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Revision Guide

Higher Level

GCSE

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Revision Guide

Higher Level

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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, Tamara Sinivassen and George Wright.
Contributors: Michael Bossart and Paddy Gannon.

With thanks to Lottie Edwards for the copyright research.

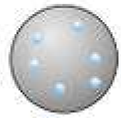
Printed by Elanders Ltd, Newcastle upon Tyne.
Clipart from Corel®
Illustrations by: Sandy Gardner Artist, email sandy@sandygardner.co.uk

The Scientific Method

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

Scientists Come Up With Hypotheses — Then Test Them

1) Scientists try to explain things. They start by observing something they don't understand.
2) They then come up with a hypothesis — a possible explanation for what they've observed.
3) The next step is to test whether the hypothesis might be right or not. This involves making a prediction based on the hypothesis and testing it by gathering evidence (i.e. data) from investigations. If evidence from experiments backs up a prediction, you're a step closer to figuring out if the hypothesis is true.



About 100 years ago, scientists hypothesised that atoms looked like this.

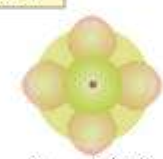
Several Scientists Will Test a Hypothesis

1) Normally, scientists share their findings in peer-reviewed journals, or at conferences.
2) Peer-review is where other scientists check results and scientific explanations to make sure they're 'scientific' (e.g. that experiments have been done in a sensible way) before they're published. It helps to detect false claims, but it doesn't mean that findings are correct — just that they're not wrong in any obvious way.
3) Once other scientists have found out about a hypothesis, they'll start basing their own predictions on it and carry out their own experiments. They'll also try to reproduce the original experiments to check the results — and if all the experiments in the world back up the hypothesis, then scientists start to think the hypothesis is true.
4) However, if a scientist does an experiment that doesn't fit with the hypothesis (and other scientists can reproduce the results) then the hypothesis may need to be modified or scrapped altogether.

After more evidence was gathered, scientists changed their hypothesis to this.

If All the Evidence Supports a Hypothesis, It's Accepted — For Now

1) Accepted hypotheses are often referred to as theories. Our currently accepted theories are the ones that have survived this 'trial by evidence' — they've been tested many times over the years and survived.
2) However, theories never become totally indisputable fact. If new evidence comes along that can't be explained using the existing theory, then the hypothesising and testing is likely to start all over again.



Now we think it's more like this.

Theories Can Involve Different Types of Models

1) A representational model is a simplified description or picture of what's going on in real life. Like all models, it can be used to explain observations and make predictions. E.g. the Bohr model of an atom is a simplified way of showing the arrangement of electrons in an atom (see p.103). It can be used to explain trends down groups in the periodic table.

   Scientists test models by carrying out experiments to check that the predictions made by the model happen as expected.

2) Computational models use computers to make simulations of complex real-life processes, such as climate change. They're used when there are a lot of different variables (factors that change) to consider, and because you can easily change their design to take into account new data.
3) All models have limitations on what they can explain or predict. E.g. ball and stick models (a type of spatial model) can be used to show how ions are arranged in an ionic compound. One of their limitations is that they don't show the relative sizes of the ions (see p.114).

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

The scientific method has developed over time, and many people have helped to develop it. From Aristotle to modern day scientists, lots of people have contributed. And many more are likely to contribute in the future.

Communication & Issues Created by Science

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

It's Important to Communicate Scientific Discoveries to the Public

Some scientific discoveries show that people should change their habits, or they might provide ideas that could be developed into new technology. So scientists need to tell the world about their discoveries.

Gene technologies are used in genetic engineering to produce genetically modified crops. Information about these crops needs to be communicated to farmers who might benefit from growing them and to the general public, so they can make informed decisions about the food they buy and eat.

Scientific Evidence can be Presented in a Biased Way

1) Reports about scientific discoveries in the media (e.g. newspapers or television) aren't peer-reviewed.
2) This means that, even though news stories are often based on data that has been peer-reviewed, the data might be presented in a way that is over-simplified or inaccurate, making it open to misinterpretation.
3) People who want to make a point can sometimes present data in a biased way. (Sometimes without knowing they're doing it.) For example, a scientist might overemphasise a relationship in the data, or a newspaper article might describe details of data supporting an idea without giving any evidence against it.

Scientific Developments are Great, but they can Raise Issues

Scientific knowledge is increased by doing experiments. And this knowledge leads to scientific developments, e.g. new technologies or new advice. These developments can create issues though. For example:

Economic issues: Society can't always afford to do things scientists recommend (e.g. investing in alternative energy sources) without cutting back elsewhere.

Personal issues: Some decisions will affect individuals. For example, someone might support alternative energy, but object if a wind farm is built next to their house.

Social issues: Decisions based on scientific evidence affect people — e.g. should fossil fuels be taxed more highly? Would the effect on people's lifestyles be acceptable...

Environmental issues: Human activity often affects the natural environment. For example, building a dam to produce electricity will change the local habitat so some species might be displaced. But it will also reduce our need for fossil fuels, so will help to reduce climate change.

Science Can't Answer Every Question — Especially Ethical Ones

1) We don't understand everything. We're always finding out more, but we'll never know all the answers.
2) In order to answer scientific questions, scientists need data to provide evidence for their hypotheses.
3) Some questions can't be answered yet because the data can't currently be collected, or because there's not enough data to support a theory.
4) Eventually, as we get more evidence, we'll answer some of the questions that currently can't be answered, e.g. what the impact of global warming on sea levels will be. But there will always be the "Should we be doing this at all?"-type questions that experiments can't help us to answer...

Think about new drugs which can be taken to boost your 'brain power'.

- Some people think they're good as they could improve concentration or memory. New drugs could let people think in ways beyond the powers of normal brains.
- Other people say they're bad — they could give you an unfair advantage in exams. And people might be pressured into taking them so that they could work more effectively, and for longer hours.

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.

Risk

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

Nothing is Completely Risk-Free

1) A hazard is something that could potentially cause harm.
2) All hazards have a risk attached to them — this is the chance that the hazard will cause harm.
3) The risks of some things seem pretty obvious, or we've known about them for a while, like the risk of causing acid rain by polluting the atmosphere, or of having a car accident when you're travelling in a car.
4) New technology arising from scientific advances can bring new risks, e.g. scientists are unsure whether nanoparticles that are being used in cosmetics and suncream might be harming the cells in our bodies. These risks need to be considered alongside the benefits of the technology, e.g. improved sun protection.
5) You can estimate the size of a risk based on how many times something happens in a big sample (e.g. 100 000 people) over a given period (e.g. a year). For example, you could assess the risk of a driver crashing by recording how many people in a group of 100 000 drivers crashed their cars over a year.
6) To make decisions about activities that involve hazards, we need to take into account the chance of the hazard causing harm, and how serious the consequences would be if it did. If an activity involves a hazard that's very likely to cause harm, with serious consequences if it does, it's considered high risk.

People Make Their Own Decisions About Risk

1) Not all risks have the same consequences, e.g. if you chop veg with a sharp knife you risk cutting your finger, but if you go scuba-diving you risk death. You're much more likely to cut your finger during half an hour of chopping than to die during half an hour of scuba-diving. But most people are happier to accept a higher probability of an accident if the consequences are short-lived and fairly minor.
2) People tend to be more willing to accept a risk if they choose to do something (e.g. go scuba diving), compared to having the risk imposed on them (e.g. having a nuclear power station built next door).
3) People's perception of risk (how risky they think something is) isn't always accurate. They tend to view familiar activities as low-risk and unfamiliar activities as high-risk — even if that's not the case. For example, cycling on roads is often high-risk, but many people are happy to do it because it's a familiar activity. Air travel is actually pretty safe, but a lot of people perceive it as high-risk.
4) People may underestimate the risk of things with long-term or invisible effects, e.g. using tanning beds.

Investigations Can be Hazardous

1) Hazards from science experiments might include:
   - Microorganisms, e.g. some bacteria can make you ill.
   - Chemicals, e.g. sulfuric acid can burn your skin and alcohols catch fire easily.
   - Fire, e.g. an unattended Bunsen burner is a fire hazard.
   - Electricity, e.g. faulty electrical equipment could give you a shock.

2) Part of planning an investigation is making sure that it's safe.
3) You should always make sure that you identify all the hazards that you might encounter. Then you should think of ways of reducing the risks from the hazards you've identified. For example:
   - If you're working with sulfuric acid, always wear gloves and safety goggles. This will reduce the risk of the acid coming into contact with 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.

You can find out about potential hazards by looking in textbooks, doing some Internet research, or asking your teacher.

Not revising — an unacceptable exam hazard...

The world's a dangerous place, but if you can recognise hazards, decide how to reduce their risks, and be happy to accept some risks, you can still have fun. Just maybe don't go skydiving with a great white shark on Friday 13th.

Designing Investigations

Dig out your lab coat and dust down your badly-scratched safety goggles... it's investigation time.

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 determine whether or not a hypothesis is right, you need to do an investigation to gather evidence. 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.
3) Investigations are used to see if there are patterns or relationships between two variables, e.g. to see if there's a pattern or relationship between the variables 'number of spots' and 'size of feet'.

Evidence Needs to be Repeatable, Reproducible and Valid

Investigations include experiments and studies.

1) Repeatable means that if the same person does an experiment again using the same methods and equipment, they'll get similar results.
2) Reproducible means that if someone else does the experiment, or a different method or piece of equipment is used, the results will still be similar.
3) If data is repeatable and reproducible, it's reliable and scientists are more likely to have confidence in it.
4) Valid results are both repeatable and reproducible AND they answer the original question. They come from experiments that were designed to be a FAIR TEST...

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

1) In a lab experiment you usually change one variable and measure how it affects another variable.
2) To make it a fair test, everything else that could affect the results should stay the same — otherwise you can't tell if the thing you're changing is causing the results or not.
3) The variable you CHANGE is called the INDEPENDENT variable.
4) The variable you MEASURE when you change the independent variable is the DEPENDENT variable.
5) The variables that you KEEP THE SAME are called CONTROL variables.

   You could find how temperature affects the rate of an enzyme-controlled reaction. The independent variable is the temperature. The dependent variable is the rate of reaction. Control variables include the concentration and amounts of reactants, pH, the time period you measure, etc.

6) Because you can't always control all the variables, you often need to use a control experiment. 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 at all.

The Bigger the Sample Size the Better

1) Data based on small samples isn't as good as data based on large samples. A sample should represent the whole population (i.e. it should share as many of the characteristics in the population as possible) — a small sample can't do that as well. It's also harder to spot anomalies if your sample size is too small.
2) The bigger the sample size the better, but scientists have to be realistic when choosing how big. For example, if you were studying the effects of living near a nuclear power plant, it'd be great to study everyone who lived near a nuclear power plant (a huge sample), but it'd take ages and cost a bomb. It's more realistic to study a thousand people, with a range of ages, gender, and race.

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

Not only do 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 or not it needs improving. Those examiners aren't half demanding.

Collecting Data

You've designed the perfect investigation — now it's time to get your hands mucky and collect some data.

Your Data Should be Repeatable, Reproducible, Accurate and Precise

1) To check repeatability you need to repeat the readings and check that the results are similar. You need to repeat each reading at least three times.
2) To make sure your results are reproducible you can cross check them by taking a second set of readings with another instrument (or a different observer).
3) Your data also needs to be ACCURATE. Really accurate results are those that are really close to the true answer. The accuracy of your results usually depends on your method — you need to make sure you're measuring the right thing and that you don't miss anything that should be included in the measurements. E.g. estimating the amount of gas released from a reaction by counting the bubbles isn't very accurate because you might miss some of the bubbles and they might have different volumes. It's more accurate to measure the volume of gas released using a gas syringe (see p.232).
4) Your data also needs to be PRECISE. Precise results are ones where the data is all really close to the mean (average) of your repeated results (i.e. not spread out).

Beth's result was a curate.

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.

Your Equipment has to be Right for the Job

1) The measuring equipment you use has to be sensitive enough to measure the changes you're looking for. For example, if you need to measure changes of 1 cm^3 you need to use a measuring cylinder or burette that can measure in 1 cm^3 steps — it'd be no good trying with one that only measures 10 cm^3 steps.
2) The smallest change a measuring instrument can detect is called its RESOLUTION. E.g. some mass balances have a resolution of 1 g, some have a resolution of 0.1 g, and some are even more sensitive.
3) Also, equipment needs to be calibrated by measuring a known value. If there's a difference between the measured and known value, you can use this to correct the inaccuracy of the equipment.

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 — unpredictable differences caused by things like human errors in measuring. The errors when you make a reading from a ruler are random. You have to estimate or round the distance when it's between two marks — so sometimes your figure will be a bit above the real one, and sometimes it will be a bit below.
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 measured from the very end of your ruler instead of from the 0 cm mark every time, all your measurements would be a bit small. Repeating the experiment in the exact same way and calculating a mean won't correct a systematic error.

If there's no systematic error, then doing repeats and calculating a mean can make your results more accurate.

4) Just to make things more complicated, if a systematic error is caused by using equipment that isn't zeroed properly, it's called a ZERO ERROR. For example, if a mass balance always reads 1 gram before you put anything on it, all your measurements will be 1 gram too heavy.
5) You can compensate for some systematic errors if you know about them though, e.g. if your mass balance always reads 1 gram before you put anything on it you can subtract 1 gram from all your results.
6) Sometimes you get a result that doesn't fit in with the rest at all. This is called an ANOMALOUS RESULT. You should investigate it and try to work out what happened. If you can work out what happened (e.g. you measured something totally wrong) you can ignore it when processing your results.

Watch what you say to that mass balance — it's very sensitive...

Weirdly, data can be really precise but not very accurate. For example, a fancy piece of lab equipment might give results that are really precise, but if it's not been calibrated properly those results won't be accurate.

Processing and Presenting Data

Processing your data means doing some calculations with it to make it more useful. Once you've done that, you can present your results in a nice chart or graph to help you spot any patterns in your data.

Data Needs to be Organised

Tables are dead useful for organising data. When you draw a table use a ruler and make sure each column has a heading (including the units).

You Might Have to Process Your Data

1) When you've done repeats of an experiment you should always calculate the mean (a type of average). To do this add together all the data values and divide by the total number of values in the sample.
2) You might also need to calculate the range (how spread out the data is). To do this find the largest number and subtract the smallest number from it.

Ignore anomalous results when calculating these.

EXAMPLE

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

Repeat 1 (cm^3)	Repeat 2 (cm^3)	Repeat 3 (cm^3)	Mean (cm^3)	Range (cm^3)
28	37	32	(28 + 37 + 32) ÷ 3 = 32	37 – 28 = 9

3) You might also need to calculate the median or mode (two more types of average). To calculate the median, put all your data in numerical order — the median is the middle value. The number that appears most often in a data set is the mode.

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.

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

Round to the Lowest Number of Significant Figures

The first significant figure of a number is the first digit that's not zero. The second and third significant figures come straight after (even if they're zeros). You should be aware of significant figures in calculations.

1) In any calculation, you should round the answer to the lowest number of significant figures (s.f.) given.
2) Remember to write down how many significant figures you've rounded to after your answer.
3) If your calculation has multiple steps, only round the final answer, or it won't be as accurate.

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.) — Final answer should be rounded to 2 s.f.

(0.24 g: 2 s.f.; 0.715 cm^3: 3 s.f.)

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

1) If the independent variable is categoric (comes in distinct categories, e.g. flower colour, blood group) you should use a bar chart to display the data.
2) You also use them if the independent variable is discrete (the data can be counted in chunks, where there's no in-between value, e.g. number of protons is discrete because you can't have half a proton).
3) There are some golden rules you need to follow for drawing bar charts:

If Your Data is Continuous, Plot a Graph

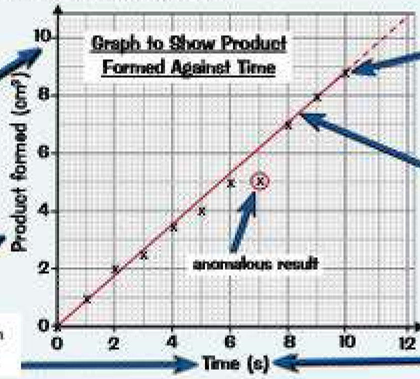
If both variables are continuous (numerical data that can have any value within a range, e.g. length, volume, temperature) you should use a graph to display the data.

Here are the rules for plotting points on a graph:

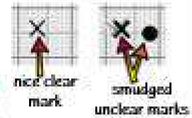
Use the biggest data values you've got to draw a sensible scale on your axes. Here, the highest amount of product formed is 8.8 cm^3, so it makes sense to label the y-axis up to 10 cm^3.

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).



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

Draw it nice and big (covering at least half of the graph paper).

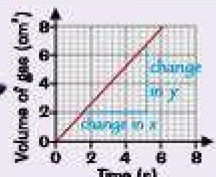
Remember to include the units.

Graphs Can Give You a Lot of Information About Your Data

1) The gradient (slope) of a graph tells you how quickly the dependent variable changes if you change the independent variable.

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

This graph shows the volume of gas produced in a reaction against time. The graph is linear (it's a straight line graph), so you can simply calculate the gradient of the line to find out the rate of reaction.



1) To calculate the gradient, pick two points on the line that are easy to read and a good distance apart.
2) Draw a line down from one of the points and a line across from the other to make a triangle. The line drawn down the side of the triangle is the change in y and the line across the bottom is the change in x.

Change in y = 6.8 – 2.0 = 4.8 cm^3 Change in x = 5.2 – 1.6 = 3.6 s

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

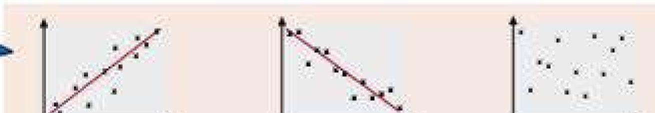
The units of the gradient are (units of y)/(units of x). cm^3/s can also be written as cm^3s^{-1}.

You can use this method to calculate other rates from a graph, not just the rate of a reaction. Just remember that a rate is how much something changes over time, so x needs to be the time.

2) To find the gradient of a curve at a certain point, draw a tangent to the curve at that point and then find the gradient of the tangent. See page 146 for details on how to do this.
3) The intercept of a graph is where the line of best fit crosses one of the axes. The x-intercept is where the line of best fit crosses the x-axis and the y-intercept is where it crosses the y-axis.

Graphs Show the Relationship Between Two Variables

1) You can get three types of correlation (relationship) between variables:
2) Just because there's correlation, it doesn't mean the change in one variable is causing the change in the other — there might be other factors involved (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 and Equations

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) It wouldn't be all that useful if I defined volume in terms of bath tubs, you defined it in terms of egg-cups and my pal Sarwat defined it in terms of balloons — we'd never be able to compare our data.
2) To stop this happening, scientists have come up with a set of standard units, called S.I. units, that all scientists use to measure their data. Here are some S.I. units you'll see in GCSE Science:

Quantity	S.I. Base Unit
mass	kilogram, kg
length	metre, m
time	second, s
amount of a substance	mole, mol
temperature	kelvin, K

Scaling Prefixes Can Be Used for Large and Small Quantities

1) Quantities come in a huge range of sizes. For example, the volume of a swimming pool might be around 2 000 000 000 cm^3, while the volume of a cup is around 250 cm^3.
2) To make the size of numbers more manageable, larger or smaller units are used. These are the S.I. base unit (e.g. metres) with a prefix in front:

prefix	tera (T)	giga (G)	mega (M)	kilo (k)	deci (d)	centi (c)	milli (m)	micro (μ)	nano (n)
multiple of unit	10^{12}	10^{9}	1 000 000 (10^{6})	1000	0.1	0.01	0.001	0.000001 (10^{-6})	10^{-9}

3) These prefixes tell you how much bigger or smaller a unit is than the base unit. So one kilometre is one thousand metres.
4) To swap from one unit to another, all you need to know is what number you have to divide or multiply by to get from the original unit to the new unit — this is called the conversion factor.

The conversion factor is the number of times the smaller unit goes into the larger unit.

- To go from a bigger unit (like m) to a smaller unit (like cm), you multiply by the conversion factor.
- To go from a smaller unit (like g) to a bigger unit (like kg), you divide by the conversion factor.

5) Here are some conversions that'll be useful for GCSE Science:

Mass can have units of kg and g.

Energy can have units of J and kJ.

Volume can have units of m^3, dm^3 and cm^3.

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

Always Check The Values Used in Equations Have the Right Units

1) Formulas and equations show relationships between variables.
2) To rearrange an equation, make sure that whatever you do to one side of the equation you also do to the other side.

You can find the speed of a wave using the equation: wave speed = frequency × wavelength. You can rearrange this equation to find the frequency by dividing each side by wavelength to give: frequency = wave speed ÷ wavelength.

3) To use a formula, you need to know the values of all but one of the variables. Substitute the values you do know into the formula, and do the calculation to work out the final variable.
4) Always make sure the values you put into an equation or formula have the right units. For example, you might have done an experiment to find the speed of a trolley. The distance the trolley travels will probably have been measured in cm, but the equation to find speed uses distance in m. So you'll have to convert your distance from cm to m before you put it into the equation.
5) To make sure your units are correct, it can help to write down the units on each line of your calculation.

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

It's easy to get in a muddle when converting between units, but there's a handy way to check you've done it right. 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're nearly at the end of a gruelling investigation, time to draw conclusions.

You Can Only Conclude What the Data Shows and NO MORE

1) Drawing conclusions might seem pretty straightforward — you just look at your data and say what pattern or relationship you see between the dependent and independent variables.

The table on the right shows the rate of a reaction in the presence of two different catalysts:

Catalyst	Rate of reaction (cm^3/s)
A	13.5
B	19.5
No catalyst	5.5

CONCLUSION: Catalyst B makes this reaction go faster than catalyst A.

2) But you've got to be really careful that your conclusion matches the data you've got and doesn't go any further.

You can't conclude that catalyst B increases the rate of any other reaction more than catalyst A — the results might be completely different.

3) You also need to be able to use your results to justify your conclusion (i.e. back up your conclusion with some specific data).

The rate of this reaction was 6 cm^3/s faster using catalyst B compared with catalyst A.

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

The hypothesis for this experiment might have been that catalyst B would make the reaction go quicker than catalyst A. If so, the data supports the hypothesis.

Correlation DOES NOT Mean Cause

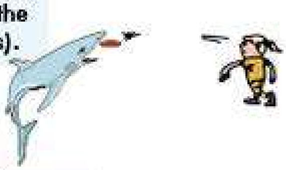
If two things are correlated (i.e. there's a relationship between them) it doesn't necessarily mean a change in one variable is causing the change in the other — this is REALLY IMPORTANT — DON'T FORGET IT. There are three possible reasons for a correlation:

1) CHANCE: It might seem strange, but two things can show a correlation purely due to chance.

For example, one study might find a correlation between people's hair colour and how good they are at frisbee. But other scientists don't get a correlation when they investigate it — the results of the first study are just a fluke.

2) LINKED BY A 3RD VARIABLE: A lot of the time it may look as if a change in one variable is causing a change in the other, but it isn't — a third variable links the two things.

For example, there's a correlation between water temperature and shark attacks. This isn't because warmer water makes sharks crazy. Instead, they're linked by a third variable — the number of people swimming (more people swim when the water's hotter, and with more people in the water you get more shark attacks).



3) CAUSE: Sometimes a change in one variable does cause a change in the other. You can only conclude that a correlation is due to cause when you've controlled all the variables that could, just could, be affecting the result.

For example, there's a correlation between smoking and lung cancer. This is because chemicals in tobacco smoke cause lung cancer. This conclusion was only made once other variables (such as age and exposure to other things that cause cancer) had been controlled and shown not to affect people's risk of getting lung cancer.

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

...although, just because I find it dull doesn't mean that I can conclude it's dull (you might think it's the most interesting thing since that kid got his head stuck in the railings near school). 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.

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) When you repeat a measurement, you often get a slightly different figure each time you do it due to random error. This means that each result has some uncertainty to it.
2) The measurements you make will also have some uncertainty in them due to limits in the resolution of the equipment you use (see page 5).
3) This all means that the mean of a set of results will also have some uncertainty to it. You can calculate the uncertainty of a mean result using the equation:
4) The larger the range, the less precise your results are and the more uncertainty there will be in your results. 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 a respiration experiment to determine the volume of carbon dioxide produced. Calculate the uncertainty of the mean.

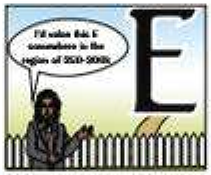
Repeat	1	2	3	mean
Volume of CO_2 produced (cm^3)	20.1	19.8	20.0	20.0

1) First work out the range:
Range = 20.1 – 19.8
= 0.300 cm^3

2) Use the range to find the uncertainty:
Uncertainty = range ÷ 2 = 0.300 ÷ 2 = 0.150 cm^3. So the uncertainty of the mean = 20.0 ± 0.150 cm^3

5) Measuring a greater amount of something helps to reduce uncertainty. For example, in a rate of reaction experiment, measuring the amount of product formed over a longer period compared to a shorter period will reduce the percentage uncertainty in your results.

Evaluations — Describe How it Could be Improved



An evaluation is a critical analysis of 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? Were there any other variables that could have affected the results? You should comment on the level of uncertainty in your results too.
4) All this analysis will allow you to say how confident you are that your conclusion is right.
5) Then you can suggest any changes to the method that would improve the quality of the results, so that you could have more confidence in your conclusion. For example, you might suggest changing the way you controlled a variable, or increasing the number of measurements you took. Taking more measurements at narrower intervals could give you a more accurate result. For example:

Enzymes have an optimum temperature (a temperature at which they work best). Say you do an experiment to find an enzyme's optimum temperature and take measurements at 10 °C, 20 °C, 30 °C, 40 °C and 50 °C. The results of this experiment tell you the optimum is 40 °C. You could then repeat the experiment, taking more measurements around 40 °C to a get a more accurate value for the optimum.

6) You could also make more predictions based on your conclusion, then further experiments could be carried out to test them.

When suggesting improvements to the investigation, always make sure that you say why you think this would make the results better.

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

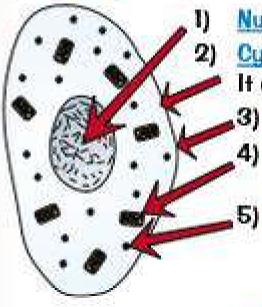
When someone first peered down a microscope at a slice of cork and drew the boxes they saw, little did they know that they'd seen the building blocks of every organism on the planet...

Organisms can be Prokaryotes or Eukaryotes

1) All living things are made of cells.
2) Cells can be either prokaryotic or eukaryotic. Eukaryotic cells are complex and include all animal and plant cells. Prokaryotic cells are smaller and simpler, e.g. bacteria (see below).
3) Eukaryotes are organisms that are made up of eukaryotic cells.
4) A prokaryote is a prokaryotic cell (it's a single-celled organism).

Plant and Animal Cells have Similarities and Differences

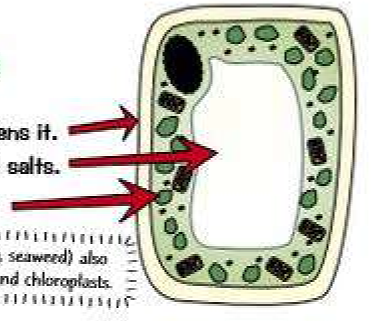
The different parts of a cell are called subcellular structures.
Most animal cells have the following subcellular structures — make sure you know them all:



1) Nucleus — contains genetic material that controls the activities of the cell.
2) Cytoplasm — gel-like substance where most of the chemical reactions happen. It contains enzymes (see page 25) that control these chemical reactions.
3) Cell membrane — holds the cell together and controls what goes in and out.
4) Mitochondria — these are where most of the reactions for aerobic respiration take place (see page 55). 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, plus a few extra things that animal cells don't have:

1) Rigid cell wall — made of cellulose. It supports the cell and strengthens it.
2) Permanent vacuole — contains cell sap, a weak solution of sugar and salts.
3) Chloroplasts — these are where photosynthesis occurs, which makes food for the plant (see page 50). They contain a green substance called chlorophyll, which absorbs the light needed for photosynthesis.

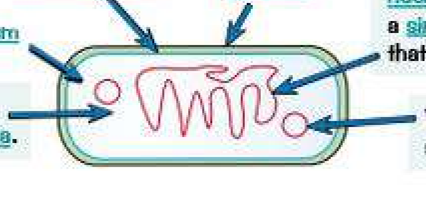


The cells of algae (e.g. seaweed) also have a rigid cell wall and chloroplasts.

Bacterial Cells Are Much Smaller

You might see the sizes of cells written in standard form (see the next page).

Bacteria are prokaryotes. Here's what a bacterial cell might look like:



Cell structures — become an estate agent...

You could get asked to estimate the area of a subcellular structure in your exam. If you do, treat it as a regular shape. For example, if it's close to a rectangle, use the area formula 'area = length × width'.

Q1 Give two differences in structure between prokaryotic and eukaryotic cells. [2 marks]

Microscopy

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

Cells are Studied Using Microscopes

1) Microscopes let us see things that we can't see with the naked eye. The microscopy techniques we can use have developed over the years as technology and knowledge have improved.
2) Light microscopes use light and lenses to form an image of a specimen and magnify it (make it look bigger). They let us see individual cells and large subcellular structures, like nuclei.
3) Electron microscopes use electrons instead of light to form an image. They have a much higher magnification than light microscopes.
4) They also have a higher resolution. (Resolution is the ability to distinguish between two points, so a higher resolution gives a sharper image.)
5) Electron microscopes let us see much smaller things in more detail, like the internal structure of mitochondria and chloroplasts. They even let us see tinier things like ribosomes and plasmids.

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

You Need to be Able to Use the Formula for Magnification

You can calculate 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. If they don't, you'll need to convert them first (see page 8).

If you want to work out the image size or the real size of the object, you can rearrange the equation using this formula triangle:

Cover up the thing you're trying to find. The parts you can still see are the formula you need to use.

EXAMPLE

A specimen is 50 μm wide. Calculate the width of the image of the specimen under a magnification of × 100. Give your answer in mm.

1) Rearrange the formula. — image size = magnification × real size
2) Fill in the values you know. — image size = 100 × 50
3) Remember the units in your answer. — = 5000 μm
4) Convert the units. — = 5 mm

Remember, to convert from micrometres (μm) to millimetres (mm), you need to divide by 1000 (see p.8). E.g. 5000 μm ÷ 1000 = 5 mm

You Need to Know How to Work With Numbers in Standard Form

1) Because microscopes can see such tiny objects, sometimes it's useful to write numbers in standard form.
2) This is where you change very big or small numbers with lots of zeros into something more manageable, e.g. 0.017 can be written 1.7×10^{-2}.
3) To do this you just need to move the decimal point left or right.
4) The number of places the decimal point moves is then represented by a power of 10 — this is positive if the decimal point's moved to the left, and negative if it's moved to the right.

EXAMPLE

A mitochondrion is approximately 0.0025 mm long. Write this figure 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. Don't forget the minus sign because the decimal point has moved right.

0.0025

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

It's all very well knowing what microscopes do — you also have to know how to actually use one.

You Need to Prepare Your Slide

If you want to look at a specimen (e.g. plant or animal cells) under a light microscope, you need to put it on a microscope slide first. A slide is a strip of clear glass or plastic onto which the specimen is mounted.

Here's how to prepare a slide to view onion cells:

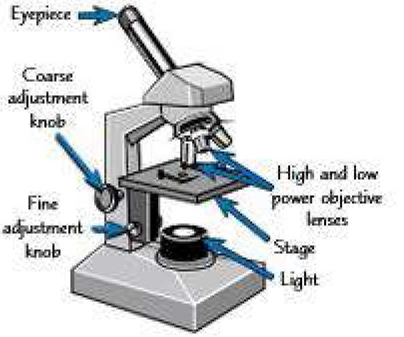
1) Add a drop of water to the middle of a clean slide.
2) Cut up an onion and separate it out into layers. Use tweezers to peel off some epidermal tissue from the bottom of one of the layers.
3) Using the tweezers, place the epidermal tissue into the water on the slide.
4) Add a drop of iodine solution. Iodine solution is a stain. Stains are used to highlight objects in a cell by adding colour to them.

5) Place a cover slip (a square of thin, transparent plastic or glass) on top. To do this, stand the cover slip upright on the slide, next to the water droplet. Then carefully tilt and lower it so it covers the specimen. Try not to get any air bubbles under there — they'll obstruct your view of the specimen.

Use a Light Microscope to Look at Your Slide

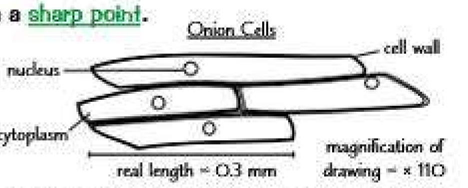
To look at your prepared slides, you need to know how to use a light microscope:

1) Clip the slide you've prepared onto the stage.
2) Select the lowest-powered objective lens (i.e. the one that produces 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. Use the coarse adjustment knob to move the stage downwards until the image is roughly in focus.
5) Adjust the focus with the fine adjustment knob, until you get a clear image of what's on the slide.
6) If you need to see the slide with greater magnification, swap to a higher-powered objective lens and refocus.



Draw Your Observations Neatly with a Pencil

1) Draw what you see under the microscope using a pencil with a sharp point.
2) Make sure your drawing takes up at least half of the space available and that it is drawn with clear, unbroken lines.
3) Your drawing should not include any colouring or shading.
4) If you are drawing cells, the subcellular structures should be drawn in proportion.
5) Remember to include a title of what you were observing and write down the magnification that it was observed under.
6) Label the important features of your drawing (e.g. nucleus, chloroplasts), using straight, uncrossed lines.



You can work out the real size of a cell by counting the number of cells you can see along 1 mm (see p.234). You can work out the magnification of your drawing using this formula: magnification = length of drawing of cell ÷ real length of cell. So here, magnification = 33 mm ÷ 0.3 mm = × 110.

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.

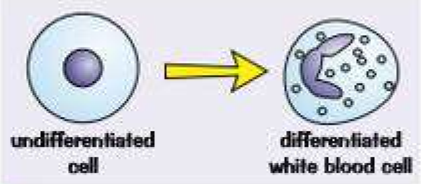
Q1 Why might you add stain to the sample on a microscope slide? [1 mark]

Cell Differentiation and Specialisation

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

Cells Differentiate to Become Specialised

1) Differentiation is the process by which a cell changes to become specialised for its job.
2) As cells change, they develop different subcellular structures and turn into different types of cells. This allows them to carry out specific functions.
3) Most differentiation occurs as an organism develops. In most animal cells, the ability to differentiate is then lost at an early stage, after they become specialised. However, lots of plant cells don't ever lose this ability.
4) The cells that differentiate in mature animals are mainly used for repairing and replacing cells, such as skin or blood cells.



5) Some cells are undifferentiated cells — they're called stem cells. There's more about them on page 16.

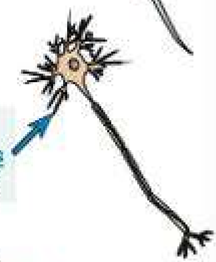
You Need To Know These Examples of Specialised Cells

SPERM CELLS are specialised for REPRODUCTION

The function of a sperm is basically to get the male DNA to the female DNA. It has a long tail and a streamlined head to help it swim to the egg. There are a lot of mitochondria in the cell to provide the energy needed. It also carries enzymes in its head to digest through the egg cell membrane.

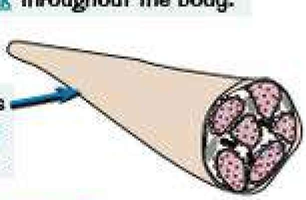
NERVE CELLS are specialised for RAPID SIGNALLING

The function of nerve cells is to carry electrical signals from one part of the body to another. These cells are long (to cover more distance) and have branched connections at their ends to connect to other nerve cells and form a network throughout the body.



MUSCLE CELLS are specialised for CONTRACTION

The function of a muscle cell is to contract quickly. These cells are long (so that they have space to contract) and contain lots of mitochondria to generate the energy needed for contraction.

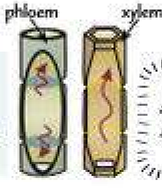


ROOT HAIR CELLS are specialised for absorbing WATER and MINERALS

Root hair cells are cells on the surface of plant roots, which grow into long "hairs" that stick out into the soil. This gives the plant a big surface area for absorbing water and mineral ions from the soil.

PHLOEM and XYLEM CELLS are specialised for TRANSPORTING SUBSTANCES

Phloem and xylem cells form phloem and xylem tubes, which transport substances such as food and water around plants. To form the tubes, the cells are long and joined end to end. Xylem cells are hollow in the centre and phloem cells have very few subcellular structures, so that stuff can flow through them.



There's more about phloem and xylem on page 40.

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

You need to know how the structure of each of the cells on this page relates to its function. Lucky you.

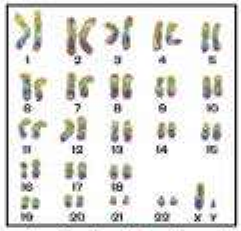
Q1 Plants transport food substances from the leaves to growing parts of the plant through phloem tubes. Give one feature of a phloem cell that makes it specialised for its function. [1 mark]

Q2 Describe how a root hair cell is specialised for its function. [2 marks]

Chromosomes and Mitosis

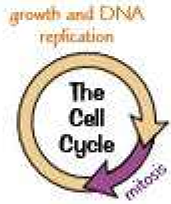
In order to survive and grow, our cells have got to be able to divide. And that means our DNA as well...

Chromosomes Contain Genetic Information

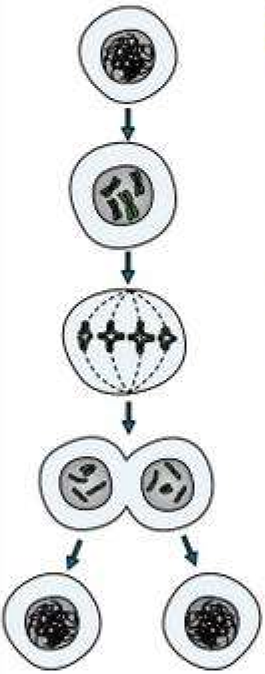


1) Most cells in your body have a nucleus. The nucleus contains your genetic material in the form of chromosomes.
2) Chromosomes are coiled up lengths of DNA molecules.
3) Each chromosome carries a large number of genes. Different genes control the development of different characteristics, e.g. hair colour.
4) Body cells normally have two copies of each chromosome — one from the organism's 'mother', and one from its 'father'. So, humans have two copies of chromosome 1, two copies of chromosome 2, etc.
5) The diagram shows the 23 pairs of chromosomes from a human cell.

The Cell Cycle Makes New Cells for Growth, Development and Repair



1) Body cells in multicellular organisms divide to produce new cells as 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 or replace cells that have been damaged.
4) The end of the cell cycle results in two new cells identical to the original cell, with the same number of chromosomes.
5) You need to know about these two main stages of the cell cycle:



Growth & DNA Replication

1) In a cell that's not dividing, the DNA is all spread out in long strings.
2) Before it divides, the cell has to grow and increase the amount of subcellular structures such as mitochondria and ribosomes.
3) It then duplicates its DNA — so there's one copy for each new cell. The DNA is copied and forms X-shaped chromosomes. Each 'arm' of the chromosome is an exact duplicate of the other.

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

Mitosis

Once its contents and DNA have been copied, the cell is ready for mitosis...

4) The chromosomes line up at the centre of the cell and cell fibres pull them apart. The two arms of each chromosome go to opposite ends of the cell.
5) Membranes form around each of the sets of chromosomes. These become the nuclei of the two new cells — the nucleus has divided.
6) Lastly, the cytoplasm and cell membrane divide.

The cell has now produced two new daughter cells. The daughter cells contain exactly the same DNA — they're identical. Their DNA is also identical to the parent 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 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]

Q1 Video Solution

Stem Cells

Stem cell research has exciting possibilities, but it's also pretty controversial.

Embryonic Stem Cells Can Turn into ANY Type of Cell

1) Differentiation is the process by which a cell changes to become specialised for its job — see p.14.
2) Undifferentiated cells, called stem cells, can divide to produce lots more undifferentiated cells. They can differentiate into different types of cell, depending on what instructions they're given.
3) Stem cells are found in early human embryos. They're exciting to doctors and medical researchers because they have the potential to turn into any kind of cell at all. This makes sense if you think about it — all the different types of cell found in a human being have to come from those few cells in the early embryo.
4) Adults also have stem cells, but they're only found in certain places, like bone marrow. Unlike embryonic stem cells, they can't turn into any cell type at all, only certain ones, such as blood cells.
5) Stem cells from embryos and bone marrow can be grown in a lab to produce clones (genetically identical cells) and made to differentiate into specialised cells to use in medicine or research.

