Cells

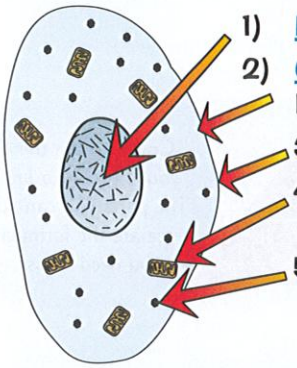
When someone first peered down a microscope at a slice of cork and drew the boxes they saw, little did they know that they'd seen the building blocks of every organism on the planet...

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

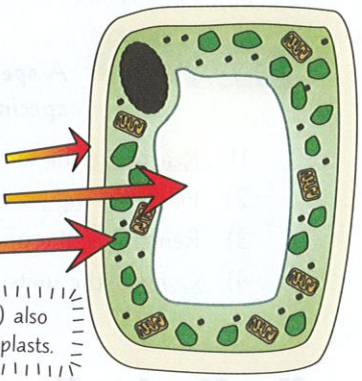
The different parts of a cell are called subcellular structures.
Most animal cells have the following subcellular structures — make sure you know them all:



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.

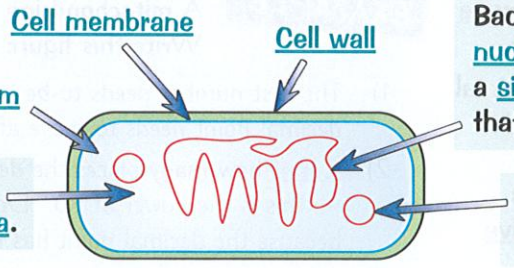


The cells of algae (e.g. seaweed) also have a rigid cell wall and chloroplasts.

Bacterial Cells Are Much Smaller

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

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



Bacterial cells don't have a 'true' nucleus — instead they have a single circular strand of DNA that floats freely in the cytoplasm.

Bacteria don't have chloroplasts or mitochondria.

They may also contain one or more small rings of DNA called plasmids.

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.
2) Fill in the values you know.
3) Remember the units in your answer.
4) Convert the units.

image size = magnification × real size
image size = 100 × 50
= 5000 µm
= 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'. 0.0025
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. 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 An onion cell is viewed under a microscope with × 100 magnification. The image of the cell is 7.5 mm wide. What is the real width of the onion cell? Give your answer in µm. [2 marks]

More on Microscopy

PRACTICAL

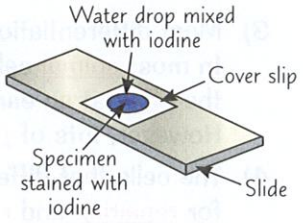
It's all very well knowing what microscopes do — you also have to know how to actually use one.

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:

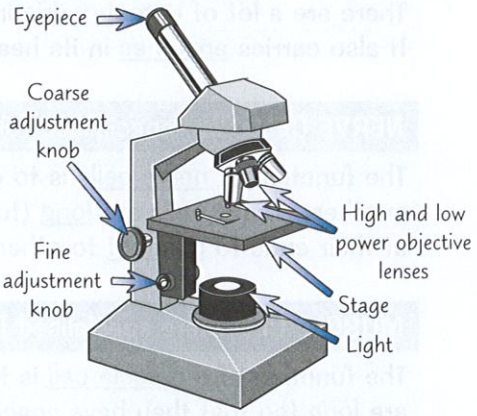
1) Add a drop of water to the middle of a clean slide.
2) Cut up an onion and separate it out into layers. Use tweezers to peel off some epidermal tissue from the bottom of one of the layers.
3) Using the tweezers, place the epidermal tissue into the water on the slide.
4) Add a drop of iodine solution. 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

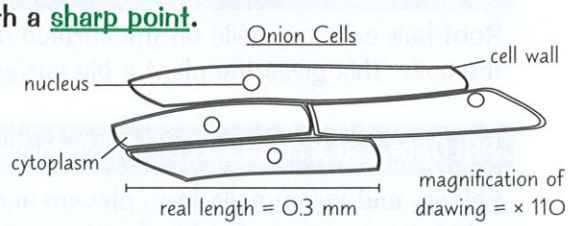
To look at your prepared slides, you need to know how to use a light microscope:

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 = x 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.

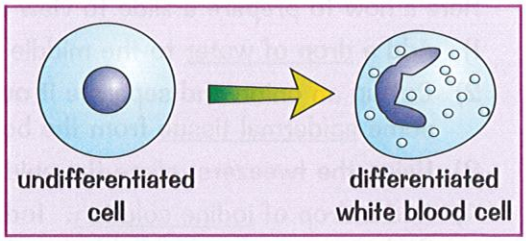
Q1 Why might you add stain to the sample on a microscope slide? [1 mark]

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

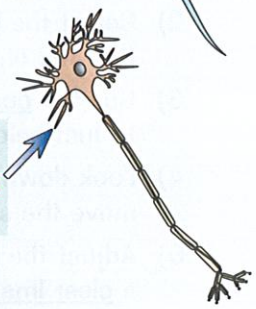
SPERM CELLS are specialised for REPRODUCTION

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.



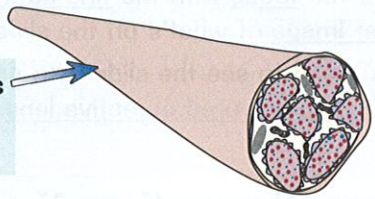
NERVE CELLS are specialised for RAPID SIGNALLING

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.



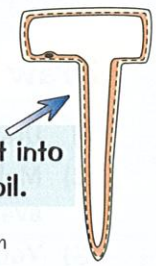
MUSCLE CELLS are specialised for CONTRACTION

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.



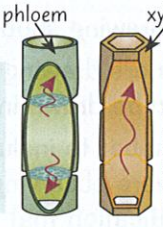
ROOT HAIR CELLS are specialised for absorbing WATER and MINERALS

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.

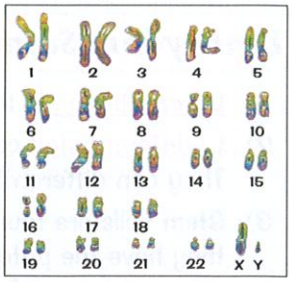
Q1 Plants transport food substances from the leaves to growing parts of the plant through phloem tubes. Give one feature of a phloem cell that makes it specialised for its function. [1 mark]

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...

