Zig Zag Education

Science Level 3 | AAQ BTEC | 610/3965/2

Course Companion

for Pearson Level 3 AAQ BTEC National in Applied Science (Extended Certificate)

Unit 1 Principles and Applications of Biology

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Contents

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Teacher's Introduction

Thank you for choosing this Course Companion which has been written specifically for the Level 3 BTEC National Extended Certificate in Applied Science (AAQ) qualification (first teaching from September 2025). The theory notes and recap questions cover the essential knowledge and understanding prescribed in the BTEC Unit 1 specification.

About Unit 1: Principles and Applications of Biology

Unit 1 (60 GLH) is assessed through a 1-hour (50-mark) written examination, which is set and marked by Pearson. There are two opportunities for assessment each year – in January and in May/June.

Unit 1 is a mandatory unit and will be assessed in a variety of styles, such as: multiple-choice questions, calculations, and short-answer and extended-response questions.

Each of the three learning aims (A–C) is given its own section in this resource. The sections are as follows:

A. Structure and function of cells and tissues
B. Structure and function of biological molecules
C. Cellular transport and enzyme activity

Remember!

Always check the exam board website for new information, including changes to the specification and sample assessment material.

Within each section there are student notes covering the specification content and structure. These aim to break down the content into manageable chunks and are further supported with diagrams, images and examples of how to structure answers.

Questions are interspersed throughout the guide to test and develop understanding. Suggested answers are included at the back of this resource.

NB the intention of the suggested answers is to save the teacher time, rather than to offer a comprehensive set of definitive answers. In some cases, there are equally valid alternative answers to those that have been given.

Best wishes and good luck to you and your students!

July 2025

A web page containing all the links listed in this resource is conveniently provided on ZigZag Education's website at ***zzed.uk/12833***

You may find this helpful for accessing the websites rather than typing in each URL.

A: Structure and function of cell

A1 Structure and function of cells and ti

Key points covered

- Ultrastructure and function of organelles in eukaryotic and prokaryotic cells
- Use of light microscope
- Similarities and di
  animal cells
- Calculating magni

A cell is the basic building block of all living organisms. Some organisms are unicellular (made of one cell) while others are multicellular (made of many cells). All cells have some core features in common, such as a cell membrane and cytoplasm, but there is great variation between **prokaryotic** cells (without a true nucleus) and **eukaryotic** cells (with a true nucleus).

prok
nucle

euka
nucle
plant

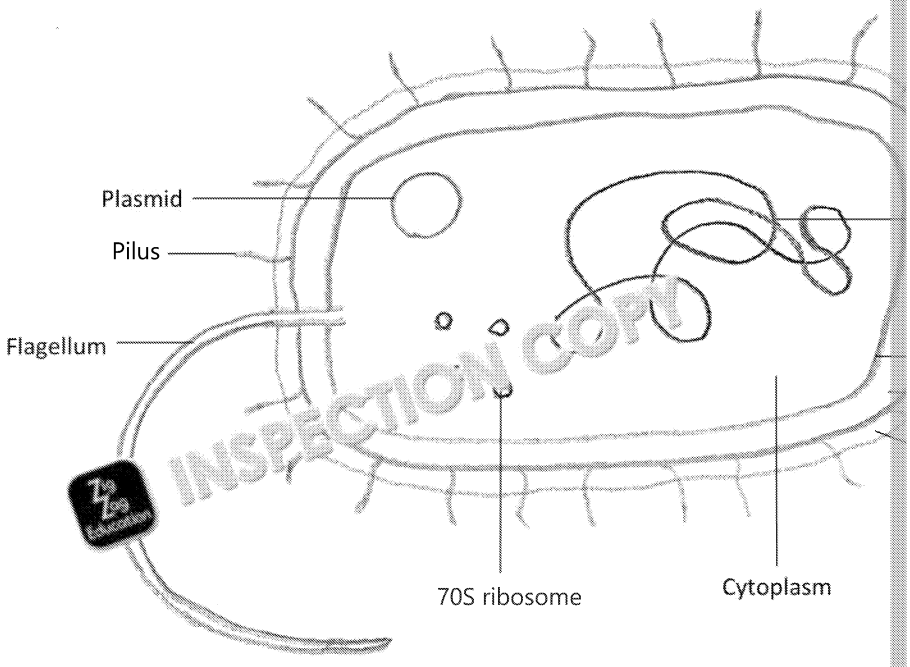
Test your knowledge

- Name the two categories of cells and give an example of each.
- State two features of a cell which are common to all cells.

Prokaryotic and eukaryotic cells

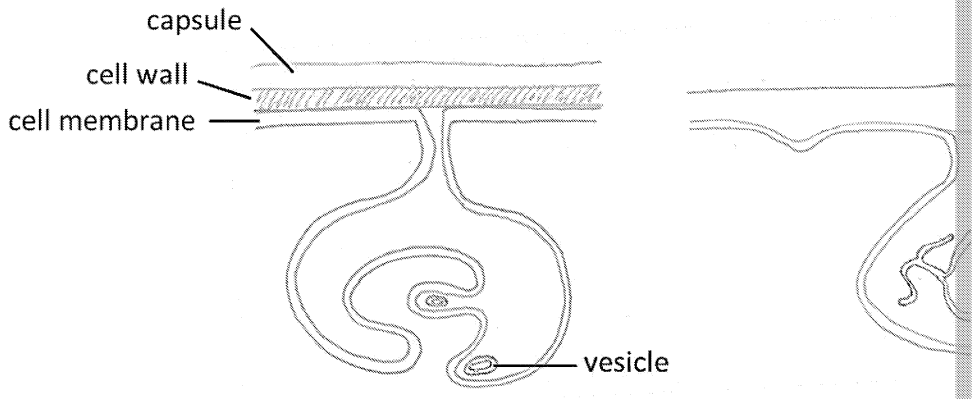
Prokaryotic cells

Prokaryotic cells include all Gram-positive and Gram-negative bacterial cells. These features that allow them to carry out a wide range of life processes that enable the These features are summarised in the table on the following page.



Cell feature	Description
Nucleoid	A region of the cell which stores the genetic inform not distinct from the rest of the cytoplasm.
Plasmid	A small, circular piece of DNA which contains a few chromosome in the nucleoid.
70S ribosomes	Smaller than the 80S ribosomes found in eukaryoti protein synthesis.
Capsule	A jelly or slime-like layer that covers the whole of t bacteria and offers protection.
Cell wall	Made of peptidoglycan and provides structural sup
Plasma membrane	The cell membrane wh[illegible]rms the boundary of t entry of subst[illegible]ce
Cytoplasm	Th[illegible]ponent of the cell, made largely of w [illegible]ic molecules (called cytosol).
M[illegible]es	Invaginations (infolds) in the plasma membrane wh by the chemical fixation process used when prepar and some Gram-negative) for microscopy (see diag
Flagella (s. flagellum)	Whip-like structures used for motility. They do not in eukaryotic cells, and are powered by chemiosmo
Pili (s. pilus)	Short hairs involved in attaching the bacteria to the Sex pili are involved in conjugation reproduction in

Mesosomes are chemical artefacts created when chemicals are applied to the cells under the electron microscope. They are convoluted membrane deformations that vesicles of varying size and shape.

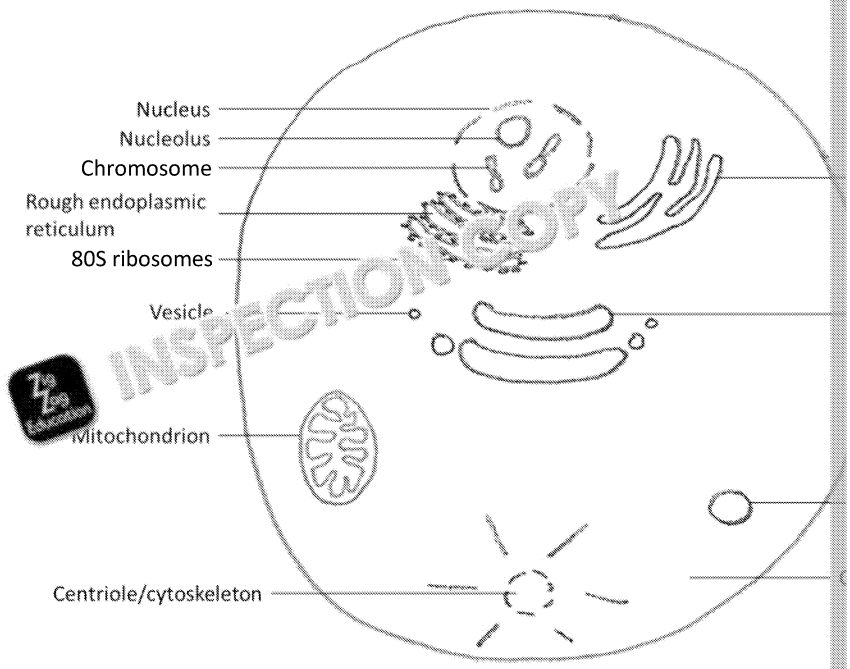


Test your knowledge

- State the function of a flagellum.
- State the difference bet[illegible]n th[illegible]rokaryotic and eukaryotic ribosomes.
- Describe how the [illegible]ry[illegible]ic nucleus and prokaryotic nucleoid differ.

Eukaryotic cells

Eukaryotic cells have complex internal cell structures. The space is divided into a n
compartments which carry out specific functions. This allows specialised and **opti**
specific chemical reactions; it groups linked processes together in the same local s
and it keeps molecules separate from other parts of the cell which might destroy, o
destroyed by, them. The key features of eukaryotic cells are listed in the table belo



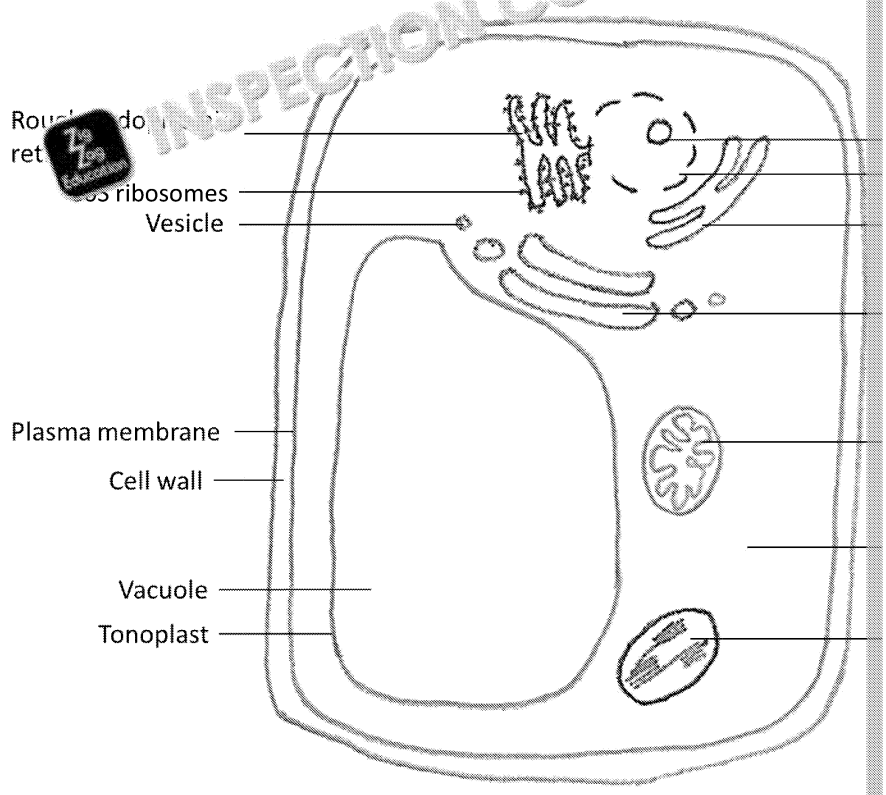
Cell feature	Description
Plasma membrane	The cell membrane which forms the boundary of t entry of substances.
Cytoplasm	The main component of the cell, made largely of w organic molecules (called cytosol).
Nucleus (p. nuclei)	Contains the genetic material for the cell.
Nucleolus	An area within the nucleus which produces riboso
80S ribosomes	Larger than the 70S ribosomes found in prokaryoti protein synthesis.
Rough endoplasmic reticulum	Flattened membranes with ribosomes attached to t protein synthesis.
Golgi apparatus	Modifies proteins after production and packages th
Smooth endoplasmic reticulum	Flattened membranes respo ble for lipid and car and storage.
Vesicles	Small, ro s which store and transport substa
Lysosomes	Small, round sacs which store and transport substa xcretion from the cell.
Mi dri (s. mit drion)	Site of the latter stages of aerobic cellular respirati
Centrioles	Part of the cytoskeleton involved in cell division (m
Cilia	Short hair-like projections from the surface of the cell. They may be sensory, such as in the nasal cavity, or mobile and regularly waft, such as in the trachea to move mucus up to the throat.

Test your knowledge

- State the function of centrioles.
- Describe how the nucleolus, the rough endoplasmic reticulum and the Golgi
- Describe the differences between vesicles and lysosomes.

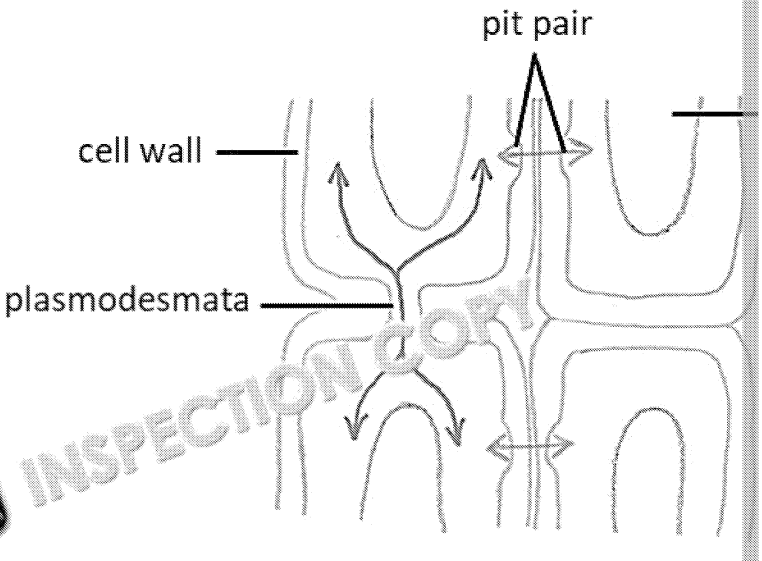
Plant-specific organelles

Plants are eukaryotic cells but because they are **producers** – they use photosynthesis to produce their own food in the form of glucose – they require some additional cell components to be able to carry out these functions. These plant-specific **organelles** are summarised in the table below.



Cell feature	Description
Cell wall	Made of cellulose and provides structural support
Chloroplasts	Contain chlorophyll and are responsible for photosynthesis
Vacuole	These large, permanent features of plant cells store water and enable the plant to maintain turgor: strength created by water pressure
Tonoplast	The membrane that surrounds the vacuole and controls the movement of substances between the cytoplasm and the vacuole.
Amyloplast	Found in roots and storage tissues (e.g. potatoes), specialised for the synthesis and storage of starch.
Plasmodesmata	Channels that connect plant cells to each other to allow communication between cells.
Pits	Thinner sections of the cell wall which form pits or pores for the exchange of water between cells. They are paired

Plasmodesmata and pits both facilitate the movement of water between cells. Plas
directly connect one cell to another, thus also facilitating the movement of other m
chemicals, as shown in the arrows on the diagram below.



Test your knowledge

- Describe how plasmodesmata and pits allow communication between plant
- Describe how the vacuole and the tonoplast are linked.

Similarities and differences between plant cells and animal

Plant cells and animal cells are both eukaryotic: they have a membrane-bound nuc
However, plants are producers and animals are consumers, so they have different
supporting processes that are reflected in the organelles that the cells contain. The
features are found in plant cells and which are found in animal cells.

Organelle	Found in plant cells?	Found
Cell wall	✓	
Large, permanent vacuole	✓	
80S ribosomes	✓	
Mitochondria	✓	
Chloroplasts	✓	
Endoplasmic reticulum	✓	
Amyloplasts	✓	
Plasmodesmata		
Golgi apparatus	✓	

Test you wledge

- Explain why plant cells require a cell wall but animal cells do not, and sugges
instead for this purpose.
- Explain why both animal and plant cells require mitochondria, but only some

Bacteria and antibiotics

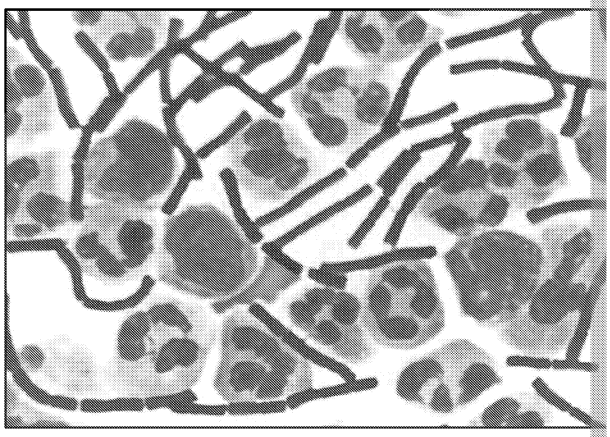
There are a great number of bacteria, many of which are pathogenic to other orga
are extremely small, of less than 10 μm in length, and therefore must be viewed us

To aid in identification, bacterial samples are stained, and the chemical compositio
their cell wall causes differences in the uptake of **stain** which leads to their
classification as either Gram-positive or Gram-negative. The capital G is importan
here as this staining technique was developed by Christian Gram in the 1880s.

The stain used is crystal violet, which is fixed with iodine and then washed off with

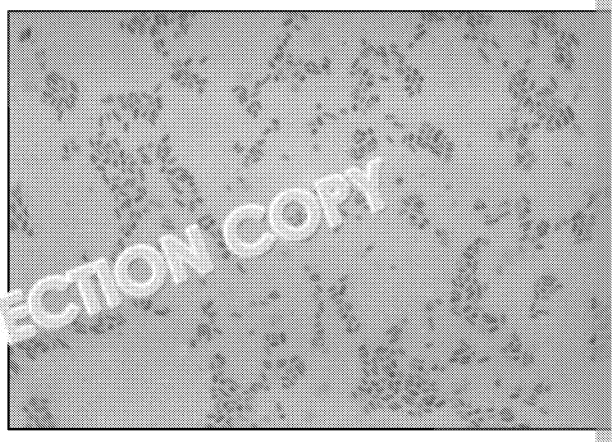
Gram-positive bacteria have almost no lipid within their cell wall, retain the crystal
purple or blue under a light microscope. They are susceptible to the antibiotic pen
formation of the cell wall, and includes the genera *Bacillus*, *Clostridium*, *Staphyloco*

In this photomicrograph, anthrax bacilli show as the dark purple rods.



Gram-negative bacteria have large amounts of lipid in their cell wall, which makes
crystal violet stain washes off. A different stain, called a counterstain, is applied: sa
Gram-negative bacteria appear red. They are resistant to penicillin because of thei
susceptible to the enzyme lysozyme, and include *Salmonella*, *Escherichia* and *Azoto*

In this photomicrograph, *Bacteroides fragilis* ss. *vulgatus* show as pink rods/dots.



Test your knowledge

- Are *Salmonella* bacteria resistant or susceptible to penicillin?
- Will *Clostridium* bacteria stain with crystal violet or safranin dye?

Microscopy

Cells are usually too small to observe without a microscope, and some cell organelles require **electron microscopes** to be viewed at all.

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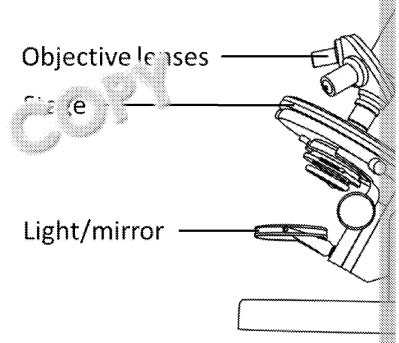
The light microscope

There are several key parts to a light microscope:

- Eyepiece lens – usually has a ×10 magnification and is the part of the microscope that is looked through.
- Objective lenses – usually three lenses of ×4, ×10 and ×40 magnification.
- Stage – where the specimen is placed.
- Focusing wheels – a coarse and fine wheel that allow the focus to be adjusted in larger and smaller increments, respectively.
- Light/mirror – which shines light through the specimen, objective lens and eyepiece.