Stem Cells May Be Able to Cure Many Diseases

1) Medicine already uses adult stem cells to cure disease. For example, stem cells transferred from the bone marrow of a healthy person can replace faulty blood cells in the patient who receives them.
2) Embryonic stem cells could also be used to replace faulty cells in sick people — you could make insulin-producing cells for people with diabetes, nerve cells for people paralysed by spinal injuries, and so on.
3) In a type of cloning, called therapeutic cloning, an embryo could be made to have the same genetic information as the patient. This means that the stem cells produced from it would also contain the same genes and so wouldn't be rejected by the patient's body if used to replace faulty cells.
4) However, there are risks involved in using stem cells in medicine. For example, stem cells grown in the lab may become contaminated with a virus which could be passed on to the patient and so make them sicker.

Some People Are Against Stem Cell Research

1) Some people are against stem cell research because they feel that human embryos shouldn't be used for experiments since each one is a potential human life.
2) Others think that curing existing 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 which, if they weren't used for research, would probably just be destroyed.
4) However, campaigners for the rights of embryos feel that scientists should concentrate more on finding and developing other sources of stem cells, so people could be helped without having to use embryos.
5) In some countries stem cell research is banned. It's allowed in the UK as long as it follows strict guidelines.

Stem Cells Can Produce Identical Plants

1) In plants, stem cells are found in the meristems (parts of the plant where growth occurs — see p.39).
2) Throughout the plant's entire life, cells in the meristem tissues can differentiate into any type of plant cell.

- These stem cells can be used to produce clones (identical copies) of whole plants quickly and cheaply.
- They can be used to grow more plants of rare species (to prevent them being wiped out).
- Stem cells can also be used to grow crops of identical plants that have desired features for farmers, for example, disease resistance.

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

Whatever your opinion is, make sure you know the uses of stem cells and the arguments for and against using them.

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

Diffusion

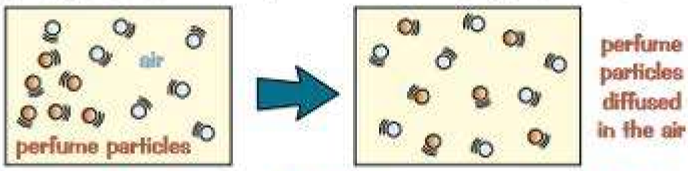
Particles move about randomly, and after a bit they end up evenly spaced. It's not rocket science, is it...

Don't Be Put Off by the Fancy Word

1) "Diffusion" is simple. It's just the gradual movement of particles from places where there are lots of them to places where there are fewer of them — it's just the natural tendency for stuff to spread out.
2) Unfortunately you also have to learn the fancy way of saying the same thing, which is this:

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

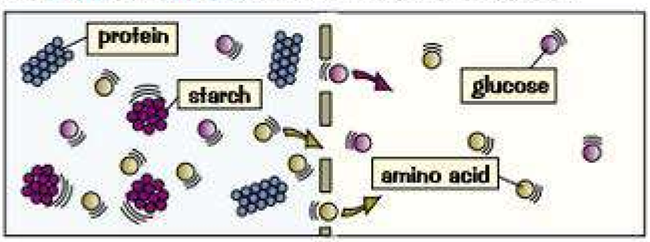
3) Diffusion happens in both solutions and gases — that's because the particles in these substances are free to move about randomly.
4) The simplest type is when different gases diffuse through each other. This is what's happening when the smell of perfume diffuses through the air in a room:



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

Cell Membranes Are Kind of Clever...

1) They're clever because they hold the cell together BUT they let stuff in and out as well.
2) Dissolved substances can move in and out of cells by diffusion.
3) Only very small molecules can diffuse through cell membranes though — things like oxygen (needed for respiration — see page 55), glucose, amino acids and water.
4) Big molecules like starch and proteins can't fit through the membrane:



5) Just like with diffusion in air, particles flow through the cell 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).
6) They're only moving about randomly of course, so they go 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.
7) The larger the surface area of the membrane, the faster the diffusion rate, because more particles can pass through at once — see page 20.

Revision by diffusion — you wish...

Wouldn't it be great if all the ideas in this book would just gradually 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]

Q1 Video Solution

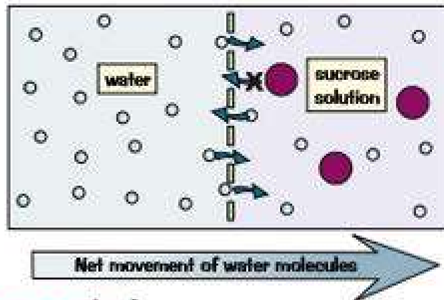
Osmosis

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

Osmosis is a Special Case of Diffusion, That's All

OSMOSIS is the movement of water molecules across a partially permeable membrane from a region of higher water concentration to a region of lower water concentration.

1) A partially permeable membrane is just one with very small holes in it. So small, in fact, only tiny molecules (like water) can pass through them, and bigger molecules (e.g. sucrose) can't.
2) The water molecules actually pass both ways through the membrane during osmosis. This happens because water molecules move about randomly all the time.
3) But because there are more water molecules on one side than on the other, there's a steady net flow of water into the region with fewer water molecules, i.e. into the stronger sugar solution.
4) This means the strong sugar solution gets more dilute. The water acts like it's trying to "even up" the concentration either side of the membrane.



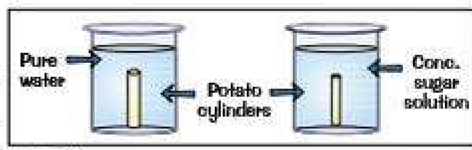
5) Osmosis is a type of diffusion — passive movement of water particles from an area of higher water concentration to an area of lower water concentration.

You can Observe the Effect of Sugar Solutions on Plant Tissue

PRACTICAL

There's a fairly dull experiment you can do to show osmosis at work.

1) You cut up an innocent potato into identical cylinders, and get some beakers with different sugar solutions in them. One should be pure water and another should be a very concentrated sugar solution (e.g. 1 mol/dm³). Then you can have a few others with concentrations in between (e.g. 0.2 mol/dm³, 0.4 mol/dm³, 0.6 mol/dm³, etc.)



2) You measure the mass of the cylinders, then leave one cylinder in each beaker for twenty four hours or so.
3) Then you take them out, dry them with a paper towel and measure their masses again.
4) If the cylinders have drawn in water by osmosis, they'll have increased in mass. If water has been drawn out, they'll have decreased in mass. You can calculate the percentage change in mass, then plot a few graphs and things.

By calculating the percentage change (see p.241), you can compare the effect of sugar concentration on cylinders that didn't have the same initial mass. An increase in mass will give a positive percentage change and a decrease will give a negative percentage change.

5) The dependent variable is the chip mass and the independent variable is the concentration of the sugar solution. All other variables (volume of solution, temperature, time, type of sugar used, etc. etc.) must be kept the same in each case or the experiment won't be a fair test.
6) Like any experiment, you need to be aware of how errors (see p.5) may arise. Sometimes they may occur when carrying out the method, e.g. if some potato cylinders were not fully dried, the excess water would give a higher mass, or if water evaporated from the beakers, the concentrations of the sugar solutions would change. You can reduce the effect of these errors by repeating the experiment and calculating a mean percentage change at each concentration.

You could also carry out this experiment using different salt solutions and see what effect they have on potato chip mass.

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.

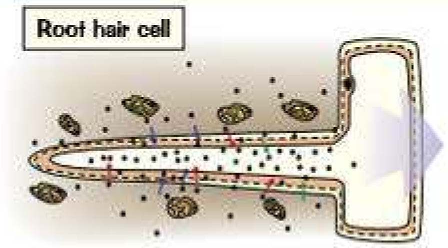
Q1 Explain what will happen to the mass of a piece of potato added to a concentrated salt solution. [2 marks]

Q1 Video Solution

Active Transport

Sometimes substances need to be absorbed against a concentration gradient, i.e. from a lower to a higher concentration. This process is lovingly referred to as ACTIVE TRANSPORT.

Root Hairs Take In Minerals and Water



1) As you saw on page 14, the cells on plant roots grow into "hairs" which stick out into the soil.
2) Each branch of a root will be covered in millions of these microscopic hairs.
3) This gives the plant a large surface area for absorbing water and mineral ions from the soil.
4) Plants need these mineral ions for healthy growth.
5) The concentration of minerals is usually higher in the root hair cells than in the soil around them.
6) So the root hair cells can't use diffusion to take up minerals from the soil.

Root Hairs Take in Minerals Using Active Transport

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

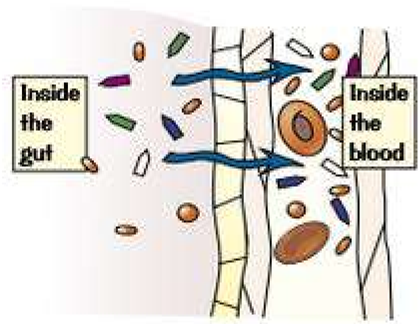
1) Minerals should move out of the root hairs if they followed the rules of diffusion. The cells must use another method to draw them in.
2) That method is, in fact, a conveniently mysterious process called "active transport".
3) Active transport allows the plant to absorb minerals from a very dilute solution, against a concentration gradient. This is essential for its growth. But active transport needs ENERGY from respiration to make it work.
4) Active transport also happens in humans, for example in taking glucose from the gut (see below), and from the kidney tubules.

We Need Active Transport to Stop Us Starving

Active transport is used in the gut when there is a lower concentration of nutrients in the gut, but a higher concentration of nutrients in the blood.

1) When there's a higher concentration of glucose and amino acids in the gut they diffuse naturally into the blood.
2) BUT — sometimes there's a lower concentration of nutrients in the gut than there is in the blood.
3) This means that the concentration gradient is the wrong way.
4) The same process used in plant roots is used here...

   ..."Active transport".
5) Active transport allows nutrients to be taken into the blood, despite the fact that the concentration gradient is the wrong way.
6) This means that glucose can be taken into the bloodstream when its concentration in the blood is already higher than in the gut. It can then be transported to cells, where it's used for respiration (see p.54).



Active transport — get on yer bike...

An important difference between active transport and diffusion is that active transport uses energy. Imagine a pen of sheep in a field. If you open the pen, the sheep will happily diffuse from the area of higher sheep concentration into the field, which has a lower sheep concentration — you won't have to do a thing. To get them back in the pen though, you'll have to put in quite a bit of energy.

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

Exchange Surfaces

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

Organisms Exchange Substances with their Environment

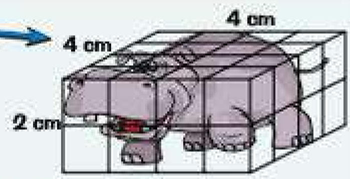
1) Cells can use diffusion to take in substances they need and get rid of waste products. For example:
   - Oxygen and carbon dioxide are transferred between cells and the environment during gas exchange.
   - In humans, urea (a waste product produced from the breakdown of proteins) diffuses from cells into the blood plasma for removal from the body by the kidneys.
2) How easy it is for an organism to exchange substances with its environment depends on the organism's surface area to volume ratio (SA : V).

You Can Compare Surface Area to Volume Ratios

A ratio shows how big one value is compared to another. The larger an organism is, the smaller its surface area is compared to its volume. You can show this by calculating surface area to volume ratios:

A hippo can be represented by a 2 cm × 4 cm × 4 cm block.
The area of a surface is found by the equation: LENGTH × WIDTH
So the hippo's total surface area is:

$(4 \times 4) \times 2$ (top and bottom surfaces of block)
$+ (4 \times 2) \times 4$ (four sides of the block)
$= 64\ \text{cm}^2$.



The volume of a block is found by the equation: LENGTH × WIDTH × HEIGHT
So the hippo's volume is $4 \times 4 \times 2 = 32\ \text{cm}^3$.

The surface area to volume ratio of the hippo can be written as 64 : 32.
To simplify the ratio, divide both sides of the ratio by the volume.
So the surface area to volume ratio of the hippo is 2 : 1.

A mouse can be represented by a 1 cm × 1 cm × 1 cm block.
Its surface area is $(1 \times 1) \times 6 = 6\ \text{cm}^2$.
Its volume is $1 \times 1 \times 1 = 1\ \text{cm}^3$.
So the surface area to volume ratio of the mouse is 6 : 1.

The cube mouse's surface area is six times its volume, but the cube hippo's surface area is only twice its volume. So the mouse has a larger surface area compared to its volume.

Multicellular Organisms Need Exchange Surfaces

1) In single-celled organisms, gases and dissolved substances can diffuse directly into (or out of) the cell across the cell membrane. It's because they have a large surface area compared to their volume, so enough substances can be exchanged across the membrane to supply the volume of the cell.
2) Multicellular organisms have a smaller surface area compared to their volume — not enough substances can diffuse from their outside surface to supply their entire volume. This means they need some sort of exchange surface for efficient diffusion (see pages 21-22 for some examples). The exchange surface structures have to allow enough of the necessary substances to pass through.
3) Exchange surfaces are ADAPTED to maximise effectiveness:
   - 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, to get stuff into and out of the blood quickly.
   - Gas exchange surfaces in animals (e.g. alveoli) are often ventilated too — air moves in and out.

Not that I'm endorsing putting 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]

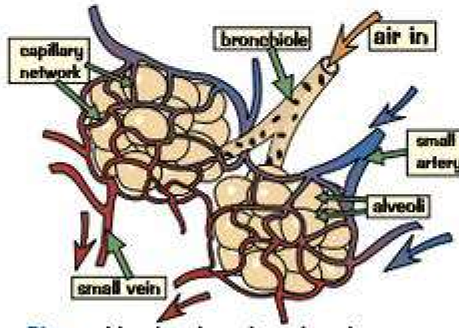
Q1 Video Solution

Exchanging Substances

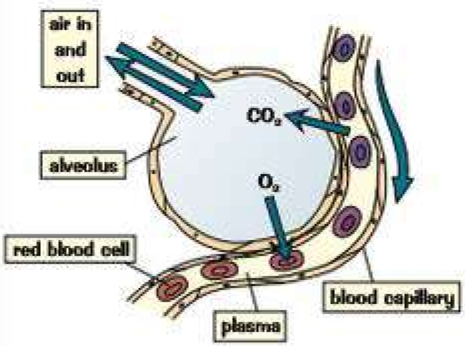
This page is about how two different parts of the human body are adapted so that substances can diffuse through them most effectively. The first bit is about how gases in the lungs get into and out of the blood. The second is about how digested food gets from the gut to the blood.

Gas Exchange Happens in the Lungs

1) The job of the lungs is to transfer oxygen to the blood and to remove waste carbon dioxide from it.
2) To do this the lungs contain millions of little air sacs called alveoli where gas exchange takes place.



Blue = blood with carbon dioxide.
Red = blood with oxygen.

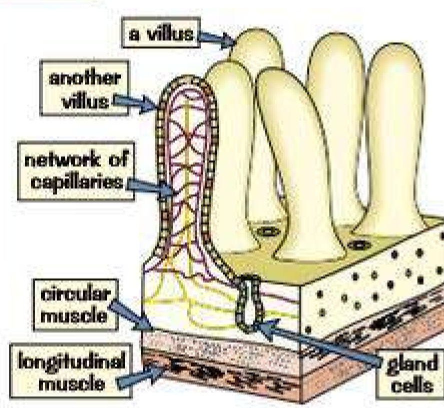


3) The alveoli are specialised to maximise the diffusion of O_2 and CO_2. They have:
   - An enormous surface area (about 75 m^2 in humans).
   - A moist lining for dissolving gases.
   - Very thin walls.
   - A good blood supply.

The Villi Provide a Really Really Big Surface Area

1) The inside of the small intestine is covered in millions and millions of these tiny little projections called villi.
2) They increase the surface area in a big way so that digested food is absorbed much more quickly into the blood.
3) Notice they have:
   - a single layer of surface cells,
   - a very good blood supply to assist quick absorption.

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]

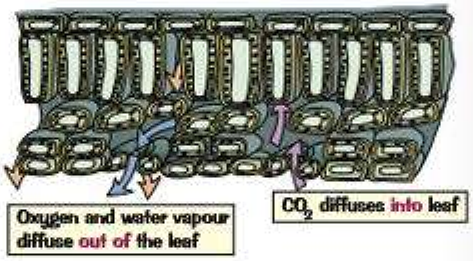
Q2 Video Solution

More on Exchanging Substances

More stuff on adaptations for diffusion now — only this time, it's plants and fish. Whoopee...

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

1) Carbon dioxide diffuses into the air spaces within the leaf, then it diffuses into the cells where photosynthesis happens. The leaf's structure is adapted so that this can happen easily.
2) The underneath of the leaf is an exchange surface. It's covered in little holes called stomata which the carbon dioxide diffuses in through.
3) Oxygen (produced in photosynthesis) and water vapour also diffuse out through the stomata. (Water vapour is actually lost from all over the leaf surface, but most of it is lost through the stomata.)
4) The size of the stomata are controlled by guard cells — see page 41. These close the stomata if the plant is losing water faster than it is being replaced by the roots. Without these guard cells the plant would soon wilt.

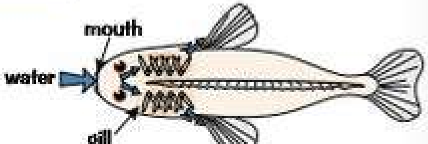


5) The flattened shape of the leaf increases the area of this exchange surface so that it's more effective.
6) The walls of the cells inside the leaf form another exchange surface. The air spaces inside the leaf increase the area of this surface so there's more chance for carbon dioxide to get into the cells.

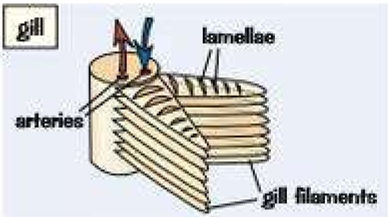
The water vapour evaporates from the cells inside the leaf. Then it escapes by diffusion because there's a lot of it inside the leaf and less of it in the air outside.

Gills Have a Large Surface Area for Gas Exchange

1) The gills are the gas exchange surface in fish.
2) Water (containing oxygen) enters the fish through its mouth and passes out through the gills. As this happens, oxygen diffuses from the water into the blood in the gills and carbon dioxide diffuses from the blood into the water.



3) Each gill is made of lots of thin plates called gill filaments, which give a big surface area for exchange of gases.



4) The gill filaments are covered in lots of tiny structures called lamellae, which increase the surface area even more.
5) The lamellae have lots of blood capillaries to speed up diffusion.
6) They also have a thin surface layer of cells to minimise the distance that the gases have to diffuse.
7) Blood flows through the lamellae in one direction and water flows over in the opposite direction. This maintains a large concentration gradient between the water and the blood.
8) The concentration of oxygen in the water is always higher than that in the blood, so as much oxygen as possible diffuses from the water into the blood.

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

There's a theme here — multicellular organisms are really well adapted for getting the substances they need to their cells. It makes sense — if they couldn't do this well, they'd die out. If you're asked in an exam how something's adapted for exchange, think about whether surface area is important — cos it often is.

Q1 Give two ways in which the structure of a gill is adapted for effective 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) Name five subcellular structures that both plant and animal cells have.
2) What three things do plant cells have that animal cells don't?
3) Where is the genetic material found in:
   a) animal cells,
   b) bacterial cells?
4) What type of organisms are bacteria — prokaryotes or eukaryotes?
5) Which gives a higher resolution — a light microscope or an electron microscope?

Differentiation and Division (p.14-15)

6) What is cell differentiation?
7) Give three ways that a sperm cell is adapted for swimming to an egg cell.
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 is mitosis used for by multicellular organisms?

Stem Cells (p.16)

12) Give two ways that embryonic stem cells could be used to cure diseases.
13) Why might some people be opposed to the use of human embryos in stem cell research?

Exchanging Substances (p.17-22)

14) What is diffusion?
15) Name three substances that can diffuse through cell membranes, and two that can't.
16) What type of molecules move by osmosis?
17) Give the two main differences between active transport and diffusion.
18) Give three adaptations of exchange surfaces that increase the efficiency of diffusion.
19) Give two ways that the villi in the small intestine are adapted for absorbing digested food.
20) Explain how leaves are adapted to maximise the amount of carbon dioxide that gets to their cells.

Cell Organisation

Some organisms contain loads of cells, but how, you might wonder, do all these cells end up making a working human or squirrel... the answer's organisation. Without it, they'd just make a meaty splodge.

Large Multicellular Organisms are Made Up of Organ Systems

1) Cells are the basic building blocks that make up all living organisms.
2) As you know from page 14, specialised cells carry out a particular function.
3) The process by which cells become specialised for a particular job is called differentiation. Differentiation occurs during the development of a multicellular organism.
4) These specialised cells form tissues, which form organs, which form organ systems (see below).
5) Large multicellular organisms (e.g. squirrels) have different systems inside them for exchanging and transporting materials.

Similar Cells are Organised into Tissues

A tissue is a group of similar cells that work together to carry out a particular function. It can include more than one type of cell.

In mammals (like humans), examples of tissues include:
1) Muscular tissue, which contracts (shortens) to move whatever it's attached to.
2) Glandular tissue, which makes and secretes chemicals like enzymes and hormones.
3) Epithelial tissue, which covers some parts of the body, e.g. the inside of the gut.

Tissues are Organised into Organs

An organ is a group of different tissues that work together to perform a certain function.

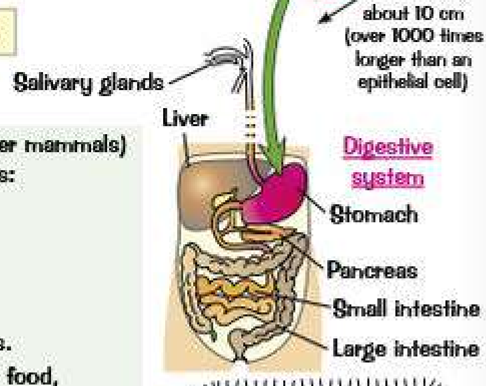
For example, the stomach is an organ made of these tissues:
1) Muscular tissue, which moves the stomach wall to churn up the food.
2) Glandular tissue, which makes digestive juices to digest food.
3) Epithelial tissue, which covers the outside and inside of the stomach.

Organs are Organised into Organ Systems

An organ system is a group of organs working together to perform a particular function.

For example, the digestive system (found in humans and other mammals) breaks down and absorbs food. It's made up of these organs:
1) Glands (e.g. the pancreas and salivary glands), which produce digestive juices.
2) The stomach and small intestine, which digest food.
3) The liver, which produces bile.
4) The small intestine, which absorbs soluble food molecules.
5) The large intestine, which absorbs water from undigested food, leaving faeces.

Organ systems work together to make entire organisms.



You need to know where these organs are on a diagram — see page 28 too.

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

So in summary, an organism consists of organ systems, which are groups of organs, which are made of tissues, which are groups of cells working together. 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 Produced by Living Things

1) Living things have thousands of different chemical reactions going on inside them all the time. These reactions need to be carefully controlled — to get the right amounts of substances.
2) You can usually make a reaction happen more quickly by raising the temperature. This would speed up the useful reactions but also the unwanted ones too... not good. There's also a limit to how far you can raise the temperature inside a living creature before its cells start getting damaged.
3) So... living things produce enzymes that act as biological catalysts. Enzymes reduce the need for high temperatures and we only have enzymes to speed up the useful chemical reactions in the body.

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

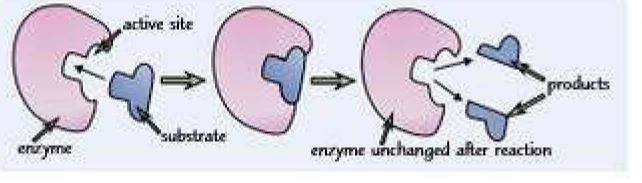
4) Enzymes are all large proteins and all proteins are made up of chains of amino acids. These chains are folded into unique shapes, which enzymes need to do their jobs (see below).

Enzymes Have Special Shapes So They Can Catalyse Reactions

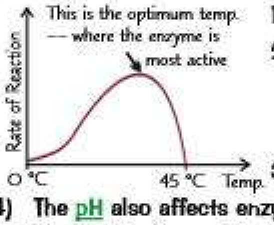
1) Chemical reactions usually involve things either being split apart or joined together.
2) Every enzyme has an active site with a unique shape that fits onto the substance involved in a reaction.
3) Enzymes are really picky — they usually only catalyse one specific reaction.
4) This is because, for the enzyme to work, the substrate has to fit into its active site. If the substrate doesn't match the enzyme's active site, then the reaction won't be catalysed.

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

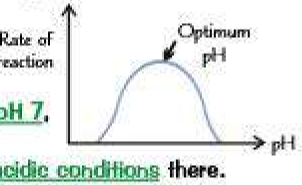
5) This diagram shows the 'lock and key' model of enzyme action. This is simpler than how enzymes actually work. In reality, the active site changes shape a little as the substrate binds to it to get a tighter fit. This is called the 'induced fit' model of enzyme action.



Enzymes Need the Right Temperature and pH



1) Changing the temperature changes the rate of an enzyme-catalysed reaction.
2) Like with any reaction, a higher temperature increases the rate at first. But if it gets too hot, some of the bonds holding the enzyme together break. This changes the shape of the enzyme's active site, so the substrate won't fit any more. The enzyme is said to be denatured.
3) All enzymes have an optimum temperature that they work best at.
4) The pH also affects enzymes. If it's too high or too low, the pH interferes with the bonds holding the enzyme together. This changes the shape of the active site and denatures the enzyme.
5) All enzymes have an optimum pH that they work best at. It's often neutral pH 7, but not always — e.g. pepsin is an enzyme used to break down proteins in the stomach. It works best at pH 2, which means it's well-suited to the acidic conditions there.



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 enzymes have an optimum pH. [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.

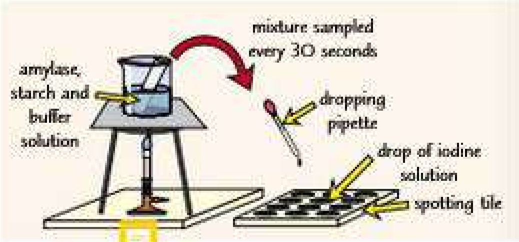
You Can Investigate the Effect of pH on Enzyme Activity

PRACTICAL

The enzyme amylase catalyses the breakdown of starch to maltose. It's easy to detect starch using iodine solution — if starch is present, the iodine solution will change from browny-orange to blue-black. This is how you can investigate how pH affects amylase activity:

You could use an electric water bath, instead of a Bunsen and a beaker of water, to control the temperature.

1) Put a drop of iodine solution into every well of a spotting tile.
2) Place a Bunsen burner on a heat-proof mat, and a tripod and gauze over the Bunsen burner. Put a beaker of water on top of the tripod and heat the water until it is 35 °C (use a thermometer to measure the temperature). Try to keep the temperature of the water constant throughout the experiment.
3) Use a syringe to add 1 cm^3 of amylase solution and 1 cm^3 of a buffer solution with a pH of 5 to a boiling tube. Using test tube holders, put the tube into the beaker of water and wait for five minutes.
4) Next, use a different syringe to add 5 cm^3 of a starch solution to the boiling tube.



5) Immediately mix the contents of the boiling tube and start a stop clock.
6) Use continuous sampling to record how long it takes for the amylase to break down all of the starch. To do this, use a dropping pipette to take a fresh sample from the boiling tube every 30 seconds and put a drop into a well. When the iodine solution remains browny-orange, starch is no longer present.
7) Repeat the whole experiment with buffer solutions of different pH values to see how pH affects the time taken for the starch to be broken down.
8) Remember to control any variables each time (e.g. concentration and volume of amylase solution) to make it a fair test.

You could use a pH meter to accurately measure the pH of your solutions.

Here's How to Calculate the Rate of Reaction

1) It's often useful to calculate the rate of reaction after an experiment. 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:

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

E.g. At pH 6, the time taken for amylase to break down all of the starch in a solution was 90 seconds. So the rate of the reaction = 1000 ÷ 90 = 11 s^{-1} (2 s.f.)

The units are in s^{-1} since rate is given per unit time.

3) If an experiment measures how much something changes over time, you calculate the rate of reaction by dividing the amount that it has changed by the time taken.

EXAMPLE

The enzyme catalase catalyses the breakdown of hydrogen peroxide into water and oxygen. During an investigation into the activity of catalase, 24 cm^3 of oxygen was released in 50 seconds (s). Calculate the rate of the reaction. Write your answer in $cm^3\ s^{-1}$.

Amount of product formed = change = 24 cm^3

Rate of reaction = change ÷ time = 24 cm^3 ÷ 50 s = 0.48 $cm^3\ s^{-1}$

$cm^3\ s^{-1}$ is another way of writing cm^3/s.

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

You could adapt this experiment to investigate how factors other than pH affect the rate of amylase activity. E.g. you could use a water bath set to different temperatures to investigate the effect of temperature.

Q1 An enzyme-controlled reaction was carried out at pH 4. After 2 minutes, 36 cm^3 of product had been released. Calculate the rate of reaction in cm^3/s. [1 mark]

Q1 Video Solution

Enzymes and Digestion

The enzymes used in digestion are produced by cells and then released into the gut to mix with food.

Digestive Enzymes Break Down Big Molecules

1) Starch, proteins and fats are BIG molecules. They're too big to pass through the walls of the digestive system, so digestive enzymes break these BIG molecules down into smaller ones like sugars (e.g. glucose and maltose), amino acids, glycerol and fatty acids. These smaller, soluble molecules can pass easily through the walls of the digestive system, allowing them to be absorbed into the bloodstream.

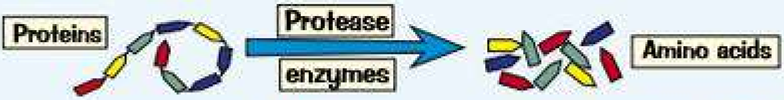
Carbohydrases Convert Carbohydrates into Simple Sugars

Amylase is an example of a carbohydrase. It breaks down starch.

Starch is a carbohydrate.

Amylase is made in three places:
1) The salivary glands 2) The pancreas 3) The small intestine

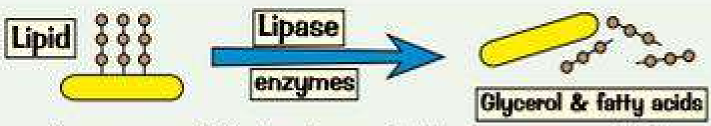
Proteases Convert Proteins into Amino Acids



Proteases are made in three places:
1) The stomach (it's called pepsin there)
2) The pancreas
3) The small intestine

Lipases Convert Lipids into Glycerol and Fatty Acids

Remember, lipids are fats and oils.



Lipases are made in two places: 1) The pancreas 2) The small intestine

2) The body makes good use of the products of digestion. They can be used to make new carbohydrates, proteins and lipids. Some of the glucose (a sugar) that's made is used in respiration (see p.54).

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) The hydrochloric acid in the stomach makes the pH too acidic for enzymes in the small intestine to work properly. Bile is alkaline — it neutralises the acid and makes conditions alkaline. The enzymes in the small intestine work best in these alkaline conditions.
3) It emulsifies fats. In other words it breaks the fat into tiny droplets. This gives a much bigger surface area of fat for the enzyme lipase to work on — which makes its digestion faster.

What do you call an acid that's eaten all the pies...

Make sure you know the examples of amylase, protease and lipase, and the reactions that they catalyse.

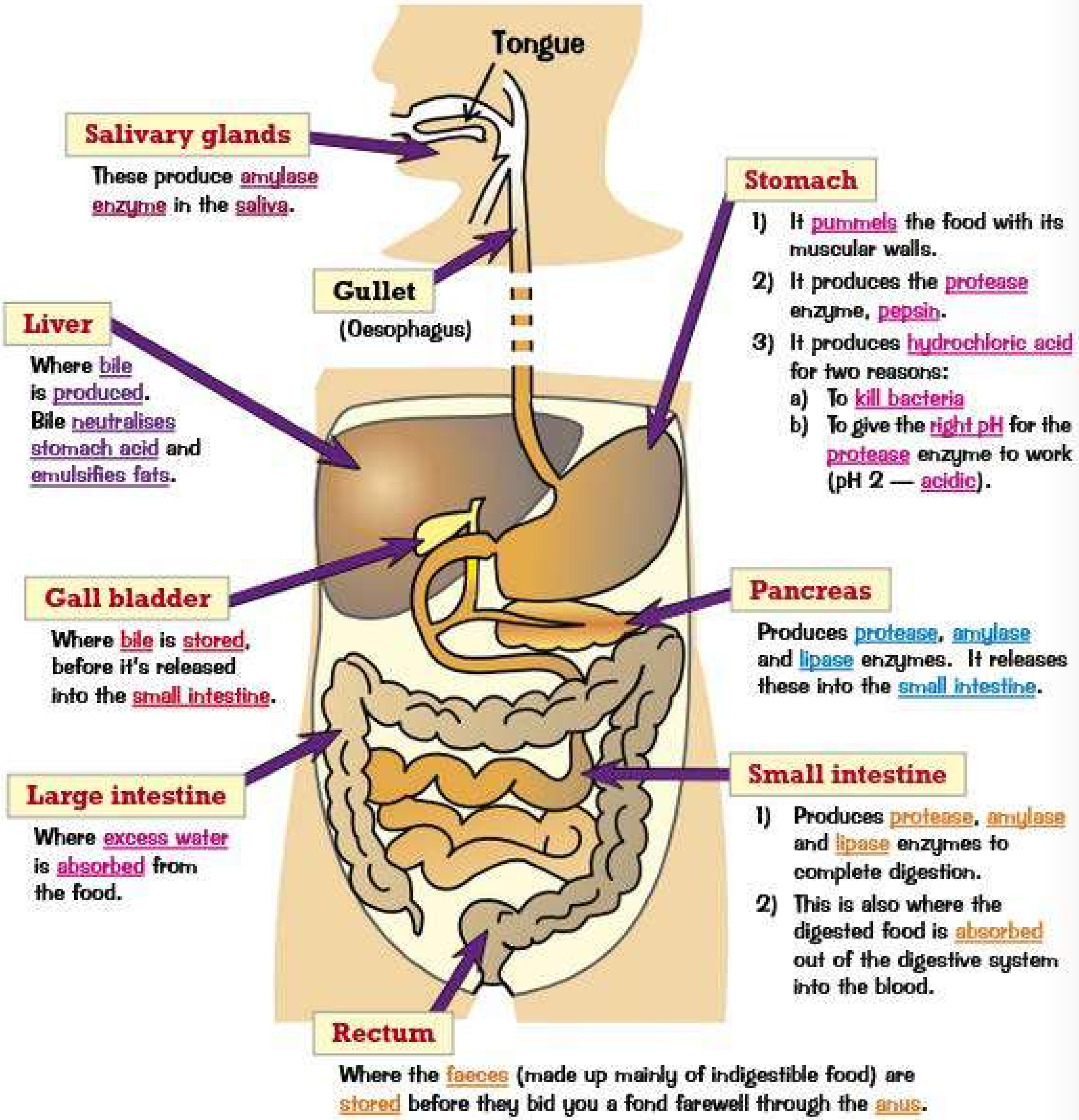
Q1 Bile is a product of the liver. Describe and explain its role in digestion. [4 marks]

More on Enzymes and Digestion

So now you know what the enzymes do, here's a nice big picture of the whole of the digestive system.

The Breakdown of Food is Catalysed by Enzymes

1) Enzymes used in the digestive system are produced by specialised cells in glands and in the gut lining.
2) Different enzymes catalyse the breakdown of different food molecules.



Mmmm — so who's for a chocolate digestive...

Did you know that the whole of your digestive system is actually a hole that goes right through your body. Think about it. It just gets loads of food, digestive juices and enzymes piled into it. Most of it's then absorbed into the body and the rest is politely stored for removal.

Q1 Name the three parts of the digestive system that produce protease enzymes. [3 marks]

Food Tests

PRACTICAL

There are some clever ways to identify what type of food molecule a sample contains. For each of the tests, 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 to get rid of the solid bits of food.

Use the Benedict's Test to Test for Sugars

Sugars are found in all sorts of foods such as biscuits, cereal and bread. There are two types of sugars — non-reducing and reducing. You can test for reducing sugars in foods using the Benedict's test:

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 and leave it in there for 5 minutes. Make sure the tube is pointing away from you.
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 — it depends on how much sugar is in the food.

Use Iodine Solution to Test for Starch

You can also check food samples for the presence of starch. Foods like pasta, rice and potatoes contain a lot of starch. Here's how to do the test:

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

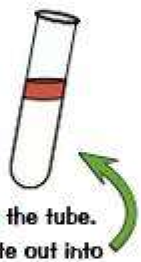
Use the Biuret Test to Test for Proteins

You can use the biuret test to see if a type of food contains protein.
Meat and cheese are protein rich and good foods to use in this test. Here's how it's done:

1) Prepare a sample of your food and transfer 2 cm^3 of your sample to a test tube.
2) Add 2 cm^3 of biuret solution to the sample and 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. If no protein is present, the solution will stay blue.

Use the Sudan III Test to Test for Lipids

Lipids are found in foods such as olive oil, margarine and milk.
You can test for the presence of lipids in a food using Sudan III stain solution.



1) Prepare a sample of the food you're testing (but you don't need to filter it). Transfer about 5 cm^3 into a test tube.
2) Use a pipette to add 3 drops of Sudan III stain solution to the test tube and gently shake the tube.
3) Sudan III stain solution stains lipids. If the sample contains lipids, the mixture will separate out into two layers. The top layer will be bright red. If no lipids are present, no separate red layer will form at the top of the liquid.

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

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

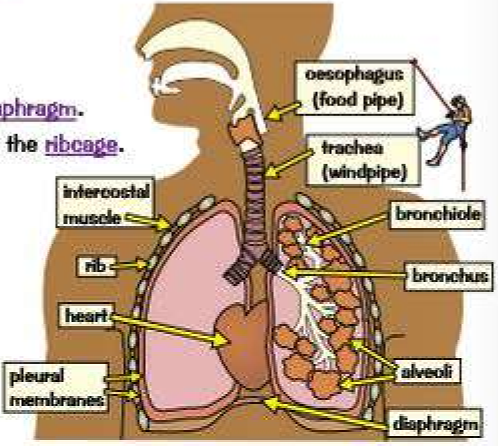
Q1 Name the chemical that you would use to test a sample for the presence of starch. [1 mark]

The Lungs

You need to get oxygen into your bloodstream to supply your cells for respiration. You also need to get rid of carbon dioxide from your blood. This all happens in your lungs when you breathe air in and out.

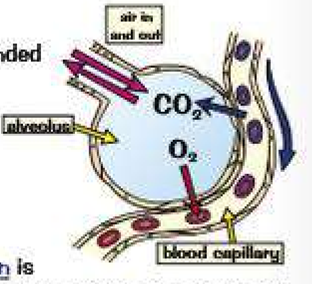
The Lungs Are in the Thorax

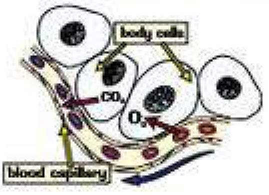
1) The thorax is the top part of your body.
2) It's separated from the lower part of the body by the diaphragm.
3) The lungs are like big pink sponges and are protected by the ribcage. They're surrounded by the pleural membranes.
4) The air that you breathe in goes through the trachea. This splits into two tubes called bronchi (each one is a bronchus), one going to each lung.
5) The bronchi split into progressively smaller tubes called bronchioles.
6) The bronchioles finally end at small bags called alveoli where the gas exchange takes place (see below).



Alveoli Carry Out Gas Exchange in the Body

1) The lungs contain millions and millions of little air sacs called alveoli, surrounded by a network of blood capillaries. This is where gas exchange happens.
2) The blood passing next to the alveoli has just returned to the lungs from the rest of the body, so it contains lots of carbon dioxide and very little oxygen. Oxygen diffuses out of the alveolus (high concentration) into the blood (low concentration). Carbon dioxide diffuses out of the blood (high concentration) into the alveolus (low concentration) to be breathed out.





3) When the blood reaches body cells oxygen is released from the red blood cells (where there's a high concentration) and diffuses into the body cells (where the concentration is low).
4) At the same time, carbon dioxide diffuses out of the body cells (where there's a high concentration) into the blood (where there's a low concentration). It's then carried back to the lungs.