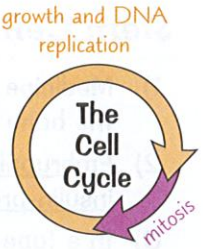
Chromosomes Contain Genetic Information



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.

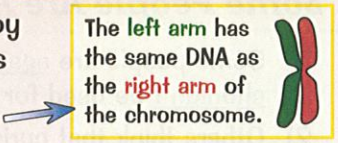
The Cell Cycle Makes New Cells for Growth, Development and Repair

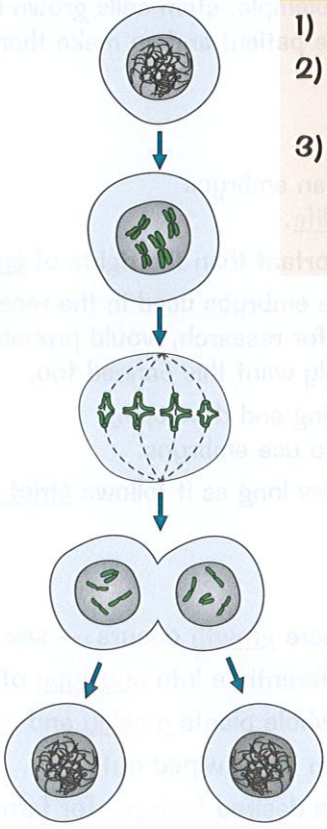
1) Body cells in multicellular organisms divide to produce new cells as part of a series of stages called the cell cycle.
2) The stage of the cell cycle when the cell divides is called mitosis.
3) Multicellular organisms use mitosis to grow or replace cells that have been damaged.
4) The end of the cell 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.





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.
This type of division produces identical cells, but there's another type which doesn't... (see page 70).

Q1 Describe the events of the cell cycle that need to occur before mitosis can begin. [2 marks]

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) One fairly convincing argument in favour of this point of view is 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. But of course, campaigners for the rights of embryos usually want this banned too.
4) These campaigners 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.
3) These stem cells can be used to produce clones (identical copies) of whole plants quickly and cheaply.
4) They can be used to grow more plants of rare species (to prevent them being wiped out).
5) 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 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

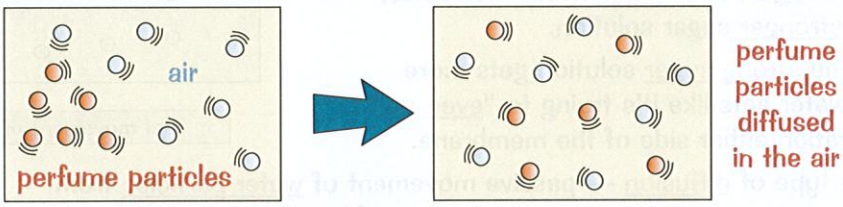
Particles move about randomly, and after a bit they end up evenly spaced. It's not rocket science, is it...

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.

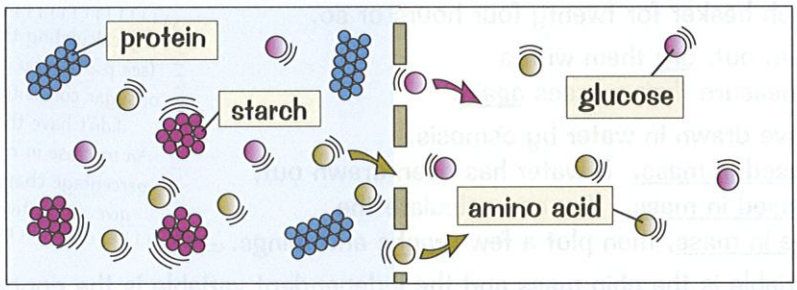
3) Diffusion happens in both solutions and gases — that's because the particles in these substances are free to move about randomly.
4) The simplest type is when different gases diffuse through each other.
This is what's happening when the smell of perfume diffuses through the air in a room:



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]

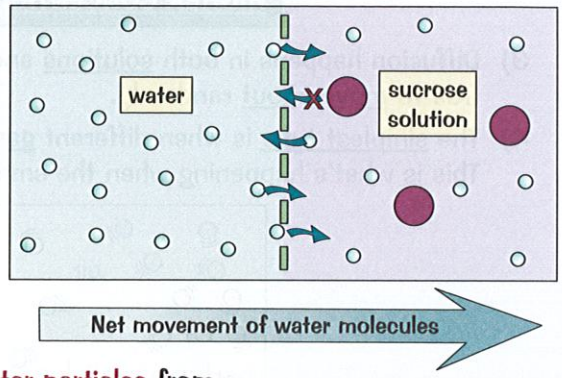
Osmosis

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.



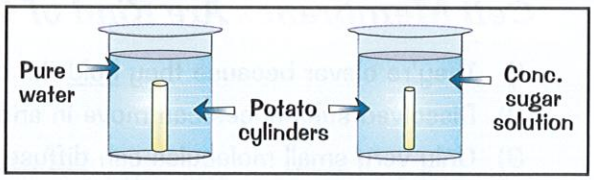
5) Osmosis is a type of diffusion — passive movement of water particles from an area of higher water concentration to an area of lower water concentration.

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/dm^3). Then you can have a few others with concentrations in between (e.g. 0.2 mol/dm^3, 0.4 mol/dm^3, 0.6 mol/dm^3, 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...

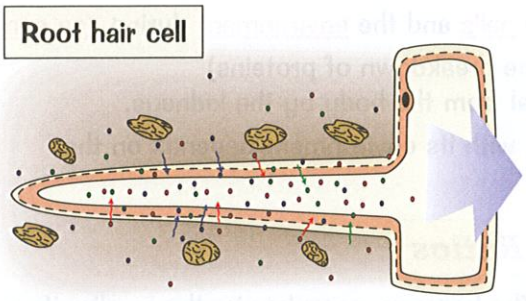
Just remember, osmosis is really just a fancy word for the diffusion of water molecules. It's simple really.

