Upper Secondary Pure Biology – Subject Code: 6093

How to use?

- This deck of notes can be used as an in-depth study guide for O level pure Biology. It contains notes for all 18 chapters found in the biology textbook, with much content adapted from the textbook, notes and exam papers.
- You are highly encouraged to add additional notes for yourself or techniques/frameworks to memorise concepts. You can choose to print this deck of notes or edit them online.
- This deck of notes is highly recommended for revision before exams and tests, as it allows students to cover all the chapters in-depth.
- This deck of notes are arranged according to the Marshall Cavendish "Biology Matters" textbook.
- What to expect for every chapter
    - O level syllabus overview
    - Notes for the chapter in Cornell form
    - Highlight of key terms
    - "O Level syllabus" important notes

Final Tips

- This deck of notes should NOT replace what you learn from your teachers. This can only act as a supplementary to aid your learning.
- When in doubt, ALWAYS FOLLOW what your BIOLOGY TEACHERS say
- Spread the word and share the notes ☺ (Sharing is caring guys!)
- Further questions – ask me! (I'll try to reply as soon as possible) https://t.me/your101nolifer
- ALL THE BEST FOR YOUR STUDIES!

Done by MF (completed in 2024)

Chapter 1: Cell Structure and Organisation

O Level syllabus

- identify and state the functions of the following cell structures (including organelles) of typical plant and animal cells from diagrams, light micrographs and as seen under the light microscope using prepared slides and fresh material treated with an appropriate temporary staining technique: cell wall, cell membrane, cytoplasm, nucleus, cell vacuoles (large, sap-filled in plant cells, small, temporary in animal cells), chloroplasts
- identify and state the functions of the following membrane systems and organelles from diagrams and electron micrographs: endoplasmic reticulum, Golgi body, mitochondria, ribosomes
- compare the structure of typical animal and plant cells
- explain how the structures of specialised cells are adapted to their functions (e.g. muscle cell – many mitochondria to supply more energy, root hair cell – large surface area of cell membrane for greater absorption, red blood cell – lack of nucleus allowing it to transport more oxygen)

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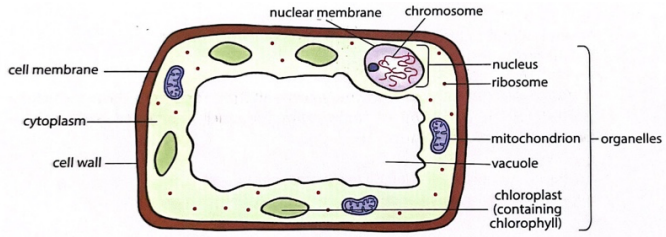
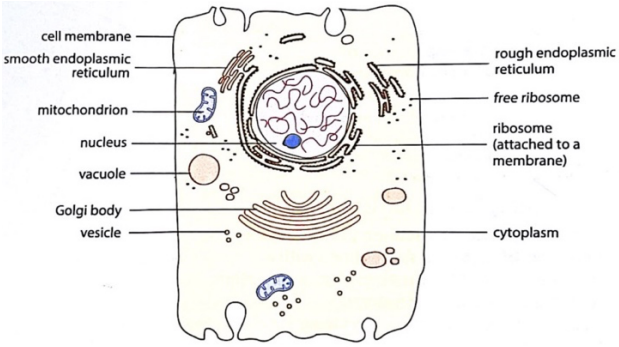
Cells

What is a cell?	A cell is a unit of life. It consists of a mass of living matter called protoplasm.
What does a protoplasm consist of?	The protoplasm consists of the cell membrane, cytoplasm and nucleus
Parts of a cell 'O Level Syllabus'	 **Figure 1.5** A generalised plant cell  **Figure 1.6** Organelles in an animal cell seen under an electron microscope *Cell membranes* - Partially permeable membrane that controls substances entering or leaving the cell *Cell Wall* - Fully permeable - Protects the cell from injury, gives the plant cell a fixed shape *Cytoplasm* - Contains organelles - Site where cell activities occur *Nucleus* - Controls cell activities such as cell growth and repair of worn-out parts - Essential for cell division