You Can Calculate the Breathing Rate in Breaths Per Minute

Rate calculations pop up all the time in biology, and you're expected to know how to do them — thankfully they're pretty easy. Breathing rate is the sort of thing that you could get asked to work out in your exam.

EXAMPLE

Bea 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...

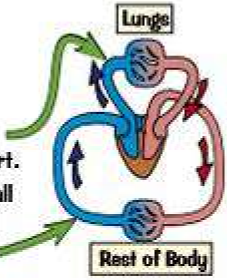
Alveoli are really well adapted for carrying out gas exchange. It could be a wise move to learn all about exactly how they're adapted. You met them back on page 21, so head back there if you need a reminder.

Q1 During a 12 minute run, Aaqib took 495 breaths.
Calculate his average breathing rate in breaths per minute. [1 mark]

Circulatory System — The Heart

The circulatory system carries food and oxygen to every cell in the body. As well as being a delivery service, it's also a waste collection service — it carries waste products to where they can be removed from the body.

The DOUBLE Circulatory System, Actually



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

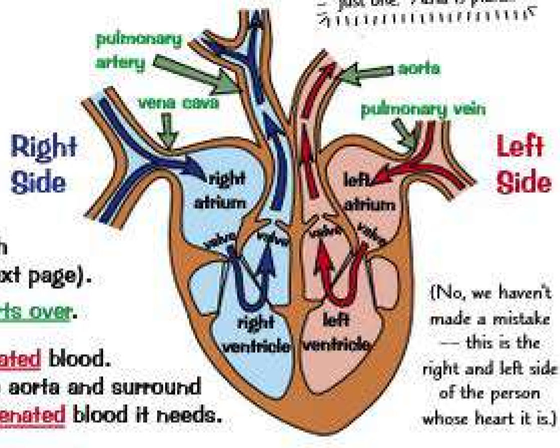
1) In the first one, the right ventricle (see below) pumps deoxygenated blood (blood without oxygen) to the lungs to take in oxygen. The blood then returns to the heart.
2) In the second one, the left ventricle (see below) pumps oxygenated blood around all the other organs of the body. The blood gives up its oxygen at the body cells and the deoxygenated blood returns to the heart to be pumped out to the lungs again.

The Heart Contracts to Pump Blood Around The Body

1) The heart is a pumping organ that keeps the blood flowing around the body. The walls of the heart are mostly made of muscle tissue.
2) The heart has valves to make sure that blood flows in the right direction — they prevent it flowing backwards.
3) This is how the heart uses its four chambers (right atrium, right ventricle, left atrium and left ventricle) to pump blood around:

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

1) Blood flows into the two atria from the vena cava and the pulmonary vein.
2) The atria contract, pushing the blood into the ventricles.
3) The ventricles contract, forcing the blood into the pulmonary artery and the aorta, and out of the heart.
4) The blood then flows to the organs through arteries, and returns through veins (see next page).
5) The atria fill again and the whole cycle starts over.



(No, we haven't made a mistake — this is the right and left side of the person whose heart it is.)

The heart also needs its own supply of oxygenated blood. Arteries called coronary arteries branch off the aorta and surround the heart, making sure that it gets all the oxygenated blood it needs.

The Heart Has a Pacemaker

1) Your resting heart rate is controlled by a group of cells in the right atrium wall that act as a pacemaker.
2) These cells produce a small electric impulse which spreads to the surrounding muscle cells, causing them to contract.
3) An artificial pacemaker is often used to control heartbeat if the natural pacemaker cells don't work properly (e.g. if the patient has an irregular heartbeat). It's a little device that's implanted under the skin and has a wire going to the heart. It produces an electric current 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]

Q2 What is the function of the coronary arteries? [1 mark]

Circulatory System — Blood Vessels

Want to know more about the circulatory system... Good. Because here's a whole extra page.

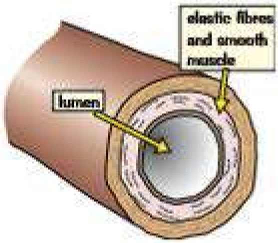
Blood Vessels are Designed for Their Function

There are three different types of blood vessel:

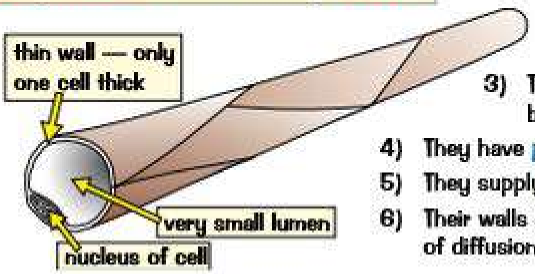
1) ARTERIES — these carry the blood away from the heart.
2) CAPILLARIES — these are involved in the exchange of materials at the tissues.
3) VEINS — these carry the blood to the heart.

Arteries Carry Blood Under Pressure

1) The heart pumps the blood out at high pressure so the artery walls are strong and elastic.
2) The walls are thick compared to the size of the hole down the middle (the "lumen" — silly name!).
3) They contain thick layers of muscle to make them strong, and elastic fibres to allow them to stretch and spring back.



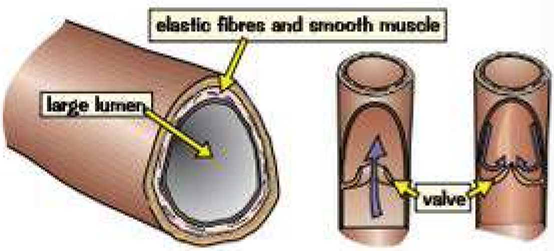
Capillaries are Really Small



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 permeable 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 increases the rate of diffusion by decreasing the distance over which it occurs.

Veins Take Blood Back to the Heart

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



You Can Calculate the Rate of Blood Flow

You might get asked to calculate the rate of blood flow in your exam. Thankfully, it's not too tricky. Take a look at this example:

EXAMPLE

1464 ml of blood passed through an artery in 4.5 minutes. Calculate the rate of blood flow through the artery in ml/min.

rate of blood flow = volume of blood ÷ number of minutes
= 1464 ÷ 4.5 = 325 ml/min

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

Here's an 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]

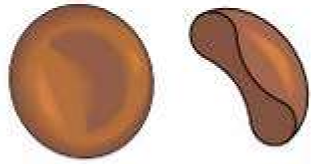
Q1 Video Solution

Circulatory System — Blood

Blood is a tissue. One of its jobs is to act as a huge transport system. There are four main things in blood...

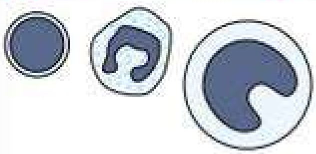
Red Blood Cells Carry Oxygen

1) The job of red blood cells is to carry oxygen from the lungs to all the cells in the body.
2) Their shape is a biconcave disc (like a doughnut) — this gives a large surface area for absorbing oxygen.
3) They don't have a nucleus — this allows more room to carry oxygen.
4) They contain a red pigment called haemoglobin.
5) In the lungs, haemoglobin binds to oxygen to become oxyhaemoglobin. In body tissues, the reverse happens — oxyhaemoglobin splits up into haemoglobin and oxygen, to release oxygen to the cells.



The more red blood cells you've got, the more oxygen can get to your cells. At high altitudes there's less oxygen in the air — so people who live there produce more red blood cells to compensate.

White Blood Cells Defend Against Infection



1) Some can change shape to gobble up unwelcome microorganisms, in a process called phagocytosis.
2) Others produce antibodies to fight microorganisms, as well as antitoxins to neutralise any toxins produced by the microorganisms.
3) 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 at a wound — to stop all your blood pouring out and to stop microorganisms getting in. (So basically platelets just float about waiting for accidents to happen.)
3) Lack of platelets can cause excessive bleeding and bruising.

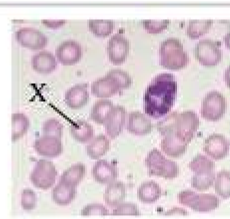
Plasma is the Liquid That Carries Everything in Blood

This is a pale straw-coloured liquid which carries just about everything:

1) Red and white blood cells and platelets.
2) Nutrients like glucose and amino acids. These are the soluble products of digestion which are absorbed from the gut and taken to the cells of the body.
3) Carbon dioxide from the organs to the lungs.
4) Urea from the liver to the kidneys.
5) Hormones.
6) Proteins.
7) Antibodies and antitoxins produced by the white blood cells.

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.



Q2 Video Solution

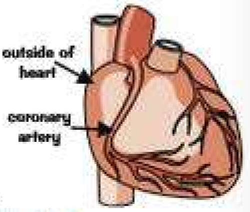
Q1 Describe the purpose of platelets in blood. [1 mark]

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

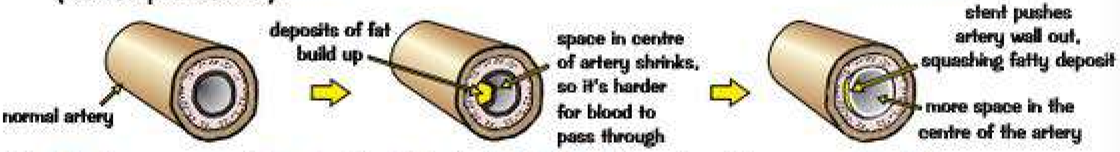
Cardiovascular Disease

Cardiovascular disease is a term used to describe diseases of the heart or blood vessels, for example coronary heart disease. This page tells you all about how stents and statins are used to combat coronary heart disease.

Stents Keep Arteries Open



1) Coronary heart disease is when the coronary arteries that supply the blood to the muscle of the heart get blocked by layers of fatty material building up. This causes the arteries to become narrow, so blood flow is restricted and there's a lack of oxygen to the heart muscle — this can result in a heart attack.
2) Stents are tubes that are inserted inside arteries. They keep them open, making sure blood can pass through to the heart muscles. This keeps the person's heart beating (and the person alive).



3) Stents are a way of lowering the risk of a heart attack in people with coronary heart disease. They are effective for a long time and the recovery time from the surgery is relatively quick.
4) On the down side, there is a risk of complications during the operation (e.g. heart attack) and a risk of infection from surgery. There is also the risk of patients developing a blood clot near the stent — this is called thrombosis.

Statins Reduce Cholesterol in the Blood

1) Cholesterol is an essential lipid that your body produces and needs to function properly. However, too much of a certain type of cholesterol (known as 'bad' or LDL cholesterol) can cause health problems.
2) Having too much of this 'bad' cholesterol in the bloodstream can cause fatty deposits to form inside arteries, which can lead to coronary heart disease.
3) Statins are drugs that can reduce the amount of 'bad' cholesterol present in the bloodstream. This slows down the rate of fatty deposits forming.

Statins Have Advantages and Disadvantages

Advantages

1) By reducing the amount of 'bad' cholesterol in the blood, statins can reduce the risk of strokes, coronary heart disease and heart attacks.
2) As well as reducing the amount of 'bad' cholesterol, statins can increase the amount of a beneficial type of cholesterol (known as 'good' or HDL cholesterol) in your bloodstream. This type can remove 'bad' cholesterol from the blood.
3) Some studies suggest that statins may also help prevent some other diseases.

Disadvantages

1) Statins are a long-term drug that must be taken regularly. There's the risk that someone could forget to take them.
2) Statins can sometimes cause negative side effects, e.g. headaches. Some of these side effects can be serious, e.g. kidney failure, liver damage and memory loss.
3) The effect of statins isn't instant. It takes time for their effect to kick in.

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

Stents and statins might be good treatments for coronary heart disease, but they're not perfect. Make sure you're aware of the drawbacks as well as the advantages of each. That way, you'll be covered if they come up in the exam.

Q1 a) How can stents be used to reduce the risk of heart attacks in people with coronary heart disease? [2 marks]
b) Suggest two disadvantages of treating patients using stents. [2 marks]

More on Cardiovascular Disease

With more fakery than a 'Rollecks' watch, this page is about artificial hearts, artificial blood and replacing heart valves. All a bit gruesome, I'll admit — but it's life-saving stuff.

An Artificial Heart Can Pump Blood Around the Body

If a patient has heart failure, doctors may perform a heart transplant (or heart and lungs transplant if the lungs are also diseased) using donor organs from people who have recently died. However, if donor organs aren't available right away or they're not the best option, doctors may fit an artificial heart.

1) Artificial hearts are mechanical devices that pump blood for a person whose own heart has failed. They're usually only used as a temporary fix, to keep a person alive until a donor heart can be found or to help a person recover by allowing the heart to rest and heal. In some cases though they're used as a permanent fix, which reduces the need for a donor heart.
2) The main advantage of artificial hearts is that they're less likely to be rejected by the body's immune system than a donor heart. This is because they're made from metals or plastics, so the body doesn't recognise them as 'foreign' and attack in the same way as it does with living tissue.
3) But surgery to fit an artificial heart (as with transplant surgery) can lead to bleeding and infection. Also, artificial hearts don't work as well as healthy natural ones — parts of the heart could wear out or the electrical motor could fail. Blood doesn't flow through artificial hearts as smoothly, which can cause blood clots and lead to strokes. The patient has to take drugs to thin their blood and make sure this doesn't happen, which can cause problems with bleeding if they're hurt in an accident.

Faulty Heart Valves Can Be Replaced With Biological or Mechanical Valves

1) The valves in the heart can be damaged or weakened by heart attacks, infection or old age.
2) The damage may cause the valve tissue to stiffen, so it won't open properly. Or a valve may become leaky, allowing blood to flow in both directions rather than just forward. This means that blood doesn't circulate as effectively as normal.
3) Severe valve damage can be treated by replacing the valve. Replacement valves can be ones taken from humans or other mammals (e.g. cows or pigs) — these are biological valves. Or they can be man-made — these are mechanical valves.
4) Replacing a valve is a much less drastic procedure than a whole heart transplant. But fitting artificial valves is still major surgery and there can still be problems with blood clots.

Artificial Blood Can Keep You Alive In An Emergency

1) When someone loses a lot of blood, e.g. in an accident, their heart can still pump the remaining red blood cells around (to get oxygen to their organs), as long as the volume of their blood can be topped up.
2) Artificial blood is a blood substitute, e.g. a salt solution ("saline"), which is used to replace the lost volume of blood. It's safe (if no air bubbles get into the blood) and can keep people alive even if they lose ⅔ of their red blood cells. This may give the patient enough time to produce new blood cells. If not, the patient will need a blood transfusion.
3) Ideally, an artificial blood product would replace the function of the lost red blood cells, so that there's no need for a blood transfusion. Scientists are currently working on products that can do this.

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

Make sure you know about the consequences of faulty heart valves or heart failure, as well as the advantages and disadvantages of the treatments on this page. Obviously if someone is really ill, it's unlikely that they'd turn down an artificial heart, artificial blood or a valve replacement — but these treatments aren't perfect.

Q1 a) Describe how faulty heart valves can lead to poor blood circulation. [2 marks]
b) Suggest how severe damage to a heart valve can be treated. [1 mark]

Q2 Suggest one disadvantage of treating coronary heart disease with an artificial heart. [1 mark]

Health and Disease

There's not a great deal about diseases and health problems that you can laugh about, so excuse me if this page is a bit dull. It's important stuff to know about though, so you'd best get cracking.

Diseases are a Major Cause of Ill Health

Health is the state of physical and mental wellbeing. Diseases are often responsible for causing ill health.

Diseases Can be Communicable or Non-Communicable

1) Communicable diseases are those that can spread from person to person or between animals and people. They can be caused by things like bacteria, viruses, parasites and fungi. They're sometimes described as contagious or infectious diseases. Measles and malaria are examples of communicable diseases. There's more about them on pages 43-45.
2) Non-communicable diseases are those that cannot spread between people or between animals and people. They generally last for a long time and get worse slowly. Asthma, cancer and coronary heart disease (see page 34) are examples of non-communicable diseases.

Different Types of Disease Sometimes Interact

Sometimes diseases can interact and cause other physical and mental health issues that don't immediately seem related. Here are a few examples:

Pathogen is just the fancy term for a microorganism that can cause a disease when it infects its host.

1) People who have problems with their immune system (the system that your body uses to help fight off infection — see p.46) have an increased chance of suffering from communicable diseases such as influenza (flu), because their body is less likely to be able to defend itself against the pathogen that causes the disease.
2) Some types of cancer can be triggered by infection by certain viruses. For example, infection with some types of hepatitis virus can cause long-term infections in the liver, where the virus lives in the cells. This can lead to an increased chance of developing liver cancer. Another example is infection with HPV (human papilloma virus), which can cause cervical cancer in women.
3) Immune system reactions in the body caused by infection by a pathogen can sometimes trigger allergic reactions such as skin rashes or worsen the symptoms of asthma for asthma sufferers.
4) Mental health issues such as depression can be triggered when someone is suffering from severe physical health problems, particularly if they have an impact on the person's ability to carry out everyday activities or if they affect the person's life expectancy.

Other Factors Can Also Affect Your Health

There are plenty of factors other than diseases that can also affect your health. For example:

1) Whether or not you have a good, balanced diet that provides your body with everything it needs, and in the right amounts. A poor diet can affect your physical and mental health.
2) The stress you are under — being constantly under lots of stress can lead to health issues.
3) Your life situation — for example, whether you have easy access to medicines to treat illness, or whether you have access to things that can prevent you from getting ill in the first place, e.g. being able to buy healthy food or access condoms to prevent the transmission 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]

Q2 Why is influenza classed as a communicable disease? [1 mark]

Risk Factors for Non-Communicable Diseases

You've probably heard the term 'risk factor' before. This page has all the info you need to know about them.

Risk Factors Increase Your Chance of Getting a Disease

1) Risk factors are things that are linked to an increase in the likelihood that a person will develop a certain disease during their lifetime. They don't guarantee that someone will get the disease.
2) Risk factors are often aspects of a person's lifestyle (e.g. how much exercise they do). They can also be the presence of certain substances in the environment (e.g. air pollution) or substances in your body (e.g. asbestos fibres — asbestos was a material used in buildings until it was realised that the fibres could build up in your airways and cause diseases such as cancer later in life).
3) Many non-communicable diseases are caused by several different risk factors interacting with each other rather than one factor alone.
4) Lifestyle factors can have different impacts locally, nationally and globally.

E.g. in developed countries, non-communicable diseases are more common as people generally have a higher income and can buy high-fat food. Nationally, people from deprived areas are more likely to smoke, have a poor diet and not exercise. This means the incidence of cardiovascular disease, obesity and Type 2 diabetes is higher in those areas. Your individual choices affect the local incidence of disease.

Some Risk Factors Can Cause a Disease Directly

1) Some risk factors are able to directly cause a disease. For example:
   1) Smoking has been proven to directly cause cardiovascular disease, lung disease and lung cancer. It damages the walls of arteries and the cells in the lining of the lungs.
   2) It's thought that obesity can directly cause Type 2 diabetes by making the body less sensitive or resistant to insulin, meaning that it struggles to control the concentration of glucose in the blood.
   3) Drinking too much alcohol has been shown to cause liver disease. Too much alcohol can affect brain function too. It can damage the nerve cells in the brain, causing the brain to lose volume.
   4) Smoking when pregnant can cause lots of health problems for the unborn baby. Drinking alcohol has similar effects.
   5) Cancer can be directly 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) However, risk factors are identified by scientists looking for correlations in data, and correlation doesn't always equal cause (see p.9). Some risk factors aren't capable of directly causing a disease. For example, a lack of exercise and a high fat diet are heavily linked to an increased chance of cardiovascular disease, but they can't cause the disease directly. It's the resulting high blood pressure and high 'bad' cholesterol levels (see p.34) that can actually cause it.

Non-Communicable Diseases Can Be Costly

1) The HUMAN cost of non-communicable diseases is obvious. Tens of millions of people around the world die from non-communicable diseases per year. People with these diseases may have a lower quality of life or a shorter lifespan. This not only affects the sufferers themselves, but their loved ones too.
2) It's also important to think about the FINANCIAL cost. The cost to the NHS of researching and treating these diseases is huge — and it's the same for other health services and organisations around the world. Families may have to move or adapt their home to help a family member with a disease, which can be costly. Also, if the family member with the disease has to give up work or dies, the family's income will be reduced. 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 an example of a type of risk factor other than an aspect of a person's lifestyle. [1 mark]

Cancer

Cancer's not a pleasant topic, but the more we understand about it, the better our chances of avoiding and beating it (and getting good marks in the exam). You're a good way through the topic, so keep going.

Cancer is Caused by Uncontrolled Cell Growth and Division

This uncontrolled growth and division is a result of changes that occur to the cells and results in the formation of a tumour (a mass of cells). Not all tumours are cancerous. They can be benign or malignant:

1) Benign — This is where the tumour grows until there's no more room. The tumour stays in one place (usually within a membrane) rather than invading other tissues in the body. This type isn't normally dangerous, and the tumour isn't cancerous.
2) Malignant — This is where the tumour grows and spreads to neighbouring healthy tissues. Cells can break off and spread to other parts of the body by travelling in the bloodstream. The malignant cells then invade healthy tissues elsewhere in the body and form secondary tumours. Malignant tumours are dangerous and can be fatal — they are cancers.

Risk Factors Can Increase the Chance of Some Cancers

Anyone can develop cancer. Having risk factors doesn't mean that you'll definitely get cancer. It just means that you're at an increased risk of developing the disease. Cancer survival rates have increased due to medical advances such as improved treatment, being able to diagnose cancer earlier and increased screening for the disease.

Risk Factors Can Be Associated With Lifestyle

Scientists have identified lots of lifestyle risk factors for various types of cancer. For example:

1) Smoking — It's a well known fact that smoking is linked to lung cancer, but research has also linked it to other types of cancer too, including mouth, bowel, stomach and cervical cancer.

2) Obesity — Obesity has been linked to many different cancers, including bowel, liver and kidney cancer. It's the second biggest preventable cause of cancer after smoking.
3) UV exposure — People who are often exposed to UV radiation from the Sun have an increased chance of developing skin cancer. People who live in sunny climates and people who spend a lot of time outside are at higher risk of the disease. People who frequently use sun beds are also putting themselves at higher risk of developing skin cancer.
4) Viral infection — Infection with some viruses has been shown to increase the chances of developing certain types of cancer. For example, infection with hepatitis B and hepatitis C viruses can increase the risk of developing liver cancer. The likelihood of becoming infected with these viruses sometimes depends on lifestyle — e.g. they can be spread between people through unprotected sex or sharing needles.

Risk Factors Can Also Be Associated With Genetics

1) Sometimes you can inherit faulty genes that make you more susceptible to cancer.
2) For example, mutations (changes) in the BRCA genes have been linked to an increased likelihood of developing breast and ovarian cancer.

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

Joking aside, UV radiation can still reach us through the clouds, and like many other lifestyle risk factors, we can take steps to reduce the risk, e.g. by keeping covered up outside and wearing sun block.

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

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

Plant Cell Organisation

You saw on page 24 how animals keep their specialised cells neat and tidy — plants are in on the act too.

Plant Cells Are Organised Into Tissues And Organs

Plants are made of organs like stems, roots and leaves. Plant organs work together to make organ systems. These can perform the various tasks that a plant needs to carry out to survive and grow — for example, transporting substances around the plant. Plant organs are made of tissues. Examples of plant tissues are:

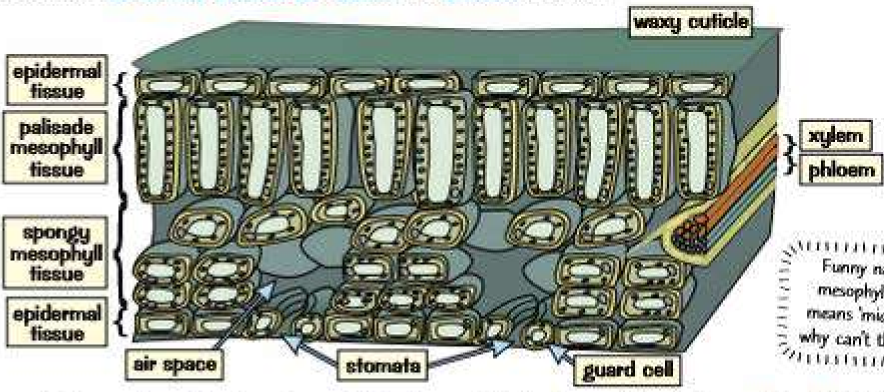
1) Epidermal tissue — this covers the whole plant.
2) Palisade mesophyll tissue — this is the part of the leaf where most photosynthesis happens.
3) Spongy mesophyll tissue — this is also in the leaf, and contains big air spaces to allow gases to diffuse in and out of cells.
4) Xylem and phloem — they transport things like water, mineral ions and food around the plant (through the roots, stems and leaves — see next page for more).
5) Meristem tissue — this is found at the growing tips of shoots and roots and is able to differentiate (change) into lots of different types of plant cell, allowing the plant to grow.

For more on photosynthesis, see page 50.

A merry stem.

The Leaf is an Organ Made Up of Several Types of Tissue

Leaves contain epidermal, mesophyll, xylem and phloem tissues.



Funny names here — like mesophyll. Mesophyll just means 'middle of a leaf'. (So why can't they just say that?)

You need to know how the structures of the tissues that make up the leaf are related to their function:

1) The epidermal tissues are covered with a waxy cuticle, which helps to reduce water loss by evaporation.
2) The upper epidermis is transparent so that light can pass through it to the palisade layer.
3) The palisade layer has lots of chloroplasts (the little structures where photosynthesis takes place). This means that they're near the top of the leaf where they can get the most light.
4) The xylem and phloem form a network of vascular bundles, which deliver water and other nutrients to the entire leaf and take away the glucose produced by photosynthesis. They also help support the structure.
5) The tissues of leaves are also adapted for efficient gas exchange (see page 22). E.g. the lower epidermis is full of little holes called stomata, which let CO_2 diffuse directly into the leaf. The opening and closing of stomata is controlled by guard cells in response to environmental conditions. The air spaces in the spongy mesophyll tissue increase the rate of diffusion of gases.

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. Maybe you could draw your own leaf diagram and label it with descriptions of the different tissue types. It would make an excellent Christmas present for someone, or an art collector might even want it.

Q1 Describe the characteristics of meristem tissue. [2 marks]

Transpiration and Translocation

You might be surprised to learn that there aren't tiny trucks that transport substances around plants. Then again, you might not be — either way, you need to learn the stuff on this page...

Phloem Tubes Transport Food:

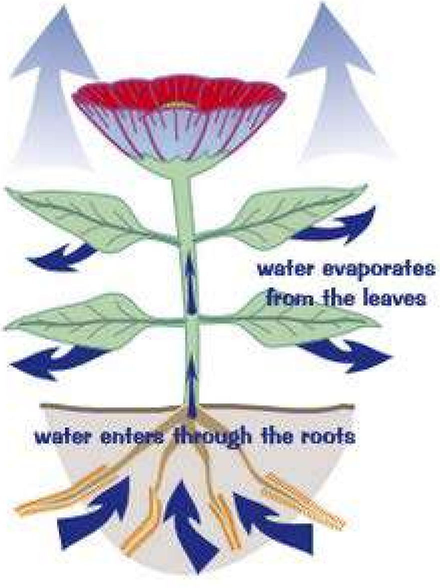
1) Made of columns of elongated living cells with small pores in the end walls to allow cell sap to flow through.
2) They transport food substances (mainly dissolved sugars) made in the leaves to the rest of the plant for immediate use (e.g. in growing regions) or for storage.
3) The transport goes in both directions.
4) 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) Made of dead cells joined end to end with no end walls between them and a hole down the middle. They're strengthened with a material called lignin.
2) They carry water and mineral ions from the roots to the stem and leaves.
3) 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 the evaporation and diffusion (see page 17) of water from a plant's surface. Most transpiration happens at the leaves.
2) This evaporation creates a slight shortage of water in the leaf, and so more water is drawn up from the rest of the plant through the xylem vessels to replace it.
3) This in turn means more water is drawn up from the roots, and so there's a constant transpiration stream of water through the plant.

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

Transpiration is just a side-effect of the way leaves are adapted for photosynthesis. They have to have stomata in them so that gases can be exchanged easily (see page 22). Because there's more water inside the plant than in the air outside, the water escapes from the leaves through the stomata by diffusion.

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

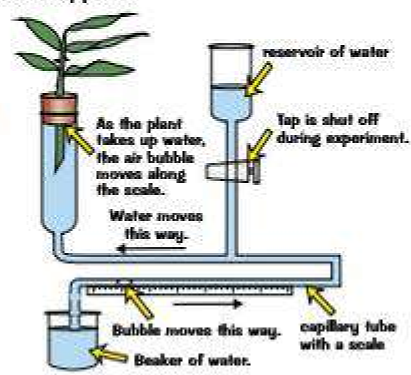
Sorry, more on transpiration. But then it's a quick dash through stomata and out of the other end of the topic.

Transpiration Rate is Affected by Four Main Things

1) LIGHT INTENSITY — the brighter the light, the greater the transpiration rate.
   Stomata begin to close as it gets darker. Photosynthesis can't happen in the dark, so they don't need to be open to let CO_2 in. When the stomata are closed, very little water can escape.
2) TEMPERATURE — the warmer it is, the faster transpiration happens.
   When it's warm the water particles have more energy to evaporate and diffuse out of the stomata.
3) AIR FLOW — the better the air flow around a leaf (e.g. stronger wind), the greater the transpiration rate.
   If air flow around a leaf is poor, the water vapour just surrounds the leaf and doesn't move away. This means there's a high concentration of water particles outside the leaf as well as inside it, so diffusion doesn't happen as quickly. If there's good air flow, the water vapour is swept away, maintaining a low concentration of water in the air outside the leaf. Diffusion then happens quickly, from an area of higher concentration to an area of lower concentration.
4) HUMIDITY — the drier the air around a leaf, the faster transpiration happens.
   This is like what happens with air flow. If the air is humid there's a lot of water in it already, so there's not much of a difference between the inside and the outside of the leaf. Diffusion happens fastest if there's a really high concentration in one place, and a really low concentration in the other.

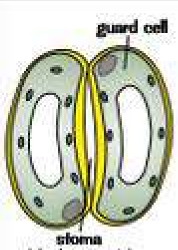
You can estimate the rate of transpiration by measuring the uptake of water by a plant. This is because you can assume that water uptake by the plant is directly related to water loss by the leaves (transpiration).

Set up the apparatus as in the diagram, and then record the starting position of the air bubble. Start a stopwatch and record the distance moved by the bubble per unit time, e.g. per hour. Keep the conditions constant throughout the experiment, e.g. the temperature and air humidity.



This piece of apparatus is called a potometer. Setting it up is quite tough — there are some tips on page 236.

Guard Cells Are Adapted to Open and Close Stomata



1) They have a kidney shape which opens and closes the stomata (page 22) in a leaf.
2) When the plant has lots of water the guard cells fill with it and go plump and turgid. This makes the stomata open so gases can be exchanged for photosynthesis.
3) When the plant is short of water, the guard cells lose water and become flaccid, making the stomata close. This helps stop too much water vapour escaping.
4) Thin outer walls and thickened inner walls make the opening and closing work.
5) They're also sensitive to light and close at night to save water without losing out on photosynthesis.
6) You usually find more stomata on the undersides of leaves than on the top. The lower surface is shaded and cooler — so less water is lost through the stomata than if they were on the upper surface.
7) Guard cells are therefore adapted for gas exchange and controlling water loss within a leaf.

I say stomaaarta, you say stomaaayta...

Different leaves will have different distributions of stomata. You can peel the epidermal tissue off some leaves and mount them on microscope slides (see page 13) to compare them. It's thrilling stuff.

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.25-29)

3) Why can enzymes be described as biological 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 lipids in a food sample.

The Lungs and Circulatory System (p.30-33)

11) Name the tubes that split off the trachea.
12) Explain the role that alveoli play in gas exchange.
13) Explain why the circulatory system in humans is described as a 'double circulatory system'.
14) Why does the heart have valves?
15) Name the four chambers of the heart.
16) How is the resting heart rate controlled in a healthy heart?
17) How are arteries adapted to carry blood away from the heart?
18) Why do red blood cells not have a nucleus?

Diseases and Risk Factors (p.34-38)

19) Give two advantages and two disadvantages of statins.
20) What is the difference between biological and mechanical replacement heart valves?
21) What is meant by a non-communicable disease?
22) Give an example of where different types of disease might interact in the body.
23) What is meant by a risk factor of a disease?
24) Which type of tumour is cancerous?

Plant Cell Organisation and Transport (p.39-41)

25) List the tissues that make up a leaf.
26) Explain how the structure of the upper epidermal tissue in a leaf is related to its function.
27) What is the function of phloem?
28) What is transpiration?
29) List the four main things that affect transpiration.
30) How could you measure the rate of transpiration?
31) 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

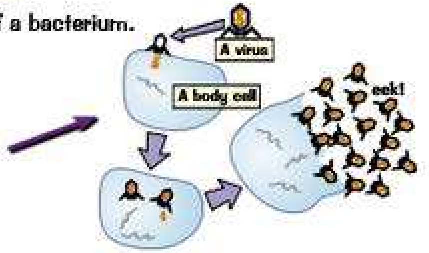
1) Pathogens are microorganisms that enter the body and cause disease.
2) They cause communicable (infectious) diseases — diseases that can easily spread (see p.36).
3) Both plants and animals can be infected by pathogens.

1. Bacteria Are Very Small Living Cells

1) Bacteria are very small cells (about 1/100th the size of your body cells), which can reproduce rapidly inside your body.
2) They can make you feel ill by producing toxins (poisons) that damage your cells and tissues.

2. Viruses Are Not Cells — They're Much Smaller

1) Viruses are not cells. They're tiny, about 1/100th the size of a bacterium.
2) Like bacteria, they can reproduce rapidly inside your body.
3) They live inside your cells and replicate themselves using the cells' machinery to produce many copies of themselves. The cell will usually then burst, releasing all the new viruses.
4) This cell damage is what makes you feel ill.



3. Protists are Single-Celled Eukaryotes

1) There are lots of different types of protists. But they're all eukaryotes (see page 11) and most of them are single-celled.
2) Some protists are parasites. Parasites live on or inside other organisms and can cause them damage. They are often transferred to the organism by a vector, which doesn't get the disease itself — e.g. an insect that carries the protist.

4. Fungi Come in Different Shapes

1) Some fungi are single-celled. Others have a body which is made up of hyphae (thread-like structures).
2) These hyphae can grow and penetrate human skin and the surface of plants, causing diseases.
3) The hyphae can produce spores, which can be spread to other plants and animals.

Pathogens Can Be Spread in Different Ways

Pathogens can be spread in many ways. Here are a few that you need to know about.

1) WATER — Some pathogens can be picked up by drinking or bathing in dirty water. E.g. cholera is a bacterial infection that's spread by drinking water contaminated with the diarrhoea of other sufferers.
2) AIR — Pathogens can be carried in the air and can then be breathed in. Some airborne pathogens are carried in the air in droplets produced when you cough or sneeze — e.g. the influenza virus that causes flu is spread this way.
3) DIRECT CONTACT — Some pathogens can be picked up by touching contaminated surfaces, including the skin. E.g. athlete's foot is a fungus which makes skin itch and flake off. It's most commonly spread by touching the same things as an infected person, e.g. shower floors and towels.

Hooray, I've avoided the classic 'he was a fungi to be with' joke...

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

Q1 Describe how viruses cause cell damage. [2 marks]

Viral, Fungal and Protist Diseases

There are heaps of diseases caused by viruses, fungi and protists, but you just need to know about these ones.

You Need to Know About Three Viral Diseases...

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, and they'll show signs of a fever (a high temperature).
3) Measles can be very serious, or even fatal, if there are complications. For example, measles can sometimes lead to pneumonia (a lung infection) or inflammation of the brain (encephalitis).
4) Most people are vaccinated against measles when they're young.

1) HIV is a virus spread by sexual contact, or by exchanging bodily fluids such as blood. This can happen when people share needles when taking drugs.
2) HIV initially causes flu-like symptoms for a few weeks. Usually, the person doesn't then experience any symptoms for several years. During this time, HIV can be controlled with antiretroviral drugs. These stop the virus replicating in the body.
3) The virus attacks the immune cells (see page 46).
4) 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.

1) Tobacco mosaic virus (TMV) is a virus that affects many species of plants, e.g. tomatoes.
2) It causes a mosaic pattern on the leaves of the plants — parts of the leaves become discoloured.
3) The discolouration means the plant can't carry out photosynthesis as well, so the virus affects growth.

Photosynthesis is important for plant growth because it produces glucose — see page 50.

...a Fungal Disease...

1) Rose black spot is a fungus that causes purple or black spots to develop on the leaves of rose plants. Who'd have guessed. The leaves can then turn yellow and drop off.
2) This means that less photosynthesis can happen, so the plant doesn't grow very well.
3) It spreads through the environment in water or by the wind.
4) Gardeners can treat the disease using fungicides and by stripping the plant of its affected leaves. These leaves then need to be destroyed so that the fungus can't spread to other rose plants.

...and a Disease Caused by a Protist

1) Malaria is caused by a protist (see the previous page).
2) Part of the malarial protist's life cycle takes place inside the mosquito. The mosquitoes are vectors (see the previous page) — they pick up the malarial protist when they feed on an infected animal.
3) Every time the mosquito feeds on another animal, it infects it by inserting the protist into the animal's blood vessels.
4) Malaria causes repeating episodes of fever. It can be fatal.
5) The spread of malaria can be reduced by stopping the mosquitoes from breeding.
6) People can be protected from mosquitoes using insecticides and mosquito nets.

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

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

Q1 What symptom of measles is shown on the skin? [1 mark]

Q2 How can rose black spot be treated so that it doesn't spread to other plants? [2 marks]

Bacterial Diseases and Preventing Disease

Sorry — I'm afraid there are some more diseases to learn about here. This time, they're diseases caused by bacteria. I don't know about you, but I'm starting to feel a bit itchy all over...

You Need to Know About Two Bacterial Diseases

1) Salmonella is a type of bacteria that causes food poisoning.
2) Infected people can suffer from fever, stomach cramps, vomiting and diarrhoea. Pleasant.
3) These symptoms are caused by the toxins that the bacteria produce (see page 43).
4) You can get Salmonella food poisoning by eating food that's been contaminated with Salmonella bacteria, e.g. eating chicken that caught the disease whilst it was alive, or eating food that has been contaminated by being prepared in unhygienic conditions.
5) In the UK, most poultry (e.g. chickens and turkeys) is given a vaccination against Salmonella. This is to control the spread of the disease.

1) Gonorrhoea is a sexually transmitted disease (STD).
2) STDs are passed on by sexual contact, e.g. having unprotected sex.
3) Gonorrhoea is caused by bacteria.
4) A person with gonorrhoea will get pain when they urinate. Another symptom is a thick yellow or green discharge from the vagina or the penis.
5) Gonorrhoea was originally treated with an antibiotic called penicillin, but this has become trickier now because strains of the bacteria have become resistant to it (see page 48).
6) To prevent the spread of gonorrhoea, people can be treated with antibiotics and should use barrier methods of contraception (see page 65), such as condoms.

The Spread of Disease Can Be Reduced or Prevented

There are things that we can do to reduce, and even prevent, the spread of disease. For example:

1) Being hygienic — Using simple hygiene measures can prevent the spread of disease. For example, doing things like washing your hands thoroughly before preparing food or after you've sneezed can stop you infecting another person.

2) Destroying vectors — By getting rid of the organisms that spread disease, you can prevent the disease from being passed on. Vectors that are insects can be killed using insecticides or by destroying their habitat so that they can no longer breed.

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

4) Vaccination — Vaccinating people and animals against communicable diseases means that they are less likely to develop the infection and then pass it on to someone else. There's more about how vaccination works on page 47.

The spread of disease — mouldy margarine...

OK, I promise, that's it. No more diseases to learn about in this Topic. You may be sick of them already (geddit?) but don't turn this page until you've got all the facts firmly attached to your cranial material.

Q1 What has made it harder to treat gonorrhoea? [1 mark]

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

Fighting Disease

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

Your Body Has a Pretty Sophisticated Defence System

1) The human body has got features that stop a lot of nasties getting inside in the first place.
2) The skin acts as a barrier to pathogens. It also secretes antimicrobial substances which kill pathogens.
3) Hairs and mucus in your nose trap particles that could contain pathogens.
4) The trachea and bronchi (breathing pipework — see page 30) secrete mucus to trap pathogens.
5) The trachea and bronchi are lined with cilia. These are hair-like structures, which waft the mucus up to the back of the throat where it can be swallowed.
6) The stomach produces hydrochloric acid. This kills pathogens that make it that far from the mouth.