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

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

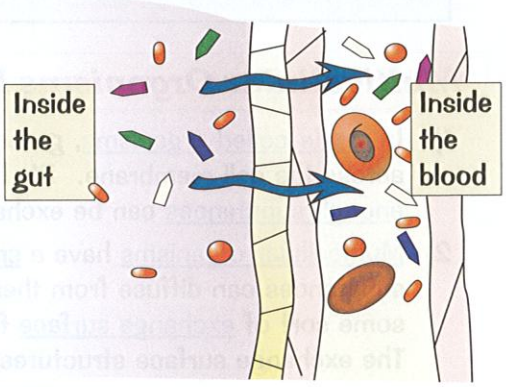
Water is taken into root hair cells by osmosis (see page 18).

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.

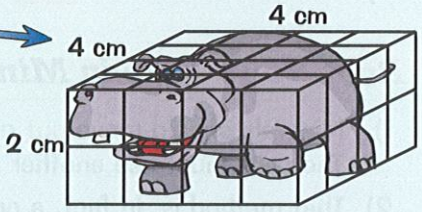
Organisms Exchange Substances with their Environment

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.

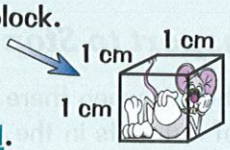


The area of a surface is found by the equation: LENGTH × WIDTH
So the hippo's total surface area is:
(4 × 4) × 2 (top and bottom surfaces of block)
+ (4 × 2) × 4 (four sides of the block)
= 64 cm².

The volume of a block is found by the equation: LENGTH × WIDTH × HEIGHT
So the hippo's volume is 4 × 4 × 2 = 32 cm³.

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 × 1) × 6 = 6 cm².
Its volume is 1 × 1 × 1 = 1 cm³.
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.

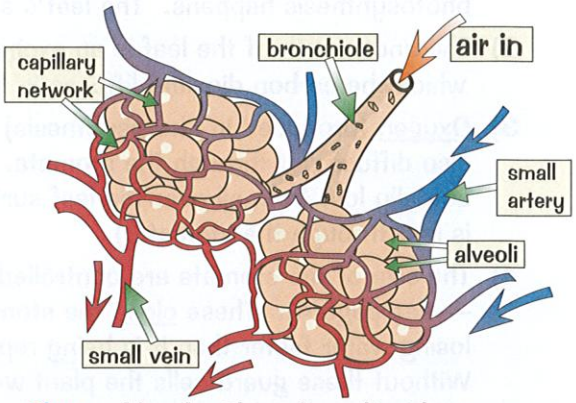
Q1 A bacterial cell can be represented by a 2 μm × 2 μm × 1 μm block.
Calculate the cell's surface area to volume ratio. [3 marks]

Exchanging Substances

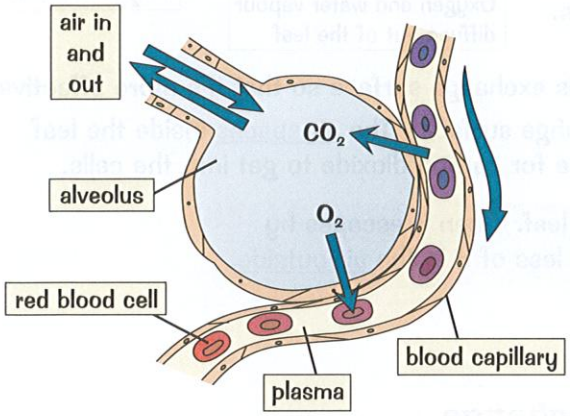
This page is about how two different parts of the human body are adapted so that substances can diffuse through them most effectively. The first bit is about how gases in the lungs get into and out of the blood. The second is about how digested food gets from the gut to the blood.

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.



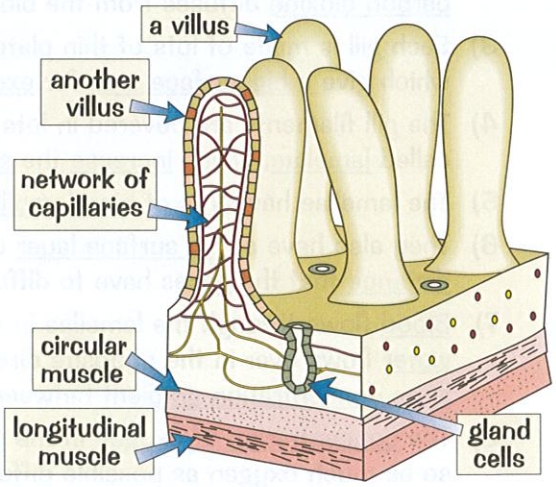
Blue = blood with carbon dioxide.
Red = blood with oxygen.



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]

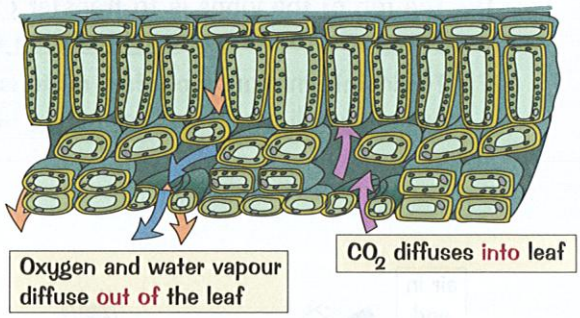
Q2 Describe how the surface area of the small intestine is maximised for absorption. [1 mark]

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.

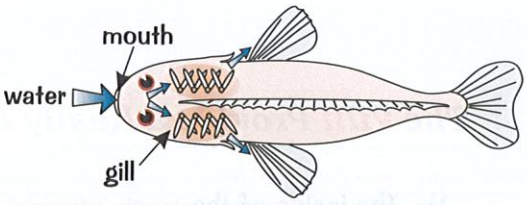


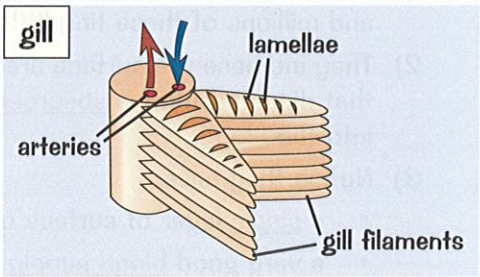
5) The flattened shape of the leaf increases the area of this exchange surface so that it's more effective.
6) The walls of the cells inside the leaf form another exchange surface. The air spaces inside the leaf increase the area of this surface so there's more chance for carbon dioxide to get into the 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 you know what that is, I'll bet. It's obvious... I mean, there's a whole load of questions staring you in the face — chances are, it's got to involve those in some way. And sure enough, it does.