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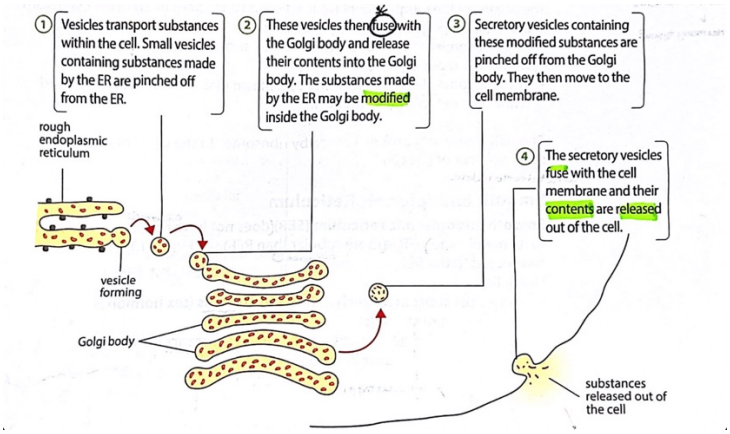
	- Contains DNA (in the form of chromatin) *Rough Endoplasmic Reticulum* - Studded with ribosomes - Synthesises proteins and transports them to the Golgi Body for secretion out of the cell *Ribosomes* - Attached to RER: Synthesises proteins that are transported out of the cell - In cytoplasm: Synthesises proteins that are to be used within the cell *Smooth Endoplasmic Reticulum* - Synthesises fats and steroids - Converts harmful substances into harmless substances via detoxification *Golgi Body* - Chemically modifies substances made by the RER - Stores and packages these substances into vesicles for secretion out of the cell (MSP = modifies, stores, packages – Malay Special Programme)  *Mitochondria (plural) / Mitochondrion (Singular)* - Site of aerobic respiration, where food substances like glucose is broken down to release energy for cell activities (growth and reproduction) *Chloroplasts* - Found in plant cells - Contains chlorophyll which converts light energy to chemical energy for the formation of glucose during photosynthesis *Vacuoles* - Store substances within the cell

<table>
<tr><td></td><td>- Plants: Large, contains sugars, mineral salts and amino acids
- Animals: Many small, contains water and food</td></tr>
<tr><td>Plant cell V.S.
Animal cell

‘O Level Syllabus’</td><td>
<table>
<tr><th>Organelle</th><th>Plant</th><th>Animal</th></tr>
<tr><td>Cell wall</td><td>Present</td><td>Absent</td></tr>
<tr><td>Chloroplast</td><td>Present</td><td>Absent</td></tr>
<tr><td>Vacuole</td><td>One large central vacuole</td><td>Many small vacuoles</td></tr>
<tr><td>Centrioles</td><td>Absent</td><td>Present</td></tr>
</table>

(don’t need to know centrioles)
</td></tr>
</table>

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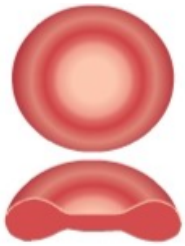
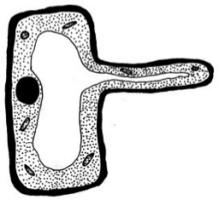
Specialised cells → 'O Level Syllabus' (MUST KNOW)

Red Blood Cell 	- Contains haemoglobin which binds to oxygen and transport it round the body. - Circular and biconcave shape to increase surface area to volume ratio so that oxygen can diffuse in and out at a faster rate. - No nucleus to enable cell to store more haemoglobin for oxygen transport - Is flexible and can squeeze through capillaries easily
Muscle Cell	- Is elongated and cylindrical in shape, contains many nuclei and mitochondria - Many mitochondria to supply energy for contraction of muscles.
Root Hair Cell 	- Long and narrow protrusion increases surface area to volume ratio for faster absorption of water by osmosis and mineral salts by diffusion and active transport from the soil solution. - Cell contains many mitochondria which release energy during respiration needed to transport mineral salts from the soil solution into the root hair cell by active transport.
Xylem Vessel 	- The xylem vessel has an empty lumen without protoplasm or cross-walls. This reduces resistance to water flowing through the xylem. It allows water and dissolved mineral salts to be conducted from the roots to the stems and leaves at a faster rate. - The xylem walls are thickened with lignin, which prevents the collapse of the vessel as it is hard and rigid. This provides mechanical support to the plant.

