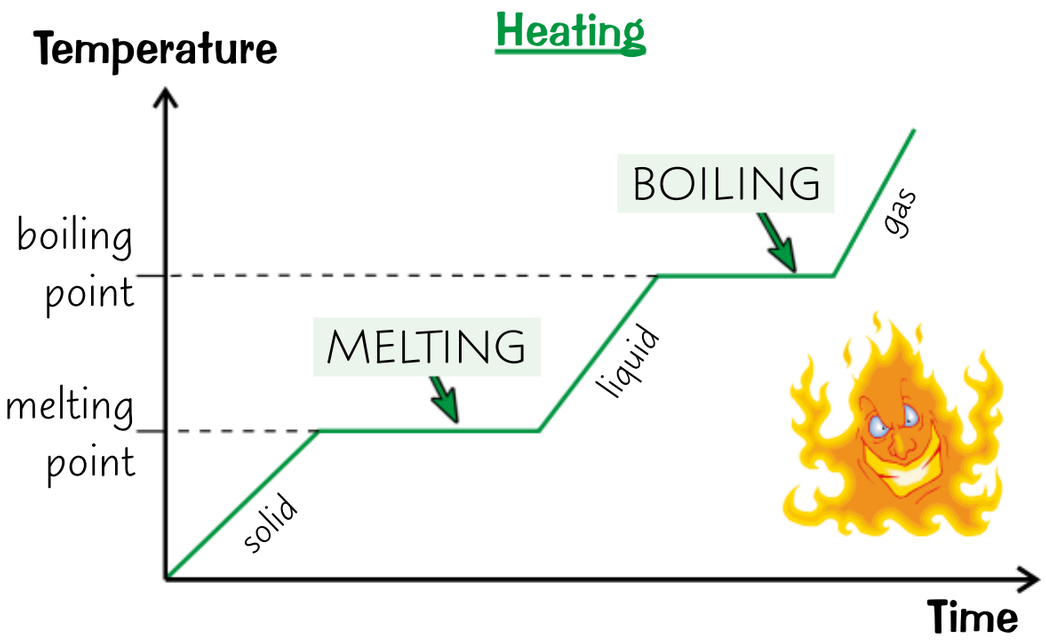
Q1 Name the following changes of state:
a) solid to liquid b) liquid to gas c) gas to liquid [3 marks]

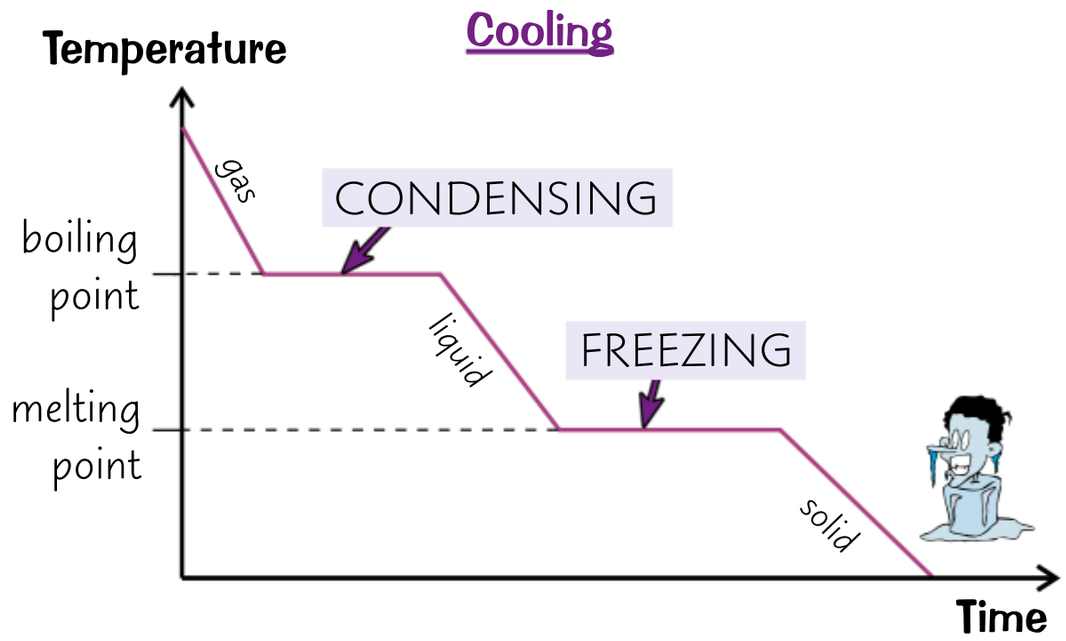
Specific Latent Heat

Specific latent heat sounds like specific heat capacity but it's very different. It's all to do with changing state.

A Change of State means Internal Energy Changes but Not Temperature

1) Heating a material transfers energy to the material.
2) This either increases the temperature of the material or changes its state (p.193).
3) During a change of state, the temperature doesn't change. But the internal energy does.
4) The energy transferred is used to break bonds between particles. It is not used to raise the temperature.
5) When a material cools, energy is transferred away from it.
6) As a material condenses or freezes, bonds form between particles. This causes energy to be released.
7) So its internal energy decreases, but its temperature stays the same during the change of state.
8) The flat spots on these graphs show that the temperature doesn't change during a change of state.





Specific Latent Heat is the Energy Needed to Change the State of a 1 kg Mass

1) The energy transferred during a change of state is called latent heat.
2) For heating, latent heat is the energy gained to cause a change of state.
3) For cooling, it is the energy released by a change in state.
4) The specific latent heat of a material is the amount of energy needed to change the state of 1 kg of the material without changing its temperature.

Don't get this confused with specific heat capacity (p.170) which is to do with changes in temperature, not changes of state.

5) You can work out the energy needed (or released) during a change of state using this formula:

$$\text{Energy (J)} = \text{Mass (kg)} \times \text{Specific Latent Heat (J/kg)} \quad \text{or:} \quad E = mL$$

6) Specific latent heat has different names for different changes of state:
   - For changing between a solid and a liquid it is called the specific latent heat of fusion.
   - For changing between a liquid and a gas it is called the specific latent heat of vaporisation.

EXAMPLE

The specific latent heat of vaporisation for water is 2 260 000 J/kg. How much energy is needed to completely boil 1.50 kg of water once it has reached its boiling point?

1) The mass and specific latent heat are in the right units, so just put them into the formula.
2) The units for the answer are joules because it's energy.

$E = mL$
$= 1.50 \times 2\,260\,000$
$= 3\,390\,000$ J

My specific latent heat of revision* is 500 J/kg...

There's a lot on this page. Re-read it and then have a go at this question to practise what you've learnt.

Q1 The SLH of fusion for a particular substance is 120 000 J/kg. How much energy is needed to melt 250 g of the substance when it is already at its melting temperature? [2 marks]

Q1 Video Solution

*the amount of energy required to turn 1 kg of revision notes into exam success

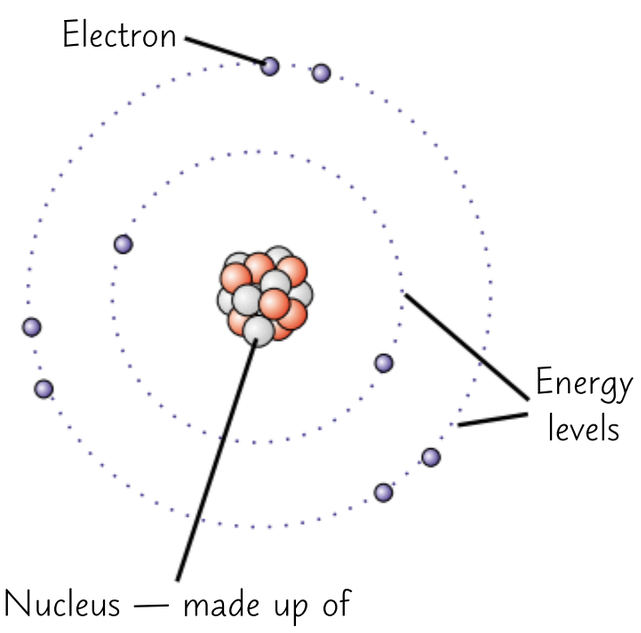
The Current Model of the Atom

You need to know everything on page 104 for both your chemistry and physics exams.

Models of the Atom have Changed Over Time

1) Scientific models (p.1) change over time. This happens when new evidence is found that can't be explained by the current model.
2) This is what happened with the model of the atom.
3) You need to LEARN the history of the atom that's on page 104 for your physics exam. Make sure you can explain the experiments that led to changes in the model of the atom.
4) Based on current evidence scientists believe the nuclear model of the atom (see below) is the best description we have.

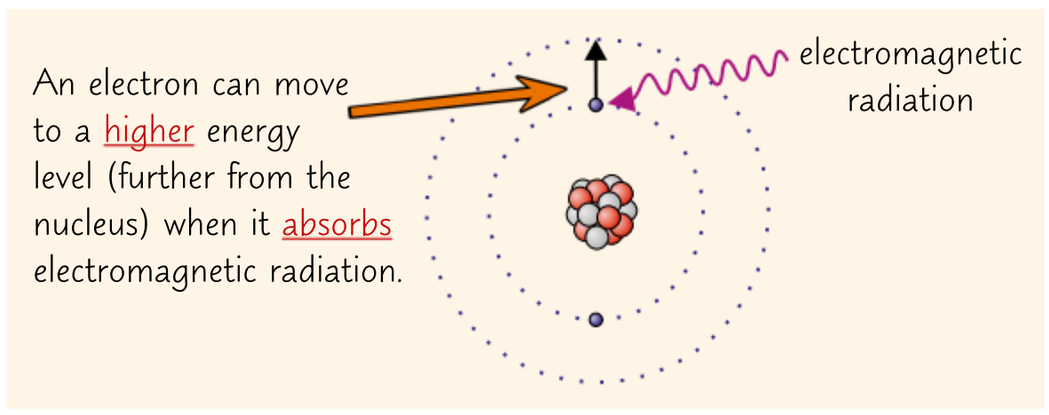
You Need to Know the Current Model of the Atom

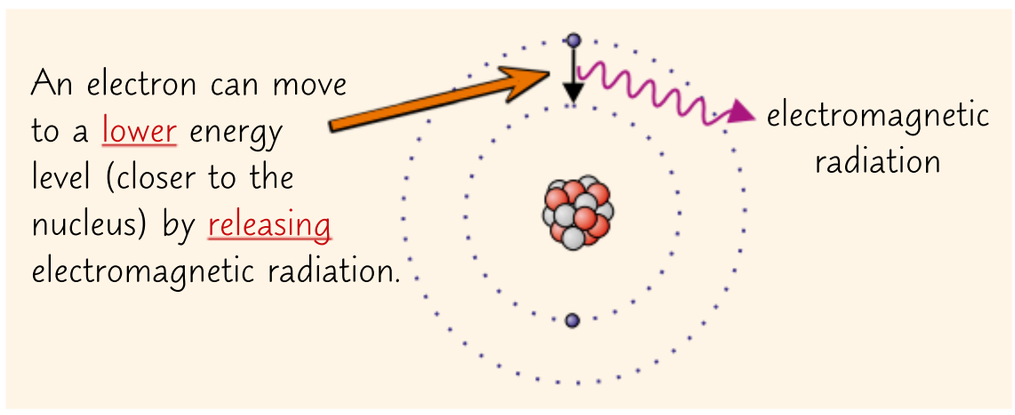


1) The current model of the atom is a nuclear model.
2) This means there is a nucleus in the centre surrounded by electrons.
3) Atoms are very small. The radius of an atom is about 1×10^{-10} m (see p.12 for more on standard form).
4) The nucleus is tiny, but it makes up most of the mass of the atom.
5) The radius of the nucleus is about 10 000 times smaller than the radius of the atom.
6) The nucleus is made up of protons and neutrons.
7) Protons are positively charged and neutrons have no charge. So the nucleus is positively charged.
8) Electrons have a negative charge. They move around (orbit) the nucleus at different distances.
9) These distances are known as energy levels.
10) Atoms have no overall charge. The number of protons = the number of electrons.

Electrons can Move Between Energy Levels

1) The further an energy level is from the nucleus, the more energy an electron in that energy level has.
2) Electrons can move between energy levels by absorbing (taking in) or releasing electromagnetic radiation (p.223).





3) If an electron in an outer energy level absorbs electromagnetic radiation, it can leave the atom.
4) If an atom loses one or more electrons it turns into a positively charged ion.

These models don't have anything on my toy trains...

This is science in action folks — as new evidence came along, the model of the atom was changed and updated.

Q1 a) What particles make up the nucleus? [2 marks]
b) State the radius of an atom and describe how this compares to the size of its nucleus. [2 marks]

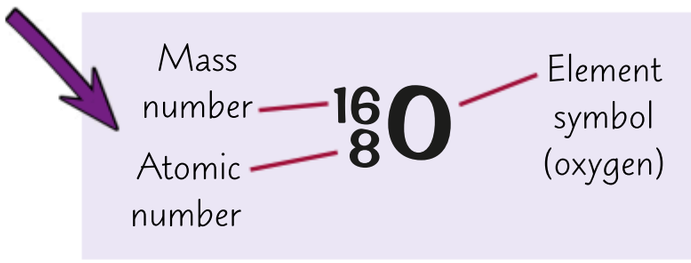
Isotopes and Nuclear Radiation

Isotopes and ionisation. They sound similar, but they're not, so read this page carefully.

Isotopes are Different Forms of the Same Element



1) The number of protons in an atom is called its atomic number.
2) The protons in a nucleus give the nucleus its positive charge.
So the atomic number of an atom tells you the charge on the nucleus.
3) The mass number of an atom is the sum of the number of protons and the number of neutrons.
4) An element is a substance only containing atoms with the same number of protons.
5) You can show information about an atom of an element like this.
6) Atoms of an element with the same number of protons but a different number of neutrons are called isotopes.
7) Isotopes of an element have the same atomic number, but a different mass number.



Some Isotopes are Unstable

1) Some isotopes are unstable.
They emit (give out) radiation from their nuclei to try and become more stable.
2) This process is called radioactive decay.
3) The radiation emitted is called nuclear radiation.
There are four different types of nuclear radiation:
4) Isotopes that give out nuclear radiation are called radioactive isotopes.

Types of Nuclear Radiation

- An alpha particle (α) is two neutrons and two protons.
- A beta particle (β) is a fast-moving electron.
- Gamma rays (γ) are waves of electromagnetic radiation (p.223).
- Neutrons (n).

You Need to Know the Properties of Ionising Nuclear Radiation

1) Ionising radiation is radiation that can knock electrons off atoms and turn them into ions.
2) The ionising power of radiation is how easily it can do this.
3) Alpha particles, beta particles and gamma rays are all types of ionising radiation.
4) They all have different properties:

'Range in air' is the distance the radiation can travel through air.

Type of radiation	Ionising power	Range in air	Stopped by
alpha particles	strong	a few centimetres	a sheet of paper
beta particles	moderate	a few metres	a sheet of aluminium
gamma rays	weak	a long distance	thick sheets of lead or metres of concrete

5) Their different ionising powers, ranges and abilities to penetrate (get through) materials make them suitable for different uses.

E.g. A medical tracer is a radioactive isotope that is injected into a patient.
The radiation it emits needs to be detected outside the patient's body.
You couldn't use a source of alpha radiation as a medical tracer.
Alpha particles wouldn't be able to pass through the body and be detected outside the body.
They are also very ionising and so could do a lot of damage (see p.201).
Medical tracers usually emit gamma rays. Gamma rays are only weakly ionising and easily pass through the body. This means they can be easily detected and do less harm than alpha particles.

Isotopes of an outfit — same dress, different accessories...

Knowing the different kinds of radiation and what can stop them usually bags you a few marks in an exam.

Q1 In order to sterilise medical equipment, radiation is directed at the equipment while it is sealed in packaging. Explain whether alpha radiation would be suitable for this use. [2 marks]

Q1 Video Solution

Nuclear Equations

Nuclear equations show radioactive decay. They look quite scary but this should help you get the hang of them.

Mass and Atomic Numbers Have to Balance

1) Nuclear equations are a way of showing radioactive decay (p.198).
2) They're normally written like this:

nucleus before decay → nucleus after decay + radiation emitted

3) There is one golden rule to remember:

The total mass and atomic numbers must be equal on both sides of the arrow.

Alpha Decay Decreases the Charge and Mass of the Nucleus

1) Alpha decay is when an alpha particle is emitted from a radioactive nucleus.
2) An alpha particle is made up of two protons and two neutrons. It is the same as a helium nucleus.
3) When a nucleus emits an alpha particle, its atomic number goes down by 2 and its mass number goes down by 4.
4) The charge of the nucleus decreases when it gives out an alpha particle.
5) An alpha particle is usually written as a helium nucleus in a nuclear equation: $^{4}_{2}\mathrm{He}$.

The nuclear equation for the decay of uranium (U) to thorium (Th) is:

Mass number → 238, Atomic number → 92

$$^{238}_{92}\mathrm{U} \rightarrow {}^{234}_{90}\mathrm{Th} + {}^{4}_{2}\mathrm{He}$$

The mass numbers on each side are equal: $238 = 234 + 4$

The atomic numbers on each side are equal: $92 = 90 + 2$

Beta Decay Increases the Charge of the Nucleus

1) Beta decay is when a beta particle is emitted from a radioactive nucleus.
2) During beta decay, a neutron in the nucleus turns into a proton.
3) This means the nucleus has one more proton, so its atomic number goes up by 1.
4) It also means the positive charge of the nucleus increases.
5) A beta particle has an atomic number of –1 so the atomic numbers balance on each side of the equation.
6) Protons and neutrons have the same mass, so the mass of the nucleus doesn't change.
7) A beta particle is an electron. It is written as $^{0}_{-1}\mathrm{e}$ in nuclear equations.



The nuclear equation for the decay of carbon (C) to nitrogen (N) is:

$$^{14}_{6}\mathrm{C} \rightarrow {}^{14}_{7}\mathrm{N} + {}^{0}_{-1}\mathrm{e}$$

The mass numbers on each side are equal: $14 = 14 + 0$

The atomic numbers on each side are equal: $6 = 7 - 1$

Gamma Rays Don't Change the Charge or Mass of the Nucleus

1) Gamma rays are a way of getting rid of extra energy from a nucleus.
2) When they are emitted, they don't change the mass or charge of the atom and nucleus.

Did someone say something about gammon?

Nuclear equations need practice to really get your head around. Why not try these questions on for size?

Q1 What type of radiation is given off in this decay? $^{8}_{3}\mathrm{Li} \rightarrow {}^{8}_{4}\mathrm{Be}$ + radiation. [1 mark]

Q2 Write the nuclear equation for $^{219}_{86}\mathrm{Rn}$ decaying to polonium (Po) by emitting an alpha particle. [3 marks]

Q2 Video Solution

Half-life

How quickly unstable isotopes decay is measured using activity and half-life — two very important terms.

The Activity of a Source is the Number of Decays per Second

1) The radiation given out by a radioactive decay can be measured with a Geiger-Muller tube and counter detector.
2) The number of decays the counter measures every second is called the count-rate.
3) The activity of a radioactive source is the rate at which it decays. This means how many unstable nuclei decay every second.
4) Activity is measured in becquerels, Bq. 1 Bq is 1 decay per second.

Radioactivity is a Totally Random Process



1) Radioactive decay is entirely random. So you can't predict exactly which nucleus in a sample will decay next, or when any one of them will decay.
2) But you can predict how long it will take for half of the nuclei to decay. This is known as a half-life.

Nuclei means more than one nucleus.

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

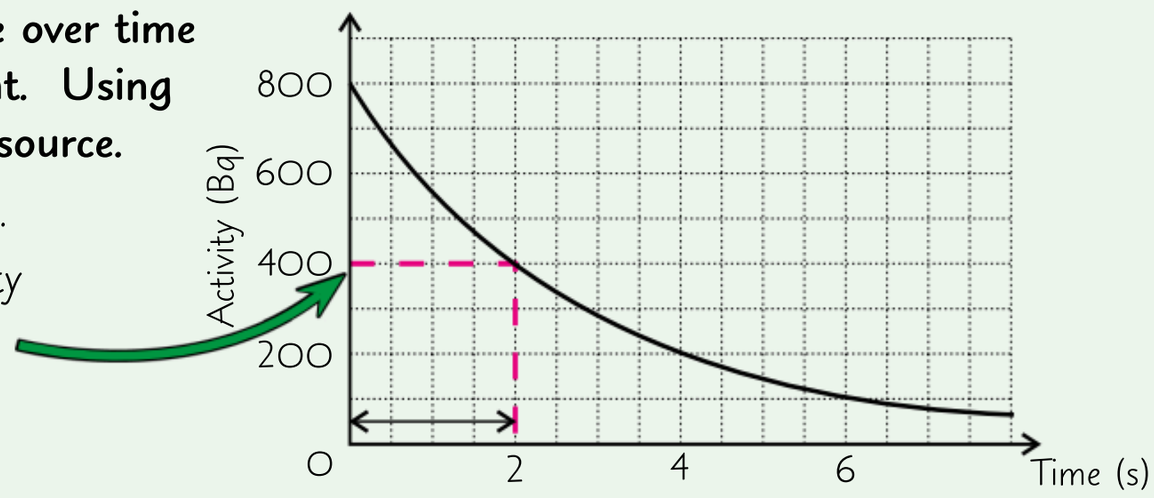
3) Half-life is also the time taken for the count-rate or activity of a sample to fall to half of its initial (starting) value.
4) The half-life of a radioactive sample will always be the same. This means it doesn't matter what activity you start with when doing half-life calculations (see below).

You Need to be able to Calculate Half-Lives

1) You may be asked to calculate the half-life of a source.
2) You just need to find out how long it takes for the activity or count-rate of the source to halve.

EXAMPLE

The activity of a radioactive source over time is shown on the graph on the right. Using the graph find the half-life of the source.



1) The initial activity when time = 0 s is 800 Bq.
2) Use the graph to find the time when the activity has halved to 400 Bq. This was at t = 2 s.
3) So, the time for the activity to halve was 2 s.

EXAMPLE

The activity of a radioactive isotope was measured. Initially it was 64 Bq. 12 seconds later it had fallen to 16 Bq. Calculate the half-life of the sample.

1) First, find how many half-lives it takes for the activity to fall to from 64 Bq to 16 Bq.
   After one half life, the activity will be 64 ÷ 2 = 32 Bq
   After two half lives, the activity will be 32 ÷ 2 = 16 Bq
2) So you know 12 s is equal to two half lives. Divide 12 by 2 to find the time for one half life.
   Time for one half life = 12 ÷ 2 = 6 s

The half-life of a box of chocolates is about five minutes...

Half-life is really important in radioactivity. Make sure you know what it is and how to calculate it.

Q1 What is meant by the activity of a radioactive substance? [1 mark]

Q2 The initial count-rate of a sample is 168 counts per second (cps). After 60 minutes, the count-rate of the sample is 21 cps. Calculate the half-life of the sample. [3 marks]

Q2 Video Solution

Irradiation and Contamination

There are risks when working with radiation. Make sure you know how to reduce them.

Ionising Radiation can Damage Cells

1) There are hazards (dangers) you need to protect yourself from when working with radioactive sources.
2) Ionising radiation can enter living cells and ionise (p.197) atoms in them.
3) This can damage the cells. This may cause cancer or kill cells off completely.

We need to know how radiation affects the human body, so we can protect ourselves from harm. So it's really important for research into the effects of radiation to be published and checked by peer review — see page 1.

Exposure to Radiation is called Irradiation

1) Objects near a radioactive source can be irradiated by it. This means radiation from the radioactive source will reach the object.
2) Irradiated objects don't become radioactive themselves.
3) The further you are from a particular source, the less radiation will reach you.
4) To help stop irradiation happening, you should:
   - Store radioactive sources in lead-lined boxes when they're not being used.
   - Stand behind barriers that will absorb radiation when using sources.
   - Keep the source as far away from you as possible, e.g. hold it at arm's length.



Warning: You won't become a superhero from being irradiated.

Contamination is Radioactive Particles Getting Onto Objects

1) If unwanted radioactive atoms get onto or into an object, the object is contaminated.
2) These contaminating atoms might then decay and release radiation which could harm you.
3) Being contaminated by a source may cause more damage than if you are irradiated by the same source, as you may carry it for a long time.
4) To help stop contamination, you should wear gloves and use tongs when handling radioactive sources.

People whose jobs involve radioactive materials often wear protective suits and face masks to help stop them being contaminated.

How Dangerous Irradiation and Contamination are Depends on the Source

1) Beta and gamma sources are the most dangerous to be IRRADIATED by. These types of radiation have long ranges (p.198). That means more radiation will reach you from a beta or gamma source than from an alpha source at the same distance.
2) They can also penetrate (travel through) your body and may damage your organs. Alpha is less dangerous because it can't get through the skin and is easily blocked, e.g. by a small air gap (p.198).

1) INSIDE the body, alpha sources are the most dangerous to be CONTAMINATED by. This is because alpha particles are the most ionising type of radiation.
2) Beta particles and gamma rays are less damaging because they are less ionising.
3) Gamma sources are the least dangerous inside the body. This is because gamma rays are the least ionising type of radiation and they mostly pass straight out without doing any damage.
4) OUTSIDE of the body, an alpha source is the least dangerous to be contaminated by. This is because alpha particles can't get through the skin and damage your organs.

Top tip number 364 — if something is radioactive, don't lick it...

Make sure you can describe how to prevent irradiation and contamination, and why it's so important that you do.

Q1 Explain why a gamma source is more dangerous to be irradiated by than an alpha source. [2 marks]

Revision Questions for Topics P3 & P4

Well, that's Topics P3 and P4 wrapped up. Time to see what you've absorbed.

- Try these questions and tick off each one when you get it right.
- When you're completely happy with a sub-topic, tick it off.

For even more practice, try the Retrieval Quizzes for Topics P3 and P4 — just scan the QR codes!

Topic P3 Quiz

The Particle Model and Motion in Gases (p.193) ☐

1) What are the three states of matter? ☐
2) Describe how particles are arranged in each state of matter. ☐
3) True or false? The colder a gas, the higher the average energy in the kinetic energy stores of its particles. ☐

Density of Materials (p.194) ☐

4) What is the formula for density? ☐
5) True or false? Solids are usually denser than gases. ☐
6) Describe how you could find the volume of an irregularly shaped object. ☐

Internal Energy and Changes of State (p.195-196) ☐

7) What is internal energy? ☐
8) What happens to the particles in a substance when that substance is heated? ☐
9) Name the five changes of state. ☐
10) True or false? Mass stays the same when a substance changes state. ☐
11) Sketch a graph of temperature against time for a gas being cooled. Your graph should show the point that the gas turns into a liquid and the point that the liquid turns into a solid. ☐
12) What is specific latent heat? ☐

The Atomic Model (p.197) ☐

Topic P4 Quiz

13) What is the overall charge of an atom? ☐
14) What happens when an electron in an atom gives out electromagnetic radiation? ☐
15) What happens to an atom if it loses one or more of its electrons? ☐

Nuclear Decay and Half-life (p.198-200) ☐

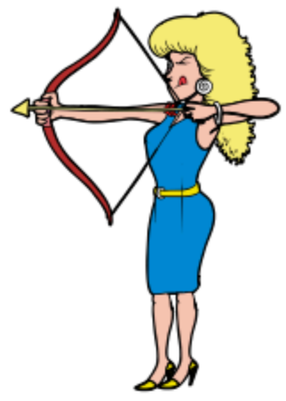
16) What is the atomic number of an atom? What is the mass number of an atom? ☐
17) Which number is the same for all atoms of an element: the atomic number or the mass number? ☐
18) What is an isotope? ☐
19) For the three types of ionising nuclear radiation, give: a) their ionising power, b) their range in air. ☐
20) How does the emission of an alpha particle change the atomic number of an atom? ☐
21) Draw the symbols for both alpha and beta radiation in nuclear equations. ☐
22) What is the activity of a substance measured in? ☐
23) Define half-life in terms of the number of nuclei of a radioactive isotope. ☐
24) Describe how to find a radioactive source's half-life, given a graph of its activity over time. ☐

Irradiation and Contamination (p.201) ☐

25) What is irradiation? ☐
26) Give two examples of how to stop: a) contamination, b) irradiation. ☐
27) Compare the hazards of being irradiated and contaminated by:
a) an alpha source, b) a gamma source. ☐

Contact and Non-Contact Forces

When you're talking about the forces acting on an object, it's not enough to just talk about the size of each force. You need to know their direction too — force is a vector, with a size and a direction.



Force is a Vector Quantity

1) Vector quantities have a magnitude (size) and a direction. For example:

Vector quantities: force, velocity, displacement, acceleration

2) Some quantities have a magnitude but no direction. These are called scalar quantities. Here are some examples of scalar quantities:

Scalar quantities: speed, distance, mass, temperature, time

3) Vectors are usually represented by an arrow.
4) The length of the arrow shows the magnitude.
5) The direction of the arrow shows the direction of the quantity.

Forces Can be Contact or Non-Contact



1) A force is a push or a pull that acts on an object.
2) Forces are caused by objects interacting with each other.
3) All forces are either contact or non-contact forces.
4) When two objects have to be touching for a force to act, the force is a contact force.

Contact force examples: friction, air resistance, tension, normal contact force

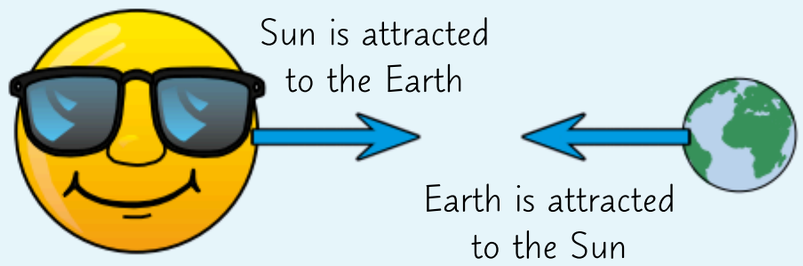
5) If the objects do not need to be touching for the force to act, the force is a non-contact force.

When an object exerts a force on a second object, the second object pushes back. This is the normal contact force.

Non-contact force examples: magnetic force, gravitational force, electrostatic force

6) When two objects interact, a force is produced on both objects. The forces on the two objects are equal in size but act in opposite directions.
7) These two forces are called an interaction pair.

- The gravitational attraction between the Earth and the Sun is an example of an interaction pair.
- A gravitational force acts on the Earth attracting it to the Sun.
- At the same time a force acts on the Sun attracting it towards the Earth.
- These forces are the same size but act in opposite directions.



My life's feeling pretty scalar — I've no idea where I'm headed...

This stuff is vital to understand if you want to make it through the rest of this topic. Better get your head down.

Q1 Name two examples of: a) a scalar quantity b) a vector quantity [4 marks]

Q2 A tennis ball is dropped from a height. Name one contact force and one non-contact force that act on the ball as it falls. [2 marks]

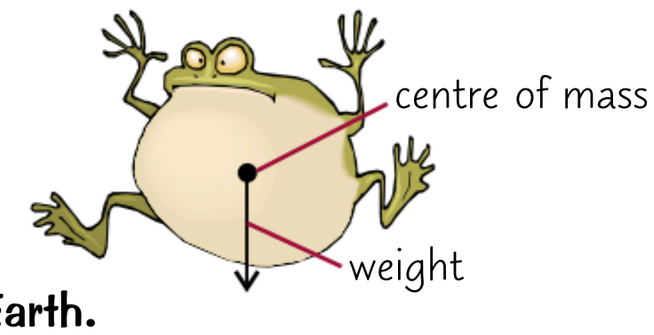
Weight, Mass and Gravity

Mass and weight are NOT the same... Read on to find out why. You know you want to.

Mass is Measured in kg

1) Mass is just the amount of matter (stuff) in an object.
2) It's measured in kilograms, kg.
3) Scientists sometimes think of all the mass in an object as being at one single point in the object.
4) This point is called the centre of mass.

Weight is Measured in Newtons

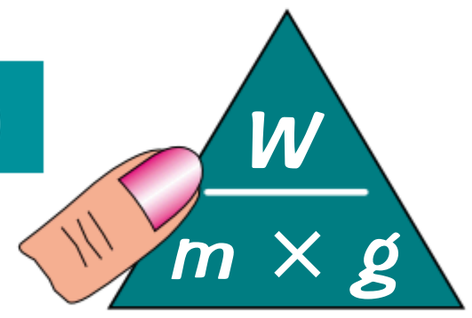


1) Weight is the force acting on an object due to gravity.
2) You can think of this force as acting from an object's centre of mass.
3) Close to Earth, this force is caused by the gravitational field around the Earth.
4) The weight of an object depends on its mass and the strength of the gravitational field it's in.
5) The gravitational field strength of Earth changes slightly depending on where you are.
6) So the weight of an object depends on its location.
7) Unlike the mass of an object which is always the same.
8) Weight is measured in newtons, N.
9) It can be measured with a calibrated spring balance (or newtonmeter).

Mass and Weight are Directly Proportional

1) You can calculate the weight of an object if you know its mass (m) and the strength of the gravitational field that it is in (g):

Weight (N) = Mass (kg) × Gravitational Field Strength (N/kg)



2) For Earth, g is around 9.8 N/kg.
3) Mass and weight are directly proportional.
4) You can write this, using the direct proportionality symbol, as $W \propto m$.

EXAMPLE

A motorcycle weighs 2401 N on Earth.

Calculate the mass of the motorcycle. (g = 9.8 N/kg)

1) First, rearrange $W = mg$ to find mass. mass = weight ÷ gravitational field strength
2) Then, put in the numbers to calculate the mass. mass = 2401 ÷ 9.8 = 245 kg

Diet tip — move to the moon*...

Remember that weight is a force due to gravity and mass is just how much stuff there is.

Q1 Calculate the weight in newtons of a 5 kg mass:
a) on Earth ($g \approx 9.8$ N/kg) b) on the Moon ($g \approx 1.6$ N/kg) [4 marks]

Q1 Video Solution

*If you don't get it, have a go at Q1

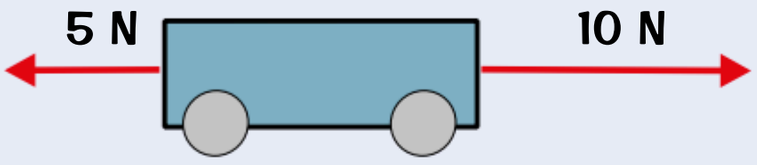
Resultant Forces and Work Done

I'm sure you're no stranger to doing work, but in physics it's all to do with transferring energy.

A Resultant Force is the Overall Force on a Point or Object

1) If a number of forces act at a single point, you can replace them with a single force.
2) This single force is called the resultant force.
3) It has the same effect as all the original forces added together.
4) You can find the resultant force when forces are acting in a straight line.
   Add together forces acting in the same direction and take away any going in the opposite direction.

A trolley is pulled by two children. One child pulls the trolley with a force of 5 N to the left. The other pulls the trolley with a force of 10 N to the right.



So the resultant force, F, is:

$F = 10\text{ N} - 5\text{ N}$
$= 5\text{ N to the right}$.

If a Force Moves an Object, Work is Done

When a force moves an object through a distance, ENERGY IS TRANSFERRED and WORK IS DONE on the object.

1) To make an object move, a force must act on it.
2) The force does 'work' to move the object.
3) This causes energy to be transferred to the object.
4) The force usually does work against frictional forces too.
5) Doing work against frictional forces causes energy to be transferred to the thermal energy store of the object.
6) This causes the temperature of the object to increase.

'Work done' and 'energy transferred' are the same thing. You need to be able to describe how energy is transferred when work is done. Look back at p.168 for more on this.



- When you push something along a rough surface (like a carpet) you are doing work against frictional forces.
- Some energy is transferred to the kinetic energy store of the object because it starts moving.
- Some is also transferred to thermal energy stores due to the work done against friction.
- This causes the overall temperature of the object to increase.

7) You can find out how much work has been done using:

$$W = Fs$$

(W = work done (J), F = force (N), s = distance (moved along the line of action of the force) (m))

The line of action of the force is the direction of the force.

8) One joule of work is done when a force of one newton causes an object to move a distance of one metre in the direction of the force.
9) You need to be able to convert joules to newton metres: 1 J = 1 Nm.

Force yourself to do some work and learn this page...

Remember, when you move an object, you do work. And if you do work, energy is transferred.