Your Immune System Can Attack Pathogens

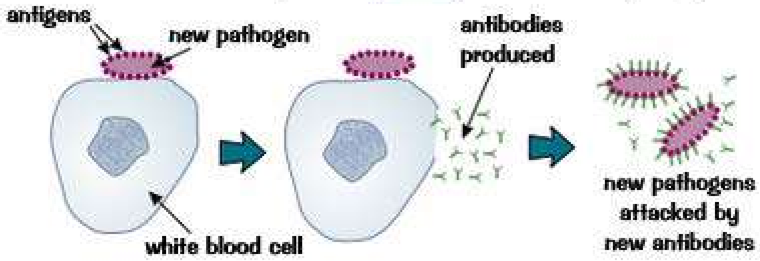
1) If pathogens do make it into your body, your immune system kicks in to destroy them.
2) The most important part of your immune system is the white blood cells. They travel around in your blood and crawl into every part of you, constantly patrolling for microbes. When they come across an invading microbe they have three lines of attack.

1. Consuming Them

White blood cells can engulf foreign cells and digest them. This is called phagocytosis.

2. Producing Antibodies

1) Every invading pathogen has unique molecules (called antigens) on its surface.
2) When some types of white blood cell come across a foreign antigen (i.e. one they don't recognise), they will start to produce proteins called antibodies to lock onto the invading cells so that they can be found and destroyed by other white blood cells. The antibodies produced are specific to that type of antigen — they won't lock on to any others.
3) Antibodies are then produced rapidly and carried around the body to find all similar bacteria or viruses.
4) If the person is infected with the same pathogen again the white blood cells will rapidly produce the antibodies to kill it — the person is naturally immune to that pathogen and won't get ill.



The white blood cells that produce antibodies are also known as B-lymphocytes.

3. Producing Antitoxins

These counteract toxins produced by the invading bacteria.

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

If you have a low level of white blood cells, you'll be more susceptible to infections. HIV attacks white blood cells and weakens the immune system, making it easier for other pathogens to invade.

Q1 What is phagocytosis? [1 mark]

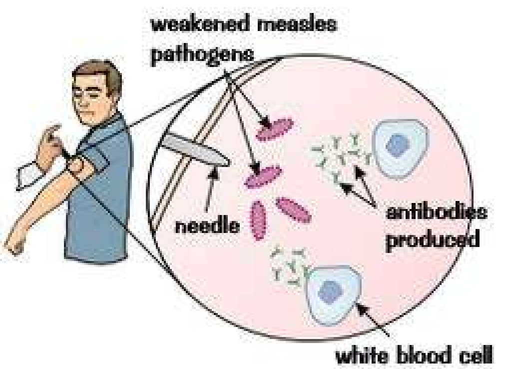
Q2 How are the trachea and the bronchi adapted to defend against the entry of pathogens? [3 marks]

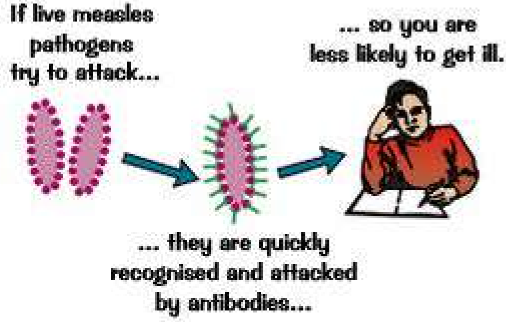
Fighting Disease — Vaccination

Vaccinations have changed the way we fight disease. We don't always have to deal with the problem once it's happened — we can prevent it happening in the first place.

Vaccinations Can Protect from Future Infections

1) When you're infected with a new pathogen, it takes your white blood cells a few days to learn how to deal with it. But by that time, you can be pretty ill.
2) Vaccinations involve injecting small amounts of dead or inactive pathogens. These carry antigens, which cause your body to produce antibodies to attack them — even though the pathogen is harmless (since it's dead or inactive). For example, the MMR vaccine contains weakened versions of the viruses that cause measles, mumps and rubella (German measles) all in one vaccine.
3) But if live pathogens of the same type appear after that, the white blood cells can rapidly mass-produce antibodies to kill off the pathogen. Cool.





There are Pros and Cons of Vaccination

PROS

1) Vaccines have helped control lots of communicable diseases that were once common in the UK (e.g. polio, measles, whooping cough, rubella, mumps, tetanus...). Smallpox no longer occurs at all, and polio infections have fallen by 99%.
2) Big outbreaks of disease — called epidemics — can be prevented if a large percentage of the population is vaccinated. 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. But if a significant number of people aren't vaccinated, the disease can spread quickly through them and lots of people will be ill at the same time.

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 maybe something more serious like a fever or seizures). But bad reactions are very rare.

Prevention is better than cure...

Deciding whether to have a vaccination means balancing risks — the risk of catching the disease if you don't have a vaccine, against the risk of having a bad reaction if you do. As always, you need to look at the evidence. For example, if you get measles (the disease), there's about a 1 in 15 chance that you'll get complications (e.g. pneumonia) — and about 1 in 500 people who get measles actually die. However, the number of people who have a problem with the vaccine is more like 1 in 1 000 000.

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

...a biscuit, nurse? Thanks very much. Sorry, couldn't face that last page — I'm squeamish about needles.*

Some Drugs Relieve Symptoms — Others Cure the Problem

1) Painkillers (e.g. aspirin) are drugs that relieve pain (no, really). However, they don't actually tackle the cause of the disease or kill pathogens, they just help to reduce the symptoms.
2) Other drugs do a similar kind of thing — reduce the symptoms without tackling the underlying cause. For example, lots of "cold remedies" don't actually cure colds.
3) Antibiotics (e.g. penicillin) work differently — they actually kill (or prevent the growth of) the bacteria causing the problem without killing your own body cells. Different antibiotics kill different types of bacteria, so it's important to be treated with the right one.
4) But antibiotics don't destroy viruses (e.g. flu or cold viruses). Viruses reproduce using your body cells, which makes it very difficult to develop drugs that destroy just the virus without killing the body's cells.
5) The use of antibiotics has greatly reduced the number of deaths from communicable diseases caused by bacteria.

Bacteria Can Become Resistant to Antibiotics

1) Bacteria can mutate (change). This can cause them to be resistant to (not killed by) an antibiotic.
2) If you have an infection, some of the bacteria might be resistant to antibiotics.
3) This means that when you treat the infection, only the non-resistant strains of bacteria will be killed.
4) The individual resistant bacteria will survive and reproduce, and the population of the resistant strain will increase. This is an example of natural selection (see page 76).
5) This resistant strain could cause a serious infection that can't be treated by antibiotics. E.g. MRSA (meticillin-resistant *Staphylococcus aureus*) causes serious wound infections and is resistant to the powerful antibiotic meticillin.
6) To slow down the rate of development of resistant strains, it's important for doctors to avoid over-prescribing antibiotics. So you won't get them for a sore throat, only for something more serious.
7) It's also important that you finish the whole course of antibiotics and don't just stop once you feel better.

Many Drugs Originally Came From Plants

1) Plants produce a variety of 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. A lot of our current medicines were discovered by studying plants used in traditional cures. For example:
   - Aspirin is used as a painkiller and to lower fever. It was developed from a chemical found in willow.
   - Digitalis is used to treat heart conditions. It was developed from a chemical found in foxgloves.
3) Some drugs were extracted from microorganisms. For example:
   - Alexander Fleming was clearing out some Petri dishes containing bacteria. He noticed that one of the dishes of bacteria also had mould on it and the area around the mould was free of the bacteria.
   - He found that the mould (called *Penicillium notatum*) on the Petri dish was producing a substance that killed the bacteria — this substance was penicillin.
4) These days, drugs are made on a large scale in the pharmaceutical industry — they're synthesised by chemists in labs. However, the process still might start with a chemical extracted from a plant.

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

Drug development is a big industry. And guess what — you're about to find out some more about it.

Q1 Which type of pathogen can antibiotics be used to kill? [1 mark]

*That's my excuse, you'll have to think of your own.

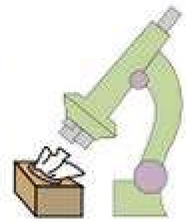
Developing Drugs

New drugs are constantly being developed. But before they can be given to the general public, they have to go through a thorough testing procedure. This is what usually happens...

There are Three Main Stages in Drug Testing

1

1) In preclinical testing, drugs are tested on human cells and tissues in the lab.
2) However, you can't use human cells and tissues to test drugs that affect whole or multiple body systems, e.g. testing a drug for blood pressure must be done on a whole animal because it has an intact circulatory system.



2

1) The next step in preclinical testing is to test the drug on live animals. This is to test efficacy (whether the drug works and produces the effect you're looking for), to find out about its toxicity (how harmful it is) and to find the best dosage (the concentration that should be given, and how often it should be given).
2) The law in Britain states that any new drug must be tested on two different live mammals. Some people think it's cruel to test on animals, but others believe this is the safest way to make sure a drug isn't dangerous before it's given to humans.

But some people think that animals are so different from humans that testing on animals is pointless.

3

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. This is to make sure that it doesn't have any harmful side effects when the body is working normally. At the start of the trial, a very low dose of the drug is given and this is gradually increased.
3) If the results of the tests on healthy volunteers are good, the drugs can be tested on people suffering from the illness. The optimum dose is found — this is the dose of drug that is the most effective and has few side effects.
4) To test how well the drug works, patients are randomly put into two groups. One is given the new drug, the other is given a placebo (a substance that's like the drug being tested but doesn't do anything). This is so the doctor can see the actual difference the drug makes — it allows for the placebo effect (when the patient expects the treatment to work and so feels better, even though the treatment isn't doing anything).
5) Clinical trials are blind — the patient in the study doesn't know whether they're getting the drug or the placebo. In fact, they're often double-blind — neither the patient nor the doctor knows until all the results have been gathered. This is so the doctors monitoring the patients and analysing the results aren't subconsciously influenced by their knowledge.
6) The results of drug testing and drug trials aren't published until they've been through peer review. This helps to prevent false claims.

Peer review is when other scientists check that the work is valid and has been carried out rigorously — see page 1.

The placebo effect doesn't work with revision...

... you can't just expect to get a good mark and then magically get it. I know, I know, there's a lot of information to take in on this page, but just read it through slowly. There's nothing too tricky here — it's just a case of going over it again and again until you've got it all firmly lodged in your memory.

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]

Q3 Why must the results from drug testing be assessed by peer review? [1 mark]

Photosynthesis and Limiting Factors

First, photosynthesis equations. 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 green plant cells — they contain pigments like chlorophyll that absorb light.
3) Energy is transferred to the chloroplasts from the environment by light.
4) Photosynthesis is endothermic — this means energy is transferred from the environment in the process.
5) The word equation for photosynthesis is:

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

6) Here's the symbol equation too:

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

Plants Use Glucose in Five Main Ways...

1) For respiration — This transfers energy from glucose (see p.54) which enables the plants to convert the rest of the glucose into various other useful substances.
2) Making cellulose — Glucose is converted into cellulose for making strong plant cell walls (see p.11).
3) Making amino acids — Glucose is combined with nitrate ions (absorbed from the soil) to make amino acids, which are then made into 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, ready for use when photosynthesis isn't happening, like in the winter. Starch is insoluble, which makes it much better for storing than glucose — a cell with lots of glucose in would draw in loads of water and swell up.

Limiting Factors Affect the Rate of Photosynthesis

1) The rate of photosynthesis is affected by intensity of light, concentration of CO_2 and temperature.
2) Any of these three factors can become the limiting factor — this just means that it's stopping photosynthesis from happening any faster.
3) These factors have a combined effect on the rate of photosynthesis, but which factor is limiting at a particular time depends on the environmental conditions:
   - at night it's pretty obvious that light is the limiting factor,
   - in winter it's often the temperature,
   - if it's warm enough and bright enough, the amount of CO_2 is usually limiting.
4) Chlorophyll can also be a limiting factor of photosynthesis.

The amount of chlorophyll in a plant can be affected by disease (e.g. infection with the tobacco mosaic virus) or environmental stress, such as a lack of nutrients. These factors can cause chloroplasts to become damaged or to not make enough chlorophyll. This means the rate of photosynthesis is reduced because they can't absorb as much light.

Now you'll have something to bore the great-grandkids with...

You'll be able to tell them how, in your day, all you needed was a bit of carbon dioxide and some water and you could make your own entertainment. But at the moment you need to learn this page...

Q1 Name the products of photosynthesis. [2 marks]

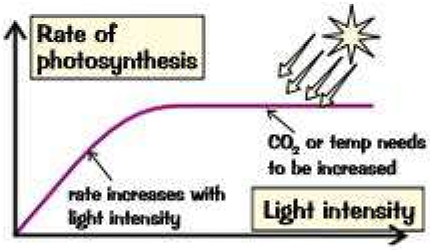
Q2 Apart from temperature, name three other limiting factors of photosynthesis. [3 marks]

The Rate of Photosynthesis

Now that you know light, CO_2 and temperature all affect the rate of photosynthesis, you also need to know how they affect the rate, so you can take a gander at a load of lovely pictures... well, graphs. I've also thrown an experiment and an equation in for good measure. I can tell these pages are going to be your favourites...

Three Important Graphs for Rate of Photosynthesis

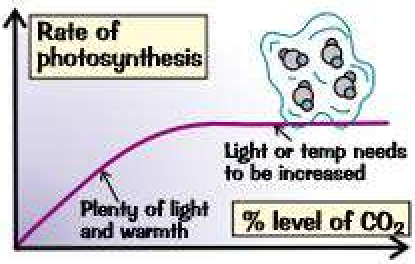
1) Not Enough Light Slows Down the Rate of Photosynthesis



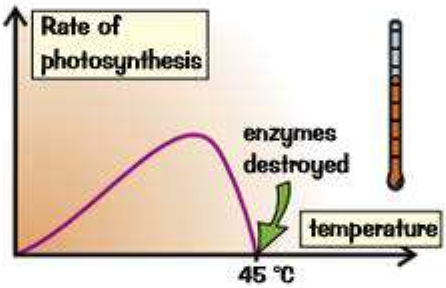
1) Light provides the energy needed for photosynthesis.
2) As the light level is raised, the rate of photosynthesis increases steadily — but only up to a certain point.
3) Beyond that, it won't make any difference — as light intensity increases, the rate will no longer increase. This is because it'll be either the temperature or the CO_2 level which is now the limiting factor, not light.
4) In the lab you can change the light intensity by moving a lamp closer to or further away from your plant (see the next page for this experiment).
5) But if you just plot the rate of photosynthesis against "distance of lamp from the plant", you get a weird-shaped graph. To get a graph like the one above you either need to measure the light intensity at the plant using a light meter or do a bit of nifty maths with your results.

2) Too Little Carbon Dioxide Also Slows it Down

1) CO_2 is one of the raw materials needed for photosynthesis.
2) As with light intensity, the amount of CO_2 will only increase the rate of photosynthesis up to a point. After this the graph flattens out — as the amount of CO_2 increases, the rate no longer increases. This shows that CO_2 is no longer the limiting factor.
3) As long as light and CO_2 are in plentiful supply then the factor limiting photosynthesis must be temperature.



3) The Temperature has to be Just Right



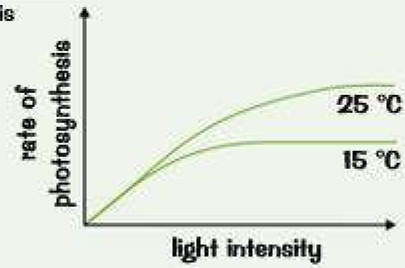
1) Usually, if the temperature is the limiting factor it's because it's too low — the enzymes needed for photosynthesis work more slowly at low temperatures.
2) But if the plant gets too hot, the enzymes it needs for photosynthesis and its other reactions will be damaged.
3) This happens at about 45 °C (which is pretty hot for outdoors, although greenhouses can get that hot if you're not careful).

The Rate of Photosynthesis

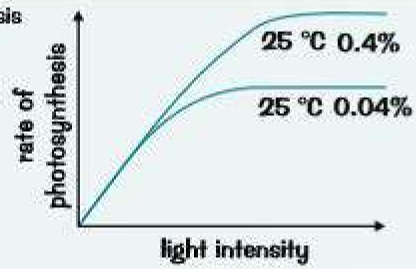
One Graph May Show the Effect of Many Limiting Factors

You could get a graph that shows more than one limiting factor on the rate of photosynthesis, for example:

1) The graph on the right shows how the rate of photosynthesis is affected by light intensity and temperature.
2) At the start, both of the lines show that as the light intensity increases, the rate of photosynthesis increases steadily.
3) But the lines level off when light is no longer the limiting factor. The line at 25 °C levels off at a higher point than the one at 15 °C, showing that temperature must have been a limiting factor at 15 °C.



1) The graph on the right shows how the rate of photosynthesis is affected by light intensity and CO_2 concentration.
2) Again, both the lines level off when light is no longer the limiting factor.
3) The line at the higher CO_2 concentration of 0.4% levels off at a higher point than the one at 0.04%. This means CO_2 concentration must have been a limiting factor at 0.04% CO_2. The limiting factor here isn't temperature because it's the same for both lines (25 °C).



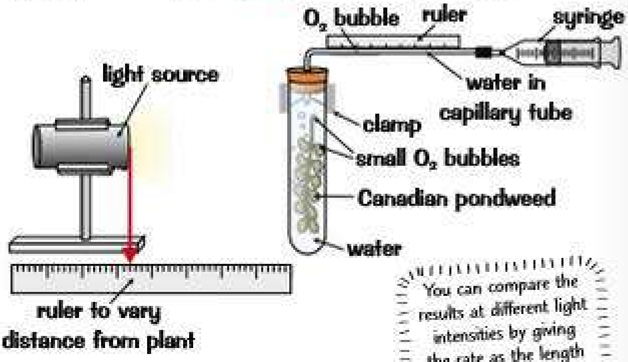
Oxygen Production Shows the Rate of Photosynthesis

PRACTICAL

Canadian pondweed can be used to measure the effect of light intensity on the rate of photosynthesis. The rate at which the pondweed produces oxygen corresponds to the rate at which it's photosynthesising — the faster the rate of oxygen production, the faster the rate of photosynthesis.

Here's how the experiment works:

1) A source of white light is placed at a specific distance from the pondweed.
2) The pondweed is left to photosynthesise for a set amount of time. As it photosynthesises, the oxygen released will collect in the capillary tube.
3) At the end of the experiment, the syringe is used to draw the gas bubble in the tube up alongside a ruler and the length of the gas bubble is measured. This is proportional to the volume of O_2 produced.



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.

4) For this experiment, any variables that could affect the results should be controlled, e.g. the temperature and time the pondweed is left to photosynthesise.
5) The experiment is repeated twice with the light source at the same distance and the mean volume of O_2 produced is calculated.
6) Then the whole experiment is repeated with the light source at different distances from the pondweed.

The apparatus above can be altered to measure the effect of temperature or CO_2 on photosynthesis. E.g. the test tube of pondweed can be put into a water bath at a set temperature, or a measured amount of sodium hydrogencarbonate can be dissolved in the water (which gives off CO_2). The experiment can then be repeated with different temperatures of water / concentrations of sodium hydrogencarbonate.

The Rate of Photosynthesis

The Inverse Square Law Links Light Intensity and Distance

1) In the experiment on the previous page, when the lamp is moved away from the pondweed, the amount of light that reaches the pondweed decreases.
2) You can say that as the distance increases, the light intensity decreases. In other words, distance and light intensity are inversely proportional to each other.
3) However, it's not quite as simple as that. It turns out that light intensity decreases in proportion to the square of the distance. This is called the inverse square law and is written out like this:

$$\text{light intensity} \propto \frac{1}{\text{distance (d)}^2}$$

This is the 'proportional to' symbol. Putting one over the distance shows the inverse. The distance is squared.

4) The inverse square law means that if you halve the distance, the light intensity will be four times greater and if you third the distance, the light intensity will be nine times greater. Likewise, if you double the distance, the light intensity will be four times smaller and if you treble the distance, the light intensity will be nine times smaller.
5) You can use $1/d^2$ as a measure of light intensity.

EXAMPLE

Use the inverse square law to calculate the light intensity when the lamp is 10 cm from the pondweed.

1) Use the formula $\frac{1}{d^2}$. — $\text{light intensity} = \frac{1}{d^2}$
2) Fill in the values you know — you're given the distance, so put that in. — $\text{light intensity} = \frac{1}{10^2}$
3) Calculate the answer. — $= 0.01$ a.u.

'a.u.' stands for 'arbitrary units'.

You can Artificially Create the Ideal Conditions for Farming

1) The most common way to artificially create the ideal environment for plants is to grow them in a greenhouse.

2) Greenhouses help to trap the Sun's heat, and make sure that the temperature doesn't become limiting. In winter a farmer or gardener might use a heater as well to keep the temperature at the ideal level. In summer it could get too hot, so they might use shades and ventilation to cool things down.
3) Light is always needed for photosynthesis, so commercial farmers often supply artificial light after the Sun goes down to give their plants more quality photosynthesis time.
4) Farmers and gardeners can also increase the level of carbon dioxide in the greenhouse. E.g. by using a paraffin heater to heat the greenhouse. As the paraffin burns, it makes carbon dioxide as a by-product.
5) Keeping plants enclosed in a greenhouse also makes it easier to keep them free from pests and diseases. The farmer can add fertilisers to the soil as well, to provide all the minerals needed for healthy growth.
6) Sorting all this out costs money — but if the farmer can keep the conditions just right for photosynthesis, the plants will grow much faster and a decent crop can be harvested much more often, which can then be sold. It's important that a farmer supplies just the right amount of heat, light, etc. — enough to make the plants grow well, but not more than the plants need, as this would just be wasting money.

With enough light, photographers can also photosynthesise...

Now don't let the inverse square law put you off learning everything on these past three pages.

Q1 An experiment was carried out to find out the effect of temperature on the rate of photosynthesis. Name two variables that should have been controlled in this experiment. [2 marks]

Q2 A plant is moved from 15 cm away from its light source to 5 cm away from its light source. Using the inverse square law, show that the light intensity becomes nine times greater. [3 marks]

Q2 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"

Respiration involves many reactions. These are really important reactions, as respiration transfers the energy that the cell needs to do just about everything — this energy is used for all living processes.

1) Respiration is not breathing in and breathing out, as you might think.
2) Respiration is the process of transferring energy from the breakdown of glucose (sugar) — and it goes on in every cell in your body continuously.
3) It happens in plants too. All living things respire. It's how they transfer energy from their food to their cells.

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

4) Respiration is exothermic — 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 (like proteins from amino acids — see below).
2) In animals it's used to allow the muscles to contract (so they can move about).
3) In mammals and birds the energy is used to keep their body temperature steady in colder surroundings. (Unlike other animals, mammals and birds keep their bodies constantly warm.)

Metabolism is ALL the Chemical Reactions in an Organism

1) In a cell there are lots of chemical reactions happening all the time, which are controlled by enzymes.
2) Many of these reactions are linked together to form bigger reactions:

reactant —enzyme→ product —enzyme→ product —enzyme→ product

Enzymes are biological catalysts — see p.25.

3) In some of these reactions, larger molecules are made from smaller ones. For example:
   - Lots of small glucose molecules are joined together in reactions to form starch (a storage molecule in plant cells), glycogen (a storage molecule in animal cells) and 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, which 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.

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, transferring energy from the food you eat. This energy is used to make molecules that our cells need.

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 cha know...

Aerobic Respiration Needs Plenty of Oxygen

1) Aerobic respiration is respiration using oxygen.
It's the most efficient way to transfer energy from glucose.
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) Here are the word and symbol equations for aerobic respiration:

glucose + oxygen ⟶ carbon dioxide + water

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

Anaerobic Respiration is Used if There's Not Enough Oxygen

When you do vigorous exercise and your body can't supply enough oxygen to your muscles, they start doing anaerobic respiration as well as aerobic respiration.

1) "Anaerobic" just means "without oxygen". It's the incomplete breakdown of glucose, making lactic acid.
2) Here's the word equation for anaerobic respiration in muscle cells:

glucose ⟶ lactic acid

3) Anaerobic respiration does not transfer nearly as much energy as aerobic respiration.
This is because glucose isn't fully oxidised (because it doesn't combine with oxygen).
4) So, anaerobic respiration is only useful in emergencies, e.g. during exercise when it allows you to keep on using your muscles for a while longer.

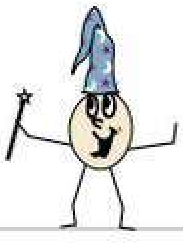
Anaerobic Respiration in Plants and Yeast is Slightly Different

1) Plants and yeast cells can respire without oxygen too, but they produce ethanol (alcohol) and carbon dioxide instead of lactic acid.
2) Here is the word equation for anaerobic respiration in plants and yeast cells:

Yeast are single-celled organisms.

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 because it's used to make bread and alcoholic drinks, e.g. beer and wine.
5) In bread-making, it's the carbon dioxide from fermentation that makes bread rise.
6) In beer and wine-making, 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 alcoholic drinks and bread. We drink and eat so much of these that making them is big bucks. And it's all down to tiny yeast cells.

Q1 What are the reactants of 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. When you exercise, some of your muscles contract more frequently than normal so you need more energy. This energy comes from increased respiration.
2) The increase in respiration in your cells means you need to get more oxygen into them.
3) Your breathing rate and breath volume increase to get more oxygen into the blood, and your heart rate increases to get this oxygenated blood around the body faster. This removes CO_2 more quickly at the same time.
4) When you do really vigorous exercise (like sprinting) your body can't supply oxygen to your muscles quickly enough, so they start respiring anaerobically (see the previous page).
5) This is NOT the best way to transfer energy from glucose because lactic acid builds up in the muscles, which gets painful.
6) Long periods of exercise also cause muscle fatigue — the muscles get tired and then stop contracting efficiently.

Remember, lactic acid is formed from the incomplete oxidation of glucose.

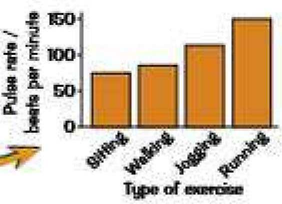
Anaerobic Respiration Leads to an Oxygen Debt

1) After resorting to anaerobic respiration, when you stop exercising you'll have an "oxygen debt".
2) An oxygen debt is the amount of extra oxygen your body needs to react with the build up of lactic acid and remove it from the cells. Oxygen reacts with the lactic acid to form harmless CO_2 and water.
3) In other words you have to "repay" the oxygen that you didn't get to your muscles in time, because your lungs, heart and blood couldn't keep up with the demand earlier on.
4) This means you have to keep breathing hard for a while after you stop, to get more oxygen into your blood, which is transported to the muscle cells.
5) The pulse and breathing rate stay high whilst there are high levels of lactic acid and CO_2.
6) Your body also has another way of coping with the high level of lactic acid — the blood that enters your muscles transports the lactic acid to the liver. In the liver, the lactic acid is converted back to glucose.

You Can Investigate The Effect of Exercise on The Body

1) You can measure breathing rate by counting breaths, and heart rate by taking the pulse.
2) E.g. you could take your pulse after:
   - sitting down for 5 minutes,
   - then after 5 minutes of gentle walking,
   - then again after 5 minutes of slow jogging,
   - then again after running for 5 minutes,

   and plot your results in a bar chart.



You put two fingers on the inside of your wrist or your neck and count the number of pulses in 1 minute.

3) Your pulse rate will increase the more intense the exercise is, as your body needs to get more oxygen to the muscles and take more carbon dioxide away from the muscles.
4) To reduce the effect of any random errors on your results, do it as a group and plot the average pulse rate for each exercise.

There's more about random error on page 5.

Oxygen debt — cheap to pay back...

At the end of a sprinting race you often see athletes breathing hard — now you know this is to get rid of the lactic acid that's built up in the muscles. But remember, the liver plays a role in breaking it down too.

Q1 Look at the graph above. Predict which type of exercise would lead to the highest concentration of lactic acid in the blood after 10 minutes. Explain your answer. [4 marks]

Q1 Video Solution

Revision Questions for Topics B3 & B4

It's all over for Topics B3 and B4 folks. So here are some questions on them...

- 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.43-45)

1) How can bacteria make us feel ill?
2) How does tobacco mosaic virus affect a plant's growth?
3) How are mosquitoes involved in the spread of malaria?
4) What are the symptoms of gonorrhoea?
5) How can destroying vectors help to prevent the spread of disease?

Fighting Disease (p.46-49)

6) What does the stomach produce that can kill pathogens?
7) Give three ways that the white blood cells can defend against pathogens.
8) Give one pro and one con of vaccination.
9) Why is it difficult to develop drugs that kill viruses without also damaging body tissues?
10) Which plant does the painkiller aspirin originate from?
11) What two things are drugs tested on in preclinical testing?
12) What is a placebo?

Photosynthesis (p.50-53)

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.
20) In the inverse square law, how are light intensity and distance linked?

Respiration and Metabolism (p.54-56)

21) What is respiration?
22) What is an exothermic reaction?
23) Name the products of aerobic respiration.
24) What is produced by anaerobic respiration in muscle cells?
25) What is the word equation for anaerobic respiration in yeast cells?
26) Name two products of the food and drink industry that fermentation is needed for.
27) Give three things that increase to supply the muscles with more oxygenated blood during exercise.
28) In what organ is lactic acid converted back to glucose?

Homeostasis

Homeostasis — a word that strikes fear into the heart of many a GCSE student. But it's really not that bad at all. This page is a brief introduction to the topic, so you need to nail all of this before you can move on.

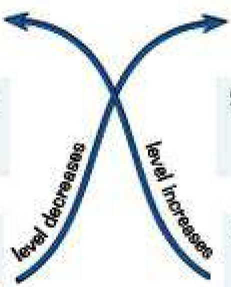
Homeostasis — Maintaining a Stable Internal Environment

1) The conditions inside your body need to be kept steady, even when the external environment changes. This is really important because your cells need the right conditions in order to function properly, including the right conditions for enzyme action (see p.25).
2) Homeostasis is all about the regulation of the conditions inside your body (and cells) to maintain a stable internal environment, in response to changes in both internal and external conditions.
3) You have loads of automatic control systems in your body that regulate your internal environment — these include both nervous and hormonal communication systems. For example, there are control systems that maintain your body temperature, blood glucose level (see page 63) and your water content.
4) All your automatic control systems are made up of three main components which work together to maintain a steady condition — cells called receptors, coordination centres (including the brain, spinal cord and pancreas) and effectors.

Negative Feedback Counteracts Changes

Your automatic control systems keep your internal environment stable using a mechanism called negative feedback. When the level of something (e.g. water or glucose) gets too high or too low, your body uses negative feedback to bring it back to normal.

1) Receptor detects a stimulus — level is too high.
2) The coordination centre receives and processes the information, then organises a response.
3) Effector produces a response, which counteracts the change and restores the optimum level — the level decreases.



1) Receptor detects a stimulus — level is too low.
2) The coordination centre receives and processes the information, then organises a response.
3) Effector produces a response, which counteracts the change and restores the optimum level — the level increases.

A stimulus is a change in the environment.

The effectors will just carry on producing the responses for as long as they're stimulated by the coordination centre. This might cause the opposite problem — making the level change too much (away from the ideal). Luckily the receptor detects if the level becomes too different and negative feedback starts again.

This process happens without you thinking about it — it's all automatic.

If you do enough revision, you can avoid negative feedback...

Negative feedback is a fancy-sounding name for a not-very-complicated idea. It's common sense really. For example, if you looked sad, I'd try and cheer you up. And if you looked really happy, I'd probably start to annoy you by flicking the backs of your ears. It stops things getting out of balance, I think.

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

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

The Nervous System

Organisms need to respond to stimuli (changes in the environment) in order to survive. A single-celled organism can just respond to its environment, but the cells of multicellular organisms need to communicate with each other first. So as multicellular organisms evolved, they developed nervous and hormonal communication systems.

The Nervous System Detects and Reacts to Stimuli

The nervous system means that humans can react to their surroundings and coordinate their behaviour.

The Nervous System is made up of Different Parts

Central Nervous System (CNS)

In vertebrates (animals with backbones) this consists of the brain and spinal cord only. In mammals, the CNS is connected to the body by sensory neurones and motor neurones.

Sensory Neurones

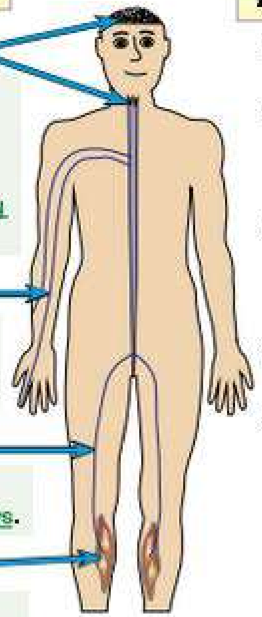
The neurones that carry information as electrical impulses from the receptors to the CNS.

Motor Neurones

The neurones that carry electrical impulses from the CNS to effectors.

Effectors

All your muscles and glands, which respond to nervous impulses.



Receptors and Effectors can form part of Complex Organs

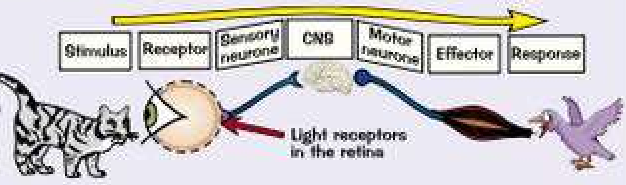
1) Receptors are the cells that detect stimuli.
2) There are many different types of receptors, such as taste receptors on the tongue and sound receptors in the ears.
3) Receptors can form part of larger, complex organs, e.g. the retina of the eye is covered in light receptor cells.
4) Effectors respond to nervous impulses and bring about a change.
5) Muscles and glands are known as effectors — they respond in different ways. Muscles contract in response to a nervous impulse, whereas glands secrete hormones.

The Central Nervous System (CNS) Coordinates the Response

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

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

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



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

Don't forget that it's only large animals like mammals and birds that have complex nervous systems. Simple animals like jellyfish don't — everything they do is a reflex response (see next page).

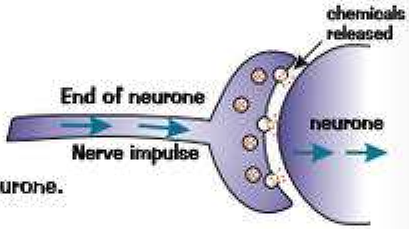
Q1 Name two types of effector. [2 marks]

Synapses and Reflexes

Neurones transmit information very quickly to and from the brain, and your brain quickly decides how to respond to a stimulus. But reflexes are even quicker...

Synapses Connect Neurones

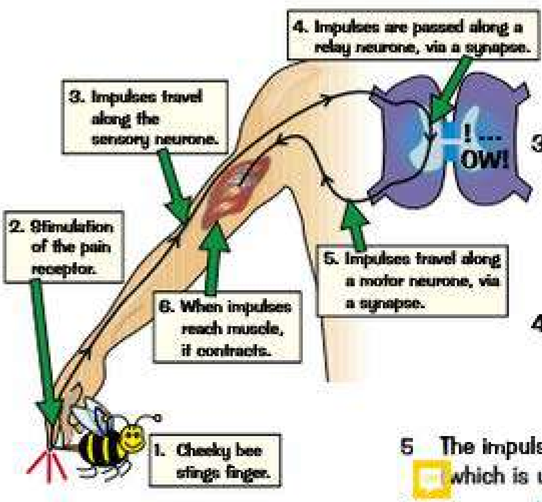
1) The connection between two neurones is called a synapse.
2) The nerve signal is transferred by chemicals which diffuse (move) across the gap.
3) These chemicals then set off a new electrical signal in the next neurone.



Reflexes Help Prevent Injury

1) Reflexes are rapid, automatic responses to certain stimuli that don't involve the conscious part of the brain — they can reduce the chances of being injured.
2) For example, if someone shines a bright light in your eyes, your pupils automatically get smaller so that less light gets into the eye — this stops it getting damaged.
3) Or if you get a shock, your body releases the hormone adrenaline automatically — it doesn't wait for you to decide that you're shocked.
4) The passage of information in a reflex (from receptor to effector) is called a reflex arc.

The Reflex Arc Goes Through the Central Nervous System



1) The neurones in reflex arcs go through the spinal cord or through an unconscious part of the brain.
2) When a stimulus (e.g. a painful bee sting) is detected by receptors, impulses are sent along a sensory neurone to a relay neurone in the CNS.
3) When the impulses reach a synapse between the sensory neurone and the relay neurone, they trigger chemicals to be released (see above). These chemicals cause impulses to be sent along the relay neurone.

   Relay neurones connect sensory neurones to motor neurones.

4) When the impulses reach a synapse between the relay neurone and a motor neurone, the same thing happens. Chemicals are released and cause impulses to be sent along the motor neurone.
5) The impulses then travel along the motor neurone to the effector (which is usually a muscle, like in this example).
6) The muscle then contracts and moves your hand away from the bee.
7) Because you don't have to think about the response (which takes time) it's quicker than normal responses.

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

Reflexes bypass your conscious brain completely when a quick response is essential — your body just gets on with things. If you had to stop and think first, you'd end up a lot more sore (or worse).

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

Investigating Reaction Time

PRACTICAL

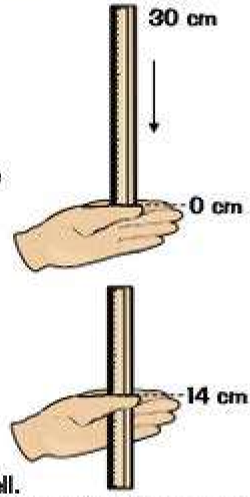
On your marks... get set... read this page.

Reaction Time is How Quickly You Respond

Reaction time is the time it takes to respond to a stimulus — it's often less than a second. It can be affected by factors such as age, gender or drugs.

You Can Measure Reaction Time

Caffeine is a drug that 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 (this should stop them moving their arm up or down during the test).
2) Hold a ruler vertically between their thumb and forefinger. Make sure that the zero end of the ruler is level with their thumb and finger. Then let go without giving any warning.
3) The person being tested should try to catch the ruler as quickly as they can — as soon as they see it fall.
4) Reaction time is measured by the number on the ruler where it's caught. The number should be read from the top of the thumb. The further down the ruler it's caught (i.e. the higher the number), the slower their reaction time.
5) Repeat the test several times then calculate the mean distance that the ruler fell.
6) The person being tested should then have a caffeinated drink (e.g. 300 ml of cola). After ten minutes, repeat steps 1 to 5.
7) You need to control any variables to make sure that this is a fair test. For example, you should use the same person to catch the ruler each time, and that person should always use the same hand to catch the ruler. Also, the ruler should always be dropped from the same height, and you should make sure that the person being tested has not had any caffeine (or anything else that may affect their reaction time) before the start of the experiment.
8) Too much caffeine can cause unpleasant side-effects, so the person being tested should avoid drinking any more caffeine for the rest of the day after the experiment is completed.

With a little bit of maths, it's possible to work out the reaction time in seconds using the mean distance.

Reaction Time Can Be Measured Using a Computer

1) Simple computer tests can also be used to measure reaction time. For example, the person being tested has to click the mouse (or press a key) as soon as they see a stimulus on the screen, e.g. a box change colour.
2) Computers can give a more precise reaction time because they remove the possibility of human error from the measurement.
3) As the computer can record the reaction time in milliseconds, it can also give a more accurate measurement.
4) Using a computer can also remove the possibility that the person can predict when to respond — using the ruler test, the catcher may learn to anticipate the drop by reading the tester's body language.

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]

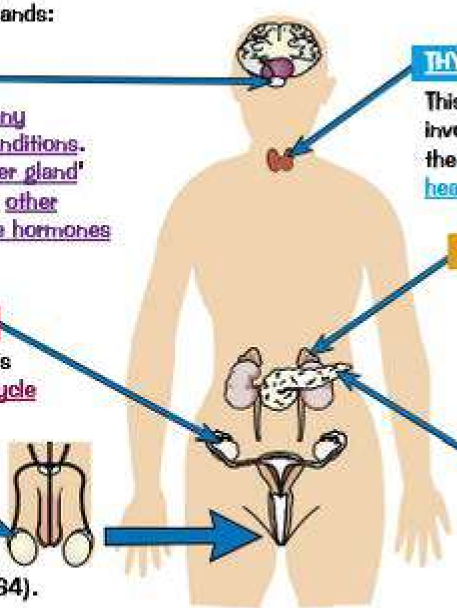
Q1 Video Solution

The Endocrine System

The other way to send information around the body (apart from along nerves) is by using hormones.