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Chapter 2: Movement of substances

O Level syllabus
- define diffusion and describe its role in nutrient uptake and gaseous exchange in plants and humans
- define osmosis, investigate and describe the effects of osmosis on plant and animal tissues
- define active transport and discuss its importance as an energy-consuming process by which substances are transported against a concentration gradient, as in ion uptake by root hairs and uptake of glucose by cells in the villi

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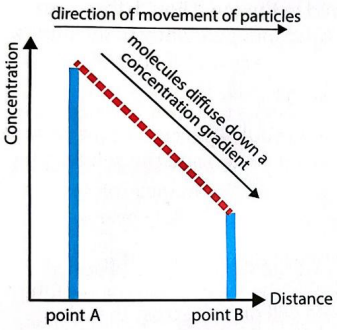
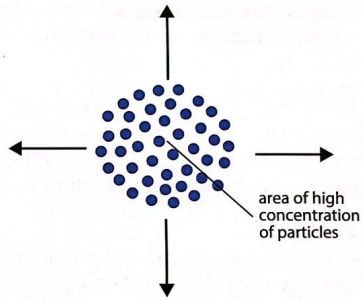
Diffusion

Concentration gradient "O level syllabus" (just need to know the term "concentration gradient")	Concentration refers to the amount of a substance within a fixed volume. Concentration gradient is the difference in concentration between two regions. (As particles of fluids poses kinetic energy, they continuously move. Since their movement is random, the particles will diffuse down the concentration gradient and become evenly spaced out after some time  **Figure 2.2** Graphical representation of diffusion  **Figure 2.3** Arrows showing direction of movement of particles as they space out
Diffusion "O level syllabus"	Diffusion is the net movement of particles (atoms, molecules or ions) from a region of higher concentration to a region of lower concentration, which is down a concentration gradient.
Diffusion across a membrane	A partially permeable membrane allows both the solvent and the solute to pass through. As a result, there can be an equal concentration of all particles on both sides of the membrane.

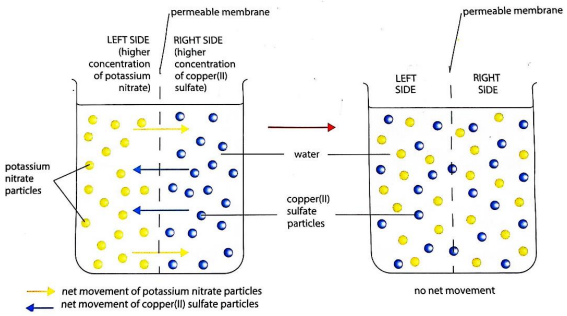
<table>
<tr>
<td></td>
<td> 

Figure 2.5 Diffusion of potassium nitrate and copper(II) sulfate particles through a permeable membrane</td>
</tr>
<tr>
<td>Factors that affect the rate of diffusion

(concentration gradient, diffusion distance, surface area-to-volume ratio)

“O level syllabus”</td>
<td><u>Diffusion distance</u>
The distance through which a substance diffuses is called the diffusion distance. The shorter the diffusion distance, the lesser time is needed for the substance to travel and rate of diffusion will be higher.

Diffusion is an important way by which oxygen and carbon dioxide move into and out of cells.

E.g.: In these situations, the diffusion distance is short, allowing diffusion to occur at a higher rate
- Exchange of oxygen and carbon dioxide in the lungs takes place by diffusion
- Plant cells such as root hair cells also take in oxygen and remove carbon dioxide by diffusion

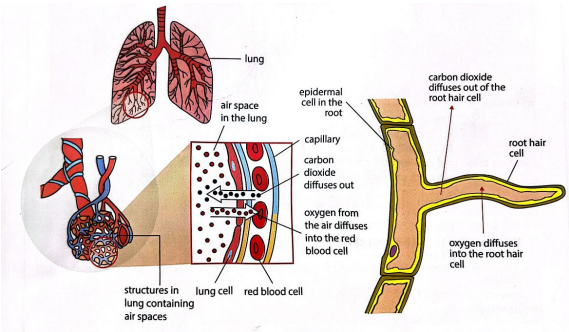
 

Figure 2.6 Gas exchange of oxygen and carbon dioxide via diffusion</td>
</tr>
<tr>
<td></td>
<td><u>Surface Area-to-volume Ratio</u>
The rate of movement of a substance across a cell membrane depends on how large the cell membrane is. The ratio between the surface area and volume of a cell is called the surface area-to-volume ratio.

The greater the surface area-to-volume ration of a cell, the higher the rate at which substances move in and out of it, higher the rate of diffusion.