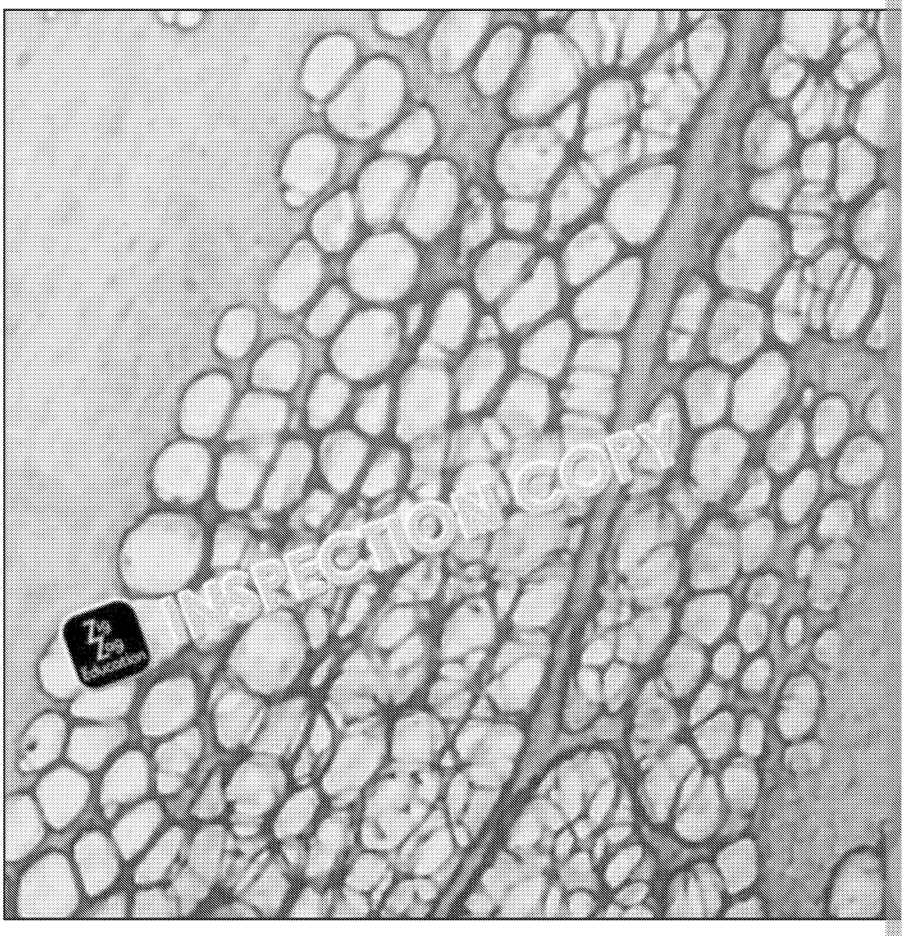


Using a light microscope

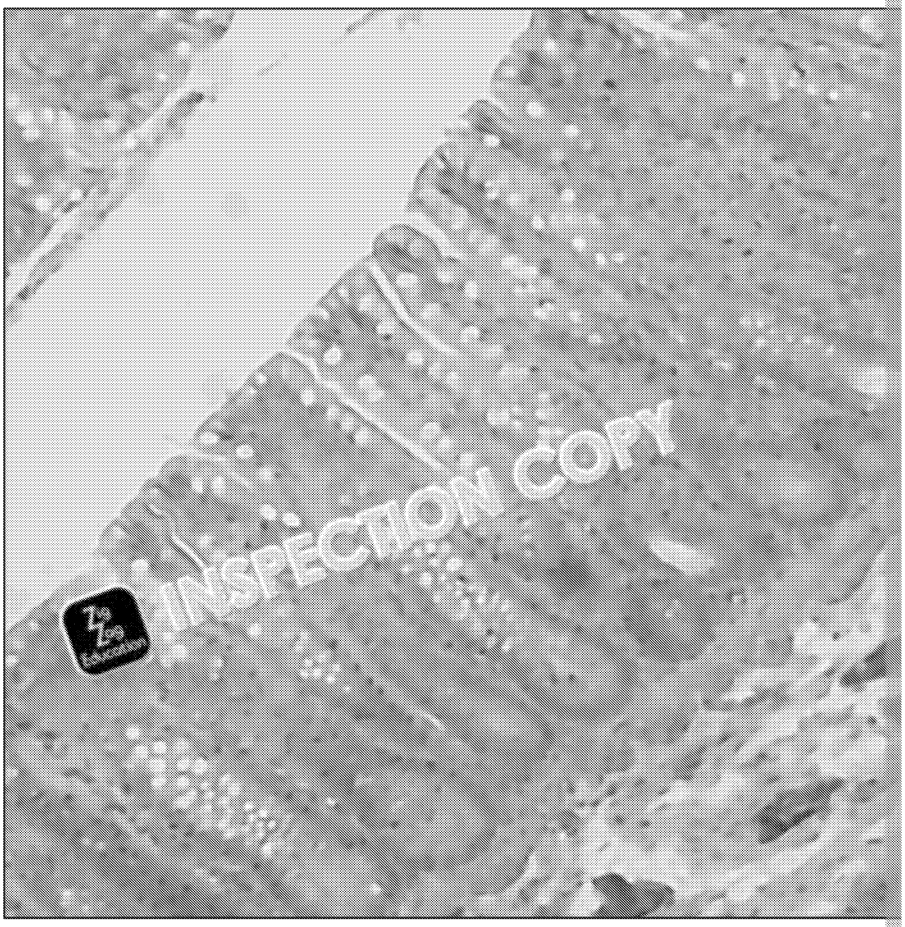
To observe a specimen using a light microscope:

1. Place slide on stage and secure with clips.
2. Set objective lens to lowest power.
3. Position stage at its highest point.
4. Turn on light / direct light onto mirror and check brightness through eyepiece
5. Use coarse then fine focusing wheel to bring specimen into focus.
6. Adjust objective lens to medium then high power and use coarse then fine focusing wheel to bring specimen into focus.

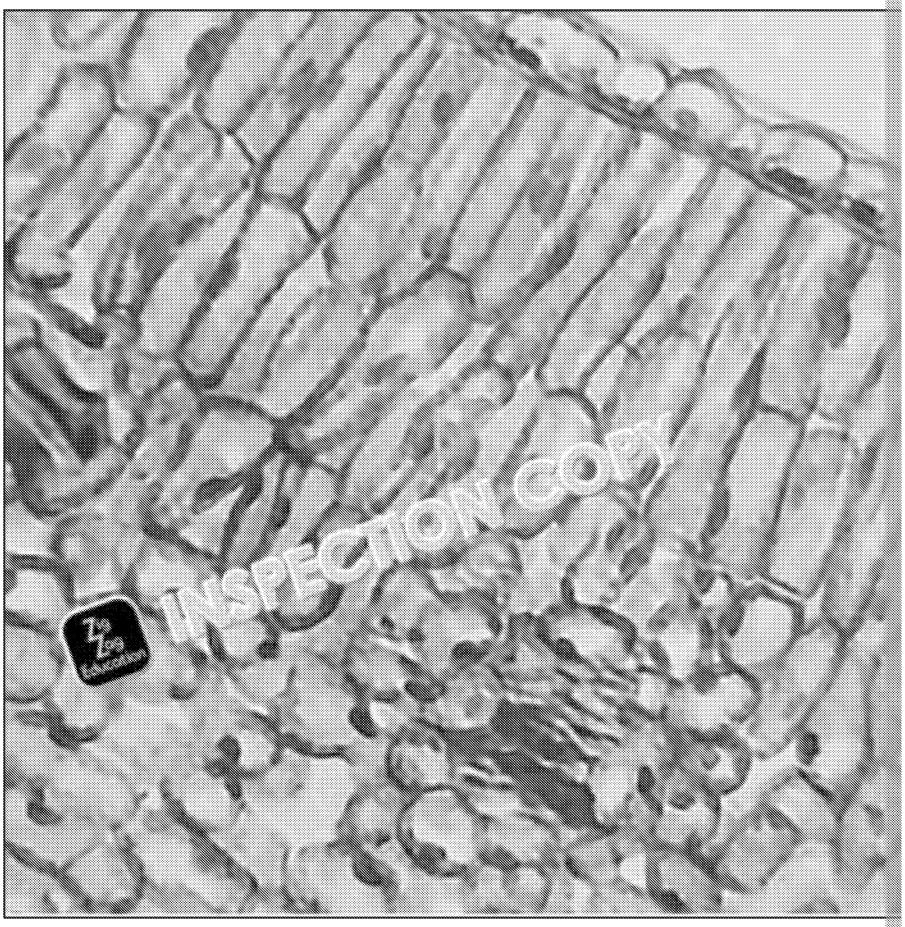
Photomicrographs showing a range of eukaryotic cells:



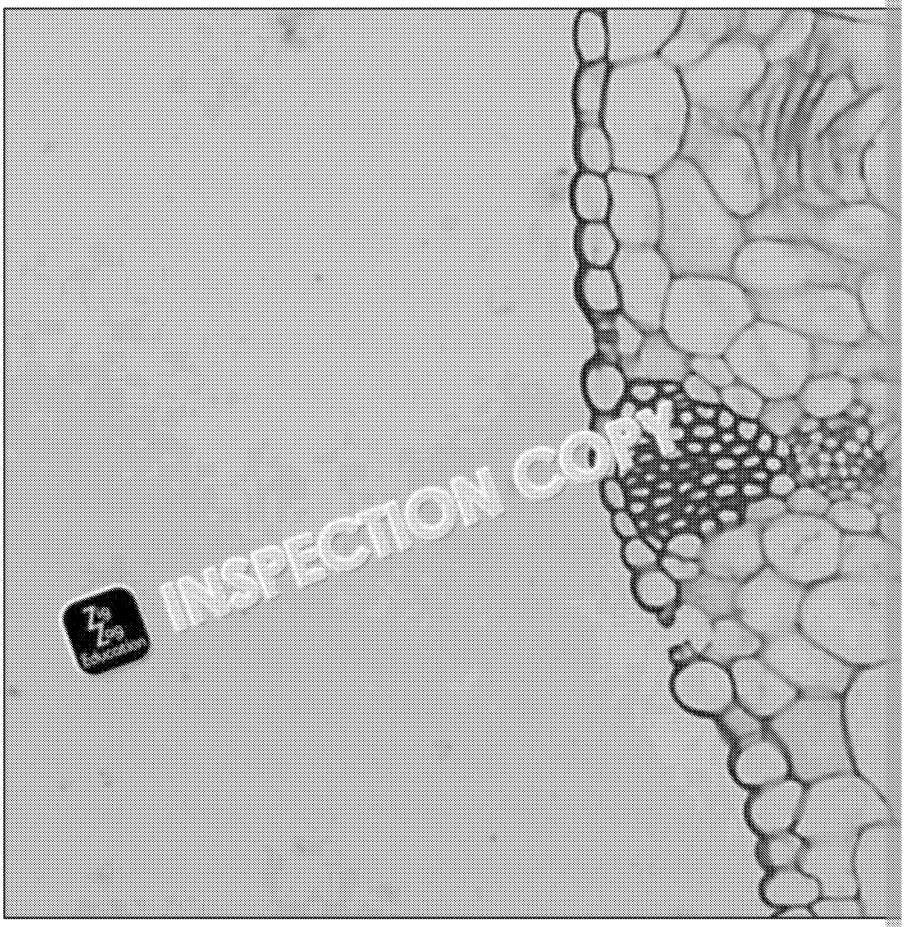
Adipose cells which store fat are visible as a layer of filled cells of di
Fat is stored in these cells as an energy store, ready for when food su



Columnar epithelial cells line the trachea and waft mucus up to the back of the throat.
the cells on the left of the image adjacent to the gap, but to see them in detail, an el



Palisade mesophyll cells in a leaf cross section, which contain many chloroplasts for photosy
also visible across the top of the image, and the spongy mesophyll cells with air spaces ar



A stoma is visible in the lower epithelial tissue layer of a plant leaf, as a gap, surrounded
allow gas exchange. On the right are air spaces between the spongy mesophyll cells
above the stoma indicates vascular tissue, which includes xylem a

Test your knowledge

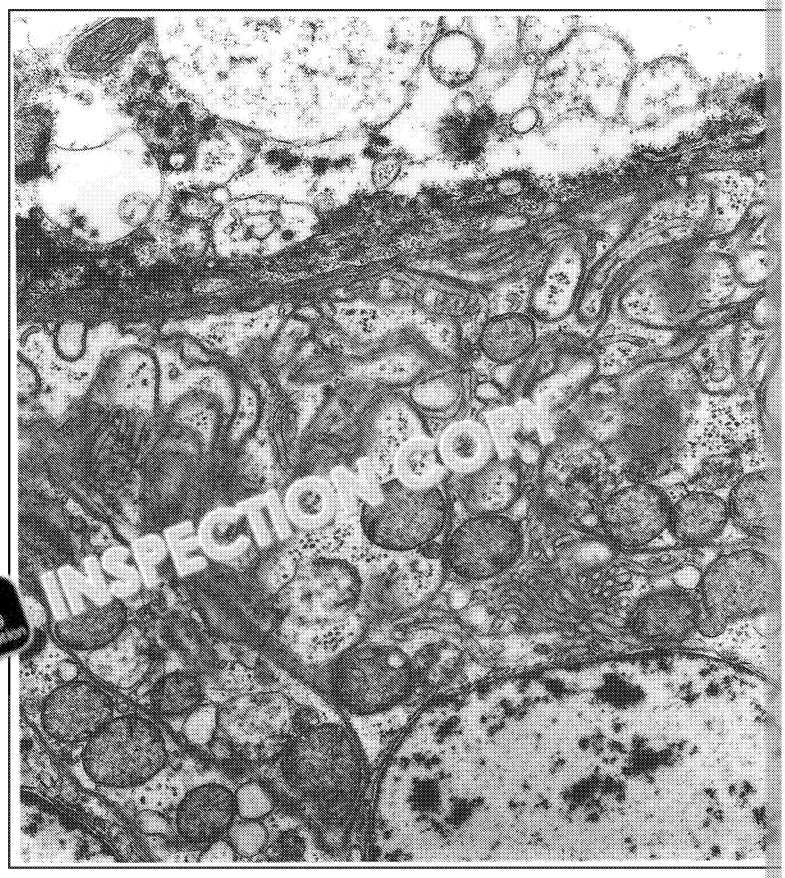
- Which objective lens should be used first when viewing a specimen using a l
- Suggest why sunlight must never be used with a light microscope which has
be better to use instead.

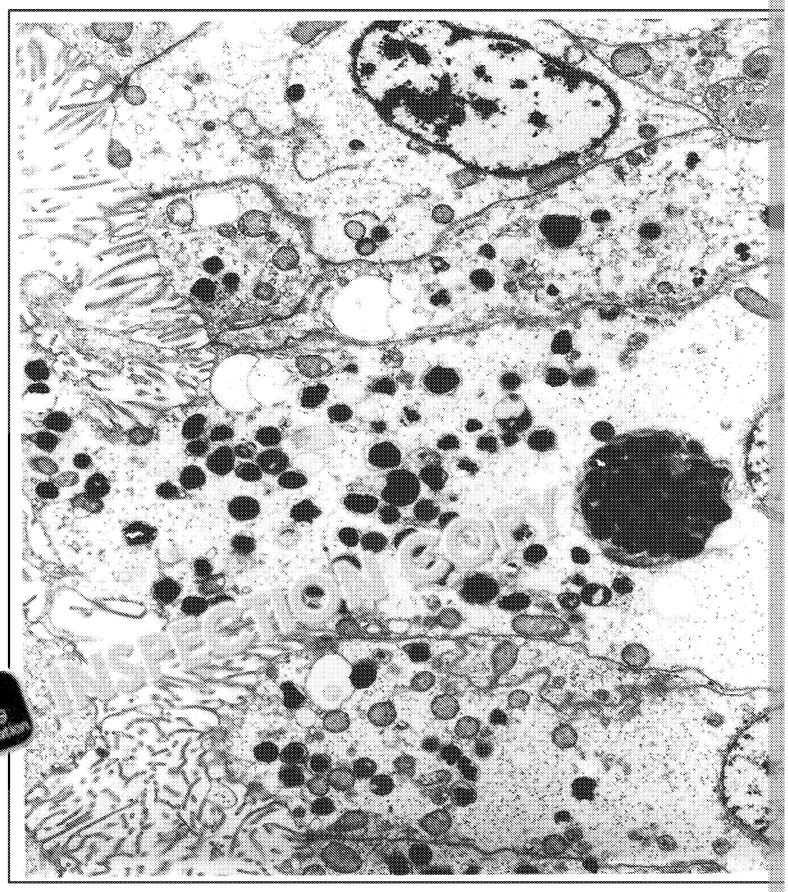
Electron microscopes

Electron microscopes use electrons, rather than visible light, to create an image. As a
resolution and magnification properties than a light microscope: up to ×2000 magni
with a light microscope, compared to up to ×500,000 magnification and 0.2 nm resol

There are two types of electron microscope: transmission and scanning. Transmis
electron beams through the sample, so the sample must be extremely thin to allow
electron microscopes bounce electrons off the surface of a specimen, which has us
This allows bulky specimens to be observed, and their surface detail examined.

An electron microscope is significantly more complex to use than a light microscop
a vacuum inside the electron microscope, so that there are no air particles to interf
This means that the specimen must be dead and carefully prepared to withstand th
beam. Stains, often containing heavy metals, must be used to show up features, an
complex and technical process.





Scanning electron microscopy produces images of 3D specimens, showing the surface det
seen with a transmission electron microscope. Colour in electron micrographs is artificially a

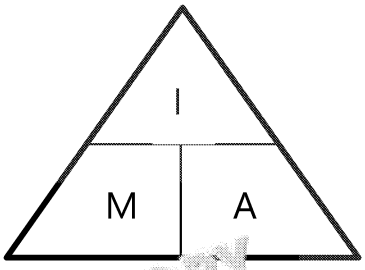
A tardigrade taken using a scanning electron microscop

Calculating magnification

To calculate the magnification of an object when viewed using a microscope, use t

$$magnification = \frac{image\ size}{actual\ size}$$

You may prefer to use the equation triangle:



When calculating magnification, remember t e fo ing:

- Always show all your working
- Include the units in all your workings.
- State wha alu ow first, then rearrange the equation.
- Conve alues so that the units are the same: if using µm for one value, t and ma d converting.
- Plug in the numbers, with their units.
- Solve the equation then check your maths by doing the calculation the other

Worked example

A red blood cell (erythrocyte) measures 7 **µm** but appears to be 2800 µm when viewed in a light microscope. Calculate the magnification of the microscope.

1. State the values that you know:
   - M = ?
   - I = 2800 µm
   - A = 7 µm
2. State the equation:
   - M = I ÷ A
3. Plug in the numbers with their units:
   - M = 2800 µm ÷ 7 µm
4. Solve the equation:
   - M = ×400
5. Check your work:
   - A × M = I
   - 7 µm × 400 = 2800 µm

Test your knowledge

You will need a calculator for these questions. Remember to show your workings

- A macrophage (type of white blood cell) measures 8.4 mm down a light mic with a magnification of ×400. Calculate the actual size of the cell, in microm
- An *amoeba* measures 2.4 µm and is being viewed at medium power with a magnification of ×100. Calculate the apparent size of the amoeba in microm

Recap questions: Structure and function of cells and tissues

1 *Salmonella* are an example of bacteria which have a plasma membrane, a cel Describe the functions of these three cell parts, and suggest why all three a of the bacteria. (4 marks)

2 Describe how plant strength and structure are maintained with cell feature

3 *Clostridium botulinum* bacteria produce the botulinum nerve toxin. How mi be identified in the lab? (4 marks)

4 Before focusing a specimen using a light microscope, the stage with the spe highest point without touching the objective lens. Explain why. (2 marks)

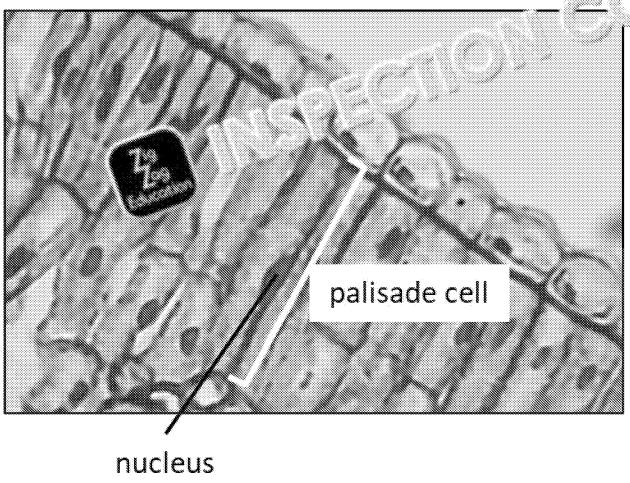
5 A specimen of Ebola virus appeared to be 143.56 mm under an electron mi of ×148,000. Calculate the actual size of this virus in micrometres. (4 mar

A2 Structure and function of specialised multicellular organisms

Key points covered

- Structure and function of plant cells and tissues, including palisade mesophyll and phloem tissue
- Structure and function of animal cells, including sperm and egg, erythrocytes, leuco

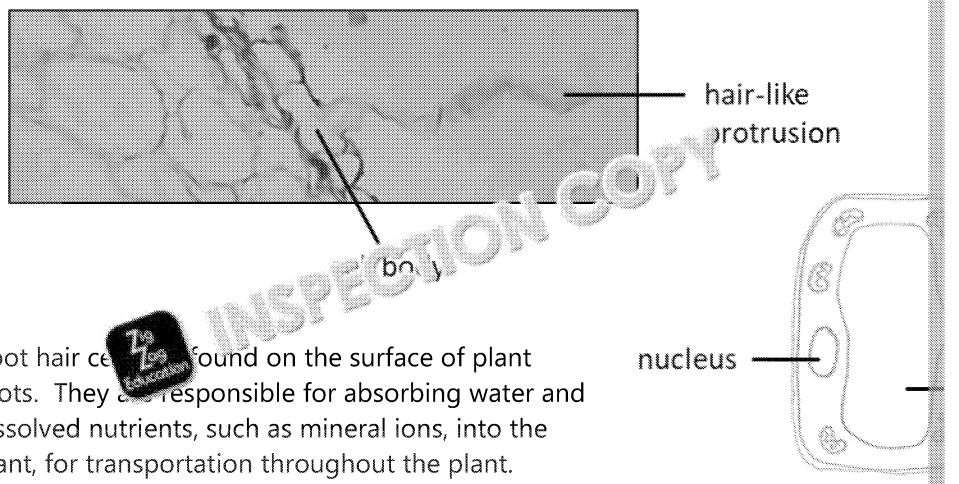
Palisade mesophyll cell



Palisade mesophyll cells are responsible for most of the photosynthesis that takes
Palisade mesophyll cells appear in the top layers of leaves. Their specialised featu

- tall, columnar shape, packed tightly together to form a continuous layer for m
- many chloroplasts for maximum photosynthesis;
- chloroplasts that can move through the cytoplasm to position themselves for
- thin cell walls for rapid gas exchange, especially carbon dioxide entering;
- large vacuole to maintain turgid pressure and ensure the optimal shape of the

Root hair cell

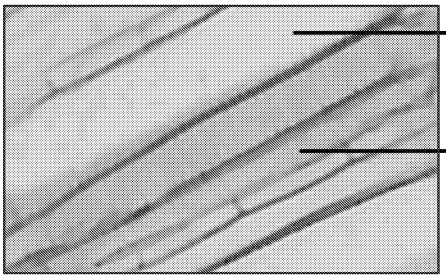


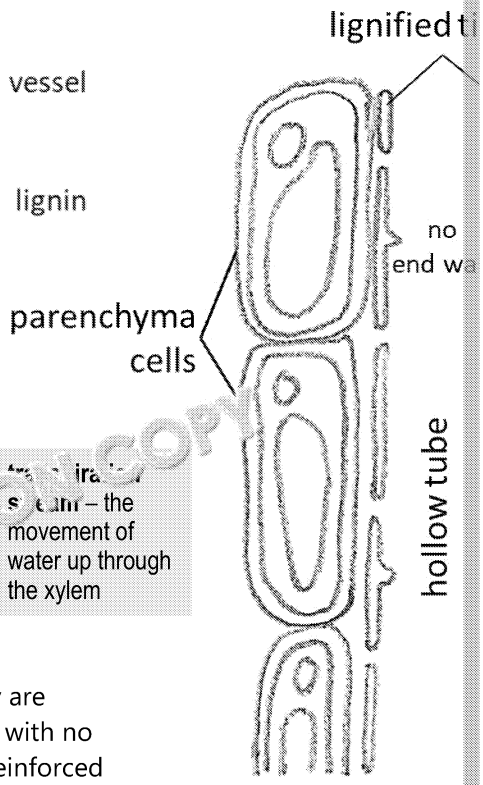
Root hair ce found on the surface of plant roots. They a esponsible for absorbing water and dissolved nutrients, such as mineral ions, into the plant, for transportation throughout the plant.