Q1 A force of 20 N pushes an object 20 cm. Calculate the work done on the object. [3 marks]

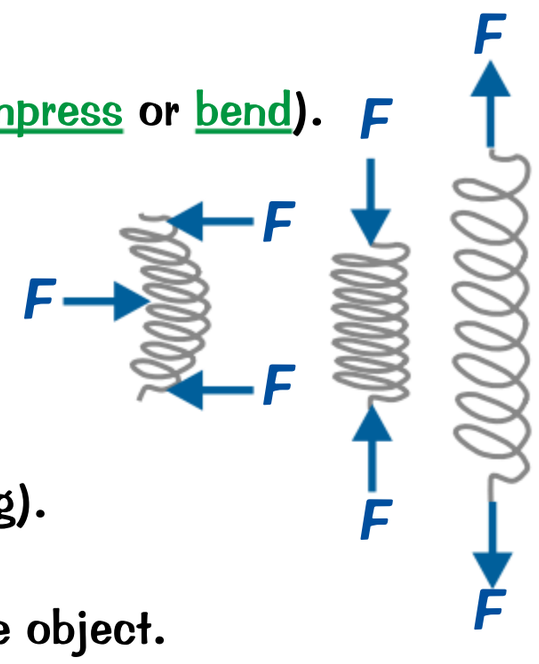
Q1 Video Solution

Forces and Elasticity

You can use forces to stretch things too. The fun never ends...

Stretching, Compressing or Bending Transfers Energy

1) When you apply a force to an object you may cause it to deform (stretch, compress or bend).
2) To do this, you need more than one force acting on the object. One force would just make the object move, not change its shape.
3) An object has been elastically deformed if it can go back to its original shape and length after the force has been removed.
4) If the object doesn't go back to how it was, it has been inelastically deformed.
5) Objects that can be elastically deformed are called elastic objects (e.g. a spring).
6) Work is done when a force stretches or compresses an object. This causes energy to be transferred to the elastic potential energy store of the object.



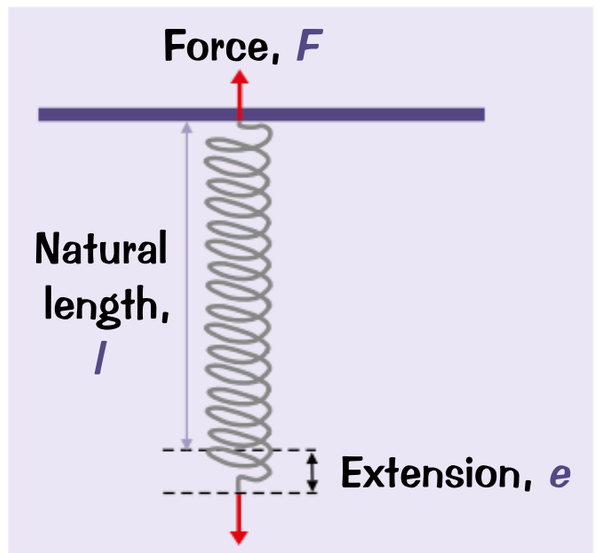
Extension is Directly Proportional to Force...

1) When a force stretches a spring, it causes it to extend.
2) This extension is the difference in length between the stretched and unstretched spring.
3) Up to a given force, the extension is directly proportional to force.
4) So long as a spring hasn't been stretched past its limit of proportionality (see below), you can use:

$$F = ke$$

F = Force (N), k = Spring constant (N/m), e = Extension (m)

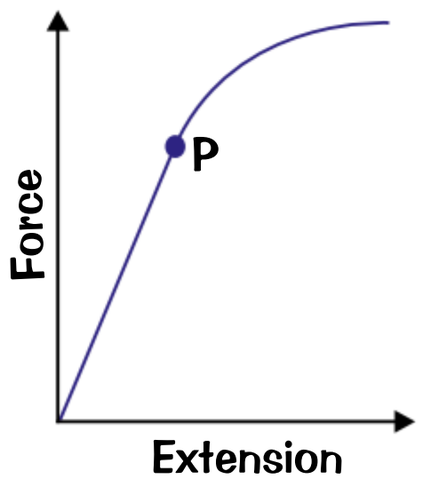
5) The spring constant depends on the object that you are stretching.
6) The equation also works for compression (where e is the difference between the natural and compressed lengths — the compression).



The length of the unstretched spring is sometimes called the spring's natural length.

...but this Stops Working when the Force is Great Enough

1) You can plot a graph of the force applied to a spring and the extension caused.
2) When the graph is a straight line, there is a linear relationship between force and extension.
3) This shows force and extension are directly proportional.
4) The gradient of the straight line is equal to k, the spring constant.
5) When the line begins to bend, the relationship is now non-linear. Force and extension are no longer directly proportional.
6) Point P on the graph (when the line starts to bend) is the limit of proportionality. Past this point, the equation $F = ke$ is no longer true.



I could make a joke, but I don't want to stretch myself...

Make sure you don't skip over any bits of this page — it's all rather important. Have a go at this question.

Q1 A spring is fixed at one end and a force of 1 N is applied to the other end, causing it to stretch. The spring extends by 2 cm. Calculate the spring constant of the spring. [4 marks]

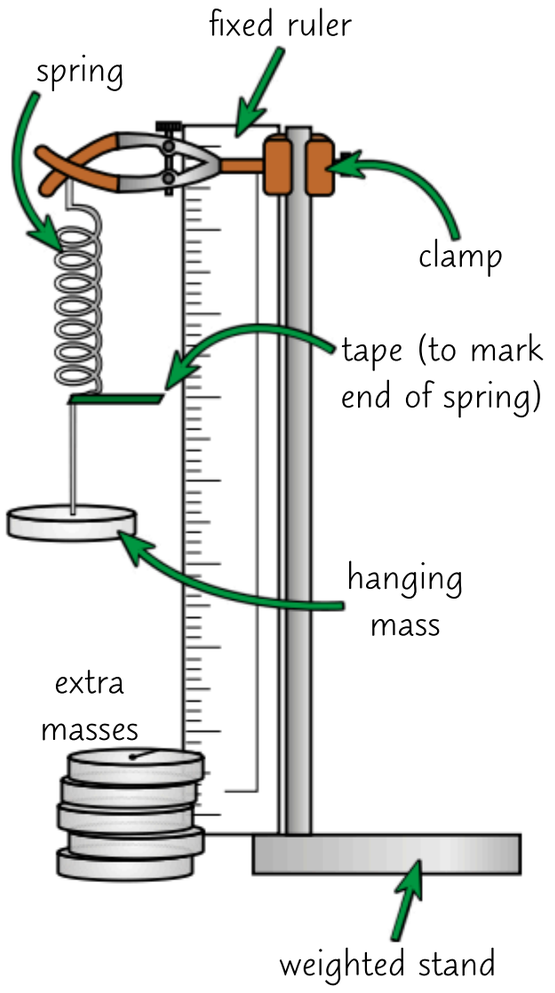
Q1 Video Solution

Investigating Springs

You can do an easy experiment to see exactly how adding masses to a spring causes it to stretch.

You Can Investigate the Link Between Force and Extension

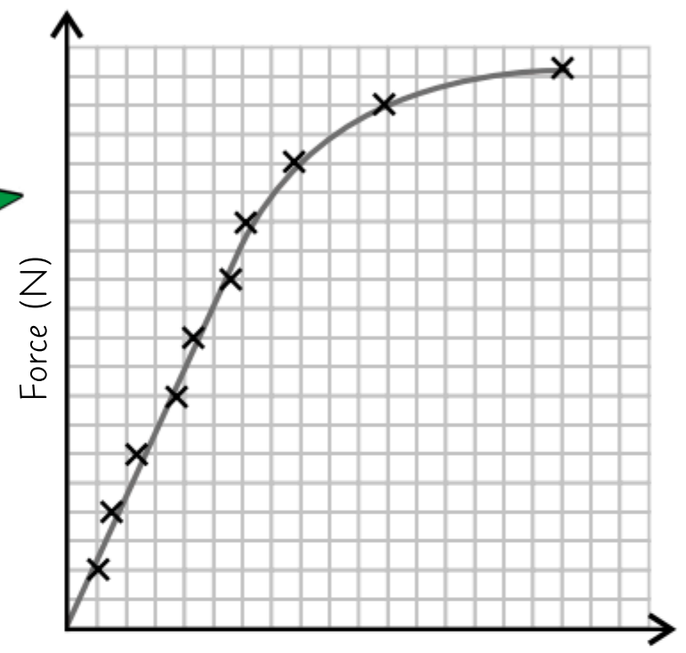
PRACTICAL



1) Set up the apparatus as shown in the diagram.
2) Measure the mass of each mass.
3) Calculate its weight (the force applied) using $W = mg$ (p.204).
4) Measure the original (natural) length of the spring.
5) Add a mass to the spring and allow it to come to rest.
6) Record the force and measure the new length of the spring.
7) Find the extension.

extension = new length – original length

8) Repeat steps 5 to 7 until you've added all the masses.
9) Plot a force-extension graph of your results.
10) You should make sure you have at least 5 measurements before the limit of proportionality (where the line starts to curve).



You Can Work Out Energy Stored for Linear Relationships

1) If a spring is not stretched past its limit of proportionality, the work done in stretching the spring can be found using:
2) For an elastic deformation, this formula can be used to calculate the energy stored in a spring's elastic potential energy store.
3) It's also the energy transferred to the spring as it's deformed, or transferred by the spring as it returns to its original shape.

Spring constant (N/m)

$$E_e = \tfrac{1}{2}ke^2$$

Elastic potential energy (J)

(Extension)^2 (m)^2

EXAMPLE

A spring with a spring constant of 500 N/m extends elastically by 10 cm. It doesn't pass its limit of proportionality.

Calculate the amount of energy stored in its elastic potential energy store.

1) First, you need to convert the extension of the spring into metres. 10 cm ÷ 100 = 0.1 m
2) Then put in the numbers you've been given. $E_e = \tfrac{1}{2}ke^2 = 0.5 \times 500 \times 0.1^2 = 2.5$ J

You can also use this equation to calculate the energy stored when a spring is compressed.

Time to spring into action and learn all this...

Make sure you know how to carry out the experiment on this page — you may be asked about it in the exam.

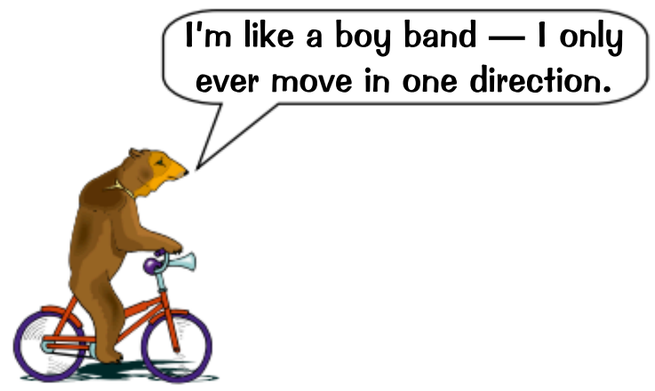
Q1 A spring with a spring constant of 40 N/m extends elastically by 2.5 cm. Calculate the amount of energy stored in its elastic potential energy store. [3 marks]

Q1 Video Solution

Distance, Displacement, Speed and Velocity

Time for a quick recap on distance and speed. You should race through this page. On your marks...

Distance is Scalar, Displacement is a Vector



1) Distance is just how far an object has moved.
2) Distance is a scalar quantity (p.203), so it doesn't involve direction.
3) Displacement is a vector quantity.
4) It measures the distance and direction in a straight line from an object's starting point to its finishing point.
5) The direction could be in relation to a point, e.g. towards the school.
6) If you walk 5 m north, then 5 m south, your displacement is 0 m but the distance travelled is 10 m.

Speed and Velocity are Both How Fast You're Going

1) Speed is a scalar and velocity is a vector:

> Speed is just how fast you're going (e.g. 30 mph or 20 m/s) with no regard to the direction.
> Velocity is speed in a given direction, e.g. 30 mph north or 20 m/s to the right.

2) To measure the speed of an object that's moving with a constant speed, time how long it takes the object to travel a certain distance. Make sure you use the correct equipment (see p.233).
3) You can then calculate the object's speed using this formula:

$s = vt$ distance travelled (m) = speed (m/s) × time (s)

4) Objects rarely travel at a constant speed.
5) When you walk, run or travel in a car, your speed is always changing.
6) In these cases, the formula above gives the average (mean) speed during that time.

You Need to Know Some Typical Everyday Speeds



1) You need to know the typical (usual) speeds of objects:

A person walking — 1.5 m/s
A person running — 3 m/s
A person cycling — 6 m/s
A car — 25 m/s
A train — 30 m/s
A passenger plane — 250 m/s

2) Lots of different things can affect the speed something travels at.
3) The speed at which a person can walk, run or cycle depends on, among other things:
   - their fitness
   - their age
   - the distance they've travelled
   - the terrain (what type of ground they are on)



4) The speeds of sound and wind also vary. A typical speed for sound in air is 330 m/s.

Ah, speed equals distance over time — that old chestnut...

Remember those typical speeds of objects — you might need to use them to make estimates.

Q1 A sprinter runs 200 m in 25 s. Calculate his speed. [3 marks]

Q1 Video Solution

Acceleration

Uniform acceleration sounds fancy, but it's just speeding up (or slowing down) at a constant rate.

Acceleration is How Quickly You're Speeding Up



1) Acceleration is the change in velocity in a certain amount of time.
2) You can find the average acceleration of an object using:

$$a = \frac{\Delta v}{t}$$

Acceleration (m/s^2) — a; Change in velocity (m/s) — Δv; Time taken (s) — t

3) Deceleration (when something slows down) is just negative acceleration.

You Need to be Able to Estimate Accelerations

You might have to estimate the acceleration of an object.
To do this, you need the typical speeds from the previous page:

An estimate is just a guess using rough numbers for things.

EXAMPLE

Olivia gets onto a bike and accelerates to a typical speed from stationary in 10 seconds. Estimate the acceleration of the bicycle.

1) First, give a sensible speed for the bicycle to be travelling at.
2) Put these numbers into the acceleration equation.
3) The ~ symbol just means it's an approximate answer.

The typical speed of a bike is about 6 m/s.

The bicycle accelerates in 10 s.

$a = \Delta v \div t$

$= 6 \div 10 = 0.6$ m/s^2

So the acceleration is ~0.6 m/s^2

Uniform Acceleration Means a Constant Acceleration

1) Constant acceleration is sometimes called uniform acceleration.
2) Acceleration due to gravity (g) is uniform for objects falling freely.
3) It's roughly equal to 9.8 m/s^2 near the Earth's surface.
4) You can use this equation for uniform acceleration:

$$v^2 - u^2 = 2as$$

(Final velocity)^2 (m/s)^2 — v; (Initial velocity)^2 (m/s)^2 — u; Acceleration (m/s^2) — a; Distance (m) — s

Initial velocity is just the starting velocity of the object.

EXAMPLE

A van travelling at 23 m/s starts decelerating uniformly at 2.0 m/s² as it heads towards a built-up area 112 m away. What will its speed be when it reaches the built-up area?

1) First, rearrange the equation so v^2 is on one side.
2) Now put the numbers in — remember a is negative because it's a deceleration.
3) Finally, square root the whole thing.

$v^2 = u^2 + 2as$

$v^2 = 23^2 + (2 \times -2.0 \times 112)$

$= 81$

$v = \sqrt{81} = 9$ m/s

Uniform problems — get a clip-on tie or use the equation above...

You might not be told what equation to use in the exam, so make sure you can spot when to use the one for uniform acceleration. Make a list of the information you're given to help you see what to do.

Q1 A ball is dropped from a height, h, above the ground. The speed of the ball just before it hits the ground is 7 m/s. Calculate the height the ball is dropped from. (acceleration due to gravity ≈ 9.8 m/s^2) [3 marks]

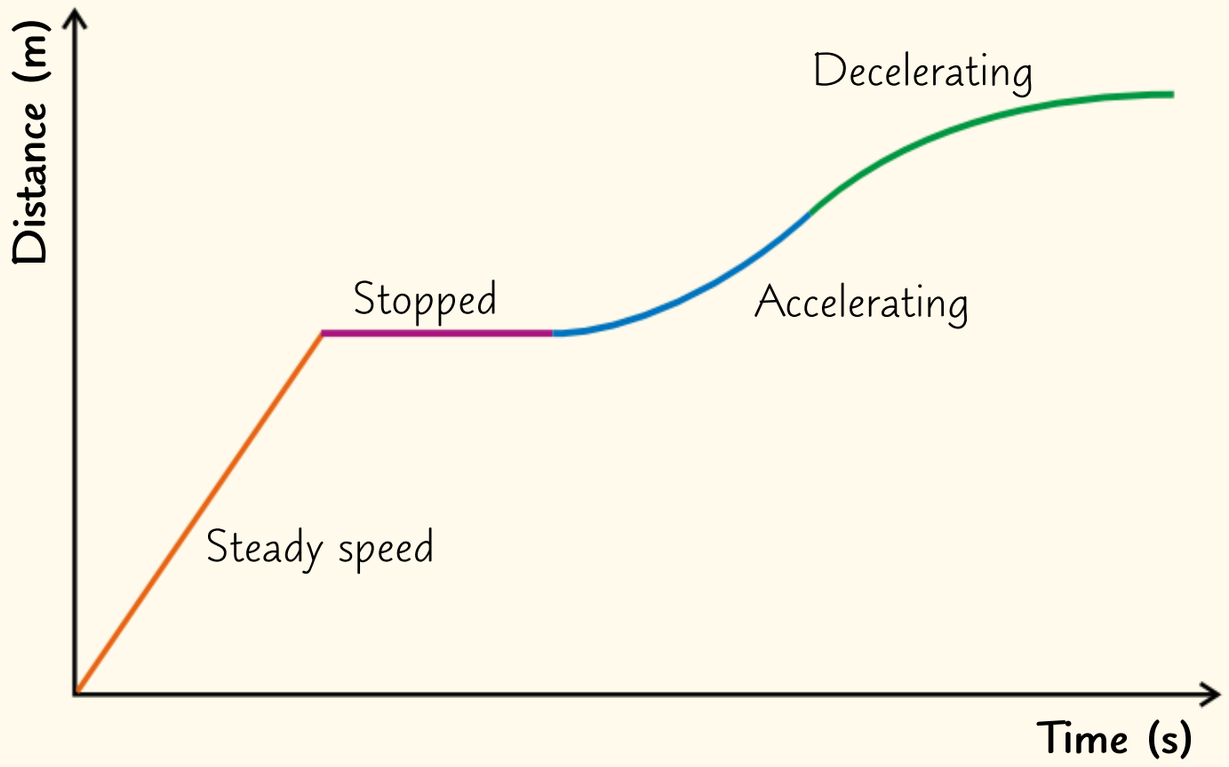
Q1 Video Solution

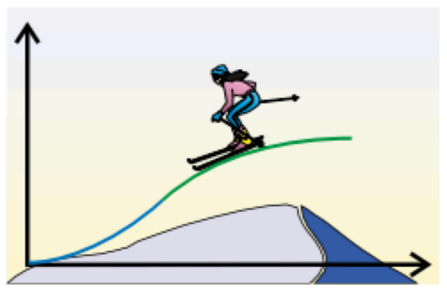
Distance-Time Graphs

You need to be able to draw and understand distance-time graphs.

You Can Show Journeys on Distance-Time Graphs

1) If an object moves in a straight line, the distance it travels can be plotted on a distance-time graph.
2) You may be asked to draw a distance-time graph for a journey.
3) Or you might have to describe a journey if you're shown a distance-time graph.





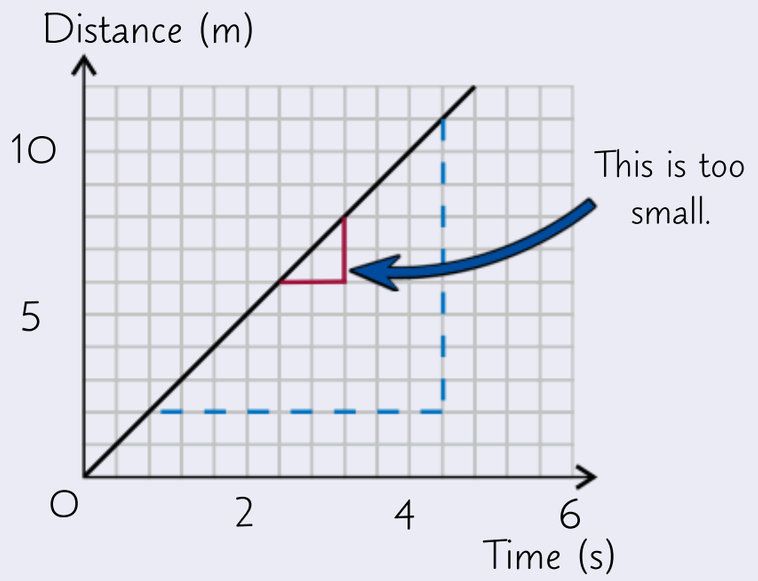
- Gradient = speed. The steeper the graph, the faster it's going.
- Flat sections are where it's stationary — it's stopped.
- Straight uphill (/) sections mean it is travelling at a steady speed.
- Curves represent acceleration or deceleration (p.209).
- A curve that is getting steeper means it's speeding up (accelerating).
- A levelling off curve means it's slowing down (decelerating).

4) You might also have to calculate an object's speed from the graph:

EXAMPLE

Using the distance-time graph on the right, calculate the speed of the car.

1) The gradient of the graph is the speed of the car.
2) Gradient = $\frac{\text{change in vertical axis}}{\text{change in horizontal axis}}$.
3) Draw a large triangle, that takes up most of the straight line.
4) Use the horizontal side of the triangle to find the change in time.
5) Use the vertical side of the triangle to find the change in distance.
6) Put the values for vertical and horizontal into the equation.



Change in time = 4.4 – 0.8 = 3.6 s
Change in distance = 11 – 2 = 9 m
Gradient = 9 ÷ 3.6 = 2.5
So speed = 2.5 m/s

Understanding motion graphs can be a real uphill struggle...

Make sure you know how to use distance-time graphs to find an object's speed.

Q1 Sketch the distance-time graph for an object that accelerates, then travels at a steady speed, and then comes to a stop. [3 marks]

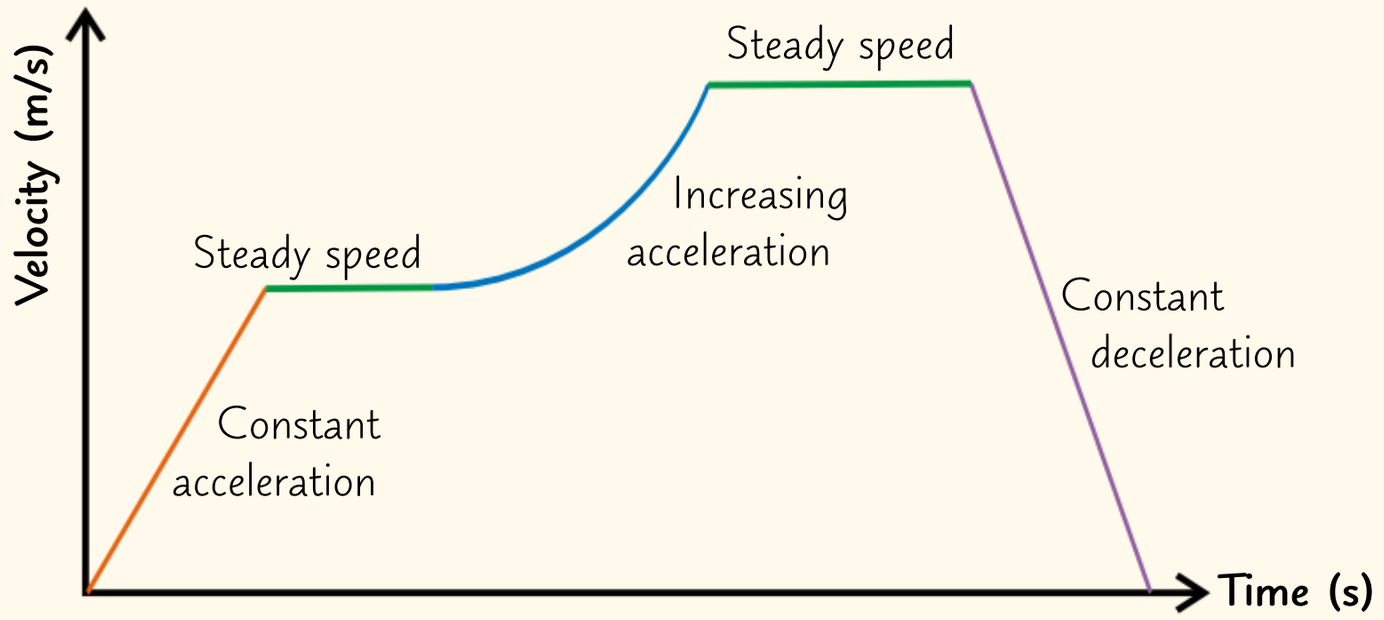
Q1 Video Solution

Velocity-Time Graphs and Terminal Velocity

This page is on velocity-time graphs and terminal velocity. Just when you thought it couldn't get more exciting.

Journeys Can be Shown on a Velocity-Time Graph

1) How an object's velocity changes as it travels can be plotted on a velocity-time graph.
2) You might have to draw a velocity-time graph for a journey.
3) Or you might have to describe a journey from a velocity-time graph.



- Gradient = acceleration. You can calculate this with a similar method to the example on the last page.
- Flat sections represent travelling at a steady speed.
- The steeper the graph, the greater the acceleration or deceleration.
- Uphill sections (/) are acceleration.
- Downhill sections (\) are deceleration.
- A curve means changing acceleration.

Friction is Always There to Slow Things Down

1) Gases and liquids are both fluids.
2) Objects moving through fluids experience drag.
3) Drag is the resistance you get in a fluid. Air resistance is a type of drag.
4) Drag acts in the opposite direction to the movement of the object.
5) Drag increases as the speed of the object increases.

Falling Objects Reach a Terminal Velocity

1) When an object first starts falling, the force of gravity is much larger than the drag slowing it down.
2) This means the object accelerates (the object speeds up).
3) As the speed increases, so does the drag.
4) This reduces the acceleration until the drag is equal to the gravitational force. The resultant force (p.205) on the object is then zero.
5) The object will fall at a constant speed. This speed is called its terminal velocity.



Falling with style

Don't let air resistance drag you down...

Make sure you know what a velocity-time graph is telling you about the acceleration of an object.

Q1 Sketch a velocity-time graph for an object that travels at a constant speed, then accelerates at a constant rate, then moves at a constant speed (that is different to the initial speed). [3 marks]

Q2 A stationary car starts accelerating increasingly for 10 s until it reaches a speed of 20 m/s. It travels at this speed for 20 s until the driver sees a hazard and brakes. He decelerates uniformly, coming to a stop 4 s after braking. Draw the velocity-time graph for this journey. [3 marks]

Q2 Video Solution

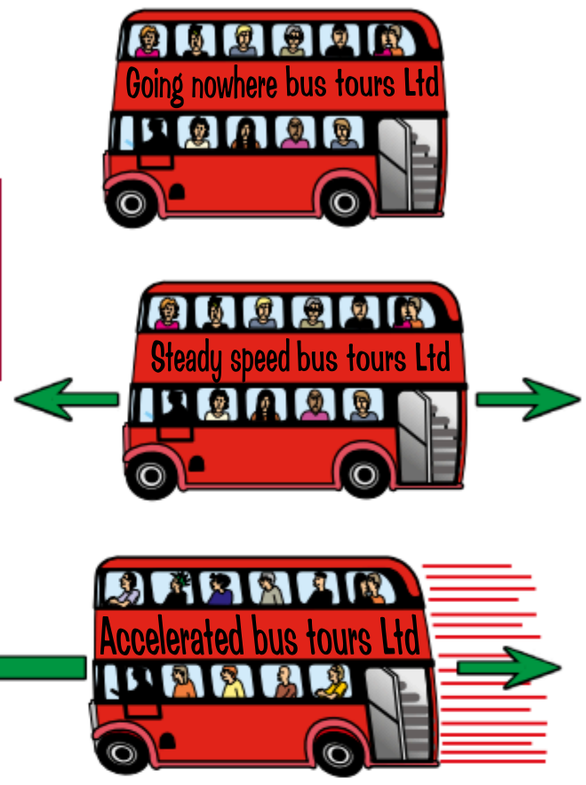
Newton's First and Second Laws

In the 1660s, a chap called Isaac Newton worked out his dead useful Laws of Motion. Here are the first two.

A Force is Needed to Change Motion

1) Newton's First Law says that a resultant force (p.205) is needed to make something start moving, speed up or slow down:

If the resultant force on a stationary object is zero, the object will remain stationary. If the resultant force on a moving object is zero, it'll just carry on moving at the same velocity (the same speed and direction).



2) So, when a train or car or bus or anything else is moving at a constant velocity, the driving and resistive forces on it must be balanced.
3) Its velocity will only change if there's a non-zero resultant force acting on it.
4) A non-zero resultant force will always produce acceleration (or deceleration) in the direction of the force.

Acceleration is Proportional to the Resultant Force

1) The larger the resultant force acting on an object, the more the object accelerates.
2) Newton's Second Law says that the force acting on an object and the acceleration of the object are directly proportional. This can be shown as $F \propto a$.
3) Newton's Second Law also says that acceleration is inversely proportional to the mass of the object.
4) So an object with a larger mass will accelerate less than one with a smaller mass, for a given force.
5) There's a formula that describes Newton's Second Law:

$$F = ma$$

(F: Resultant force (N); a: Acceleration (m/s^2); m: Mass (kg))

6) You can use Newton's Second Law to get an idea of the forces involved in large accelerations of everyday transport.
7) You may need some typical vehicle masses first though:
Car — 1000 kg, Bus — 10 000 kg, Loaded Lorry — 30 000 kg

EXAMPLE

Estimate the resultant force on an average car as it accelerates from rest to a typical speed.

1) Estimate the speed of the car and the time taken to reach that speed.
2) Use the speed and time taken to estimate the acceleration of the car.
3) Put these numbers and the mass of the car into $F = ma$.

A typical speed of a car is ~25 m/s.
It takes ~10 s to reach this.

So $a = \Delta v \div t$
$= 25 \div 10 = 2.5$ m/s^2

Remember, the ~ sign means approximately.

Mass of a car is ~1000 kg.
$F = ma = 1000 \times 2.5 = 2500$ N
So the resultant force is ~2500 N.

Accelerate your learning — force yourself to revise...

Make sure you've got your head around both these laws, before moving on to Newton's third and final law.

Q1 Find the force needed for an 80 kg man on a 10 kg bike to accelerate at 0.25 m/s^2. [2 marks]

Q1 Video Solution

Newton's Third Law

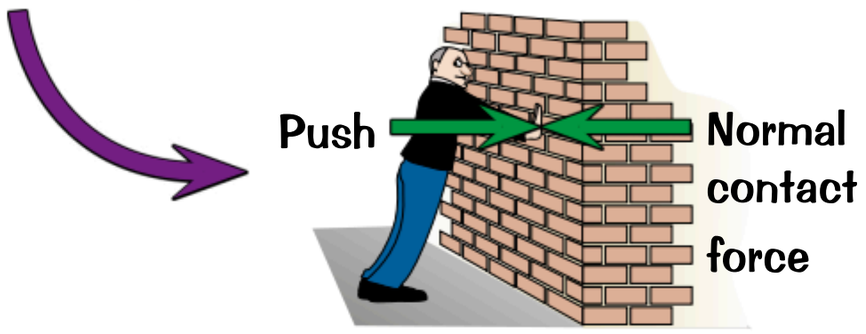
This page is on Newton's Third Law. Make sure you really understand what's going on with it.

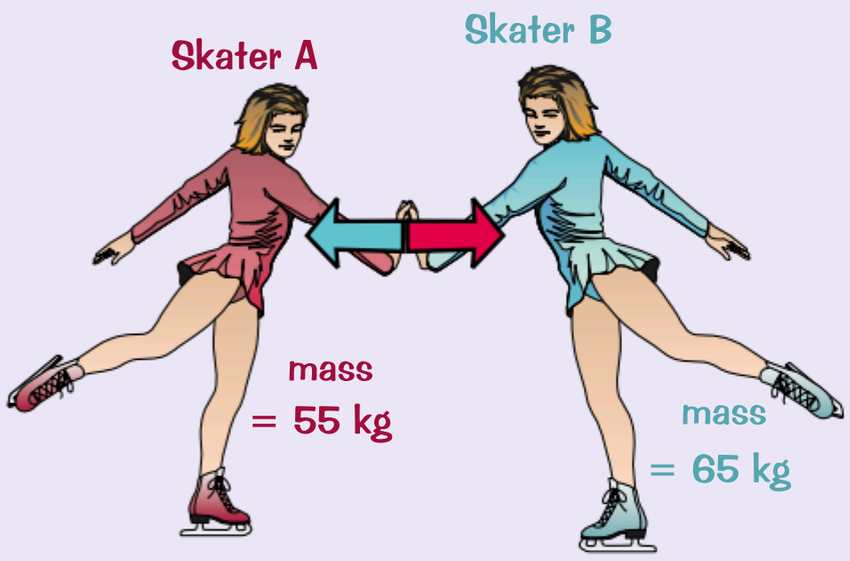
Newton's Third Law Involves Equal and Opposite Forces

Newton's Third Law says:

> **When two objects interact, the forces they exert on each other are equal and opposite.**

1) This means if you push something, it will push back against you, just as hard.
2) And as soon as you stop pushing, so does the object.
3) You may be thinking "if the forces are always equal, how does anything ever go anywhere?".
4) The important thing to remember is that the two forces are acting on different objects.





- Skater A pushes on skater B.
- When she does, she feels an equal and opposite force from skater B's hand.
- Both skaters feel the same sized force, in opposite directions.
- This causes them to accelerate away from each other.
- Skater A will be accelerated more than skater B, because she has a smaller mass.
- Remember $a = F \div m$.

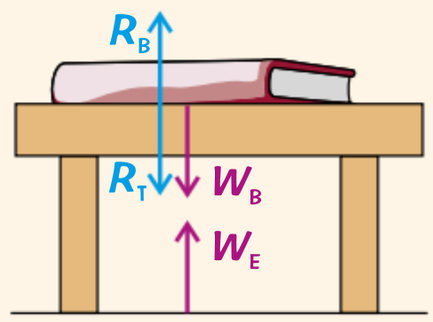
It's More Complicated for an Object in Equilibrium

Imagine a book sat on a table in equilibrium (the resultant force on the book is zero):

1) The weight of the book pulls it down, and the normal contact force from the table pushes it up.
2) This is NOT Newton's Third Law.
3) These forces are different types and they're both acting on the book.

The pairs of forces due to Newton's Third Law in this case are:

- The book being pulled down by gravity towards the Earth (W_B) and the Earth being pulled up by the book (W_E).
- The normal contact force from the table pushing up on the book (R_B) and the normal contact force from the book pushing down on the table (R_T).



Newton's fourth law — revision must be done with tea...

Thankfully, Newton only came up with three laws that you have to learn, although his third law can be quite tricky. Take your time, look at each object one by one, and work out all the forces acting on it.

Q1 A car moves at a constant velocity along a road, so that it is in equilibrium. Give an example of a pair of forces that demonstrate Newton's Third Law in this situation. [1 mark]

Q1 Video Solution

PRACTICAL

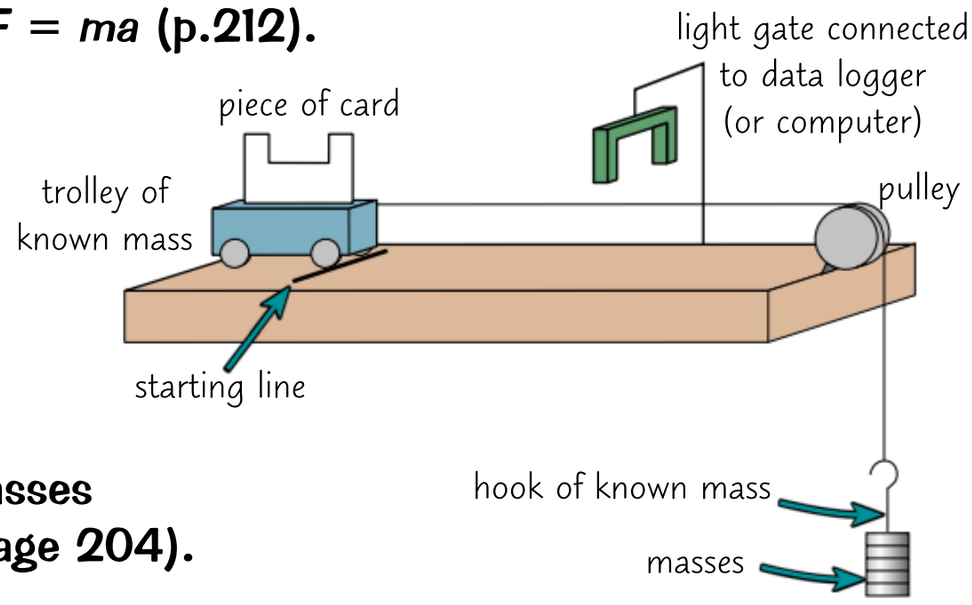
Investigating Motion

Now you've learnt the different laws of motion why not test them with a practical...