- Try these questions and tick off each one when you get it right.
- When you've done all the questions under a heading and are completely happy with it, tick it off.

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) ☐

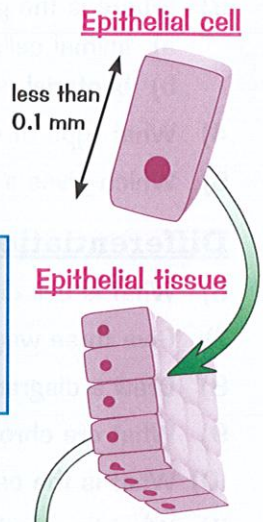
14) What is diffusion? ☐
15) Name three substances that can diffuse through cell membranes, and two that can't. ☐
16) What type of molecules move by osmosis? ☐
17) Give the two main differences between active transport and diffusion. ☐
18) Give three adaptations of exchange surfaces that increase the 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

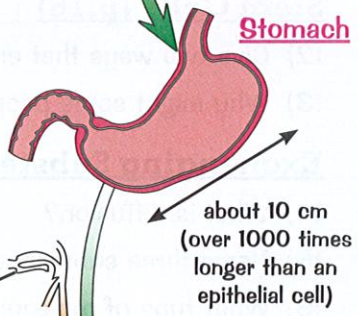
A tissue is a group of similar cells that work together to carry out a particular function. It can include more than one type of cell.

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.

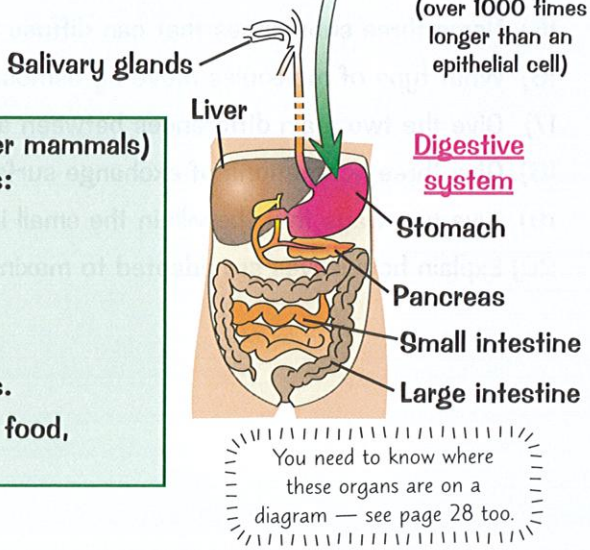


Organs are Organised into Organ Systems

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.

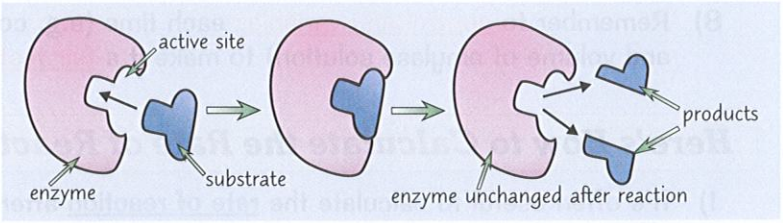
4) Enzymes are all large proteins and all proteins are made up of chains of amino acids. These chains are folded into unique shapes, which enzymes need to do their jobs (see below).

Enzymes Have Special Shapes So They Can Catalyse Reactions

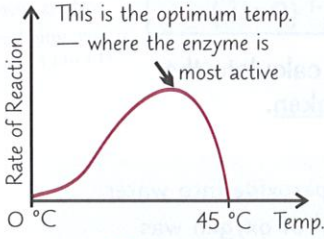
1) Chemical reactions usually involve things either being split apart or joined together.
2) Every enzyme has an active site with a unique shape that fits onto the substance involved in a reaction.
3) Enzymes are really picky — they usually only catalyse one specific reaction.
4) This is because, for 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.

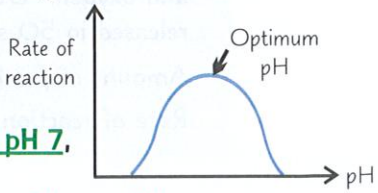
5) This diagram shows the 'lock and key' model of enzyme action. This is simpler than how enzymes actually work. In reality, the active site changes shape a little as the substrate binds to it to get a tighter fit. This is called the 'induced fit' model of enzyme action.



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.

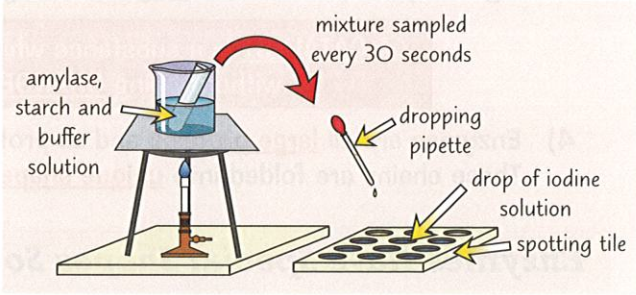
You Can Investigate the Effect of pH on Enzyme Activity

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:

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



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 easily adapt this experiment to investigate how factors other than pH affect the rate of amylase activity. For example, 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 60 seconds, 33 cm^3 of product had been released. Calculate the rate of reaction in $cm^3\ s^{-1}$. [1 mark]

Enzymes and Digestion

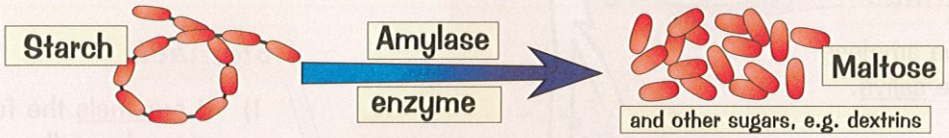
The enzymes used in digestion are produced by cells and then released into the gut to mix with food.

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.

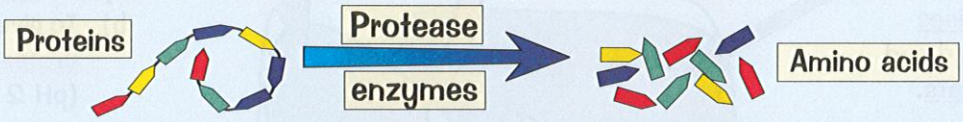


Starch is a carbohydrate.