Root hair cells have two key specialised features:

- the hair-like protrusion which significantly increases the surface area of the ce for water and nutrient absorption;
- a significant number of mitochondria, which provide energy for active transpo including nitrates and magnesium.

Xylem tissue





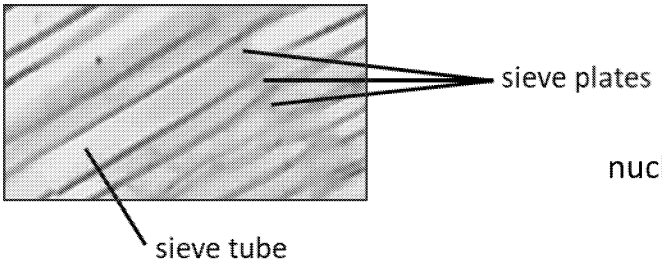
Xylem vessels transport water up the plant from roots, through shoots to the leaves, forming the **transpiration stream**. This is essential for replacing water and dissolved mineral ions through the

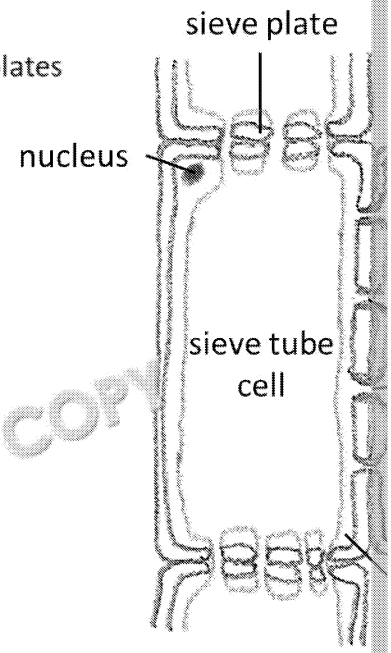
Transpiration stream – the movement of water up through the xylem

Xylem vessels are highly specialised. They are formed from dead cells joined end to end with no end plates or cytoplasm. Their walls are reinforced with lignin – a strong carbohydrate – which is impervious to water. These features mean that:

- water can only leave through structured pits in the vessel walls, so water reach
- there are no obstructions through the vessel to slow down the movement of w
- the vessel is strong and stays open even when water pressure is low.

Phloem tissue





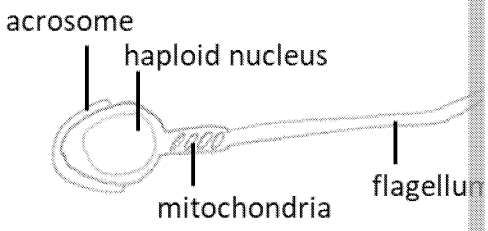
Phloem tissue is responsible for moving sucrose and other dissolved nutrients, including amino acids, from where they are made to where they are needed. Phloem tissue is made of living sieve tube cells connected end to end. The end plates have holes in them called sieve plates, and these allow the movement of substances from one cell to another. Adjacent to the sieve tube cells are companion cells which facilitate the movement of substances into or out of the vessel.

The sieve tube cells have a large, wide vacuole through which the substances move but do retain their nucleus, pushed up against the cell wall to maximise the space a

The companion cells have large quantities of mitochondria which provide energy i This is required for active transport by membrane-bound carrier proteins which are the substances from the source cells into the companion cell, then into the sieve tu

Sperm cell

Sperm cells carry the genetic material from the male and fuse with the female egg during fertilisation to start the creation of a new organism. As a **gamete**, they have 50 % of the DNA that a normal body cell contains: they are **haploid**.

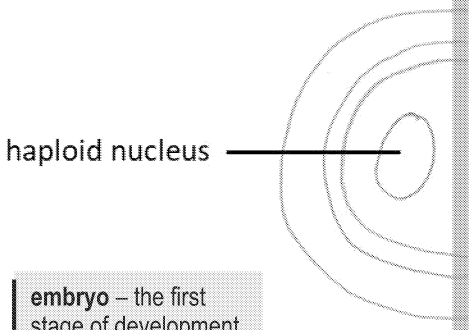


They also have a number of other specialised features:

- a flagellum which provides a whip-like tail to propel the sperm through its environment;
- many mitochondria which provide ATP to fue' ... ment;
- an acrosome on the head of the cell ... contains enzymes capable of diges... enabling fertilisation.

Egg ce...

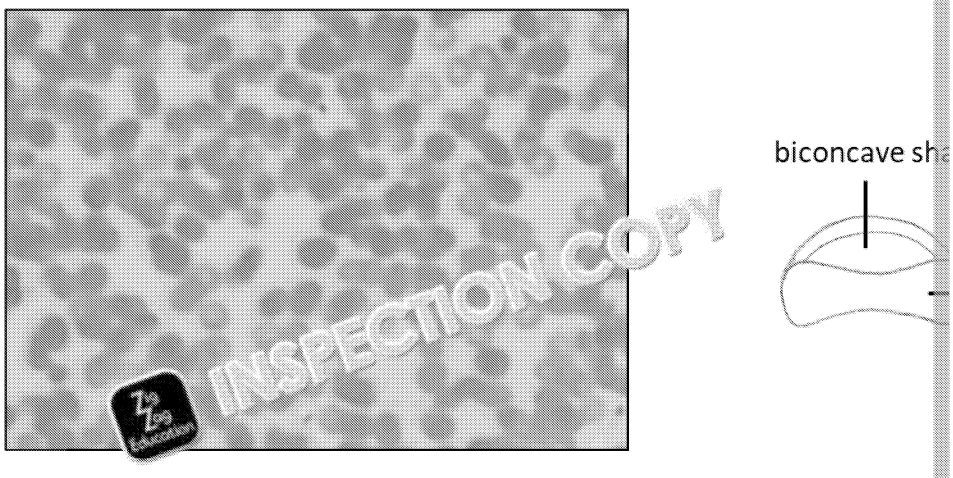
Egg cells car... genetic material from the female and are fertilised by a sperm cell. They are also a gamete, so are haploid, containing half the normal body cell amount of DNA. Other specialised features include:



embryo – the first stage of development of a multicellular organism

- a rich cytoplasm with lipids and lysosomes, providing sufficient nutrients for early stage **embryo**nic development until the placenta is available for this purpose;
- a jelly-like layer outside the cell membrane, called the zona pellucida, which p...
- a further layer on the outside, containing ovary follicle cells.

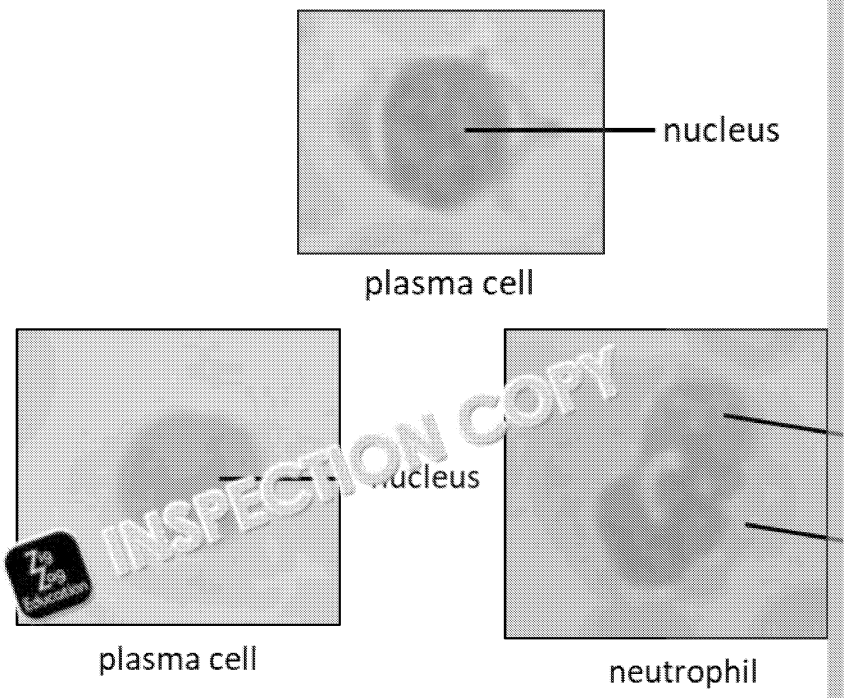
Erythrocytes



Erythrocytes are red blood cells. They transport oxygen around the body. Their specialised features include:

- no nucleus, maximising space for haemoglobin;
- haemoglobin, an iron-containing **conjugated** protein, which binds oxygen;
- a biconcave disc structure which increases the surface area so increases the rate of diffusion of oxygen into or out of the cell.

Leucocytes

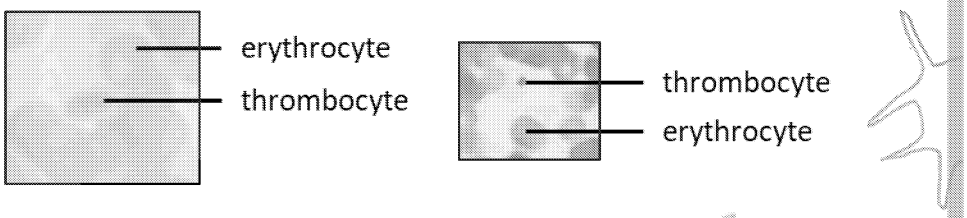


Leucocytes are white blood cells. There are many different types of leucocytes, all
the immune system.

Neutrophils are the most easily identifiable, because of their multi-lobed nucleus.
through small gaps between cells to reach the source of infection. They have gran
many enzyme-containing lysosomes which are used to destroy pathogens.

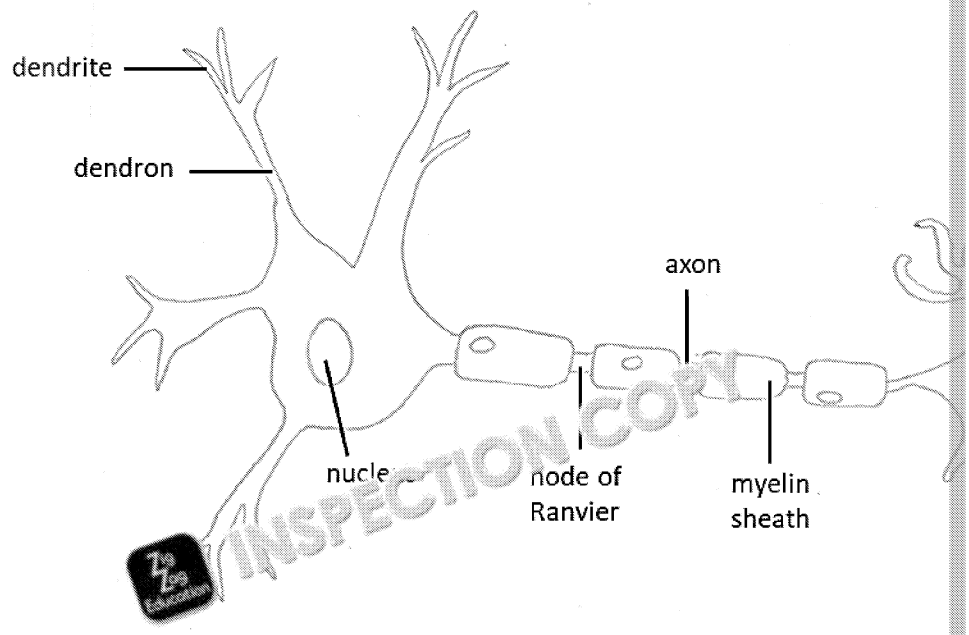
Plasma cells have a large nucleus and a large quantity of rough endoplasmic reticu
manufacture large quantities of antibodies, which provide a specific response to an

Thrombocytes



Thrombocytes, or platelets, are essential for blood clotting and scab formation.
They are made from the remnants of other cells, contain no nucleus, and have many
surface **protrusions** which allow them to attach to blood vessel walls and each other
plug a hole. They cause blood clotting by releasing chemicals to trigger this process
and are therefore essential in reducing blood loss.

Neurones



Neurones are highly specialised cells responsible for conducting electrical signals t
brain and then to effectors, enabling our body to understand and respond rapidly t
external environment. They are so specialised and complex in structure that, once
which is why nerve damage is usually permanent.

Neurones have the following specialised features:

- dendrons, which divide into dendrites, to connect to other neurones or recept
  per neurone, allowing multiple pathways to be possible;
- a long axon which connects one neurone to another in different parts of the b
- multiple terminals at the axon, so the neurone can connect to multiple other ne
- a myelin sheath, present on many but not all neurones, and created by Schwa
  axon and prevent it from being interrupted;
- nodes of Ranvier on the axon between each myelin sheath, which allow the el
  axon, thus greatly increasing its speed by up to 100 times.

Test your knowledge

- State which cell has a biconcave disc shape and no nucleus, and explain why
  its function.
- State which cell has sieve end plates and little cytoplasm, and explain why th
  its function.
- State which cell has a flagellum and mitochondria, and explain why these are
  its function.
- State which cell has either a [illegible] nucleus or a large nucleus and lots
  why these are essential to function.

Recollections: Structure and function of specialised cells

1 Thrombocytopaenia is a disease where there are low numbers of thrombo
symptoms of this disease and why it could be dangerous if left untreated.

2 An over-enthusiastic gardener brushes the roots of their plants before repl
damage this will cause to the plant roots, and what the impact of this dama

3 Plants which have been grown to be lignin-deficient are often also dwarfed.
be the case. (4 marks)

A3 Structure and function of biological

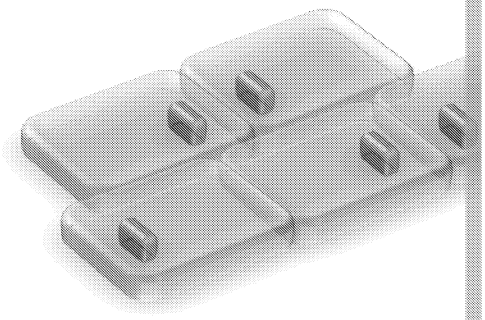
Key points covered

- The structure and function of specialised tissues, including epithelial, endothelial, muscular and nervous tissue
- Diseases that are caused by damage to some of these tissues
- How nerve impuls
  including saltatory
- The function of the
- Chemical imbalanc
  drugs on the syna

Epithelial tissue

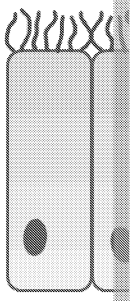
Squamous epithelium

Squamous epithelial tissue is made th , flat cells, one layer thick, which form gas exchange. For example in the lungs are responsible for the exchan between the ai th vity and the blo apillaries. This occurs efficie across the squamous epithelium because of the specialised features of the cells.



Columnar epithelium

Columnar epithelium in the lungs comprises of two types of tall, column-shaped cells: ciliated cells and goblet cells. These cells work together to protect the lungs from pathogens: goblet cells release mucus which traps pathogens and dirt particles; cilia on the ciliated cells waft this mucus up the trachea to the throat so it can be coughed up and spat out or swallowed.



Chronic obstructive pulmonary disease (COPD)

Chronic obstructive **pulmonary** disease, or COPD, is a collection of diseases of the lungs, including emphysema and chronic bronchitis. These are long-lasting conditi often caused by smoking, but frequent and long-term inhalati n of other particula including flour, coal dust and welding fumes, can al so cause the disease.

Emphysema is a disease of the alveoli in the lungs, where the inner lining of alveoli many small alveoli merge in to fewer larger alveoli instead. This reduces the surfac can occur, causing b thlessness, wheezing and an increased production of wate

Bronchitis re s to inflammation of the bronchi, which are branches of pipework in inflammatory response is produced by these columnar cells, restricting the diamet harder to inhale and exhale. An increase in mucus production also occurs because

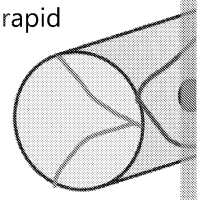
Test your knowledge

- Describe the appearance of squamous epithelial cells and explain why this h
- Describe the structure and function of goblet cells and their role in the sympt

Endothelial tissue

Structure and function

Endothelial cells make up the wall of blood vessels, including the capillaries (see diagram on previous page). Endothelial tissue is very similar to squamous epithelial tissue: the cells are thin and flat and facilitate rapid exchange of nutrients and waste products between the blood vessels and the body tissues. They also regulate the amount of fluid that exchanges between these two tissues and ensure that the blood remains fluid and does not clot unnecessarily.



Atherosclerosis

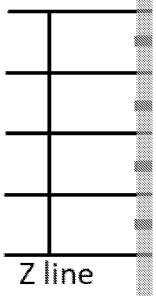
Atherosclerosis is a disease which is caused by damage to the endothelial cells of the blood vessels. The endothelial cells can be damaged by high blood pressure, high cholesterol, smoking, and inflammatory conditions such as lupus and arthritis. The damage causes particles in the blood to stick to the cells, gradually causing a build-up of plaque. This narrows the blood vessel, reducing blood flow to that part of the body. The plaque can also rupture or break off, which leads to a sudden blockage in the blood vessel. This can cause a blood clot elsewhere, causing secondary symptoms.

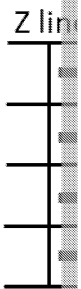
Test your knowledge

- Name two functions of endothelial cells: one similar to epithelial cells, and one different.
- Explain how atherosclerosis develops, by using one risk factor and one secondary symptom. Then provide a flow chart of the development of the process.

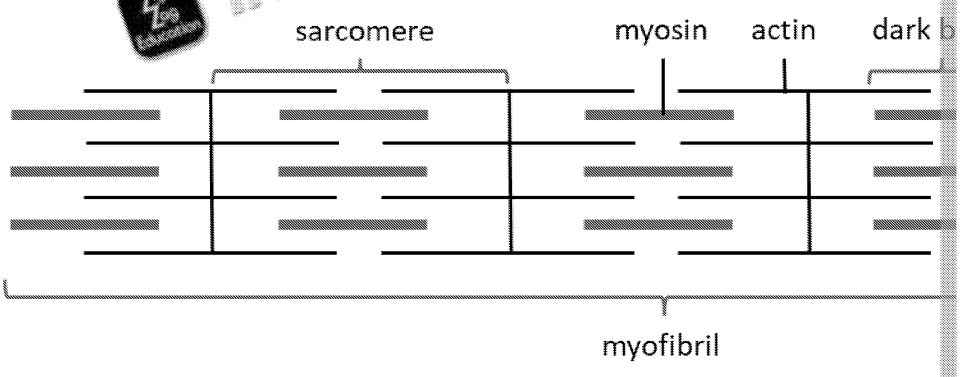
Muscular tissue

Skeletal or striated muscle fibres form muscles within our body that can be consciously controlled. They are made up of millions of tiny units called sarcomeres, which contain actin and myosin proteins that work together to produce muscle contraction.

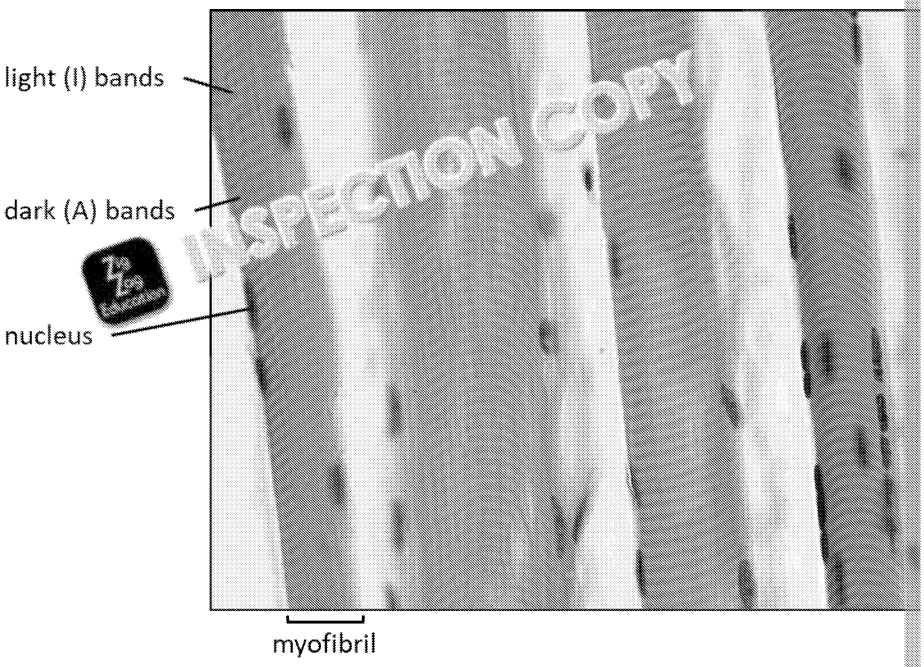




Many **sarcomeres** form together into a cylindrical fibre called a **myofibril**, and many myofibrils make up muscle fibres, which are grouped into motor units and then grouped again to form muscle tissue.



In the photomicrograph of skeletal tissue, below, the striations of sarcomeres are clearly visible. The dark bands (A bands) are where myosin is present, and are particularly dark where actin and myosin overlap. The light bands (I bands) are where only actin is present. The fibres are aligned with each other so that they produce muscle contraction in one direction to be most effective. It is also possible to see the nuclei of the muscle cells – the dark oval dots. In striated muscle, one nucleus is shared between several muscle cells: they are multinucleated. This removes the nucleus from the muscle fibres, which would prevent them from contracting effectively.



There are two types of muscle fibres: fast-twitch and slow-twitch. As their names s
contraction varies considerably between these two groups of muscles, and therefo
muscle varies depending on the job of the muscle group they are found in.