You can Investigate how Mass and Force Affect Acceleration

It's time for an experiment that tests Newton's Second Law, $F = ma$ (p.212).

1) Set up the apparatus as shown on the right.
2) The mass, m, that you'll be accelerating is the total mass of the trolley, hook and the added masses.
3) You can measure m using a mass balance.
4) The force, F, causing the acceleration is the weight of the hook and the masses on the hook.
5) To find F, first measure the mass of the hook and any masses on the hook. Then multiply this by g (as $W = mg$, see page 204).
6) The acceleration, a, is found by following this method:



1) Mark a starting line on the table the trolley is on. This is so that the trolley always travels the same distance to the light gate.
2) Place the trolley on the starting line.
3) Hold the trolley so the string is tight and not touching the table. Then release it.
4) Record the acceleration measured by the light gate as the trolley passes through it.

For more on how light gates work have a look at page 239.

Now you can investigate the things that affect Newton's Second Law...

Investigating How Mass Affects Acceleration

To investigate the effect of mass, you need to change the mass but keep the force the same.
Remember, the mass (m) is the mass of the trolley, the hook and any extra masses added together.

1) The force is the weight of the hook and any masses on the hook.
2) So, keep the mass on the hook the same.
3) Add masses to the trolley one at a time to increase the total mass being accelerated.
4) Record the acceleration, a, for each total mass, m.
5) You should find that as the mass goes up, the acceleration goes down.
6) This agrees with Newton's Second Law — mass and acceleration are inversely proportional.

Investigating How Force Affects Acceleration

This time, you need to change the force without changing the total mass of the trolley, hook and masses.

1) Start with all the extra masses loaded onto the trolley.
2) Moving the masses from the trolley to the hook will keep the total mass, m, the same.
3) But it will increase the force, F (the weight of the hook and the masses on the hook).
4) Each time you move a mass, record the new force, and measure the acceleration.
5) You should find that as the force goes up, the acceleration goes up.
6) This agrees with Newton's Second Law — force and acceleration are directly proportional.

My acceleration increases with nearby cake...

Know the ins and outs of that experiment — you could be asked about any part of it, or to describe the whole thing.

Q1 In the experiment above, what force is accelerating the trolley? [1 mark]

Stopping Distance and Thinking Distance

This page is all about cars, but unfortunately it's not as fun as it sounds... It's even better — it's about safety...

Stopping Distance = Thinking Distance + Braking Distance



1) In an emergency, a driver may perform an emergency stop.
2) During an emergency stop, the maximum force is applied by the brakes. This is so the vehicle stops in the shortest possible distance.
3) The distance it takes to stop a vehicle in an emergency is its stopping distance. It is found by:

Stopping Distance = Thinking Distance + Braking Distance

4) THINKING DISTANCE is how far the vehicle travels during the driver's reaction time.
5) The reaction time is the time between the driver seeing a hazard and applying the brakes.
6) BRAKING DISTANCE is the distance taken to stop under the braking force (once the brakes are applied).

Stopping Distances for Different Speeds can be Estimated

1) You need to be able to estimate the stopping distance of vehicles.
2) The heavier a vehicle is, or the faster it's travelling, the longer its stopping distance will be.
3) As a guide, typical car stopping distances are: 23 m at 30 mph, 73 m at 60 mph, 96 m at 70 mph.

Stopping Distances Affect Safety

1) The longer it takes to perform an emergency stop, the higher the risk of crashing into whatever's in front.
2) So the shorter a vehicle's stopping distance, the safer it is.
3) You need to be able to describe how different factors can affect the safety of a journey.
4) For example, how driving if you're tired is unsafe. There's more on this below.

Thinking Distance is Determined by the Driver's Reactions

1) Thinking distance is affected by:
   - Your SPEED — the faster you're going, the further you'll travel during the time you take to react.
   - Your REACTION TIME — the longer your reaction time (see p.217), the longer your thinking distance.
2) A driver's reaction times can be affected by tiredness, drugs or alcohol.
3) Distractions can also affect your ability to react.

   - Driving while tired is unsafe as it makes you slower to react.
   - This increases your reaction time, which increases your thinking distance.
   - This means your stopping distance is longer, so you're more likely to crash.

   - Driving above the speed limit is unsafe.
   - You travel further in your reaction time than you would at a lower speed.
   - This increases your thinking (and so stopping) distance.



Stop right there — and learn this page...

Before moving on, make sure you can explain the factors that affect a person's thinking distance.

Q1 Give one factor that affects thinking distance. [1 mark]

Braking Distance

You need to know what energy changes occur when a car stops. Don't worry — it'll all make sense soon enough.

Braking Distance Depends on a Few Different Factors Affecting the Car

Braking distance is affected by:

1) Your SPEED: for a given braking force, the faster a vehicle travels, the longer it takes to stop.
2) WEATHER or ROAD SURFACE:
   - If there is less grip between a vehicle's tyres and the road, it can cause the vehicle to skid.
   - Skidding increases the braking distance of a car.
   - Water, ice, oil or leaves on the road all reduce grip.

   Icy conditions increase the chance of skidding. This increases the braking distance, which increases the stopping distance. So more room should be left between cars to be safe.
3) The CONDITION of your TYRES:
   - Bald tyres (ones that don't have any tread left) cannot get rid of water in wet conditions.
   - This leads to them skidding on top of the water.
4) How good your BRAKES are:
   - If brakes are worn, they won't be able to apply as much force.
   - So it takes longer to stop a vehicle travelling at a given speed (see below).

Braking Relies on Friction Between the Brakes and Wheels

1) When the brake pedal is pushed, brake pads are pressed onto the wheels.
2) The brake pads cause friction, which causes work to be done (p.205).
3) Remember, when work is done, energy is transferred (p.168).
4) Energy is transferred from the kinetic energy store of the vehicle to the thermal energy stores of the brakes.
5) The brakes increase in temperature.
6) To stop a vehicle, the brakes must transfer all of the energy from the kinetic store, so:

$$\text{Energy in the vehicle's kinetic energy store} = \text{Work done by the brakes}$$
$$\tfrac{1}{2} \times m \times v^2 = F \times d$$

m: mass of the car; v: speed of car; F: braking force; d: braking distance

7) The faster a vehicle is going, the more energy it has in its kinetic energy store.
8) So more work needs to be done to stop it.
9) This means that as the speed of a vehicle increases, the force needed to make it stop within a certain distance also increases.
10) A larger braking force means a larger deceleration.
11) Very large decelerations can be dangerous because they may cause brakes to overheat. This means the brakes won't work as well.
12) Very large decelerations may also cause the vehicle to skid.

To claim your free brakes test, stop here...

If you ever find yourself in charge of a vehicle, hopefully you'll remember this page and it'll help you to be safer on the roads. Even if you don't plan on driving, this page is still very important for your exams.

Q1 A car with a mass of 1000 kg is travelling in a straight line at a speed of 10 m/s. The driver spots a hazard and applies the brakes. The car is 50 m from the hazard when the brakes are applied. Calculate the minimum braking force required for the car to stop before the hazard. [5 marks]

Q1 Video Solution

Reaction Times

Go long! You need fast reaction times to avoid getting hit in the face when playing catch.



A Typical Reaction Time is 0.2 s – 0.9 s

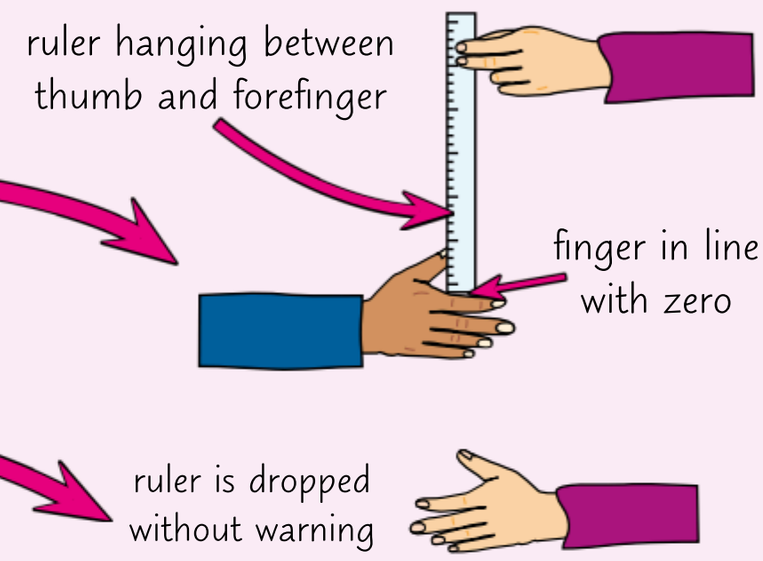
1) Everyone's reaction time is different.
2) A typical reaction time is between 0.2 and 0.9 s.
3) You can do simple experiments to investigate your reaction time — more on these below.

You can Measure Reaction Times with the Ruler Drop Test

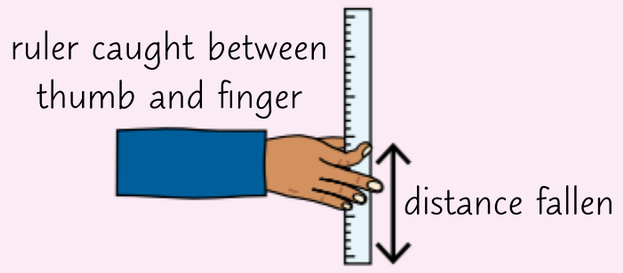
1) As reaction times are so short, you haven't got a chance of measuring one with a stopwatch.
2) One way of measuring reaction times is to use a computer-based test.
For example, clicking a mouse when the screen changes colour.

Another method to measure reaction times is the ruler drop test:

1) Sit with your arm resting on the edge of a table.
2) Get someone else to hold a ruler so it hangs between your thumb and forefinger, lined up with zero.
3) You may need a third person to be at eye level with the ruler to check it's lined up.
4) Without giving any warning, the person holding the ruler should drop it.
5) Close your thumb and finger to try to catch the ruler as quickly as possible.



6) The measurement on the ruler at the point where it is caught is how far the ruler dropped in the time it took you to react.
7) The longer the distance, the longer the reaction time.
8) You can calculate how long the ruler falls for (the reaction time) because acceleration due to gravity is constant.
9) To find the reaction time, you can use the equation:



$$t = \frac{\sqrt{2as}}{a}$$

You DON'T need to learn this equation. It comes from squishing $v^2 - u^2 = 2as$ and $a = \Delta v \div t$ from p.209 together.

- t is the reaction time in seconds, s.
- a is the acceleration due to gravity. $a = 9.8$ m/s^2.
- s is how far the ruler fell before it was caught, in metres, m.

10) It's hard to do this experiment accurately, but you can do a few things to improve your results.
- Do a lot of repeats and calculate an average reaction time.
- Add a blob of modelling clay to the bottom to help the ruler to fall straight down.
- Make it a fair test — use the same ruler for each repeat, and have the same person dropping it.

Test a friend's reaction time by throwing this book at them...

Q1 Video Solution

Not really. Instead re-read this page and make sure you can describe the experiment. Much more fun.

Q1 Mark's reaction time is tested using the ruler drop test. He is tested in the early afternoon and at night. In the afternoon, he catches the ruler after it has fallen a distance of 16.2 cm. At night, he catches the ruler after it has fallen 18.5 cm.

a) Calculate Mark's reaction time in the afternoon. Give your answer to 2 significant figures. [5 marks]

b) Explain why Mark's thinking distance might be longer when driving in the evening. [2 marks]

Revision Questions for Topic P5

Well, that's it for Topic P5. See how you've done with this summary.

- Try these questions and tick off each one when you get it right.
- When you're completely happy with a sub-topic, tick it off.

For even more practice, try the Retrieval Quiz for Topic P5 — just scan this QR code!

Topic P5 Quiz

Forces and Work Done (p.203-205) ☑

1) Explain the difference between scalar and vector quantities. ☐
2) True or false? Time is a vector quantity. ☐
3) What is the difference between contact and non-contact forces? ☐
4) True or false? Mass is a force measured in newtons. ☐
5) What is the formula for calculating the weight of an object? ☐
6) What is a resultant force? ☐
7) Give the formula for calculating the work done by a force. Explain what each symbol means. ☐
8) How many joules of work does 1 Nm equal? ☐

Stretching, Compressing and Bending (p.206-207) ☑

9) What is the difference between an elastic and an inelastic deformation? ☐
10) What is the limit of proportionality? ☐
11) Give the equation that links force, extension and the spring constant of an object. ☐
12) Describe an experiment you could do to investigate the relationship between force and extension. ☐

Motion (p.208-214) ☑

13) What is the difference between displacement and distance? ☐
14) Estimate the speed of a person walking. ☐
15) Write down the equation that links acceleration, velocity and time. ☐
16) For what type of acceleration can you use the equation $v^2 - u^2 = 2as$? ☐
17) What does the gradient represent for: a) a distance-time graph? b) a velocity-time graph? ☐
18) State Newton's three laws of motion. ☐
19) Describe an experiment that you could do to investigate Newton's Second Law. ☐

Car Safety (p.215-217) ☑

20) What is the stopping distance of a vehicle? How can it be calculated? ☐
21) Give two things that affect a person's reaction time. ☐
22) State four things that can affect the braking distance of a vehicle. ☐
23) Explain why the temperature of a car's brakes increase during braking. ☐
24) What is a typical reaction time? ☐
25) Briefly describe an experiment you could do to compare people's reaction times. ☐
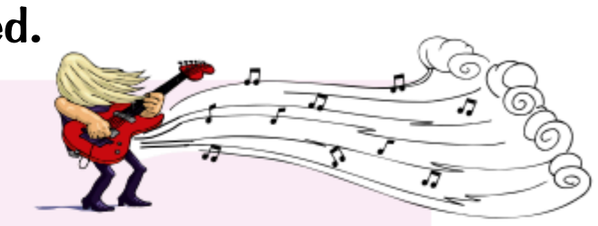
Transverse and Longitudinal Waves

Waves transfer energy from one place to another without transferring any matter (stuff).

Waves Transfer Energy but not Matter

1) When a wave travels through a medium, the particles of the medium vibrate.
2) A medium is just a fancy word for whatever the wave is travelling through (e.g. water, air).
3) The particles transfer energy between each other as they vibrate (see p.167).
4) BUT overall, the particles stay in the same place — only energy is transferred.

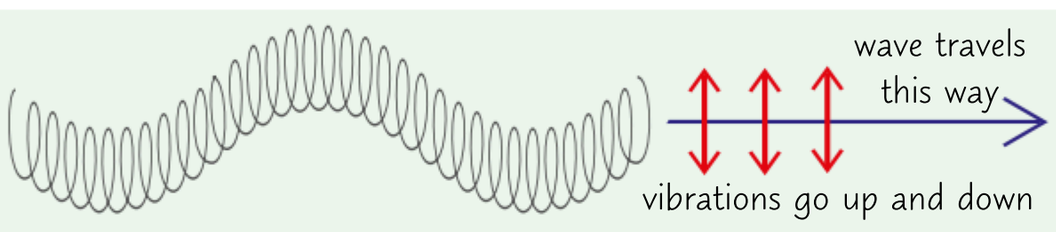
- For example, if you drop a twig into calm water, ripples spread out. The ripples don't carry the water (or the twig) away with them though.
- And if you strum a guitar string, the sound waves don't carry the air away from the guitar. If they did, you'd feel a wind whenever there was a sound.



All Waves are Either Transverse or Longitudinal

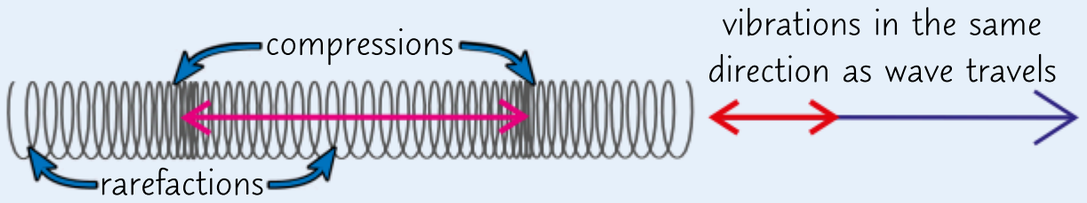
1) In transverse waves, the vibrations are perpendicular (at right angles) to the direction of energy transfer.
2) Examples of transverse waves are light (p.223), ripples on water (see p.221) and waves on a string.

A spring wiggled up and down gives a transverse wave.



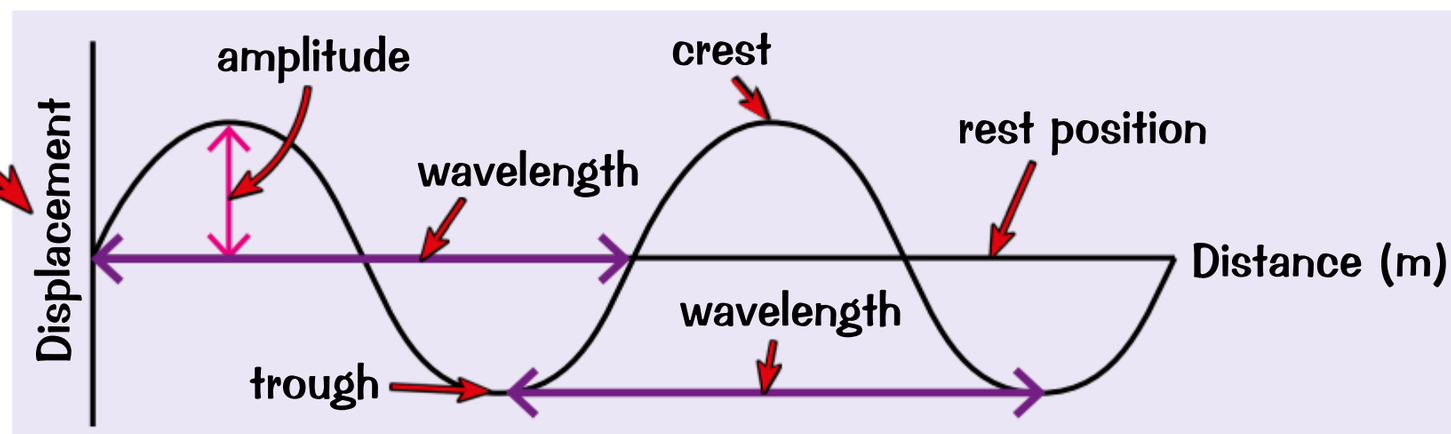
3) In longitudinal waves, the vibrations are in the same direction as the energy transfer.
4) They have compressions (where the particles squish together), and rarefactions (where they spread out).
5) A sound wave is an example of a longitudinal wave.

If you push the end of a spring you get a longitudinal wave.



You Need to Know these Words to Describe Waves

Displacement is how far a particle on the wave is from its rest position.



1) The amplitude is the maximum displacement of a point on the wave from its undisturbed (rest) position.
2) The wavelength is the distance between one point on a wave and the same point on the next wave. For example, the distance between the trough of one wave and the trough of the wave next to it.
3) Frequency is the number of complete waves passing a certain point each second.
4) Frequency is measured in hertz (Hz). 1 Hz is 1 wave per second.
5) Period is the amount of time it takes for one complete wave to pass a certain point.

So, that's the wave basics...

Make sure you've got all this clear in your head, otherwise the rest of the topic will just be a blur of nonsense.

Q1 Give two examples of transverse waves. [2 marks]

Frequency, Period and Wave Speed

You need to know how to calculate and measure the speed of a wave.

Frequency and Period are Linked

You can find the period of a wave from its frequency:

$$T = \frac{1}{f}$$

Period (s) — Frequency (Hz)

EXAMPLE

Calculate the period of a wave with a frequency of 2 Hz.

$T = 1 \div f = 1 \div 2 = 0.5$ s

Wave Speed = Frequency × Wavelength

1) The wave speed is how fast the wave is moving.
2) It is the speed at which energy is being transferred through the medium.
3) The wave equation applies to all waves:

Wave speed (m/s) = frequency (Hz) × wavelength (m)

$$v = f\lambda$$

EXAMPLE

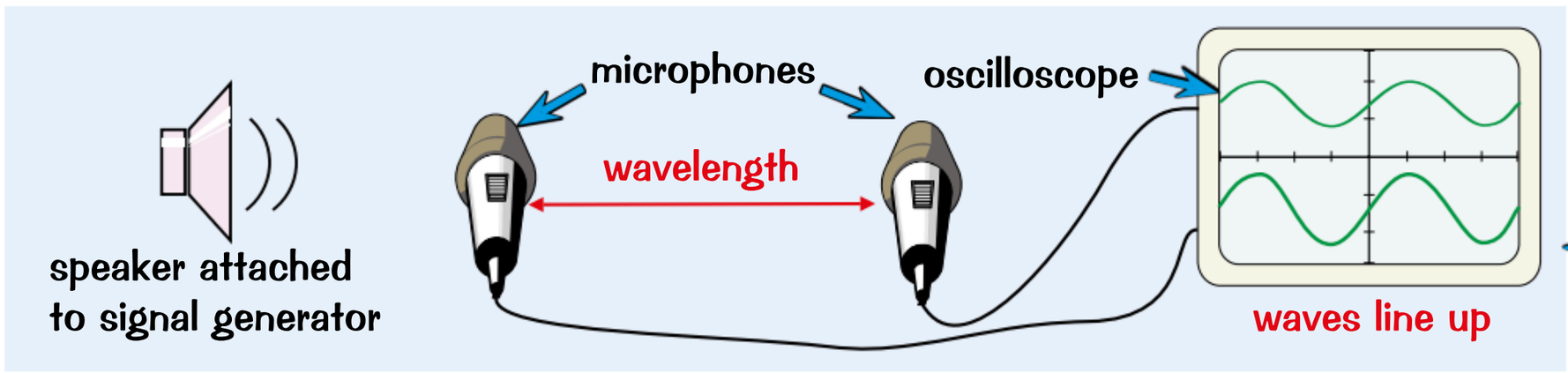
A radio wave has a frequency of 12 000 000 Hz.
Find its wavelength. (The speed of radio waves in air is 3×10^8 m/s.)

1) Rearrange the wave speed equation for wavelength.
2) Put in the values you've been given.
   Watch out — the speed is in standard form (p.12).

$\lambda = v \div f$
$= (3 \times 10^8) \div (12\,000\,000)$
$= 25$ m

Use an Oscilloscope to Measure the Speed of Sound

1) Connect two microphones to an oscilloscope (a device which shows waves on a screen).
2) Connect a signal generator to a speaker. This will let you generate sound waves at a set frequency.



3) Set up the oscilloscope so the waves reaching each microphone are shown separately.
4) Start with both microphones next to the speaker. The waves on the oscilloscope should line up.
5) Slowly move one microphone away. Stop when the two waves line up again on the display.
6) This means the microphones are now exactly one wavelength apart.
7) Measure the distance between the microphones to find the wavelength (λ).
8) Use the formula $v = f\lambda$ to find the speed (v) of the sound waves passing through the air.
9) The frequency (f) is whatever you set the signal generator to.
10) The speed of sound in air is around 330 m/s, so check your results roughly agree with this.

Looks like the perfect setup for a karaoke duet...

Make sure you understand each step of that method above — you could be tested on it in the exams.

Q1 A wave has a speed of 0.15 m/s and a wavelength of 7.5 cm. Calculate its frequency. [4 marks]

Q1 Video Solution

Investigating Waves

PRACTICAL

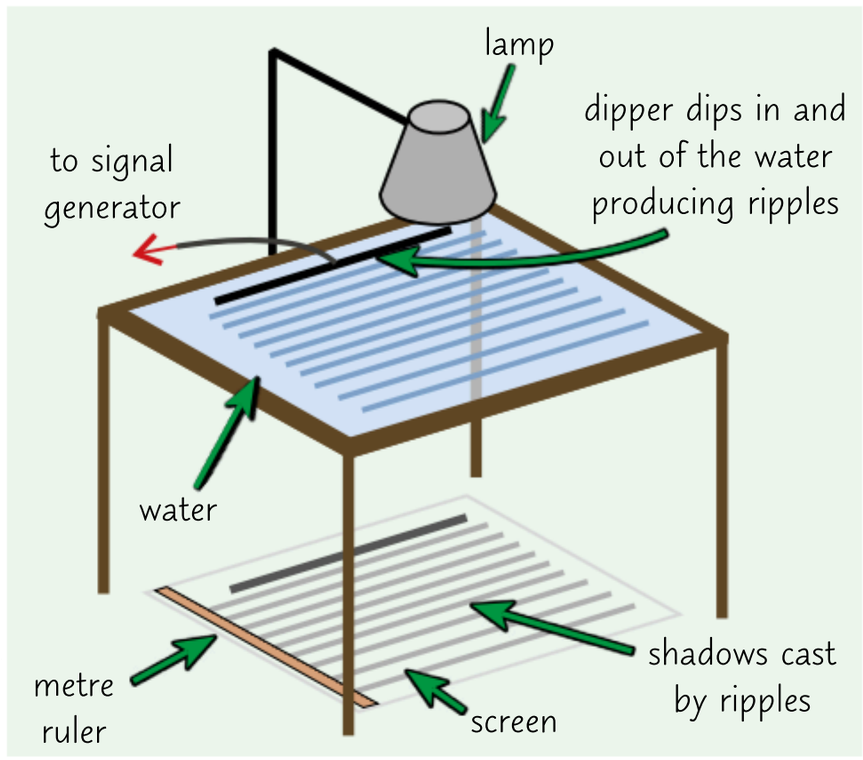
Choosing suitable equipment means making sure it's right for the job. It's important here.

Measure the Speed of Water Ripples Using a Ripple Tank

1) Attach a signal generator to the ripple tank dipper.
2) Turn on the signal generator to create waves.
3) Find the frequency of the waves by counting the number of ripples that pass a point in 10 seconds and dividing by 10.
4) Use a lamp to create shadows of the ripples on a screen below the tank. Place a metre ruler beside the shadows.
5) The distance between each shadow line is equal to one wavelength.
6) Measure the wavelength accurately like this:

- Measure the distance across 10 gaps between the shadow lines.
- Divide this distance by 10 to find the average wavelength.

This is a good method for measuring the wavelength of moving waves or small wavelengths.

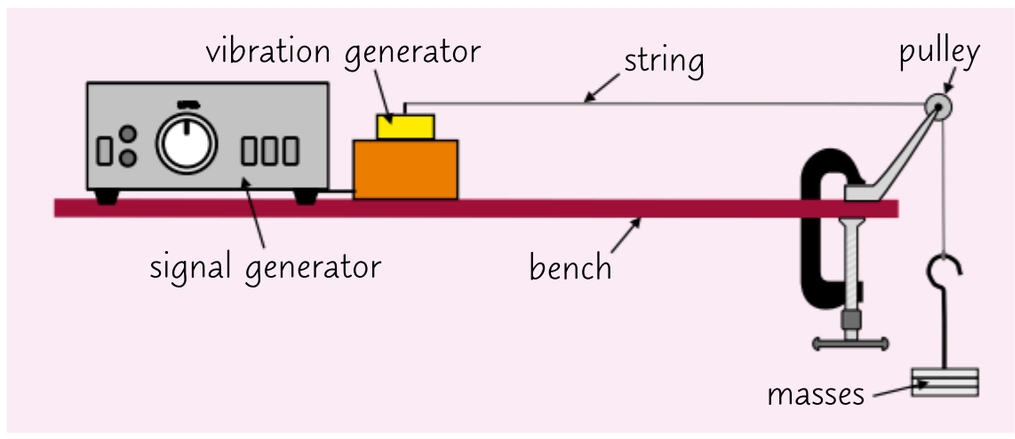


Make sure you do this experiment in a darkened room.

7) If you're struggling to measure the distance, you could take a photo of the shadows and ruler, and find the wavelength from the photo instead.
8) Use $v = f\lambda$ to calculate the wave speed of the waves.
9) This set-up is suitable for investigating waves, because it allows you to measure the wavelength without disturbing the waves.

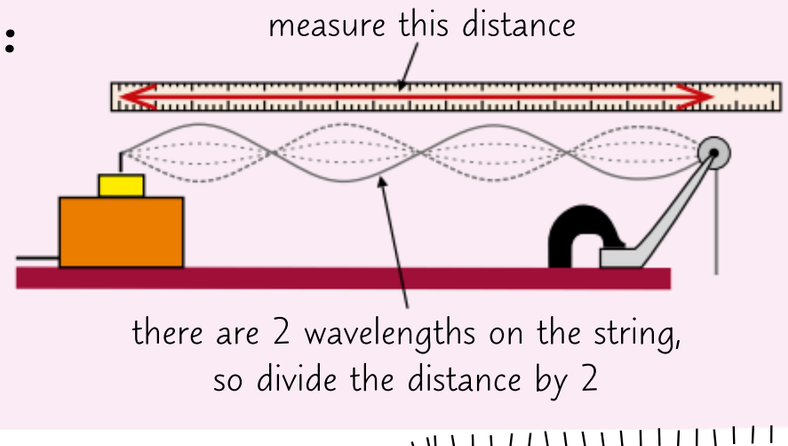
You can Use the Wave Equation for Waves on Strings

1) Set up the equipment shown on the right.
2) The vibration generator vibrates at a fixed frequency, set by the signal generator.
3) Turn on the signal generator and the string will start to vibrate.
4) Adjust the frequency of the signal generator until there's a clear wave on the string.



To measure the wavelength of these waves accurately:

- Count how many wavelengths are on the string. Each vibrating loop is half a wavelength.
- Measure the length of the whole vibrating string.
- Divide by the number of wavelengths to give the length of one wavelength.



5) The frequency of the wave is whatever the signal generator is set to.
6) You can find the speed of the wave using $v = f\lambda$.
7) This set-up is suitable for investigating waves on a string because it's easy to see and measure the wavelength (and frequency).

It's ok if you don't have a whole number of wavelengths on the string. If there are 3 loops, there are one-and-a-half wavelengths on the string. Divide the length of the string by 1.5.

Surf's up, it's time to, like, totally measure some waves...

We use sound waves, ripples and waves on strings as they're easy to make and there are ways of 'seeing' them.

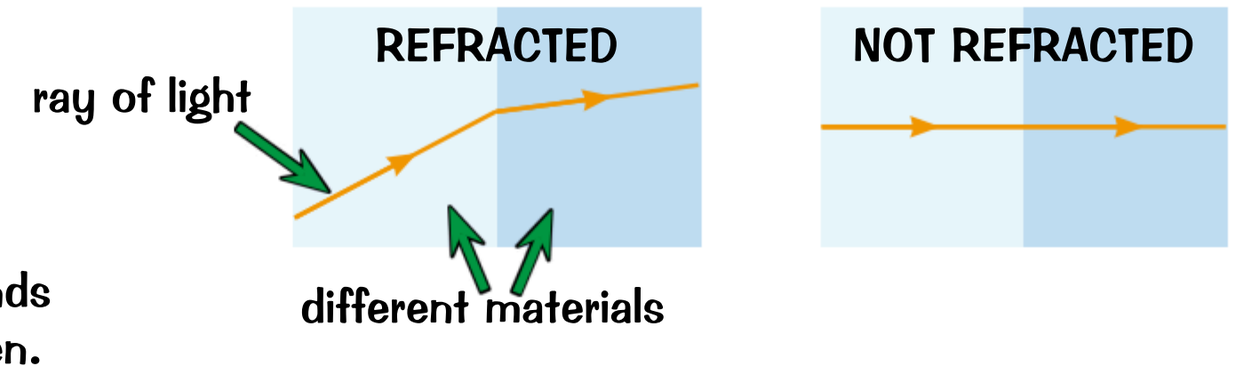
Q1 Describe a suitable experiment to measure the wavelength of a water wave. [3 marks]

Refraction

Grab a glass of water and put a straw in it. The straw looks like it's bending. But it's not magic, it's refraction.

Refraction — Waves Changing Direction

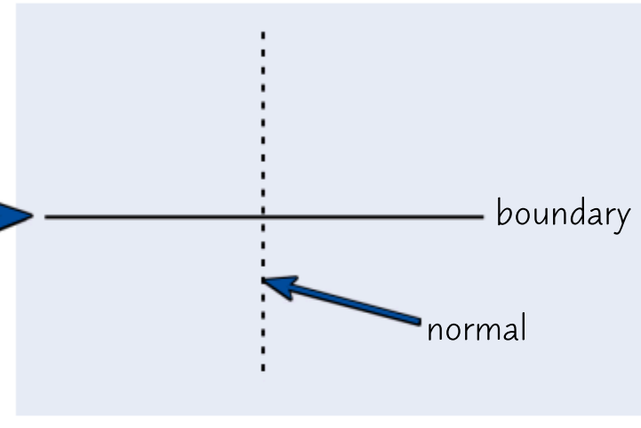
1) When a wave crosses a boundary between two materials it can change direction.
2) This is known as refraction.
3) Waves are only refracted if they meet the boundary at an angle.
4) How much a wave is refracted by depends on the two materials it's passing between.



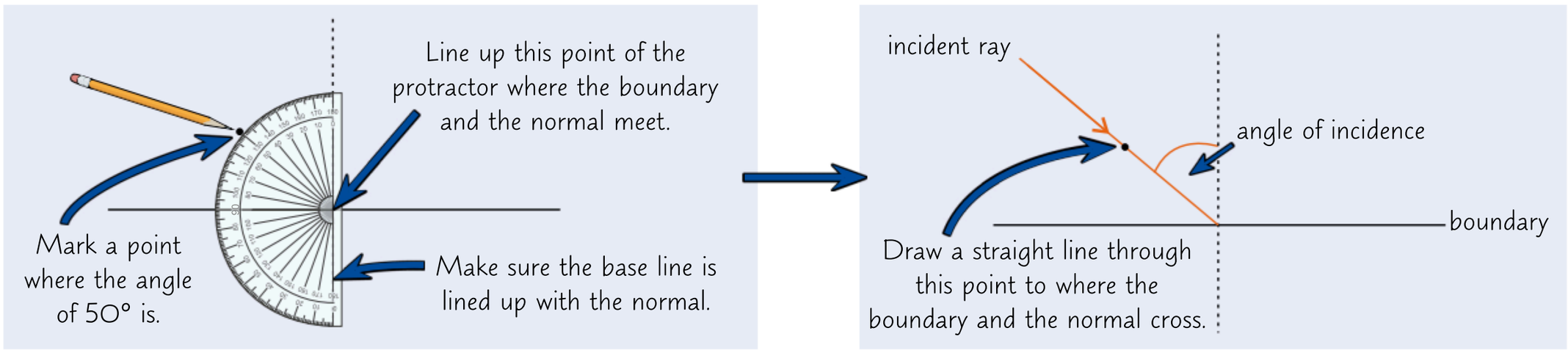
Ray Diagrams Show the Path of a Wave

- Rays are straight lines that show the direction a wave is travelling in.
- You can construct a ray diagram for a refracted light ray.