Amylase is made in three places:

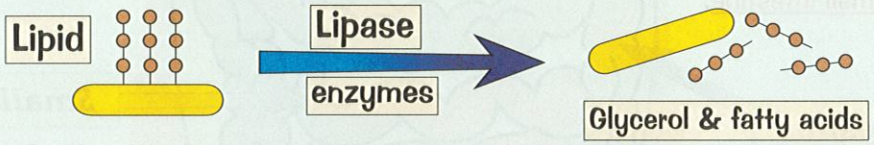
1) The salivary glands 2) The pancreas 3) The small intestine

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.

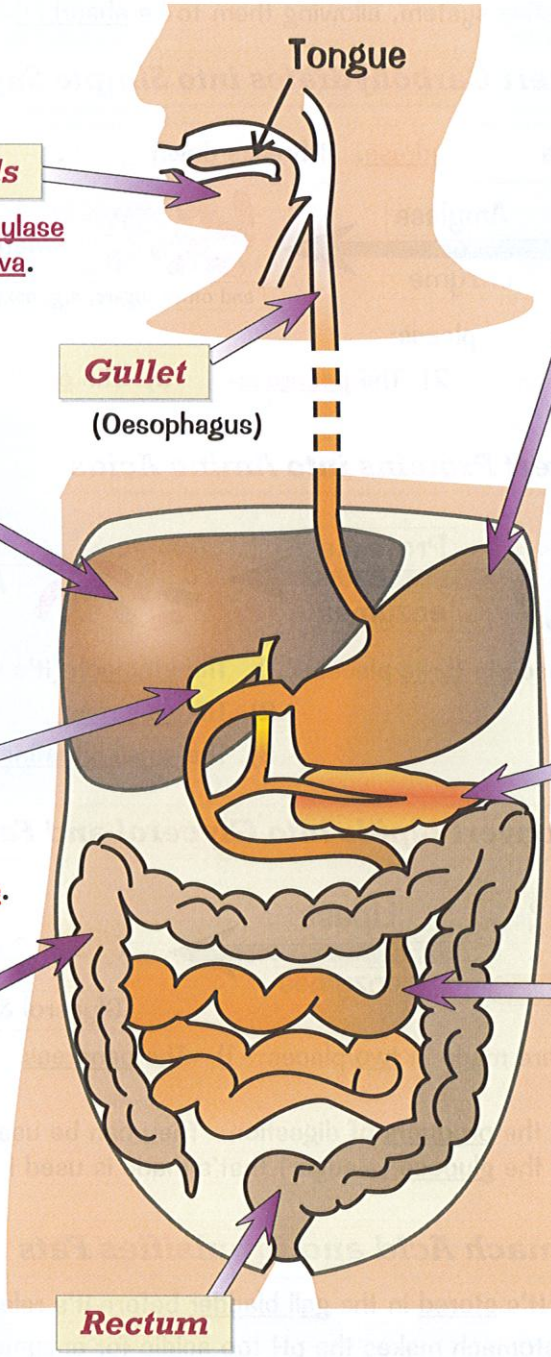
Q1 Bile is a product of the liver. Describe and explain its role in digestion. [4 marks]

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.



Salivary glands

These produce amylase enzyme in the saliva.

Gullet

(Oesophagus)

Liver

Where bile is produced. Bile neutralises stomach acid and emulsifies fats.

Gall bladder

Where bile is stored, before it's released into the small intestine.

Large intestine

Where excess water is absorbed from the food.

Stomach

1) It pummels the food with its muscular walls.
2) It produces the protease enzyme, pepsin.
3) It produces hydrochloric acid for two reasons:
   a) To kill bacteria
   b) To give the right pH for the protease enzyme to work (pH 2 — acidic).

Pancreas

Produces protease, amylase and lipase enzymes. It releases these into the small intestine.

Small intestine

1) Produces protease, amylase and lipase enzymes to complete digestion.
2) This is also where the digested food is absorbed out of the digestive system into the blood.

Rectum

Where the faeces (made up mainly of indigestible food) are stored before they bid you a fond farewell through the anus.

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.

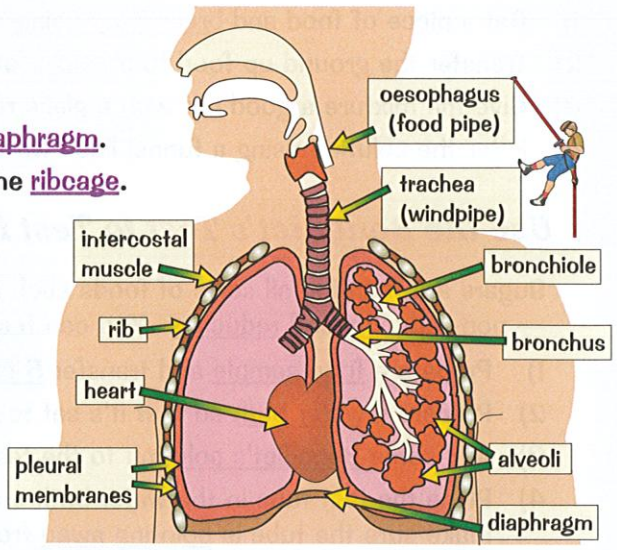
Q1 Name the chemical that you would use to test a sample for the presence of starch. [1 mark]

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.

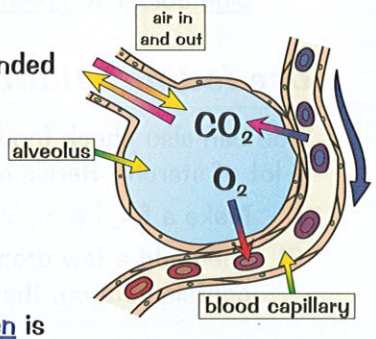
The Lungs Are in the Thorax

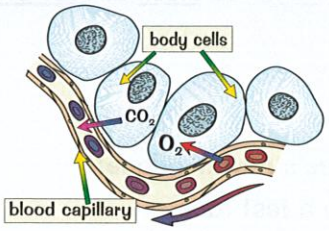
1) The thorax is the top part of your body.
2) It's separated from the lower part of the body by the diaphragm.
3) The lungs are like big pink sponges and are protected by the ribcage. They're surrounded by the pleural membranes.
4) The air that you breathe in goes through the trachea. This splits into 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:

Bob takes 91 breaths in 7 minutes. Calculate his 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...