Slow-twitch muscle fibres can contract for longer periods of time than fast-twitch
muscle fibres are required for endurance-based activities, including standing uprig
time, where the muscles in the back and legs must remain contracted in order to
In comparison, fast-twitch muscle fibres contract quickly and powerfully, but can o
are therefore useful for quick activities like fast movement from the arms (e.g. in te

Test your knowledge

- Draw a diagram to show actin, myosin, a sar er, a myofibril, and the da
- Describe the key differences betwee - and slow-twitch muscle fibres.

Nervous tissue

Neurone structure

In the previous section you saw how neurones are structured. Neurones transmit electrical signals down the axon, connecting one neurone to another at the synaps (see later). Sodium and potassium **ions** move into or out of the cell via gateways i the membrane. These charged particles cause the membrane to be **polarised** (positively or negatively charged), and polarisation moves like a wave down the ax

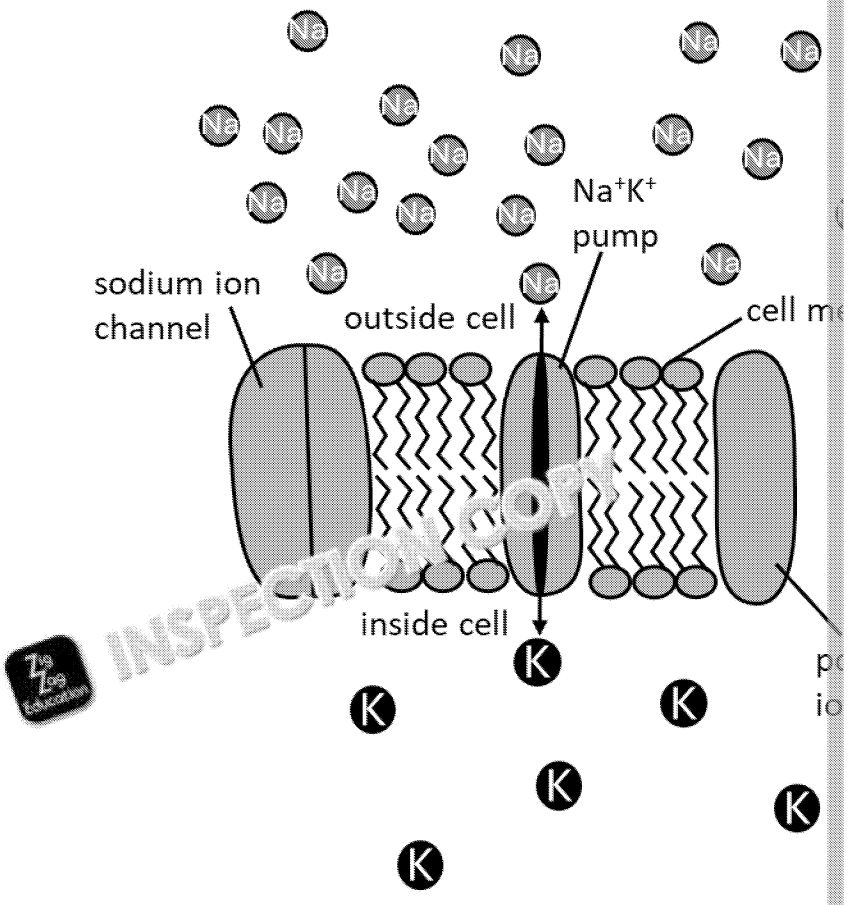
In myelinated neurones, the wave can jump from one node of Ranvier to another, of the myelin sheath. This greatly speeds up transmission, from 1 m/s along unmy myelinated axons. This is important especially in long neurones, such as motor ne have a significant distance to be transmitted over and mu so rapidly and relia and some sensory neurones, do not need myelina on e ause of the length of the

Nerve impulse conduct n

Resting potential

A neurone ts electrical impulse along the axon using positively charged (Na$^+$). Whe erve is at rest, the cell is polarised with a resting potential of abo more positively charged sodium ions outside the axon than there are positively ch axon. This is maintained by:

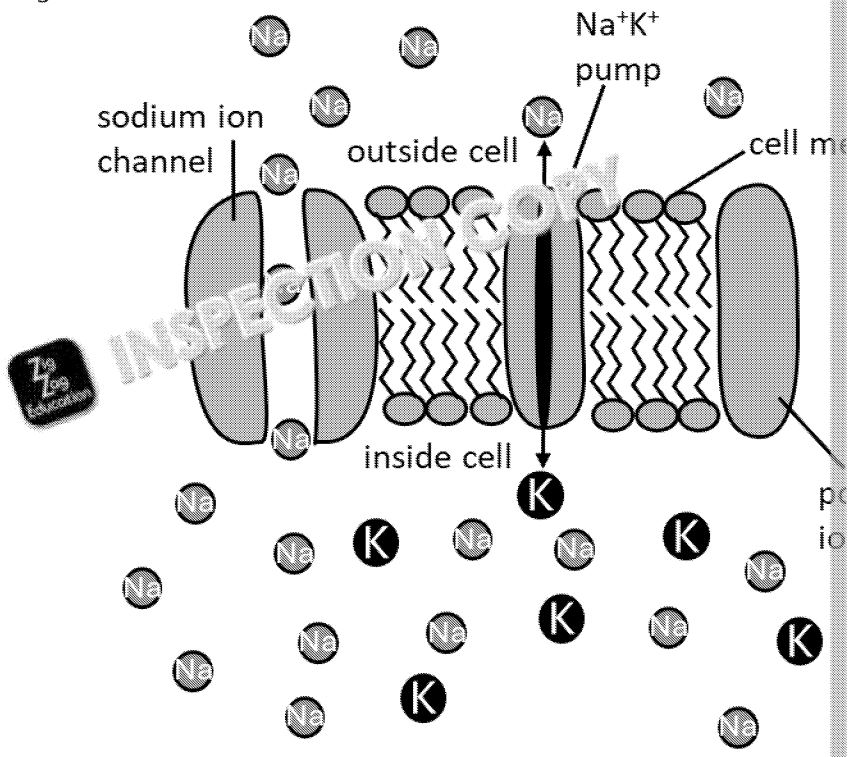
- the sodium-potassium pump, which pumps two K^+ ions into the axon for every three Na^+ ions it pumps out;
- the sodium ion channel being closed, so no sodium ions can re-enter the axon;
- the potassium ion channel being closed but leaky, so potassium ions diffuse down their **electrochemical gradient** and out of the axon.



Action potential

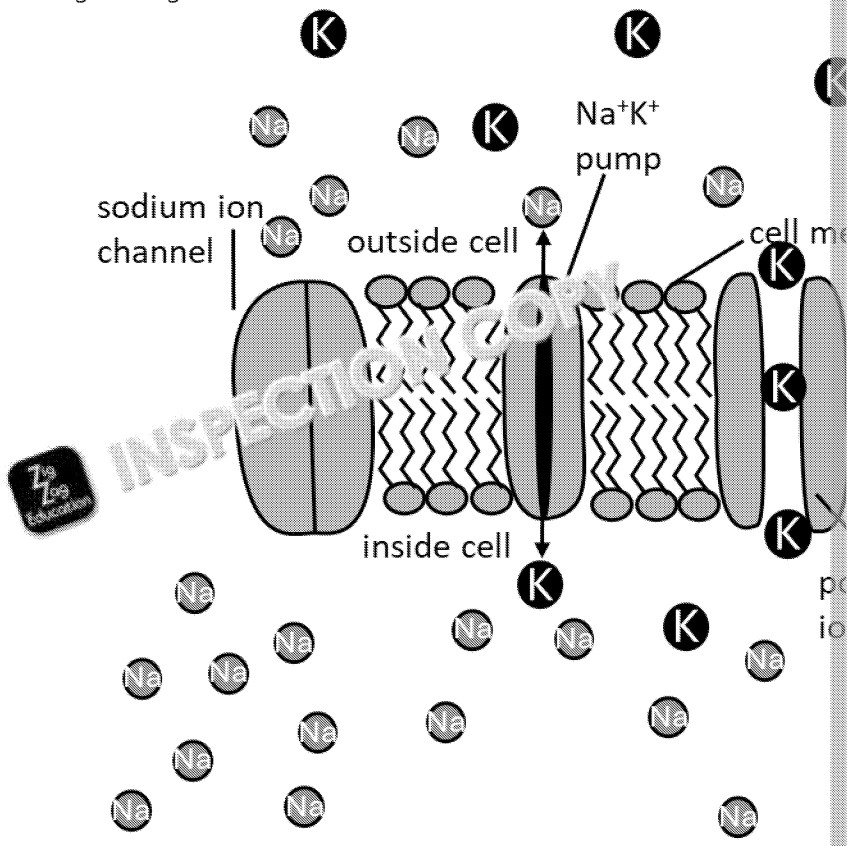
On action of a stimulus, such as a nerve receptor being triggered, the nerve **depolarises**. This occurs because the sodium ion channels open, allowing sodium ions to flood through into the axon down their electrochemical gradient.

The membrane is now more permeable to sodium ions. This causes depolarisation the inside of the neurone is less negative than outside. Depolarisation continues until the voltage across the membrane reaches +40 mV.



Repolarisation

When the voltage reaches +40 mV, the sodium ion channels close, and the potassi
The membrane is now no longer permeable to sodium ions but is now very perme
Potassium ions move down their electrochemical gradient from inside the axon to
become more negative again.

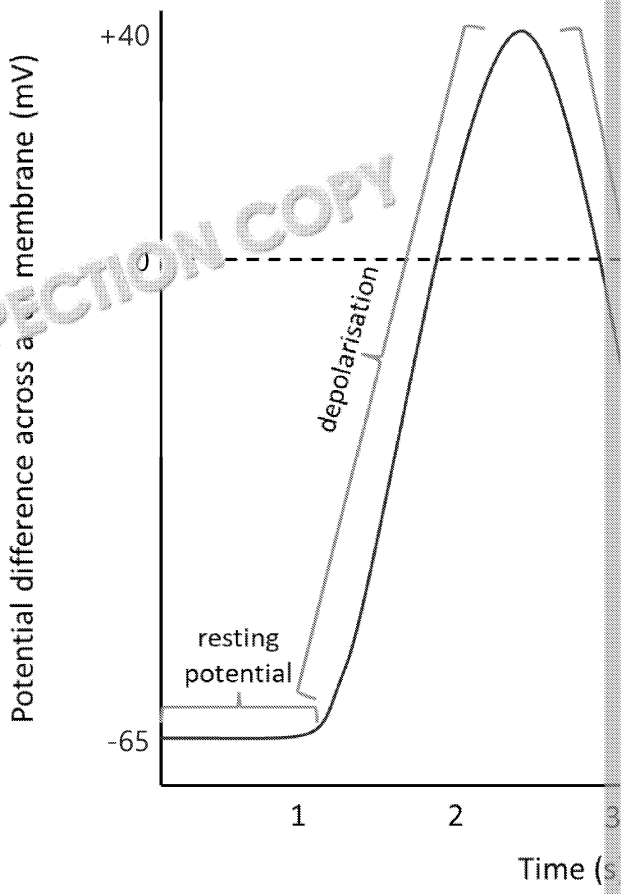


Hyperpolarisation

The process of potassium ions leaving the axon carries on beyond -70 mV, which w
This is called hyperpolarisation. This causes the potassium ion channels to close, s
pump is working: the membrane has low permeability to sodium and potassium io
resting potential, and it is ready for the next signal to activate it again.

Reading a nerve impulse from a potential difference graph

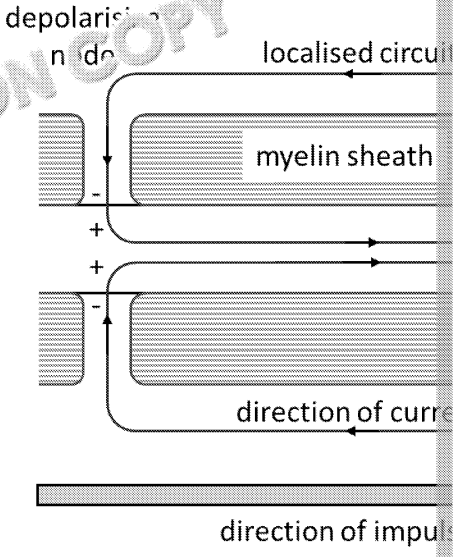
The potential difference across the axon membrane during the phases of nerve transmission can be represented on a graph. The phases of resting potential, depolarisation, repolarisation and hyperpolari re clearly visibl



Saltatory conduction

Saltatory conduction is the process of propagating a nerve impulse along the axon
myelinated neurone. In unmyelinated neurones, the process of depolarisation and
repolarisation to return to the resting potential has to happen along the entire leng
the neurone. In myelinated neurones, most of the axon is **insulated** by the myelin
This means that depolarisation and repolarisation can only happen at the nodes of
where no myelin sheath is present to prevent the movement of ions into or out of

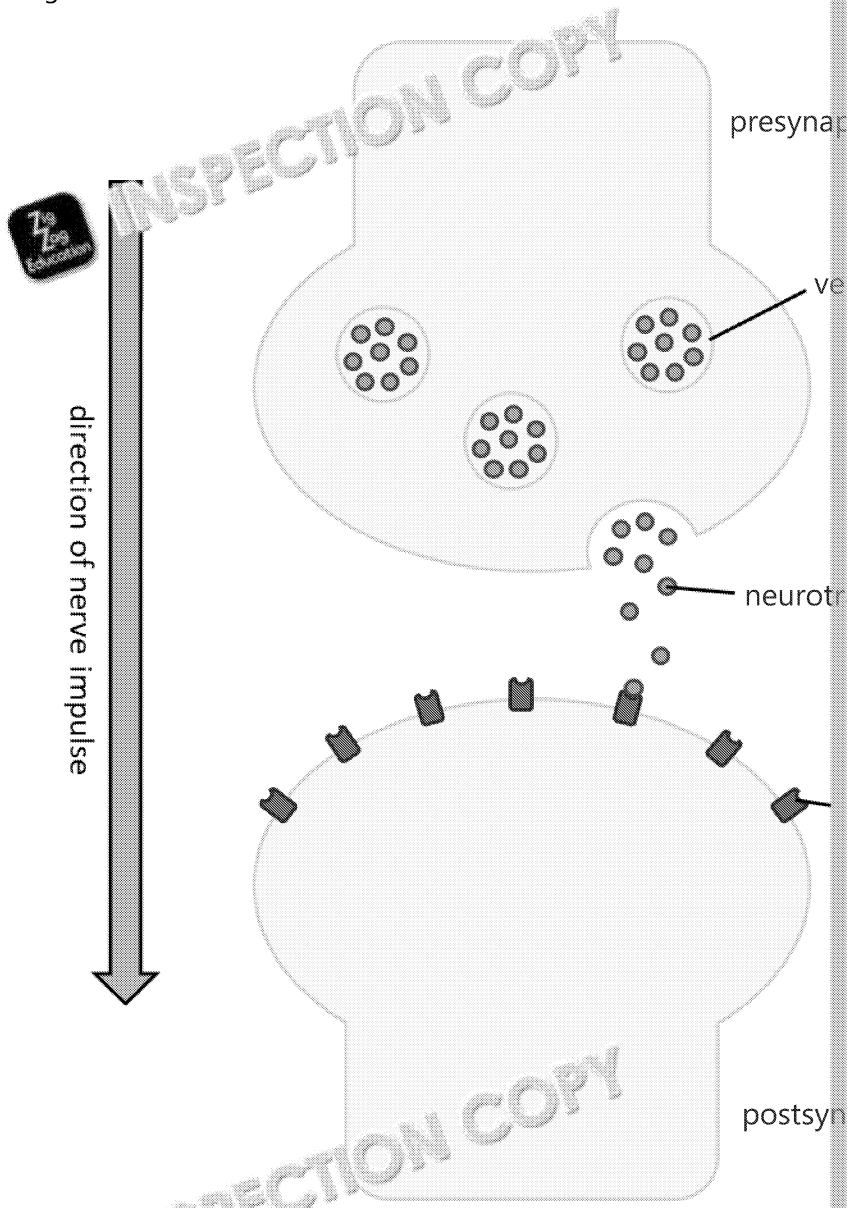
The effect of the myelin sheath is that depolarisation occurs at one node of Ranvier, but the next node remains at the resting potential. This establishe localised circuit between the odes: at the depolarising n movement of ions into on causes the axon to be positively ged and the outside to be negatively charged. Conversely at the next node along which is at its resting potential, the axon is negatively charged and the outside is positively charged. The impulse jumps along the axon from node to node, at far greater speeds than could be achieved without the myelin sheath.



The synapse

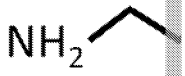
The synapse is the gap between two interconnecting neurones. Where these two c
about 20 nm wide: the synaptic gap. It is large enough to prevent the nerve impuls
electrical form, so it is exchanged for a chemical message instead.

When the nerve impulse arrives at the presynaptic terminus, it triggers vesicles containing a **neurotransmitter** to move and fuse with the presynaptic membrane. This releases the neurotransmitter into the synaptic gap, and the neurotransmitter diffuses across the gap. The neurotransmitter binds to a receptor on the postsynaptic membrane, which triggers an onward neural impulse to be generated and the message to be sent down the next neurone.



Neurotrans a essential for this process, and also for ensuring that the mes
direction. T stored in vesicles in the end of the presynaptic neurone only, so
direction. Furthermore, receptors are only present on the postsynaptic neurone, so
the neurotransmitters to bind to. Together, these two features ensure that the nerve impulse continues onwards and cannot go back down the axon it has just moved along.

There are many different neurotransmitters, including serotonin, dopamine, acetylcholine, endorphins and adrenaline. The diagram to the right shows dopamine.



Brain damage due to chemical imbalance

The brain is a delicate organ and can be subject to disease. Chemical imbalances i
cause a range of diseases by either slowing down or desensitising the nerve impuls
speeding it up or extending it. Any imbalance in this process will lead to impaired

Parkinson's disease is a chronic and progressive condition with a range of sympto
hands, arms, legs, face and the jaw; stiffness in arms, legs or torso; slow and poorly
balance and impaired ability to speak. It is thought to be caused by the loss of fun
dopamine as a neurotransmitter, which over time prevents these neurones from co
effectively, leading to the range of symptoms.

There are many other diseases caused in a similar way. Many mental health illness
neurotransmitters in the brain. Alzheimer's disease is caused by a build-up of plaq
specific neurones from functioning. Motor neurone disease and multiple sclerosis
myelin sheath surrounding neurones inhibiting their function.

Effect of drugs on the synapse

Drugs can a ow synapses work, because synapses involve the transmission of
another. Th t that a drug has depends on the drug. Drugs can:

- increase or decrease the speed at which neurotransmitters are manufactured
  precursors available or inhibiting enzymes that synthesise the neurotransmitte
- increase the quantity of neurotransmitter available by inhibiting the enzymes t
- decrease the quantity of neurotransmitter available by causing the vesicles to
  neurotransmitters are degraded by enzymes in the cytoplasm;
- increase or decrease the quantity of neurotransmitter released into the synapt
- prevent or accelerate the reuptake of neurotransmitter by the presynaptic ter
  time that the neurotransmitter is attached to the receptor or in the synaptic g
- simulate the effect of the neurotransmitter by binding to the receptor instead,
  the neurotransmitter binding.

Agonistic drugs replicate the function of the neurotransmitter by binding to the sy
the effect of the neurotransmitter and enhances transmission in the onward neuro
produce these effects.

Antagonistic drugs bind to the synaptic receptors and prevent the neurotransmitte
synaptic transmission in the onward neurone. Cannabinoids and alcohol are exam

Test your knowledge

- Describe what is meant by resting potential.
- Describe how saltatory conduction enables a very fast nervous impulse.
- Describe the features of the synapse.
- Describe three ways in which the synapse can be affected by drugs.

Recap question: structure and function of biological tissue

1 Desc e similarities and differences between epithelial and endothelial
2 Explain how muscle fibres are arranged and why this is necessary for their
3 Describe how changing membrane permeability causes a nerve impulse to be

B: Structure and function of biolog

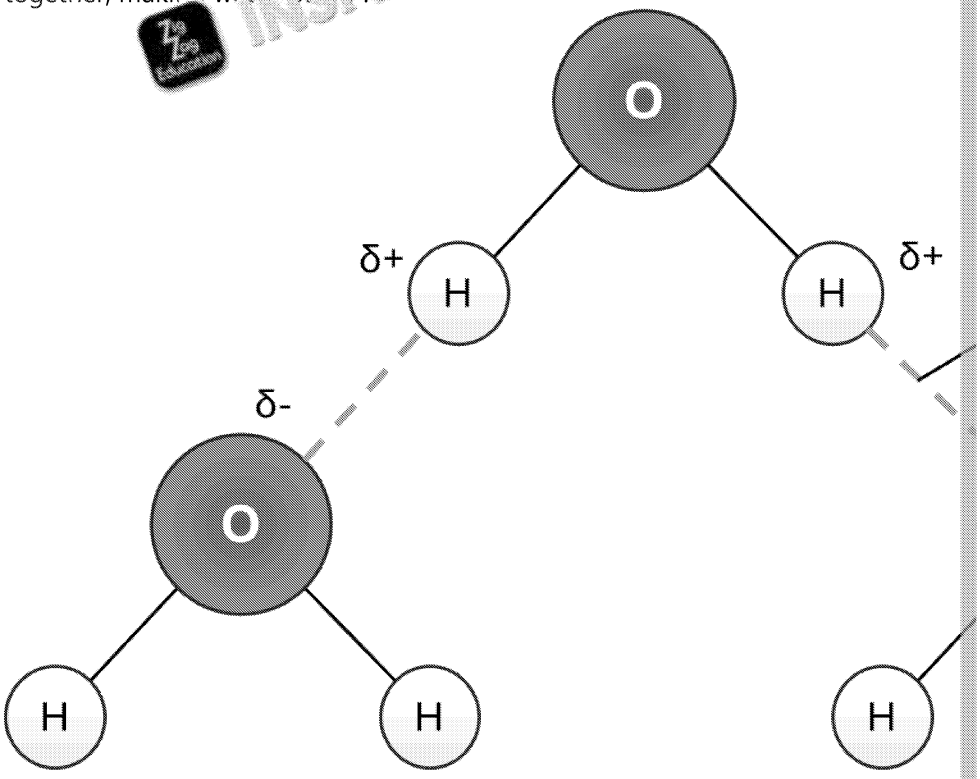
B1 Structure and function of water

Key points covered

- Structure and function of water molecules, including their polar nature
- Function of water, including as a solvent, a transporter and a balance

Structure of water

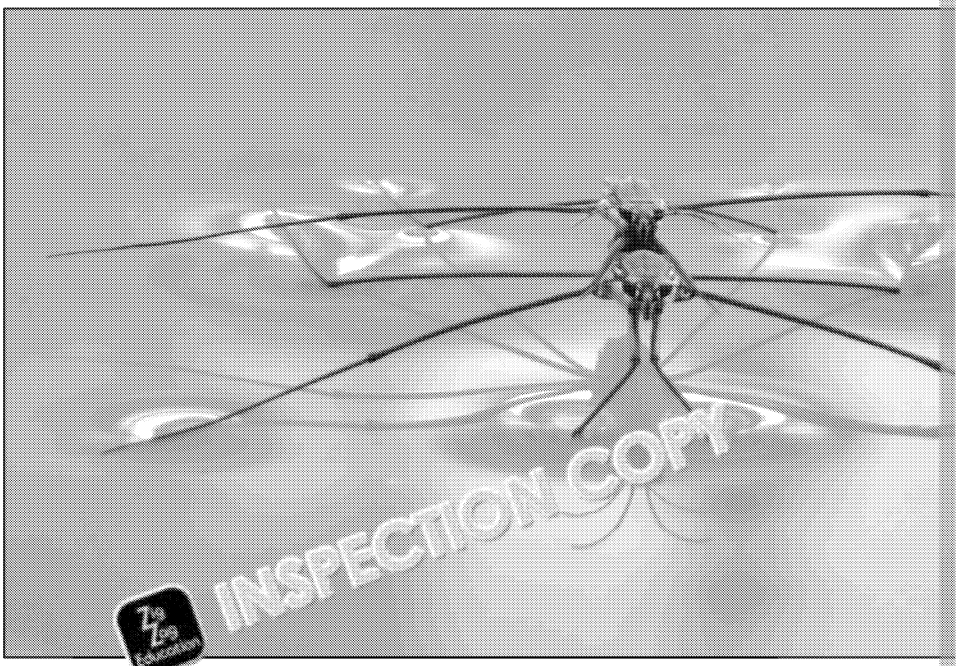
Water, or H_2O, is a simple covalently bonded molecule consisting of two positively charged hydrogen atoms and one negatively charged oxygen atom. This creates a polar molecule, with positive charges on the hydrogens and negative charges on the other, which allows hydrogen bonds to form, binding water molecules together, making water sticky.