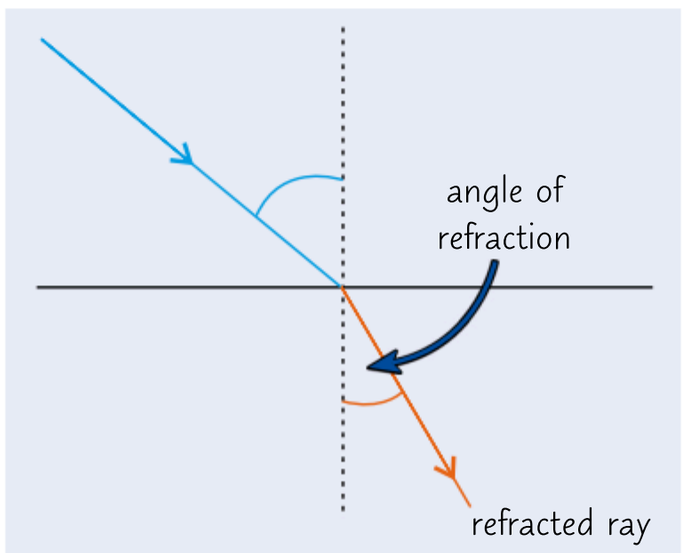
1) Start by drawing the boundary between your two materials.
2) Then draw a dotted line at right angles to the boundary.
3) This line is known as the 'normal' to the boundary.
   Normal just means 'at right angles'.
4) Next draw the incident ray. This is the ray that meets the boundary at the normal.
5) The angle between the incident ray and the normal is called the angle of incidence.
6) You need to use a protractor to draw or measure it.



7) So to draw an incident ray with an angle of incidence of 50°:



8) Now draw the refracted ray on the other side of the boundary.
9) The angle of refraction is the angle between the refracted ray and the normal.





Lights, camera, refraction...

Refraction is a common behaviour of waves, so make sure you really understand it before moving on.

Q1 Draw a ray diagram for a ray of light meeting a boundary at an angle of incidence of 55°, and crossing into a second material with an angle of refraction of 35°. [3 marks]

Q1 Video Solution

Electromagnetic Waves

The light waves that we see are just one small part of a big group of electromagnetic waves...

Electromagnetic Waves Transfer Energy

1) Electromagnetic (EM) waves are transverse waves (p.219).
2) They transfer energy from a source to an absorber.

1) A camp fire is a source.
2) It transfers energy to its surroundings by giving out infrared radiation.
3) Infrared radiation is a type of EM wave.
4) These infrared waves are absorbed by objects.
5) Energy is transferred to the objects' thermal energy stores.
6) This causes the objects to warm up.

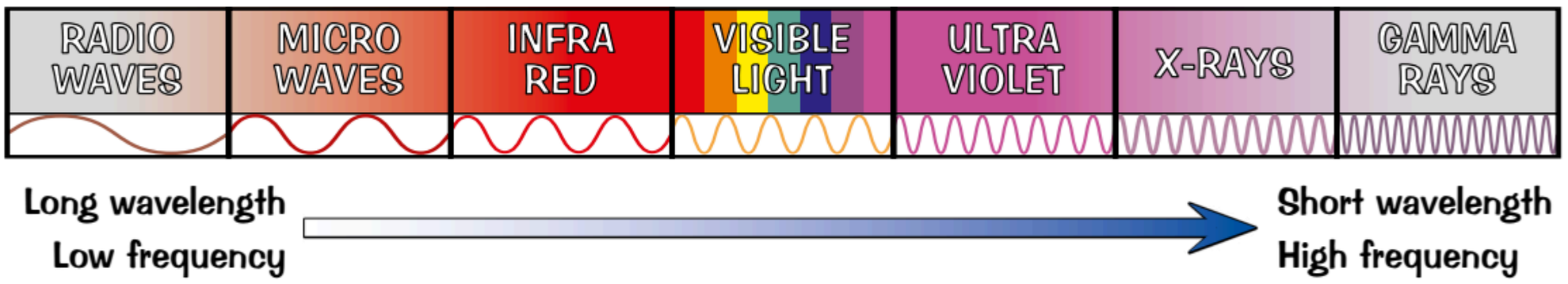


3) All EM waves travel at the same speed through air or a vacuum (space).
4) This speed is much faster than the speed of sound in air.

Sound waves have a much bigger wavelength and a much lower frequency than light.

There's a Continuous Spectrum of EM Waves

1) EM waves vary in wavelength and frequency.
2) There are EM waves of every wavelength within a certain range.
3) This is known as a continuous spectrum.
4) The spectrum is split up into seven groups based on wavelength and frequency.



5) Our eyes can only detect a small part of this spectrum — visible light.

Changes In Atoms Produce the Spectrum of EM Waves

1) EM radiation can be absorbed or produced by changes in atoms and their nuclei.
2) There are lots of different changes that can happen in atoms. For example:
   - Electrons can move between energy levels in atoms (see p.197).
   - Changes in the nucleus of an atom can create gamma rays (see p.199).
3) Each different change produces or absorbs a different frequency of EM wave.
4) This is why atoms can generate (create) EM waves over a large range of frequencies.
5) It is also why atoms can absorb a range of frequencies.

Learn about the EM spectrum and wave goodbye to exam stress...

Nothing too difficult here, just a lot of facts to remember. Here's a handy way to remember the order of EM waves: 'Rock Music Is Very Useful for eXperiments with Goats'.

Q1 State the type of electromagnetic wave that has the lowest frequency. [1 mark]

Q2 Name the section of the electromagnetic spectrum that humans can see. [1 mark]

Uses of EM Waves

EM waves are used for all sorts of stuff — and radio waves are definitely the most fun. They make your car radio and your TV work. Life would be pretty quiet without them.

Radio Waves are Used Mainly for Communication

1) Radio and TV signals can be sent by radio waves.
2) Very short wavelength signals are used for FM radio and TV.
3) They have to be in direct sight of the receiver when they're sent, with nothing in the way, so they can't travel very far.
4) Longer wavelength radio waves can travel further.
5) They can be used to send radio signals around the world.



Microwaves are Used for Satellites and Cooking

1) Communication with satellites uses microwaves, e.g. for satellite TV and satellite phones.
2) A signal is sent into space to a satellite dish high above the Earth.
3) The satellite sends the signal back to Earth in a different direction.
4) A satellite dish on the ground receives the signal.



1) Microwave ovens use microwaves to cook food.
2) The oven gives out microwaves, which are absorbed by water in the food.
3) Energy carried by the microwaves is transferred to the water molecules, causing them to heat up.
4) This causes the rest of the food to heat up and quickly cooks it.

Infrared Radiation Can be Used to Cook and Heat Things

1) Infrared (IR) radiation is given out by all objects.
2) The hotter the object, the more infrared radiation it gives out.
3) When an object absorbs infrared radiation, energy is transferred to the object's thermal energy store. This makes it warm up.
4) Infrared radiation can be used in many ways:

1) Infrared cameras detect IR radiation and create a picture.
2) This is useful for seeing where a house is losing energy.
3) It can also allow you to see hot objects in the dark.



The different colours mean different amounts of IR radiation are being detected from those areas. Here, the redder the colour, the more infrared radiation is being detected.

1) Infrared radiation can also be used to warm things.
2) Electric heaters release lots of IR radiation to warm a room.
3) And food can be cooked using infrared radiation.

Surfers hate microwaves...

Who knew we used microwaves for more than cooking chips in less than 3 minutes? Turns out, they're dead handy.

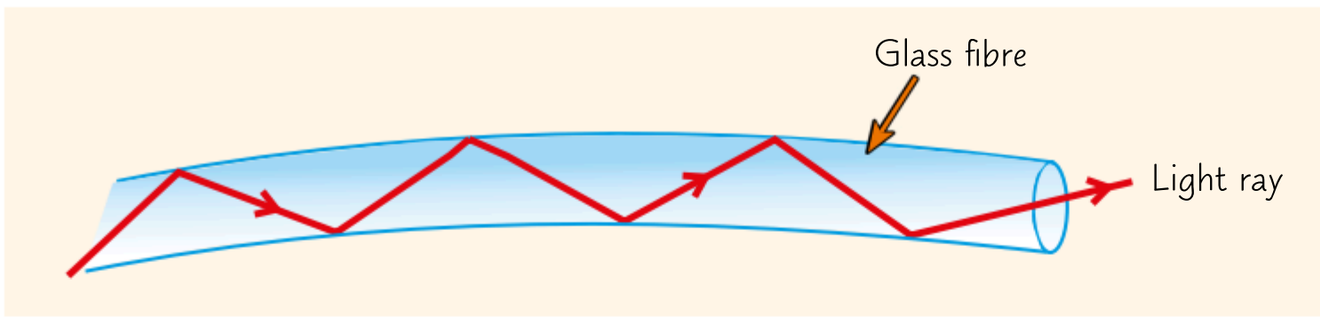
Q1 State one use of radio waves. [1 mark]

More Uses of EM Waves

Haven't had enough uses of EM waves? Good, because here's a few more. Get learning.

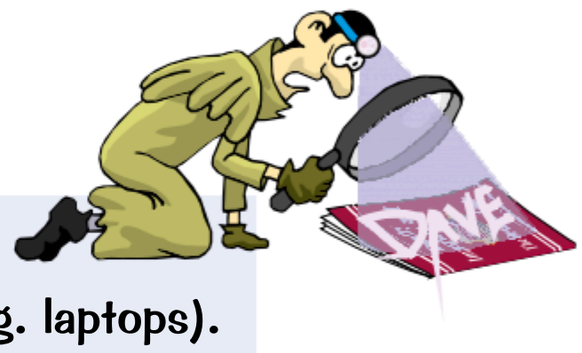
Fibre Optic Cables Use Visible Light to Send Data

1) Optical fibres are thin glass or plastic tubes that can carry data over long distances.
2) They're often used to send information to telephones or computers.
3) Information is sent as light rays that bounce back and forth along the fibre.



Ultraviolet Radiation Gives You a Suntan

1) When some materials absorb UV light, they give off visible light.
2) This can be pretty useful:

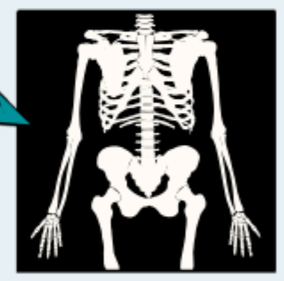


1) Energy-efficient lights use UV radiation to produce visible light.
2) Security pens can be used to mark property with your name (e.g. laptops).
3) Under UV light the ink will glow, but it's invisible otherwise.
4) This can help the police find out who stolen property belongs to.

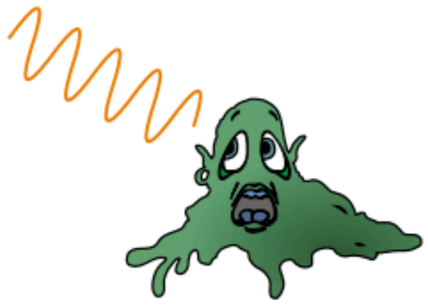
3) Ultraviolet radiation (UV) is also produced by the Sun. It's what gives you a suntan.
4) UV lamps can be used to give people a suntan without the Sun (but this can be dangerous).

X-rays and Gamma Rays are Used in Medicine

1) X-rays pass easily through flesh but not through bones or metal.
2) This can be used to create an X-ray image to check for broken bones.
3) X-rays can also treat people with cancer.
4) This is because they can kill cells. They are aimed at the cancer cells to kill them.



1) Gamma rays (p.198) can also kill cells.
2) They can be used to treat cancer in the same way as X-rays.
3) They can also be used to sterilise (remove germs from) medical equipment.
   The equipment is blasted with gamma rays which kills any living things on it.
4) Gamma rays are also really good at passing through your body.
5) This is why small amounts of them are used in 'medical tracers'.
   How they move around the body can be tracked.
   This can tell doctors if organs are working as they should.



Don't lie to an X-ray — they can see right through you...

I hate to say it, but go back to page 224 and read all of the uses for EM waves again to really learn them.

Q1 State two uses of X-rays. [2 marks]

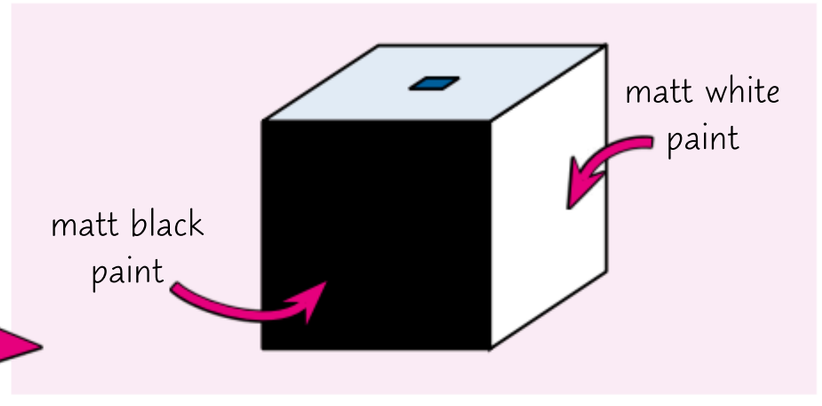
PRACTICAL

Investigating IR Radiation

Now it's time to see how the surface of an object affects how much infrared radiation it gives out.
I know, you can hardly contain your excitement. Neither can I.

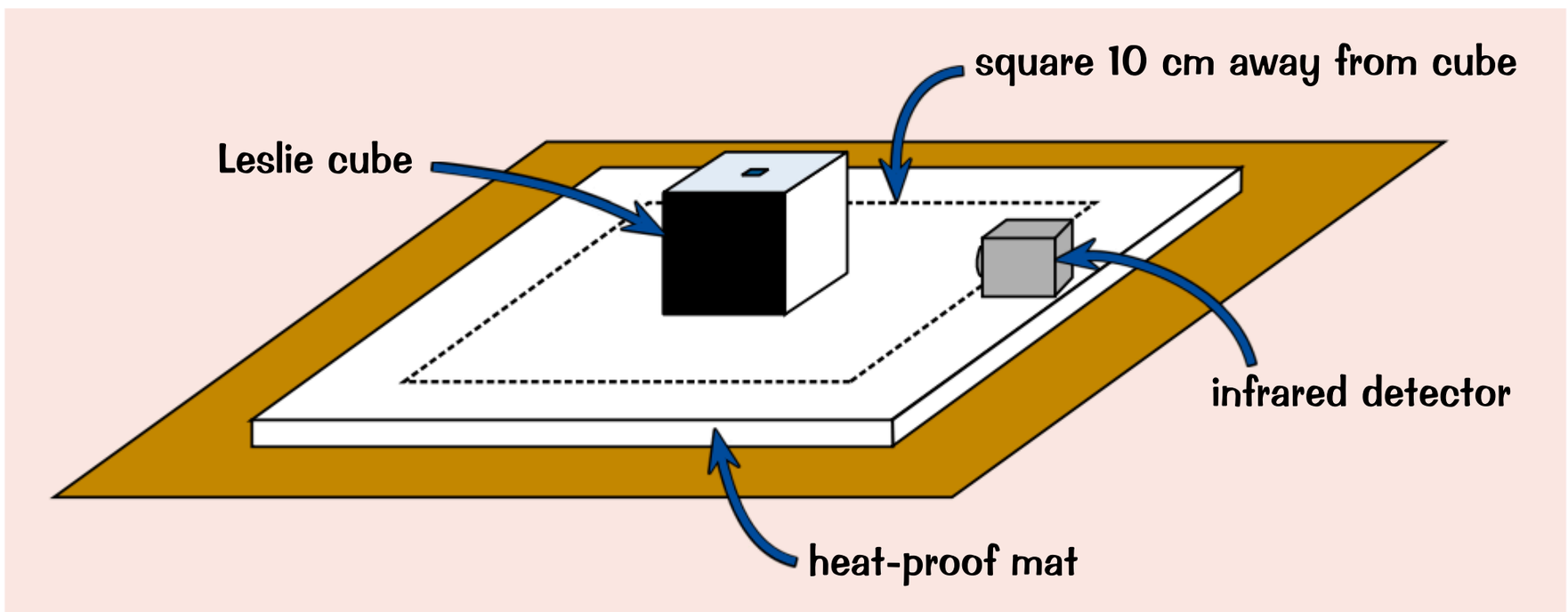
Different Surfaces Emit Different Amounts of IR Radiation

1) The amount of infrared radiation an object gives out depends on its temperature — see p.224.
2) It also depends on its surface.
3) This includes how rough or shiny it is, and its colour.
4) You can investigate how much IR radiation different surfaces emit using a Leslie cube.
5) A Leslie cube is a hollow, metal cube.
6) The four side faces have different surfaces.
7) For example, matt (dull) black paint, matt white paint, shiny metal and dull metal.



You Can Investigate Emission With a Leslie Cube

1) Place an empty Leslie cube on a heat-proof mat.
2) Draw a square around the cube that is 10 cm from all faces of the cube.
3) Fill the Leslie cube with boiling water and wait for the cube to warm up.
4) Use the square you've drawn to hold an infrared detector 10 cm away from one of the cube's vertical faces.
5) Record the amount of IR radiation it detects.



6) Repeat steps 4) and 5) for each of the four faces.
7) The face that had the highest reading is giving off the most IR radiation.
8) You should find that the black surface is radiating more IR radiation than the white one.
9) Matt surfaces should give off more than shiny ones.
10) As always, you should repeat the experiment to check your results.

Feelin' hot hot hot...

When doing this experiment, you could also place your hand near each surface of the cube (but not touching, it'll be super hot). You'll be able to feel which surface is giving off more infrared radiation.

Q1 What surface is the best emitter of infrared radiation out of:
a) a black surface and a white surface? b) a shiny surface and a matt surface? [2 marks]

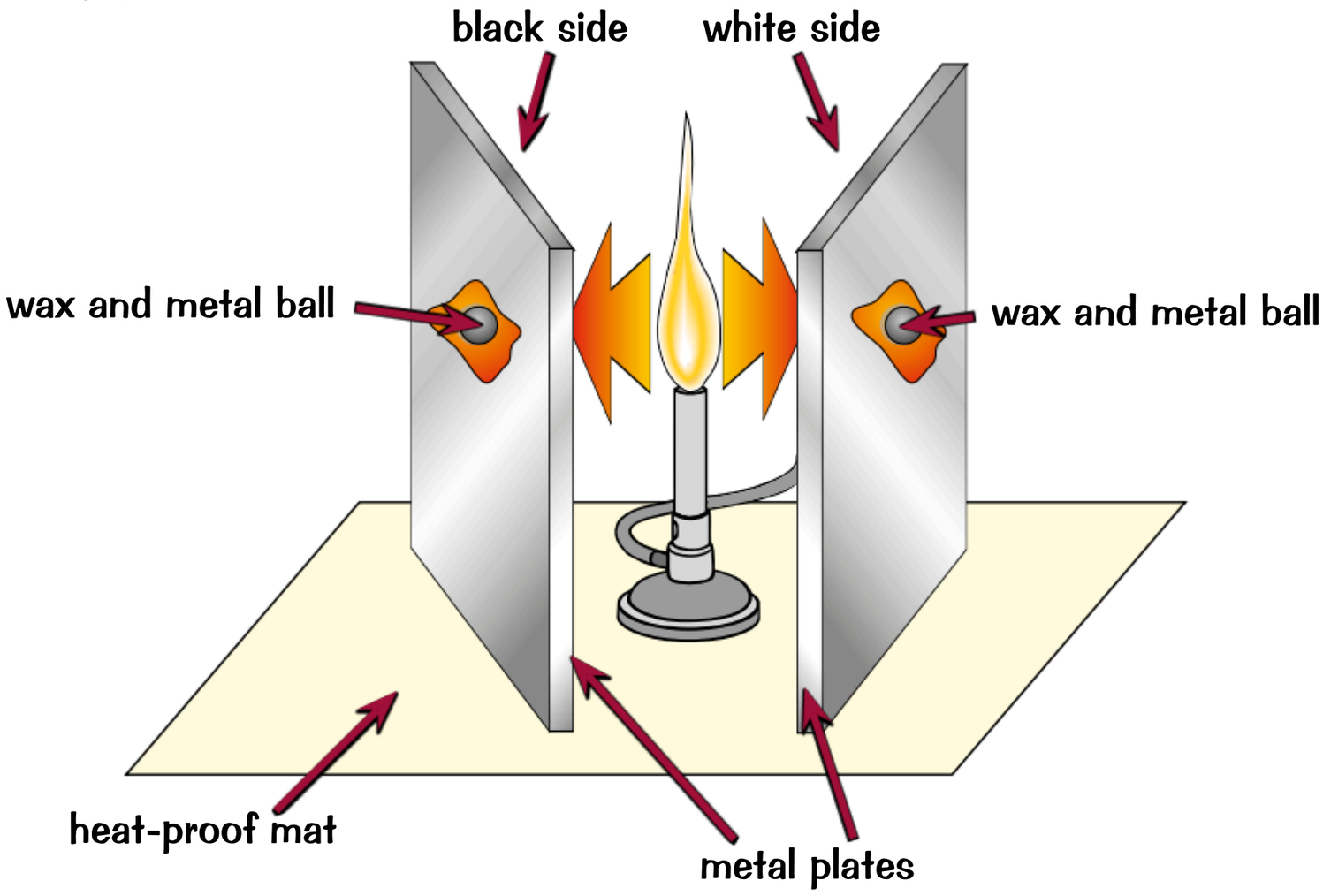
Investigating IR Absorption

PRACTICAL

Have you ever noticed that wearing black clothes on a hot day makes you feel really warm?
Turns out there's some science behind it...

You Can Investigate Absorption with the Melting Wax Trick

1) The amount of infrared radiation absorbed by different materials also depends on the surface.
2) You can do an experiment to show this.
3) You'll need a Bunsen burner, candle wax, metal plates and metal balls.
4) The metal plates should be identical except their back surface.
5) E.g. one plate will have a black back, and the other will have a white back.
6) Set up the equipment as shown:



Here's how to do it:

1) Place a Bunsen burner on a heat-proof mat.
2) Stick a metal ball to each identical side of the metal plates with hot candle wax.
3) Leave the candle wax to cool. The wax will harden and hold the ball in place.
4) Then face the back of these plates towards the flame.
5) They should both be the same distance away from the flame.
6) Record which ball falls first.

Explaining the Results

1) The plates absorb infrared radiation given out by the Bunsen burner.
2) Energy is transferred to the thermal energy stores of the candle wax.
3) The candle wax starts to melt, causing the balls to fall.
4) The ball will fall quicker from the plate that is better at absorbing infrared radiation.
5) You should find that the ball on the plate with the black back falls first.
6) This means the black surface was better at absorbing infrared radiation than the white surface.

Wear a black hat to help your brain absorb this information...

...probably best not to rely on that for the exam, though. There's nothing for it — get learning.

Q1 Give two ways in which the experiment above is made a fair test. [2 marks]

Dangers of Electromagnetic Waves

Okay, so you know how useful electromagnetic radiation can be — well, it can also be pretty dangerous.

Some EM Radiation Can be Harmful to People

1) When EM radiation enters living tissue — like you — it can be dangerous.
2) High frequency waves like UV, X-rays and gamma rays can all cause lots of damage.
3) UV radiation damages surface cells.
4) This can lead to sunburn and can cause skin to age faster than it should.
5) Some more serious effects are blindness and a higher risk of skin cancer.
6) X-rays and gamma rays are types of ionising radiation.
   This means they can knock electrons off atoms, p.197.
7) This can destroy cells or mutate (change) genes. This can cause cancer.



You Can Measure Risk Using the Radiation Dose in Sieverts

1) UV radiation, X-rays and gamma rays can all be useful as well as harmful (see page 225).
2) Radiation dose (measured in sieverts) is a measure of the risk of harm from the body being exposed to radiation.
3) The risk depends on the total amount of radiation absorbed and how harmful the type of radiation is.
4) A sievert is pretty big, so millisieverts (mSv) are often used.
   1000 mSv = 1 Sv.

Risk can be Different for Different Parts of the Body

1) A CT scan uses X-rays to create a detailed picture of inside a patient's body.
2) The table shows the radiation dose received by two different parts of a patient's body when having CT scans.

	Radiation dose (mSv)
Head	2.0
Chest	8.0

3) You can see that the radiation dose from a chest scan is 4 times larger than from a head scan — (2.0 mSv × 4 = 8.0 mSv).
4) Remember, radiation dose measures the risk of harm.
5) This means that if a patient has a CT scan on their chest, they are four times more likely to be harmed than if they have a head scan.

This is not an excuse to stay in bed all day...

A small dose of radiation every now and then is very low risk — so X-rays are nothing to worry about.

Q1 Give two effects of a person being exposed to too much UV radiation. [2 marks]

Q2 What property of gamma rays and X-rays makes them dangerous to humans? [1 mark]

Permanent and Induced Magnets

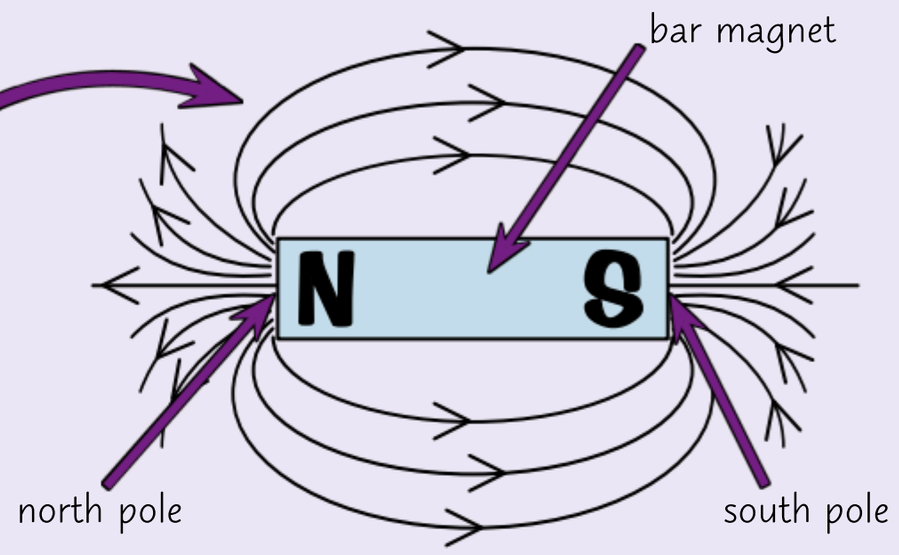
I think magnetism is an attractive subject, but don't get repelled by the exam — revise.

Magnets Exert Forces on Each Other

1) All magnets have a north (or north seeking) pole and a south (or south seeking) pole.
2) When two magnets are close, they exert a non-contact force on each other.
3) Two poles that are the same (like poles) repel each other.
4) Two different (unlike) poles attract each other.
5) There are also forces between magnets and magnetic materials. These forces are always attractive.
6) Iron, steel, nickel and cobalt are all magnetic materials.

Objects don't need to be touching for a non-contact force to act between them — see p.203.

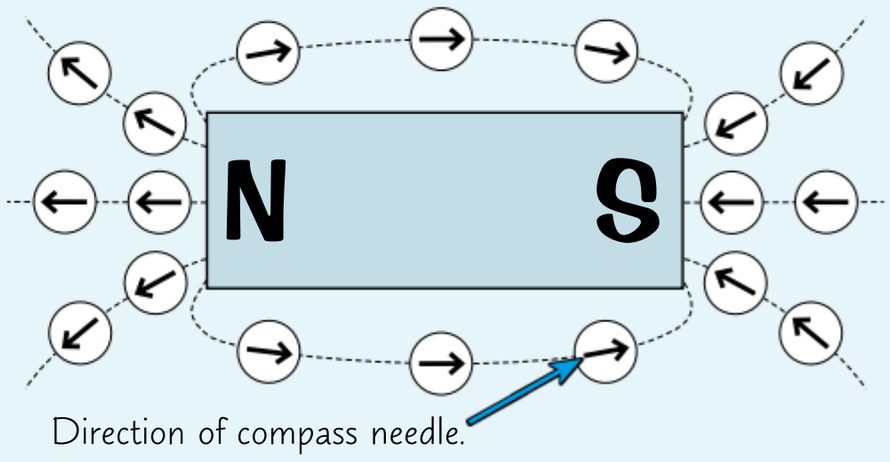
1) The area around a magnet where it can exert a force is its magnetic field.
2) Magnetic fields can be shown with magnetic field lines.
3) The lines go from north to south. They show which way the force would push a north pole at that point.
4) Lines closer together mean a stronger magnetic field.
5) The closer to a magnet you are, the stronger the field is.
6) The magnetic field is strongest at the poles.
7) This means the magnetic force is strongest here too.



A Compass Shows the Direction of a Magnetic Field

1) The needle of a compass is a tiny bar magnet. It points in the direction of any magnetic field that it's in.
2) So you can use a compass to plot magnetic field patterns:

- Draw around a magnet on a piece of paper.
- Put a compass by the magnet.
- Mark the direction the compass needle points in by drawing a dot at each end of the needle.
- Move the compass so that the tail end of the needle is where the tip of the needle was before.
- Repeat this lots of times. Join up all the marks. You will end up with a drawing of one field line.



Direction of compass needle.

3) When they're not near a magnet, compasses always point north.
4) This is because they point in the direction of the Earth's magnetic field.
5) So the inside (core) of the Earth must be magnetic.

Magnets Can be Permanent or Induced

1) Permanent magnets create their own magnetic field.
2) An induced magnet turns into a magnet when it's put into another magnetic field.
3) When you take away the magnetic field, induced magnets quickly stop being magnets.
   A fancy way to say this is to say that they lose their magnetism (or most of it).
4) Permanent magnets and induced magnets always attract each other.

Magnets are like farmers — surrounded by fields...

Magnetism is tricky and takes a while to make sense. Learn these basics — you'll need them.

Q1 What will happen when the north poles of two magnets are brought close together? [1 mark]

Electromagnetism

A magnetic field is also found around a wire that has a current passing through it.

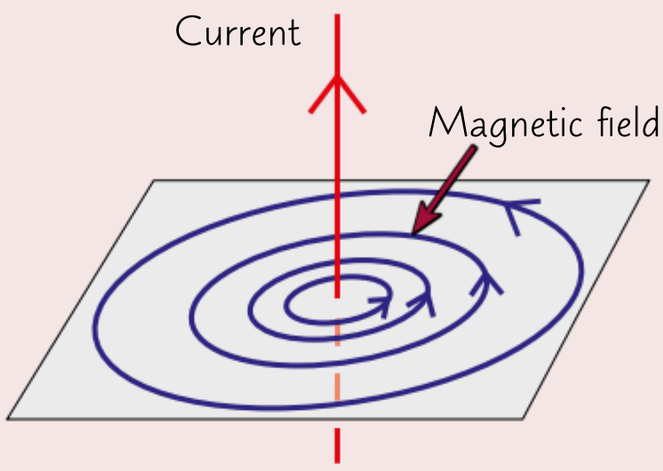
A Current Creates a Magnetic Field

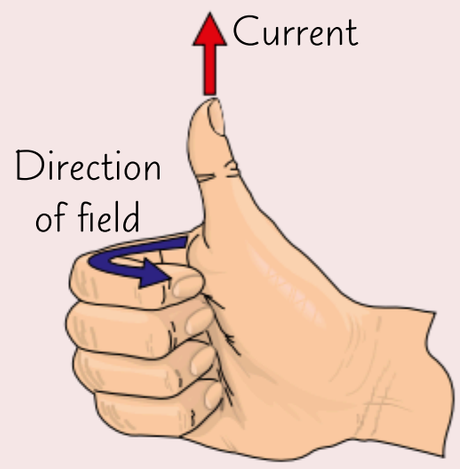


1) A current flowing through a wire creates a magnetic field.
2) You can see this by placing a compass near to the wire. The compass will move to point in the direction of the field.
3) You can use this to draw the field, just like on the previous page.
4) The field is made up of circles around the wire (see below).
5) You can also use the right-hand thumb rule to quickly work out which way the field goes:

The Right-Hand Thumb Rule

- Point your right thumb in the direction of current.
- Curl your fingers.
- The direction of your fingers is the direction of the field.

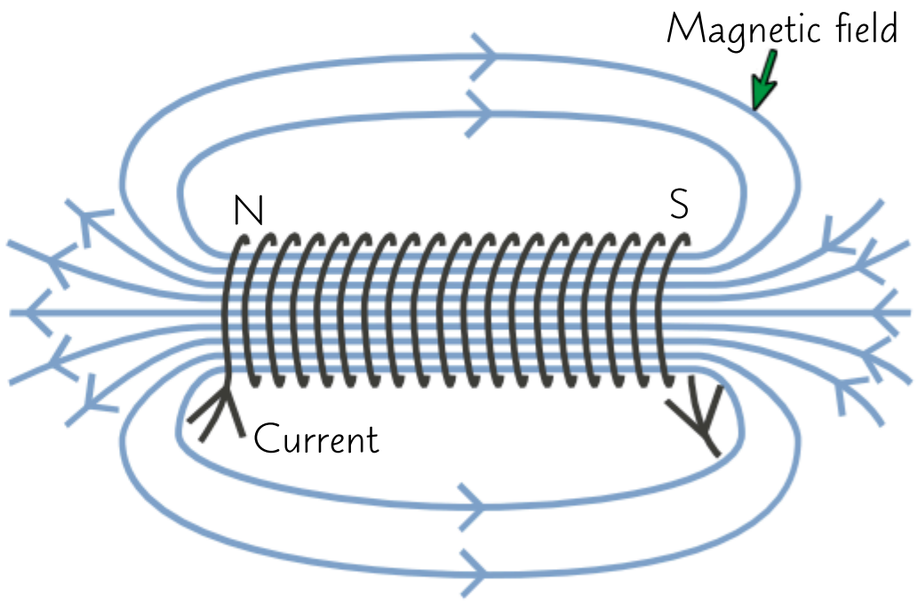




6) Reversing (swapping) the direction of the current reverses the direction of the magnetic field.
7) The closer to the wire you are, the stronger the magnetic field gets.
8) And the larger the current through the wire is, the stronger the field is.

A Solenoid is a Coil of Wire

1) If you wrap a wire into a coil it's called a solenoid.
2) The magnetic field inside a solenoid is strong and uniform.
3) Uniform means the field has the same strength and direction everywhere.
4) The magnetic field outside a coil, is just like the one around a bar magnet.
5) Wrapping a wire into a solenoid increases the strength of the magnetic field produced by the current in the wire.



- This is because the field lines around each loop of wire line up with each other.
- So lots of field lines end up close to each other and pointing in the same direction.
- The closer together field lines are, the stronger the field is.

6) You can increase the field strength even more by putting a block of iron in the coil.
7) A solenoid with an iron core is called an ELECTROMAGNET.

Strong, in uniform and a magnetic personality — I'm a catch...

Short, but not very sweet. This topic can be tricky to get your head around, so have another read of this page.

Q1 Draw the magnetic field for a current-carrying wire. [2 marks]

Q1 Video Solution

Revision Questions for Topics P6 & P7

Whew, that's Topics P6 and P7 over. Time to see how much you can remember.

- Try these questions and tick off each one when you get it right.
- When you're completely happy with a sub-topic, tick it off.

For even more practice, try the Retrieval Quizzes for Topics P6 and P7 — just scan the QR codes!

Topic P6 Quiz

Wave Properties (p.219-222) ☑

1) What is the difference between transverse and longitudinal waves?
2) What is the amplitude of a wave?
3) What is the wavelength of a wave?
4) How are the frequency and period of a wave linked?
5) Write down the equation that links wave speed, frequency and wavelength.
6) Describe an experiment you could do to measure:
   a) the speed of sound in air.
   b) the speed of waves on a string.
7) Sketch a ray diagram showing the refraction of a light ray between two materials.

Uses and Dangers of Electromagnetic Waves (p.223-228) ☑

8) True or false? All electromagnetic waves are transverse.
9) Give an example of electromagnetic waves transferring energy from a source to an absorber.
10) True or false? Gamma rays have the longest wavelength of EM waves.
11) Give an everyday use of infrared radiation.
12) What type of radiation is used to transmit a signal through an optical fibre?
13) How could you use a Leslie cube to investigate infrared emission by different surfaces?
14) True or false? The amount of infrared radiation absorbed by an object depends on the surface of the object.
15) What does the term 'ionising radiation' mean?
16) What does radiation dose in sieverts measure?

Magnets (p.229) ☑

17) True or false? The force between a north pole and a south pole is attractive.
18) True or false? A magnet always repels a magnetic material.
19) In what direction do magnetic field lines point?
20) How can you draw a magnetic field pattern of a bar magnet using a compass?
21) Describe the behaviour of a compass that is far away from any magnets.

Topic P7 Quiz

Electromagnetism (p.230) ☑

22) Explain how to use the right-hand thumb rule to find the direction of a magnetic field around a wire.
23) What is a solenoid?
24) Sketch the shape of the magnetic field around a solenoid.
25) How can you increase the strength of a solenoid's magnetic field?