Some cells are specifically adapted to absorb substances. For example, root hair cells and the epithelial cells, which line the small intestine. Such cells often have long narrow protrusions or folds in the membrane. These greatly increase the surface area-to-volume ration of the cell membrane.</td>
</tr>
</table>

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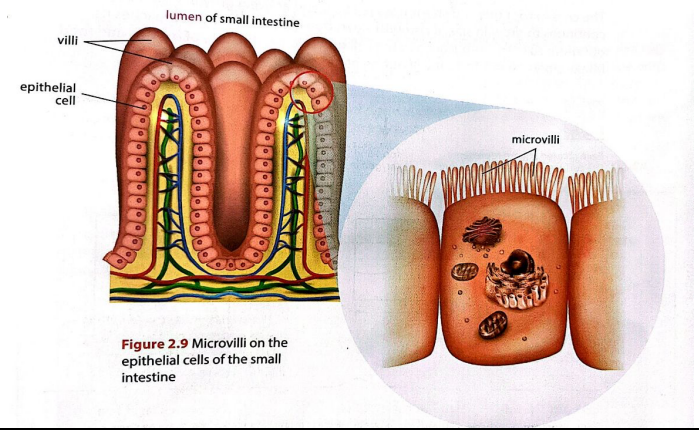
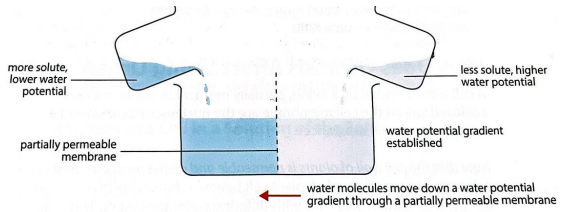
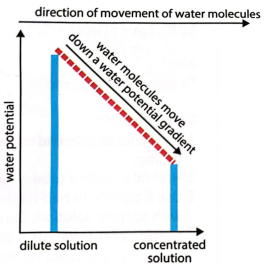
	 **Figure 2.9** Microvilli on the epithelial cells of the small intestine

Osmosis (usually test experiments for this, please know)

What is water potential?	Water potential is the measure of the tendency of water molecules to move from one place to another. A dilute solution would have higher water potential due to the lower concentration of solute. Water molecules will then move out of the dilute solution and into the concentrated solution through osmosis. When a partially permeable membrane separates two solutions of different water potential, a concentration gradient is established. Water molecules would then move from a region with higher water potential to a region with a lower one, down a concentration gradient.  **Figure 2.17** Water potential gradient set up in the container
Osmosis "O level syllabus"	Osmosis is the net movement of water molecules from a region of higher water potential to a region of lower water potential, through a partially permeable membrane. (Osmosis MUST water POTENTIAL) (CELL MEMBRANE NEEDED) 

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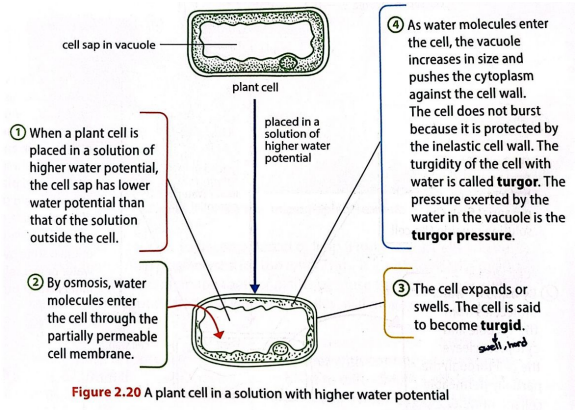
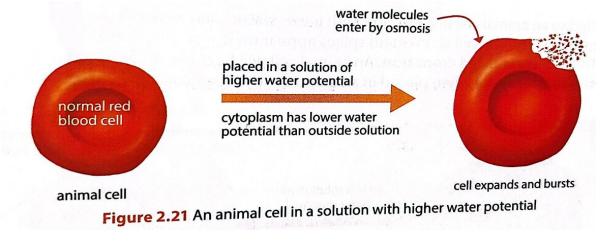
	Similar to diffusion, the rate of osmosis can be affected by factors like: - Water potential gradient - Distance over which water molecules need to move - surface area-to-volume ratio
How osmosis affects living organisms? "O level syllabus" (high water potential, low concentration of other substances / low water potential, high concentration of other substances)	<u>What happens to a cell in a solution of higher water potential?</u> When a cell is placed in a solution with a higher water potential, water molecules will move from a region of higher water potential (outside the cell), into a region of lower water potential (inside the cell). A plant cell will expand or swell. Plant cells are protected by an inelastic cell wall. Plants are supported by the pressure of water inside the cells pressing outwards on the cells wall. (describe texture: TURGID)  **Figure 2.20** A plant cell in a solution with higher water potential An animal cell will swell and may even burst in a solution of high water potential. This is because it lacks a cell wall.  **Figure 2.21** An animal cell in a solution with higher water potential
	<u>What happens to a cell in a solution with same water potential?</u> Cells immersed in a solution with the same water potential as their cytoplasm will not change their size or shape.