Functions of water

Water is a solvent: many other chemicals can dissolve in water due to its polar nature. In sodium chloride (NaCl), the Na^+ ions are attracted to the negatively charged oxygen atoms, and the Cl^- ions are attracted to the positively charged hydrogen ions. Because water is able to act as a solvent, it is an excellent medium for chemical reactions to take place within, and for substances to be transported in. This is why water makes up more than 70 % of the content of the cytoplasm in cells.

The polar nature of water makes it 'sticky': water molecules adhere to other water molecules. This cohesion and adhesion enables water to be drawn through cells and vessels, such as xylem, by capillary action. The hydrogen bonds between water molecules means that one molecule drags the molecule behind the next molecule, and so on. Like a long train, when the first molecule moves, pro... pathway of water molecules, they will all move through the system.



The cohesive nature of water is also visible on its surface: water forms a 'skin'. This attracted to each other more than other particles in the environment, through hyd pond skaters, with a low density and a high surface area can be supported by the w tension that exists between the water molecules.

The polar nature of water also enables it to regulate pH and electrolytes, by formin other polar molecules including ions, amino acids and nucleic acids. This manages electrolytes and the overall pH of the solution.

Water has a high specific heat capacity. This means that it requires a substantial a water by 1 °C. Therefore, water is relatively thermostable, doesn't heat up or cool can offset temperature changes caused by exothermic or endothermic chemical re abiotic climate changes such as winter or summer. This enables life to thrive and b

Water unusually becomes less dense as a solid than it is as a liquid, meaning that s This provides an insulating layer on the top of bodies of water such as lakes and se below it slightly warmer than it would otherwise be, and being more hospitable to

Test your knowledge

- Explain why water's high specific heat capacity is important for survival of li
- Describe what is meant by 'polar', and which fea[illegible] water it is responsib

Recap questions: Str[illegible] function of water

1 Expla[illegible] hydrogen bonds form between water molecules. (3 marks)

2 Use t[illegible] nature of water to explain how cohesion tension pulls water of a plant. (5 marks)

3 Explain, using the properties of water, why lakes hidden deep within perma remain for many thousands of years. (3 marks)

B2 Structure and function of carbohydra

Key points covered

- Structure of carbohydrates, including monosaccharides, disaccharides and polysaccharides
- Function of carboh energy storage an

Structure of carbohydrates

Carbohydrates include a diverse range of molecules from simple sugars to comple a variety of functions, including as a store of energy and to create structures within wide range of structures and functions, they all contain carbon, hydrogen and

Monosaccharides (single sugar carbohydrates) are able to form straight chains or at the end of the chain, and in monosaccharides these are either an aldehyde grou

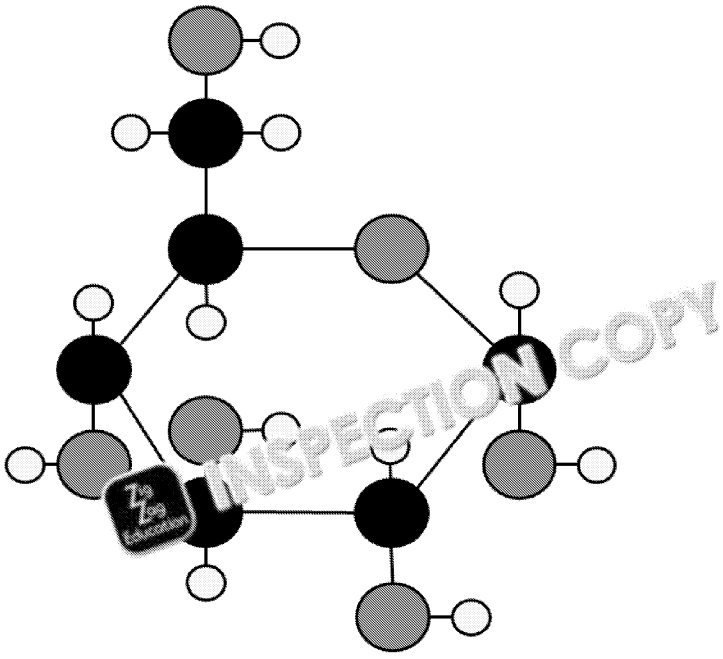
Monosaccharides are able to join together to form disaccharides and polysacchari of carbohydrate molecules, each with different structures and properties.

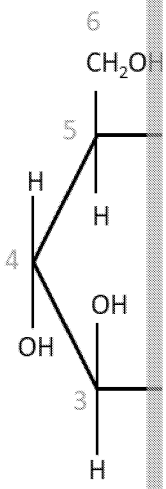
Monosaccharides

Monosaccharides are monomers: a single unit of a carbohydrate that cannot be m can combine together to make more complex molecules.

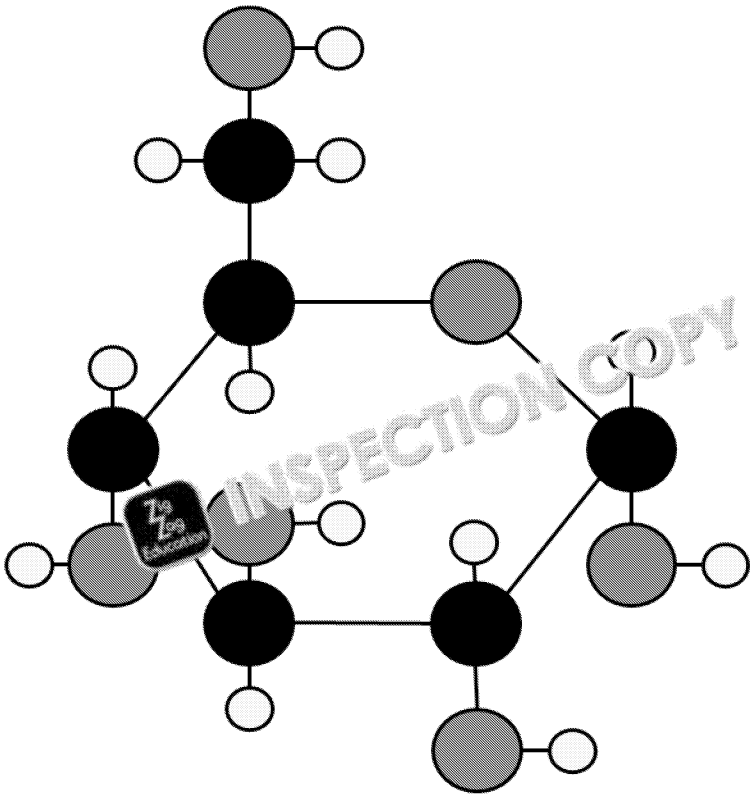
Monosaccharides include α glucose and β glucose, galactose, fructose, ribose and

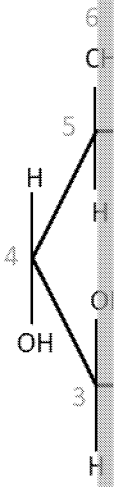
α glucose, $C_6H_{12}O_6$, contains six carbon atoms, and therefore is a hexose sugar. Th carbon-1 is positioned down, as highlighted in the 2D structural diagram, below.





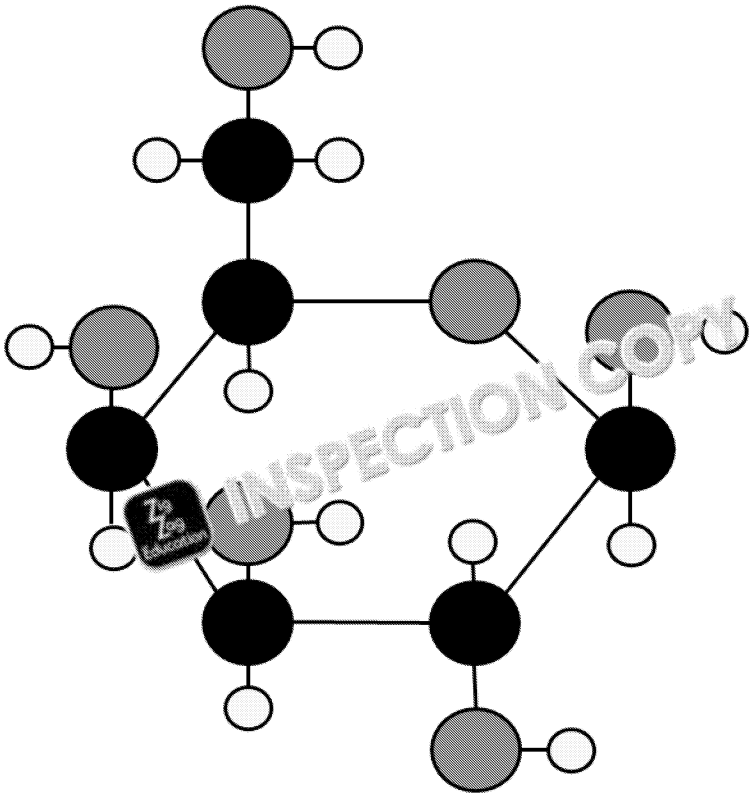
β glucose is otherwise identical to α glucose, except for the orientation of the OH g
the diagram below.

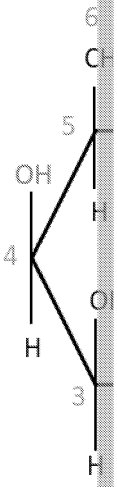




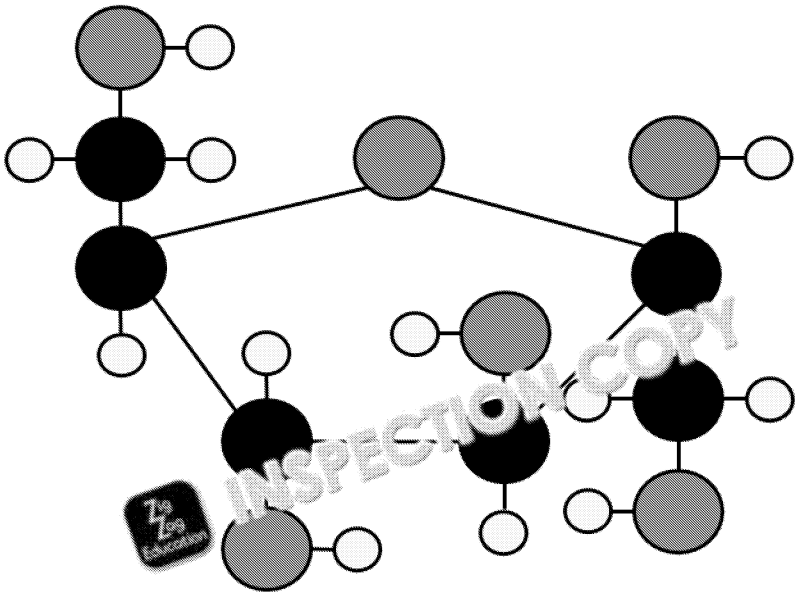
Both these sugars are polar, so are soluble in water.

Galactose, another hexose sugar, adds on one further structural change from β glu
OH group is reversed, as shown in the diagram below. Both differences between α
highlighted. When glucose and galactose bind, lactose is made.



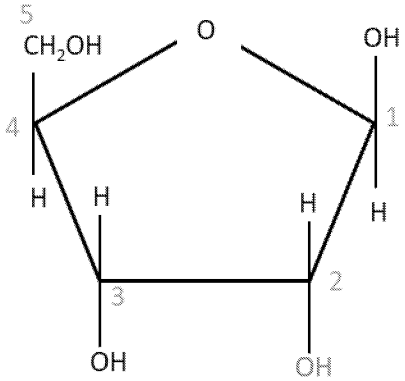


Fructose, a sugar found in many fruits, is also a hexose sugar; however, when found pentagon ring with two CH_2OH groups as appendages, as shown in the diagram be

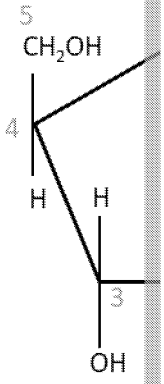


Ribose and deoxyribose are pentose sugars, containing five carbon atoms. Ribose deoxyribose forms the sugar part of DNA.

Ribose differs from fructose by missing the first CH_2OH group:



Deoxyribose differs fr
a hydrogen replaces a



Disaccharides

Disaccharides comprise two monosaccharides, joined together in a condensation re

- lactose – a fusion of glucose and galactose – found in and related produc
- maltose – a fusion of two α glucose molecule se n brewing and forms pa
- sucrose – one glucose and one fructo nc er – a sweet sugar which, whe and coffee drinks, on breakfa nd used in baking.

The **conden n r** involves the fusion of two OH gro th the expulsion of H_2O and the formation of chemical bond with oxygen bridging the gap. In the formation of maltose, for instance, the condensation reaction takes place between hydroxyl groups on carbons 1 and 4. This forms a 1,4 glycosidic bond, as shown in the diagram on the right.

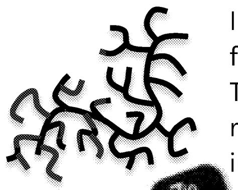
condensation reaction – chemical reaction which joi two molecules together wit the expulsion of water

Polysaccharides

Polysaccharides are long chain molecules comprising of many monomers joined to The monomers involved, and which carbons are linked together, will determine the

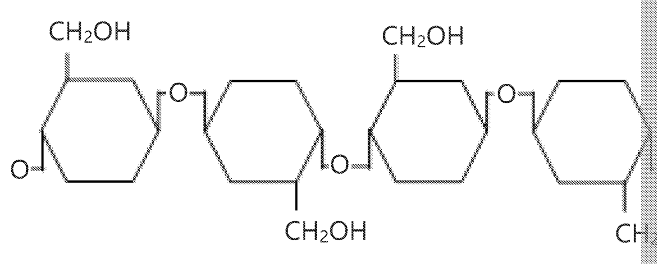
For instance, joining α glucose molecules together with only 1,4 glycosidic bonds f amylose. This chain twists into a helix because of the angle of the bonds, and beca stabilise it, it is insoluble in water.

If the same bonding pattern occurs but is occasionally interrupted by 1,6 glycosidic polysaccharide called amylopectin is made. Amylopectin and amylose are combine as a store of energy.



In animals, the same bonding structures are used, but 1,6 glycosi frequently, introducing more branches into the chains, to form a This is also used for energy storage, but because of the heavily b rapidly digested and the glucose used in respiration to supply er important for animals than plants.

Cellulose is another polysaccharide, found in plant cell walls. Cellulose is formed w joined one after another. However, for this to work, every other monomer must be the two OH groups close enough together to react. This creates a long, straight ch adjacent chains of cellulose, thus creating tough, fibrous tissue that can reinforce t



Test your knowledge

- State which monomers form cellulose and describe how they are joined toge fibrous chains.
- Describe a condensation reaction.
- State the differences between α glucose and β glucose, galactose and fructo
- Describe how a hexose and a pentose sugar differ and how they are similar.

Function of carbohydrates

Glucose is used by cells in cellular respiration to produce ATP: the currency of ener any cellular process that requires energy, such as active transport or muscle contrac energy, these processes cannot occur, so a supply of glucose is essential for every c

Glucose is stored as starch (in plants) and glycogen (in animals), so carbohydrates f energy in an organism's body, storing water-soluble glucose in an insoluble form movement of water in or out of the cell.

Carbohydrates such as cellulose, may have an important structural role in an orga strong, fibrous structures which reinforce plant cell walls and provide a source of fi important for gut health. Chitin is found in the cell walls of fungi, and the exoskele made using a modified form of carbohydrate which includes nitrogen as well.

Test your knowledge

- State three functions of carbohydrates and give an example of a carbohydra
- Explain why water insolubility is important in polysaccharides.

Testing for carbohydrates

Testing for reducing sugars using Benedict's solution

All monosaccharides are **reducing sugars**. It is possible to identify the presence o reducing sugars in a sample by testing it with Benedict's solution. The presence o reducing sugar causes the Benedict's solution to change colour from light blue to red, or a mixture of the two colours. This is due to the sugars having a free ketone aldehyde group, which reduces copper ions in the solution from Cu^{2+} ($Cu_{(II)}$) to Cu^{+} changing the colour of the solution relative to the proportion of reducing sugars p

To test for reducing sugars:

1. Ensure the sample to be tested is in liquid form: grind to a paste with distilled
2. Add an equal volume of Benedict's solution to the sa
3. Heat in a water bath at approximately 90 °C f ou minutes.

If the solution changes colour, it indi a approximate quantity of reducing su because this is a qualitative t cannot give you an exact figure.

Colour of solution	Approximate concentration of re
Blue	None
Green	Very low
Yellow	Low
Orange	Medium
Red	High

Testing for starch using iodine

Starch can be tested for using iodine. Iodine is an orange-brown solution but turn blue-black in the presence of starch. A few drops on the substance are enough to indicate whether starch is present or not. This photograph of starch-stained courgette shows starch collected in specific areas of the fruit.

Potatoes are stores of carbohydrates and are full of starch:

Even parts of a

Test your knowledge

- Name two red g sugars and describe the test for them.
- State su g colours and what they indicate for the reducing sugars a

Recap questions: Structure and function of carbohydrates

1 Describe how the polymerisation of α glucose forms starch, but β glucose

2 Plant sap transports sugars in the form of sucrose, a disaccharide. What c turn in the presence of this sugar, and why? (3 marks)

3 Sucrose from the maple tree sap is collected and boiled in dilute hydrochlo sucrose into glucose and fructose. What colour will Benedict's solution tu

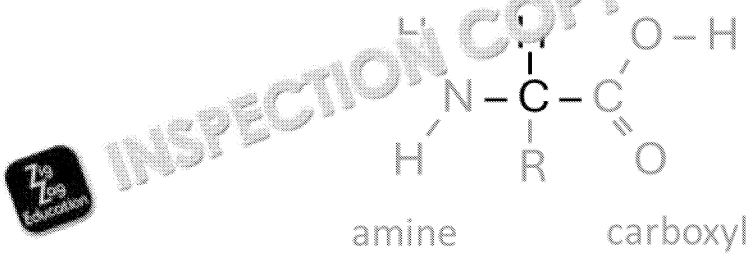
B3 Structure and function of proteins

Key points covered

- Structure of proteins, including primary, secondary, tertiary and quaternary structures
- Function of protei and functional rol

Structure of proteins

Proteins are made up of amino acids. Amino acids contain a central carbon atom, hydrogen, a carboxyl group, an amine group and an R grou which differs for each

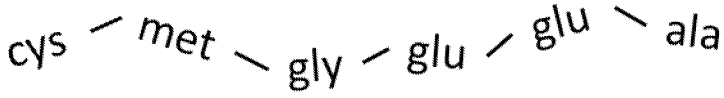


Amino acids are linked together to create long polypeptide chains, which undergo before being functional. Each amino acid has particular properties relating to its s amino groups can accept H^+ ions (protons) so are basic, whereas carboxyl groups Non-polar amino acids are hydrophobic, and polar amino acids are hydrophilic, ju

Proteins have many functions within the body, broadly grouped in two categories Many are comprised of several subunits or prosthetic groups which ensure the co protein is possible.

Primary structure

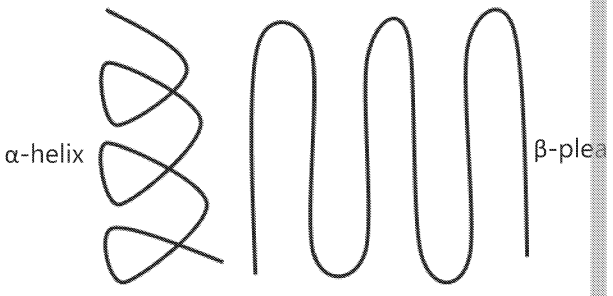
To build a protein, firstly the correct amino acids must be assembled in the right order. This sequence is determined by the gene encoding the protein and involves the translation of the mRNA triplet code into a **polypeptide** chain by ribosomes. Amino acids are bonded together with **peptide bonds** which are formed through condensation reactions, much like carbohydrates.