Measuring Techniques

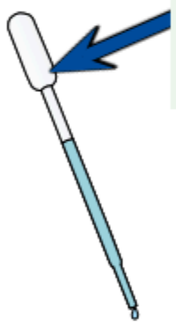
Safety specs out and lab coats on, it's time to find out about the skills you'll need in experiments...

Mass Should Be Measured Using a Balance

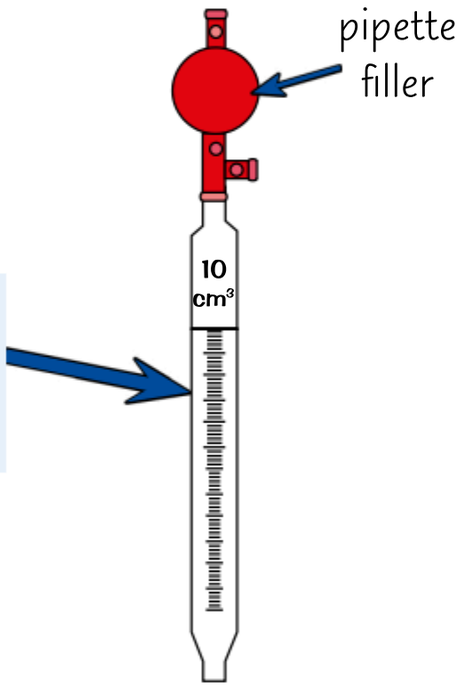
1) To measure mass, put the container you're measuring the substance into on the balance.
2) Set the balance to exactly zero. Then add your substance and read off the mass.
3) If you want to transfer the substance to a new container, you need to make sure that the mass you transfer is the same as the mass you measured. There are different ways you can do this. For example:
   - If you're dissolving a mass of a solid in a solvent to make a solution, you could wash any remaining solid into the new container using the solvent.
   - You could set the balance to zero before you put your weighing container on the balance. Then reweigh the weighing container after you've transferred the substance. Use the difference in mass to work out exactly how much substance you've transferred.

Different Ways to Measure Liquids

1) There are a few methods you might use to transfer a volume of liquid:

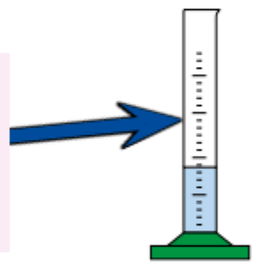


Dropping pipette — Use this if you only want a couple of drops of liquid. It's also used if you don't need an accurate volume of liquid.

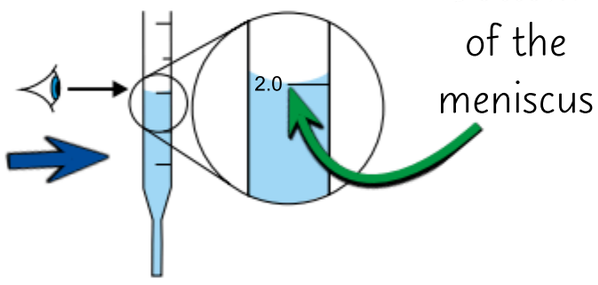


Pipette — Use this if you want an accurate volume of liquid. The pipette filler lets you safely control the amount of liquid you're drawing up.

Measuring cylinders — These come in many different sizes. You need to use one that's the right size for the measurement you want to make (you don't want one that's too big).



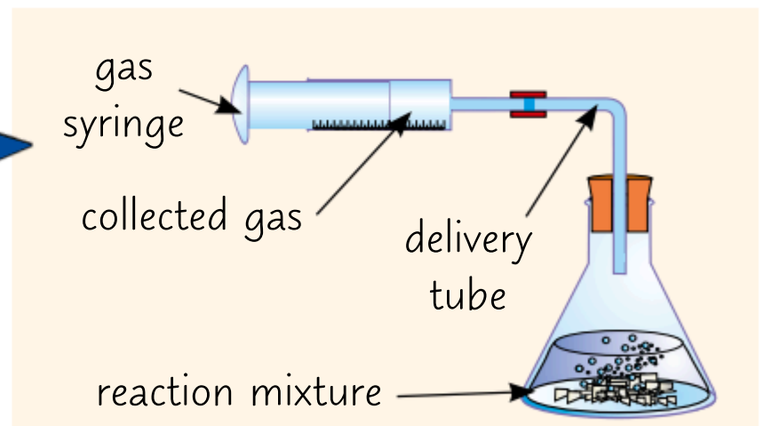
2) To measure the volume of a liquid, read the volume from the bottom of the meniscus (the curved upper surface of the liquid) when it's at eye level.



You Can Measure Gas Volumes

There are a few ways you can measure the volume of a gas:

1) Gas syringe — this is the most accurate way to measure gas volume.
   - Make sure the gas syringe is the right size for your measurements.
   - Make sure the plunger moves smoothly.
   - Read the volume from the scale on the syringe.



2) Upturned measuring cylinder filled with water — read more about this on page 237.
3) Counting the bubbles produced or measuring the length of a gas bubble drawn along a tube (see p.52).
   - These methods are less accurate.
   - But they will give you results that you can compare.

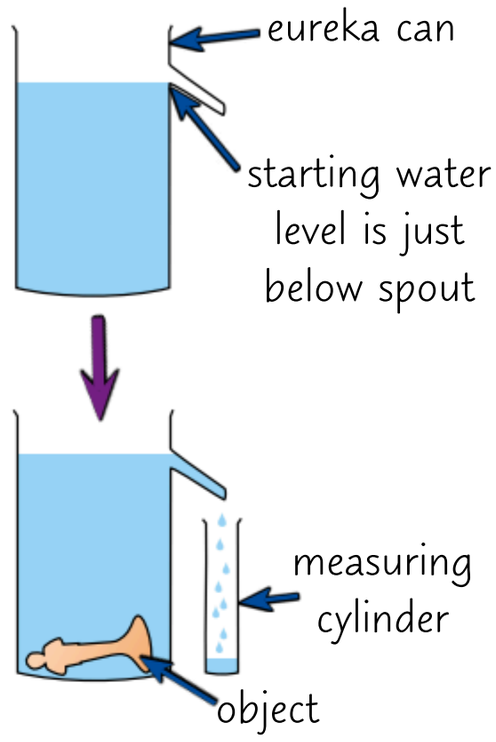
Always make sure your equipment is sealed so no gas can escape. This will make your results more accurate.

Measuring Techniques

Eureka Cans Measure the Volumes of Solids

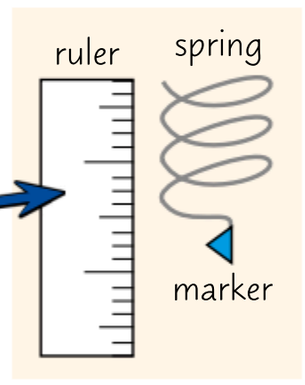
1) A eureka can is a beaker with a spout.
2) It's used with a measuring cylinder to find the volume of an irregularly shaped solid object (p.194).
3) Here are a few things you need to do when you use one:

- Fill it with water so the water level is above the spout.
- Let the water drain from the spout, leaving the water level just below the start of the spout. (This means all the water moved by an object goes into the measuring cylinder.)
- After adding the object, wait until the spout has stopped dripping before measuring the volume. This will give you a more accurate result.



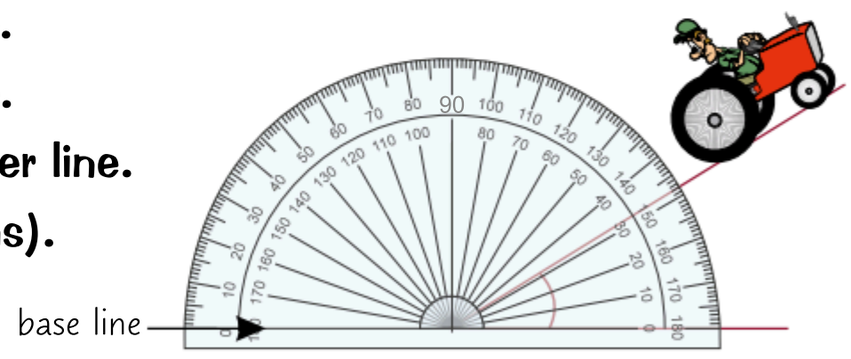
Measure Most Lengths with a Ruler

1) Make sure you choose the right ruler to measure length:
   - In most cases a centimetre ruler can be used.
   - Metre rulers are handy for large distances.
   - Micrometers are used for measuring tiny things (e.g. the diameter of a wire).
2) The ruler should always be alongside what you want to measure.
3) It may be tricky to measure just one of something (e.g. water ripples, p.221). Instead, you can measure the length of ten of them together. Then divide by ten to find the length of one.
4) You might need to take lots of measurements of the same object (e.g. a spring). If so, make sure you always measure from the same point on the object. Draw or stick small markers onto the object to line your ruler up against.
5) Make sure the ruler and the object are always at eye level when you take a reading.



Use a Protractor to Find Angles

1) Place the middle of the protractor on the pointy bit of the angle.
2) Line up the base line of the protractor with one line of the angle.
3) Use the scale on the protractor to measure the angle of the other line.
4) Use a sharp pencil to draw lines at an angle (e.g. in ray diagrams). This helps to reduce errors when measuring the angles.



Measure Temperature Using a Thermometer



1) Make sure the bulb of your thermometer is completely under the surface of the substance.
2) If you're taking a starting temperature, you should wait for the temperature to stop changing.
3) Read your measurement off the scale at eye level.

You May Have to Measure the Time Taken for a Change

1) You should use a stopwatch to time experiments. These measure to the nearest 0.1 s.
2) Always make sure you start and stop the stopwatch at exactly the right time.
3) You can set an alarm on the stopwatch so you know exactly when to stop an experiment or take a reading.



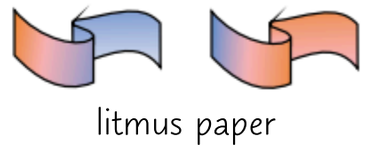
Measuring Techniques

There are Different Methods for Measuring pH

1) Indicator solutions can be used to estimate pH. Add a couple of drops of the indicator to the solution you want to test. It will change colour depending on if it's in an acid or an alkali (see p.128).

2) There are also paper indicators. These are strips of paper that contain indicator. If you spot some solution onto indicator paper, the paper will change colour to show the pH.

- Litmus paper turns red in acidic conditions and blue in alkaline conditions.
- Universal indicator paper can be used to estimate the pH based on its colour.


litmus paper

3) Indicator paper is useful when:

- You don't want to change the colour of all of the substance.
- The substance is already coloured (so it might hide the colour of the indicator).
- You want to find the pH of a gas — hold a piece of damp indicator paper in a gas sample.

4) pH probes measure pH electronically (see page 128). They are more accurate than indicators.

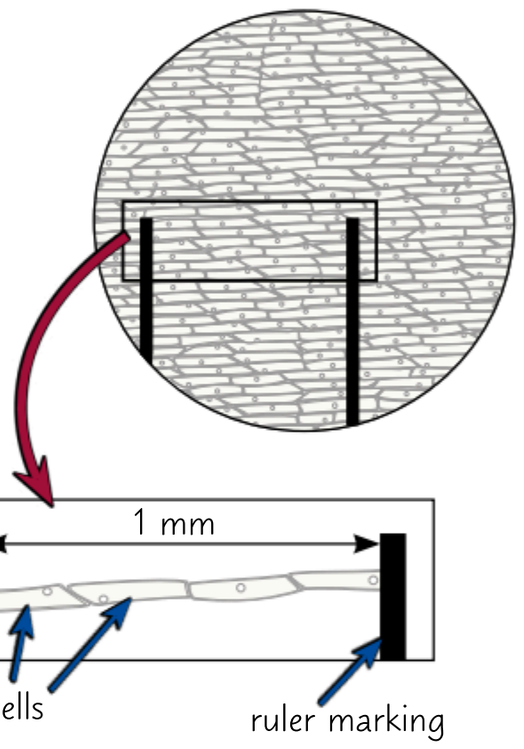
You Can Measure the Size of a Single Cell

When viewing cells under a microscope, you might need to work out their size.

To work out the size of a single cell:

1) Place a clear, plastic ruler on top of your microscope slide.
2) Clip the ruler and slide onto the stage.
3) Select the objective lens that gives an overall magnification of x 100.
4) Use the coarse adjustment knob and the fine adjustment knob to see a clear image of the cells.
5) Move the ruler so that the cells are lined up along 1 mm.
6) Count the number of cells along this 1 mm sample.
7) 1 mm = 1000 μm. So you can calculate the size of a single cell using this formula:

You can read all about using a microscope on page 13.



$$\text{length of cell } (\mu\text{m}) = \frac{1000\ \mu\text{m}}{\text{number of cells counted in sample}}$$

EXAMPLE

Under a microscope, 4 cells were counted in 1 mm.

Calculate the size of one cell. Give your answer in μm.

1 mm is the same as 1000 μm, so you just need to put the number of cells into the formula.

$$\text{length of cell } (\mu\text{m}) = \frac{1000\ \mu\text{m}}{4} = 250\ \mu\text{m}$$

Experimentus apparatus...

It's too bad, but being a wizard won't help you here. Make sure you get your head down and learn these techniques inside out. They need to be second nature when it comes to any practicals.



Safety and Ethics

Before you start any experiment, you need to know what safety measures you should be taking. They depend on your method, your equipment and the chemicals you're using.

To Make Sure You're Working Safely in the Lab You Need to...



1) Wear sensible clothing (e.g. shoes that will protect your feet from spillages). Also:
   - Wear a lab coat to protect your skin and clothing.
   - Wear safety goggles to protect your eyes, and gloves to protect your hands.
2) Be aware of general safety in the lab. E.g. don't touch any hot equipment.
3) Follow any instructions that your teacher gives you carefully.
4) Chemicals and equipment can be hazardous (dangerous). E.g. some chemicals are flammable (they catch fire easily) — this means you must be careful not to use a Bunsen burner near them.
5) Here are some tips for working with chemicals and equipment safely...

Working with chemicals

1) Make sure you're working in an area that's well ventilated (has a good flow of air).
2) If you're doing an experiment that produces nasty gases (such as chlorine), carry out the experiment in a fume hood. This means the gas can't escape out into the room you're working in.
3) Never touch any chemicals (even if you're wearing gloves):
   - Use a spatula to transfer solids between containers.
   - Carefully pour liquids between containers using a funnel. This will help prevent spillages.
4) Be careful when you're mixing chemicals, as a reaction might occur. E.g. if you're diluting a liquid, always add the concentrated substance to the water. This stops it getting hot.

Working with equipment

1) Use clamp stands to stop masses and equipment falling.
2) Make sure masses are not too heavy (so they don't break the equipment they're used with).
3) Use pulleys that are not too long (so hanging masses don't hit the floor during the experiment).
4) Let hot materials cool before moving them. Or wear insulated gloves while handling them.
5) If you're using an immersion heater, you should always let it dry out in air. This is just in case any liquid has leaked inside the heater.
6) When working with electronics, make sure you use a low voltage and current. This prevents the wires overheating. It also stops damage to components.



You Need to Think About Ethical Issues

Any organisms that you use in your experiments need to be treated safely and ethically. This means:

1) Animals should be handled carefully.
2) Any captured wild animals should be returned to their habitat after the experiment.
3) Any animals kept in the lab should be well cared for. E.g. they should have plenty of space.
4) Other students that take part in any experiment should be happy to do so.

Safety first...

I know — lab safety isn't the most exciting topic. But it's very important. Not only will it stop you from blowing your eyebrows off, it'll help you pick up more marks in the exam. And that IS worth getting excited about...

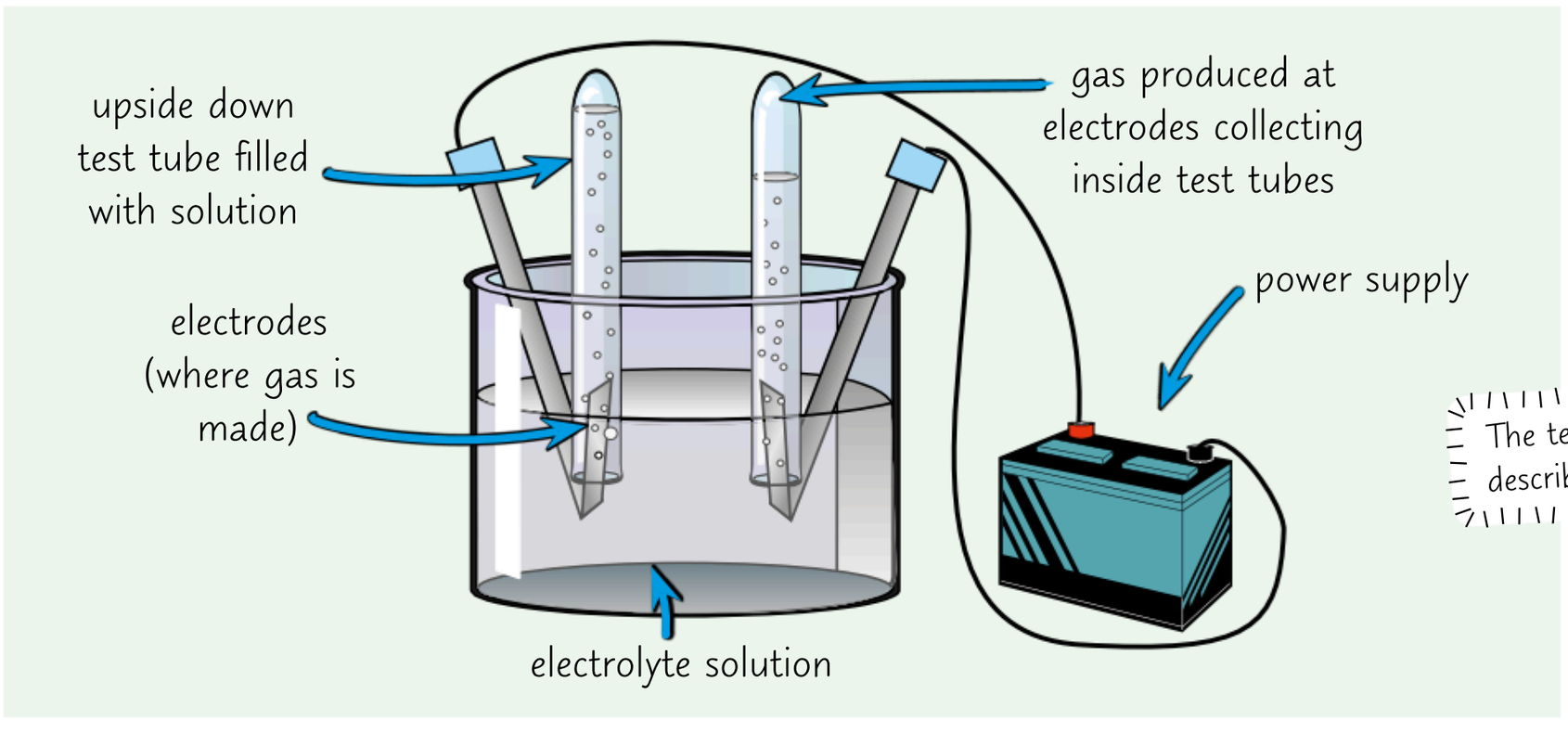
Setting Up Experiments

Setting up the equipment for an experiment in the right way is important. Learn these set-ups...

You Can Identify the Products of Electrolysis

There's more about electrolysis on p.132-133.

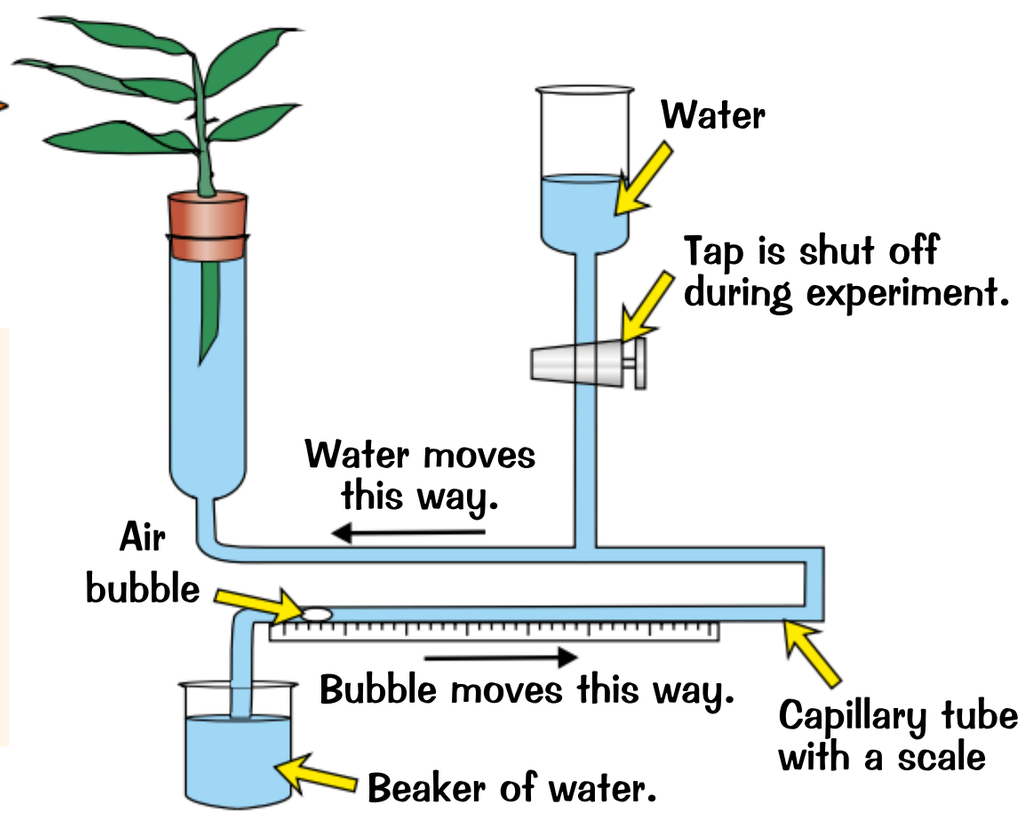
1) When you electrolyse a salt solution:
   - At the cathode, you'll get a pure metal coating the electrode OR bubbles of hydrogen gas.
   - At the anode, you'll get bubbles of oxygen gas OR a halogen.
2) You may have to do some tests to find out what's been made.
3) To do this, you need to set up the equipment correctly to collect any gas that's produced.
   The easiest way to collect the gas is in a test tube.
4) Here's how to set up the equipment...



The tests for gases are described on page 153.

Set Up a Potometer to Measure Transpiration Rate

1) A potometer is a special piece of equipment.
2) You set it up as shown in the diagram.
3) You can use a potometer to estimate transpiration rate (see page 40).
   Here's what you do:
   - Record the starting position of the air bubble.
   - Start a stopwatch.
   - As the plant takes up water, the air bubble gets sucked along the tube.
   - Record how far the air bubble moves in a set time.
   - Then you can estimate the transpiration rate.



EXAMPLE

A potometer was used to estimate the transpiration rate of a plant cutting. The bubble moved 25 mm in 10 minutes. Estimate the transpiration rate.

To estimate the transpiration rate, divide the distance the bubble moved by the time taken.

$$\text{Transpiration rate} = \frac{\text{distance bubble moved}}{\text{time taken}} = \frac{25 \text{ mm}}{10 \text{ min}}$$

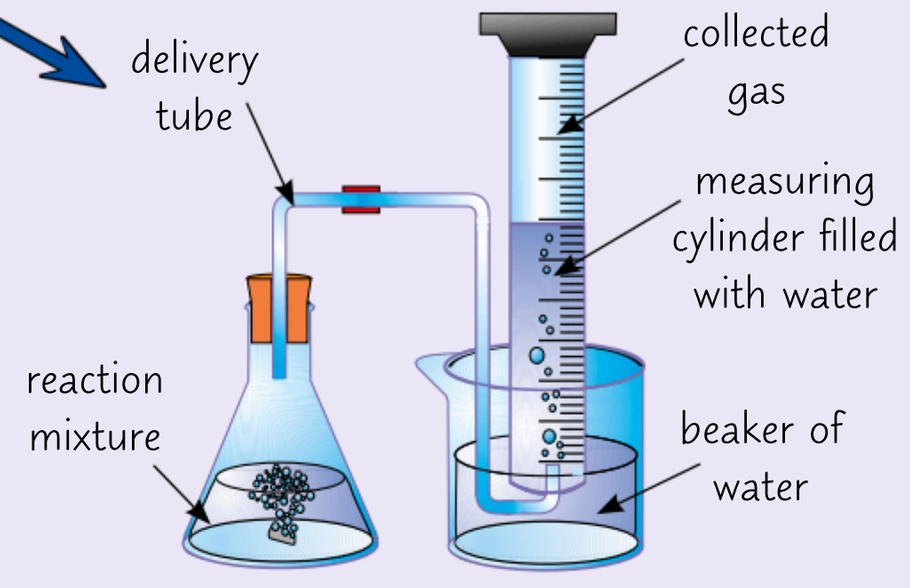
$$= 2.5 \text{ mm/min}$$

Setting Up Experiments

You Can Collect a Gas in a Measuring Cylinder

1) You can use a measuring cylinder turned upside down and filled with water to collect gas.
2) Then you can measure the gas volume. Here's how you do it:

1) Set up the equipment like in the diagram.
2) Record the starting level of the water in the measuring cylinder.
3) Any gas from the reaction will pass through the delivery tube and into the measuring cylinder.
4) The gas will push the water out of the measuring cylinder.
5) Record the end level of water in the measuring cylinder.
6) Calculate the volume of gas produced — subtract the end level of water from the starting level of water.

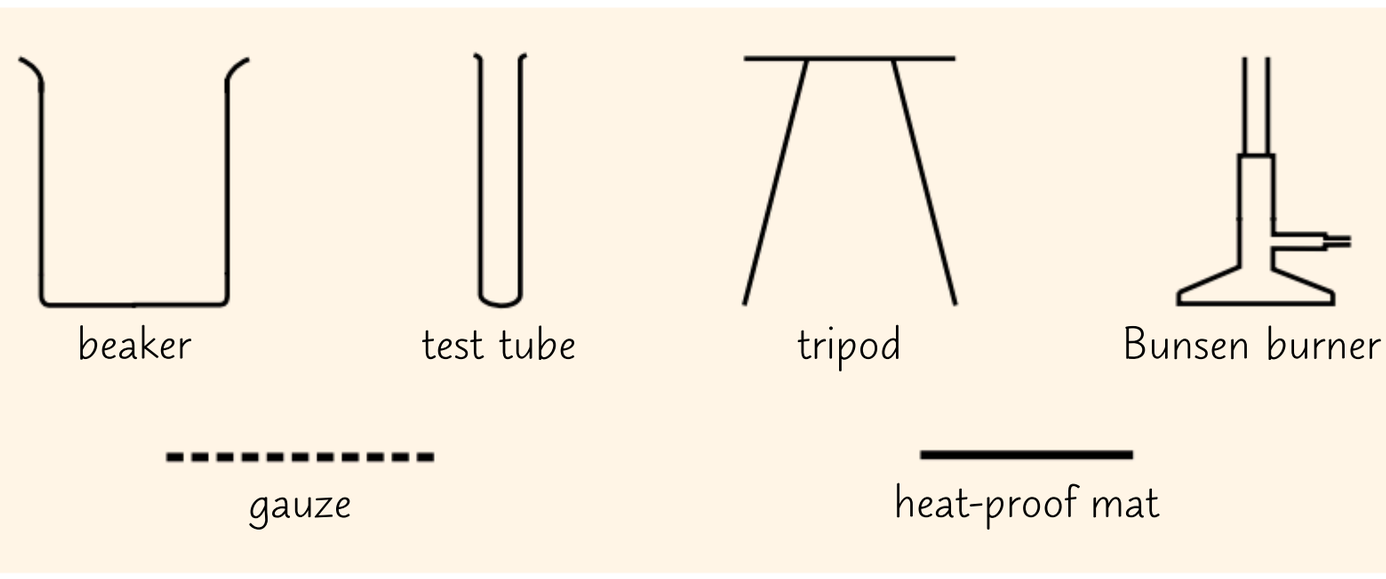


Make sure the delivery tube is inside the measuring cylinder. This stops the gas escaping out into the air.

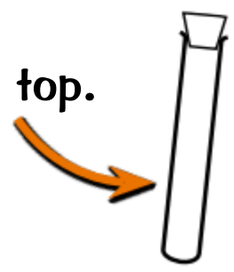
3) You can use the method above to collect a gas sample to test.
   - Use a test tube instead of a measuring cylinder.
   - When the test tube is full of gas, you can put a bung in it. This lets you store the gas for later.

Make Sure You Can Draw Diagrams of Your Equipment

1) Your method should include a labelled diagram of how your equipment will be set up.
2) Use scientific drawings — each piece of equipment is drawn as if you're looking at it from the side.
3) For example:



4) The beaker and test tube above aren't sealed. To show them sealed, draw a bung in the top.





Science exams — they're a set-up...

It looks like there's a lot of equipment to remember on these pages. Have a go at drawing diagrams of each set-up and labelling the equipment. Then look back at the page and see what you got right. It'll soon stick like superglue.

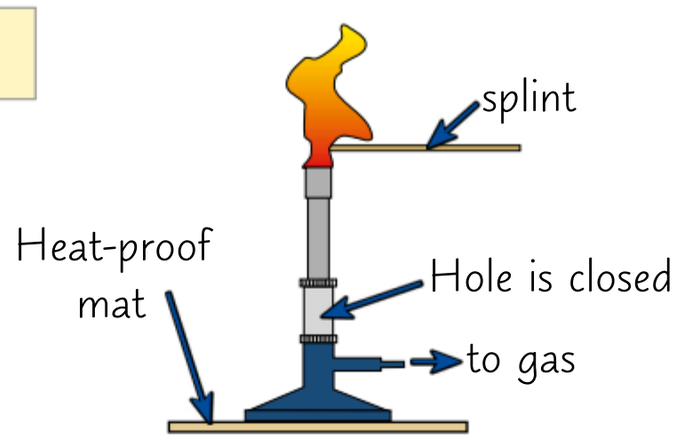
Heating Substances

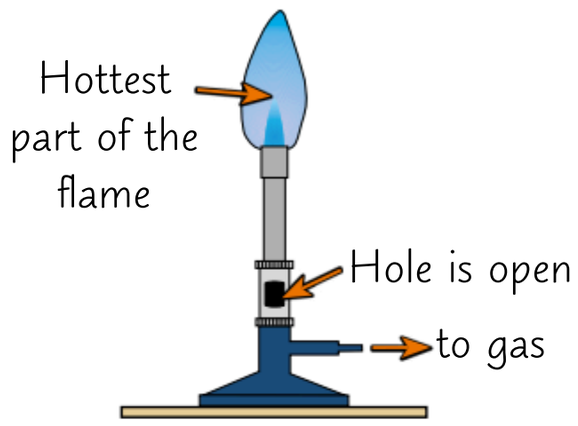
You need to be able to decide on the best and safest method for heating a substance...

Bunsen Burners Heat Things Quickly

Here's how to use a Bunsen burner...

1) Connect the Bunsen burner to a gas tap.
Check that the hole is closed.
2) Place the Bunsen burner on a heat-proof mat.
3) Light a splint and hold it over the Bunsen burner.
4) Now, turn on the gas.
The Bunsen burner should light with a yellow flame.
5) Open the hole to turn the flame blue.
The more open the hole, the hotter the flame.
6) Heat things just above the blue cone — this is the hottest part of the flame.
7) When the Bunsen burner isn't heating anything, close the hole.
This makes the flame yellow and easy to see.
8) If you're heating a container (with your substance in it) in the flame, hold it at the top with a pair of tongs.
9) If you're heating a container over the flame, put a tripod and gauze over the Bunsen burner before you light it. Then place the container on the gauze.



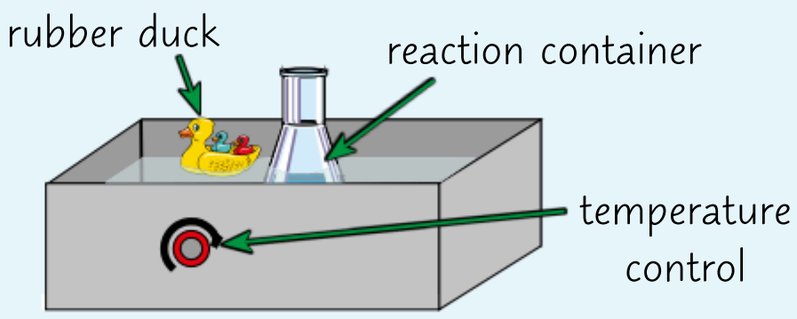


Water Baths & Electric Heaters Have Set Temperatures

1) A water bath is a container filled with water. It can be heated to a specific temperature.
2) A simple water bath can be made by heating a beaker of water over a Bunsen burner.
   - The temperature is checked with a thermometer.
   - However, it's hard to keep the temperature of the water constant.
3) An electric water bath will check and change the temperature for you. Here's how you use one:

- Set the temperature on the water bath.
- Allow the water to heat up.
- Place your container (with your substance in it) in the water bath using tongs.
- The level of the water outside the container should be just above the level of the substance inside it.
- The substance will be warmed to the same temperature as the water.

A water bath



The substance in the container is surrounded by water, so the heating is very even.

4) Electric heaters often have a metal plate that can be heated to a specific temperature.
   - Place your container on top of the hot plate.
   - You can heat substances to higher temperatures than you can in a water bath. (You can't use a water bath to heat something higher than 100 °C.)
   - You have to stir the substance to make sure it's heated evenly.

A bath and an electric heater — how I spend my January nights...

My science teacher used to play power ballads when the Bunsens were alight. Then he'd sway like he was at a gig.

Working with Electronics

Electrical devices are used in loads of experiments. Make sure you know how to use them.

There Are a Few Ways to Measure Potential Difference and Current

Voltmeters Measure Potential Difference

1) Connect the voltmeter in parallel (p.186) across the component you want to test.
2) The wires that come with a voltmeter are usually red (positive) and black (negative). These go into the red and black coloured ports on the voltmeter.
3) Then read the potential difference from the scale (or from the screen if the voltmeter is digital).

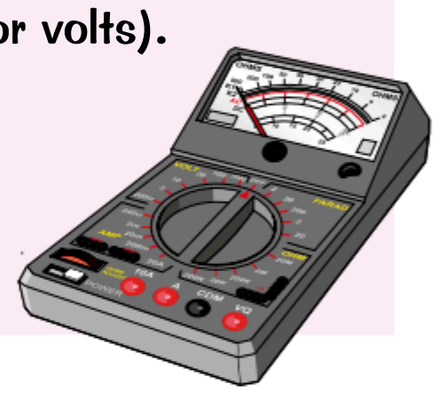
Ammeters Measure Current

1) Connect the ammeter in series (p.185) with the component you want to test.
2) Ammeters usually have red and black ports to show you where to connect your wires.
3) Read off the current shown on the scale (or screen).

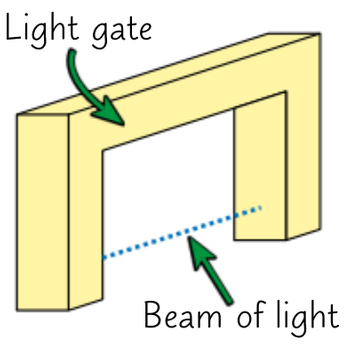
Turn your circuit off between readings. This stops wires overheating and affecting your results (page 181).

Multimeters Measure Both

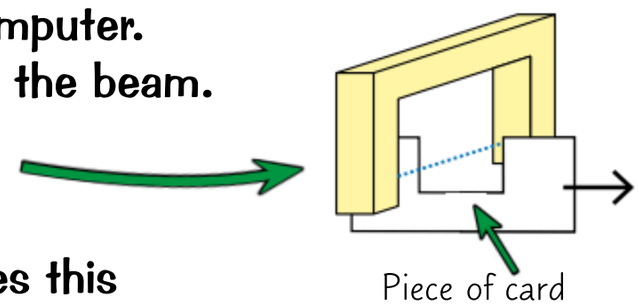
1) Multimeters measure a range of things — usually potential difference, current and resistance.
2) To find potential difference, plug the red wire into the port that has a 'V' (for volts).
3) To find the current, use the port labelled 'A' (for amps).
4) The dial on the multimeter should then be turned to the relevant section — for example, to measure the current in amps, turn the dial to 'A'.
5) The screen will display the value you're measuring.