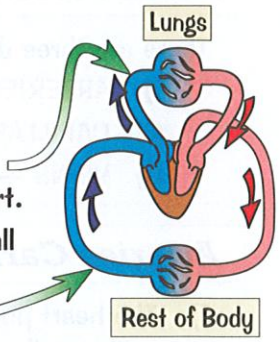
Alveoli are really well adapted for carrying out gas exchange. It could be a wise move to learn all about exactly how they're adapted. You met them back on page 21, so head back there if you need a reminder.

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:

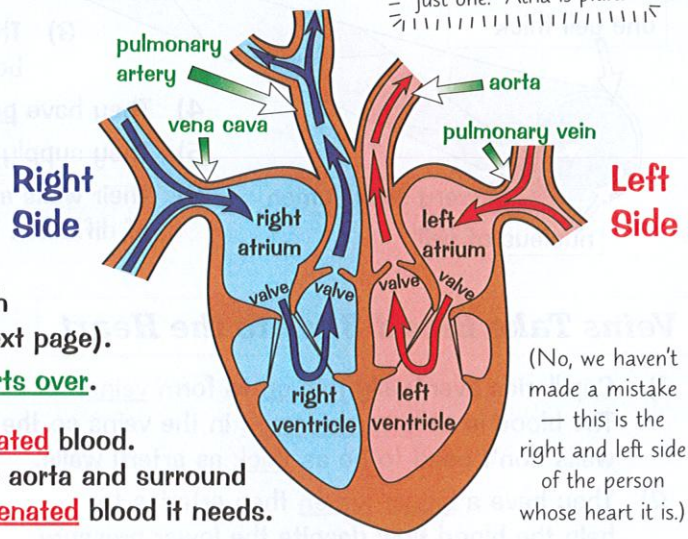
1) In the first one, the right ventricle (see below) pumps deoxygenated blood (blood without oxygen) to the lungs to take in oxygen. The blood then returns to the heart.
2) In the second one, the left ventricle (see below) pumps oxygenated blood around all the other organs of the body. The blood gives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

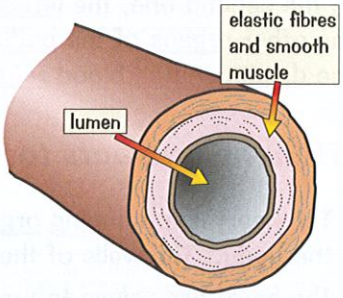


There are three different types of blood vessel:

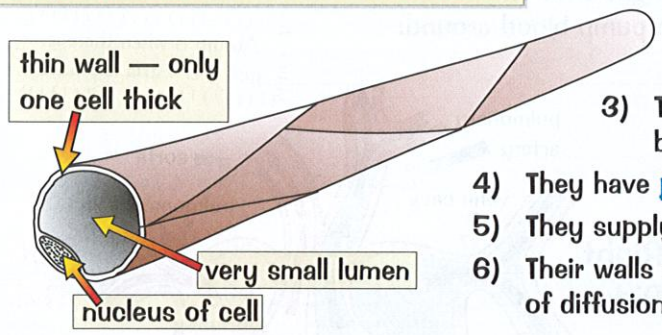
1) ARTERIES — these carry the blood away from the heart.
2) CAPILLARIES — these are involved in the exchange of materials at the tissues.
3) VEINS — these carry the blood to the heart.

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.



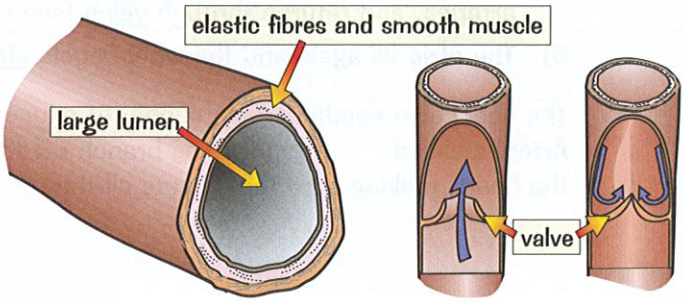
Capillaries are Really Small



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.

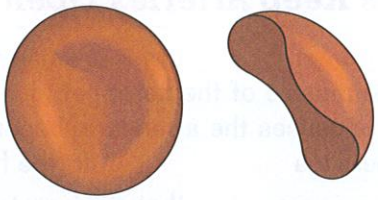
Q1 Describe how veins are adapted to carry blood back to the heart. [2 marks]

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...

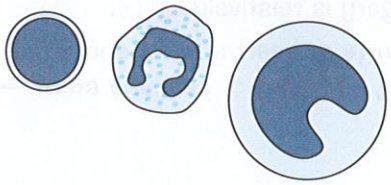
Red Blood Cells Carry Oxygen

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...

When you're ill the doctor often takes a blood sample for analysis. Blood tests can be used to diagnose loads of things — not just disorders of the blood. This is because the blood transports so many chemicals produced by so many organs... and it's easier to take blood than, say, a piece of muscle.

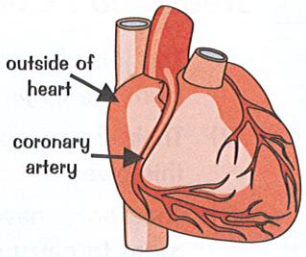
Q1 Describe the purpose of platelets in blood. [1 mark]

Q2 Outline three ways in which red blood cells are adapted to carry oxygen. [3 marks]

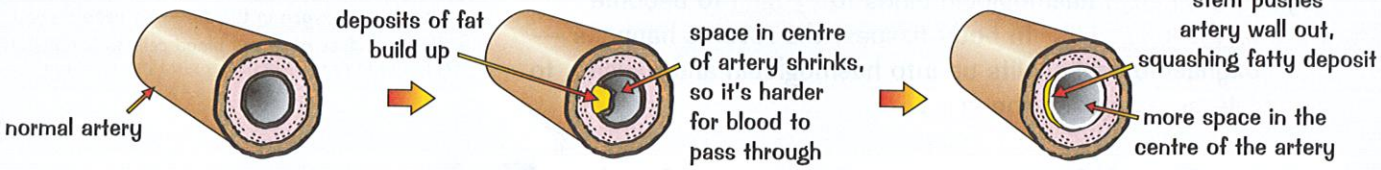
Cardiovascular Disease

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

1) 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.
2) 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.
3) 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.
4) 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 $\frac{2}{3}$ 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.