Hormones Are Chemical Messengers Sent in the Blood

1) Hormones are chemical molecules released directly into the blood. They are carried in the blood to other parts of the body, but only affect particular cells in particular organs (called target organs). Hormones control things in organs and cells that need constant adjustment.
2) Hormones are produced in (and secreted by) various glands, called endocrine glands. These glands make up your endocrine system.
3) Hormones tend to have relatively long-lasting effects.
4) Here are some examples of glands:



THE PITUITARY GLAND
The pituitary gland produces many hormones that regulate body conditions. It is sometimes called the 'master gland' because these hormones act on other glands, directing them to release hormones that bring about change.

THYROID
This produces thyroxine, which is involved in regulating things like the rate of metabolism, heart rate and temperature.

ADRENAL GLAND
This produces adrenaline, which is used to prepare the body for a 'fight or flight' response (see page 67).

OVARIES — females only
Produce oestrogen, which is involved in the menstrual cycle (see page 64).

THE PANCREAS
This produces insulin, which is used to regulate the blood glucose level (see next page).

TESTES — males only
Produce testosterone, which controls puberty and sperm production in males (see page 64).

Hormones and Nerves Have Differences

NERVES:
Very FAST action.
Act for a very SHORT TIME.
Act on a very PRECISE AREA.

HORMONES:
SLOWER action.
Act for a LONG TIME.
Act in a more GENERAL way.

So if you're not sure whether a response is nervous or hormonal, have a think...

1) If the response is really quick, it's probably nervous. Some information needs to be passed to effectors really quickly (e.g. pain signals, or information from your eyes telling you about the lion heading your way), so it's no good using hormones to carry the message — they're too slow.
2) But if a response lasts for a long time, it's probably hormonal. For example, when you get a shock, a hormone called adrenaline is released into the body (causing the fight or flight response, where your body is hyped up ready for action). You can tell it's a hormonal response (even though it kicks in pretty quickly) because you feel a bit wobbly for a while afterwards.

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

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

Q1 Why is the pituitary gland referred to as the 'master gland'? [1 mark]

Controlling Blood Glucose

Blood glucose is also controlled as part of homeostasis. Insulin and glucagon are the two hormones involved.

Insulin and Glucagon Control Blood Glucose Level

1) Eating foods containing carbohydrate puts glucose (a type of sugar) into the blood from the gut.
2) The normal metabolism of cells removes glucose from the blood.
3) Vigorous exercise removes much more glucose from the blood.
4) Excess glucose can be stored as glycogen in the liver and in the muscles.
5) The level of glucose in the blood must be kept steady. Changes are monitored and controlled by the pancreas, using the hormones insulin and glucagon, in a negative feedback cycle:

So insulin removes glucose from the blood.

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

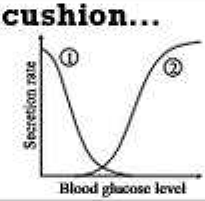
Diabetes is a condition that affects your ability to control your blood sugar level. There are two types:

1) Type 1 diabetes is where the pancreas produces little or no insulin. This means a person's blood glucose level can rise to a level that can kill them. People with Type 1 diabetes need insulin therapy — this usually involves several injections of insulin throughout the day, most likely at mealtimes. This makes sure that glucose is removed from the blood quickly once the food has been digested, stopping the level getting too high. It's a very effective treatment. The amount of insulin that needs to be injected depends on the person's diet and how active they are. As well as insulin therapy, people with Type 1 diabetes need to think about limiting the intake of food rich in simple carbohydrates, e.g. sugars (which cause the blood glucose to rise rapidly) and taking regular exercise (which helps to remove excess glucose from the blood).
2) Type 2 diabetes is where a person becomes resistant to their own insulin (they still produce insulin, but their body's cells don't respond properly to the hormone). This can also cause a person's blood sugar level to rise to a dangerous level. Being overweight can increase your chance of developing Type 2 diabetes, as obesity is a major risk factor in the development of the disease. Type 2 diabetes can be controlled by eating a carbohydrate-controlled diet and getting regular exercise.

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

This stuff can seem a bit confusing at first, but if you learn those two diagrams, it should get a bit easier.

Q1 The graph shows the relative secretion rates of insulin and glucagon as the blood glucose level increases. Which curve represents glucagon? Explain your answer. [2 marks]



Q1 Video Solution

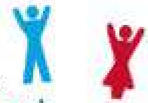
Puberty and the Menstrual Cycle

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

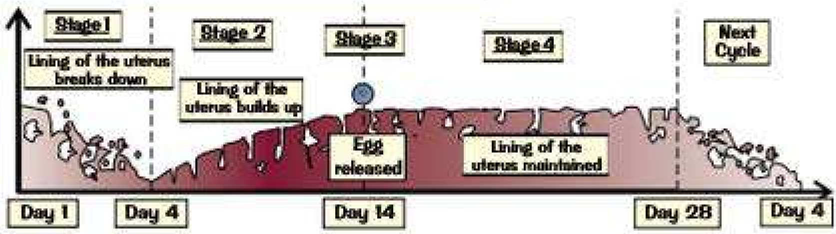
Hormones Promote Sexual Characteristics at Puberty

At puberty, your body starts releasing sex hormones that trigger off secondary sexual characteristics (such as the development of facial hair in men and breasts in women) and cause eggs to mature in women.

- In men, the main reproductive hormone is testosterone.
  It's produced by the testes and stimulates sperm production.
- In women, the main reproductive hormone is oestrogen. It's produced by the ovaries.
  As well as bringing about physical changes, oestrogen is also involved in the menstrual cycle.



The Menstrual Cycle Has Four Stages



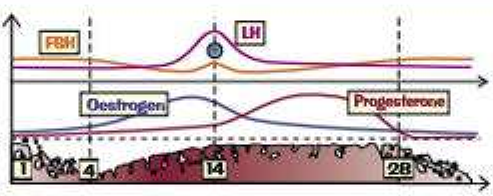
Stage 1 Day 1 — menstruation starts. The uterus lining breaks down for about four days.

Stage 2 The uterus lining builds up again, from day 4 to day 14, into a thick spongy layer full of blood vessels, 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 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 and the whole cycle starts again.

It's Controlled by Four Hormones



1 FSH (Follicle-Stimulating Hormone)

1) Produced in the pituitary gland.
2) Causes an egg to mature in one of the ovaries, in a structure called a follicle.
3) Stimulates the ovaries to produce oestrogen.

2 Oestrogen

1) Produced in the ovaries.
2) Causes the lining of the uterus to grow.
3) Stimulates the release of LH (which causes the release of an egg) and inhibits release of FSH.

3 LH (Luteinising Hormone)

1) Produced by the pituitary gland.
2) Stimulates the release of an egg at day 14 (ovulation).

4 Progesterone

1) Produced in the ovaries by the remains of the follicle after ovulation.
2) Maintains the lining of the uterus during the second half of the cycle. When the level of progesterone falls, the lining breaks down.
3) Inhibits the release of LH and FSH.

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

Learn this page until you know what hormone does what and understand the graphs.

Q1 Name the hormone that stimulates 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 ovulated egg. Contraception tries to stop this happening.

Hormones Can Be Used to Reduce Fertility

1) Oestrogen can be used to prevent the release of an egg — so it can be used as a method of contraception.
2) This may seem kind of strange (since naturally oestrogen helps stimulate the release of eggs). But if oestrogen is taken every day to keep the level of it permanently high, it inhibits the production of FSH, and after a while egg development and production stop and stay stopped.
3) Progesterone also reduces fertility, e.g. by stimulating the production of thick mucus which prevents any sperm getting through and reaching an egg.
4) The pill is an oral contraceptive containing oestrogen and progesterone (known as the combined oral contraceptive pill).
5) It's over 99% effective at preventing pregnancy, but it can cause side effects like headaches and nausea and it doesn't protect against sexually transmitted diseases.
6) There's also a progesterone-only pill — it has fewer side effects than the pill, and is just as effective.
7) There are other methods of contraception that use hormones:

- The contraceptive patch contains oestrogen and progesterone (the same as the combined pill). It's a small (5 cm × 5 cm) patch that's stuck to the skin. Each patch lasts one week.
- The contraceptive implant is inserted under the skin of the arm. It releases a continuous amount of progesterone, which stops the ovaries releasing eggs, makes it hard for sperm to swim to the egg, and stops any fertilised egg implanting in the uterus. An implant can last for three years.
- The contraceptive injection also contains progesterone. Each dose lasts 2 to 3 months.
- An intrauterine device (IUD) is a T-shaped device that is inserted into the uterus to kill sperm and prevent implantation of a fertilised egg. There are two main types — plastic IUDs that release progesterone and copper IUDs that prevent the sperm surviving in the uterus.

Barriers Stop Egg and Sperm Meeting

1) Non-hormonal forms of contraception are designed to stop the sperm from getting to the egg.
2) Condoms are worn over the penis during intercourse to prevent the sperm entering the vagina. There are also female condoms that are worn inside the vagina. Condoms are the only form of contraception that will protect against sexually transmitted diseases.
3) A diaphragm is a shallow plastic cup that fits over the cervix (the entrance to the uterus) to form a barrier. It has to be used with spermicide (a substance that disables or kills the sperm).
4) Spermicide can be used alone as a form of contraception, but it is not as effective (only about 70-80%).

There are Other Ways to Avoid Pregnancy

STERILISATION — Sterilisation involves cutting or tying the fallopian tubes (which connect the ovaries to the uterus) in a female, or the sperm duct (the tube between the testes and penis) in a male. This is a permanent procedure. However, there is a very small chance that the tubes can rejoin.

'NATURAL' METHODS — Pregnancy may be avoided by finding out when in the menstrual cycle the woman is most fertile and avoiding sexual intercourse on those days. It's popular with people who think that hormonal and barrier methods are unnatural, but it's not very effective.

ABSTINENCE — The only way to be completely sure that sperm and egg don't meet is to not have intercourse.

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. If you do, make sure you weigh up and write about both the pros and the cons of each method. Exciting stuff.

Q1 Name two forms of contraception that reduce fertility by releasing oestrogen. [2 marks]

More on Controlling Fertility

Scientific advances in understanding fertility have led to many infertile women being helped to have babies.

Hormones Can Be Used to Increase Fertility

1) Some women have levels of FSH (follicle-stimulating hormone) that are too low to cause their eggs to mature. This means that no eggs are released and the women can't get pregnant.
2) The hormones FSH and LH can be given to women in a fertility drug to stimulate ovulation.

PROS

It helps a lot of women to get pregnant when previously they couldn't... pretty obvious.

CONS

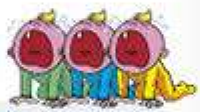
It doesn't always work — some women may have to do it many times, which can be expensive.

Too many eggs could be stimulated, resulting in unexpected multiple pregnancies (twins, triplets, etc.).

IVF Can Also Help Couples to Have Children

If a woman cannot get pregnant using medication, she may chose to try IVF ("*in vitro* fertilisation").

1) IVF involves collecting eggs from the woman's ovaries and fertilising them in a lab using the man's sperm.
2) IVF treatment can also involve a technique called Intra-Cytoplasmic Sperm Injection (ICSI), where the sperm is injected directly into an egg. It's useful if the man has a very low sperm count.
3) The fertilised eggs are then grown into embryos in a laboratory incubator.
4) Once the embryos are tiny balls of cells, one or two of them are transferred to the woman's uterus to improve the chance of pregnancy.
5) FSH and LH are given before egg collection to stimulate several eggs to mature (so more than one egg can be collected).



PRO Fertility treatment can give an infertile couple a child — a pretty obvious benefit.

CONS

Multiple births can happen if more than one embryo grows into a baby — these are risky for the mother and babies (there's a higher risk of miscarriage, stillbirth...).

The success rate of IVF is low — the average success rate in the UK is about 26%. This makes the process incredibly stressful and often upsetting, especially if it ends in multiple failures.

As well as being emotionally stressful, the process is also physically stressful for the woman. Some women have a strong reaction to the hormones — e.g. abdominal pain, vomiting, dehydration.

Advances in microscope techniques have helped to improve the techniques (and therefore the success rate) of IVF. Specialised micro-tools have been developed to use on the eggs and sperm under the microscope. They're also used to remove single cells from the embryo for genetic testing (to check that it is healthy — see page 74). More recently, the development of time-lapse imaging (using a microscope and camera built into the incubator) means that the growth of the embryos can be continuously monitored to help identify those that are more likely to result in a successful pregnancy.

Some People Are Against IVF

1) The process of IVF often results in unused embryos that are eventually destroyed. Because of this, some people think it is unethical because each embryo is a potential human life.
2) The genetic testing of embryos before implantation also raises ethical issues as some people think it could lead to the selection of preferred characteristics, such as gender or eye colour.

Nothing funny here, sorry...

Fertility treatment can help to increase the chance of pregnancy, but it can be hard on those involved.

Q1 What is the role of FSH and LH during IVF? [1 mark]

Q2 Give one drawback to using hormones to increase fertility. [1 mark]

Adrenaline and Thyroxine

You've met a lot of human hormones so far, but two more won't hurt. Then that's it, I promise...

Adrenaline Prepares You for "Fight or Flight"

1) Adrenaline is a hormone released by the adrenal glands, which are just above the kidneys (see p.62).
2) Adrenaline is released in response to stressful or scary situations — your brain detects fear or stress and sends nervous impulses to the adrenal glands, which respond by secreting adrenaline.
3) It gets the body ready for 'fight or flight' by triggering mechanisms that increase the supply of oxygen and glucose to cells in the brain and muscles. For example, adrenaline increases heart rate.

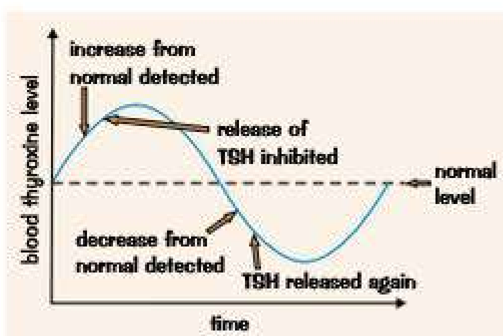
Hormone Release can be Affected by Negative Feedback

Your body can control the levels of hormones (and other substances) in the blood using negative feedback systems. When the body detects that the level of a substance has gone above or below the normal level, it triggers a response to bring the level back to normal again. Here's an example of just that:

Thyroxine Regulates Metabolism

Thyroxine is made in the thyroid gland from iodine and amino acids.

1) Thyroxine is a hormone released by the thyroid gland, which is in the neck (see p.62).
2) It plays an important role in regulating the basal metabolic rate — the speed at which chemical reactions in the body occur while the body is at rest. Thyroxine is also important for loads of processes in the body, such as stimulating protein synthesis for growth and development.
3) Thyroxine is released in response to thyroid stimulating hormone (TSH), which is released from the pituitary gland.
4) A negative feedback system keeps the amount of thyroxine in the blood at the right level — when the level of thyroxine in the blood is higher than normal, the secretion of TSH from the pituitary gland is inhibited (stopped). This reduces the amount of thyroxine released from the thyroid gland, so the level in the blood falls back towards normal.



Negative feedback sucks, especially from your science teacher...

You can think about negative feedback working like a thermostat — if the temperature gets too low, the thermostat will turn the heating on, then if the temperature gets too high, it'll turn the heating off again.

Q1 Name the gland that releases thyroxine. [1 mark]

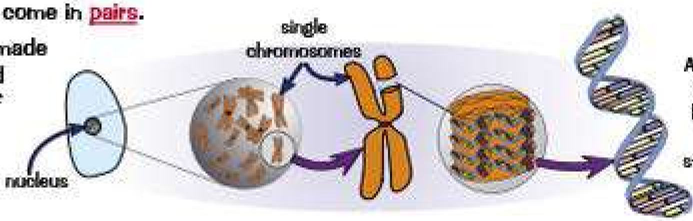
Q2 Describe the response if the level of thyroxine in the blood gets too high. [3 marks]

DNA

The first step in understanding genetics is getting to grips with DNA and genes.

Chromosomes Are Really Long Molecules of DNA

1) DNA stands for deoxyribonucleic acid. It's the chemical that all of the genetic material in a cell is made up from.
2) It contains coded information — basically all the instructions to put an organism together and make it work.
3) So it's what's in your DNA that determines what inherited characteristics you have.
4) DNA is found in the nucleus of animal and plant cells, in really long structures called chromosomes.
5) Chromosomes normally come in pairs.
6) DNA is a polymer. It's made up of two strands coiled together in the shape of a double helix.



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 (tells the cells to make) a particular sequence of amino acids which are put together to make a specific protein.
3) Only 20 amino acids are used, but they make up thousands of different proteins.
4) Genes simply tell cells in what order to put the amino acids together.
5) DNA also determines what proteins the cell produces, e.g. haemoglobin, keratin.
6) That in turn determines what type of cell it is, e.g. red blood cell, skin cell.

Every Organism Has a Genome

1) Genome is just the fancy term for the entire set of genetic material in an organism.
2) Scientists have worked out the complete human genome.
3) Understanding the human genome is a really important tool for science and medicine for many reasons.

   1) It allows scientists to identify genes in the genome that are linked to different types of disease.
   2) Knowing which genes are linked to inherited diseases could help us to understand them better and could help us to develop effective treatments for them.
   3) Scientists can look at genomes to trace the migration of certain populations of people around the world. All modern humans are descended from a common ancestor who lived in Africa, but humans can now be found all over the planet. The human genome is mostly identical in all individuals, but as different populations of people migrated away from Africa, they gradually developed tiny differences in their genomes. By investigating these differences, scientists can work out when new populations split off in a different direction and what route they took.

Insert joke about genes and jeans here...

There are so many, I thought you could come up with your own as a bit of light relief.
Make sure that you're clued up on this stuff about DNA, genes and proteins before you move on.

Q1 What is a gene? [3 marks]

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

Reproduction

Ooo err, reproduction... Surely you knew it'd come up at some point. It can happen in two different ways...

Sexual Reproduction Produces Genetically Different Cells

1) Sexual reproduction is where genetic information from two organisms (a father and a mother) is combined to produce offspring which are genetically different to either parent.
2) In sexual reproduction, the mother and father produce gametes by meiosis (see next page) — e.g. egg and sperm cells in animals.
3) In humans, each gamete contains 23 chromosomes — half the number of chromosomes in a normal cell. (Instead of having two of each chromosome, a gamete has just one of each.)
4) The egg (from the mother) and the sperm cell (from the father) then fuse together (fertilisation) to form a cell with the full number of chromosomes (half from the father, half from the mother).

SEXUAL REPRODUCTION involves the fusion of male and female gametes.
Because there are TWO parents, the offspring contain a mixture of their parents' genes.

Fertilisation:

5) This is why the offspring inherits features from both parents — it's received a mixture of chromosomes from its mum and its dad (and it's the chromosomes that decide how you turn out).
6) This mixture of genetic information produces variation in the offspring. Pretty cool, eh.
7) Flowering plants can reproduce in this way too. They also have egg cells, but their version of sperm is known as pollen. Hmm... I'm having second thoughts about frolicking in that meadow now.

Asexual Reproduction Produces Genetically Identical Cells

1) In asexual reproduction there's only one parent so the offspring are genetically identical to that parent.
2) Asexual reproduction happens by mitosis — an ordinary cell makes a new cell by dividing in two (see page 15).
3) The new cell has exactly the same genetic information (i.e. genes) as the parent cell — it's called a clone.

In ASEXUAL REPRODUCTION there's only ONE parent. There's no fusion of gametes, no mixing of chromosomes and no genetic variation between parent and offspring. The offspring are genetically identical to the parent — they're clones.

4) Bacteria, some plants and some animals reproduce asexually.

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

The main messages on this page are that: 1) sexual reproduction needs two parents and forms cells that are genetically different to the parents, so there's lots of genetic variation. And 2) asexual reproduction needs just one parent to make genetically identical cells, so there's no genetic variation in the offspring.

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]

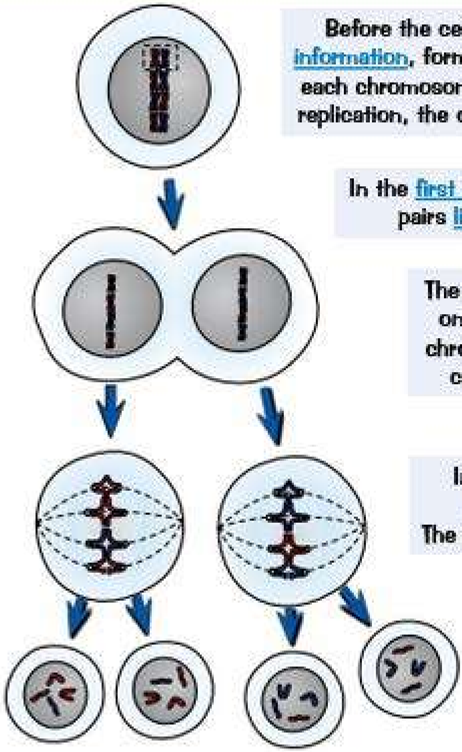
Meiosis

Now I bet you're wondering how gametes end up with half the number of chromosomes of a normal cell...

Gametes Are Produced by Meiosis

1) As you know from the previous page, gametes only have one copy of each chromosome, so that when gamete fusion takes place, you get the right amount of chromosomes again (two copies of each).
2) To make gametes which only have half the original number of chromosomes, cells divide by meiosis. This process involves two cell divisions. In humans, it only happens in the reproductive organs (the ovaries in females and testes in males).

Meiosis Produces Cells With Half the Normal Number of Chromosomes



Before the cell starts to divide, it duplicates its genetic information, forming two armed chromosomes — one arm of each chromosome is an exact copy of the other arm. After replication, the chromosomes arrange themselves into pairs.

The genetic information is stored in DNA — see p.68.

In the first division in meiosis the chromosome pairs line up in the centre of the cell.

The pairs are then pulled apart so each new cell only has one copy of each chromosome. Some of the father's chromosomes (shown in blue) and some of the mother's chromosomes (shown in red) go into each new cell.

In the second division, the chromosomes line up again in the centre of the cell. The arms of the chromosomes are pulled apart.

You get four gametes, each with only a single set of chromosomes in it. Each of the gametes is genetically different from the others because the chromosomes all get shuffled up during meiosis and each gamete only gets half of them, at random.

The Cell Produced by Gamete Fusion Replicates Itself

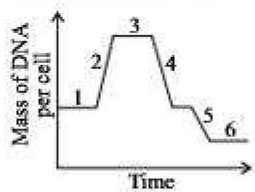
1) After two gametes have fused during fertilisation, the resulting new cell divides by mitosis to make a copy of itself.
2) Mitosis repeats many times to produce lots of new cells in an embryo.
3) As the embryo develops, these cells then start to differentiate (see page 14) into the different types of specialised cell that make up a whole organism.

There's loads on mitosis on page 15.

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

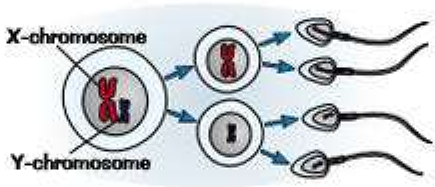
Now for a couple of very important little chromosomes...

Your Chromosomes Control Whether You're Male or Female

There are 23 pairs of chromosomes in every human body cell (page 15). Of these, 22 are matched pairs of chromosomes that just control characteristics. The 23rd pair are labelled XY or XX. They're the two chromosomes that decide your sex — whether you turn out male or female.

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

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

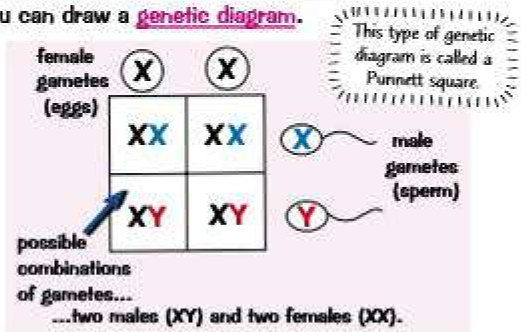


When making sperm, the X and Y chromosomes are drawn apart in the first division in meiosis (see the previous page). There's a 50% chance each sperm cell gets an X-chromosome and a 50% chance it gets a Y-chromosome.

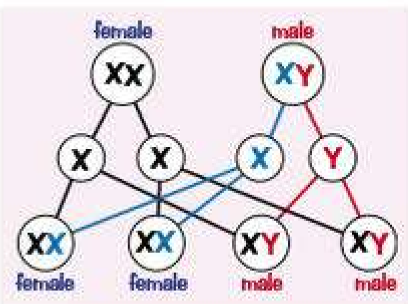
A similar thing happens when making eggs. But the original cell has two X-chromosomes, so all the eggs have one X-chromosome.

Genetic Diagrams Show the Possible Gamete Combinations

1) To find the probability of getting a boy or a girl, you can draw a genetic diagram.
2) Genetic diagrams are just models that are used to show all the possible genetic outcomes when you cross together different genes or chromosomes.
3) Put the possible gametes (eggs or sperm) from one parent down the side, and 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. The pairs of letters in the middle show the possible combinations of the gametes.



5) There are two XX results and two XY results, so there's the same probability of getting a boy or a girl.
6) Don't forget that this 50:50 ratio is only a probability at each pregnancy.



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. The possible combinations of the offspring are shown in the bottom circles.
4) Remember, only one of these possibilities would actually happen for any one offspring.

Have you got the Y-factor...

Most genetic diagrams you'll see in exams concentrate on a gene instead of a chromosome. But the principle's the same. Don't worry — there are loads of other examples on the following pages.

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

Genetic Diagrams

Genetic diagrams, eh. They're not as scary as they look — you just need to practise them...

Some Characteristics are Controlled by Single Genes

1) What genes you inherit control what characteristics you develop.
2) Different genes control different characteristics. Some characteristics are controlled by a single gene, e.g. mouse fur colour and red-green colour blindness in humans.
3) However, most characteristics are controlled by several genes interacting.
4) All genes exist in different versions called alleles (which are represented by letters in genetic diagrams).
5) You have two versions (alleles) of every gene in your body — one on each chromosome in a pair.
6) If an organism has two alleles for a particular gene that are the same, then it's homozygous for that trait. If its two alleles for a particular gene are different, then it's heterozygous.
7) If the two alleles are different, only one can determine what characteristic is present. The allele for the characteristic that's shown is called the dominant allele (use a capital letter for dominant alleles — e.g. 'C'). The other one is called recessive (and you show these with small letters — e.g. 'c').
8) For an organism to display a recessive characteristic, both its alleles must be recessive (e.g. cc). But to display a dominant characteristic the organism can be either CC or Cc, because the dominant allele overrules the recessive one if the plant/animal/other organism is heterozygous.
9) Your genotype is the combination of alleles you have. Your alleles work at a molecular level to determine what characteristics you have — your phenotype.

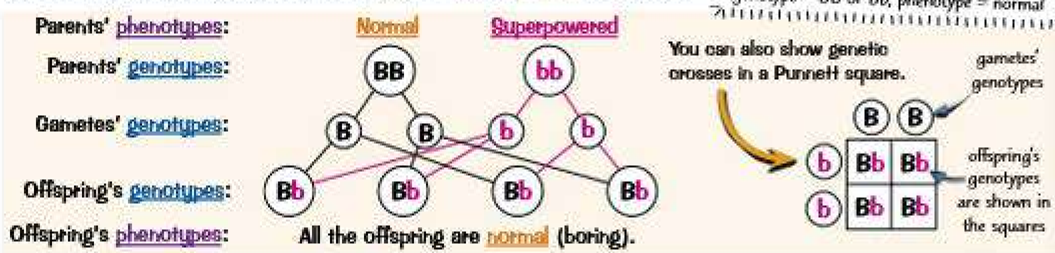
Genetic Diagrams Show the Possible Alleles of Offspring

Suppose you start breeding hamsters with superpowers. The allele which causes hamsters to have superpowers is recessive ("b"), whilst normal (boring) behaviour is due to a dominant allele ("B").

1) A superpowered hamster must have the genotype bb. But a normal hamster could be BB or Bb.

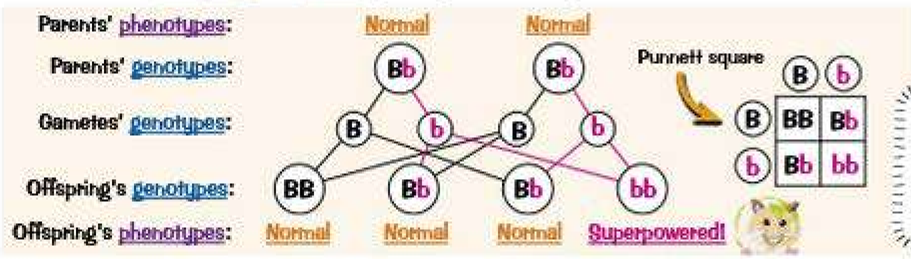
genotype = BB or Bb, phenotype = normal

2) Here's what happens if you breed from two homozygous hamsters:



	B	B
b	Bb	Bb
b	Bb	Bb

3) If two of these offspring now breed, you'll get the next generation:



	B	b
B	BB	Bb
b	Bb	bb

But remember — genetic diagrams only tell you probabilities. They don't say definitely what'll happen.

4) That's a 3:1 ratio of normal to superpowered offspring in this generation (a 1 in 4 or 25% probability of superpowers).

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

You need to be able to produce and interpret both of these types of genetic diagram for the exam.

Q1 Define genotype and phenotype. [2 marks]

More Genetic Diagrams

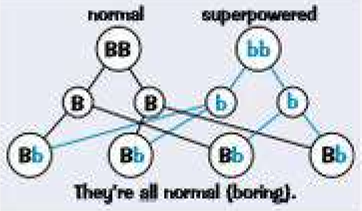
You've got to be able to predict and explain the outcomes of crosses between individuals for each possible combination of dominant and recessive alleles of a gene. You should be able to draw a genetic diagram and work it out — but it'll be easier if you've seen them all before. So here are a couple more examples for you. You also need to know how to interpret another type of genetic diagram called a family tree...

All the Offspring are Normal

For a reminder on the terms homozygous and heterozygous, head to page 72.

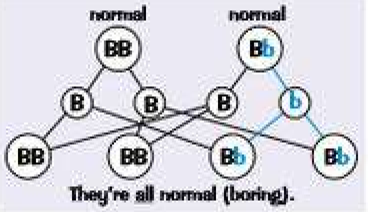
Let's take another look at the superpowered hamster example from page 72:

In this cross, a homozygous dominant hamster (BB) is crossed with a homozygous recessive hamster (bb). All the offspring are normal (boring).



They're all normal (boring).

But, if you crossed a homozygous dominant hamster (BB) with a heterozygous hamster (Bb), you would also get all normal (boring) offspring.



They're all normal (boring).

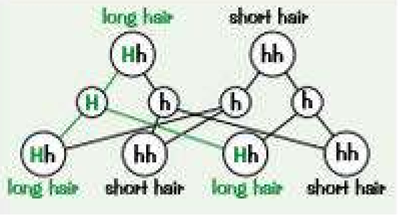
To find out which it was you'd have to breed the offspring together and see what kind of ratio you got that time — then you'd have a good idea. If it was 3:1, it's likely that you originally had BB and bb.

There's a 1:1 Ratio in the Offspring

A cat with long hair was bred with another cat with short hair. The long hair is caused by a dominant allele 'H', and the short hair by a recessive allele 'h'.

They had 8 kittens — 4 with long hair and 4 with short hair.

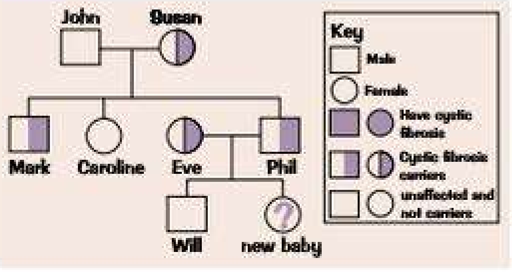
This is a 1:1 ratio — it's what you'd expect when a parent with only one dominant allele (heterozygous — Hh) is crossed with a parent with two recessive alleles (homozygous recessive — hh).



You Need to be Able to Interpret Family Trees

Knowing how inheritance works can help you to interpret a family tree — this is one for cystic fibrosis (p.74).

1) From the family tree, you can tell that the allele for cystic fibrosis isn't dominant because plenty of the family carry the allele but don't have the disorder.
2) There is a 25% chance that the new baby will have the disorder and a 50% chance that it will be a carrier, as both of its parents are carriers but are unaffected. The case of the new baby is just the same as in the genetic diagram on page 74 — so the baby could be unaffected (FF), a carrier (Ff) or have cystic fibrosis (ff).



It's enough to make you go cross-eyed...

In the exam, you might get a family tree showing the inheritance of a dominant allele — in this case, there won't be any carriers shown. Now, here's a fascinating practice question about peas...

Q1 Round peas are caused by the dominant allele, R. The allele for wrinkly peas, r, is recessive. Using a Punnett square, predict the ratio of plants with round peas to plants with wrinkly peas for a cross between a heterozygous pea plant and a pea plant that is homozygous recessive. [3 marks]

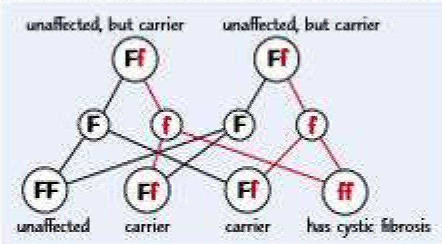
Q1 Video Solution

Inherited Disorders

Some disorders can be inherited from your parents. Many of these can be screened for in embryos.

Cystic Fibrosis is Caused by a Recessive Allele

Cystic fibrosis is a genetic disorder of the cell membranes. It results in the body producing a lot of thick sticky mucus in the air passages and in the pancreas.

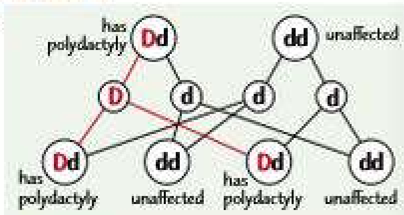


1) The allele which causes cystic fibrosis is a recessive allele, 'f', carried by about 1 person in 25.
2) Because it's recessive, people with only one copy of the allele won't have the disorder — they're known as carriers.
3) For a child to have the disorder, both parents must be either carriers or have the disorder themselves.
4) 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

Polydactyly is a genetic disorder where a baby's born with extra fingers or toes. It doesn't usually cause any other problems so isn't life-threatening.

1) The disorder is caused by a dominant allele, 'D', and so can be inherited if just one parent carries the defective allele.
2) The parent that has the defective allele will have the condition too since the allele is dominant.
3) As the genetic diagram shows, there's a 50% chance of a child having the disorder if one parent has one D allele.



Embryos Can Be Screened for Genetic Disorders

1) During *in vitro fertilisation* (IVF), embryos are fertilised in a laboratory, and then implanted into the mother's womb.
2) Before being implanted, it's possible to remove a cell from each embryo and analyse its genes.
3) Many genetic disorders can be detected in this way, such as cystic fibrosis.
4) It's also possible to get DNA from an embryo in the womb and test that for disorders.
5) There are lots of ethical, social and economic concerns surrounding embryo screening.
6) Embryonic screening is quite controversial 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 terminate the pregnancy.
9) Here are some more arguments for and against screening:

Against Embryonic Screening

1) It implies that people with genetic problems are 'undesirable' — this could increase prejudice.
2) There may come a point where everyone wants to screen their embryos so they can pick the most 'desirable' one, e.g. they want a blue-eyed, blond-haired, intelligent boy.
3) Screening is expensive.

For Embryonic Screening

1) It will help to stop people suffering.
2) Treating disorders costs the Government (and the taxpayers) 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...

Try writing a balanced argument for and against embryo screening — it's good practice.

Q1 Why won't someone heterozygous for the cystic fibrosis allele have the disorder? [3 marks]

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 — e.g. in a room full of people you'll see different colour hair, individually shaped noses, a variety of heights, etc.
3) These differences are called the variation within a species. Variation can be huge within a population.
4) Variation can be genetic — this means it's caused by differences in genotype. Genotype is all of the genes and alleles that an organism has. An organism's genotype affects its phenotype — the characteristics that it displays.
5) An organism's genes are inherited (passed down) from its parents (see page 69).
6) It's not only genotype that can affect an organism's phenotype though — interactions with its environment (conditions in which it lives) can also influence phenotype. For example, a plant grown on a nice sunny windowsill could grow luscious and green. The same plant grown in darkness would grow tall and spindly and its leaves would turn yellow — these are environmental variations.
7) Most variation in phenotype is determined by a mixture of genetic and environmental factors. 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) Occasionally, a gene may mutate. A mutation is a rare, random change in an organism's DNA that can be inherited. Mutations occur continuously.
2) Mutations mean that the gene is altered, which produces a genetic variant (a different form of the gene).

Alleles (see page 72) are genetic variants.

3) As the gene codes for the sequence of amino acids that make up a protein, gene mutations sometimes lead to changes in the protein that it codes for.
4) Most genetic variants have very little or no effect on the protein the gene codes for. Some will change it to such a small extent that its function is unaffected. This means that most mutations have no effect on an organism's phenotype.
5) Some variants have a small influence on the organism's phenotype — they alter the individual's characteristics but only slightly. For example:

   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.

6) Very occasionally, variants can have such a dramatic effect that they determine phenotype. For example:

   The genetic disorder, cystic fibrosis, is caused by a mutation that has a huge effect on phenotype. The gene codes for a protein that controls the movement of salt and water into and out of cells. However, the protein produced by the mutated gene doesn't work properly. This leads to excess mucus production in the lungs and digestive system, which can make it difficult to breathe and to digest food.

7) If the environment changes, and the new phenotype makes an individual more suited to the new environment, it can become common throughout the species relatively quickly 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.

Charles Darwin

Only the Fittest Survive

Charles Darwin came up with a really important theory about evolution, called evolution by natural selection.

1) Darwin knew that organisms in a species show wide variation in their characteristics (phenotypic variation). He also knew that organisms have to compete for limited resources in an ecosystem.
2) He concluded that the organisms with the most suitable characteristics for the environment would be more successful competitors and would be more likely to survive. This idea is called the 'survival of the fittest'.
3) The successful organisms that survive are more likely to reproduce and pass on the genes for the characteristics that made them successful to their offspring.
4) The organisms that are less well adapted would be less likely to survive and reproduce, so they are less likely to pass on their genes to the next generation.
5) Over time, beneficial characteristics become more common in the population and the species changes — it evolves.

New Discoveries Have Helped to Develop the Theory

1) Darwin's theory wasn't perfect. Because the relevant scientific knowledge wasn't available at the time, he couldn't give a good explanation for why new characteristics appeared or exactly how individual organisms passed on beneficial adaptations to their offspring.
2) However, the discovery of genetics supported Darwin's idea — it provided an explanation of how organisms born with beneficial characteristics can pass them on (i.e. via their genes) and showed that it is genetic variants (see page 75) that give rise to phenotypes that are suited to the environment. Other evidence was also found by looking at fossils of different ages (the fossil record) — this allows you to see how changes in organisms developed slowly over time. The relatively recent discovery of how bacteria are able to evolve to become resistant to antibiotics also further supports evolution by natural selection. The theory of evolution by natural selection is now widely accepted.

The Development of a New Species is Called Speciation

1) Over a long period of time, the phenotype of organisms can change so much because of natural selection that a completely new species is formed. This is called speciation.
2) Speciation happens when populations of the same species change enough to become reproductively isolated — this means that they can't interbreed to produce fertile offspring.

Extinction is When No Individuals of a Species Remain

The fossil record contains many species that don't exist any more — these species are said to be extinct.

Species become extinct for these reasons:

1) The environment changes too quickly (e.g. destruction of habitat).
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 or a collision with an asteroid).

Dodos are now extinct. Humans not only hunted them, but introduced other animals which ate all their eggs, and we destroyed the forest where they lived — they really didn't stand a chance...

"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

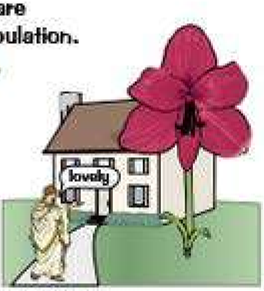
Selective Breeding

'Selective breeding' sounds like it has the potential to be a tricky topic, but it's actually dead simple. You take the best plants or animals and breed them together to get the best possible offspring. That's it.