Light Gates Measure Time, Speed and Acceleration



1) A light gate sends a beam of light from one side of the gate to a detector on the other side.
2) When something passes through the gate, the light beam is interrupted.
3) The gate measures when the beam was interrupted and how long it was interrupted for.
4) Light gates can be connected to a computer.
5) To find the speed of an object, type the length of the object into the computer. The computer will calculate the speed of the object as it passes through the beam.
6) To measure acceleration, use an object that interrupts the signal twice, e.g. a piece of card with a gap cut into the middle.
7) The light gate measures the speed for each section of the object. It uses this to calculate the object's acceleration. This can then be read from the computer screen.
8) Light gates can be used instead of a stop watch. This will reduce the errors in your experiment.



Have a look at page 214 for an example of a light gate being used.

That's not a gate — where are the hinges...

After finishing this page, you should be able to take on any electrical experiment that they throw at you... ouch.

Sampling

I love samples... especially when I'm a bit peckish in the supermarket and they're handing out free cheese. Unfortunately, this page isn't about those samples. It's a lot more useful than that...

Sampling Should be Random

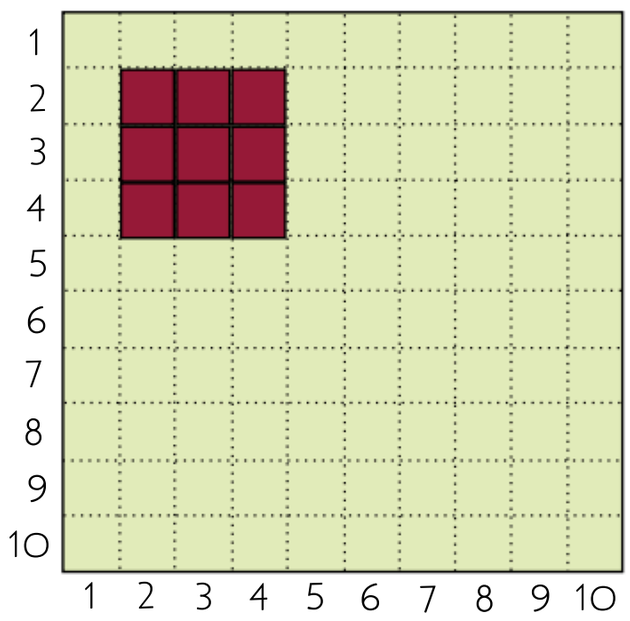
1) When you're investigating a population, it's usually not possible to study every single organism in it.
2) This means that you need to take samples of the population.
3) The samples need to accurately represent the whole population.
   This is so you can use them to draw conclusions about the whole population.
4) To make sure a sample represents the population, it should be random.

Organisms Should Be Sampled At Random Sites in an Area

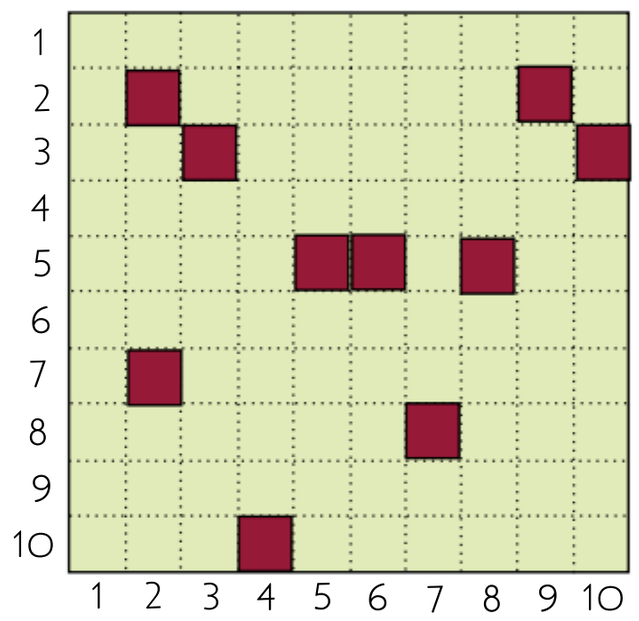
1) Quadrats can be used to take population samples of an organism in an area (see page 87).
2) If you're looking at plant species in a field...

- Divide the field into a grid.
- Label the grid along the bottom and up the side with numbers.
- Use a random number generator (e.g. on a computer or calculator) to select coordinates, e.g. (2,7).
- Place your quadrats at these coordinates to take your samples.

Non-random sampling
Only looks at a small part of the field.



Random sampling
Randomly selects squares from all over the field.



Health Data Should be Taken from Randomly Selected People

You need to use random sampling to choose members of the population you're interested in.

E.g. a scientist is looking at health data in country X. She wants to know how many people in the country have both Type 2 diabetes and heart disease:

1) Hospital records show that 270 196 people in the country have Type 2 diabetes.
2) These people are given a number between 1 and 270 196.
3) A random number generator is used to choose the sample group — e.g. it selects individuals with the numbers #72 063, #11 822, #193 123, etc.
4) The records of the sample group are used to find the number of people with heart disease in it.
5) The proportion of people in the sample group who have heart disease is worked out.
6) This can be used to estimate the total number of people with Type 2 diabetes who also have heart disease.

'Eeny, meeny, miny, moe' just doesn't cut it any more...

Sampling is an important part of an investigation. It needs to be done randomly, or the data won't be worth much.

Comparing Results

Being able to compare your results is really important. Here is one way you might do it. I spoil you.

Percentage Change Allows you to Compare Results

1) When investigating the change in a variable, you may want to compare results that didn't have the same starting value.

- For example, you may want to compare the change in mass of potato cylinders left in different concentrations of sugar solution (see page 18).
- The cylinders probably all had different masses to start with.



2) To do this you can calculate the percentage change. You work it out like this:

$$\text{percentage (\%) change} = \frac{\text{final value} - \text{original value}}{\text{original value}} \times 100$$

3) A positive percentage change means that the value increased.
A negative percentage change means that the value decreased.

EXAMPLE

A student is investigating the effect of the concentration of sugar solution on potato cells.

She records the mass of potato cylinders before and after placing them in sugar solutions of different concentrations. The table below shows some of her results.

Potato cylinder	Concentration (mol/dm^3)	Mass at start (g)	Mass at end (g)
1	0.0	7.5	8.7
2	1.0	8.0	6.8

Which potato cylinder had the largest percentage change?

1) Stick each set of results into the equation: $\%\text{ change} = \frac{\text{final value} - \text{original value}}{\text{original value}} \times 100$

potato cylinder 1: $\frac{8.7 - 7.5}{7.5} \times 100 = 16\%$

The mass at the start is the original value.

The mass at the end is the final value.

potato cylinder 2: $\frac{6.8 - 8.0}{8.0} \times 100 = -15\%$

Here, the mass has decreased so the percentage change is negative.

2) Compare the results.

16% is greater than 15%. So potato cylinder 1 (in the 0.0 mol/dm^3 sugar solution) had the largest percentage change.

Percentage change in how much I love maths after this page — 0%

Aaaand that's the end of Practical Skills, folks. Go forth, and science like you've never sciened before...

Answers

Topic B1 — Cell Biology

p.11 — Cells

Q1 Any two from: e.g. bacterial cells are smaller than animal cells ***[1 mark]***. / Bacterial cells don't have mitochondria but animal cells do ***[1 mark]***. / Bacterial cells don't have a true nucleus but animal cells do ***[1 mark]***. / Bacterial cells have circular DNA but animal cells don't ***[1 mark]***. / Bacterial cells have a cell wall but animal cells don't ***[1 mark]***. / Bacterial cells have plasmids but animal cells don't ***[1 mark]***.

p.12 — Microscopy

Q1 real size = image size ÷ magnification
= 2.4 mm ÷ 40
= 0.06 mm ***[1 mark]***
0.06 × 1000 = 60 µm ***[1 mark]***

p.13 — More on Microscopy

Q1 To make parts of the cell easier to see ***[1 mark]***.

p.14 — Cell Differentiation and Specialisation

Q1 The cell has a hair-like shape, which gives it a large surface area ***[1 mark]*** to absorb water and minerals from the soil ***[1 mark]***.

p.15 — Chromosomes and Mitosis

Q1 a) 11 ÷ (62 + 11) = 0.150...
0.150... × 100 = 15% ***[1 mark]***

b) E.g. she could see the X-shaped chromosomes in the middle of the cells. / She could see the arms of the chromosomes being pulled apart ***[1 mark]***.

p.16 — Stem Cells

Q1 Copies of the plant can be made by taking stem cells from the meristem of the plant ***[1 mark]*** and growing them into new, genetically identical plants (clones) ***[1 mark]***.

p.17 — Diffusion

Q1 a) The ink will diffuse / spread out through the water ***[1 mark]***. This is because the ink particles will move from where is a higher concentration of them (the drop of ink) to where there is a lower concentration of them (the surrounding water) ***[1 mark]***.

b) The ink particles will diffuse / spread out faster ***[1 mark]***.

Q2 The larger the surface area of the membrane the faster the diffusion rate ***[1 mark]***. This is because more particles can pass through at the same time ***[1 mark]***.

p.18 — Osmosis

Q1 Water will move out of the piece of potato by osmosis ***[1 mark]***, so its mass will decrease ***[1 mark]***.

p.19 — Active Transport

Q1 Active transport allows nutrients such as glucose to move from a lower concentration in the gut to a higher concentration in the blood (against the concentration gradient) ***[1 mark]***.

p.20 — Exchanging Substances

Q1 Surface area:
(2 × 2) × 2 = 8
(2 × 1) × 4 = 8
8 + 8 = 16 μm^2 ***[1 mark]***
Volume:
2 × 2 × 1 = 4 μm^3 ***[1 mark]***
So the surface area to volume ratio is 16 : 4, or 4 : 1 ***[1 mark]***.

p.21 — More on Exchanging Substances

Q1 E.g. they have a large surface area. / They have a moist lining for dissolving gases. / They have very thin walls. / They have a good blood supply. ***[1 mark]***

Q2 The damage to the villi is likely to reduce the surface area for absorption ***[1 mark]***. Therefore, less iron can be absorbed from the digested food in the small intestine into the blood ***[1 mark]***.

p.22 — More on Exchanging Substances

Q1 Any two from: e.g. it's made up of lots of thin plates that give a large surface area. / The plates have lots of capillaries. / The plates have a thin layer of surface cells. ***[2 marks — 1 mark for each correct answer]***

Topic B2 — Organisation

p.24 — Cell Organisation

Q1 That it is made up of different tissues ***[1 mark]*** that work together to perform a particular function ***[1 mark]***.

p.25 — Enzymes

Q1 If the pH is too high it affects the bonds holding the active site together ***[1 mark]***. This changes the shape of the active site and denatures the enzyme ***[1 mark]***.

p.26 — Investigating Enzymatic Reactions

Q1 2.5 min × 60 = 150 seconds ***[1 mark]***
1000 ÷ 150 = 6.666... = 6.7 s^{-1} ***[1 mark]***

p.27 — Enzymes and Digestion

Q1 Bile neutralises the stomach acid and makes conditions in the small intestine alkaline ***[1 mark]***. The enzymes of the small intestine work best in these alkaline conditions ***[1 mark]***. It also emulsifies fats / breaks down fats into tiny droplets ***[1 mark]***. This gives a bigger surface area of fat for the enzyme lipase to work on, which makes digestion faster ***[1 mark]***.

p.28 — Food Tests

Q1 iodine solution ***[1 mark]***

p.29 — The Lungs

Q1 304 ÷ 8 = 38 breaths per minute ***[1 mark]***

p.30 — Circulatory System — The Heart

Q1 The right ventricle ***[1 mark]***.

p.31 — Circulatory System — Blood Vessels

Q1 2.175 l × 1000 = 2175 ml ***[1 mark]***
2175 ÷ 8.7 = 250 ml/min ***[1 mark]***

Q2 They have a big lumen to help the blood flow despite the low pressure ***[1 mark]***. They have valves to keep the blood flowing in the right direction ***[1 mark]***.

p.32 — Circulatory System — Blood

Q1 They help the blood to clot at a wound ***[1 mark]***.

Q2 To carry oxygen from the lungs to all the cells in the body ***[1 mark]***.

p.33 — Cardiovascular Disease

Q1 Any two from: e.g. there is a risk of a heart attack during the operation. / There's a risk of infection from surgery. / There's a risk of the patient developing a blood clot near the stent ***[2 marks]***.

p.34 — More on Cardiovascular Disease

Q1 Any one from: e.g. surgery to fit an artificial heart can lead to bleeding and infection. / Artificial hearts don't work as well as healthy natural ones. / Blood doesn't flow through the heart as smoothly, which could cause clots and lead to strokes. / The patient has to take blood thinning drugs to prevent blood clots, which could cause problems with bleeding if they're hurt in an accident ***[1 mark]***.

p.35 — Health and Disease

Q1 The state of physical and mental wellbeing ***[1 mark]***.

p.36 — Risk Factors for Non-Communicable Diseases

Q1 Substances in a person's body. / Substances in a person's environment ***[1 mark]***.

p.37 — Cancer

Q1 Uncontrolled growth and division of cells ***[1 mark]***.

Q2 Any three from: e.g. smoking / obesity / UV exposure / viral infection ***[3 marks]***.

p.38 — Plant Cell Organisation

Q1 Meristem tissue is found at the growing tips of roots and shoots ***[1 mark]***.

p.39 — Transpiration and Translocation

Q1 Xylem is made up of dead cells joined together end to end ***[1 mark]*** with no end walls between them and a hole down the middle ***[1 mark]***.
It is strengthened by lignin ***[1 mark]***.

p.40 — Transpiration and Stomata

Q1 Aloe vera, because the transpiration rate will be higher in the hot, dry area ***[1 mark]***, so the aloe vera will have fewer stomata to help conserve water ***[1 mark]***.

Topic B3 — Infection and Response

p.42 — Communicable Disease

Q1 Any two from: e.g. bacteria / viruses / protists / fungi ***[2 marks]***.

Q2 To prevent pathogens being spread onto food and then being eaten by someone else (infecting them) ***[1 mark]***.

p.43 — Bacterial Diseases

Q1 Any two from: fever / stomach cramps / vomiting / diarrhoea ***[2 marks]***.

Q2 New strains of the bacteria that are resistant to antibiotics/penicillin ***[1 mark]***.

p.44 — Viral Diseases

Q1 By sexual contact / exchanging bodily fluids / sharing needles ***[1 mark]***.

Answers

p.45 — Fungal and Protist Diseases

Q1 Using a fungicide ***[1 mark]*** and by stripping the affected leaves off the plant and destroying them ***[1 mark]***.

Q2 a protist ***[1 mark]***

p.46 — Fighting Disease

Q1 They release mucus ***[1 mark]*** to trap pathogens ***[1 mark]***. / They have cilia ***[1 mark]***, which move the mucus (containing pathogens) up to the back of the throat where it can be swallowed ***[1 mark]***.

p.47 — Fighting Disease — Vaccination

Q1 Basia's white blood cells recognise the antigens on the flu virus and rapidly produce antibodies, which kill the pathogen ***[1 mark]***. Cassian's white blood cells don't recognise the antigens, so it takes a while for them to produce antibodies and he becomes ill in the meantime ***[1 mark]***.

p.48 — Fighting Disease — Drugs

Q1 bacteria ***[1 mark]***

p.49 — Developing Drugs

Q1 Whether the drug works and has the effect you're looking for ***[1 mark]***.

Q2 To make sure that the drug doesn't have any harmful side effects when the body is working normally ***[1 mark]***.

Topic B4 — Bioenergetics

p.50 — Photosynthesis

Q1 Glucose ***[1 mark]*** and oxygen ***[1 mark]***.

p.52 — The Rate of Photosynthesis

Q1 a) C ***[1 mark]***

b) E.g. CO_2 level / temperature ***[1 mark]***.

p.53 — Respiration and Metabolism

Q1 Any two from: e.g. to build up larger molecules from smaller ones. / To move about. / In mammals and birds, to keep warm. ***[2 marks — 1 mark for each correct answer]***

Q2 The sum of all of the reactions that happen in a cell or the body ***[1 mark]***.

p.54 — Aerobic and Anaerobic Respiration

Q1 glucose + oxygen → carbon dioxide + water ***[2 marks — 1 mark for correct reactants, 1 mark for correct products]***

Q2 fermentation ***[1 mark]***

p.55 — Exercise

Q1 Running is a more intense type of exercise than walking ***[1 mark]***, so more anaerobic respiration will be taking place in the muscles ***[1 mark]***. Anaerobic respiration produces lactic acid, so running will lead to more lactic acid being in the blood ***[1 mark]***.

Topic B5 — Homeostasis and Response

p.57 — Homeostasis

Q1 To maintain the right conditions for cells to work properly and for enzymes to work properly ***[1 mark]***.

Q2 receptor ***[1 mark]***

p.58 — The Nervous System

Q1 Muscles ***[1 mark]***, glands ***[1 mark]***.

p.59 — Synapses and Reflexes

Q1 A fast, automatic response to a stimulus ***[1 mark]***.

Q2 a) muscle ***[1 mark]***

b) The heat stimulus is detected by receptors in the hand ***[1 mark]***, which send impulses along a sensory neurone to the CNS ***[1 mark]***. The impulses are transferred to a relay neurone ***[1 mark]***. They are then transferred to a motor neurone and travel along it to the effector/muscle ***[1 mark]***.

p.60 — Investigating Reaction Time

Q1 a) 242 + 256 + 253 + 249 + 235 = 1235 ***[1 mark]***
1235 ÷ 5 = 247 ms ***[1 mark]***

b) Any two from: e.g. the hand each person used to click the mouse / the computer equipment/programme used / the amount of energy drink they consumed / the type of energy drink used / the time between consuming the energy drink and taking the test ***[2 marks]***.

p.61 — The Endocrine System

Q1 They are carried in the blood ***[1 mark]***.

p.62 — Controlling Blood Glucose

Q1 Curve 2, because it starts rising after curve 1 starts to rise ***[1 mark]***. Insulin is released when the blood glucose concentration gets too high, so insulin must be the second curve ***[1 mark]***.

p.63 — Puberty and the Menstrual Cycle

Q1 FSH/follicle-stimulating hormone ***[1 mark]***

Q2 testes ***[1 mark]***

p.64 — Controlling Fertility

Q1 Any two from: e.g. oral contraceptives / contraceptive patch / contraceptive injection / contraceptive implant / some IUDs ***[2 marks]***.

p.65 — More on Controlling Fertility

Q1 They stop the sperm from getting to the egg ***[1 mark]***.

Topic B6 — Inheritance, Variation and Evolution

p.66 — DNA

Q1 A small section of DNA found on a chromosome ***[1 mark]***.

Q2 All of the genetic material in the organism ***[1 mark]***.

p.67 — Reproduction

Q1 mitosis ***[1 mark]***

Q2 Because there are two parents, the offspring contain a mixture of their parents' genes ***[1 mark]***. This mixture of genes produces variation ***[1 mark]***.

p.68 — Meiosis

Q1 23 ***[1 mark]***

p.69 — X and Y Chromosomes

Q1 XX ***[1 mark]***

p.70 — Genetic Diagrams

Q1 The mix of alleles you have ***[1 mark]***.

p.71 — Inherited Disorders

Q1 75% / 3 in 4 chance ***[1 mark]***

p.72 — Family Trees and Embryo Screening

Q1 Ff ***[1 mark]***

p.73 — Variation

Q1 Differences between members of the same species ***[1 mark]*** that have been caused by the environment/conditions something lives in ***[1 mark]***.

p.74 — Evolution

Q1 There was a variety of tongue lengths in the moth population ***[1 mark]***. Moths with longer tongues got more food/nectar and were more likely to survive ***[1 mark]***. These moths were more likely to reproduce and pass on the genes responsible for their long tongues ***[1 mark]***. So, over time, longer tongues became more common in the moth population ***[1 mark]***.

p.75 — Antibiotic-Resistant Bacteria

Q1 E.g. there is no effective treatment for the infection / people are not immune to the new strain ***[1 mark]***.

p.76 — More on Antibiotic-Resistant Bacteria

Q1 Taking the complete course makes sure that all the bacteria are destroyed ***[1 mark]***. This means that there are none left to mutate and develop into antibiotic-resistant strains ***[1 mark]***.

p.77 — Selective Breeding

Q1 Select rabbits with floppy ears ***[1 mark]*** and breed them together to produce offspring ***[1 mark]***. Select offspring with floppy ears and breed them together ***[1 mark]***. Repeat this over many generations until all of the offspring have floppy ears ***[1 mark]***.

Q2 Selective breeding reduces the gene pool ***[1 mark]***. This causes an increased chance of organisms inheriting harmful genetic defects ***[1 mark]***. There is also an increased chance that a population could be wiped out by a new disease ***[1 mark]***.

p.78 — Genetic Engineering

Q1 E.g. disease resistance / herbicide resistance / resistance to insect attack / bigger fruit / better fruit ***[1 mark]***.

p.79 — Fossils

Q1 Fossils are the remains of organisms from many thousands of years ago ***[1 mark]***, found in rocks ***[1 mark]***.

p.81 — Classification

Q1 B and C ***[1 mark]***.

Q2 *Castor* ***[1 mark]***

Topic B7 — Ecology

p.83 — Competition

Q1 Any three from: e.g. light / water / space / mineral ions ***[3 marks]***.

Q2 The water boatmen would not have to compete with the diving beetles for food ***[1 mark]*** so there would be more food for the water boatmen ***[1 mark]***.

p.84 — Abiotic and Biotic Factors

Q1 Any four from: moisture level / light intensity / temperature / carbon dioxide level / wind intensity / wind direction / soil pH / mineral content of soil ***[4 marks]***.

p.85 — Adaptations

Q1 a) A behavioural adaptation ***[1 mark]***.

b) E.g. it has webbed feet/flippers to help it swim for food ***[1 mark]***. / It has a thick layer of fat to help it keep in heat ***[1 mark]***.

Answers

p.86 — Food Chains

Q1 a) grass ***[1 mark]***
b) three ***[1 mark]***
c) grasshopper ***[1 mark]***
d) The population of grasshoppers could increase ***[1 mark]*** as there's nothing to eat them ***[1 mark]***. The population of snakes could decrease ***[1 mark]*** as there's nothing for them to eat ***[1 mark]***.

p.87 — Using Quadrats

Q1 1200 ÷ 0.25 = 4800
4800 × 0.75 = 3600 buttercups in total
[2 marks for correct answer, otherwise 1 mark for correct working]

p.88 — Using Transects

Q1 They could mark out a line across the field ***[1 mark]***. Then they could count all of the dandelions that touch the line / count the number of dandelions in quadrats placed along the line ***[1 mark]***.

p.89 — The Water Cycle

Q1 a) By evaporation / transpiration ***[1 mark]***.
b) By providing them with fresh water ***[1 mark]***.

p.90 — The Carbon Cycle

Q1 Microorganisms break them down ***[1 mark]***.
Q2 By plants in photosynthesis ***[1 mark]***.

p.91 — Biodiversity and Waste Management

Q1 The variety of different species of organisms on Earth, or within an ecosystem ***[1 mark]***.

p.92 — Global Warming

Q1 Global warming causes higher temperatures, which cause ice to melt and seawater to expand ***[1 mark]***. This causes the sea level to rise ***[1 mark]***, which leads to flooding of low-lying land and therefore the loss of habitats ***[1 mark]***.

p.93 — Deforestation and Land Use

Q1 To clear land for farming to provide more food ***[1 mark]***. To grow crops to make biofuels ***[1 mark]***.

p.94 — Maintaining Ecosystems and Biodiversity

Q1 Hedgerows and field margins can be reintroduced around single-crop fields ***[1 mark]***. These provide a habitat for lots of types of organisms ***[1 mark]***.
Q2 Breeding programmes breed endangered animals in captivity to make sure the species survives if they die out in the wild ***[1 mark]***. Individuals can sometimes be released into the wild to boost or replace a population ***[1 mark]***.

Topic C1 — Atomic Structure and the Periodic Table

p.96 — Atoms

Q1 protons = atomic number = 31 ***[1 mark]***
electrons = protons = 31 ***[1 mark]***
neutrons = mass number – atomic number
= 70 – 31 = 39 ***[1 mark]***

p.97 — Elements

Q1 E.g. isotopes are atoms with the same number of protons but a different number of neutrons / isotopes have the same atomic number but different mass numbers ***[1 mark]***.
Q2 Relative atomic mass =
$$\frac{(92.2 \times 28) + (4.7 \times 29) + (3.1 \times 30)}{92.2 + 4.7 + 3.1}$$
[1 mark]
$$= \frac{2581.6 + 136.3 + 93}{100} = \frac{2810.9}{100}$$
= 28.109 = 28.1 ***[1 mark]***

p.98 — Compounds

Q1 (2 × Na) + (1 × C) + (3 × O) = 6 ***[1 mark]***
Q2 Aluminium — 2 atoms, sulfur — 3 atoms and oxygen — 12 atoms ***[1 mark]***.

p.99 — Chemical Equations

Q1 $2Fe + 3Cl_2 \rightarrow 2FeCl_3$ ***[1 mark]***
Q2 a) water → hydrogen + oxygen ***[1 mark]***
b) $2H_2O \rightarrow 2H_2 + O_2$
[1 mark for correct reactants and products, 1 mark for correctly balancing]

p.100 — Mixtures

Q1 Any two from: e.g. filtration / crystallisation / simple distillation / fractional distillation /chromatography ***[1 mark for each, up to a maximum of 2 marks]***.

p.101 — Chromatography

Q1 The dye cannot dissolve in the solvent ***[1 mark]***.

p.102 — More Separation Techniques

Q1 Pour the solution into an evaporating dish and slowly heat the solution until crystals start to form or some of the solvent has evaporated ***[1 mark]***. Leave the dish to cool until crystals form ***[1 mark]***. Filter ***[1 mark]*** and then dry the crystals ***[1 mark]***.

p.103 — Distillation

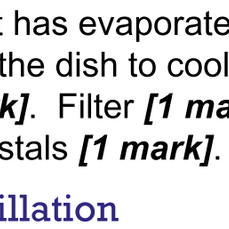
Q1 Ethanol ***[1 mark]***. Ethanol has the second lowest boiling point and will be collected once all the methanol has been distilled off and the temperature increased ***[1 mark]***.

p.104 — The History of the Atom

Q1 In the plum pudding model, the atom is a ball of positive charge with electrons spread throughout it ***[1 mark]***.

p.105 — Electronic Structure

Q1 2 ***[1 mark]***
Q2 2,8,8 or



[1 mark]

p.106 — Development of the Periodic Table

Q1 By atomic weight ***[1 mark]***.
Q2 He left gaps ***[1 mark]***. He switched the order of some elements ***[1 mark]***.

p.107 — The Modern Periodic Table

Q1 2 ***[1 mark]***
Q2 Both chlorine and bromine are in Group 7 and so have the same number of electrons in their outer shell ***[1 mark]***.

p.108 — Metals and Non-Metals

Q1 non-metal ***[1 mark]***
Q2 Any two from: e.g. metals tend to be strong / good conductors of heat / good at conducting electricity / malleable / high melting/boiling temperatures ***[1 mark for each, up to a maximum of 2 marks]***.

p.109 — Group 1 Elements

Q1 lithium + water → lithium hydroxide + hydrogen ***[1 mark]***
Q2 All Group 1 metals have the same number of electrons in their outer shell ***[1 mark]***.

p.110 — Group 7 Elements

Q1 $Br_2 + 2NaI \rightarrow 2NaBr + I_2$ ***[1 mark]***

p.111 — Group 0 Elements

Q1 Xenon has a higher boiling point than neon ***[1 mark]***.

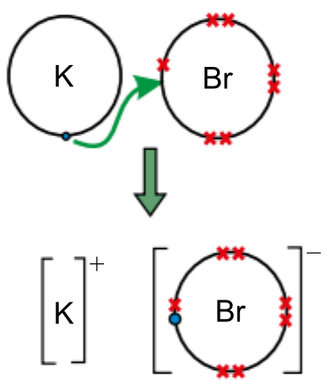
Topic C2 — Bonding, Structure and Properties of Matter

p.113 — Formation of Ions

Q1 Noble gas electronic structures have a full shell of outer electrons ***[1 mark]***, which is a very stable structure ***[1 mark]***.
Q2 a) 1– ***[1 mark]***
b) 2+ ***[1 mark]***
c) 1+ ***[1 mark]***

p.114 — Ionic Bonding

Q1 electrostatic forces/ionic bonds ***[1 mark]***
Q2



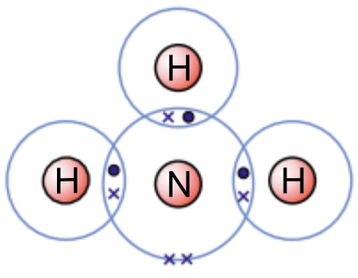
[1 mark for arrow showing electron transferred from potassium to bromine, 1 mark for correct outer shell electron configurations (with or without inner shells), 1 mark for correct charges]

p.115 — Ionic Compounds

Q1 a) It will have a high melting point ***[1 mark]*** because a lot of energy is needed to break the strong attraction between the ions/the strong ionic bonds ***[1 mark]***.
b) When melted, the ions are free to move, so they can carry electric charge ***[1 mark]***.
c) The compound contains magnesium and sulfide ions. Magnesium is in Group 2 so forms 2+ ions ***[1 mark]***, and sulfur is in Group 6 so forms 2– ions ***[1 mark]***. The charges balance with one of each ion, so the empirical formula is MgS ***[1 mark]***.

p.116 — Covalent Bonding

Q1



[1 mark for 3 shared pairs of electrons, 1 mark for correct number of electrons in outer shell of each atom (with or without inner shells on nitrogen)]

Answers

p.117 — Simple Molecular Substances

Q1 The intermolecular forces between molecules of O_2 are weak and don't need much energy to break ***[1 mark]***.

Q2 N_2 molecules aren't charged/There aren't any free electrons or ions ***[1 mark]***.

p.118 — Polymers and Giant Covalent Structures

Q1 $(C_2H_3Cl)_n$ ***[1 mark]***

Q2 To melt diamond you have to break the covalent bonds between atoms which are very strong ***[1 mark]*** but to melt poly(ethene) you only have to break the weaker intermolecular forces which needs less energy ***[1 mark]***. So diamond has a higher melting point ***[1 mark]***.

p.119 — Structures of Carbon

Q1 E.g. graphite contains layers of carbon atoms ***[1 mark]*** arranged in hexagons ***[1 mark]***. Each carbon atom forms three covalent bonds ***[1 mark]***. There are no covalent bonds between the sheets ***[1 mark]***.

p.120 — Metallic Bonding

Q1 The electrostatic attraction ***[1 mark]*** between the positive metal ions and the shared negative electrons ***[1 mark]***.

Q2 Copper is a good electrical conductor ***[1 mark]***.

Q3 Pure copper would be too soft to use for a door hinge, but alloys are harder than pure metals, so are suitable ***[1 mark]***.

p.121 — States of Matter

Q1 The gaseous state ***[1 mark]***.

p.122 — Changing State

Q1 a) solid ***[1 mark]***

b) liquid ***[1 mark]***

c) liquid ***[1 mark]***

d) gas ***[1 mark]***

Topic C3 — Quantitative Chemistry

p.123 — Relative Formula Mass

Q1 a) A_r of H = 1 and A_r of O = 16
M_r of H_2O = (2 × 1) + 16 = 18 ***[1 mark]***

b) A_r of Li = 7, A_r of O = 16 and A_r of H = 1
So M_r of LiOH = 7 + 16 + 1 = 24 ***[1 mark]***

c) A_r of H = 1, A_r of S = 32 and A_r of O = 16
M_r of H_2SO_4 = (2 × 1) + 32 + (4 × 16) = 98 ***[1 mark]***

Q2 A_r of K = 39, A_r of O = 16 and A_r of H = 1
M_r of KOH = 39 + 16 + 1 = 56 ***[1 mark]***
$\frac{39}{56} \times 100 = 70\%$ ***[1 mark]***

p.124 — Conservation of Mass

Q1 Total mass on the left-hand side
= $M_r(H_2SO_4) + 2 \times M_r(NaOH)$
M_r of H_2SO_4 = (2 × 1) + 32 + (4 × 16) = 98
2 × M_r of NaOH = 2 × (23 + 16 + 1) = 80
So total mass on the left-hand side
= 98 + 80 = 178 ***[2 marks for 178, 1 mark for either 98 or 80]***
Total mass on right-hand side
= $M_r(Na_2SO_4) + 2 \times M_r(H_2O)$
M_r of Na_2SO_4 = (2 × 23) + 32 + (4 × 16) = 142
2 × M_r of H_2O = 2 × [(2 × 1) + 16] = 36
142 + 36 = 178 ***[2 marks for 178, 1 mark for either 142 or 36]***
The total M_r on the left-hand side is equal to the total M_r on the right-hand side, so mass is conserved ***[1 mark]***.

p.125 — More on Conservation of Mass

Q1 One of the reactants is a gas ***[1 mark]*** and the products are solid, liquid or aqueous ***[1 mark]***.

Q2 The mass will decrease ***[1 mark]***.

p.126 — Concentrations of Solutions

Q1 Volume = 15 ÷ 1000
= 0.015 dm^3 ***[1 mark]***
Concentration = mass ÷ volume
= 0.6 ÷ 0.015
= 40 g/dm^3 ***[1 mark]***

Topic C4 — Chemical Changes

p.128 — Acids and Bases

Q1 red/orange ***[1 mark]***

Q2 alkaline ***[1 mark]***

p.129 — Reactions of Acids

Q1 calcium carbonate + hydrochloric acid → calcium chloride + carbon dioxide + water ***[1 mark for calcium chloride, 1 mark for carbon dioxide and water]***
$CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$
[1 mark for the correctly balanced equation]

p.130 — The Reactivity Series and Extracting Metals

Q1 $2PbO + C \rightarrow 2Pb + CO_2$
[1 mark for the correct products, 1 mark for the correctly balanced equation]

Q2 Carbon is less reactive than calcium and therefore will not reduce calcium oxide / Calcium is more reactive than carbon, so calcium oxide won't be reduced by carbon ***[1 mark]***.

p.131 — Reactions of Metals

Q1 $2Na_{(s)} + 2H_2O_{(l)} \rightarrow 2NaOH_{(aq)} + H_{2(g)}$
[1 mark for correct reactants and products, 1 mark for correctly balancing, 1 mark for state symbols]

p.132 — Electrolysis

Q1 a) chlorine gas/Cl_2 ***[1 mark]***

b) calcium atoms/Ca ***[1 mark]***

p.133 — Electrolysis of Aqueous Solutions

Q1 a) bromine gas/Br_2 [***1 mark]***

b) copper atoms/Cu ***[1 mark]***

Topic C5 — Energy Changes

p.134 — Exothermic and Endothermic Reactions

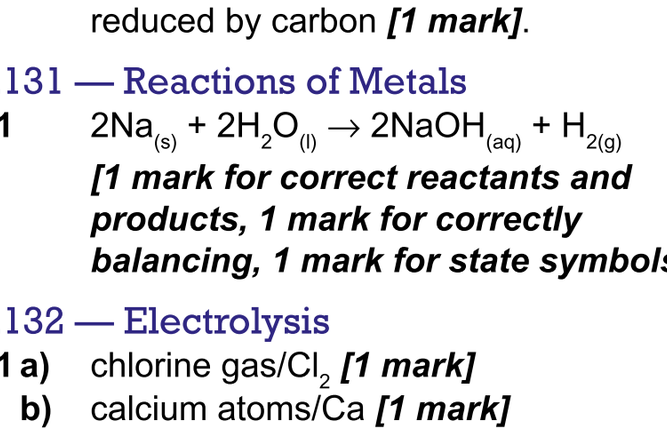
Q1 exothermic ***[1 mark]***

p.135 — Measuring Energy Changes

Q1 They help to stop energy being lost to the surroundings ***[1 mark]***.

p.136 — Reaction Profiles

Q1



[1 mark for correct axes, 1 mark for correct energy levels of reactants and products, 1 mark for correct shape of curve linking the reactants to the products]

Topic C6 — The Rate and Extent of Chemical Change

p.138 — Rates of Reaction

Q1 The activation energy for a reaction is the minimum amount of energy that particles need to react ***[1 mark]***.

p.139 — Factors Affecting Rates of Reaction

Q1 The experiment using the powdered magnesium ***[1 mark]***, because the powder has a higher surface area to volume ratio than the solid strip ***[1 mark]***.

p.140 — Measuring Rates of Reaction

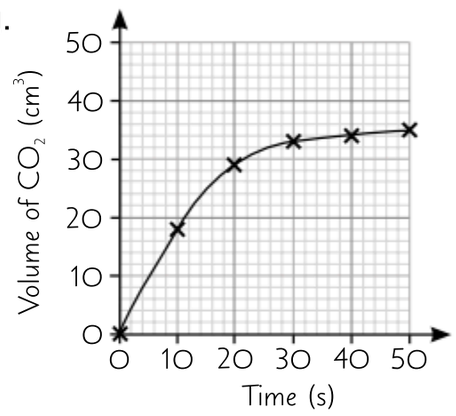
Q1 E.g. a gas syringe ***[1 mark]***.

p.141 — More on Measuring Rates

Q1 Any two from: e.g. volume of HCl added, mass of magnesium used, surface area of the magnesium ***[1 mark for each, up to a maximum of 2 marks]***.

p.142 — Graphs of Reaction Rate Experiments

Q1 E.g.