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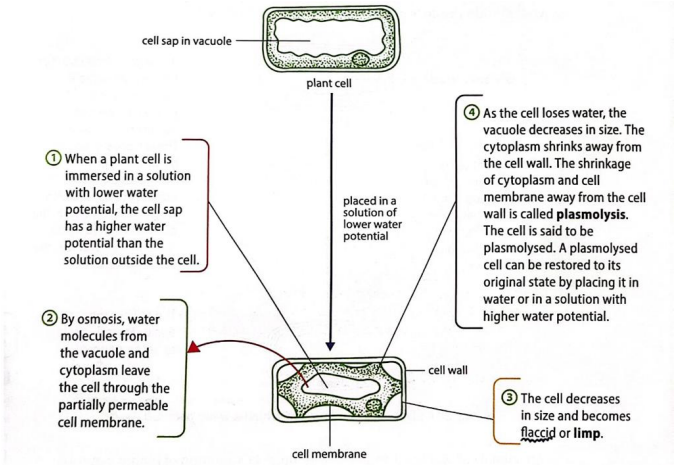
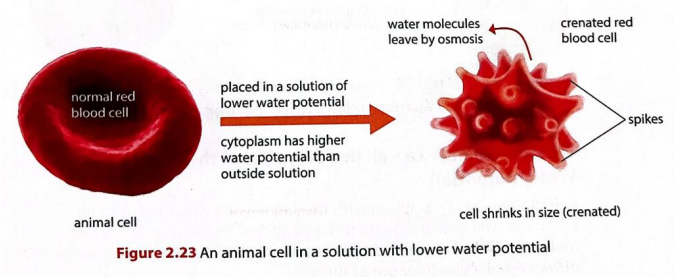
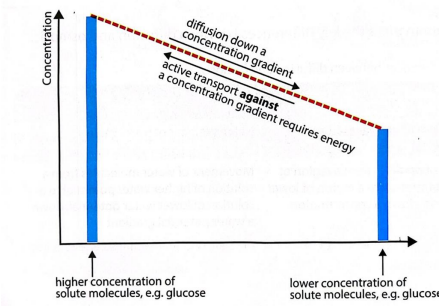
	The movement of water molecules is the same in both directions. Hence, there is no net movement of water molecules in or out of the cell.
	<u>What happens to a cell in a solution with lower water potential?</u> When a cell is placed in a solution with a lower water potential. Water molecules will move from a region of higher water potential (inside the cell) to a region of lower water potential (outside the cell) A plant cell will decrease in size and becomes flaccid.  **Figure 2.22** A plant cell in a solution with lower water potential An animal cell will lose water. The cell will shrink and spikes appear in the cell → crenation. An animal cell will eventually die due to dehydration.  **Figure 2.23** An animal cell in a solution with lower water potential
Why is turgor important to plants?	Turgor = how turgid cells are The movements of certain plant parts are due to changes in turgor. E.g.

	changes in the turgor of the guard cells causes the opening and closing of the stomata. Plasmolysis causes cells to become flaccid. Cells will be killed if they remain plasmolysed for too long.

Active Transport

Definition "O level syllabus"	Active transport is the process in which energy is used to move the particles of a substance across a membrane against its concentration gradient, that is, from a region where the particles are of lower concentration to a region where they are of higher concentration. (CELL MEMBRANE NEEDED)  **Figure 2.30** Difference between active transport and diffusion
Diffusion vs active transport	**Table 2.3** Differences between diffusion and active transport **Diffusion** / **Active Transport** Net movement of particles from a region of higher concentration to a region of lower concentration, down a concentration gradient / Net movement of particles from a region of lower concentration to a region of higher concentration, against a concentration gradient Energy from respiration not required / Energy from respiration required Cell membrane not required / Cell membrane required
Where does active transport occur? "O level syllabus"	Active transport occurs only in living cells because living cells respire. The energy used in active transport is from the energy used in respiration. In Human body, examples of active transport include the uptake of glucose by microvilli of epithelial cells in the small intestine, and from the kidney tubules into the blood capillaries.