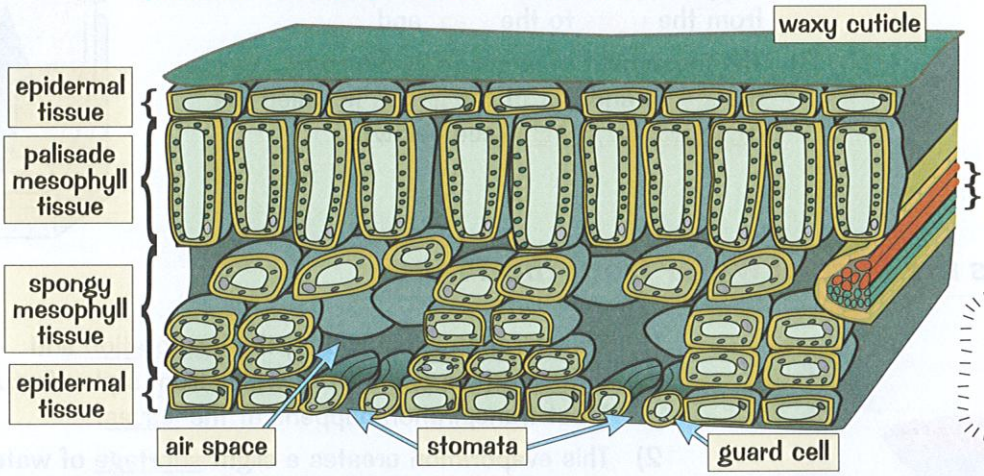
For more on photosynthesis, see page 50.



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.

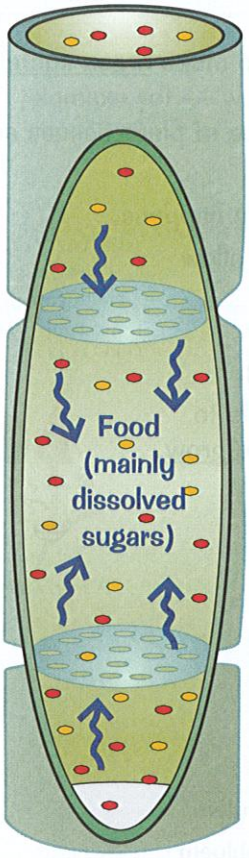
Plant cell organisation — millions of members worldwide...

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

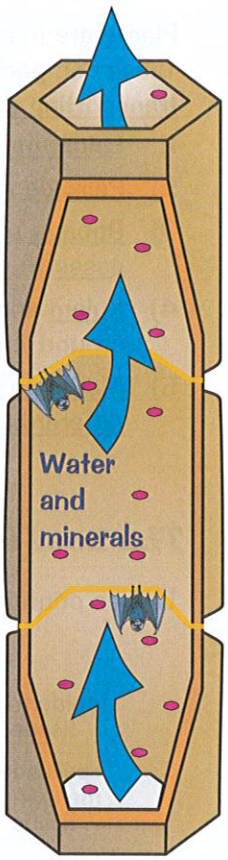
You might be surprised to learn that there aren't tiny trucks that transport substances around plants. Then again, you might not be — either way, you need to learn the stuff on this page...



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.

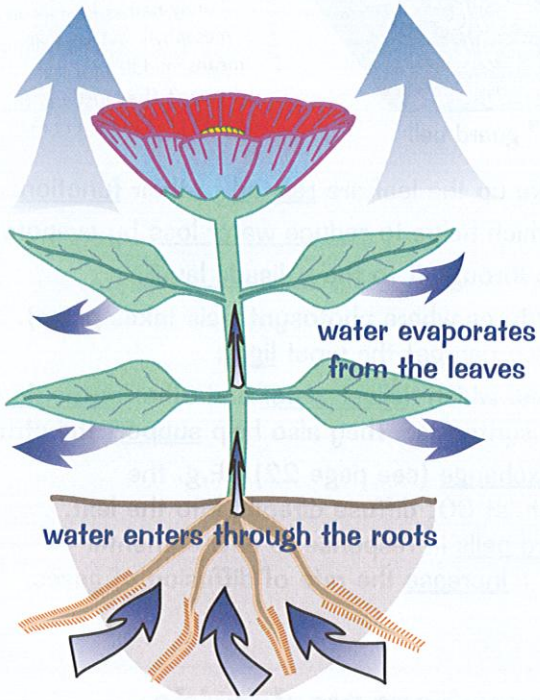
Cell sap is a liquid that's made up of the substances being transported and water.



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.

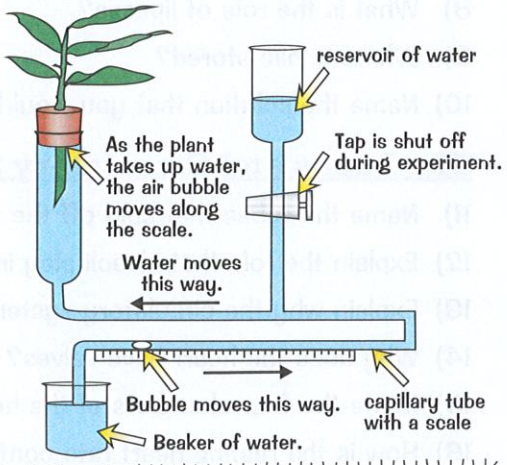
2) TEMPERATURE — the warmer it is, the faster transpiration happens.
When it's warm the water particles have more energy to evaporate and diffuse out of the stomata.

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.

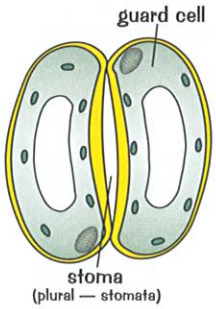
You can estimate the rate of transpiration by measuring the uptake of water by a plant. This is because you can assume that water uptake by the plant is directly related to water loss by the leaves (transpiration).