[1 mark for correctly marking on all 6 points, 1 mark for choosing a sensible scale for the axes, 1 mark for drawing a line of best fit]

p.143 — Working Out Reaction Rates

Q1 Mean rate = amount of reactant used ÷ time
= 6.0 g ÷ 200 s ***[1 mark]***
= 0.03 g/s ***[1 mark]***

p.144 — Reversible Reactions

Q1 A reaction is at equilibrium when both the forward and backward reactions are happening at the same rate ***[1 mark]***.

Topic C7 — Organic Chemistry

p.146 — Hydrocarbons

Q1 $C_2H_6 + 3½O_2 \rightarrow 2CO_2 + 3H_2O$ or $2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$
[1 mark for correct reactants and products, 1 mark for correctly balancing]

p.147 — Crude Oil

Q1 Crude oil is formed from the remains of plankton/plants and animals that died millions of years ago ***[1 mark]***.

Q2 One day crude oil will run out ***[1 mark]***.

p.148 — Fractional Distillation

Q1 The diagram shows that hydrocarbons in petrol have a shorter chain length than the hydrocarbons in diesel, so petrol has a lower boiling point than diesel ***[1 mark]***.

p.149 — Cracking

Q1 $C_5H_{12} \rightarrow C_2H_4 + C_3H_8$ ***[1 mark]***

Topic C8 — Chemical Analysis

p.150 — Purity and Formulations

Q1 The sample melts over a range of temperatures ***[1 mark]***. The melting point is lower than that of pure aspirin ***[1 mark]***.

Answers

p.151 — Paper Chromatography

Q1 E.g. to identify substances in a mixture ***[1 mark]***.

p.152 — Using Chromatograms

Q1 $R_f = \frac{6.3}{8.4} = 0.75$ ***[1 mark]***.

p.153 — Tests for Gases

Q1 carbon dioxide ***[1 mark]***

Topic C9 — Chemistry of the Atmosphere

p.155 — The Evolution of the Atmosphere

Q1 Sedimentary rocks are formed when sea organisms die and fall to the seabed ***[1 mark]***. These become buried and squashed down over millions of years forming rocks ***[1 mark]***.

p.156 — Greenhouse Gases and Climate Change

Q1 The sun gives out short wavelength radiation ***[1 mark]*** which is reflected back by the Earth as long wavelength/ thermal radiation ***[1 mark]***. The thermal radiation is absorbed by greenhouse gases in the atmosphere ***[1 mark]***. Greenhouse gases give out the thermal radiation in all directions including back towards the Earth, causing the temperature to rise ***[1 mark]***.

p.157 — Carbon Footprints

Q1 E.g. governments can put a limit on the amount of greenhouse gases that a business can make and sell licences for emissions up to this point ***[1 mark]***. They can tax companies based on the amount of greenhouse gases that they emit to encourage them to cut down on emissions ***[1 mark]***.

p.158 — Air Pollution

Q1 Any two from: e.g. particulates (soot) / unburnt fuels / carbon monoxide / carbon dioxide / water vapour ***[1 mark for each, up to a maximum of 2 marks]***.

Topic C10 — Using Resources

p.159 — Finite and Renewable Resources

Q1 A finite resource will take a long time to be remade or will not be remade at all ***[1 mark]***. A renewable resource can be replaced within a fairly short amount of time ***[1 mark]***.

p.160 — Reuse and Recycling

Q1 Any two from: e.g. saves energy needed to make new metals / saves limited supplies of metals from the earth / cuts down on the amount of waste going to landfill ***[1 mark for each, up to a maximum of 2 marks]***.

p.161 — Life Cycle Assessments

Q1 Getting the raw materials / manufacture and packaging / using the product / product disposal ***[2 marks for all four stages — otherwise 1 mark for two correct stages]***.

p.162 — Using Life Cycle Assessments

Q1 E.g. the measurements of some effects are based on the judgement and feelings of the person carrying out the assessment ***[1 mark]***. Some life cycle assessments only show some of the impacts on the environment ***[1 mark]***.

p.163 — Potable Water

Q1 E.g. the water is filtered using a wire mesh, and then using filter beds ***[1 mark]***. The filtered water is then sterilised using chlorine / ozone / ultraviolet light ***[1 mark]***.

p.164 — Desalination

Q1 E.g. seawater is passed through a membrane. The membrane purifies the water by letting the water molecules through but trapping the salts ***[1 mark]***.

p.165 — Waste Water Treatment

Q1 Screening — sewage is screened to remove any large bits of material and grit ***[1 mark]***.
Sedimentation — heavier solids sink to the bottom to form sludge, while the lighter effluent floats on the top ***[1 mark]***.

Topic P1 — Energy

p.167 — Energy Stores and Systems

Q1 Mechanically ***[1 mark]***, electrically ***[1 mark]***, by heating ***[1 mark]*** and by radiation ***[1 mark]***.

p.168 — Conservation of Energy and Energy Transfers

Q1 Energy is transferred mechanically ***[1 mark]*** from the kinetic energy store of the wind ***[1 mark]*** to the kinetic energy store of the windmill ***[1 mark]***.

p.169 — Kinetic and Potential Energy Stores

Q1 The change in height is 5.0 m. So the energy transferred from the gravitational potential energy store is:
$E_p = mgh = 2.0 \times 9.8 \times 5.0$
$= 98$ J ***[1 mark]***
This is transferred to the kinetic energy store of the object,
so $E_k = 98$ J ***[1 mark]***
$E_k = \frac{1}{2}mv^2$
so $v^2 = 2E_k \div m$ ***[1 mark]***
$= (2 \times 98) \div 2.0$ ***[1 mark]***
$= 98$ m^2/s^2
$v = \sqrt{98} = 9.899...$
$= 9.9$ m/s (to 2 s.f.) ***[1 mark]***

p.170 — Energy Transfers by Heating

Q1 $\Delta E = mc\Delta\theta$
so $\Delta\theta = \Delta E \div (m \times c)$ ***[1 mark]***
$= 50\,000 \div (5 \times 4200)$
$= 2.380...$ °C ***[1 mark]***
So the new temperature
$= 5 + 2.380... = 7.380...$
$= 7$ °C (to 1 s.f.) ***[1 mark]***

p.171 — Investigating Specific Heat Capacity

Q1 $E = P \times t = 80 \times 200$ ***[1 mark]***
$= 16\,000$ J ***[1 mark]***
$\Delta E = mc\Delta\theta$, so
$c = \Delta E \div (m \times \Delta\theta)$ ***[1 mark]***
$= 16\,000 \div (2 \times 20)$ ***[1 mark]***
$= 400$ J/kg°C ***[1 mark]***

p.172 — Power

Q1 $P = E \div t$
$t = 2 \times 60 = 120$ s ***[1 mark]***
$P = 4800 \div 120$ ***[1 mark]***
$= 40$ W ***[1 mark]***

p.173 — Reducing Unwanted Energy Transfers

Q1 Any one from: e.g. make the walls thicker / make the walls out of a material with a low thermal conductivity / put in thermal insulation (e.g. loft insulation) ***[1 mark]***.

p.174 — Efficiency

Q1 efficiency = useful output energy transfer ÷ total input energy transfer
$= 225 \div 300$ ***[1 mark]***
$= 0.75$ ***[1 mark]***

Q2 efficiency = useful power output ÷ total power input
$= 900 \div 1200 = 0.75$ ***[1 mark]***
useful output energy transfer
= efficiency × total input energy transfer ***[1 mark]***
$= 0.75 \times 72\,000$ ***[1 mark]***
$= 54\,000$ J ***[1 mark]***

p.175 — Energy Resources and Their Uses

Q1 a) renewable ***[1 mark]***
b) non-renewable ***[1 mark]***
c) non-renewable ***[1 mark]***
d) renewable ***[1 mark]***

p.176 — Wind, Solar and Geothermal

Q1 E.g. wind power can be unreliable as they don't provide a constant supply of energy because sometimes there's no wind / the turbines have to be stopped because the wind is too strong ***[1 mark]***. Geothermal power plants are reliable because the hot rocks are always hot ***[1 mark]***.

p.177 — Hydro-electricity, Waves and Tides

Q1 E.g. it disturbs the seabed / it disturbs the habitats of animals ***[1 mark]***

p.178 — Bio-fuels and Non-renewables

Q1 E.g. they're reliable / they can respond quickly to changes in demand ***[2 marks — 1 mark for each correct answer]***

Q2 E.g. burning oil releases carbon dioxide, which contributes to global warming. / It produces sulfur dioxide which causes acid rain, which is harmful to trees and animals. / Oil spills can occur when transporting oil, which can harm/kill animals that live in and around the sea ***[3 marks —1 mark for each correct answer]***.

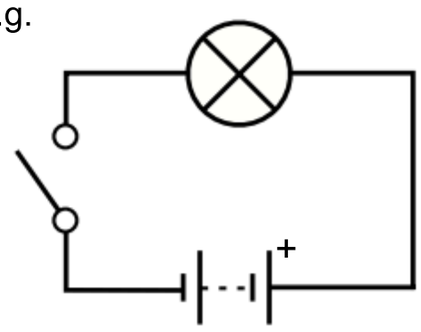
p.179 — Trends in Energy Resource Use

Q1 Any two from: e.g. building new renewable power plants is expensive / people don't want to live near new power plants / renewable energy resources are less reliable than non-renewable energy resources / electric cars are more expensive than petrol cars. ***[2 marks — 1 mark for each correct answer]***

Topic P2 — Electricity

p.180 — Current and Circuit Symbols

Q1 E.g.



[3 marks for all symbols correctly drawn and connected in a single loop, otherwise 2 marks for all three symbols correct or 1 mark for one or two symbols correct]

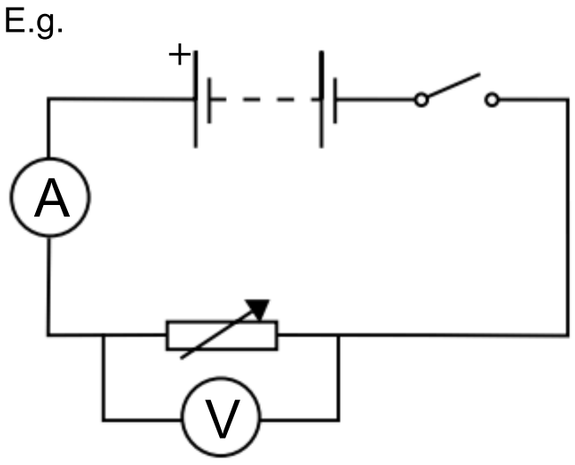
Answers

p.181 — Resistance and $V = IR$

Q1 $V = IR$ so $R = V \div I$ ***[1 mark]***
$= 230 \div 5.0$ ***[1 mark]***
$= 46\ \Omega$ ***[1 mark]***

p.182 — Investigating Resistance

Q1 E.g.



[1 mark for all circuit symbols correct, 1 mark for battery, variable resistor (test wire) and ammeter connected in series, 1 mark for voltmeter connected in parallel with the variable resistor (test wire)]

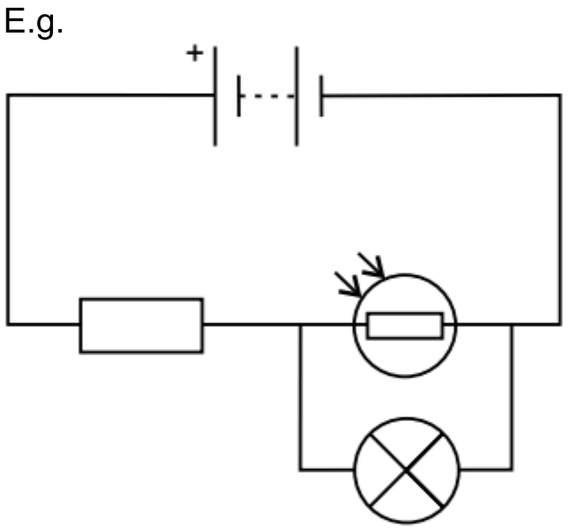
You'll still get the marks if you didn't include a switch in your circuit — but it's useful to help you control your experiment.

p.183 — *I-V* Characteristics

Q1 As the current through the lamp increases, the temperature of its filament increases ***[1 mark]*** causing its resistance to increase ***[1 mark]***.
A larger resistance means less current can flow per unit potential difference, and so the graph gets shallower ***[1 mark]***.

p.184 — Circuit Devices

Q1 E.g.



[1 mark for all symbols correct, 1 mark for the LDR connected in series with a resistor and a source of potential difference, 1 mark for the bulb connected in parallel with the LDR]

p.185 — Series Circuits

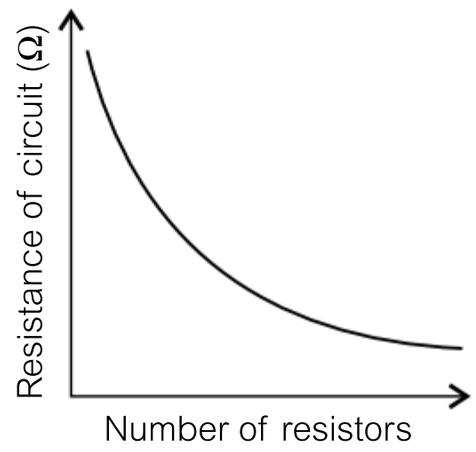
Q1 $R_{total} = 4 + 5 + 6 = 15\ \Omega$ ***[1 mark]***
$V = I \times R = 0.6 \times 15$ ***[1 mark]***
$= 9$ V ***[1 mark]***

p.186 — Parallel Circuits

Q1 The total current through the circuit decreases ***[1 mark]*** as there are fewer paths for the current to take ***[1 mark].***
The total resistance of the circuit increases ***[1 mark]*** as, using $V = IR$, a decrease in the total current means an increase in the total resistance ***[1 mark].***

p.187 — Investigating Circuits

Q1



[1 mark for correct axes, 1 mark for correctly drawn curve]

p.188 — Electricity in the Home

Q1 a) 230 V ***[1 mark]***
b) (around) 0 V ***[1 mark]***
c) 0 V ***[1 mark]***

p.189 — Power of Electrical Appliances

Q1 $E = P \times t$ so $P = E \div t$ ***[1 mark]***
$= 6000 \div 30$ ***[1 mark]***
$= 200$ W ***[1 mark]***

Q2 $E = P \times t$ ***[1 mark]***
$= 250 \times (2 \times 60 \times 60)$
$= 1\ 800\ 000$ J ***[1 mark]***
$E = 375 \times (2 \times 60 \times 60)$
$= 2\ 700\ 000$ J ***[1 mark]***
So change in energy is
$2\ 700\ 000 - 1\ 800\ 000$
$= 900\ 000$ J ***[1 mark]***

p.190 — More on Power

Q1 $E = Q \times V$
$= 10\ 000 \times 200$ ***[1 mark]***
$= 2\ 000\ 000$ J ***[1 mark]***

Q2 $P = V \times I$
$= 12 \times 4.0$ ***[1 mark]***
$= 48$ W ***[1 mark]***

Q3 $R = P \div I^2$ ***[1 mark]***
$= 2300 \div 10.0^2$ ***[1 mark]***
$= 23\ \Omega$ ***[1 mark]***

p.191 — The National Grid

Q1 The national grid is a system of cables and transformers ***[1 mark]***.

Topic P3 — Particle Model of Matter

p.193 — The Particle Model and Motion in Gases

Q1 Decreasing the temperature of the gas means that the gas particles have less energy in their kinetic energy stores ***[1 mark]***. They hit the container walls less often so the total force applied is lower ***[1 mark]***. A lower force means a lower pressure ***[1 mark]***.

p.194 — Density of Materials

Q1 Gemstone's mass = 0.019 kg
$= 0.019 \times 1000$
$= 19$ g ***[1 mark]***
Gemstone's volume = volume of water pushed out of eureka can = 7.0 cm^3
$\rho = m \div V$
$= 19 \div 7.0$ ***[1 mark]***
$= 2.714...$
$= 2.7\ g/cm^3$ (to 2 s.f.) ***[1 mark]***

p.195 — Internal Energy and Changes of State

Q1 a) melting ***[1 mark]***
b) boiling / evaporating ***[1 mark]***
c) condensing ***[1 mark]***

p.196 — Specific Latent Heat

Q1 $E = m \times L = 0.25 \times 120\ 000$ ***[1 mark]***
$= 30\ 000$ J ***[1 mark]***

Topic P4 — Atomic Structure

p.197 — The Current Model of the Atom

Q1 a) neutrons ***[1 mark]***, protons ***[1 mark]***
b) The radius of an atom is around 1×10^{-10} m ***[1 mark]***. The radius of a nucleus is less than 1/10 000 of this ***[1 mark]***.

p.198 — Isotopes and Nuclear Radiation

Q1 E.g. Alpha would not be suitable because it is stopped by a few cm of air or a sheet of paper ***[1 mark]***. It would not be able to pass through the packaging to sterilise the equipment ***[1 mark]***.

p.199 — Nuclear Equations

Q1 beta particle ***[1 mark]***

Q2 $^{219}_{86}Rn \rightarrow {}^{215}_{84}Po + {}^{4}_{2}He$
[1 mark for correct layout, 1 mark for correct symbol for an alpha particle, 1 mark for total atomic and mass numbers being equal on both sides]

p.200 — Half-life

Q1 The number of decays per second ***[1 mark]***.

Q2 Initial count-rate = 168 cps
After 1 half-life,
count-rate = $168 \div 2 = 84$ cps
After 2 half-lives,
count-rate = $84 \div 2 = 42$ cps
After 3 half-lives,
count-rate = $42 \div 2 = 21$ cps ***[1 mark]***
So, it took 3 half-lives for the count-rate to drop to 21 cps. This means that 60 minutes is equal to 3 half-lives ***[1 mark]***.
So, the half-life of the sample
$= 60 \div 3 = 20$ minutes ***[1 mark]***

p.201 — Irradiation and Contamination

Q1 Gamma rays can penetrate through skin and can get to organs ***[1 mark]*** whereas alpha particles are stopped by skin and blocked by a small air gap ***[1 mark]***.

Topic P5 — Forces

p.203 — Contact and Non-Contact Forces

Q1 a) Any two from: e.g. speed / distance / mass / temperature / time ***[2 marks]***
b) Any two from: e.g. displacement / force / acceleration / velocity ***[2 marks]***

Q2 Contact force: air resistance ***[1 mark]***
Non-contact force: gravitational force ***[1 mark]***

p.204 — Weight, Mass and Gravity

Q1 a) $W = mg = 5 \times 9.8$ ***[1 mark]***
$= 49$ N ***[1 mark]***
b) $W = 5 \times 1.6$ ***[1 mark]*** $= 8$ N ***[1 mark]***

p.205 — Resultant Forces and Work Done

Q1 20 cm = 0.2 m ***[1 mark]***
$W = Fs = 20 \times 0.2$ ***[1 mark]***
$= 4$ J ***[1 mark]***

p.206 — Forces and Elasticity

Q1 2 cm = 0.02 m ***[1 mark]***
$F = ke$ so $k = F \div e$ ***[1 mark]***
$= 1 \div 0.02$ ***[1 mark]***
$= 50$ N/m ***[1 mark]***

p.207 — Investigating Springs

Q1 2.5 cm = 0.025 m ***[1 mark]***
$E_e = \frac{1}{2}ke^2 = \frac{1}{2} \times 40 \times (0.025)^2$ ***[1 mark]***
$= 0.0125$ J ***[1 mark]***

Answers

p.208 — Distance, Displacement, Speed and Velocity

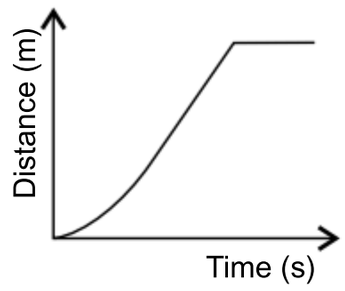
Q1 $s = vt$ so $v = s \div t$ ***[1 mark]***
$= 200 \div 25$ ***[1 mark]***
$= 8$ m/s ***[1 mark]***

p.209 — Acceleration

Q1 $u = 0$ m/s, $v = 7$ m/s, $a = g = 9.8$ m/s^2,
$s = (v^2 - u^2) \div 2a$ ***[1 mark]***
$= (49 - 0) \div (2 \times 9.8)$ ***[1 mark]***
$= 2.5$ m ***[1 mark]***

p.210 — Distance-Time Graphs

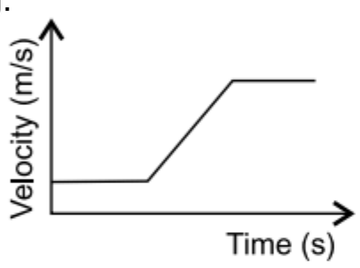
Q1 E.g.



[1 mark for a curved line with an increasing positive gradient, 1 mark for the line becoming a straight line with a positive gradient, 1 mark for the line then becoming horizontal]

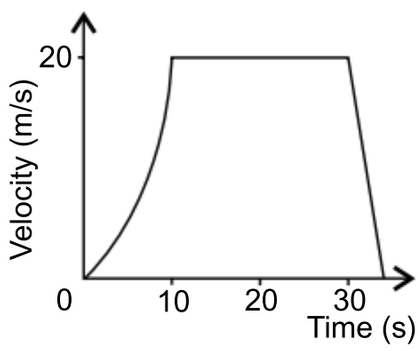
p.211 — Velocity-Time Graphs and Terminal Velocity

Q1 E.g.



[1 mark for a straight, horizontal line representing constant speed, 1 mark for a straight line with a positive gradient representing constant acceleration, 1 mark for a straight, horizontal line at a different velocity to the initial velocity to represent a different constant speed]

Q2



[1 mark for an upwards curved acceleration line to 20 m/s, 1 mark for a straight line representing steady speed, 1 mark for a straight line representing deceleration]

p.212 — Newton's First and Second Laws

Q1 $F = ma = (80 + 10) \times 0.25$ ***[1 mark]***
$= 22.5$ N ***[1 mark]***

p.213 — Newton's Third Law

Q1 Any one from: e.g the gravitational force of the Earth attracts the car and the gravitational force of the car attracts the Earth ***[1 mark]*** / the car exerts a normal contact force down against the ground and the normal contact force from the ground pushes up against the car ***[1 mark]*** / the car (tyres) pushes the road backwards and the road pushes the car (tyres) forwards ***[1 mark].***

p.214 — Investigating Motion

Q1 The weight of the hook and the masses attached to it ***[1 mark]***.

p.215 — Stopping Distance and Thinking Distance

Q1 E.g. speed / reaction time / tiredness / drugs / alcohol / distractions ***[1 mark]***

p.216 — Braking Distance

Q1 Energy in car's kinetic energy store
$= \frac{1}{2} \times m \times v^2$
$= \frac{1}{2} \times 1000 \times 10^2$ ***[1 mark]***
$= 50\,000$ J ***[1 mark]***
To stop the car, the brakes must do work to transfer all the energy away from the car's kinetic energy store:
$\frac{1}{2} \times m \times v^2 = F \times d$ ***[1 mark]***
So $F \times d = 50\,000$
Rearrange for F:
$F = 50\,000 \div d$
$= 50\,000 \div 50$ ***[1 mark]***
$= 1000$ N ***[1 mark]***

p.217 — Reaction Times

Q1 a) $v^2 - u^2 = 2as$
$v^2 = 2 \times 9.8 \times 0.162 + 0$ ***[1 mark]***
$= 3.1752$ m^2/s^2
$v = \sqrt{3.1752} = 1.781...$ m/s ***[1 mark]***
$a = \Delta v \div t$ so
$t = \Delta v \div a$ ***[1 mark]***
$= 1.781... \div 9.8$ ***[1 mark]*** $= 0.181...$ s
$= 0.18$ s (to 2 s.f.) ***[1 mark]***

b) His reaction time is longer in the evening ***[1 mark]*** so whilst driving, he may take longer to react to a hazard, meaning his thinking distance would be longer ***[1 mark]***.

Topic P6 — Waves

p.219 — Transverse and Longitudinal Waves

Q1 Any two from: e.g. light / ripples on water / waves on a string ***[2 marks]***

p.220 — Frequency, Period and Wave Speed

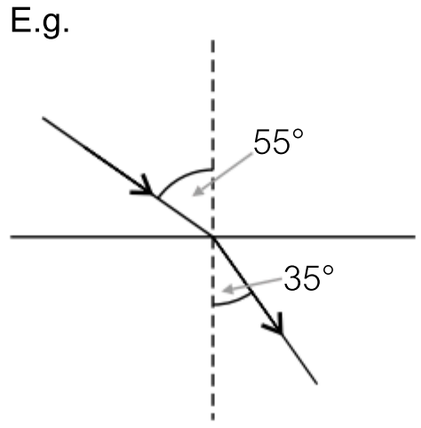
Q1 $7.5 \div 100 = 0.075$ m ***[1 mark]***
wave speed = frequency × wavelength, so frequency = wave speed ÷ wavelength ***[1 mark]***
$= 0.15 \div 0.075$ ***[1 mark]***
$= 2$ Hz ***[1 mark]***

p.221 — Investigating Waves

Q1 E.g. attach a signal generator to a dipper and place it in a ripple tank filled with water to create some waves ***[1 mark]***. Place a screen underneath the ripple tank, then turn on a lamp and dim the other lights in the room ***[1 mark]***. Measure the distance between shadow lines that are 10 wavelengths apart on the screen beneath the tank, then divide this number by 10 — this is equal to the wavelength of the water waves ***[1 mark]***.

p.222 — Refraction

Q1 E.g.



[1 mark for correctly drawing the boundary and the normal, 1 mark for drawing an incident ray at the correct angle, 1 mark for drawing the refracted ray at the correct angle]

p.223 — Electromagnetic Waves

Q1 Radio waves ***[1 mark]***
Q2 Visible light ***[1 mark]***

p.224 — Uses of EM Waves

Q1 E.g. TV / radio signals ***[1 mark]***.

p.225 — More Uses of EM Waves

Q1 E.g. seeing broken bones ***[1 mark]*** and treating cancer ***[1 mark]***

p.226 — Investigating IR Radiation

Q1 a) black ***[1 mark]***
b) matt ***[1 mark]***

p.227 — Investigating IR Absorption

Q1 Any two from: e.g. the plates are an equal distance from the bunsen burner / the same wax is used / the same amount of wax is used / identical metal balls are used / the plates are identical (except for their different coloured sides). ***[2 marks — 1 mark for each correct answer]***

p.228 — Dangers of Electromagnetic Waves

Q1 Any two from: e.g. damage to surface cells / sunburn / faster ageing of the skin / blindness / increased risk of skin cancer. ***[2 marks — 1 mark for each correct effect]***

Q2 E.g. They are both ionising (which means they can knock electrons off atoms) ***[1 mark]***.

Topic P7 — Magnetism and Electromagnetism

p.229 — Permanent and Induced Magnets

Q1 They'll repel each other ***[1 mark]***.

p.230 — Electromagnetism

Q1 E.g. for current out of the page:

[1 mark for concentric circles getting further apart, 1 mark for arrows on field lines with correct direction]

Answers

Glossary

Abiotic factor	A non-living factor in an environment.
Acceleration	A change in velocity in a certain amount of time.
Accurate result	A result that is really close to the true answer.
Acid	A substance with a pH of less than 7 that forms H^+ ions in water.
Activation energy	The minimum amount of energy that reactant particles must have when they collide in order to react.
Active transport	The movement of particles against a concentration gradient (from an area of lower concentration to an area of higher concentration) using energy from respiration.
Activity (radioactive)	The number of nuclei of a sample that decay per second.
Adaptation	A feature that helps an organism to survive in the conditions of its natural environment.
Aerobic respiration	Respiration that uses oxygen. It produces carbon dioxide and water.
Air resistance	The frictional force caused by air on a moving object.
Alkali	A substance with a pH of more than 7 that forms OH^- ions in solution.
Alkali metal	An element in Group 1 of the periodic table. E.g. sodium, potassium etc.
Alkane	A saturated hydrocarbon with the general formula C_nH_{2n+2}. E.g. methane, ethane etc.
Alkene	An unsaturated hydrocarbon that contains a carbon-carbon double bond and has the general formula C_nH_{2n}. E.g. ethene, propene etc.
Allele	An alternative version of a gene.
Alloy	A metal that is a mixture of two or more metals, or a mixture involving metals and non-metals.
Alpha decay	A type of radioactive decay in which an alpha particle is given out from a decaying nucleus.
Alpha particle	A positively-charged particle made up of two protons and two neutrons (a helium nucleus).
Alpha particle scattering experiment	An experiment in which alpha particles were fired at gold foil to see if they were deflected. It led to the plum pudding model being abandoned in favour of the nuclear model of the atom.
Alternating current (ac)	Current that is constantly changing direction.
Alveolus	A tiny air sac in the lungs, where gas exchange occurs.
Amino acid	A small molecule that is a building block of proteins.
Ammeter	A component used to measure the current through a component. It is always connected in series with the component.
Amplitude	The maximum displacement of a point on a wave from its undisturbed position.
Anaerobic respiration	Respiration without oxygen. It produces lactic acid in humans, and carbon dioxide and ethanol in plants and yeast.
Angle of incidence	The angle the incident ray of a wave makes with the normal at a boundary.
Angle of refraction	The angle a refracted ray makes with the normal when a wave refracts at a boundary.
Anion	A particle with a negative charge, formed when one or more electrons are gained.
Anomalous result	A result that doesn't fit in with the rest of the data.
Antibiotic	A drug used to kill or prevent the growth of bacteria.
Antibiotic resistance	When bacteria aren't killed by an antibiotic.
Antibody	A protein produced by white blood cells in response to the presence of an antigen (e.g. on the surface of a pathogen).
Antigen	A molecule on the surface of a cell. Foreign antigens trigger white blood cells to make antibodies.
Antitoxin	A protein produced by white blood cells that stops toxins from working.

Artery	A blood vessel that carries blood away from the heart.
Asexual reproduction	When organisms reproduce by mitosis to produce genetically identical offspring.
Atmosphere	The layer of air that surrounds a planet.
Atom	A neutral particle made up of protons and neutrons in the nucleus, with electrons surrounding the nucleus.
Atomic number	The number of protons in the nucleus of an atom. It's also known as proton number.
Base	A substance that reacts with acids in neutralisation reactions.
Behavioural adaptation	A way in which an organism behaves that helps it to survive in its environment.
Beta decay	A type of radioactive decay in which a beta particle is given out from a decaying nucleus.
Beta particle	A high-speed electron emitted in beta decay.
Bias	Unfairness in the way data is presented, possibly because the presenter is trying to make a particular point (sometimes without knowing they're doing it).
Binomial system	The system used in classification for naming organisms using a two-part Latin name.
Bio-fuel	A renewable energy resource made from plant products or animal dung.
Biodiversity	The variety of different species of organisms on Earth, or within an ecosystem.
Biotic factor	A living factor in an environment.
Braking distance	The braking distance is the distance a vehicle travels after the brakes are applied until it comes to a complete stop, as a result of the braking force.
Capillary	A type of blood vessel involved in the exchange of materials at tissues.
Carbohydrase	A type of digestive enzyme that catalyses the breakdown of a carbohydrate (like starch) into simple sugars. Amylase is a carbohydrase.
Carbon footprint	A measure of the amounts of greenhouse gases released by a product, a service or an event.
Cardiovascular disease	Disease of the heart or blood vessels.
Catalyst	A substance that increases the speed of a reaction, without being changed or used up.
Categoric data	Data that comes in clear categories, e.g. blood type (A+, B–, etc.), metals (copper, zinc, etc.).
Cation	A particle with a positive charge, formed when one or more electrons are lost.
Cell membrane	A membrane surrounding a cell, which holds it together and controls what goes in and out.
Cell wall	A structure surrounding some cell types, which gives strength and support.
Cellulose	A molecule which strengthens cell walls in plants and algae.
Central nervous system (CNS)	The brain and spinal cord. It's where reflexes and actions are coordinated.
Chemical bond	The attraction of two atoms for each other, caused by the sharing or transfer of electrons.
Chlorophyll	A green substance found in chloroplasts which absorbs light for photosynthesis.
Chloroplast	A structure found in plant cells and algae. It is the site of photosynthesis.
Chromatogram	The pattern of spots formed as a result of separating a mixture using chromatography.
Chromatography	An analytical method used to separate the substances in a mixture based on how the components interact with a mobile phase and a stationary phase.
Chromosome	A long molecule of DNA found in the nucleus. Each chromosome carries many genes.
Climate change	A change in the Earth's climate. E.g. global warming, changing rainfall patterns etc.
Clinical trial	A set of drug tests on human volunteers.
Clone	An organism that is genetically identical to another organism.
Closed system	A system where neither matter nor energy can enter or leave. The net change in total energy in a closed system is always zero.

Collision theory	The theory that in order for a reaction to occur, particles must collide with sufficient energy.
Combustion	An exothermic reaction between a fuel and oxygen.
Communicable disease	A disease that can spread between individuals.
Community	The populations of different species living in a habitat.
Compound	A substance made up of atoms of at least two different elements, chemically joined together.
Concentration	The amount of a substance in a certain volume of solution, given in units of 'units of amount of substance'/'units of volume'.
Conservation of energy principle	Energy can be transferred usefully from one energy store to another, stored or dissipated — but it can never be created or destroyed.
Contamination (radioactive)	The presence of unwanted radioactive atoms on or inside an object.
Continuous data	Numerical data that can have any value within a range (e.g. length, volume or temperature).
Contraceptive	A method of preventing pregnancy. Some methods use hormones and some do not.
Control experiment	An experiment that's kept under the same conditions as the rest of an investigation, but doesn't have anything done to it.
Control variable	A variable in an experiment that is kept the same.
Coordination centre	An organ (e.g. the brain, spinal cord or pancreas) that processes information from receptors and organises a response from the effectors.
Coronary artery	A blood vessel which supplies blood to the heart muscle.
Coronary heart disease	A disease in which fatty deposits build up in the coronary arteries, causing them to become narrow.
Correlation	A relationship between two variables.
Covalent bond	A chemical bond formed when atoms share a pair of electrons.
Covalent substance	A substance where the atoms are held together by covalent bonds.
Cracking	The process that is used to break long-chain hydrocarbons down into shorter, more useful hydrocarbons. Two types of cracking are catalytic cracking and steam cracking.
Crystallisation	The formation of solid crystals as water evaporates from a solution. For example, salt solutions undergo crystallisation to form solid salt crystals.
Current	The flow of electric charge. The size of the current is the rate of flow of charge. Measured in amperes (A).
Cystic fibrosis	An inherited disorder of the cell membranes caused by a recessive allele.
Cytoplasm	A gel-like substance in a cell where most of the chemical reactions take place.
Deforestation	The cutting down of forests (large areas of trees).
Delocalised electron	An electron that isn't associated with a particular atom or bond and is free to move within a structure.
Density	A substance's mass per unit volume.
Dependent variable	The variable in an experiment that is measured.
Diabetes	A condition that affects the body's ability to control its blood glucose level.
Differentiation	The process by which a cell becomes specialised for its job.
Diffusion	The spreading out of particles from an area of higher concentration to an area of lower concentration.
Diode	A circuit component that only allows current to flow through it in one direction. It has a very high resistance in the other direction.
Direct current (dc)	Current that always flows in the same direction.
Displacement	The straight-line distance and direction from an object's starting position to its finishing position.