Secondary structure

The secondary structure is formed with the interaction be ee the partially H^+ ar and the partially O^- carboxyl group on a non-a ia ent ino acid. Hydrogen bond creating either α-helices or β-pleated ets reas of folding within the protein. A possible; this creates initial st i y in he structure which is further reinforced dur

The folding y depending on the amino acids contained within the chain. Globu α-helices an ated sheets, whereas actin and myosin, found in muscle, are made



Tertiary structure

The tertiary structure involves further bonding between non-adjacent amino acids, interaction between the amino acids and the external environment. There are a nu form at this level:

- Ionic bonding occurs with the loss or gain of electrons between differently ch bonds that are very stable.
- Disulfide bridges/bonds form strong covalent bonds between two nearby cys methionine) amino acids, because they are the only amino acids to contain su which offer great stability to the protein.
- Hydrogen bonds are weakly interactive and occur between different R groups, secondary structure.
- Van der Waals forces are weak forces between atoms du to differences in the help to provide further stability to the structure o rotein.
- Hydrophobic interactions bring hydroph ic mi acids into the centre away

Quaternary structure

Some proteins are m de of more than one polypeptide strand. The formation of t the combin f multiple strands into one protein and may also involve the add such as iron .

Proteins which are made only of two or more polypeptide strands are called **non-conjugated** proteins. These consist only of protein, and include insulin, which is a globular protein, and collagen, which is a fibrous protein.

Other proteins contain multiple polypeptide strands and other non-protein components, such as ions, and are called **conjugated** proteins. Haemoglobin is a complex globular conjugated protein made of four separate polypeptide strands, where each strand also contains a haem group – an Fe^{2+} ion – which binds oxygen.

Proteins can be functional or structural in nature, and globular (spherical) or fibrou Common proteins include:

- Functional:
  - haemoglobin – carries oxygen in red blood cells
  - insulin – hormone that regulates blood sugar levels
  - lipase – an enzyme that digests lipids
- Structural:
  - keratin – builds hair, nails, claws
  - collagen – builds strong connective tissue such as ligaments and tendons

Test your knowledge

- Describe the key features of primary, secondary, tertia and quaternary pro
- Name an example of a fibrous non-conjugate rotein, and a globular conju

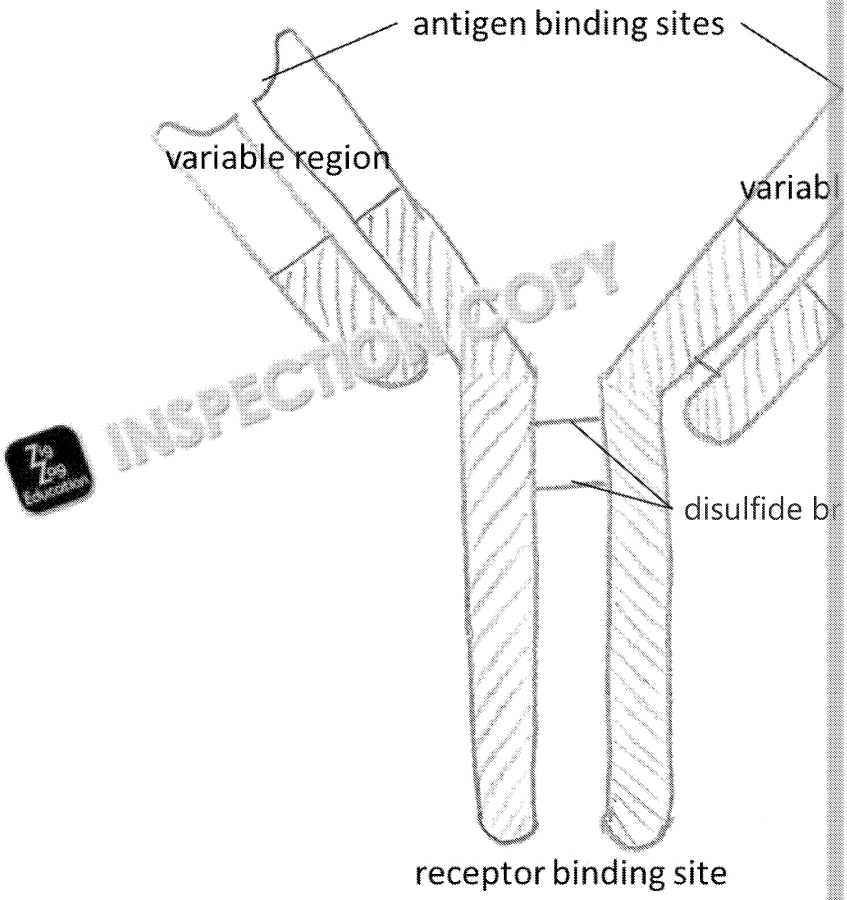
Function of protein

Given that DNA encode the proteins used in our body, it should be unsurprisi which are f a wide variety of shapes and functions.

Muscles are made of two significant proteins called actin and myosin. They interac the actin filament over the myosin filament. This shortens the total length, contrac between the two actin fibres narrows during contraction.

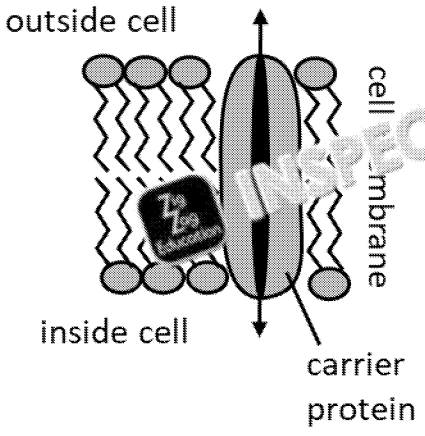
All biological enzymes are proteins. Enzymes catalyse chemical reactions, significan They are fundamental to the function and survival of organisms and are responsible and catabolism (breaking down) of molecules. Common examples include digestive (digests starch to maltose) and trypsin (digests some proteins into amino acids); and peroxide into water and oxygen at the end of the electron transport chain reactions

Antibodies, produced by special leucocytes called plasma cells, are proteins. They
pathogen as an invader which needs to be destroyed, and for grouping pathogens
able to move around the body. They are Y-shaped proteins with various sections
region which differs depending on the pathogen.



ou

Antibodies bind antigens. Antigens are molecules that protrude (stick out) from the surface of the cell, identifying the cell and its function. These are specific to the organism and can differ between individuals in the species: the antigens on your cells are specific to your cells only, for instance. This is useful to the immune system because it helps to identify cells that are non-self (not from your body). These cells should not be in your body and therefore need to be destroyed. These antigens are used by leucocytes to identify pathogenic cells for destruction.



Other pro... th...ough the cell memb
wit... ...e ...ide of the cell. Carrier protei
m...lecules against the concentration grad
transport. They bind a molecule on the
(cellular form of stored energy) to chang
molecule through the cell membrane int
brought into a plant's root using carrier
across the membrane in a neurone.

Proteins can also be hormones, such as insulin. Hormones are chemical messenge
stream from the gland that they are released from (with insulin, this is the pancreas
the liver) where an effect is triggered. This allows a coordinated response to happe
change in environment.

Some proteins, such as haemoglobin, are responsible for transporting other molec
Haemoglobin binds oxygen in the lungs where it is at high concentration, and relea
oxygen is at a lower concentration. The presence of iron ions enables this function
function is demonstrated because the part of the gene coding for the haemoglobi
has been highly conserved for millions of years.

Proteins are essential in the process of tissue growth and re . There are many p
process of cell mitosis (division of body cells), and the ge ral maintenance of cells

Proteins are also essential in blood ... and provide a number of blood clottin
form a cascade or chain rea ... rapidly turns dissolved fibrinogen into insolu
for plugging th hol ... blood vessel wall. Fibrin also traps platelets and blood
clot, which ... create a scab, under which new skin cells can grow and repair t

Test your knowledge

- State three functions of proteins and give three examples of proteins with th
- State why proteins are needed to transport molecules into a cell and what fe
- Describe how antibodies and antigens interact.

Testing for proteins

It is possible to test for the presence of proteins within a solution. A light blue rea
used, which turns purple in the presence of protein. Biuret solution includes sodiu
solution. In this test, the copper ions in the alkaline solution (sodium hydroxide) fo
bonds in the protein, causing the change in colour.

To test for proteins:

1. Add an equal volume of sodium hydroxide solution to the sample solution.
2. Add copper sulfate solution a few drops at a time to the solution until it turns
3. Mix the solution and leave for a few minutes.
4. If protein is present, the solution will turn purple.

Test your knowledge

- Name the two solutions which make up Biuret's sol ...
- State the colour change expected when test ... Biuret's solution if prote

Recap question ... e and function of proteins

1 Desc ... different bonding interactions occurring to hold the tertiary st
(5 mar ...)

2 Catalase contains four iron(II) ions. Describe its structure and function. (4

B4 Structure and function of nucleic aci

Key points covered

- Structure of nucleic acids, including DNA and RNA
- Function of nuclei

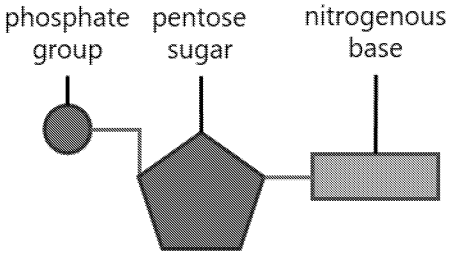
Structure of nucleic acids

Nucleic acids are polymers made from repeated nucleotide monomers. The nuclec
minor differences leading to the four different DNA bases and four RNA bases. Th
because they encode information: instructions which allow the processing of DNA
which are uniquely designed for their specific cellular r... ch...nges to the order o
can lead to a different protein being produced, wh ch ...sually, although not alwa

Nucleotide structure

The nucleotide is th... ...er which, when combined with many others, forms th
There are t... ...ti...s to the nucleotide:

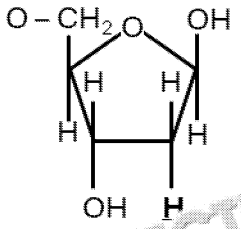
- the pho... ...e group (PO_4^{2-})
- the pentose sugar group (deoxyribose in DNA, and ribose in RNA) with five ca
- the nitrogenous base (guanine, cytosine, adenine, thymine or uracil)
  - in DNA, the bases C, G, A and T are present, and pair G with C and A with
  - in RNA, the base T is replaced by U



The phosphate grou
carbon atom

The carbon atoms are labelled 1 to 5 anticlockwise around the pentose sugar, start
atom (see diagrams on next page).

The sugar in DNA is deoxyribose: it is without an oxygen (deoxy) off the second carbon, highlighted in bold underlined.



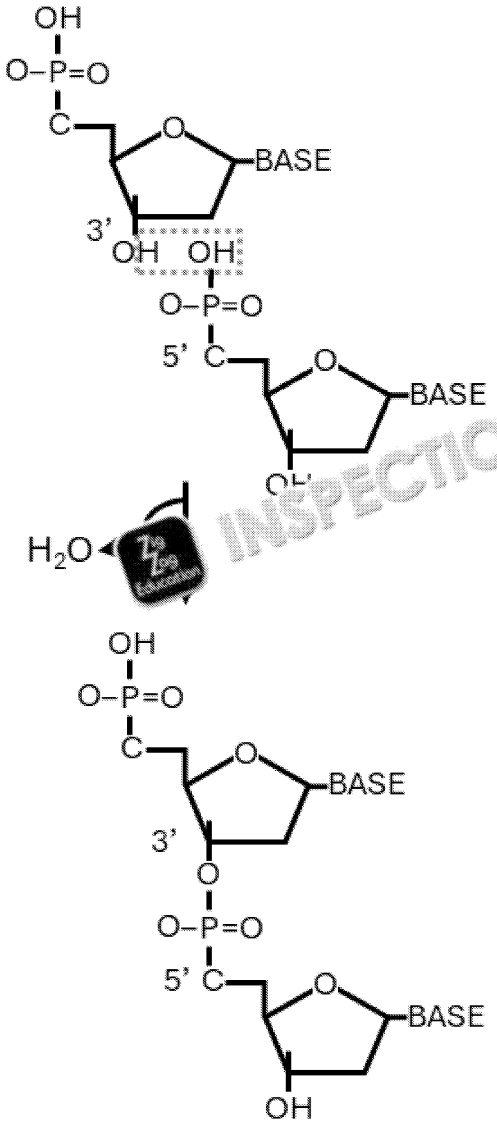
The sugar in RNA is rib
missing in DNA), bound
carbon, highlighted in b

The five bases – G, C, A, T, U – are grouped into purine and pyrimidine forms.

- Pyrimi... ...he longer of the two words) are the single-ring (shorter) nitroge
  and ura...
- Purines (the shorter of the two words) are the double-ring (longer) nitrogenou

When base pairing occurs in the DNA double helix and the ribosome (during polyp
or to form the structure of tRNA for instance), a purine base pairs with a pyrimidine
to keep DNA of equal width throughout: if two purines were to pair together, the D
normal; if two pyrimidines paired together, the DNA strand would be narrower tha
governed by the number of hydrogen bonds formed between the pair of bases. G
bonds when paired together; A and T (or U in RNA) form two hydrogen bonds. Hy
interacting but provide sufficient stability to the structure.

Polynucleotide structure



Nucleotides can be joined togethe
DNA or RNA. Phosphodiester bon
nucleotides in a condensation reac
undone with a hydrolysis reaction.
between the phosphate group att
and the hydroxyl group attached t
pentose ring (3').

The staggered nature of this bond
seen in DNA.

DN

DN is double-stranded. The sens
strand is orientated 5'–3' and cont
the code for protein. The antisens
strand is orientated 3'–5'.
They are **antiparallel**.

Complementary base pairing bin
the two strands of the double heli
together. Guanine pairs with cytosi
with three hydrogen bonds; adenine
with thymine with two hydrogen bo

RNA

There are three forms of RNA: mes
(rRNA) and transfer (tRNA). These
nucleotides containing the bases G
condensation reactions as shown v
complementary base pairing occu

Test your knowledge

- State which bases complementary pair with G and T and describe how hydr
  influences these pairings.
- Name the two forms of bases and describe how they differ.
- State the name of the bond that joins one nucleotide to another, and descri
  formation occurs.

Function of nucleotides

DNA

Sections of DNA called genes encode for proteins. The order of the DNA bases di
any changes to the order of the bases can lead to a loss of information called a mu

Different versions of genes are called alleles, and contain slight differences in the b
This leads to the expression of slightly different proteins, resulting in changes to th

RNA

RNA has different functions depending on the type of RNA.

- mRNA is responsible for transferring the DNA code of a gene out of the nucle
of protein synthesis.
- rRNA forms part of the ribosome which translates the mRNA code into a poly
- tRNA is responsible for binding the correct amino acid to the growing polypepti

In more detail, the process of protein synthesis is:

- **Transcription**:
  1. The section of DNA containing the gene to be transcribed is 'unzipped': t
  two strands are broken by DNA helicase and the strand untwists.
  2. The antisense strand is copied into mRNA using complementary base pai
  mRNA strand contains the same sequence of bases as the sense strand o
  ribose nucleic acids are used, and thymine is swapped for uracil.
  3. The enzyme RNA polymerase joins the sequence of mRNA bases togethe
  condensation reactions to form phosphodiester bonds.
  4. The mRNA strand detaches from the DNA strand and leaves the nucleus
- **Translation**:
  5. The mRNA strand joins to a ribosome (containing rRNA and other enzym
  RER membrane.
  6. The mRNA strand is read by the ribosome three codons (bases) at a time
  to a complementary tRNA which has the corresponding amino acid boun
  7. The enzyme peptidyl transferase binds each amino acid to the next with a
  growing polypeptide chain.
  8. Once the stop codon is reached, no further amino acids are added to the
  and mRNA are released from the ribosome.
  9. The polypeptide chain is further processed into the final protein. This inc
  conjugates, before it is ready for use within or outside the cell.

Test your knowledge

- State the function of DNA and m, r and tRNA.
- Outline the process of transcription and translation of DNA into protein.

Recap questions: Structure and function of nucleic acids

1 Explain how complementary base pairing works and why this is necessary for
structure of DNA. (5 marks)

2 Calculate what percentage of the other bases will be recorded if a sample h

3 Convert the following DNA antisense strand into its corresponding mRNA
G T A A G C C T A G A T T C T G C A

B5 Structure and function of lipids

Key points covered

- Structure of fats, oils and waxes
- Esterification of glycerides
- Testing for lipids
- Function of lipids, membranes and h

Structure of lipids

Lipids include fats, oils, waxes and steroids. Fats are solid and oils are liquid at roo carbon, hydrogen and oxygen but unlike carbohydrates, they're non-polar molec molecules are evenly distributed, so there is no area which is negatively charged o makes them not water-soluble (because water is a polar molecule: O^- and H^+). The elements: phospholipids contain a ph ha group, for instance.

Lipids are highly compl large molecules which are not made from repeating mo similar feat th families:

- Triglyc ontain one glycerol and three fatty acids.
- Phospholipids contain one glycerol, two fatty acids and a phosphate group.
- Fatty acids can be saturated or unsaturated (see next).

Saturated and unsaturated fats

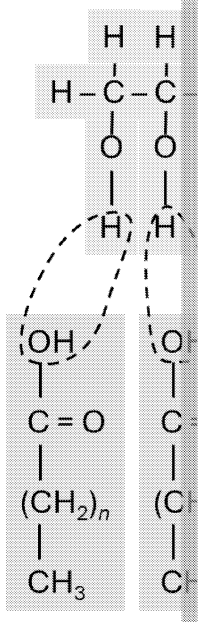
Fatty acids are long carbon chains with hydrogens bonded. Saturation describes whether all the carbons are fully loaded with hydrogen atoms, or whether some hydrogens are missing, allowing carbon to form a double bond.

Saturated fats have no carbon–carbon double bonds and so are fully saturated with hydrogen. This creates straight chains with no kinks, which means the molecules can pack close to each other, making them solid at room temperature: fats.

Unsaturated fatty acid chains have some hydrogen atoms 'missing', meaning that there are carbon–carbon double bonds in the chains. This forms kinks in the chains, so the molecules cannot pack so closely together. This means they are liquid at room temperature: oils. Monounsaturated fats have only one carbon–carbon double bond. Polyunsaturated fats have two or more carbon–carbon double bonds.

Esterification

Diglycerides and triglycerides are formed when a glycerol bonds to two (di-) or three (tri-) fatty acid chains, in a condensation reaction (release of water) called esterification. One water molecule is released for each fatty acid chain bound to glycerol. The lengths of the fatty acid chains can vary significantly.



Test your knowledge

- Define the term 'saturated' and describe the difference between saturated and unsaturated fatty acids.
- Explain why fats are solids and oils are liquids at room temperature, with reference to their fatty acid chains.
- Describe the process of esterification.
- State the components of a phospholipid and a triglyceride.

Function of lipids

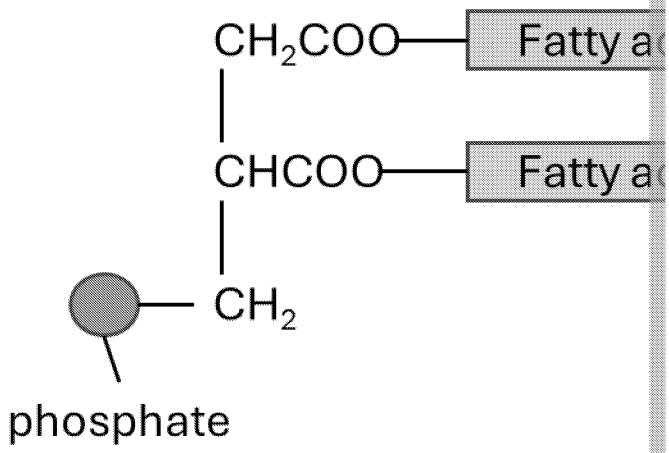
Lipids have many functions:

- they can be used as a source of energy or for storing energy;
- they can provide insulation and protection of organs;
- they are used to create cellular membranes;
- they are used as hormones.

Lipids are good sources of energy because the density of chemical bonds means g
stored per gram compared to carbohydrates. Therefore, consuming fats provides a
fats can be stored in adipose tissue, they provide a long-term source of energy, too
storing energy is needed for work coming up, like completing long migration route
poor food availability.

Fats are dense because of their saturated c
Lipids are insulators because there
transfer energy, which means they can be used to provide insulation and protectio
animals such as whales a
made of thick layers of fat to provide insulation
Around all vi
ga
e is a layer of fat which provides some protection agains

Phospholipids comprise a glycerol molecule with two fatty acid chains and a phosp



This structure results in a hydrophilic (water-loving) head (the glycerol and phosphate section) and a hydrophobic (water-hating) tail (the fatty acid chains). They are amphipathic (hydrophobic and hydrophilic), and the polar nature of a phospholipid means it orientates itself with the hydrophobic tails facing away from water, such as the cytoplasm. When multiple phospholipids are aligned alongside each other, and, when one line of phospholipids is lined up opposite another line facing in the opposite direction, so the hydrophobic tai
cing inwards, they form a bilayer: a membrane.

All cell membranes are formed in this manner, such as around mitochondria, chloroplasts and the t
vacuoles. In addition, a single layer of phospholipi
fo
a capsule or a sphere in cytoplasm, trapping hydrophobic contents ins
This is useful for cellular transport. Or, the tails can stick out with the hydrophilic heads in the water, such as in the lungs, thus forming a surfactant, which helps to keep the alveoli open and not stuck together.

Lipids can also act as hormones when in the form of steroids. All steroids have the same basic shape:

- four hydrophobic carbon rings;
- a variable end;
- a hydrophilic hydroxyl group at one end.

They include testosterone, oestradiol and cholesterol, and can pass through the phospholipid cellular membrane because they are non-polar.

HO

Test your knowledge

- Explain why lipids are a good source of energy and in which cells lipids are s
- Describe the shape of a phospholipid and explain why this is useful for build
- Name two steroid hormones.

Testing for lipids

Lipids can be tested for using the emulsion test. As a liquid, mix the sample with e This is best done in a test tube with a bung! If a lipid is present, it will form a white solution cloudy and opaque. If left undisturbed for a few minutes, the mixture will a layer on the top of the ethanol as they are less dense.

Test your knowledge

- Name and describe the test for lipids.