Selective Breeding is Very Simple

Selective breeding is when humans artificially select the plants or animals that are going to breed so that the genes for particular characteristics remain in the population. 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.
- Dogs with a good, gentle temperament.
- Decorative plants with big or unusual flowers.



This is the basic process involved in selective breeding:

1) From your existing stock, select the ones which have the characteristics you're after.
2) Breed them with each other.
3) Select the best of the offspring, and breed them together.
4) Continue this process over several generations, and the desirable trait gets stronger and stronger. Eventually, all the offspring will have the characteristic.

Selective breeding is also known as 'artificial selection'.

In agriculture (farming), selective breeding can be used to improve yields. E.g. to improve meat yields, a farmer could breed together the cows and bulls with the best characteristics for producing meat, e.g. large size. After doing this for several generations the farmer would get cows with a very high meat yield.

5) Selective breeding is nothing new — people have been doing it for thousands of years. It's how we ended up with edible crops from wild plants and how we got domesticated animals like cows and dogs.

The Main Drawback is a Reduction in the Gene Pool

1) The main problem with selective breeding is that it reduces the gene pool — the number of different alleles (forms of a gene) in a population. This is because the farmer keeps breeding from the "best" animals or plants — which are all closely related. This is known as inbreeding.
2) Inbreeding can cause health problems because there's more chance of the organisms inheriting harmful genetic defects when the gene pool is limited. Some dog breeds are particularly susceptible to certain defects because of inbreeding — e.g. pugs often have breathing problems.
3) There can also be serious problems if a new disease appears, because there's not much variation in the population. All the stock are closely related to each other, so if one of them is going to be killed by a new disease, the others are also likely to succumb to it.

Selective Breeding → Reduction in the number of different alleles (forms of a gene) → Less chance of any resistant alleles being present in the population

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 Explain how you could selectively breed for floppy ears in rabbits. [4 marks]

Q2 What potential issues can selective breeding cause? [3 marks]

Q1 Video Solution

Genetic Engineering

Genetic engineering is an interesting area of science with exciting possibilities, but there might be dangers too...

Genetic Engineering Transfers Genes Between Organisms

The basic idea of genetic engineering is to transfer a gene responsible for a desirable characteristic from one organism's genome into another organism, so that it also has the desired characteristic.

1) A useful gene is isolated (cut) from one organism's genome using enzymes and is inserted into a vector.
2) The vector is usually a virus or a bacterial plasmid (a fancy piece of circular DNA found in bacterial cells), depending on the type of organism that the gene is being transferred to.
3) When the vector is introduced to the target organism, the useful gene is inserted into its cell(s).
4) Scientists use this method to do all sorts of things. For example:
   1) Bacteria have been genetically modified to produce human insulin that can be used to treat diabetes.
   2) Genetically modified (GM) crops have had their genes modified, e.g. to improve the size and quality of their fruit, or make them resistant to disease, insects and herbicides (chemicals used to kill weeds).
   3) Sheep have been genetically engineered to produce substances, like drugs, in their milk that can be used to treat human diseases.
   4) Scientists are researching genetic modification treatments for inherited diseases caused by faulty genes, e.g. by inserting working genes into people with the disease. This is called gene therapy.

5) In some cases, the transfer of the gene is carried out when the organism receiving the gene is at an early stage of development (e.g. egg or embryo). This means that the organism develops with the characteristic coded for by the gene.

Genetic Engineering is a Controversial Topic

1) Genetic engineering is an exciting area of science, which has the potential for solving many of our problems (e.g. treating diseases, more efficient food production etc.), but not everyone thinks it's a great idea.
2) There are worries about the long-term effects of genetic engineering — that changing an organism's genes might accidentally create unplanned problems, which could get passed on to future generations.

There Are Pros and Cons of GM Crops

1) Some people say that growing GM crops will affect the number of wild flowers (and so the population of insects) that live in and around the crops — reducing farmland biodiversity.
2) Not everyone is convinced that GM crops are safe and some people are concerned that we might not fully understand the effects of eating them on human health. E.g. people are worried they may develop allergies to the food — although there's probably no more risk for this than for eating usual foods.
3) A big concern is that transplanted genes may get out into the natural environment. For example, the herbicide resistance gene may be picked up by weeds, creating a new 'superweed' variety.
4) On the plus side, the characteristics chosen for GM crops can increase the yield, making more food.
5) People living in developing nations often lack nutrients in their diets. GM crops could be engineered to contain the nutrient that's missing. For example, 'golden rice' is a GM rice crop that contains beta-carotene — lack of this substance causes blindness.
6) GM crops are already being grown in some places, often without any problems.

If only there was a gene to make revision easier...

Make sure you've got everything on this page firmly in your noggin. You need to understand the lot.

Q1 Outline one benefit and one concern about GM crops. [2 marks]

Fossils

Fossils are great. If they're well-preserved, you can see what oldy-worldy creatures looked like. They also show how living things have evolved. Although we're not sure how life started in the first place...

Fossils are the Remains of Plants and Animals

Fossils are the remains of organisms from many thousands of years ago, which are found in rocks. They provide the evidence that organisms lived ages ago. Fossils can tell us a lot about how much or how little organisms have changed (evolved) over time. 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, bones etc., which don't decay easily, can last a long time when buried.
2) They're eventually replaced by minerals as they decay, forming a rock-like substance shaped like the original hard part.
3) The surrounding sediments also turn to rock, but the fossil stays distinct inside the rock and eventually someone digs it up.

2) FROM CASTS AND IMPRESSIONS

1) Sometimes, fossils are formed when an organism is buried in a soft material like clay. The clay later hardens around it and the organism decays, leaving a cast of itself. An animal's burrow or a plant's roots (rootlet traces) can be preserved as casts.
2) Things like footprints can also be pressed into these materials when soft, leaving an impression when it hardens.

3) FROM PRESERVATION IN PLACES WHERE NO DECAY HAPPENS

1) In amber (a clear yellow 'stone' made from fossilised resin) and tar pits there's no oxygen or moisture so decay microbes can't survive.
2) In glaciers it's too cold for the decay microbes to work.
3) Peat bogs are too acidic for decay microbes.
(A fully preserved man they named 'Pete Marsh' was found in a bog.)

But No One Knows How Life Began

Fossils show how much or how little different organisms have changed (evolved) as life has developed on Earth over millions of years. But where did the first living thing come from...

1) There are various hypotheses suggesting how life first came into being, but no one really knows.
2) Maybe the first life forms came into existence in a primordial swamp (or under the sea) here on Earth. Maybe simple organic molecules were brought to Earth on comets — these could have then become more complex organic molecules, and eventually very simple life forms.
3) These hypotheses can't be supported or disproved because there's a lack of good, valid evidence:
   - Many early forms of life were soft-bodied, and soft tissue tends to decay away completely — so the fossil record is incomplete.
   - 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.

Don't get bogged down by all this information...

It's a bit mind-boggling really how fossils can still exist even millions of years after the organism died. They really are fascinating things, and scientists have learned a whole lot from studying them in detail.

Q1 Suggest what makes low-oxygen environments suitable for the formation of fossils. [2 marks]

Antibiotic-Resistant Bacteria

The discovery of antibiotics, like penicillin, was a huge benefit to medicine — suddenly bacterial infections that had often been fatal could be cured. But unfortunately they might not be a permanent solution.

Bacteria can Evolve and Become Antibiotic-Resistant

1) Like all organisms, bacteria sometimes develop random mutations (changes) in their DNA. These can lead to changes in the bacteria's characteristics, e.g. being less affected by a particular antibiotic. This can lead to antibiotic-resistant strains forming as the gene for antibiotic resistance becomes more common in the population.
2) To make matters worse, because bacteria are so rapid at reproducing, they can evolve quite quickly.
3) For the bacterium, the ability to resist antibiotics is a big advantage. It's better able to survive, even in a host who's being treated to get rid of the infection, and so it lives for longer and reproduces many more times. This increases the population size of the antibiotic-resistant strain.

The gene for antibiotic resistance becomes more common in the population because of natural selection — see page 76 for more.

- Antibiotic-resistant strains are a problem for people who become infected with these bacteria because they aren't immune to the new strain and there is no effective treatment. This means that the infection easily spreads between people. Sometimes drug companies can come up with a new antibiotic that's effective, but 'superbugs' that are resistant to most known antibiotics are becoming more common.
- MRSA is a relatively common 'superbug' that's really hard to get rid of. It often affects people in hospitals and can be fatal if it enters their bloodstream.

Antibiotic Resistance is Becoming More Common

1) For the last few decades, we've been able to deal with bacterial infections pretty easily using antibiotics. The death rate from infectious bacterial diseases (e.g. pneumonia) has fallen dramatically.
2) But the problem of antibiotic resistance is getting worse — partly because of the overuse and inappropriate use of antibiotics, e.g. doctors prescribing them for non-serious conditions or infections caused by viruses.

Antibiotics don't kill viruses — see p.48.

3) The more often antibiotics are used, the bigger the problem of antibiotic resistance becomes, so it's important that doctors only prescribe antibiotics when they really need to:

   It's not that antibiotics actually cause resistance — they create a situation where naturally resistant bacteria have an advantage and so increase in numbers.

4) It's also important that you take all the antibiotics a doctor prescribes for you:

   Taking the full course makes sure that all the bacteria are destroyed, which means that there are none left to mutate and develop into antibiotic-resistant strains.

5) In farming, antibiotics can be given to animals to prevent them becoming ill and to make them grow faster. This can lead to the development of antibiotic-resistant bacteria in the animals which can then spread to humans, e.g. during meat preparation and consumption. Increasing concern about the overuse of antibiotics in agriculture has led to some countries restricting their use.
6) The increase in antibiotic resistance has encouraged drug companies to work on developing new antibiotics that are effective against the resistant strains. Unfortunately, the rate of development is slow, which means we're unlikely to be able to keep up with the demand for new drugs as more antibiotic-resistant strains develop and spread. It's also a very costly process.

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

The reality of 'superbugs' is even scarier than giant earwigs. Microorganisms 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 Suggest a situation where antibiotics could be prescribed inappropriately. [1 mark]

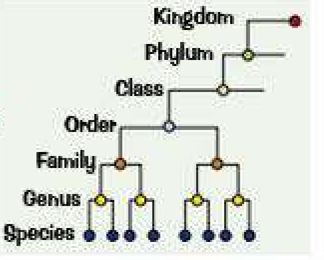
Q2 Explain why it's important that people take the full course of antibiotics they are prescribed. [2 marks]

Classification

It seems to be a basic human urge to want to classify things — that's the case in biology anyway...

Classification is Organising Living Organisms into Groups

1) Traditionally, organisms have been classified according to a system first proposed in the 1700s by Carl Linnaeus, which groups living things according to their characteristics and the structures that make them up.
2) In this system (known as the Linnaean system), living things are first divided into kingdoms (e.g. the plant kingdom).
3) The kingdoms are then subdivided into smaller and smaller groups — phylum, class, order, family, genus, species.



Classification Systems Change Over Time

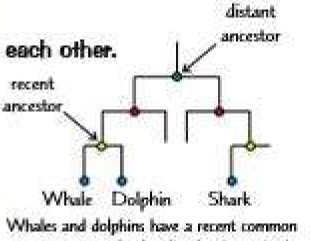
1) As knowledge of the biochemical processes taking place inside organisms developed and microscopes improved (which allowed us to find out more about the internal structures of organisms), scientists put forward new models of classification.
2) In 1990, Carl Woese proposed the three-domain system. Using evidence gathered from new chemical analysis techniques such as RNA sequence analysis, he found that in some cases, species thought to be closely related in traditional classification systems are in fact not as closely related as first thought.
3) In the three-domain system, organisms are first of all split into three large groups called domains:
    1) ARCHAEA — Organisms in this domain are primitive bacteria. They're often found in extreme places such as hot springs and salt lakes.
    2) BACTERIA — This domain contains true bacteria like *E. coli* and *Staphylococcus*. Although they often look similar to Archaea, there are lots of biochemical differences between them.
    3) EUKARYOTA — This domain includes a broad range of organisms including fungi (page 43), plants, animals and protists (page 43).
4) These are then subdivided into smaller groups — kingdom, phylum, class, order, family, genus, species.

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 second part refers to the species. E.g. humans are known as *Homo sapiens*. '*Homo*' is the genus and '*sapiens*' is the species.
3) The binomial system is used worldwide and means that scientists in different countries or who speak different languages all refer to a particular species by the same name — avoiding potential confusion.

Evolutionary Trees Show Evolutionary Relationships

1) Evolutionary trees show how scientists think different species are related to each other.
2) They show common ancestors and relationships between species. The more recent the common ancestor, the more closely related the two species — and the more characteristics they're likely to share.
3) Scientists analyse lots of different types of data to work out evolutionary relationships. For living organisms, they use the current classification data (e.g. DNA analysis and structural similarities). For extinct species, they use information from the fossil record (see page 76).

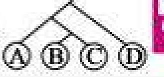


Whales and dolphins have a recent common ancestor so are closely related. They're both more distantly related to sharks.

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

Revision Questions for Topics B5 & B6

You've finished Topics B5 and B6 — Hoorah. Now have a go at these 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 B5 and B6 — just scan the QR codes!

Homeostasis and the Nervous System (p.58-61)

Topic B5 Quiz

1) Explain how negative feedback helps to maintain a stable internal environment.
2) What makes up the central nervous system and what does it do?
3) What is a synapse?
4) What is the purpose of a reflex action?

Hormones in Humans (p.62-67)

5) Give two differences between nervous and hormonal responses.
6) What effect does the hormone glucagon have on blood glucose level?
7) Describe two effects of FSH on the body.
8) Which of the following is a hormonal contraceptive — condom, plastic IUD or diaphragm?
9) Briefly describe how IVF is carried out.
10) How does adrenaline prepare the body for 'fight or flight'?

DNA, Genes, Reproduction and Meiosis (p.68-70)

Topic B6 Quiz

11) What is meant by 'double helix'?
12) What do genes code for?
13) What is the name for the entire set of 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.71-74)

16) What is the probability that offspring will have the XX combination of sex chromosomes?
17) What are alleles?
18) What does it mean if someone is heterozygous for a gene?
19) What is the chance of a child being born with polydactyly if one parent has a single dominant allele for the gene that controls it?
20) Give two arguments for and two arguments against screening embryos for genetic disorders.

Variation and Evolution (p.75-76)

21) What is variation?
22) Explain how beneficial characteristics can become more common in a population over time.

Selective Breeding and Genetic Engineering (p.77-78)

23) How might farmers use selective breeding?
24) What is genetic engineering?

Fossils, Antibiotic-Resistant Bacteria and Classification (p.79-81)

25) Give two ways that fossils can be formed.
26) What leads to the formation of antibiotic-resistant strains of bacteria?
27) Name the groups that organisms are classified into in the Linnaean system.
28) Who proposed the 'three-domain system' of classification in 1990?

Competition

Ecology is all about organisms and the environment they live in, and how the two interact. Simples.

First Learn Some Words to Help You Understand Ecology...

This topic will make a lot more sense if you become familiar with these terms first:

1) Habitat — the place where an organism lives.
2) Population — all the organisms of one species living in a habitat.
3) Community — the populations of different species living in a habitat.
4) Abiotic factors — non-living factors of the environment, e.g. temperature.
5) Biotic factors — living factors of the environment, e.g. food.
6) Ecosystem — the interaction of a community of living organisms (biotic) with the non-living (abiotic) parts of their environment.

There's more about abiotic and biotic factors on the next page.

Organisms Compete for Resources to Survive

Organisms need things from their environment and from other organisms in order to survive and reproduce:

1) Plants need light and space, as well as water and mineral ions (nutrients) from the soil.
2) Animals need space (territory), food, water and mates.

Organisms compete with other species (and members of their own species) for the same resources.

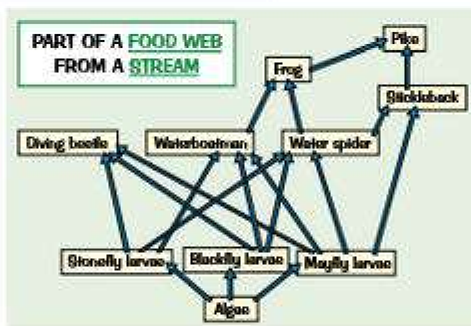
Any Change in Any Environment can Have Knock-on Effects

In a community, each species depends on other species for things such as food, shelter, pollination and seed dispersal — this is called interdependence.

The interdependence of all the living things in an ecosystem means that any major change in the ecosystem (such as one species being removed) can have far-reaching effects.

The diagram on the right shows part of a food web (a diagram of what eats what) from a stream.

Stonefly larvae are particularly sensitive to pollution. Suppose pollution killed them in this stream. The table below shows some of the effects this might have on some of the other organisms in the food web.



Organism	Effect of loss of stonefly larvae	Effect on population
Blackfly larvae	Less competition for algae	Increase
	More likely to be eaten by predators	Decrease
Water spider	Less food	Decrease
Stickleback	Less food (if water spider or mayfly larvae numbers decrease)	Decrease

Remember that food webs are very complex and that these effects are difficult to predict accurately.

In some communities, all the species and environmental factors are in balance so that the population sizes are roughly constant (they may go up and down in cycles — see p.86). These are called stable communities. Stable communities include tropical rainforests and ancient oak woodlands.

I'm dependent on the cocoa tree...

If my source of chocolate was removed, it would have far-reaching effects on my revision and grades. Seriously though, make sure you know what organisms compete for in an ecosystem. Then try these...

Q2 Video Solution

Q1 Give three things plants compete for in an ecosystem. [3 marks]

Q2 Using the food web above, suggest what might happen to the frog population if the stickleback population decreased. [2 marks]

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 can have a big effect on a community...

Abiotic Factors Can Vary in an Ecosystem...

Abiotic factors are non-living factors. For example:

1) Moisture level
2) Light intensity
3) Temperature
4) Carbon dioxide level (for plants)
5) Wind intensity and direction
6) Oxygen level (for aquatic animals)
7) Soil pH and mineral content

A change in the environment could be an increase or decrease in an abiotic factor, e.g. an increase in temperature. These changes can affect the size of populations in a community. This means they can also affect the population sizes of other organisms that depend on them (see previous page).

For example, a decrease in light intensity, temperature or level of carbon dioxide could decrease the rate of photosynthesis in a plant species (see p.50). This could affect plant growth and cause a decrease in the population size.

For example, a decrease in the mineral content of the soil (e.g. a lack of nitrates) could cause nutrient deficiencies. This could also affect plant growth and cause a decrease in the population size.

Animals depend on plants for food, so a decrease in a plant population could affect the animal species in a community.

...and So Can Biotic Factors

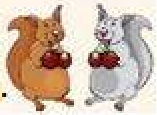
Biotic factors are living factors. Here are some examples:

1) New predators arriving
2) Competition — one species may outcompete another so that numbers are too low to breed
3) New pathogens
4) Availability of food

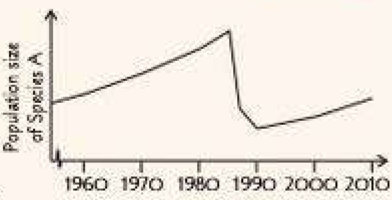
A change in the environment could be the introduction of a new biotic factor, e.g. a new predator or pathogen. These changes can also affect the size of populations in a community, which can have knock-on effects because of interdependence (see previous page).

For example, a new predator could cause a decrease in the prey population. There's more about predator-prey populations on p.86.

For example, red and grey squirrels live in the same habitat and eat the same food. Grey squirrels outcompete the red squirrels — so the population of red squirrels is decreasing.



The following graph shows the effect of a new pathogen on Species A. The population size of species A was increasing up until 1985, when it decreased rapidly until 1990 — suggesting that 1985 was the year that the new pathogen arrived. The population started to rise again after 1990.



Exams — a type of abiotic factor affecting my environment...

So, two lists of factors that would be a good idea to learn. I reckon this is a prime time for shutting the book, scribbling them all down and then checking how you did. It's the only way they'll get firmly wedged in your brain.

Q1 Give four examples of abiotic factors that could affect a plant species. [4 marks]

Q2 Cutthroat trout are present in lakes in Yellowstone National Park. In the last few decades, lake trout have been introduced to the lakes. However, lake trout have emerged as predators of the cutthroat trout. Give two other biotic factors that could affect the size of the cutthroat trout population. [2 marks]

Adaptations

Life exists in so many different environments because the organisms that live in them have adapted to them.

Adaptations Allow Organisms to Survive

Organisms, including microorganisms, are adapted to live in different environmental conditions. The features or characteristics that allow them to do this are called adaptations. Adaptations can be:

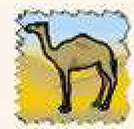
1) Structural

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're camouflaged against the snow. This helps them avoid predators and sneak up on prey.

Animals that live in cold places (like whales) have a thick layer of blubber (fat) and a low surface area to volume ratio to help them retain heat.

Animals that live in hot places (like camels) have a thin layer of fat and a large surface area to volume ratio to help them lose heat.



2) Behavioural

These are ways that organisms behave. Many species (e.g. swallows) migrate to warmer climates during the winter to avoid the problems of living in cold conditions.

3) Functional

These are things that go on inside an organism's body that can be related to processes like reproduction and metabolism (all the chemical reactions happening in the body). For example:

Desert animals conserve water by producing very little sweat and small amounts of concentrated urine.

Brown bears hibernate over winter. They lower their metabolism which conserves energy, so they don't have to hunt when there's not much food about.

Microorganisms Have a Huge Variety of Adaptations...

...so that they can live in a wide range of environments:

Some microorganisms (e.g. bacteria) are known as extremophiles — they're adapted to live in very extreme conditions. For example, some can live at high temperatures (e.g. in super hot volcanic vents), and others can live in places with a high salt concentration (e.g. very salty lakes) or at high pressure (e.g. deep sea vents).

In a nutshell, it's horses for courses...

In the exam, you might have to say how an organism is adapted to its environment. Look at its characteristics (e.g. colour/shape) as well as the conditions it has to cope with (e.g. predation/temperature) and you'll be sorted.

Q1 The diagram on the right shows a penguin. Penguins live in the cold, icy environment of the Antarctic. They swim in the sea to hunt for fish to eat. Some penguins also huddle together in large groups to keep warm.

a) What type of adaptation is being described when penguins 'huddle together'? [1 mark]

b) Explain one structural adaptation a penguin has 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. Strap yourself in and prepare for some 'edge of your seat' learning, because the show is about to begin...

Food Chains Show What's Eaten by What in an Ecosystem

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) When a green plant produces glucose, some of it is used to make other biological molecules in the plant.
4) These biological molecules are the plant's biomass — the mass of living material.
5) Biomass can be thought of as energy stored in a plant.
6) Energy is transferred through living organisms in an ecosystem when organisms eat other organisms.
7) Producers are eaten by primary consumers. Primary consumers are then eaten by secondary consumers and secondary consumers are eaten by tertiary consumers. Here's an example of a food chain:

Consumers are organisms that eat other organisms. 'Primary' means 'first', so primary consumers are the first consumers in a food chain. Secondary consumers are second and tertiary consumers are third.

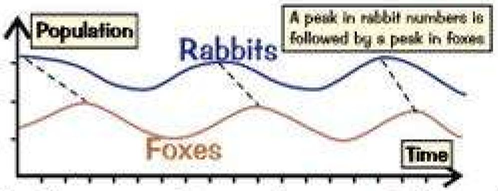
5000 dandelions... feed... 100 rabbits... which feed... 1 fox.

Populations of Prey and Predators Go in Cycles

Consumers that hunt and kill other animals are called predators, and their prey are what they eat.
In a stable community containing prey and predators (as most of them do of course):

For more about a stable community see page 83.

1) The population of any species is usually limited by the amount of food available.
2) If the population of the prey increases, then so will the population of the predators.
3) However as the population of predators increases, the number of prey will decrease.



E.g. More grass means more rabbits.
More rabbits means more foxes.
But more foxes means fewer rabbits.
Eventually fewer rabbits will mean fewer foxes again.
This up and down pattern continues...

4) Predator-prey cycles are always out of phase with each other. This is because it takes a while for one population to respond to changes in the other population. E.g. when the number of rabbits goes up, the number of foxes doesn't increase immediately because it takes time for them 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

This is where the fun starts. Studying ecology gives you the chance to rummage around in bushes, get your hands dirty and look at some real organisms, living in the wild. Hold on to your hats folks...

Organisms Live in Different Places Because The Environment Varies

1) As you know from page 83, a habitat is the place where an organism lives, e.g. a playing field.
2) The distribution of an organism is where an organism is found, e.g. in a part of the playing field.
3) Where an organism is found is affected by environmental factors (see page 84). An organism might be more common in one area than another due to differences in environmental factors between the two areas. For example, in the playing field, you might find that daisies are more common in the open than under trees, because there's more light available in the open.
4) There are a couple of ways to study the distribution of an organism. You can:
   - measure how common an organism is in two sample areas (e.g. using quadrats) and compare them.
   - study how the distribution changes across an area, e.g. by placing quadrats along a transect (p.88).

   Both of these methods give quantitative data (numbers) about the distribution.

Use Quadrats to Study The Distribution of Small Organisms

A quadrat is a square frame enclosing a known area, e.g. 1 m². To compare how common an organism is in two sample areas (e.g. shady and sunny spots in that playing field) just follow these simple steps:

1) Place a 1 m² quadrat on the ground at a random point within the first sample area. E.g. divide the area into a grid and use a random number generator to pick coordinates.
2) Count all the organisms 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.

A quadrat

EXAMPLE

Anna counted the number of daisies in 7 quadrats within her first sample area and 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 m² in the shade, and 22 daisies per m² (lots more) in the open field.

You Can Also Work Out the Population Size of an Organism in One Area

EXAMPLE

Students used quadrats, each with an area of 0.5 m², to randomly sample daisies on an open field. The students found a mean of 10.5 daisies per quadrat. The field had an area of 800 m². Estimate the population of daisies on the field.

1) Work out the mean number of organisms per m². $1 \div 0.5 = 2$
   $2 \times 10.5 = 21$ daisies per m²
2) Then multiply the mean by the total area (in m²) of the habitat. $800 \times 21 = 16\,800$ daisies on the open field

The population size of an organism is sometimes called its abundance.

If your quadrat has an area of 1 m², the mean number of organisms per m² is just the same as the mean number per quadrat.

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 1200 m² field was randomly sampled for buttercups using a quadrat with an area of 0.25 m². A mean of 0.75 buttercups were found per quadrat. Estimate the total population of buttercups. [2 marks]

Q1 Video Solution

PRACTICAL

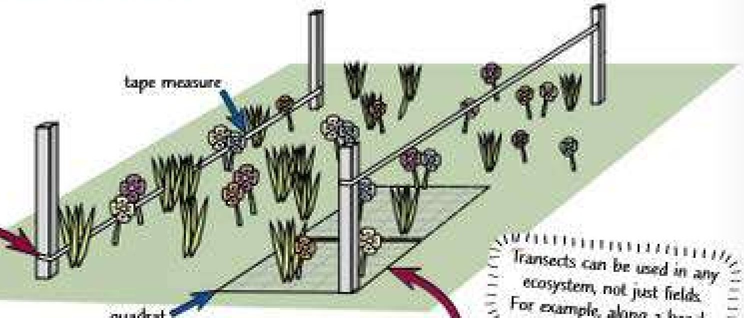
Using Transects

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 (like plants) 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) Then collect data along the line.
3) You can do this by just counting all the organisms you're interested in that touch the line.
4) Or, you can collect data by using quadrats (see previous page). These can be placed next to each other along the line or at intervals, for example, every 2 m.



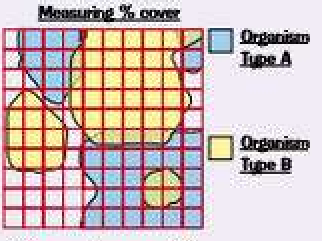
Transects can be used in any ecosystem, not just fields. For example, along a beach.

You Can Estimate the Percentage Cover of a Quadrat

If it's difficult to count all the individual organisms in the quadrat (e.g. if they're grass) you can calculate the percentage cover. This means estimating the percentage area of the quadrat covered by a particular type of organism, e.g. by counting the number of little squares covered by the organisms.

EXAMPLE

Some students were measuring the distribution of organisms from one corner of a school playing field to another, using quadrats placed at regular intervals along a transect. Below is a picture of one of the quadrats. Calculate the percentage cover of each organism, A and B.



You count a square if it's more than half covered.

1) Count the number of squares covered by organism A. — Type A = 42 squares
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), then multiply the result by 100. — (42/100) × 100 = 0.42 × 100 = 42%
3) Do the same for organism B. — Type B = 47 squares; (47/100) × 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 a organism across an area, you could use a transect. You can either use them alone or along with quadrats. Now who's for a game of tennis... I've got my transect up.

Q1 What is a transect? [1 mark]

Q2 Some students want to measure how the distribution of dandelions changes across a field, from one corner to another. Describe a method they could use to do this. [2 marks]

Q3 How could you estimate the number of organisms in a quadrat, if they are difficult to count? [1 mark]

The Water Cycle

Water on planet Earth is constantly recycled. This is lucky for us because without water, we wouldn't survive. And I don't just mean there'd be no paddling pools, ice lollies or bubble baths...

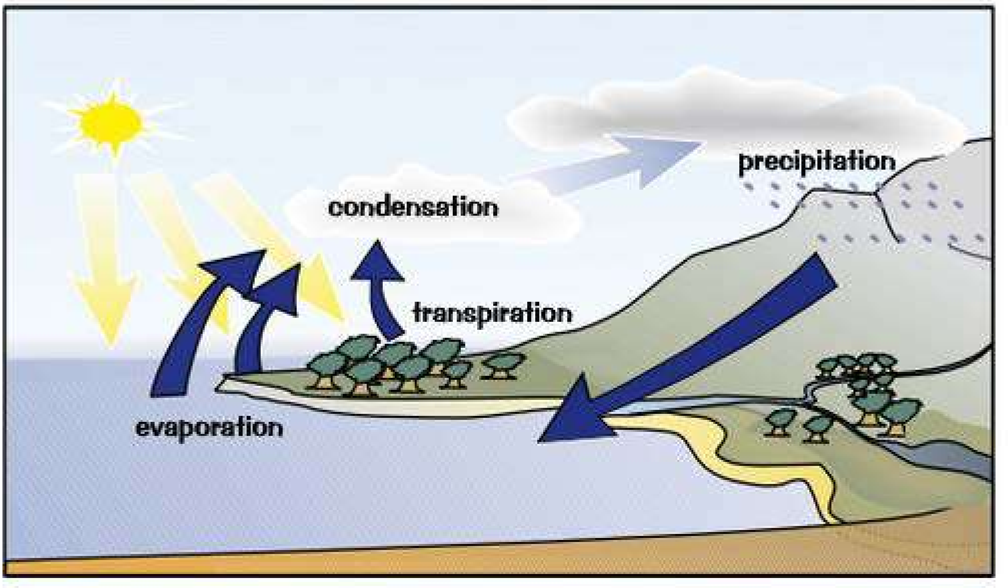
The Water Cycle Means Water is Endlessly Recycled

There has only ever been a fixed amount of water on the Earth.

The water here on planet Earth is constantly recycled.
Strange but true...

1) Energy from the Sun makes water evaporate from the land and sea, turning it into water vapour.
2) Water also evaporates from plants — this is known as transpiration (see p.40).
3) The warm water vapour is carried upwards (as warm air rises). When it gets higher up it cools and condenses to form clouds.
4) Water falls from the clouds as precipitation (usually rain, but sometimes snow or hail) onto land, where it provides fresh water for plants and animals.
5) Some of this water is absorbed by the soil and is taken up by plant roots. This provides plants with fresh water for things like photosynthesis. Some of the water taken up by plants becomes part of the plants' tissues and is passed along to animals in food chains.
6) Like plants, animals need water for the chemical reactions that happen in their bodies. Animals return water to the soil and atmosphere through excretion (processes that get rid of the waste products of chemical reactions, e.g. sweating, urination and breathing out).
7) Water that doesn't get absorbed by the soil will runoff into streams and rivers.
8) From here, the water then drains back into the sea, before it evaporates all over again.

Animals also get fresh water by drinking from streams and rivers.



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 — a continuous process with no beginning or end. Water that falls to the ground as rain (or any other kind of precipitation) will eventually end up back in the clouds again.

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]

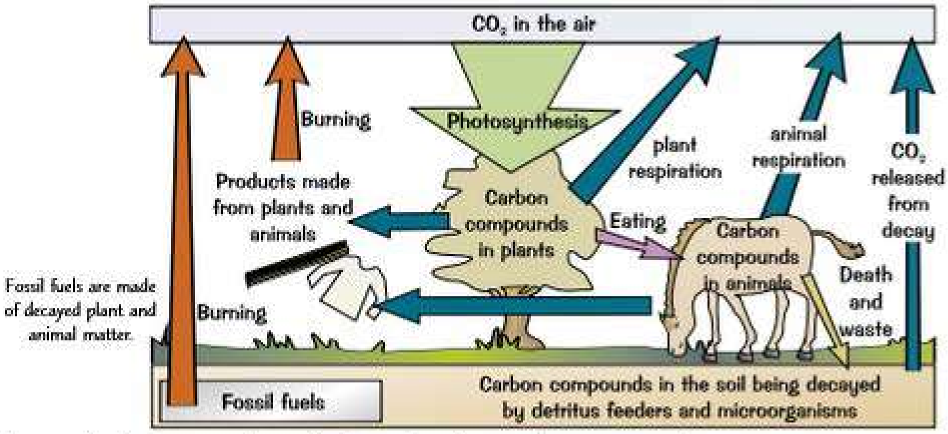
The Carbon Cycle

Recycling may be a buzz word for us but it's old school for nature. All the nutrients in our environment are constantly being recycled — there's a nice balance between what goes in and what goes out again.

Elements are Cycled Back to the Start of the Food Chain by Decay

1) Living things are made of materials they take from the world around them. E.g. plants turn elements like carbon, oxygen, hydrogen and nitrogen from the soil and the air into the complex compounds (carbohydrates, proteins and fats) that make up living organisms. These get passed up the food chain.
2) These materials are returned to the environment in waste products, or when the organisms die and decay.
3) Materials decay because they're broken down (digested) by microorganisms. This happens faster in warm, moist, aerobic (oxygen rich) conditions because microorganisms are more active in these conditions.
4) Decay puts the stuff that plants need to grow (e.g. mineral ions — see point 1) back into the soil.
5) In a stable community, the materials that are taken out of the soil and used by plants etc. are balanced by those that are put back in. There's a constant cycle happening.

The Constant Cycling of Carbon is called the Carbon Cycle



That can look a bit complicated at first, but it's actually pretty simple:

1) CO_2 is removed from the atmosphere by green plants and algae during photosynthesis. The carbon is used to make glucose, which can be turned into carbohydrates, fats and proteins that make up the bodies of the plants and algae.
2) When the plants and algae respire, some carbon is returned to the atmosphere as CO_2.
3) When the plants and algae are eaten by animals, some carbon becomes part of the fats and proteins in their bodies. The carbon then moves through the food chain.
4) When the animals respire, some carbon is returned to the atmosphere as CO_2.
5) When plants, algae and animals die, other animals (called detritus feeders) and microorganisms feed on their remains. When these organisms respire, CO_2 is returned to the atmosphere.
6) Animals also produce waste that is broken down by detritus feeders and microorganisms.
7) The combustion (burning) of wood and fossil fuels also releases CO_2 back into the air.
8) So the carbon (and energy) is constantly being cycled — from the air, through food chains (via plants, algae and animals, and detritus feeders and microorganisms) and eventually back out into the air again.

The energy that green plants and algae get from photosynthesis is transferred up the food chain.

What goes around comes around...

Carbon is very important for living things — it's the basis for all the organic 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

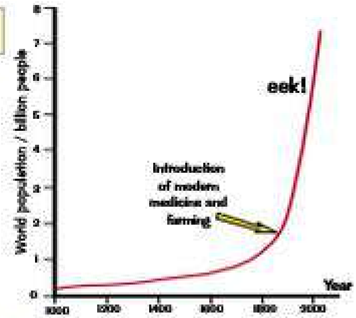
Unfortunately, human activity can negatively affect the planet and its variety of life. Read on for bad news...

Earth's Biodiversity is Important

Biodiversity is the variety of different species of organisms on Earth, or within an ecosystem.

1) High biodiversity is important. It makes sure that ecosystems (see p.83) are stable because different species depend on each other for things like shelter and food. Different species can also help to maintain the right physical environment for each other (e.g. the acidity of the soil).
2) For the human species to survive, it's important that a good level of biodiversity is maintained.
3) Lots of human actions, including waste production (see below) and deforestation (see p.93), as well as global warming (see next page) are reducing biodiversity. However, it's only recently that we've started taking measures to stop this from continuing.

There are Over Seven Billion People in the World...



1) The population of the world is currently rising very quickly, and it's not slowing down — look at the graph...
2) This is mostly due to modern medicine and farming methods, which have reduced the number of people dying from disease and hunger.
3) This is great for all of us humans, but it means we're having a bigger effect on the environment we live in.

...With Increasing Demands on the Environment

When the Earth's population was much smaller, the effects of human activity were usually small and local. Nowadays though, our actions can have a far more widespread effect.

1) Our increasing population puts pressure on the environment, as we take the resources we need to survive.
2) But people around the world are also demanding a higher standard of living (and so demand luxuries to make life more comfortable — cars, computers, etc.). So we use more raw materials (e.g. oil to make plastics), but we also use more energy for the manufacturing processes. This all means we're taking more and more resources from the environment more and more quickly.
3) Unfortunately, many raw materials are being used up quicker than they're being replaced. So if we carry on like we are, one day we're going to run out.

We're Also Producing More Waste

As we make more and more things we produce more and more waste, including waste chemicals. And unless this waste is properly handled, more harmful pollution will be caused. Pollution affects water, land and air and kills plants and animals, reducing biodiversity.

Water — Sewage and toxic chemicals from industry can pollute lakes, rivers and oceans, affecting the plants and animals that rely on them for survival (including humans). And the chemicals used on land (e.g. fertilisers, pesticides and herbicides) can be washed into water.

Land — We use toxic chemicals for farming (e.g. pesticides and herbicides). We also bury nuclear waste underground, and we dump a lot of household waste in landfill sites.

Air — Smoke and acidic gases released into the atmosphere can pollute the air, e.g. sulfur dioxide can cause acid rain.

More people, more mess, less space, fewer resources...

Biodiversity's a useful thing, but the increasing rate of species extinction means that it's being reduced every day.

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

Global Warming

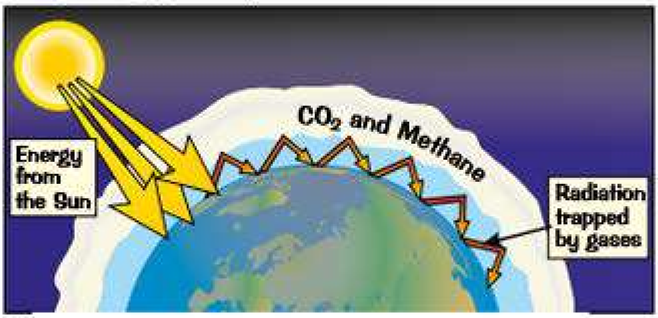
The Earth is getting warmer. Climate scientists are now trying to work out what the effects of global warming might be — sadly, it's not as simple as everyone having nicer summers.

Carbon Dioxide and Methane Trap Energy from the Sun

1) The temperature of the Earth is a balance between the energy it gets from the Sun and the energy it radiates back out into space.
2) Gases in the atmosphere naturally act like an insulating layer. They absorb most of the energy that would normally be radiated out into space, and re-radiate it in all directions (including back towards the Earth). This increases the temperature of the planet.

This is what happens in a greenhouse. The Sun shines in, and the glass helps keeps some of the energy in.

3) If this didn't happen, then at night there'd be nothing to keep any energy in, and we'd quickly get very cold indeed. But recently we've started to worry that this effect is getting a bit out of hand...
4) There are several different gases in the atmosphere which help keep the energy in. They're called "greenhouse gases", and the main ones whose levels we worry about are carbon dioxide (CO_2) and methane — because the levels of these two gases are rising quite sharply.
5) The Earth is gradually heating up because of the increasing levels of greenhouse gases — this is global warming. Global warming is a type of climate change and causes other types of climate change, e.g. changing rainfall patterns.