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 Explain how low light intensity affects the rate of transpiration. [3 marks]

Revision Questions for Topic B2

Well, that's Topic B2 finished. Now it's time for *the* greatest quiz on Earth. Please hold your excitement in.

- Try these questions and tick off each one when you get it right.
- When you've done all the questions under a heading and are completely happy with it, tick it off.

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.

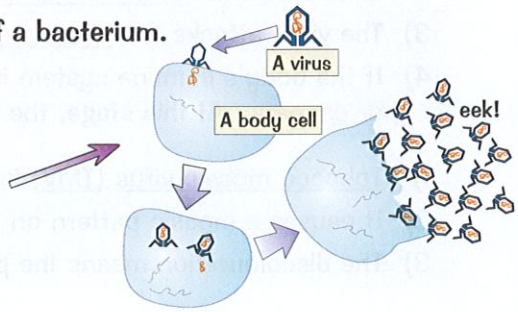


1. Bacteria Are Very Small Living Cells

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 a brain infection called encephalitis.
4) Most people are vaccinated against measles when they're young.

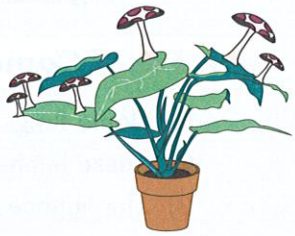
1) HIV is a virus spread by sexual contact, or by exchanging bodily fluids such as blood. This can happen when people share needles when taking drugs.
2) HIV initially causes flu-like symptoms for a few weeks. Usually, the person doesn't then experience any symptoms for several years. During this time, 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 can't 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

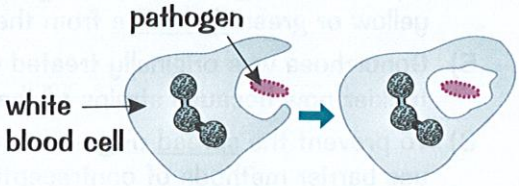
1) The human body has got features that stop a lot of nasties getting inside in the first place.
2) The skin acts as a barrier to pathogens. It also secretes antimicrobial substances which kill pathogens.
3) Hairs and mucus in your nose trap particles that could contain pathogens.
4) The trachea and 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.

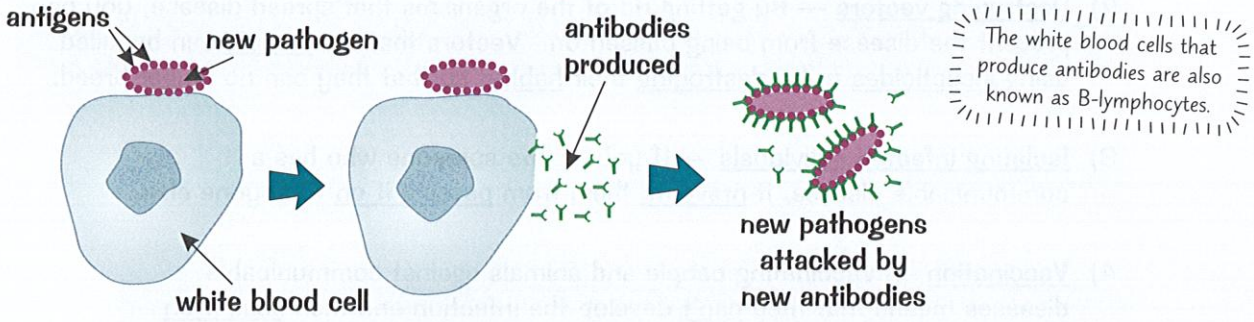
1. Consuming Them

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.



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]

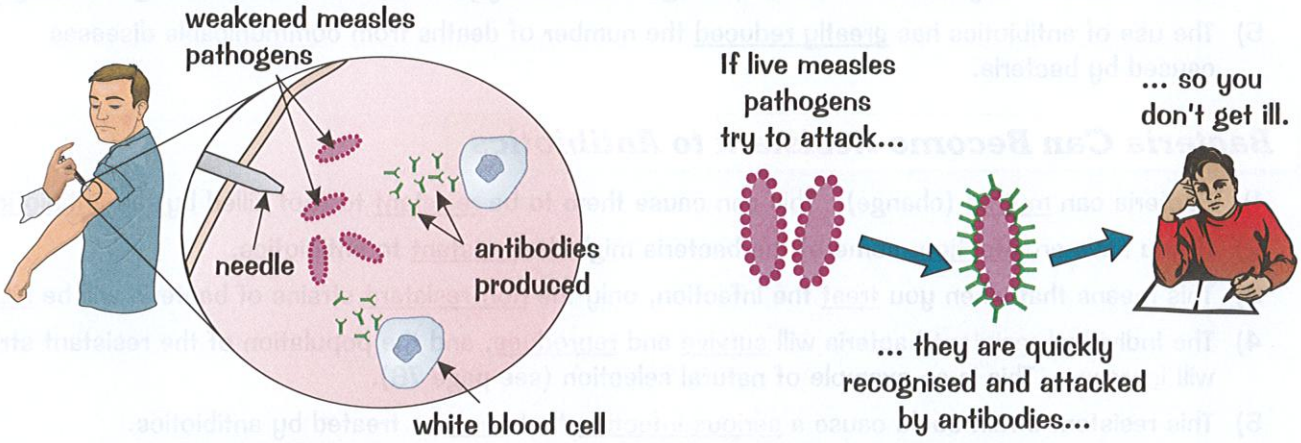
Q2 How are the trachea and the bronchi adapted to defend against the entry of pathogens? [3 marks]

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.

Vaccination — Protects 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 What do vaccinations stimulate white blood cells to produce? [1 mark]

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 Chooooooooo — 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]

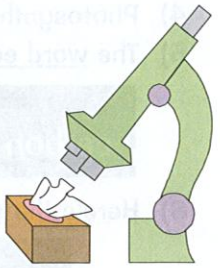
*That's my excuse, you'll have to think of your own.

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) 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]

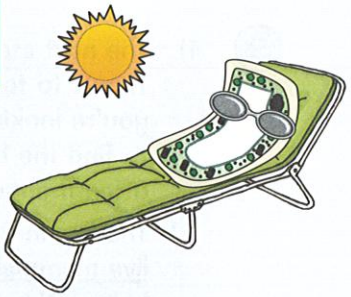
Photosynthesis and Limiting Factors

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]