Recap questions: Structure and function of lipids

1 A student tests three substances for the presence of lipids. Sample A turns after about 7 minutes; sample B turns ethanol cloudy but no separation occ ethanol colourless and unchanged. Which sample contains a lipid? Explain

2 Compare and contrast a triglyceride and a phospholipid. (7 marks)

C: Cellular transport and enzy

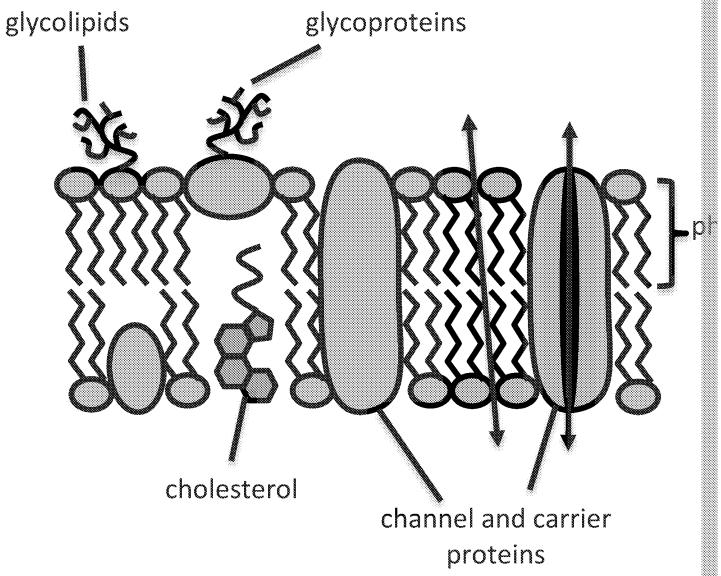
C1 Cell transport mechanisms

Key points covered

- The structure of the cell surface membrane, including the fluid mosaic model
- How molecules are transported, including by diffusion, facilitated diffusion, osmosis and active transport
- Endocytosis and e
- Surface area, volu living organisms

Structure of the cell surface membrane

The cell surface membrane, and most membranes within living organisms (especially eukaryotic ones), is largely made from phospholipids. The amphipathic nature of phospholipids means that they form as a double layer, hydrophobic tails pointing inwards away from the water-based cytoplasm, and hydrophilic heads forming the membrane's inner and outer surface.



Embedded within the phospholipid membrane are many other components:

- channel proteins, which do not change shape, and carrier proteins, which do c would otherwise be unable to pass through the hydrophobic middle of the m
- aquaporins, a specialist form of carrier protein, transp water;
- cholesterol, a steroid, adjusts the fluidity of th em ane and allows adjustm temperature changes;
- glycoproteins (proteins with ates attached) and glycolipids (phosph attached) allow cell- munication, cell recognition and adhesion.

This is know e fluid mosaic model and describes how cell membranes are ass This formatio provides a flexible barrier which can be adapted to suit the specific It can separate parts of a cell, such as the mitochondrial space from the cytoplasm, functions to take place within uniquely controlled microenvironments. The membr vesicles (see bulk transport, later) which enables bulk transportation of substances membrane means that many substances are naturally prevented from moving thro because they are too large to pass through the tightly packed membrane, or becau pass through the hydrophobic middle. This enables the cell to control the entry an

The elements embedded within the cell membrane may have one of many functions, including:

- enabling cell-to-cell recognition and communication, including identifying the cell as self or foreign, and the binding of hormones;
- adhesion between cells to form tissues, including by forming a **glycocalyx**, gap or tight junctions and **desmosomes**;
- channels between cells, such as **plasmodesmata** in plant cells, to enable long-range transportation of substances such as water, ions and sugars;
- providing channels to facilitate the movement of substances by diffusion, osmosis and active transport, including ions, carbohydrates and proteins.

Test your knowledge

- Describe the fluid mosaic model.
- State three benefits of this model to cells.
- List four functions that may be carried out by components of the cell membr

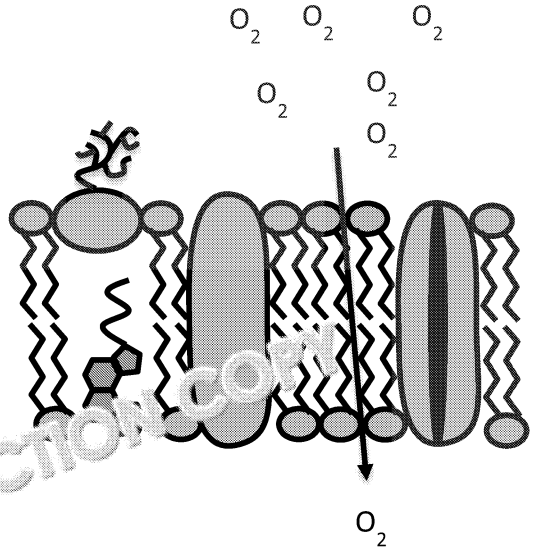
Transporting molecules

Some molecules can freely pass through the phospholipid membrane; others cann are required in higher concentrations inside the cell than they are present outside t specialist transport.

Diffusion and osmosis

Diffusion is the net movement of particles from an area of higher concentration to therefore down the concentration gradient. It does not require energy, and the mo through a membrane, but if they do, they will do so freely. Particle movement is ra the concentration gradient, but the overall direction of movement is down the grad

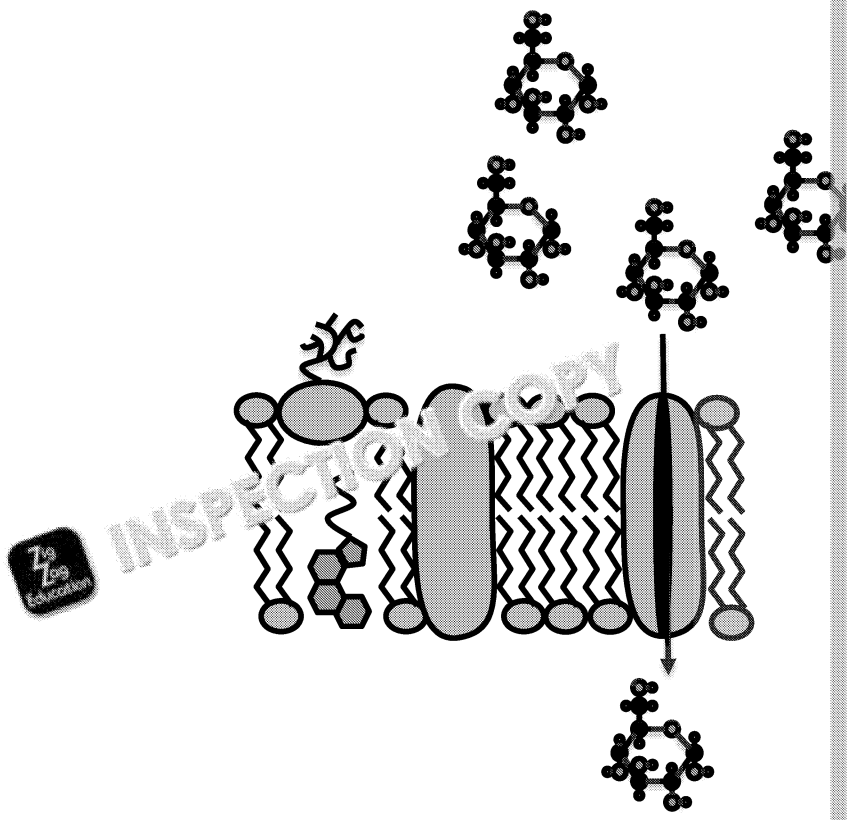
The diagram below shows diffusion of oxygen through the cell membrane.



Some molecules can diffuse through the cell membrane: oxygen and carbon dioxide uncharged molecules that can pass unhindered through the membrane. This is the s

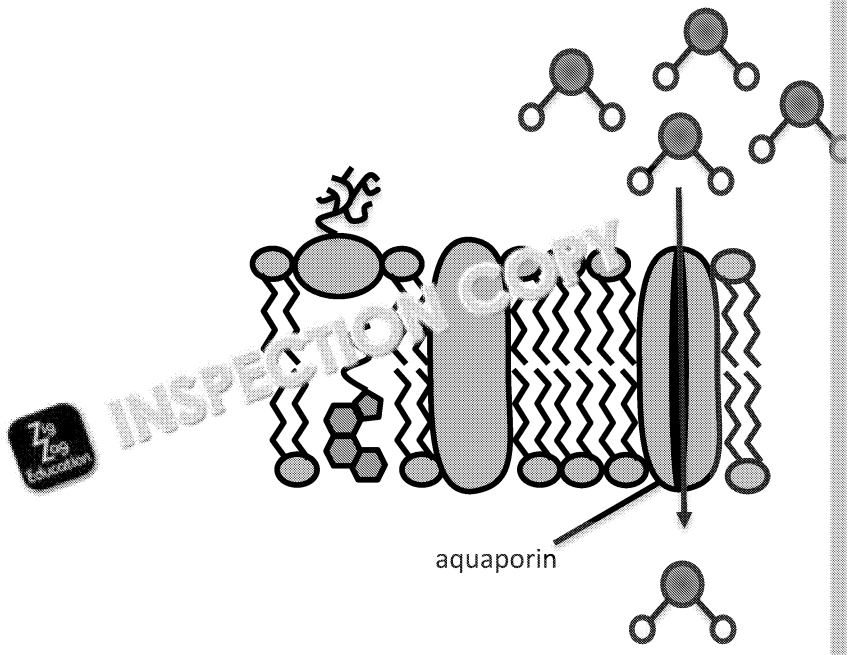
Facilitated diffusion is the next step up; as with diffusion, particles diffuse down the move through a protein channel instead of the phospholipid bilayer. Some ions a cannot pass through the hydrophobic middle of the membrane. Channel proteins proteins do, and both provide selective permeability.

The simplified diagram below shows glucose being moved through the cell membr



Osmosis is a specialised form of diffusion: it is the net movement of water particles potential to an area of lower water potential, therefore down the water potential g permeable membrane. In order to facilitate the movement of the polarised water hydrophobic bilayer, the water molecules pass through aquaporins: integral memb whole membrane).

The diagram below shows water passing through an aquaporin, an integral membr

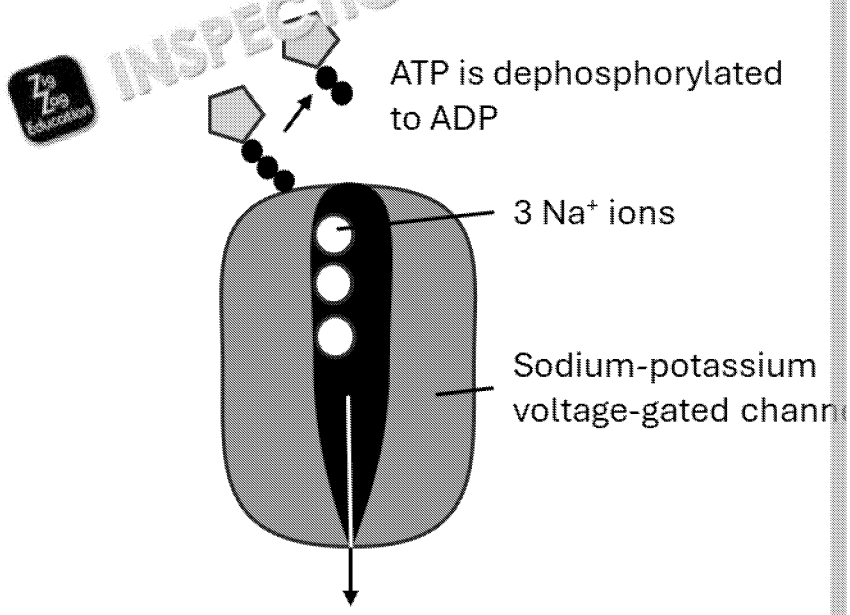


Active transport

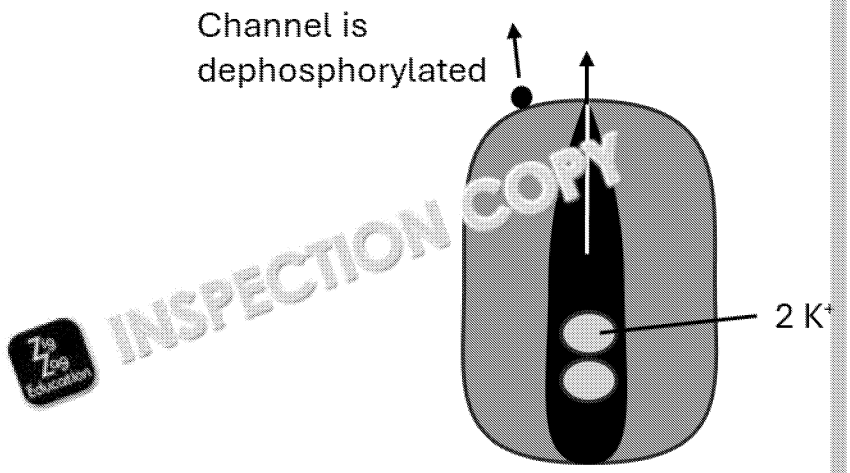
Active transport is the net movement of particles against the concentration gradie
requires ATP.

Indirect active transport requires the passive movement of one substance to enabl
Examples include the movement of glucose from the small intestine into the blood
the kidney nephron, using a sodium-dependent glucose cotransporter. Sodium io
the concentration gradient, and ATP is used to transport glucose against the conce
substances are transported in the same direction, from outside to inside the cell, a
carrier protein.

Gated channel proteins are another example of active transp . Sodium-potassiu
found in neurone axons and are responsible for ge ti membrane potential.
molecule bind and, on dephosphorylation of P, Na$^+$ ions are moved through



Next, two K$^+$ ions bind to the inside of the channel, causing the dephosphorylation
causes it to change shape and transport the K$^+$ ions through the membrane and o



Bulk transport

When many molecules need to be transported at once, or the substances to be mo
through membrane proteins, bulk transport is required. Transport into the cell is c
out of the cell is called exocytosis. Bulk transport occurs when a part of the phosp
breaks off into a vesicle.

Endocytosis involves the **invagination** of the main cell membrane around a substa
external to the cell, thus capturing it and bringing it into the cell. Phagocytosis (us
capture and destroy invading pathogens) and pinocytosis (used to transport liquid
cell) are examples of this process.

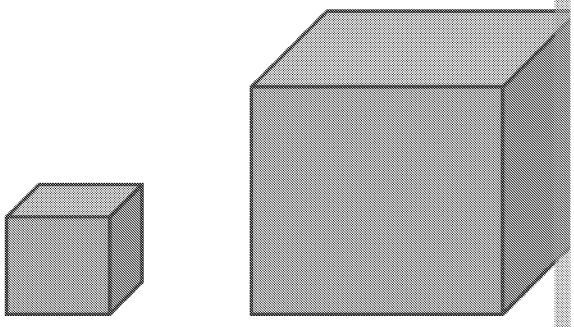
Exocytosis involves converting part of an organelle, such as the Golgi body or the r
into a vesicle. This is used when transporting carbohydrates, lipids and proteins fo
in digestion or with antibodies.

Test your knowledge

- State the difference between phagocytosis and pinocytosis.
- Describe the differences between diffusion, osmosis and facilitated diffusion.
- Explain why bulk transport may be used instead of active transport.

Surface-area-to-volume ratio

The surface-area-to-volume ratio describes how the surface area of an organism re
Generally, as an organism's size increases, the surface-area-to-volume ratio decrea
area over which substances can diffuse to supply the growing volume.



1cm wide	2cm wide
SA = 6cm^3	SA = 24cm^3
V = 1cm^3	V = 8cm^3
Ratio = 6:1	Ratio = 3:1

Surface area and its relationship to the volume of matter contained within the surfa
diffusion: the surface area limits how much diffusion can take place per second – th
the distance that the substances have to travel once they have got over the initial c
substances have to travel, the longer this will take, so the larger the cell is, the less
nutrients in and waste products out at a rate throughout the whole cell that allows

To get around this, organisms have instead evolved to split one large cell into lots
them specialised functions within the organism's body, and create systems such as
that enable substances (such as oxygen and carbon dioxide) to be exchanged at o
the lungs), and then transported around the body (by the circulatory system) to wh
the other cells). Each cell in a multicellular organism's body has a highly specialise
that cell to work as effectively as possible. Some of these specialised cells were ex

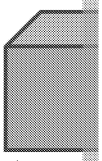
Understanding the impact of surface-area-to-volume ratio on aspects such as cell s
is fundamental in biology. It underpins many of the unique adaptations seen in m
organisms' bodies.

Calculating surface-area-to-volume ratio is usually done on the assumption that th
cuboid in shape. However, this is obviously not true of any organism, and most or
adaptations which maximise surface-area-to-volume ratio. In the example of the g
area of the lungs of humans is vast: if the lungs were spread out to their maximum
approximately half a tennis court! However, this is bundled up within the body int
thereby creating a vast surface-area-to-volume ratio. Plants have similar adaptatio
of a leaf is maximised to ensure light collection and gas exchange for photosynthes
roots of plants have a substantial surface area created by the protrusions of the roo
surface area by approximately 23 times!

Let's look at that in more detail:

If a root hair cell is a 15 [illegible] then:

surface area = width × height × number of faces
= 15 µm × 15 µm × 6
= 1350 µm²



volume = width × height × depth
= 15 µm × 15 µm × 15 µm
= 3375 µm³

not to

So, its surface-area-to-volume ratio is 1350 : 3375 or 1 : 2.5 (0.4 : 1)

However, the root hair cell has a hair-like protrusion. Let's say that measures 1500
of 5 µm. So, the surface area and volume of the protrusion are:

surface area = width × height × number of faces
= 1500 µm × 5 µm × 4 faces (we will ignore the small surfaces at each
accounted for in the main cube)
= 30 000 µm² + 1350 µm² = 31 350 µm²

volume = width × height × depth
= 1500 µm × 5 µm × 5 µm
= 37 500 µm³ + 3375 µm³ = 40 875 µm³

So, the surface-area-to-volume ratio of the root hair cell with protrusion is 31 350
is nearly twice that without the protrusion.

Test your knowledge

- State the equations for calculating surface area and volume.
- Describe why surface-area-to-volume ratio is such an important factor when
organism's body.

Recall questions: Cell transport mechanisms

1 Calculate the total surface-area-to-volume ratio of a cube-shaped organism
adaptations that may be present to increase this ratio further. (5 marks)

2 Suggest why root hair cells have a large number of mitochondria and many
in their cell membrane. (3 marks)

3 Mitochondria, chloroplasts, vacuoles, the nucleus, and endoplasmic reticula
membrane-bound organelles within eukaryotic cells. Explain why organelle
membrane. (3 marks)

C2 Enzymes as biological catalysts

Key points covered

- Enzyme structure and function
- Models describing enzyme function, including collision theory and lock and key theory
- Calculating rate of
- Factors that affect pH, temperature a

Enzyme structure

Enzymes are biological **catalysts**: they speed up the rate of a reaction, perhaps by several million times. If it weren't for enzymes, it is unlikely that life on Earth would exist, as the rates of reaction would be so slow life would not be able to survive and evolve.

Enzymes are globular proteins, folded into a specific tertiary (3D) structure which contains an active site where the substrate binds, and the reaction is catalysed. Some enzymes have conjugates, known as cofactors, which activate the enzyme when bound, and leave the enzyme in its inactive, apoenzyme, state when not bound. This is useful for controlling enzyme function, especially if the chemical reaction it is catalysing must only be conducted on molecules outside of the cell, such as in digestion.

Test your knowledge

- Describe the structure of an enzyme.
- Describe how cofactors control enzyme function.

Function of enzymes

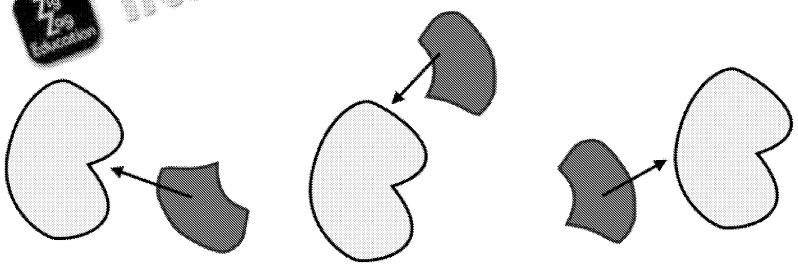
Enzymes catalyse chemical reactions by bringing together substrates to be **anabol** or enabling the **catabolism** of one substrate into two or more smaller products. T are not used up in the process and remain available to catalyse further reactions.

Enzymes are highly specific for their substrate(s). The active site is shaped such tha only one substance can be rightfully catalysed by the enzyme, although similarly s molecules can act as inhibitors by temporarily or permanently blocking the active s and preventing the actual reaction from taking place.

Several theories exist to explain how enzymes function, including collision theory a

Collision theory

Collision theory explains that in order for a reaction to take place, the enzyme an successfully. This means that the substrate(s) must enter the active site of the enzy the reaction to be catalysed. The higher the number of successful collisions, the hi



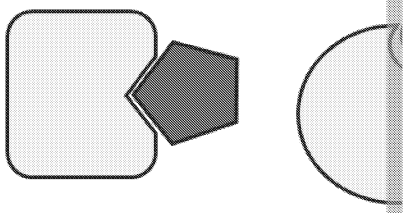
None of these collisions will result in a successfully catalysed reaction.

Lock and key theory

The lock and key theory states that the shape of the substrate and the shape of the
specific and complementary to each other. Just like a lock and its key, only one su
site of an enzyme to form the enzyme–substrate complex. This requires both the c
combination, plus a successful collision.

Be clear though: it is a complementary fit; the enzyme and substrate are **not** the same shape.

All of these enzymes and their substrates are specific and complementary to each other.



Measuring rates of reaction

The rate of reaction is a measure of how quickly the enzyme is converting substrate
of reaction is the fastest, as the greatest number of substrates exist in solution, and
chance that the enzyme and substrate will collide successfully, rather than the enzy
This is why, provided that all other conditions remain the same throughout the exp
reaction is the fastest, it provides the best indication of the overall rate of reaction.

Test your knowledge

- Describe the structure of an enzyme.
- Write a sentence with fewer than 10 words which summarises the collision t
- Convert the stages of the lock and key theory of enzyme function into a flow
- Explain why the initial rate of enzyme reaction will be fastest.