The Consequences of Global Warming Could be Pretty Serious

There are several reasons to be worried about global warming. Here are a few:

1) Higher temperatures cause seawater to expand and ice to melt, causing the sea level to rise. It has risen a little bit over the last 100 years. This is beginning to increase the frequency of flooding in some areas. If sea level keeps rising, it'll be bad news for people and animals living in low-lying places, and could result in the loss of habitats (where organisms live).
2) The distribution of many wild animal and plant species is changing as temperatures increase and the amount of rainfall changes in different areas. Some species are becoming more widely distributed, e.g. species that need warmer temperatures are spreading further as the conditions they thrive in exist over a wider area. Other species are becoming less widely distributed, e.g. species that need cooler temperatures have smaller ranges as the conditions they thrive in exist over a smaller area.
3) There have been changes in migration patterns, e.g. some birds may be migrating further north, as more northern areas are getting warmer.
4) Biodiversity (see p.91) could be reduced if some species are unable to survive a change in the climate, so become extinct.

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 could lead to the loss of low-lying habitats. [3 marks]

Deforestation and Land Use

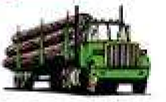
Trees and peat bogs trap carbon dioxide and lock it up. The problems start when it escapes...

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 — for example, if it requires deforestation or the destruction of habitats like peat bogs and other areas of peat.

Deforestation Means Chopping Down Trees

Deforestation is the cutting down of forests. This causes big problems when it's done on a large-scale, such as cutting down rainforests in tropical areas. It's done for various reasons, including:



- To clear land for farming (e.g. cattle or rice crops) to provide more food.
- To grow crops from which biofuels based on ethanol can be produced.

Deforestation Can Cause Many Problems

More CO_2 in the atmosphere causes global warming (see previous page), which leads to climate change.

LESS CARBON DIOXIDE TAKEN IN

1) Cutting down loads of trees means that the amount of carbon dioxide removed from the atmosphere during photosynthesis is reduced.
2) Trees 'lock up' some of the carbon that they absorb during photosynthesis in their wood, which can remove it from the atmosphere for hundreds of years. Removing trees means that less is locked up.

MORE CARBON DIOXIDE IN THE ATMOSPHERE

1) Carbon dioxide is released when trees are burnt to clear land. (Carbon in wood doesn't contribute to atmospheric pollution until it's released by burning.)
2) Microorganisms feeding on bits of dead wood release carbon dioxide as a waste product of respiration.

LESS BIODIVERSITY

1) Biodiversity (p.91) is the variety of different species — the more species, the greater the biodiversity.
2) Habitats like forests can contain a huge number of different species of plants and animals, so when they are destroyed there is a danger of many species becoming extinct — biodiversity is reduced.

Destroying Peat Bogs Adds More CO_2 to the Atmosphere

1) Bogs are areas of land that are acidic and waterlogged. Plants that live in bogs don't fully decay when they die, because there's not enough oxygen. The partly-rotted plants gradually build up to form peat.
2) So the carbon in the plants is stored in the peat instead of being released into the atmosphere.
3) However, peat bogs are often drained so that the area can be used as farmland, or the peat is cut up and dried to use as fuel. It's also sold to gardeners as compost. Peat is being used faster than it forms.
4) When peat is drained, it comes into more contact with air and some microorganisms start to decompose it. When these microorganisms respire, they use oxygen and release carbon dioxide, contributing to global warming (see the previous page).
5) Carbon dioxide is also released when peat is burned as a fuel.
6) Destroying the bogs also destroys (or reduces the area of) the habitats of some of the animals, plants and microorganisms that live there, so reduces biodiversity.

Pete Boggs Demolition Ltd — the name in habitat destruction...

So removing trees and peat results in more atmospheric CO_2, which contributes to global warming. Bad times.

Q1 Suggest why deforestation can result in a higher CO_2 concentration in the atmosphere. [3 marks]

Maintaining Ecosystems and Biodiversity

It's really important that biodiversity is maintained, but other factors also have to be taken into account.

Programmes Can be Set Up to Protect Ecosystems and Biodiversity

It's important that biodiversity is maintained at a high enough level to make sure that ecosystems are stable (see page 83). In some areas, programmes have been set up by concerned citizens and scientists to minimise damage by human activities (see p.91) to ecosystems and biodiversity. Here are a few examples:

1) Breeding programmes have been set up to help prevent endangered species from becoming extinct. These are where animals are bred in captivity to make sure the species survives if it dies out in the wild. Individuals can sometimes be released into the wild to boost or re-establish a population.
2) Programmes to protect and regenerate rare habitats like mangroves, heathland and coral reefs have been started. Protecting these habitats helps to protect the species that live there — preserving the ecosystem and biodiversity in the area.
3) There are programmes to reintroduce hedgerows and field margins around fields on farms where only a single type of crop is grown. Field margins are areas of land around the edges of fields where wild flowers and grasses are left to grow. Hedgerows and field margins provide a habitat for a wider variety of organisms than could survive in a single crop habitat.
4) Some governments have introduced regulations and programmes to reduce the level of deforestation taking place and the amount of carbon dioxide being released into the atmosphere by businesses. This could reduce the increase of global warming (see page 92).
5) People are encouraged to recycle to reduce the amount of waste that gets dumped in landfill sites. This could reduce the amount of land taken over for landfill, leaving ecosystems in place.

Conflicting Pressures Can Affect How Biodiversity is Maintained

Sadly for noble biodiversity warriors, maintaining biodiversity isn't as simple as you would hope. There are lots of conflicting pressures that have to be taken into account. For example:

1) Protecting biodiversity costs money. For example, governments sometimes pay farmers a subsidy to reintroduce hedgerows and field margins to their land. It can also cost money to keep a watch on whether the programmes and regulations designed to maintain biodiversity are being followed. There can be conflict between protecting biodiversity and saving money — money may be prioritised for other things.
2) Protecting biodiversity may come at a cost to local people's livelihood. For example, reducing the amount of deforestation is great for biodiversity, but the people who were previously employed in the tree-felling industry could be left unemployed. This could affect the local economy if people move away with their family to find work.
3) There can be conflict between protecting biodiversity and protecting our food security. Sometimes certain organisms are seen as pests by farmers (e.g. locusts and foxes) and are killed to protect crops and livestock so that more food can be produced. As a result, however, the food chain and biodiversity can be affected.
4) Development is important, but it can affect the environment. Many people want to protect biodiversity in the face of development, but sometimes land is in such high demand that previously untouched land with high biodiversity has to be used for development, e.g. for housing developments on the edge of towns, or for new agricultural land in developing countries.

Revision or sleep — now that's a conflicting pressure...

Like many situations in ecology, maintaining biodiversity isn't black and white. There are lots of factors to take into account before decisions on the best way to go forward can be made.

Q1 Give an example of how biodiversity can be increased in areas that farm single crops. [2 marks]

Q2 How could wild populations of endangered species be preserved by breeding programmes? [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 question 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 are biotic and abiotic factors?
4) What are functional adaptations?

Food Chains (p.86)

5) What do food chains always start with?
6) Explain what happens to the population size of a predator if its prey becomes more common in an ecosystem.

Quadrats and Transects (p.87-88)

7) Explain how a quadrat can be used to investigate the distribution of clover plants in two areas.
8) Suggest why you might use a transect when investigating the distribution of organisms.

The Water and Carbon Cycles (p.89-90)

9) When water vapour cools and condenses in the atmosphere, what does it change into?
10) Explain how microorganisms return carbon to the atmosphere.

Human Impacts on the Planet (p.91-94)

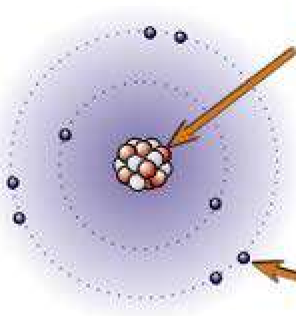
11) Suggest why it's important to have high biodiversity in an ecosystem.
12) Name two gases linked to global warming.
13) Give an example of how global warming could reduce biodiversity.
14) Why might humans carry out deforestation?
15) Explain why the destruction of peat bogs adds more carbon dioxide to the atmosphere.
16) How can recycling programmes help to protect ecosystems?

Atoms

All substances are made of atoms. They're really tiny — too small to see, even with your microscope. 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

Atoms have a radius of about 0.1 nanometres (that's 1×10^{-10} m). There are a few different (and equally useful) modern models of the atom — but chemists tend to like the model below best.



A nanometre (nm) is one billionth of a metre. Shown in standard form, that's 1×10^{-9} m. Standard form is used for showing really large or really small numbers.

The Nucleus

1) It's in the middle of the atom.
2) It contains protons and neutrons.
3) The nucleus has a radius of around 1×10^{-14} m (that's around 1/10 000 of the radius of an atom)
4) It has a positive charge because of the protons.
5) Almost the whole mass of the atom is concentrated in the nucleus.

The Electrons

1) Move around the nucleus in electron shells.
2) They're negatively charged and tiny, but they cover a lot of space.
3) The volume of their orbits determines the size of the atom.
4) Electrons have virtually no mass.

Protons are heavy and positively charged.
Neutrons are heavy and neutral.
Electrons are tiny and negatively charged.

Particle	Relative Mass	Charge
Proton	1	+1
Neutron	1	0
Electron	Very small	–1

(Electron mass is often taken as zero.)

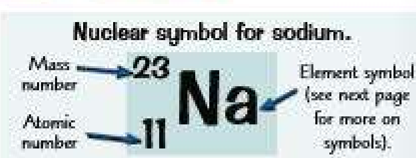
Number of Protons Equals Number of Electrons

1) Atoms are neutral — they have no charge overall (unlike ions).
2) This is because they have the same number of protons as electrons.
3) The charge on the electrons is the same size as the charge on the protons, but opposite — so the charges cancel out.
4) 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.

Atomic Number and Mass Number Describe an Atom

1) The nuclear symbol of an atom tells you its atomic (proton) number and mass number.
2) The atomic number tells you how many protons there are.
3) The mass number tells you the total number of protons and neutrons in the atom.
4) To get the number of neutrons, just subtract the atomic number from the mass number.



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 super important. If you get to grips with the basic facts then you'll have a better chance understanding the rest of chemistry. Crack on.

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 Consist of Atoms With the Same Atomic Number

1) Atoms can have different numbers of protons, neutrons and electrons. It's the number of protons in the nucleus that decides what type of atom it is.
2) For example, an atom with one proton in its nucleus is hydrogen and an atom with two protons is helium.
3) If a substance only contains atoms with the same number of protons it's called an element. There are about 100 different elements
4) So all the atoms of a particular element (e.g. nitrogen) have the same number of protons and different elements have atoms with different numbers of protons.

Atoms Can be Represented by Symbols

Atoms of each element can be represented by a one or two letter symbol — it's a type of shorthand that saves you the bother of having to write the full name of the element.

Some make perfect sense, e.g. C = carbon O = oxygen Mg = magnesium

Others less so, e.g. Na = sodium Fe = iron Pb = lead

Most of these odd symbols actually come from the Latin names of the elements.

You'll see these symbols on the periodic table (see page 106).

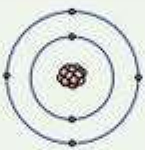
Isotopes are the Same Except for Extra Neutrons

1) Isotopes are different forms of the same element, which have the same number of protons but a different number of neutrons.
2) So isotopes have the same atomic number but different mass numbers.
3) A very popular example of a pair of isotopes are carbon-12 and carbon-13.

The number of neutrons is just the mass number minus the atomic number.

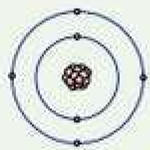
Carbon-12

$^{12}_{6}C$ 6 Protons, 6 Electrons, 6 Neutrons



Carbon-13

$^{13}_{6}C$ 6 Protons, 6 Electrons, 7 Neutrons



4) Because many elements can exist as a number of different isotopes, relative atomic mass (A_r) is used instead of mass number when referring to the element as a whole. This is an average mass taking into account the different masses and abundances (amounts) of all the isotopes that make up the element.
5) You can use this formula to work out the relative atomic mass of an element:

$$\text{relative atomic mass } (A_r) = \frac{\text{sum of (isotope abundance} \times \text{isotope mass number)}}{\text{sum of abundances of all the isotopes}}$$

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.

$$\text{Relative atomic mass} = \frac{(69.2 \times 63) + (30.8 \times 65)}{69.2 + 30.8} = \frac{4359.6 + 2002}{100} = \frac{6361.6}{100} = 63.616 = 63.6$$

It's elemental my dear Watson...

Atoms, elements and isotopes — make sure you know what they are and the differences between them.

Q1 A substance consists of atoms which all have the same number of protons and electrons but different numbers of neutrons. Explain why this substance is an element. [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

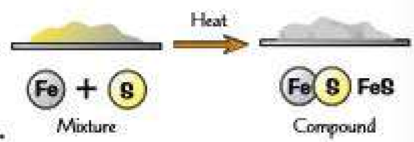
It would be great if we only had to deal with elements. But unluckily for you, elements can mix and match to make lots of new substances called compounds. And this makes things a little bit more complicated...

Atoms Join Together to Make Compounds

1) When elements react, atoms combine with other atoms to form compounds.
2) Compounds are substances formed from two or more elements, the atoms of each are in fixed proportions throughout the compound and they're held together by chemical bonds.
3) Making bonds involves atoms giving away, taking or sharing electrons. Only the electrons are involved — the nuclei of the atoms aren't affected at all when a bond is made.
4) It's usually difficult to separate the original elements of a compound out again — a chemical reaction is needed to do this.
5) A compound which is formed from a metal and a non-metal consists of ions. The metal atoms lose electrons to form positive ions and the non-metal atoms gain electrons to form negative ions. The opposite charges (positive and negative) of the ions mean that they're strongly attracted to each other. This is called ionic bonding. Examples of compounds which are bonded ionically include sodium chloride, magnesium oxide and calcium oxide.

> 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.

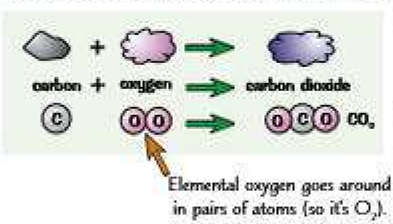
6) A compound formed from non-metals consists of molecules. Each atom shares an electron with another atom — this is called covalent bonding. Examples of compounds that are bonded covalently include hydrogen chloride gas, carbon monoxide, and water.
7) The properties of a compound are usually totally different from the properties of the original elements. For example, if iron (a lustrous magnetic metal) and sulfur (a nice yellow powder) react, the compound formed (iron sulfide) is a dull grey solid lump, and doesn't behave anything like either iron or sulfur.



A Formula Shows What Atoms are in a Compound

Just as elements can be represented by symbols, compounds can be represented by formulas. The formulas are made up of elemental symbols in the same proportions that the elements can be found in the compound.

1) For example, carbon dioxide, CO_2, is a compound formed from a chemical reaction between carbon and oxygen. It contains 1 carbon atom and 2 oxygen atoms.



2) 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.
3) There might be brackets in a formula, e.g. calcium hydroxide is $Ca(OH)_2$. The little number outside the bracket applies to everything inside the brackets. So in $Ca(OH)_2$ there's 1 calcium atom, 2 oxygen atoms and 2 hydrogen atoms.

Here are some examples of formulas which might come in handy:

1) Carbon dioxide — CO_2
2) Ammonia — NH_3
3) Water — H_2O
4) Sodium chloride — $NaCl$
5) Carbon monoxide — CO
6) Hydrochloric acid — HCl
7) Calcium chloride — $CaCl_2$
8) Sodium carbonate — Na_2CO_3
9) Sulfuric acid — H_2SO_4

If you don't revise, it will only compound your problems...

You know when you were little and taught to share things? Turns out atoms have been doing this since the start of the universe. Maybe we could all learn a thing or two from those little guys.

Q2 Video Solution

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]

Chemical Equations

Chemical equations are fundamental to chemistry. Pretty much like tomato ketchup is to a bacon butty. Mmm... bacon butties... Sorry, I got distracted. Let's do this.

Chemical Changes are Shown Using Chemical Equations

One way to show a chemical reaction is to write a word equation. It's not as quick as using chemical symbols and you can't tell straight away what's happened to each of the atoms, but it's dead easy.

Here's an example — you're told that methane burns in oxygen giving carbon dioxide and water:

The molecules on the left-hand side of the equation are called the reactants (because they react with each other).

methane + oxygen → carbon dioxide + water

The molecules 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

Chemical changes can be shown in a kind of shorthand using symbol equations. 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 where needed. Take this equation for reacting sulfuric acid with sodium hydroxide:

$$H_2SO_4 + NaOH \rightarrow Na_2SO_4 + H_2O$$

3) The formulas are all correct but the numbers of some atoms don't match up on both sides.
4) You can't change formulas like H_2SO_4 to H_2SO_5. You can only put numbers in front of them.

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 to try and sort it out.
2) See where it gets you. It may create another imbalance, but if so, pencil in another number and see where that gets you.
3) Carry on chasing unbalanced elements and it'll sort itself out pretty quickly.

EXAMPLE

In the equation above you'll notice we're short of H atoms on the RHS (Right-Hand Side).

1) The only thing you can do about that is make it $2H_2O$ instead of just H_2O:

$$H_2SO_4 + NaOH \rightarrow Na_2SO_4 + 2H_2O$$

2) But that now gives too many H atoms and O atoms on the RHS, so to balance that up you could try putting 2NaOH on the LHS (Left-Hand Side):

$$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$$

3) And suddenly there it is! Everything balances. And you'll notice the Na just sorted itself out.

Revision is all about getting the balance right...

Balancing equations is all about practice. Once you have a few goes you'll see it's much less scary than it seemed before you took on, challenged and defeated this page. Go grab some chemistry glory.

Q2 Video Solution

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]

Mixtures and Chromatography

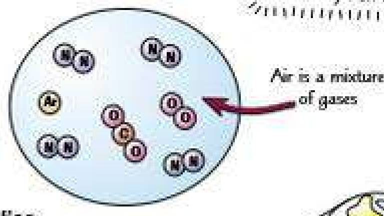
Mixtures in chemistry are just like mixtures in baking, lots of separate things all mixed together. But most of the time they're considerably less delicious. And you probably shouldn't eat them. Or put them in an oven.

Mixtures are Easily Separated — Not Like Compounds

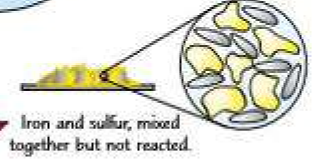
1) Unlike in a compound, there's no chemical bond between the different parts of a mixture.
2) The parts of a mixture can be either elements or compounds, and they can be separated out by physical methods such as filtration (p. 101), crystallisation (p.101), simple distillation (p.102), fractional distillation (p.102) and chromatography (see below).

A physical method is one that doesn't involve a chemical reaction, so doesn't form any new substances.

3) Air is a mixture of gases, mainly nitrogen, oxygen, carbon dioxide and argon. The gases can all be separated out fairly easily.
4) Crude oil is a mixture of different length hydrocarbon molecules.
5) The properties of a mixture are just a mixture of the properties of the separate parts — the chemical properties of a substance aren't affected 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.

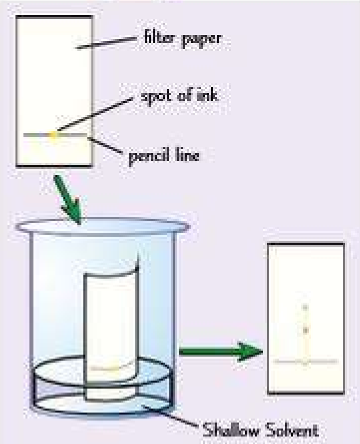


You Need to Know How to Do Paper Chromatography

PRACTICAL

One method of separating substances in a mixture is through chromatography. This technique 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 are insoluble and won't dissolve in the solvent.)
2) Add a spot of the ink to the line and place the sheet in a beaker of solvent, e.g water.
3) The solvent used depends on what's being tested. Some compounds dissolve well in water, but sometimes other solvents, like ethanol, are needed.



4) Make sure the ink isn't touching the solvent — you don't want it to dissolve into it.
5) Place a lid on top of the container to stop the solvent evaporating.
6) The solvent seeps up the paper, carrying the ink with it.
7) Each different dye in the ink will move up the paper at a different rate so the dyes will separate out. Each dye will form a spot in a different place — 1 spot per dye in the ink.
8) If any of the dyes in the ink are insoluble (won't dissolve) in the solvent you've used, they'll stay on the baseline.
9) When the solvent has nearly reached the top of the paper, take the paper out of the beaker and leave it to dry.
10) 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.

Chemistry and fun are a mixture — easily separated...

Chromatography is actually mighty useful in real life. It's used to test athletes' urine samples for performance enhancing drugs, and also to test unknown substances at crime scenes. Eeek...

Q1 Explain why you shouldn't use a pen to draw a line on the filter paper for paper chromatography. [1 mark]

More Separation Techniques

PRACTICAL

Filtration and crystallisation are methods of separating mixtures. Chemists use these techniques 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

1) Filtration can be used if your product is an insoluble solid that needs to be separated from a liquid reaction mixture.
2) It can be used in purification as well. For example, solid impurities in the reaction mixture can be separated out using filtration.

Insoluble means the solid can't be dissolved in the liquid.

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 it's described as being soluble. There are two methods you can use to separate a soluble salt from a solution — evaporation and crystallisation.

You don't have to use a Bunsen burner, you could use a water bath, or an electric heater.

Evaporation

1) Pour the solution into an evaporating dish.
2) Slowly heat the solution. The solvent will evaporate and the solution will get more concentrated. Eventually, crystals will start to form.
3) Keep heating the evaporating dish until all you have left are dry crystals.

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 decompose (break down) when its heated. Otherwise, you'll have to use crystallisation.

Crystallisation

You should also use crystallisation if you want to make nice big crystals of your salt.

1) Pour the solution into an evaporating dish and gently heat the solution. Some of the solvent will evaporate and the solution will get more concentrated.
2) Once some of the solvent has evaporated, or when you see crystals start to form (the point of crystallisation), remove the dish from the heat and leave the solution to cool.
3) The salt should start to form crystals as it becomes insoluble in the cold, highly concentrated solution.
4) Filter the crystals out of the solution, and leave them in a warm place to dry. You could also use a drying oven or a desiccator.

Salt crystallising out of solution.

Filtration and Crystallisation can be Used to Separate Rock Salt

1) Rock salt is simply a mixture of salt and sand (they spread it on the roads in winter).
2) Salt and sand are both compounds — but salt dissolves in water and sand doesn't. This vital difference in their physical properties gives a great way to 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) Evaporate the water from the salt so that it forms dry crystals.

You can heat the mixture to help dissolve the salt.

You could also use crystallisation here if you wanted to make nice, big crystals.

Revise mixtures — just filter out the important bits...

Two out of three 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 A student needs to produce pure crystals of copper sulfate from an aqueous solution of copper sulfate. Describe how the student could use crystallisation for this process. [4 marks]

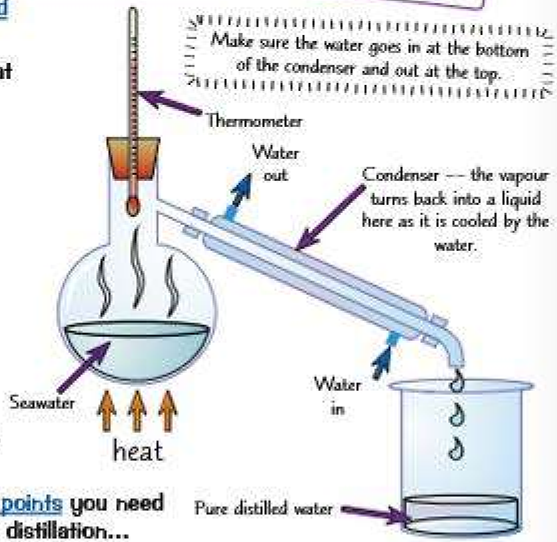
Distillation

Distillation is used to separate mixtures which contain liquids. There are two types that you should know about — simple and fractional. Hopefully, this page will 'distil' everything you need to know... ho ho.

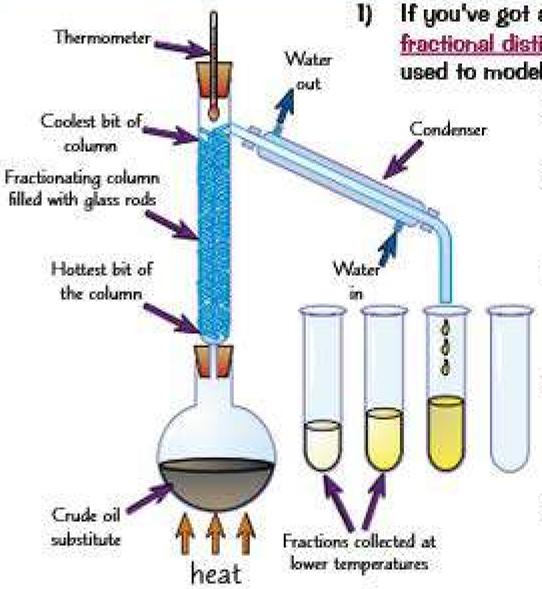
Simple Distillation is Used to Separate Out Solutions

PRACTICAL

1) Simple distillation is used for separating out a liquid from a solution.
2) The solution is heated. The part of the solution that has the lowest boiling point evaporates first.
3) The vapour is then cooled, condenses (turns back into a liquid) and is collected.
4) The rest of the solution is left behind in the flask.
5) You can use simple distillation to get pure water from seawater. The water evaporates and is condensed and collected. Eventually you'll end up with just the salt left in the flask.
6) The problem with simple distillation is that you can only use it to separate things with very different boiling points — if the temperature goes higher than the boiling point of the substance with the higher boiling point, they will mix again.
7) If you have a mixture of liquids with similar boiling points you need another method to separate them — 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. Here is a lab demonstration that can be used to model fractional distillation of crude oil at a refinery.
2) You put your mixture in a flask and stick a fractionating column on top. Then you heat it.
3) The different liquids will all have different boiling points — so they will evaporate at different temperatures.
4) The liquid with the lowest boiling point evaporates first. When the temperature on the thermometer matches the boiling point of this liquid, it will reach the top of the column.
5) Liquids with higher boiling points might also start to evaporate. But the column is cooler towards the top. So they will only get part of the way up before condensing and running back down towards the flask.
6) When the first liquid has been collected, you raise the temperature until the next one reaches the top.

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.

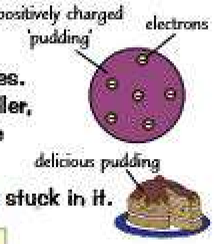
Q1 Propan-1-ol, methanol and ethanol have boiling points of 97 °C, 65 °C and 78 °C respectively. A student uses fractional distillation to separate a mixture of these compounds. State which liquid will be collected in the second fraction and explain why. [2 marks]

Q1 Video Solution

The History of the Atom

You might have thought you were done with the atom after page 96. Unfortunately amigo, 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...

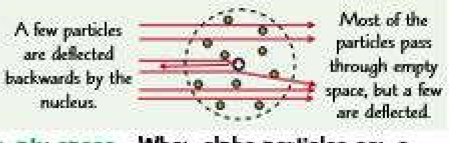
The Theory of Atomic Structure Has Changed Over Time



1) At the start of the 19th century John Dalton described atoms as solid spheres, and said that different spheres made up the different elements.
2) In 1897 J J Thomson concluded from his experiments that atoms weren't solid spheres. His measurements of charge and mass showed that an atom must contain even smaller, negatively charged particles — electrons. The 'solid sphere' idea of atomic structure had to be changed. The new theory was known as the 'plum pudding model'.
3) The plum pudding model showed the atom as a ball of positive charge with electrons stuck in it.

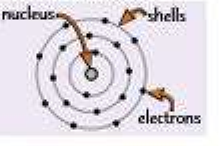
Rutherford Showed that the Plum Pudding Model Was Wrong

1) In 1909 Ernest Rutherford and his student Ernest Marsden conducted the famous alpha particle scattering experiments. They fired positively charged alpha particles at an extremely thin sheet of gold.
2) From the plum pudding model, they were expecting the particles to pass straight through the sheet or be slightly deflected at most. This was because the positive charge of each atom was thought to be very spread out through the 'pudding' of the atom. But, whilst most of the particles did go straight through the gold sheet, some were deflected more than expected, and a small number were deflected backwards. So the plum pudding model couldn't be right.
3) Rutherford came up with an idea to explain this new evidence — the nuclear model of the atom. In this, there's a tiny, positively charged nucleus at the centre, where most of the mass is concentrated. A 'cloud' of negative electrons surrounds this nucleus — so most of the atom is empty space. When alpha particles came near the concentrated, positive charge of the nucleus, they were deflected. If they were fired directly at the nucleus, they were deflected backwards. Otherwise, they passed through the empty space.



Bohr's Nuclear Model Explains a Lot

1) Scientists realised that electrons in a 'cloud' around the nucleus of an atom, as Rutherford described, would be attracted to the nucleus, causing the atom to collapse. Niels Bohr's nuclear model of the atom suggested that all the electrons were contained in shells.
2) Bohr proposed that electrons orbit the nucleus in fixed shells and aren't anywhere in between. Each shell is a fixed distance from the nucleus.
3) Bohr's theory of atomic structure was supported by many experiments and it helped to explain lots of other scientists' observations at the time.



Further Experiments Showed the Existence of Protons

1) Further experiments by Rutherford and others showed that the nucleus can be divided into smaller particles, which each have the same charge as a hydrogen nucleus. These particles were named protons.
2) About 20 years after scientists had accepted that atoms have nuclei, James Chadwick carried out an experiment which provided evidence for neutral particles in the nucleus which are now called neutrons. The discovery of neutrons resulted in a model of the atom which was pretty close to the modern day accepted version, known as the nuclear model (see page 96).

I wanted to be a model — but I ate too much plum pudding...

In science, other people's work is constantly being built upon — increasing our understanding of a topic.

Q1 Describe the 'plum pudding' model of the atom. [1 mark]

Q2 Rutherford devised an experiment where alpha particles were fired through gold foil. Most of the particles passed through the foil, but some were deflected by different angles, and some were even deflected backwards. Explain why this disproves the plum pudding model. [2 marks]

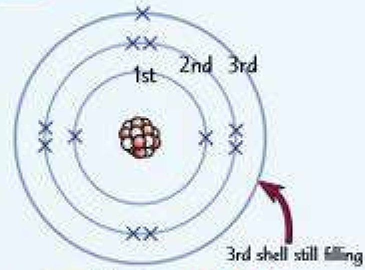
Electronic Structure

The fact that electrons occupy 'shells' around the nucleus is what causes the whole of chemistry. Remember that, and watch how it applies to each bit of it. It's ace.

Electron Shell Rules:

1) Electrons always occupy shells (sometimes called energy levels).
2) The lowest energy levels are always filled 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 much happier when they have full electron shells — like the noble gases in Group 0.
5) In most atoms, the outer shell is not full and this makes the atom want to react to fill it.

Electron configurations can be shown as diagrams like this...



...or as numbers like this: 2, 8, 1

Both of the configurations above are for sodium.

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 nitrogen?

1) Nitrogen's atomic number is 7. This means it has 7 protons... so it must have 7 electrons.
2) Follow the 'Electron Shell Rules' above. The first shell can only take 2 electrons and the second shell can take a maximum of 8 electrons.

So the electronic structure for nitrogen must be 2, 5.

EXAMPLE What is the electronic structure of magnesium?

1) 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 and the second shell can take a maximum of 8 electrons, so the third shell must also be partially filled.

So the electronic structure for magnesium must be 2, 8, 2

Here are some more examples of electronic structures:

H Hydrogen

1
Proton no. = 1

He Helium

2
Proton no. = 2

Li Lithium

2,1
Proton no. = 3

C Carbon

2,4
Proton no. = 6

Ne Neon

2,8
Proton no. = 10

Ca Calcium

2,8,8,2
Proton 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 Give the electronic structure of aluminium (atomic number = 13). [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. No sirree. Early chemists looked to try and understand patterns in the elements' properties to get a bit of understanding.

In the Early 1800s Elements Were Arranged By Atomic Weight

Until quite recently, there were two obvious ways to categorise elements:

1) Their physical and chemical properties. 2) Their atomic weight.

1) Remember, scientists had no idea of atomic structure or of protons, neutrons or electrons, so there was no such thing as atomic number to them. (It was only in the 20th century after protons and electrons were discovered that it was realised the elements were best arranged in order of atomic number.)

Atomic weight is equivalent to what we now call "relative atomic mass".

2) Back then, the only thing they could measure was atomic weight, and so the known elements were arranged in order of atomic weight. When this was done, a periodic pattern was noticed in the properties of the elements. This is where the name 'periodic table' comes from — ta da...
3) Early periodic tables were not complete and some elements were placed in the wrong group. This is because elements were placed in the order of atomic weight and did not take into account their properties.

Dmitri Mendeleev Left Gaps and Predicted New Elements

1) In 1869, Dmitri Mendeleev overcame some of the problems of early periodic tables by taking 50 known elements and arranging them into his Table of Elements — with various gaps as shown.

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) Mendeleev put the elements mainly in order of atomic weight but did switch that order if the properties meant it should be changed. An example of this can been seen with Te and I — iodine actually has a smaller atomic weight but is placed after tellurium as it has similar properties to the elements in that group.

3) Gaps were left in the table to make sure that elements with similar properties stayed in the same groups. Some of these gaps indicated the existence of undiscovered elements and allowed Mendeleev to predict what their properties might be. When they were found and they fitted the pattern it helped confirm Mendeleev's ideas. For example, Mendeleev made really good predictions about the chemical and physical properties of an element he called ekasilicon, which we know today as germanium.

The discovery of isotopes (see page 97) in the early 20th century confirmed that Mendeleev was correct to not place elements in a strict order of atomic weight but to also take account of their properties. Isotopes of the same element have different masses but have the same chemical properties so occupy the same position on the periodic table.

You should come back to this page periodically...

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 classified in the early 1800s? [1 mark]

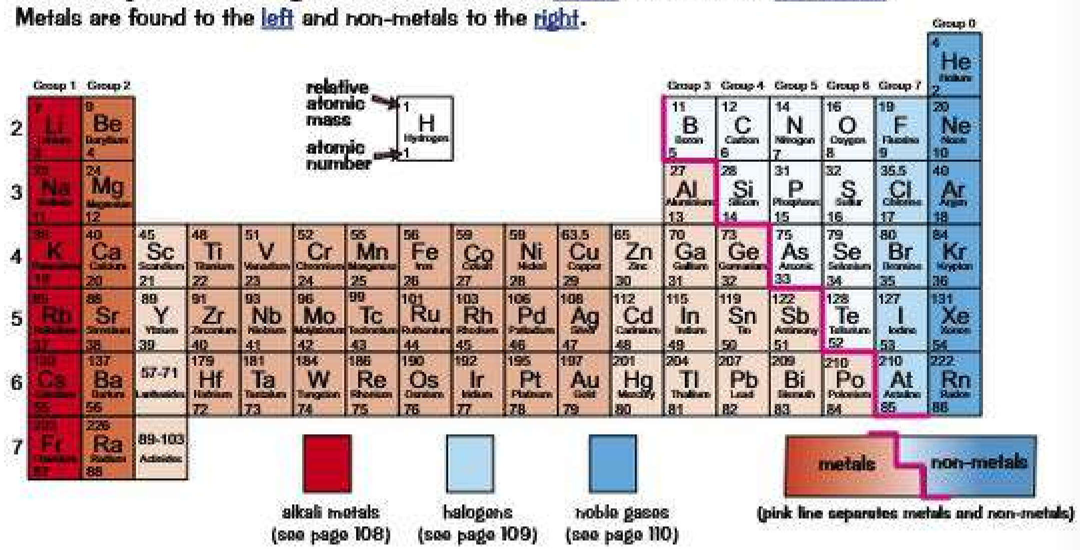
Q2 Describe two changes that Mendeleev made to early periodic tables. [2 marks]

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 100ish elements, which all materials are made of.
2) In the periodic table the elements are laid out in order of increasing atomic (proton) number. Arranging the elements like this means there are repeating patterns in the properties of the elements. (The properties are said to occur periodically, hence the name periodic table.)
3) If it wasn't for the periodic table organising everything, you'd have a heck of a job remembering all those properties. It's ace.
4) It's a handy tool for working out which elements are metals and which are non-metals. Metals are found to the left and non-metals to the right.



5) Elements with similar properties form columns.
6) These vertical columns are called groups.
7) The group number tells you how many electrons there are in the outer shell. For example, Group 1 elements all have one electron in their outer shell and Group 7 all have seven electrons in their outer shell. The exception to the rule is group 0, for example Helium has two electrons in its outer shell. This is useful as the way atoms react depends upon the number of electrons in their outer shell. So all elements in the same group are likely to react in a similar way.
8) If you know the properties of one element, you can predict properties of other elements in that group — and in the exam, you might be asked to do this. For example the Group 1 elements are Li, Na, K, Rb, Cs and Fr. They're all metals and they react in a similar way (see page 108).
9) You can also make predictions about trends in reactivity. E.g. in Group 1, the elements react more vigorously as you go down the group. And in Group 7, reactivity decreases as you go down the group.
10) The rows are called periods. Each new period represents another full shell of electrons.

I'm in a chemistry band — I play the symbols...

Because the periodic table is organised into groups and periods, it allows us to see trends in both reactivity and properties. And this means we can make predictions on how reactions will occur. How neat is that?

Q1 Using a periodic table, state how many electrons beryllium has in its outer shell. [1 mark]

Q2 Chlorine reacts in a similar way to bromine. Suggest a reason why. [1 mark]

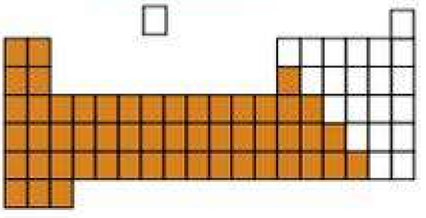
Q3 Sodium readily forms 1+ ions. Suggest what ions potassium forms and explain why. [1 mark]

Metals and Non-Metals

I can almost guarantee 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 generally form positive ions when they react.



The orange elements are metals

The white elements are non-metals

The Electronic Structure of Atoms Affects How They Will React

1) Atoms generally react to form a full outer shell. They do this via losing, gaining or sharing electrons.
2) Metals to the left of the periodic table don't have many electrons to remove and metals towards the bottom of the periodic table have outer electrons which are a long way from the nucleus so feel a weaker attraction. Both these effects means that not much energy is needed to remove the electrons so it's feasible for the elements to react to form positive ions with a full outer shell.
3) For non-metals, forming positive ions is much more difficult. This is as they are either to the right of the periodic table — where they have lots of electrons to remove to get a full outer shell, or towards the top — where the outer electrons are close to the nucleus so feel a strong attraction. It's far more feasible for them to either share or gain electrons to get a full outer shell.

Metals and Non-Metals Have Different Physical Properties

1) All metals have metallic bonding which causes them to have similar basic 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.

Don't try this at home, you'll die.

2) As non-metals don't have metallic bonding, they don't tend to exhibit the same properties as metals. They tend to be dull looking, more brittle, aren't always solids at room temperature, don't generally conduct electricity and often have a lower density.

Non-metals form a variety of different structures so have a wide range of chemical properties.

You can 'rock out' to metal, you can sway gently to non-metal...

Metals and non-metals are like chalk and cheese... Though I hope there's no metal in your cheese.

Q1 Iodine generally reacts by forming negative ions. Is iodine a metal or a non-metal? [1 mark]

Q2 State three properties of metals. [3 marks]

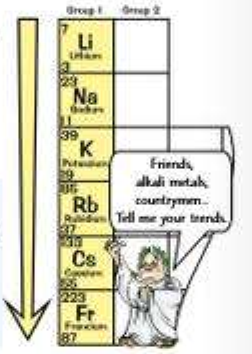
Q3 State whether metals generally form positive or negative ions. Explain why they form these ions with reference to their position in the periodic table. [4 marks]

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 which makes them very reactive and gives them similar properties.
3) The alkali metals are all soft and have low density.
4) The trends for the alkali metals as you go down Group 1 include:
   - Increasing reactivity — the outer electron is more easily lost as the attraction between the nucleus and electron decreases, because the electron is further away from the nucleus the further down the group you go.
   - Lower melting and boiling points.
   - Higher relative atomic mass.



Alkali Metals Form Ionic Compounds with Non-Metals

Don't worry, there's more on ionic compounds on page 114.