Displacement reaction	A reaction where a more reactive element replaces a less reactive element in a compound.
Displayed formula	A chemical formula that shows the atoms in a covalent compound and all the bonds between them.
Distance-time graph	A graph showing how the distance travelled by an object changes over a period of time.
Distillation	A way of separating out a liquid from a mixture. You heat the mixture until the bit you want evaporates, then cool the vapour to turn it back into a liquid.
Distribution	Where organisms are found within an area.
DNA	Deoxyribonucleic acid. The molecule in cells that stores genetic information.
Dominant allele	An allele whose characteristic always appears in an organism, whether it has two copies of the allele or only one.
Double-blind trial	A clinical trial where neither the doctors nor the patients know who has received the drug and who has received the placebo until all the results have been gathered.
Drag	The frictional force caused by any fluid (a liquid or gas) on a moving object.
Earth wire	The green and yellow wire in an electrical cable that only carries current when there's a fault. It stops exposed metal parts of an appliance from becoming live.
Ecosystem	The interaction of a community of organisms with the non-living parts of their environment.
Effector	Either a muscle or gland which responds to nervous impulses.
Efficacy	Whether something, e.g. a drug, works or not.
Efficiency	The proportion of input energy transfer which is usefully transferred. Also the proportion of input power which is usefully output.
Elastic deformation	An object undergoing elastic deformation will return to its original shape and length once any forces being applied to it are removed.
Elastic object	An object which can be elastically deformed.
Elastic potential energy store	Anything that has been stretched or compressed, e.g. a spring, has energy in its elastic potential energy store.
Electrode	An electrical conductor which is submerged in the electrolyte during electrolysis.
Electrolysis	The process of breaking down a substance using electricity.
Electrolyte	A liquid or solution used in electrolysis to conduct electricity between the two electrodes.
Electromagnet	A solenoid with an iron core.
Electromagnetic (EM) spectrum	A continuous spectrum of all the possible wavelengths of electromagnetic waves.
Electron	A negatively charged particle that orbits the nucleus of an atom.
Electron shell	A region of an atom that contains electrons. It's also known as an energy level.
Electronic structure	The number of electrons in an atom (or ion) of an element and how they are arranged.
Electrostatic force	A force of attraction between opposite charges.
Element	A substance that is made up only of atoms with the same number of protons.
Empirical formula	A chemical formula showing the simplest possible whole number ratio of atoms in a compound.
Endothermic reaction	A reaction which takes in energy from the surroundings.
Energy level	A region of an atom that contains electrons. It's also known as an electron shell.
Energy store	A means by which an object stores energy. There are different types of energy store: thermal (or internal), kinetic, gravitational potential, elastic potential, chemical, magnetic, electrostatic and nuclear.
Enzyme	A protein that acts as a biological catalyst.
Equilibrium (physics)	A state in which all the forces acting on an object are balanced, so the resultant force is zero.

Equilibrium (reactions)	The point at which the rates of the forward and backward reactions in a reversible reaction are the same, and so the amounts of reactants and products in the reaction container don't change.
Eukaryotic cell	A complex cell, such as a plant or animal cell.
Evolution	The changing of the inherited characteristics of a population over time.
Excretion	The removal of waste products from the body.
Exothermic reaction	A reaction which transfers energy to the surroundings.
Extinction	When no living individuals of a species remain.
Extremophile	An organism that's adapted to live in seriously extreme conditions.
Fair test	A controlled experiment where the only thing being changed is the independent variable.
Family tree	A diagram that shows how a characteristic is inherited in a group of related people.
Feedstock	A raw material used to produce other substances through industrial processes.
Fermentation	The process of anaerobic respiration in yeast cells.
Fertilisation	The fusion of a male and a female gamete during sexual reproduction.
Fertility	The ability to conceive a child.
Filtration	A physical method used to separate an insoluble solid from a liquid.
Finite resource	A resource that isn't replaced at a quick enough rate to be considered replaceable.
Flammability	How easy it is to ignite a substance.
Fluid	A substance that can flow — either a liquid or a gas.
Force	A push or a pull on an object caused by it interacting with something.
Formulation	A useful mixture with a precise purpose made by following a formula.
Fossil	The remains of an organism from many years ago, which is found in rock.
Fossil fuel	The fossil fuels are coal, oil and natural gas. They're non-renewable energy resources that we burn to generate electricity.
Fossil record	The history of life on Earth preserved as fossils.
Fraction	A group of hydrocarbons that condense together when crude oil is separated using fractional distillation. E.g. petrol, naphtha, kerosene etc.
Fractional distillation	A process that can be used to separate substances in a mixture according to their boiling points.
Frequency	The number of complete waves passing a certain point per second. Measured in hertz, Hz.
Friction	A force that opposes an object's motion. It acts in the opposite direction to motion.
Functional adaptation	Something that goes on inside an organism's body which helps it to survive in its environment.
Gamete	A sex cell, e.g. an egg cell or a sperm cell in animals.
Gamma decay	A type of radioactive decay in which a gamma ray is given out from a decaying nucleus.
Gamma ray	A high-frequency, short-wavelength electromagnetic wave.
Geiger-Müller tube	A particle detector that is used with a counter to measure count rate.
Gene	A short section of DNA, found on a chromosome. A gene contains the instructions needed to make a protein, so it controls the development of a characteristic.
General formula	A formula that can be used to find the molecular formula of any member of a homologous series.
Genetic engineering	The process of cutting out a useful gene from one organism's genome and putting it into another organism's cells.
Genetically modified (GM) crop	A crop which has had its genes modified using genetic engineering.
Genome	All of the genetic material in an organism.
Genotype	What alleles you have, e.g. Tt.

Geothermal power	A renewable energy resource where energy is transferred from the thermal energy stores of hot rocks underground and is used to generate electricity or to heat buildings.
Giant covalent structure	A large molecule made up of a very large number of atoms held together by covalent bonds (also known as a macromolecule).
Gland	An organ that produces and secretes hormones.
Global dimming	The decrease in the amount of sunlight reaching the Earth's surface due to an increase in the amount of particulates in the atmosphere.
Global warming	The increase in the average temperature of the Earth.
Glycogen	A molecule that acts as a store of glucose in liver and muscle cells.
Gradient	The slope of a line graph. It shows how quickly the variable on the *y*-axis changes with the variable on the *x*-axis.
Gravitational potential energy (g.p.e) store	Anything that has mass and is in a gravitational field has energy in its gravitational potential energy store.
Greenhouse effect	When greenhouse gases in the atmosphere absorb long wavelength radiation and re-radiate it in all directions, including back towards Earth, helping to keep the Earth warm.
Greenhouse gas	A gas that can absorb long wavelength radiation.
Group	A column in the periodic table.
Guard cell	A type of cell found on either side of a stoma. A pair of these cells controls the stoma's size.
Habitat	The place where an organism lives.
Haemoglobin	A red pigment found in red blood cells which carries oxygen.
Half-life	The time it takes for the number of nuclei of a radioactive isotope in a sample to halve. OR The time it takes for the count rate (or activity) of a radioactive sample to fall to half its initial level.
Hazard	Something that could cause harm (e.g. fire, electricity, etc.).
Heterozygous	When an organism has two alleles for a particular gene that are different.
Homeostasis	The regulation of conditions inside your body and cells in order to maintain a stable internal environment.
Homologous series	A group of chemicals that react in a similar way because they have the same functional group. E.g. the alcohols or the carboxylic acids.
Homozygous	When an organism has two alleles for a particular gene that are the same.
Hormone	A chemical messenger which travels in the blood to act on a target cell.
Hydrocarbon	A compound that is made from only hydrogen and carbon.
Hypothesis	A possible explanation for a scientific observation.
I-V characteristic	A graph of current against potential difference for a component.
Inbreeding	When closely related animals or plants are bred together.
Incomplete combustion	When a fuel burns but there isn't enough oxygen for it to burn completely. Products can include carbon monoxide and carbon particulates. Also known as partial combustion.
Independent variable	The variable in an experiment that is changed.
Indicator	A substance that changes colour above or below a certain pH.
Induced magnet	An object that turns into a magnet when it is placed inside another magnetic field.
Inelastic deformation	An object undergoing inelastic deformation will not return to its original shape and length once the forces being applied to it are removed.
Infrared (IR) radiation	A type of electromagnetic wave that is given out by all objects. It can also be absorbed by objects which makes the object hotter.
Inherited disorder	A disorder caused by a faulty allele, which can be passed on to an individual's offspring.

Insoluble	A substance is insoluble if it does not dissolve in a particular solvent.
Insulin	A hormone produced and secreted by the pancreas when the blood glucose level is too high. It causes cells to take up more glucose from the blood, reducing the blood glucose level.
Interdependence	Where, in a community, different species depend on each other for things such as food, shelter, pollination and seed dispersal.
Intermolecular force	A force of attraction that exists between molecules.
Internal energy	The total energy that a system's particles have in their kinetic and potential energy stores.
Ion	A charged particle formed when one or more electrons are lost or gained from an atom or molecule.
Ionic bond	A strong attraction between oppositely charged ions.
Ionic compound	A compound that contains positive and negative ions held together in a regular arrangement (a lattice) by electrostatic forces of attraction.
Ionic lattice	A closely-packed regular arrangement of particles held together by electrostatic forces of attraction.
Ionising radiation	Radiation that has enough energy to knock electrons off atoms.
Irradiation	Exposure to radiation.
Isotope	A different form of the same element, which has atoms with the same number of protons (atomic number), but a different number of neutrons (and so different mass number).
Joules	The standard unit of energy.
Kinetic energy store	Anything that's moving has energy in its kinetic energy store.
Latent heat	The energy required to change the state of a substance without changing its temperature.
Lattice	A closely-packed regular arrangement of particles.
Life cycle assessment	An assessment of the environmental impact of a product over the course of its life.
Light-dependent resistor (LDR)	A resistor whose resistance is dependent on light intensity. The resistance decreases as light intensity increases.
Limit of proportionality	The point beyond which the force applied to an elastic object is no longer directly proportional to the extension of the object.
Limiting factor	A factor which prevents a reaction from going any faster.
Line of action (of a force)	A straight line passing through the point at which the force is acting in the same direction as the force.
Linear graph	A straight line graph.
Lipase	A type of digestive enzyme that catalyses the breakdown of lipids into fatty acids and glycerol, in the small intestine.
Litmus	A single indicator that's blue in alkalis and red in acids.
Live wire	The brown wire in an electrical cable that carries an alternating potential difference from the mains.
Longitudinal wave	A wave in which the vibrations are along the same line as the direction of energy transfer.
Lubricant	A substance used between two objects to reduce friction between surfaces.
Magnetic field	A region where magnetic materials (like iron and steel) experience a force.
Magnetic material	A material (such as iron, steel, cobalt or nickel) which is attracted to magnets.
Mass number	The total number of protons and neutrons in an atom.
Mean (average)	A measure of average found by adding up all the data and dividing by the number of values there are.
Median (average)	A measure of average found by selecting the middle value from a data set arranged in order from smallest to largest.
Meiosis	A type of cell division where a cell divides twice to produce four genetically different gametes. It occurs in the reproductive organs.

Menstrual cycle	A monthly sequence of events during which the body prepares the lining of the uterus (womb) in case it receives a fertilised egg, and releases an egg from an ovary. The uterus lining then breaks down if the egg has not been fertilised.
Meristem tissue	Tissue found at the growing tips of plant shoots and roots that is able to differentiate into any type of plant cell.
Metabolism	All the chemical reactions that happen in a cell (or in the body).
Metal	An element that can form positive ions when it reacts.
Metal ore	Rocks that are found naturally in the Earth's crust containing enough metal to make the metal profitable to extract.
Metallic bond	The attraction between metal ions and delocalised electrons in a metal.
Microwave	A type of electromagnetic wave that can be used for cooking and satellite communications.
Mitochondria	Structures in a cell where most of the reactions for aerobic respiration take place.
Mitosis	A type of cell division where a cell divides once, to form two new identical cells.
Mixture	A substance made from two or more elements or compounds that aren't chemically bonded to each other.
Mobile phase	In chromatography, the mobile phase is a gas or liquid where the molecules are able to move.
Mode (average)	A measure of average found by selecting the most frequent value from a data set.
Model	A simple way of describing or showing what's going on in real life.
Molecule	A particle made up of at least two atoms held together by covalent bonds.
Molecular formula	A chemical formula showing the actual number of atoms of each element in a compound.
Motor neurone	A nerve cell that carries electrical impulses from the CNS to effectors.
MRSA	A strain of bacteria that is resistant to most known antibiotics.
Mutation	A random change in an organism's DNA.
National grid	The network of transformers and cables that distributes electrical power from power stations to consumers.
Natural resource	A resource formed without human input.
Natural selection	The process by which species evolve.
Nervous system	The organ system in animals that allows them to respond to changes in their environment.
Neurone	A nerve cell. Neurones transmit information around the body, including to and from the CNS.
Neutral substance	A substance with a pH of 7.
Neutral wire	The blue wire in an electrical cable that current in an appliance normally flows through. It is around 0 V.
Neutralisation reaction	The reaction between acids and bases that leads to the formation of neutral products — usually a salt and water.
Neutron	A particle found in the nucleus of an atom. It has no charge.
Newton's First Law	An object will remain at rest or travelling at a constant velocity unless it is acted on by a resultant force.
Newton's Second Law	The acceleration of an object is directly proportional to the resultant force acting on it, and inversely proportional to its mass.
Newton's Third Law	When two objects interact, they exert equal and opposite forces on each other.
Non-communicable disease	A disease that cannot spread between individuals.
Non-contact force	A force that can act between objects that are not touching.
Non-metal	An element that doesn't form positive ions when it reacts, with the exception of hydrogen.
Non-renewable energy resource	An energy resource that is non-renewable cannot be made at the same rate as it's being used.

Normal (at a boundary)	A line that's perpendicular (at 90°) to a surface at the point of incidence (where a wave hits the surface).
Nuclear model	An accepted theory which describes the atom as having a tiny, positively charged nucleus surrounded by shells which are occupied by negative electrons.
Nucleus (atom)	The centre of an atom, containing protons and neutrons.
Nucleus (of a cell)	A structure found in animal and plant cells which contains the genetic material that controls the activities of the cell.
Obesity	A condition where a person has an excessive amount of body fat, to the point where it poses a risk to their health.
Ohmic conductor	A conductor with resistance that is constant at a constant temperature. It has a linear *I*-*V* characteristic.
Optimum dose	The dose of a drug that is most effective and has few side effects.
Optimum level (in the body)	A level of something (e.g. water, ions or glucose) that enables the body to work at its best.
Organ	A group of different tissues that work together to perform a function.
Organ system	A group of organs working together to perform a function.
Organic compound	A chemical compound that contains carbon atoms.
Osmosis	The movement of water molecules across a partially permeable membrane from a region of higher water concentration to a region of lower water concentration.
Oxidation	A reaction where electrons are lost or oxygen is gained by a species.
Oxygen debt	The amount of extra oxygen that your body needs after exercise.
Paper chromatography	An analytical technique that can be used to separate and analyse coloured substances.
Parallel circuit	A circuit in which every component is connected separately to the positive and negative ends of the battery.
Partially permeable membrane	A membrane with tiny holes in it, which lets some molecules through but not others.
Pathogen	A microorganism that causes disease, e.g. a bacterium, virus, protist or fungus.
Peer-review	The process in which other scientists check the results and explanations of an investigation before they are published.
Period	A row in the periodic table.
Period (of a wave)	The time taken for one complete wave to pass a certain point.
Periodic table	A table of all the known elements, arranged in order of atomic number so that elements with similar chemical properties are in groups.
Permanent magnet	An object that always has its own magnetic field around it.
Permanent vacuole	A structure in plant cells that contains cell sap.
pH scale	A scale from 0 to 14 that is used to measure how acidic or alkaline a solution is.
Phagocytosis	The process by which white blood cells engulf (surround) pathogens and digest them.
Phenotype	The characteristics you have, e.g. brown eyes.
Phloem	A type of plant tissue which transports food substances (dissolved sugars) around a plant.
Photosynthesis	The process by which plants use energy to convert carbon dioxide and water into glucose and oxygen.
Physical change	A change where you don't end up with a new substance — it's the same substance as before, just in a different form. (A change of state is a physical change.)
Placebo	A substance that is like a drug being tested, but which doesn't do anything.
Plasma	The liquid part of blood, which carries blood cells and other substances around the body.
Platelet	A small fragment of a cell found in the blood, which helps blood to clot at a wound.

Plum pudding model	A disproved theory of the atom as a ball of positive charge with electrons inside it.
Polydactyly	An inherited disorder caused by a dominant allele, where a person has extra fingers or toes.
Polymer	A long chain molecule that is formed by joining lots of smaller molecules (monomers) together.
Potable water	Water that is safe for drinking.
Potential difference	The driving force that pushes electric charge around a circuit, measured in volts (V). Also known as pd or voltage.
Power	The rate of transferring energy (or doing work). Normally measured in watts (W).
Precipitate	A solid that is formed in a solution during a chemical reaction.
Precise result	When all the data is close to the mean.
Predator	An animal that hunts and kills other animals for food.
Prediction	A statement based on a hypothesis that can be tested.
Pressure	The force per unit area exerted on a surface.
Prey	An animal that is hunted and killed by another animal for food.
Primary consumer	An organism in a food chain that feeds on a producer.
Producer	An organism at the start of a food chain that makes its own food using energy from the Sun.
Product	A substance that is formed in a chemical reaction.
Prokaryotic cell	A small, simple cell, e.g. a bacterium.
Protease	A type of digestive enzyme that catalyses the breakdown of proteins into amino acids, in the stomach and small intestine.
Protein	A large biological molecule made up of long chains of amino acids.
Protist	A type of pathogen. Protists are often transferred to other organisms by a vector.
Proton	A positively charged particle found in the nucleus of an atom.
Punnett square	A type of genetic diagram.
Pure substance	A substance that only contains one compound or element throughout.
Quadrat	A square frame enclosing a known area. It is used to study the distribution of organisms.
Radiation dose	A measure of the risk of harm to your body due to exposure to radiation.
Radio wave	A type of electromagnetic wave mainly used for radio and TV signals.
Radioactive decay	The random process of a radioactive substance giving out radiation from the nuclei of its atoms.
Radioactive substance	A substance that spontaneously gives out radiation from the nuclei of its atoms.
Random error	A difference in the results of an experiment caused by unpredictable events, e.g. human error in measuring.
Range	The difference between the smallest and largest values in a set of data.
Rate of reaction	How fast the reactants in a reaction are changed into products.
Ray	A straight line showing the path along which the wave moves.
Ray diagram	A diagram that shows the path of light waves.
Reactant	A substance that reacts in a chemical reaction.
Reaction profile	A graph that shows how the energy in a reaction changes as the reaction progresses (also known as an energy level diagram).
Reaction time	The time taken for a person to react after an event (e.g. seeing a hazard).
Reactivity series	A list of elements arranged in order of their reactivity. The most reactive elements are at the top and the least reactive at the bottom.
Receptor	A group of cells that are sensitive to a stimulus (e.g. receptor cells in the eye detect light).
Recessive allele	An allele whose characteristic only appears in an organism if it has two copies of the allele.

Reduction	A reaction where electrons are gained or oxygen is lost.
Reflex	A fast, automatic response to a stimulus.
Refraction	When a wave changes direction as it passes across the boundary between two materials at an angle to the normal.
Relative atomic mass (A_r)	The average mass of the atoms of an element measured relative to the mass of one atom of carbon-12. The relative atomic mass of an element is the same as its mass number in the periodic table.
Relative formula mass (M_r)	All the relative atomic masses (A_r) of the atoms in a compound added together.
Relay neurone	A nerve cell that carries electrical impulses from sensory neurones to motor neurones.
Renewable energy resource	An energy resource that is renewable is one that is being, or can be, made at the same rate (or faster) than it's being used.
Repeatable result	A result that will come out the same if the experiment is repeated by the same person using the same method and equipment.
Repeating unit	The shortest repeating section of a polymer.
Reproducible result	A result that will come out the same if someone different does the experiment.
Resistance	Anything in a circuit that reduces the flow of charge. Measured in ohms, Ω.
Respiration	The process of breaking down glucose to transfer energy, which goes on in every cell.
Resultant force	A single force that can replace all the forces acting on an object to give the same effect as the original forces acting altogether.
Reversible reaction	A reaction where the products of the reaction can themselves react to produce the original reactants.
R_f value	In chromatography, the ratio between the distance travelled by a dissolved substance and the distance travelled by a solvent.
Ribosome	A structure in a cell, where proteins are made.
Right-hand thumb rule	The rule to work out the direction of the magnetic field around a current-carrying wire. Your thumb points in the direction of the current, and your fingers curl in the direction of the magnetic field.
Risk	The chance that a hazard will cause harm.
Risk factor	Something that is linked to an increased chance that a person will develop a disease.
S.I. unit	A standard unit of measurement, recognised by scientists all over the world.
Scalar	A quantity that has magnitude but no direction.
Secondary consumer	An organism in a food chain that eats a primary consumer.
Selective breeding (artificial selection)	When humans select the plants or animals that are going to breed together, so that the genes for useful characteristics become more common in the population.
Sensory neurone	A nerve cell that carries electrical impulses from a receptor in a sense organ to the CNS.
Series circuit	A circuit in which every component is connected in a line, end to end.
Sex chromosome (humans)	One of the 23rd pair of chromosomes, X or Y. Together they determine whether an individual is male or female.
Sexual reproduction	When two gametes combine to produce a new individual that is genetically different.
Significant figure	The first significant figure of a number is the first non-zero digit. The second, third and fourth significant figures follow on immediately after it.
Simple distillation	A way of separating a liquid out from a mixture if there are large differences in the boiling points of the substances.
Simple molecule	A molecule made up of only a few atoms held together by covalent bonds.
Solar cell	A device that generates electricity directly from the Sun's radiation.
Solenoid	A coil of wire.

Solute	A substance dissolved in a solvent to make a solution.
Solution	A mixture made up of one substance (the solute) dissolved in another (the solvent).
Solvent	A liquid in which another substance (a solute) can be dissolved.
Solvent front	The point the solvent has reached up the filter paper during paper chromatography.
Species	A group of similar organisms that can reproduce to give fertile offspring.
Specific heat capacity	The amount of energy (in joules) needed to raise the temperature of 1 kg of a material by 1°C.
Specific latent heat (SLH)	The amount of energy needed to change 1 kg of a substance from one state to another without changing its temperature. (For cooling, it is the energy released by a change in state.)
Specific latent heat of fusion	The specific latent heat for changing between a solid and a liquid (melting or freezing).
Specific latent heat of vaporisation	The specific latent heat for changing between a liquid and a gas (evaporating, boiling or condensing).
Stable community	A community where all the species and environmental factors are in balance. This means that the population sizes stay about the same.
Standard form	A number written in the form $A \times 10^n$, where A is a number between 1 and 10.
State of matter	The form which a substance can take — e.g. solid, liquid or gas.
State symbol	The letter, or letters, in brackets that are placed after a substance in an equation to show what physical state it's in. E.g. gaseous carbon dioxide is shown as $CO_{2(g)}$.
Statins	A group of drugs that are used to decrease the risk of heart and circulatory disease.
Stationary phase	In chromatography, the stationary phase is a solid or really thick liquid where molecules are unable to move.
Stem cell	An undifferentiated cell that can become one of many different types of cell, or produce more stem cells.
Stent	A wire mesh tube that's put inside an artery to help keep it open.
Stimulus	A change in the environment.
Stoma	A tiny hole in the surface of a leaf.
Stopping distance	The distance covered by a vehicle in the time between the driver spotting a hazard and the vehicle coming to a complete stop. It's the sum of the thinking distance and the braking distance.
Structural adaptation	A feature of an organism's body structure that helps it to survive in its environment.
Sustainable development	An approach to development that takes into the account the needs of present society while not damaging the lives of those in the future.
Synapse	A connection between two neurones.
System	The object, or group of objects, that you're considering.
Systematic error	An error that is consistently made throughout an experiment.
Tangent	A straight line that touches a curve at a particular point without crossing it.
Terminal velocity	The maximum velocity a falling object can reach without any added driving forces. It's the velocity at which the resistive forces (drag) acting on the object match the force due to gravity (weight).
Tertiary consumer	An organism in a food chain that eats a secondary consumer.
Theory	A hypothesis which has been accepted by the scientific community because there is good evidence to back it up.
Thermal conductivity	A measure of how quickly an object transfers energy by heating through conduction.
Thermal decomposition	A reaction where one substance chemically changes into at least two new substances when it's heated.
Thermal insulator	A material with a low thermal conductivity.

Thermistor	A resistor whose resistance is dependent on the temperature. The resistance decreases as temperature increases.
Thinking distance	The distance a vehicle travels during the driver's reaction time (before the brakes have been applied).
Three-core cable	An electrical cable containing a live wire, a neutral wire and an earth wire.
Tissue	A group of similar cells that work together to carry out a function.
Toxicity	How harmful something is, e.g. a drug.
Toxin	A poison. Toxins are often produced by bacteria.
Transect	A line which can be used to study the distribution of organisms across an area.
Transformer	A device which can change the potential difference of an ac supply.
Translocation	The movement of food substances (e.g. dissolved sugars) around a plant.
Transpiration stream	The movement of water from a plant's roots, through the xylem and out of the leaves.
Transverse wave	A wave in which the vibrations are perpendicular (at 90°) to the direction of energy transfer.
Tumour	A growth of abnormal cells.
Ultraviolet (UV) radiation	A type of electromagnetic wave, the main source of which is sunlight.
Uncertainty	The amount of error measurements might have.
Universal indicator	A wide range indicator that changes colour depending on the pH of the solution that it's in.
Urea	A waste product (produced from the breakdown of proteins in the liver).
Vaccination	Injecting dead or inactive pathogens to produce an immune response that will help to protect you against the same pathogen in the future.
Valid result	A repeatable and reproducible result from an experiment designed to be a fair test.
Valve	A structure in the heart or in a vein that prevents blood from flowing in the wrong direction.
Variation	The differences that exist between individuals.
Vector (in disease)	An organism that transfers a disease from one animal or plant to another, which doesn't get the disease itself.
Vector (physics)	A quantity which has both magnitude (size) and a direction.
Vein	A blood vessel that carries blood to the heart.
Velocity	The speed and direction of an object.
Velocity-time graph	A graph showing how the velocity of an object changes over a period of time.
Virus	A tiny disease-causing agent that can only replicate within body cells.
Viscosity	How runny or gloopy a substance is.
Visible light	The part of the electromagnetic spectrum that we can see with our eyes.
Voltmeter	A component used to measure the potential difference across a component. Always connected in parallel with the component.
Wave	A vibration that transfers energy without transferring any matter.
Wavelength	The length of a full cycle of a wave, e.g. from a crest to the next crest.
Weight	The force acting on an object due to gravity.
White blood cell	A blood cell that is also part of the immune system, defending the body against disease.
Work done	The energy transferred when a force moves an object through a distance, or by a moving charge.
X-ray	A high-frequency, short-wavelength electromagnetic wave. It is mainly used in medical imaging and treatment.
Xylem	A type of plant tissue which transports water and mineral ions around a plant.

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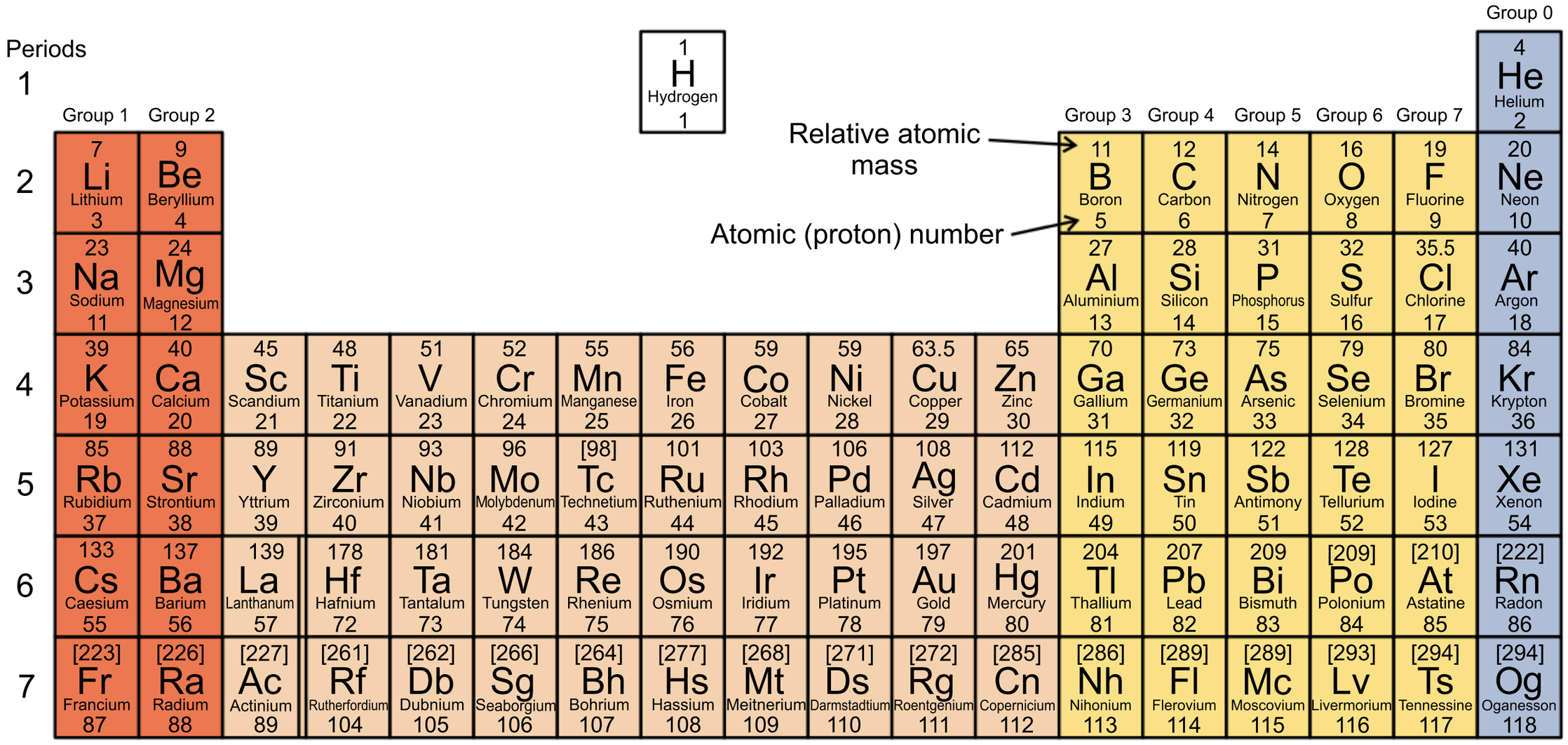
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The Periodic Table



The Lanthanides (atomic numbers 58-71) and the Actinides (atomic numbers 90-103) are not shown in this table.

Formula Triangles

Formula Triangles

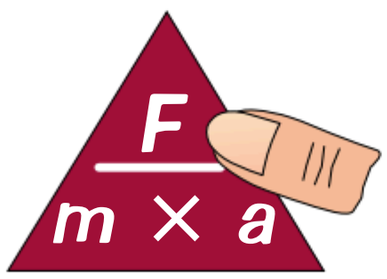
It's pretty important to learn how to put any formula into a triangle. There are two easy rules:

1) If the formula is "$A = B \times C$" then A goes on the top and $B \times C$ goes on the bottom.
2) If the formula is "$A = B \div C$" then B must go on the top
(because that's the only way it'll give "B divided by something")
— and so pretty obviously A and C must go on the bottom.

Two Examples:

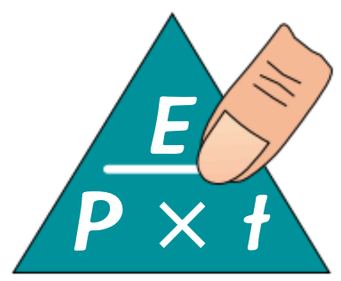
$F = ma$

turns into:



$P = E \div t$

turns into:



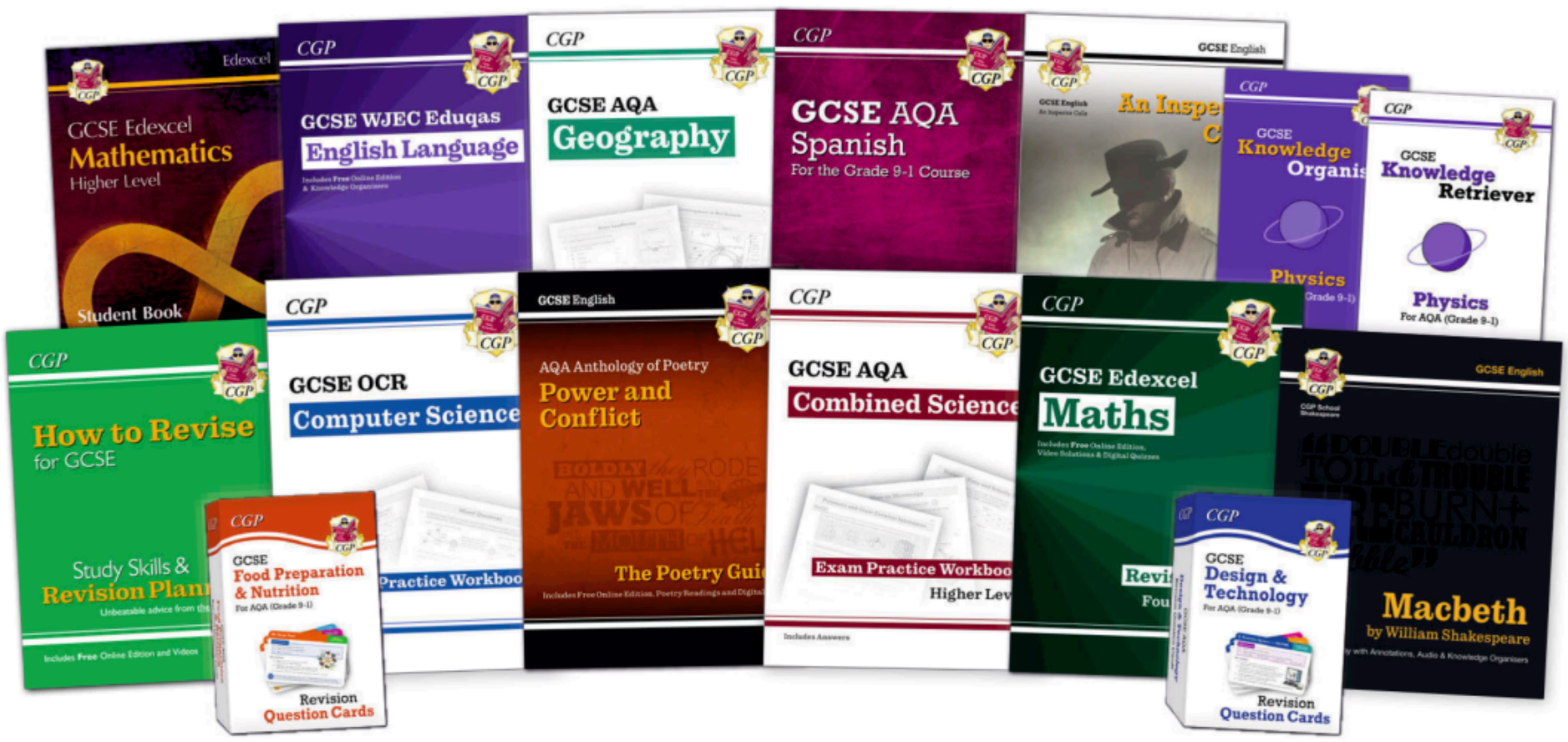
How to use them: Cover up the thing you want to find and write down what's left showing.

EXAMPLE: To find m from the first one, cover up m and you get $\frac{F}{a}$ left showing, so "$m = \frac{F}{a}$".

Using Formulas — the Three Rules:

1) Find a formula which contains the thing you want to find together with the other things which you've got values for. Convert that formula into a formula triangle.
2) Think very carefully about all the units, then stick the numbers in.
3) Work out the answer and check that it is sensible.

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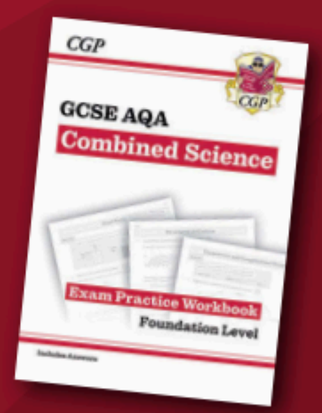
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