Factors affecting enzyme activity

The rate of an enzyme-catalysed reaction is at its fastest when all conditions are op
temperature, pH, enzyme concentration and substrate concentration.

Effect of temperature

Temperature represents how much kinetic energy is available in a system.
At low temperatures, kinetic energy is low, so particles move slowly.
Their low speed and low energy collisions mean that reaction rate is low.

As temperature increases, kinetic energy increases. This increases both the speed that the particles move at, and the energy with which they collide. Therefore, as temperature increases, rate increases.

An increase in rate continues up until the optimum temperature, when rate reaches its maximum. After this, an increase in temperature causes a decrease in rate as the enzyme denatures. Essentially, kinetic energy continues to increase but, while this makes the particles move faster and collide with more energy, the particles in the enzyme itself vibrate faster which, at temperatures beyond the optimum, destabilises the shape of the enzyme, leading to denaturing.

At temperatures just above the optimum, denaturing is not permanent and can be reversed. However, when the temperature moves significantly beyond the optimum denatured and this cannot be reversed.

The optimum temperature and the degree to which an enzyme can withstand above by enzyme, and also between different species variants of enzymes. For instance, e that live in very cold conditions have low optimum temperatures and cannot withst the optimum. However, organisms which live in very hot conditions have enzymes temperatures and are usually much more thermostable. Amylase, responsible for c very thermostable and can function well at temperatures at least 20 °C beyond its

Effect of pH

The pH of a substrate measures the number of H^+ ions present within the solution. H^+ ions, the lower the pH and the more acidic the solution is.

Enzymes work optimally in a narrow pH range, dependent on the conditions. Enzy stomach are optimised for pH 0–2 (enzyme 1 on the graph), whereas enzymes that optimally in pH 8–9 (enzyme 3 on the graph). Most cellular enzymes work best at graph), but this varies throughout the cell depending on the type of reactions bein unique conditions within the organelle.

At the optimum pH, the enzyme is surrounded by the appropriate balance of positive and negative charges to allow it to adopt its correct shape and therefore its specific active site. This means that reaction rate will be fastest because the enzyme is specific and complementary to its substrate.

At pHs outside of the optimum pH, in either direction, the number of positive and negative charges in solution changes and this affects the shape of the enzyme. Ions in the active site which were preferentially hidden away from charges in the surrounding solution may well move to be nearer it, while ions on the outside of the enzyme may be repelled towards the centre of the enzyme by the surroundings. This causes disruption to the shape of the enzyme, denaturing it.

As with temperature, minor movements away from the optimum pH can be tolerat rate of reaction, they will not cause it to stop entirely. A return to the optimum pH renature and rate to return to its optimum. However, the further away from the op the lower the reaction rate will be until reaction rate reaches zero. The enzyme will cannot be reversed.

Effect of substrate and enzyme concentration

Substrate and enzyme concentration affects rate because of the availability of molecules to either be catalysed or do the catalysis. In either case, as the concentration increases, the rate increases until another factor limits the rate of reaction. For instance, as substrate concentration increases, the rate increases until the concentration of enzymes limits the rate of reaction because there are simply not enough enzymes to catalyse the reaction any faster, and adding more substrate does not improve this situation, but rather creates a longer queue! Similarly, if enzyme concentration is increased, reaction rate increases until the substrate concentration reduces because all the substrates have been converted into products. At this point, enzymes are empty and unable to catalyse the reaction because of the lack of substrate. In both scenarios, adding more of the other part (more enzyme if substrate concentration is increasing, or more substrate if enzyme concentration is increasing limiting factor is reached. This assumes that temperature and pH are both optimal

Test your knowledge

- Describe the effect of increasing temperature increase up to the optimum on rate of en
- Draw a graph to show how pH affects the rate of enzyme reaction.
- Describe how the rate of reaction changes as enzyme concentration changes

Recap questions: Enzymes as biological catalysts

1 Amylase, present in the mouth to digest starch into maltose, is denatured i Explain why. (5 marks)

2 Hyperthermia (extreme heat) can be fatal. Explain why this is the case, with r

3 If supermarket trolleys are substrates, and checkout tills are enzymes, use t increasing enzyme concentration will increase rate. (2 marks)

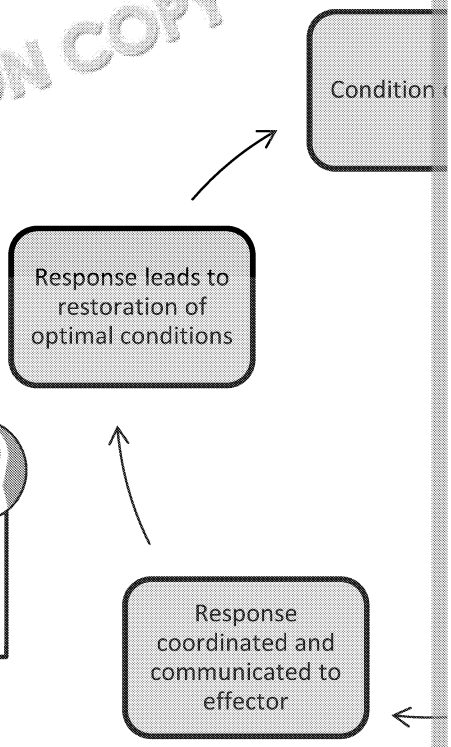
C3 Homeostasis

Key points covered

- The purpose and general function of homeostasis
- Examples of negative feedback loops and how they control body function
- Positive feedback loops and how they control body function
- The roles of the auton nervous systems
- The role of the endoc adrenaline response
- What happens if hom

What is homeostasis?

Homeostasis is the maintenance of a constant internal environment. As the conditions move away from th optimum, receptors c s detect the change m nicate this to the control The control centre coordinates the response and sends a message to the effector which leads to changes that bring conditions back to the optimum once more.



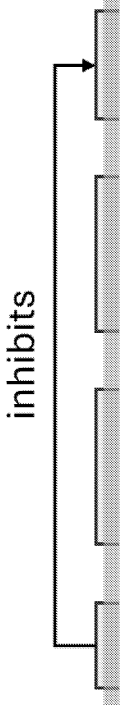
Test your knowledge

- Give a definition for the term homeostasis.
- Draw a flow chart to show the process of homeostasis.

Negative feedback loops

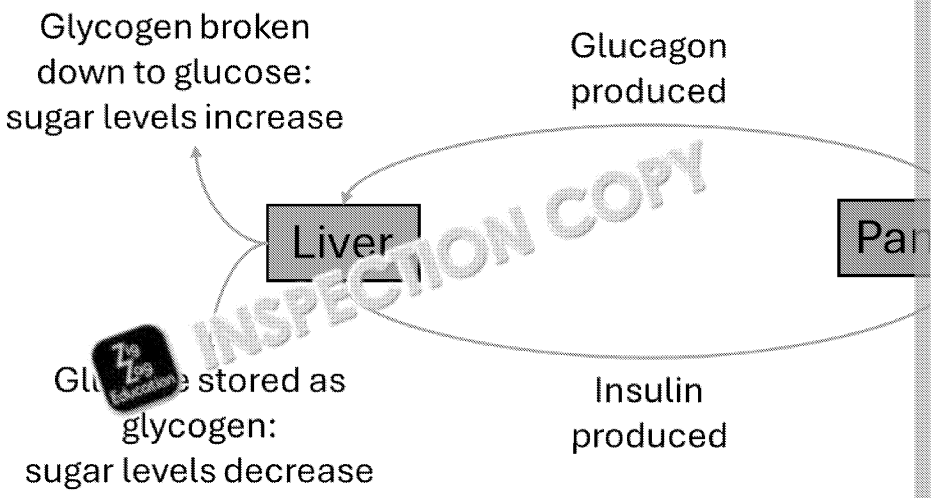
Negative feedback loops operate an internal braking system. The production of one response inhibits the driver of that response, and this provides a self-regulating system.

As the second response decreases, the inhibition of the first response decreases too. This enables the first respons to trigger more of the second response, which inc ea es ortion of the first response. This keeps the le el a latively constant rate because accelera i by he first response causes the second response to s d n the first response.



Blood sugar levels

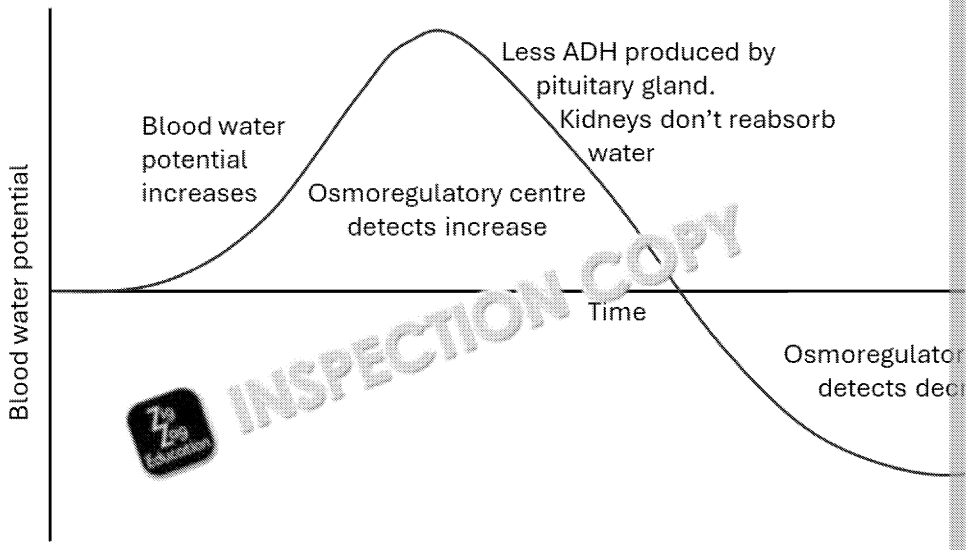
Blood glucose level homeostasis is maintained through negative feedback. As glu
is triggered to release insulin, which drives the liver to convert glucose into glycog
the blood sugar level, causing the reduction in insulin production and, if levels dec
glucagon instead. Glucagon encourages the liver to break down glycogen into glu
blood. This continuous adjustment maintains blood glucose homeostasis.



Body fluids (osmoregulation) and blood pressure

Osmoregulation (blood water potential) is regulated by the osmoregulatory centre
and controlled by the kidneys. As blood water potential increases, the osmoregula
and causes the pituitary gland to secrete less ADH (antidiuretic hormone). Less AD
are inserted into the kidney tubules, so less water is reabsorbed, and more is sent t
More dilute urine is produced, and the water potential of the blood returns to opti

If water potential decreases, this too is detected by the osmoregulatory centre and
secrete more ADH. More aquaporins are inserted into the kidney tubule walls, mea
reabsorbed and less water is sent to the bladder for excretion. More concentrated
potential returns to optimum levels again.



Blood pressure changes due to many different factors, including the restriction or
blood volume and concentration of solutes such as sugar, and changes triggered b
to managing blood pressure is by adjusting blood volume. Baroreceptors present
can also trigger the pituitary gland to either increase or decrease its release of AD
same as above.

Gas concentration

Gas concentration in the blood is controlled by gas exchange at the lungs; howeve
depending on the concentration of carbon dioxide and oxygen in the blood. As ca
sensory receptors detect the change and send nerve signals to the diaphragm and
breathing (inhalation and exhalation) and thus the release of carbon dioxide from t
oxygen into the blood via the lungs. If carbon dioxide levels increase quickly, these
frequently, increasing breathing rate, leading to deeper and more rapid breathing s

Test your knowledge

- Draw a summary process diagram to show how homeostasis is maintained w
- Draw and label a graph to show how blood glucose le[illegible]s change over the c
  this is monitored and responded to.

Positive feedback loops

Fewer syste[illegible] c[illegible]d by positive feedback loops. These operate by [illegible]ng a response which increases the number of triggers, thus increasing the strength of response further. This drives the situation increasingly quickly away from the initial starting point, as the response escalates.

Blood clotting

Blood clotting is one example of a positive feedback loop. This is desirable because blood clotting reduces blood loss and therefore increases survival chances. Blood clotting occurs when a blood vessel is damaged. Substances released by the damaged blood vessel wall cells encourage platelets to accumulate at the site. These platelets in turn release more of this hormone, which attracts more platelets to the site, which release more hormone, attracting more platelets. This causes the very rapid accumulation of platelets at the site of injury, leading to a swift and growing blood clotting response.

triggers

Labour contractions

Labour contractions are another example of a positive feedback loop. In preparatio
mother will experience uterine contractions which increase in frequency and intens
the baby being born. This is caused by the pituitary gland releasing a hormone cal
uterine contractions, which push the baby down towards the birth canal. As the ba
cervix, this makes the cervix trigger the pituitary gland to release more oxytocin. U
frequency and intensity as this positive feedback loop escalates and only ceases wh
have been delivered.

Test your knowledge

- Use the flow chart [illegible] to convert either the blood clotting or the labou
  into a [illegible]ch

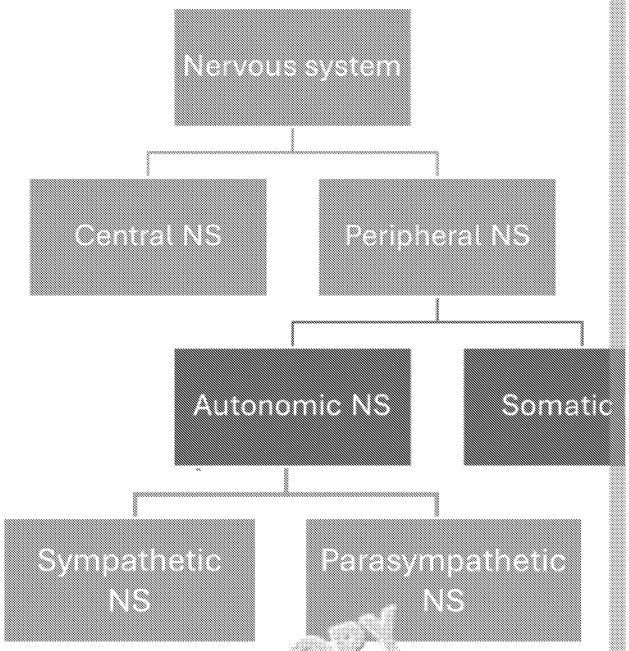
The nervous and endocrine systems

The nervous and endocrine (hormone) systems are interconnected, and each can t
their own system. For instance, in the positive feedback example of labour contra
on the cervix sends nervous signals to the pituitary gland, which triggers the relea
Likewise, the detection of changes in blood water potential by the hypothalamus c
to the pituitary gland which causes it to change the amount of ADH released, whic
reabsorbed by the kidneys.

The nervous system produces short-lived, rapid responses, using neurones to conv
the body. The endocrine system, conversely, produces responses that last longer (
reversed, such as with growth or puberty) but are delivered more slowly, using the
messages with hormones which attach to receptors on the ... et cells.

Nervous system	Endo
Rapid response	Slower response
Short-lived respon...	Longer-lived response,
Uses neur...	Uses bloodstream
Electrical signals	Hormonal signals
Triggers muscles or glands	Triggers target cells via

The peripheral nervous system



The nervous system is divided into two ma... tic... the central nervous system a
system. The central nervous syste... ...e brain and spinal cord, and the pe
all the other parts of the ... ...em. As a result, the central nervous system co
whereas the ... ...he ... ...ous system contains sensory and motor neurones.

The peripher... ...ervous system is further subdivided into the somatic nervous system a
The somatic nervous system is responsible for all consciously controlled responses: an
control happens through the somatic nervous system. Sensors (such as for taste, smel
pressure) send signals through sensory neurones, and responses are coordinated and
to effectors (skeletal muscles or glands). The autonomic nervous system controls unco

All nervous responses start with a stimulus, which is detected by a receptor. The si
neurones to the control centre (usually the brain but could be the spinal cord or a
is coordinated via relay neurones. The effect is transmitted via motor neurones to

The autonomic nervous system

The autonomic nervous system is responsible for the automatic control of body sy
rate and digestion. These systems are adjusted automatically and without conscio
involuntary. They operate using sensors which detect changes to the status. This
to a control centre (such as the brain or the pancreas), which coordinates the respo
muscles (smooth or cardiac) or glands, to deliver an appropriate response. Any pa
nervous or endocrine, and it often switches between the two systems.

The autonomic nervous system is divided into two further sections: the sympathet
The sympathetic system controls the excitation responses, including the adrenaline
system controls the relaxing responses, including sleep.

The role of the hypothalamus

The hypothalamus is a small section of th[illegible] which is responsible for controllin
It has two areas which deal with th[illegible]etic and parasympathetic nervous syst
for many functions, includi[illegible]oural responses such as sleeping, eating and t
next), maint[illegible]asis through negative feedback loops, including blood
levels, and i[illegible]ucing hormones which trigger hormonal production in other pa
pituitary glan[illegible] which is situated directly next to it. It therefore has both nervous a
enables the efficient communication between these two systems.

The adrenaline response

The adrenaline response is a sympathetic nervous system response leading to a fig
When a situation is encountered which triggers the adrenaline response, such as a
unpredictable situation, the hypothalamus triggers a range of nervous and hormon

One set of responses involves the activation of the sympathetic nervous system wh
smooth muscles and also activates the adrenal medulla which causes the release o
hormones into the blood.

A second set of responses involves the hypothalamus activating the adrenal-cortic
causes the pituitary gland to release a hormone which travels to the adrenal cortex
hormones into the blood.

The adrenal glands are found on the top of the kidneys and are responsible for the
of hormones. Those hormones released through the adrenaline response cause ma
body, including:

- an increase in heart and breathing rate, to ensure maximum oxygen saturatio
- a suppression of digestion and the redirection of blood from the digestive sys
  (such as those required for running);
- the dilation of pupils, to maximise visual acuity;
- diversion of brain function away from managi[illegible]u[illegible]asking to solely concen
  responded to;
- a release of glucose from sto[illegible]s liver and muscle cells), to enable high
  maximum ATP produ[illegible]

This comple[illegible]multifaceted response involves the nervous and endocrine syste
body, in a ra[illegible]y produced response which can last a reasonably long time.

Test your knowledge

- Create a tree diagram to show how the nervous system is divided into its se
- Create a flow diagram to show how the adrenaline response occurs through
  hormonal responses.
- List the physiological responses of the adrenaline response.

Disturbing homeostasis

If homeostasis is not maintained, ill health will be experienced. The ability to maint very young and the very old and can be affected by a number of factors. As the bo homeostasis effectively deteriorates, as nervous pathways, receptors and effectors responsive. Glands which produce hormones can produce less hormone, which me loops become less effective because less hormone is released initially, meaning less happens as a result. Disturbances in thyroid hormone levels are common in older maintain blood pressure. This can lead to damage to the heart which, when couple conditions such as diet and exercise levels, can lead to life-critical conditions such a diabetes, and stroke.

Drug and alcohol abuse cause a great range of damage to the body, including by a damage to heart and cardiovascular tissue, affecting heart rate and rhythm control, including to the liver, lungs and digestive system, and impairment in brain function This can lead to loss of memory or other conscious functions such as reasoning, sp impairment of core functions such as homeostasis and sleep.

These effects build up gradually over time, and do not require excessive use of cocaine, to be visible. Occasional cigarette smoking, and drinking small but regular these impacts if sustained over a long period of time.

Maintenance of a well-balanced diet, regular and varied exercise and only small an consumption will enable the body to maintain optimum health conditions for as lo events excluded.

Test your knowledge

- List three factors which can cause a reduction in the body's ability to maintai
- State two symptoms of poor homeostatic control.

? *Recap questions: Homeostasis*

1 A student drinks a large quantity of a very sugary drink. Describe and expla this. (8 marks)

2 Another student is about to deliver their first major presentation to their s They are feeling nervous and have sweaty palms, a high heart rate, and are effects have been triggered. (5 marks)

3 Plants respond to hormones through positive feedback loops, too. The ho ripening via a positive feedback loop. Describe how this response occurs, understanding of human positive feedback loops. (4 marks)

Answers for Recap Que

A: Structure and function of cells and ti

Structure and function of cells and tissues

1. Plasma membrane: controls entry and exit of substances from the cell (1); cel
   capsule provides protection from external environment (1)
   Each part provides a different form of control or protection (1)
   Without which the bacteria would be more susceptible to damage from exter
2. Cell wall provides structural support and strength (1); the vacuole provides tu
3. Stained with crystal violet (1); fixed with iodine (1); w[illegible] with alcohol (1); a
   microscope (1)
4. Prevent the lens and slide/specimen [illegible]g each other (1); which could da
5. Correctly arranged equation: A = [illegible]age size ÷ magnification (1)
   Correct use of equation: A = 143.56 mm or 143 560 µm ÷ 148 000 (1)
   Conver[illegible]or [illegible] to µm, either before the division or after (1)
   Correc[illegible]r in micrometres: 0.97 µm (1)

Structure and function of specialised cells in multicellular o

1. Two potential symptoms from: difficulty stopping bleeding; bruising under th
   tiredness (2)
   Dangerous if left untreated because could lead to significant blood loss (1)
2. Damage will be removal of hair-like protrusions from root hair cells (1)
   This will significantly reduce the surface area of the root (1)
   And reduce the uptake of water and mineral ions into the plant (1)
3. Lignin required for xylem walls (1)
   Makes walls impervious to water (1)
   Lack of lignin may prevent water and mineral ions from being transported up
   This would slow growth, causing dwarfism (1)

Structure and function of biological tissues

1. Cells are in one layer thick (1) and closely grouped together (1) to form a me
   Epithelial tissue forms linings of lungs and other organs (1)
   Endothelial tissue forms lining of blood vessels (1)
2. Myofibrils are aligned end to end (1) and fibrils form fibres (1) which form mu
   Fibres are aligned in the same direction (1) so that when muscle fibres contra
   create a larger effect (1)
3. During resting potential, the membrane is impervious to sodium ions because
   closed (1), partially permeable to potassium ions because the potassium ion g
   ions are only transported through the sodium potassi[illegible]ump (1).
   On activation, the sodium ion channel opens [illegible]nd th[illegible]embrane becomes pe
   increases the membrane potential (1) [illegible]diu[illegible]ions diffuse into the axon (1).
   The potassium ion gateway o[illegible]en[illegible], increasing the permeability of the me
   depolarises the axon [illegible]
   After h[illegible]pola[illegible], membrane potential returns to the resting potential a
   returns [illegible]mal (1).

Preview of Answers Ends Here