1) The Group 1 elements don't need much energy to lose their one outer electron to form a full outer shell, so they readily form 1+ ions.
2) It's so easy for them to lose their outer electron that they only ever react to form ionic compounds. These compounds are generally white solids that dissolve in water to form colourless solutions.

Reaction with Water Produces Hydrogen Gas

1) When Group 1 metals are put in water, they react very vigorously.
2) The more reactive (lower down in the group) an alkali metal is, the more violent the reaction.
3) Lithium, sodium and potassium float and move around the surface, fizzing furiously.
4) They produce hydrogen. The amount of energy given out when they react increases down the group. For potassium and below in the group, there's enough energy to ignite hydrogen.
5) They also form hydroxides that dissolve in water to give alkaline solutions.

$$2Na_{(s)} + 2H_2O_{(l)} \rightarrow 2NaOH_{(aq)} + H_{2\,(g)}$$

sodium + water → sodium hydroxide + hydrogen

The other Group 1 metals react with water in a similar way.

Reaction with Chlorine Produces a Salt

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, reactivity increases so the reaction with chlorine gets more vigorous.

$$2Na_{(s)} + Cl_{2(g)} \rightarrow 2NaCl_{(s)}$$

sodium + chlorine → sodium chloride

Group 1 Metals React with Oxygen

The Group 1 metals can react with oxygen to form a metal oxide. Different types of oxide will form depending on the Group 1 metal.

- Lithium reacts to form lithium oxide (Li_2O).
- Sodium reacts to form a mixture of sodium oxide (Na_2O) and sodium peroxide (Na_2O_2).
- Potassium reacts to form a mixture of potassium peroxide (K_2O_2) and potassium superoxide (KO_2).

The reactions with oxygen are why Group 1 metals tarnish in the air — the metal reacts with oxygen in the air to form a dull metal oxide layer.

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 Explain the trend in reactivity as you go down Group 1. [2 marks]

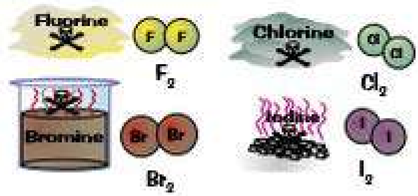
Q1 Video Solution

Group 7 Elements

The Group 7 elements are known as the halogens. The whole 'trend thing' happens with the halogens as well — that shouldn't come as a surprise.

The Halogens are All Non-Metals with Coloured Vapours

Fluorine is a very reactive, poisonous yellow gas.
Chlorine is a fairly reactive, poisonous dense green gas.
Bromine is a dense, poisonous, red-brown volatile liquid.
Iodine is a dark grey crystalline solid or a purple vapour.
They all exist as molecules which are pairs of atoms.

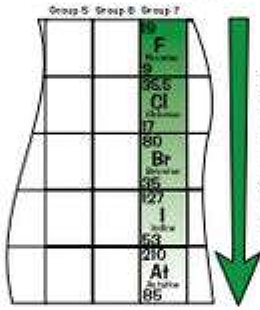


Learn These Trends:

As you go DOWN Group 7, the halogens:

1) become LESS REACTIVE — it's harder to gain an extra electron, because the outer shell's further from the nucleus.
2) have HIGHER MELTING AND BOILING POINTS.
3) have HIGHER RELATIVE ATOMIC MASSES.

All the Group 7 elements react in similar ways. This is because they all have seven electrons in their outer shell.



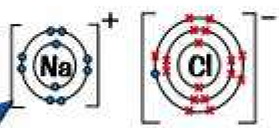
You can use these trends to predict properties of halogens. For example, you know that iodine will have a higher boiling point than chlorine as it's further down the group in the periodic table.

Halogens can Form Molecular Compounds

Halogen atoms can share electrons via covalent bonding (see page 115) with other non-metals so as to achieve a full outer shell. For example HCl, PCl_5, HF and CCl_4 contain covalent bonds. The compounds that form when halogens react with non-metals all have simple molecular structures (see p.116).

Halogens Form Ionic Bonds with Metals

1) The halogens form 1– ions called halides (F^-, Cl^-, Br^- and I^-) when they bond with metals, for example Na^+Cl^- or $Fe^{3+}Br^-_3$.
2) The compounds that form have ionic structures.
3) The diagram shows the bonding in sodium chloride, NaCl.

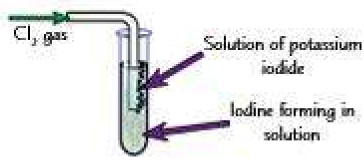


More Reactive Halogens Will Displace Less Reactive Ones

A displacement reaction can occur between a more reactive halogen and the salt of a less reactive one. E.g. chlorine can displace bromine and iodine from an aqueous solution of its salt (a bromide or iodide). Bromine will also displace iodine because of the trend in reactivity.

$$Cl_{2\,(g)} + 2KI_{(aq)} \rightarrow I_{2\,(aq)} + 2KCl_{(aq)}$$
Pale green → Brown

$$Cl_{2\,(g)} + 2KBr_{(aq)} \rightarrow Br_{2\,(aq)} + 2KCl_{(aq)}$$
Pale green → Orange



Halogens — one electron short of a full shell...

Group 7 elements that are higher up displace those that are lower down in displacement reactions. So if you think of displacement reactions like boxing matches, fluorine would be the heavyweight champion.

Q1 Give the balanced symbol equation for the displacement reaction between bromine and sodium iodide. [1 mark]

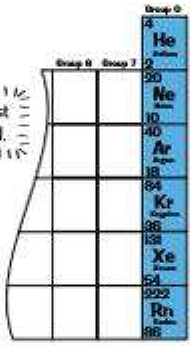
Q1 Video Solution

Q2 Why do Group 7 elements get less reactive as you go down the group from fluorine to iodine? [3 marks]

Group 0 Elements

The Group 0 elements are known as noble gases — stuffed full of every honourable virtue. They don't react with very much and you can't even see them — making them, well, a bit dull really.

Group 0 Elements are All Inert, Colourless Gases



1) Group 0 elements are called the noble gases and include the elements helium, neon and argon (plus a few others).
2) They all have eight electrons in their outer energy level, apart from helium which has two, giving them a full outer-shell. As their outer shell is energetically stable they don't need to give up or gain electrons to become more stable. This means they are more or less inert — they don't react with much at all.
3) They exist as monatomic gases — single atoms not bonded to each other.
4) All elements in Group 0 are colourless gases at room temperature.
5) As the noble gases are inert they're non-flammable — they won't set on fire.

Helium only has electrons in the first shell, which only needs 2 to be filled.

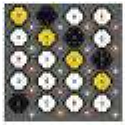
There are Patterns in the Properties of the Noble Gases

1) The boiling points of the noble gases increase as you move down the group along with increasing relative atomic mass.

Noble Gas
helium
neon
argon
krypton
xenon
radon

Increasing boiling point ↓

2) The increase in boiling point is due to an increase in the number of electrons in each atom leading to greater intermolecular forces between them which need to be overcome. There's more on intermolecular forces for small molecules on page 116.



Here's another pattern. You don't have to learn this one...

3) In the exam you may be given the boiling point of one noble gas and asked to estimate the value 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

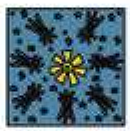
Radon and krypton have boiling points of –62 °C and –153 °C respectively. Predict the boiling point of xenon.

Xenon comes in between radon and krypton in the group so you can predict that its boiling point would be halfway between their boiling points: (–153) + (–62) = –215

–215 ÷ 2 = –107.5 ≈ –108 °C

So, xenon should have a boiling point of about –108 °C.

The actual boiling point of xenon is –108 °C — just as predicted. Neat!



...or this one.

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]

Q2 Argon is very unreactive. Using your knowledge of its electronic structure, explain why. [2 marks]

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) Sketch an atom. Label the nucleus and the electrons.
2) What is the charge of a proton?
3) True or False? Elements contain more than one type of atom.
4) Give the formula for:
   a) Carbon dioxide   b) Sodium carbonate
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.100-102)

6) What is the difference between a compound and a mixture?
7) What is the name of the pattern formed from carrying out paper chromatography?
8) Which method of separation is useful to separate an insoluble solid from a liquid?
9) Give the name of a method to separate a soluble solid from a liquid.
10) Which method of distillation would you use to separate liquids with similar boiling points?

Electronic Structure and the History of the Periodic Table (p.103-106)

11) Who discovered that the plum pudding model was wrong?
12) Who first devised an experiment that proved the existence of the neutron?
13) What is the electronic structure of sodium?
14) Why did Mendeleev leave gaps in his Table of Elements?

Groups of the Periodic Table (p.107-110)

15) How are the group number and the number of electrons in the outer shell of an element related?
16) What kind of ions do metals form?
17) Where are non-metals on the periodic table?
18) State three trends as you go down Group 1.
19) State the products of the reaction of sodium and water.
20) How do the boiling points of halogens change as you go down the group from fluorine to astatine?
21) What is the charge of the ions that halogens form when they react with metals?
22) Predict whether iodine is displaced by chlorine in a solution of potassium iodide.
23) What is the trend in boiling point as you go down Group 0?

Formation of Ions

Ions crop up all over the place in chemistry. You're gonna have to be able to explain how they form and predict the charges of simple ions formed by elements in Groups 1, 2, 6 and 7. You'd better get on...

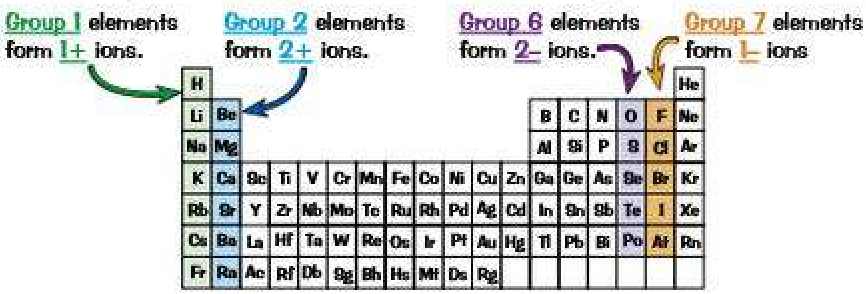
Ions are Made When Electrons are Transferred

1) Ions are charged particles — they can be single atoms (e.g. Cl^-) or groups of atoms (e.g. NO_3^-).
2) When atoms lose or gain electrons to form ions, all they're trying to do is get a full outer shell like a noble gas (also called a "stable electronic structure"). Atoms with full outer shells are very stable.
3) When metals form ions, they lose electrons from their outer shell to form positive ions.
4) When non-metals form ions, they gain electrons into their outer shell to form negative ions.
5) The number of electrons lost or gained is the same as the charge on the ion. E.g. If 2 electrons are lost the charge is 2+. If 3 electrons are gained the charge is 3–.

Remember that the noble gases are in Group 0 of the periodic table.

Groups 1 & 2 and 6 & 7 are the Most Likely to Form Ions

1) The elements that most readily form ions are those in Groups 1, 2, 6 and 7.
2) Group 1 and 2 elements are metals and they lose electrons to form positive ions (cations).
3) Group 6 and 7 elements are non-metals. They gain electrons to form negative ions (anions).
4) You don't have to remember what ions most elements form — nope, you just look at the periodic table.
5) 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.



- A sodium atom (Na) is in Group 1 so it loses 1 electron to form a sodium ion (Na^+) with the same electronic structure as neon: $Na \rightarrow Na^+ + e^-$.
- A magnesium atom (Mg) is in Group 2 so it loses 2 electrons to form a magnesium ion (Mg^{2+}) with the same electronic structure as neon: $Mg \rightarrow Mg^{2+} + 2e^-$.
- A chlorine atom (Cl) is in Group 7 so it gains 1 electron to form a chloride ion (Cl^-) with the same electronic structure as argon: $Cl + e^- \rightarrow Cl^-$.
- An oxygen atom (O) is in Group 6 so it gains 2 electrons to form an oxide ion (O^{2-}) with the same electronic structure as neon: $O + 2e^- \rightarrow O^{2-}$.

Have a look back at page 104 for how to work out electronic structures.

I've got my ion you...

Some elements like to gain electrons, some elements like to lose electrons, but they all want to have a full outer shell. Poor little electron shells, all they want in life is to be full...

Q1 Video Solution

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]

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

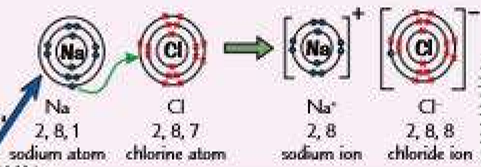
When a metal and a non-metal react together, the metal atom loses electrons to form a positively charged ion and the non-metal gains these electrons to form a negatively charged ion. These oppositely charged ions are strongly attracted to one another by electrostatic forces. This attraction is called an ionic bond.

Dot and Cross Diagrams Show How Ionic Compounds are Formed

Dot and cross diagrams show the arrangement of electrons in an atom or ion. Each electron is represented by a dot or a cross. So these diagrams can show which atom the electrons in an ion originally came from.

Sodium Chloride (NaCl)

The sodium atom gives up its outer electron, becoming an Na^+ ion. The chlorine atom picks up the electron, becoming a Cl^- (chloride) ion.



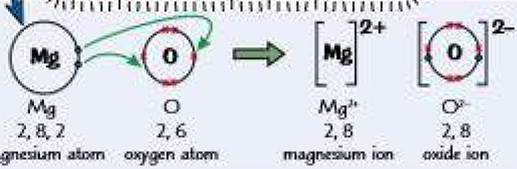
Remember, you can work out how many electrons an atom will gain or lose from its group number.

Here, the dots represent the Na electrons and the crosses represent the Cl electrons (all electrons are really identical, but this is a good way of following their movement).

Here we've only shown the outer shells of electrons on the dot and cross diagram — it makes it much simpler to see what's going on.

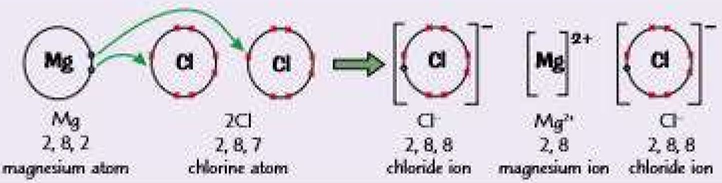
Magnesium Oxide (MgO)

The magnesium atom gives up its two outer electrons, becoming an Mg^{2+} ion. The oxygen atom picks up the electrons, becoming an O^{2-} (oxide) ion.



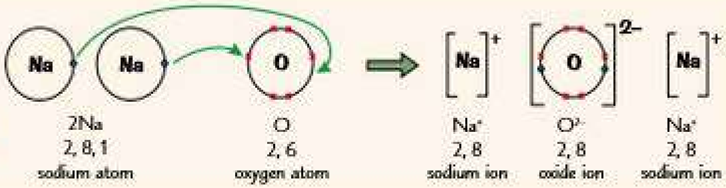
Magnesium Chloride ($MgCl_2$)

The magnesium atom gives up its two outer electrons, becoming an Mg^{2+} ion. The two chlorine atoms pick up one electron each, becoming two Cl^- (chloride) ions.



Sodium Oxide (Na_2O)

Two sodium atoms each give up their single outer electron, becoming two Na^+ ions. The oxygen atom picks up the two electrons, becoming an O^{2-} ion.



Dot and cross diagrams are useful for showing how ionic compounds are formed, but they don't show the structure of the compound, the size of the ions or how they're arranged. But hey-ho — nothing's perfect.

Any old ion, any old ion — any, any, any old ion...

You need to be able to describe how ionic compounds are formed using both words and dot and cross diagrams. It gets easier with practice, so here are some questions to get you started.

Q1 Describe, in terms of electron transfer, how sodium (Na) and chlorine (Cl) react to form sodium chloride (NaCl). [3 marks]

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

I'd take everything on this page with a pinch of salt if I were you... Ho ho ho — I jest, it's important really.

Ionic Compounds Have A Regular Lattice Structure

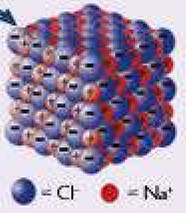
1) Ionic compounds have a structure called a giant ionic lattice.
2) The ions form a closely packed regular lattice arrangement and there are very strong electrostatic forces of attraction between oppositely charged ions, in all directions in the lattice.

The electrostatic attraction between the oppositely charged ions is ionic bonding.

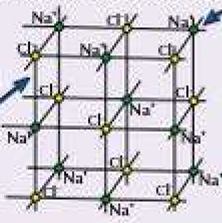
A single crystal of sodium chloride (table salt) is one giant ionic lattice. The Na^+ and Cl^- ions are held together in a regular lattice. The lattice can be represented in different ways...

This model shows the relative sizes of the ions, as well as the regular pattern of an ionic crystal, but it only lets you see the outer layer of the compound.

Make sure you learn what the structure of sodium chloride looks like.



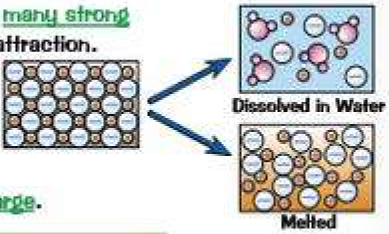
The Na⁺ and Cl⁻ ions alternate.



This is a ball and stick model. It shows the regular pattern of an ionic crystal and shows how all the ions are arranged. It also suggests that the crystal extends beyond what's shown in the diagram. The model isn't to scale though, so the relative sizes of the ions may not be shown. Also, in reality, there aren't gaps between the ions.

Ionic Compounds All Have Similar Properties

1) They all have high melting points and high boiling points due to the many strong bonds between the ions. It takes lots of energy to overcome this attraction.
2) When they're solid, the ions are held in place, so the compounds can't conduct electricity. When ionic compounds melt, the ions are free to move and they'll carry electric charge.
3) Some ionic compounds dissolve in water. The ions separate and are all free to move in the solution, so they'll carry electric charge.

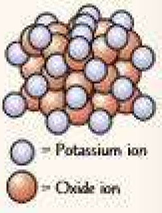


Look at Charges to Find the Formula of an Ionic Compound

1) You might have to work out the empirical formula of an ionic compound from a diagram of the compound.
2) If it's a dot and cross diagram, count up how many atoms there are of each element. Write this down to give you the empirical formula.
3) If you're given a 3D diagram of the ionic lattice, use it to work out what ions are in the ionic compound.
4) You'll then have to 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?

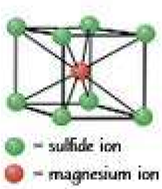
1) Look at the diagram to work out what ions are in the compound. — The compound contains potassium and oxide ions.
2) Work out what charges the ions will form. — Potassium is in Group 1 so forms 1+ ions. Oxygen is in Group 6 so forms 2– ions.
3) Balance the charges so the charge of the empirical formula is zero. — A potassium ion only has a 1+ charge, so you'll need two of them to balance out the 2– charge of an oxide ion. The empirical formula is K_2O.



Giant ionic lattices — all over your chips...

Here's where you can get a little practice working out formulas for 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 113) but others form strong covalent bonds.
This is where atoms share electrons with each other so that they've got full outer shells.

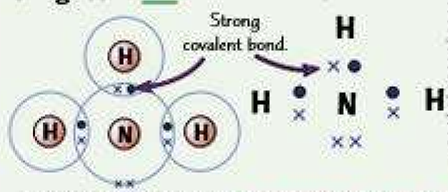
Covalent Bonds — Sharing Electrons

1) When non-metal atoms bond together, they share pairs of electrons to make covalent bonds.
2) The positively charged nuclei of the bonded atoms are attracted to the shared pair of electrons by electrostatic forces, making covalent bonds very strong.
3) Atoms only share electrons in their outer shells (highest energy levels).
4) Each single covalent bond provides one extra shared electron for each atom.
5) Each atom involved generally makes enough covalent bonds to fill up its outer shell. Having a full outer shell gives them the electronic structure of a noble gas, which is very stable.
6) Covalent bonding happens in compounds of non-metals (e.g. H_2O) and in non-metal elements (e.g. Cl_2).

There are Different Ways of Drawing Covalent Bonds

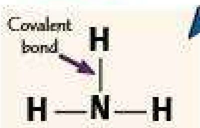
1) You can use dot and cross diagrams to show the bonding in covalent compounds.
2) Electrons drawn in the overlap between the outer orbitals of two atoms are shared between those atoms.
3) Dot and cross diagrams are useful for showing which atoms the electrons in a covalent bond come from, but they don't show the relative sizes of the atoms, or how the atoms are arranged in space.

Nitrogen has five outer electrons...

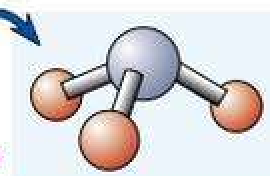


...so it needs to form three covalent bonds to make up the extra three electrons needed.

You don't have to draw the orbitals in these diagrams. The important thing is that you get all the dots and crosses in the right places.



4) The displayed formula of ammonia (NH_3) shows the covalent bonds as single lines between atoms.
5) This is a great way of showing how atoms are connected in large molecules. However, they don't show the 3D structure of the molecule, or which atoms the electrons in the covalent bond have come from.
6) The 3D model of ammonia shows the atoms, the covalent bonds and their arrangement in space next to each other. But 3D models can quickly get confusing for large molecules where there are lots of atoms to include. They don't show where the electrons in the bonds have come from, either.

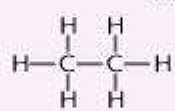


7) You can find the molecular formula of a simple molecular compound from any of these diagram by counting up how many atoms of each element there are.

A molecular formula shows you how many atoms of each element are in a molecule.

EXAMPLE

A diagram of the molecule ethane is shown on the right. Use the diagram to find the molecular formula 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

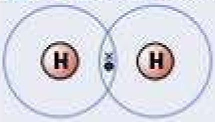
These molecules might be simple, but you've still gotta know about them. I know, the world is a cruel place.

Learn These Examples of Simple Molecular Substances

Simple molecular substances are made up of molecules containing a few atoms joined together by covalent bonds. Here are some common examples that you should know...

Hydrogen, H_2

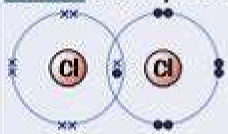
Hydrogen atoms have just one electron. They only need one more to complete the first shell...



...so they often form single covalent bonds, either with other hydrogen atoms or with other elements, to achieve this.

Chlorine, Cl_2

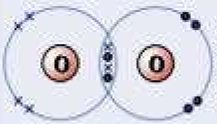
Each chlorine atom needs just one more electron to complete the outer shell...



...so two chlorine atoms can share one pair of electrons and form a single covalent bond.

Oxygen, O_2

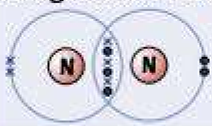
Each oxygen atom needs two more electrons to complete its outer shell...



...so in oxygen gas two oxygen atoms share two pairs of electrons with each other making a double covalent bond.

Nitrogen, N_2

Nitrogen atoms need three more electrons...

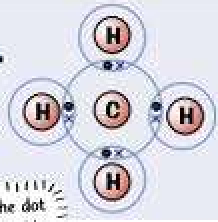


...so two nitrogen atoms share three pairs of electrons to fill their outer shells. This creates a triple bond.

Methane, CH_4

Carbon has four outer electrons, which is half a full shell.

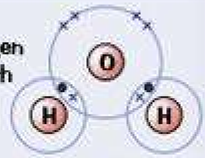
It can form four covalent bonds with hydrogen atoms to fill up its outer shell.



Make sure you can also draw the dot and cross diagram of ammonia, NH_3, which is on the previous page.

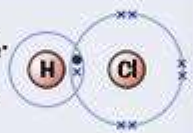
Water, H_2O

In water molecules, the oxygen shares a pair of electrons with two H atoms to form two single covalent bonds.

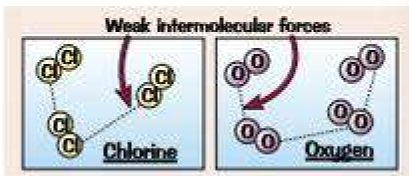


Hydrogen Chloride, HCl

This is very similar to H_2 and Cl_2. Again, both atoms only need one more electron to complete their outer shells.



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. By contrast, the forces of attraction between these molecules are very weak.
3) To melt or boil a simple molecular compound, you only need to break these feeble intermolecular forces and not the covalent bonds. So the melting and boiling points are very low, because the molecules are easily parted from each other.
4) Most molecular substances are gases or liquids at room temperature.
5) As molecules get bigger, the strength of the intermolecular forces increases, so more energy is needed to break them, and the melting and boiling points increase.
6) Molecular compounds don't conduct electricity, simply because they aren't charged, so there are no free electrons or ions.

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]

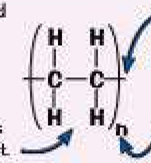
Q2 Explain why nitrogen, N_2, doesn't conduct electricity. [1 mark]

Polymers and Giant Covalent Structures

Wouldn't it be simply marvellous if only simple molecular substances had covalent bonds, and it was now time to put your feet up? Well it's not like that. Polymers and giant covalent substances also have covalent bonds.

Polymers Are Long Chains of Repeating Units

1) In a polymer, lots of small units are linked together to form a long molecule that has repeating sections.
2) All the atoms in a polymer are joined by strong covalent bonds.
3) Instead of drawing out a whole long polymer molecule (which can contain thousands or even millions of atoms), you can draw the shortest repeating section, called the repeating unit, like this:

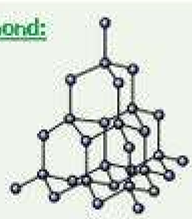


4) To find the molecular formula of a polymer, write down the molecular formula of the repeating unit in brackets, and put an 'n' outside.
5) So for poly(ethene), the molecular formula of the polymer is $(C_2H_4)_n$.
6) The intermolecular forces between polymer molecules are larger than between simple covalent molecules, so more energy is needed to break them. This means most polymers are solid at room temperature.
7) The intermolecular forces are still weaker than ionic or covalent bonds, so they generally have lower boiling points than ionic or giant molecular compounds.

Giant Covalent Structures Are Macromolecules

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 as 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 — not even when molten (except for a few weird exceptions such as graphite, see next page).
4) The main examples that you need to know about are diamond and graphite, which are both made from carbon atoms only, and silicon dioxide (silica).

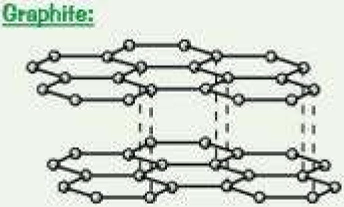
Diamond:



Each carbon atom forms four covalent bonds in a very rigid giant covalent structure.

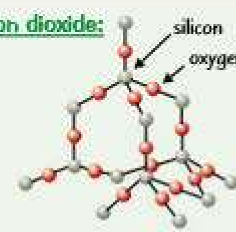
There's more about diamond and graphite, as well as other types of carbon structure, on the next page.

Graphite:



Each carbon atom forms three covalent bonds to create layers of hexagons. Each carbon atom also has one delocalised (free) electron.

Silicon dioxide:



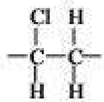
Sometimes called silica, this is what sand is made of. Each grain of sand is one giant structure of silicon and oxygen.

What do you call a vehicle made of sand? Sili-car...

To melt or boil a simple molecular substance or a polymer, only the weakish intermolecular forces need to be broken. To melt or boil a giant covalent substance, you have to break very strong covalent bonds.

Q1 Video Solution

Q1 The repeating unit of poly(chloroethene) is shown on the right. What's the molecular formula of poly(chloroethene)? [1 mark]

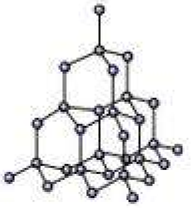


Q2 Predict, with reasoning, whether diamond or poly(ethene) has a higher melting point. [3 marks]

Allotropes of Carbon

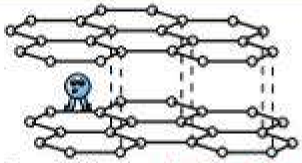
Allotropes are different structural forms of the same element in the same physical state. Carbon's got lots...

Diamond is Very Hard



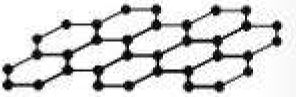
1) Diamond has a giant covalent structure, made up of carbon atoms that each form four covalent bonds. This makes diamond really hard.
2) Those strong covalent bonds take a lot of energy to break and give diamond a very high melting point.
3) It doesn't conduct electricity because it has no free electrons or ions.

Graphite Contains Sheets of Hexagons



1) In graphite, each carbon atom only forms three covalent bonds, creating sheets of carbon atoms arranged in hexagons.
2) There aren't any covalent bonds between the layers — they're only held together weakly, so they're free to move over each other. This makes graphite soft and slippery, so it's ideal as a lubricating material.
3) Graphite's got a high melting point — the covalent bonds in the layers need loads of energy to break.
4) Only three out of each carbon's four outer electrons are used in bonds, so each carbon atom has one electron that's delocalised (free) and can move. So graphite conducts electricity and thermal energy.

Graphene is One Layer of Graphite

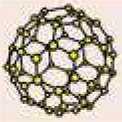


Graphene is a sheet of carbon atoms joined together in hexagons. The sheet is just one atom thick, making it a two-dimensional substance.

The network of covalent bonds makes it very strong. It's also incredibly light, so can be added to composite materials to improve their strength without adding much weight.

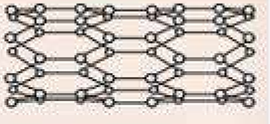
Like graphite, it contains delocalised electrons so can conduct electricity through the whole structure. This means it has the potential to be used in electronics.

Fullerenes Form Spheres and Tubes



Buckminsterfullerene was the first fullerene to be discovered. It's got the molecular formula C_{60} and forms a hollow sphere.

1) Fullerenes are molecules of carbon, shaped like closed tubes or hollow balls.
2) They're mainly made up of carbon atoms arranged in hexagons, but can also contain pentagons (rings of five carbon atoms) or heptagons (rings of seven carbon atoms).
3) Fullerenes can be used to 'cage' other molecules. The fullerene structure forms around another atom or molecule, which is then trapped inside. This could be used to deliver a drug into the body.
4) Fullerenes have a huge surface area, so they could help make great industrial catalysts — individual catalyst molecules could be attached to the fullerenes. Fullerenes also make great lubricants.



Fullerenes can form nanotubes — tiny carbon cylinders.

The ratio between the length and the diameter of nanotubes is very high.

Nanotubes can conduct both electricity and thermal energy (heat).

They also have a high tensile strength (they don't break when they're stretched).

Technology that uses very small particles such as nanotubes is called nanotechnology. Nanotubes can be used in electronics or to strengthen materials without adding much weight, such as in tennis racket frames.

Greetings in the Caribbean — they're 'allo-tropical...

Before you go on, make sure you can explain the properties of all these allotropes of carbon.

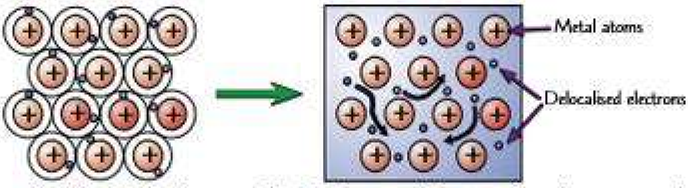
Q1 Give three uses of fullerenes. [3 marks]

Metallic Bonding

Ever wondered what makes metals tick? Well, either way, this is the page for you.

Metallic Bonding Involves Delocalised Electrons

1) Metals also consist of a giant structure.
2) The electrons in the outer shell of the metal atoms are delocalised (free to move around). There are strong forces of electrostatic attraction between the positive metal ions and the shared negative electrons.
3) These forces of attraction hold the atoms together in a regular structure and are known as metallic bonding. Metallic bonding is very strong.



4) Substances that are held together by metallic bonding include metallic elements and alloys (see below).
5) It's the delocalised electrons in the metallic bonds which produce all the properties of metals.

Most Metals are Solid at Room Temperature

The electrostatic forces between the metal atoms and the delocalised sea of electrons are very strong, so need lots of energy to be broken.

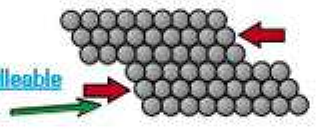
This means that most compounds with metallic bonds have very high melting and boiling points, so they're generally solid at room temperature.

Metals are Good Conductors of Electricity and Heat

The delocalised electrons carry electrical charge and thermal (heat) energy through the whole structure, so metals are good conductors of electricity and heat.

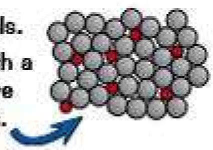
Most Metals are Malleable

The layers of atoms in a metal can slide over each other, making metals malleable — this means that they can be bent or hammered or rolled into flat sheets.



Alloys are Harder Than Pure Metals

1) Pure metals often aren't quite right for certain jobs — they're often too soft when they're pure so are mixed with other metals to make them harder. Most of the metals we use everyday are alloys — a mixture of two or more metals or a metal and another element. Alloys are harder and so more useful than pure metals.
2) Different elements have different sized atoms. So when another element is mixed with a pure metal, the new metal atoms will distort the layers of metal atoms, making it more difficult for them to slide over each other. This makes alloys harder than pure metals.



I saw a metal on the bus once — he was the conductor...

If your knowledge of metals is still feeling a bit delocalised, the questions below will help...

Q1 Copper is a metallic element. Describe and explain what property of copper makes it suitable for using in electrical circuits. [2 marks]

Q2 Suggest why an alloy of copper, rather than pure copper, is used to make hinges for doors. [1 mark]

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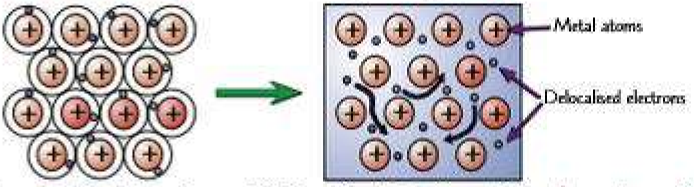

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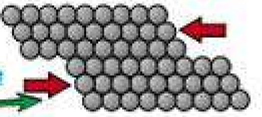

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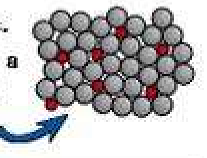

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States of Matter

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

Materials come in three different forms — solid, liquid and gas. These are the three states of matter. Which state something is at a certain temperature (solid, liquid or gas) depends on how strong the forces of attraction are between the particles of the material. How strong the forces are depends on THREE THINGS:

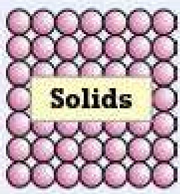
a) the material (the structure of the substance and the type of bonds holding the particles together),

b) the temperature,

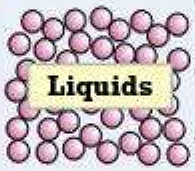
c) the pressure.

The particles could be atoms, ions or molecules.

You can use a model called particle theory to explain how the particles in a material behave in each of the three states of matter by considering each particle as a small, solid, inelastic sphere.



1) In solids, there are strong forces of attraction between particles, which holds them close together in fixed positions to form a very regular lattice arrangement.
2) The particles don't move from their positions, so all solids keep a definite shape and volume, and don't flow like liquids.
3) The particles vibrate about their positions — the hotter the solid becomes, the more they vibrate (causing solids to expand slightly when heated).



1) In liquids, there's a weak force of attraction between the particles. They're randomly arranged and free to move past each other, but they tend to stick closely together.
2) Liquids have a definite volume but don't keep a definite shape, and will flow to fill the bottom of a container.
3) The particles are constantly moving with random motion. The hotter the liquid gets, the faster they move. This causes liquids to expand slightly when heated.

1) In gases, the force of attraction between the particles is very weak — they're free to move and are far apart. The particles in gases travel in straight lines.
2) Gases don't keep a definite shape or volume and will always fill any container.
3) The particles move constantly with random motion. The hotter the gas gets, the faster they move. Gases either expand when heated, or their pressure increases.

Particle theory is a great model for explaining the three states of matter, but it isn't perfect. In reality, the particles aren't solid or inelastic and they aren't spheres — they're atoms, ions or molecules. Also, the model doesn't show the forces between the particles, so there's no way of knowing how strong they are.

State Symbols Tell You the State of a Substance in an Equation

You saw on page 99 how a chemical reaction can be shown using a word equation or symbol equation. Symbol equations can also include state symbols next to each substance — they tell you what physical state the reactants and products are in:

(s) — solid (l) — liquid (g) — gas (aq) — aqueous

'Aqueous' means 'dissolved in water'.

For example, aqueous hydrochloric acid reacts with solid calcium carbonate to form aqueous calcium chloride, liquid water and carbon dioxide gas:

$$2HCl_{(aq)} + CaCO_{3(s)} \rightarrow CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$$

Phew, what a page — particle-ularly gripping stuff...

I think it's pretty clever the way you can explain all the differences between solids, liquids and gases with just a page full of pink snooker balls. Anyway, that's the easy bit. The not-so-easy bit is learning it all.

Q1 Substance A does not have a definite shape or volume. What state is it in? [1 mark]

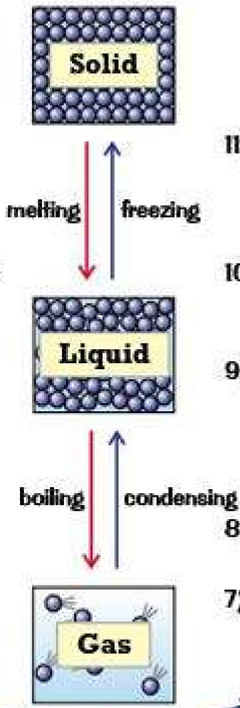
Changing State

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

Physical changes don't change the particles — just their arrangement or their energy.

1) When a solid is heated, its particles gain more energy.
2) This makes the particles vibrate more, which weakens the forces that hold the solid together.
3) At a certain temperature, called the melting point the particles have enough energy to break free from their positions. This is called MELTING and the solid turns into a liquid.
4) When a liquid is heated, again the particles get even more energy.
5) This energy makes the particles move faster, which weakens and breaks the bonds holding the liquid together.
6) At a certain temperature, called the boiling point, the particles have enough energy to break their bonds. This is BOILING (or evaporating). The liquid becomes a gas.



7) As a gas cools, the particles no longer have enough energy to overcome the forces of attraction between them.
8) Bonds form between the particles.
9) At the boiling point, so many bonds have formed between the gas particles that the gas becomes a liquid. This is called CONDENSING.
10) When a liquid cools, the particles have less energy, so move around less.
11) There's not enough energy to overcome the attraction between the particles, so more bonds form between them.
12) At the melting point, so many bonds have formed between the particles that they're held in place. The liquid becomes a solid. This is FREEZING.

So, the amount of energy needed for a substance to change state depends on how strong the forces between particles are. 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

You might be asked to predict what state a substance is in at a certain temperature. If the temperature's below the melting point of substance, it'll be a solid. If it's above the boiling point, it'll be a gas. 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 molecular 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.

So the answer's bromine. It melts at –7 °C and boils at 59 °C. So, it'll be a liquid at room temperature.

Some people are worth melting for...

Make sure you can describe what happens to particles, and the forces between them, as a substance is heated and cooled. Then learn all the technical terms, and 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

Revision Questions for Topic C2

Now you've finished Topic C2, I bet I can guess what you're after next. Some questions to test how much of this topic 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 Quiz for Topic C2 — just scan this QR code!

Topic C2 Quiz

Ions and Ionic Compounds (p.112-114)

1) What type of ion do elements from each of the following groups form?
   a) Group 1
   b) Group 7
2) Describe how an ionic bond forms.
3) Sketch dot and cross diagrams to show the formation of:
   a) sodium chloride b) magnesium oxide c) magnesium chloride d) sodium oxide
4) Describe the structure of a crystal of sodium chloride.
5) List the main properties of ionic compounds.

Covalent Substances (p.115-118)

6) Describe how covalent bonds form.
7) Sketch dot and cross diagrams showing the bonding in a molecule of:
   a) hydrogen b) water c) hydrogen chloride
8) Explain why simple molecular compounds typically have low melting and boiling points.
9) Describe the structure of a polymer.
10) Give three examples of giant covalent substances.
11) Explain why graphite can conduct electricity.
12) Explain how fullerenes could be used to deliver drugs into the body.

Metallic Bonding (p.119)

13) What is metallic bonding?
14) List three properties of metals and explain how metallic structure causes each property.
15) Explain why alloys are harder than pure metals.

States of Matter (p.120-121)

16) Name the three states of matter.
17) What is the state symbol of an aqueous substance?
18) What is the name of the temperature at which a liquid becomes a gas?
19) How does the strength of the forces between particles influence the temperature at which a substance changes state?