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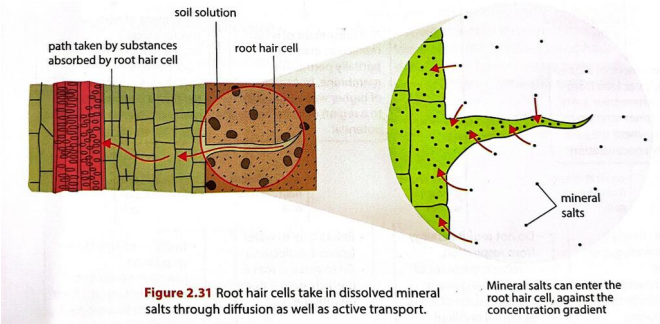
	In plants, root hair cells can take in mineral salts form the soil solution by diffusion or active transport, depending on the concentration of mineral salts in the soil solution.  **Figure 2.31** Root hair cells take in dissolved mineral salts through diffusion as well as active transport. Mineral salts can enter the root hair cell, against the concentration gradient

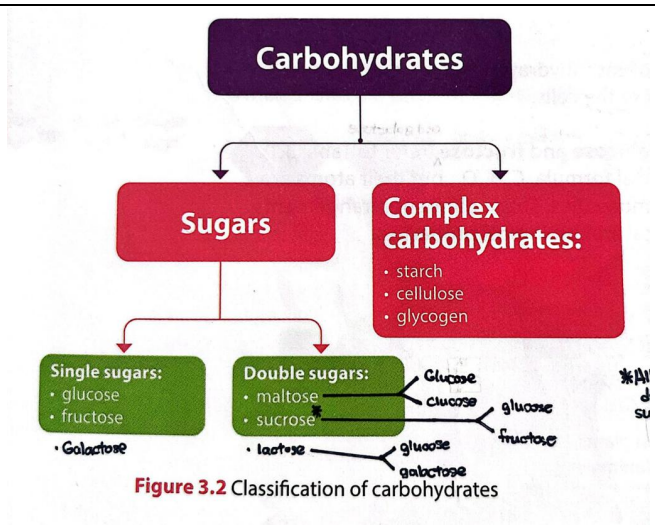
Chapter 3: Biological Molecules

O Level Syllabus

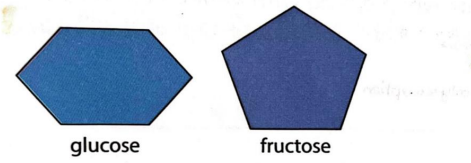
- list the chemical elements which make up:
  - carbohydrates
  - fats
  - proteins
- state the main roles of carbohydrates, fats and proteins in living organisms:
  - carbohydrates as an immediate source of energy
  - fats for insulation and long-term storage of energy
  - proteins for growth and repair of cells
- describe and carry out tests for:
  - starch (using iodine in potassium iodide solution)
  - reducing sugars (using Benedict's solution)
  - protein (using biuret solution)
  - fats (using ethanol)
- state that large molecules are synthesised from smaller basic units:
  - cellulose, glycogen and starch from glucose
  - polypeptides and proteins from amino acids
  - lipids such as fats from glycerol and fatty acids

Carbohydrates

What are carbohydrates? "O level syllabus"	Carbohydrates are organic molecules made up of the elements carbon, hydrogen and oxygen. The hydrogen and oxygen atoms are present in the ratio 2: 1.
How can we classify carbohydrates?	We can classify carbohydrates as single sugars (monosaccharides), double sugars (disaccharides) or complex carbohydrates (polysaccharides).

What is the detailed classification of carbohydrates?	 **Figure 3.2** Classification of carbohydrates

Sugars

Simple sugar	Simple sugar is the basic unit of carbohydrates. The common single sugars are glucose, fructose and galactose. They have the same chemical formula, $C_6H_{12}O_6$, but their atoms are arranged differently within the molecules. Glucose is found in plants and animals. Fructose is common in plants but rare in animals.  **Figure 3.4** Structures of glucose and fructose
Double sugars	A double sugar is formed when two single sugars are joined together. Lactose = Glucose + Galactose Sucrose (only non-reducing sugar) = Glucose + Fructose Maltose = Glucose + Glucose A double sugar can be split into two simple sugar molecules by using an organic molecule called an enzyme. *Condensation reaction* vs *Hydrolysis reaction* *(not important)* - Condensation reaction involves the removal of one water molecule, simple sugar + simple sugar → double sugar + water (e.g. Glucose + Glucose → Maltose + Water)

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<table>
<tr>
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<td>
- Hydrolysis reaction involves the addition of one water molecule, double sugar + water → Glucose + Glucose
(e.g. maltose → (enzyme maltase) Glucose + Glucose
</td>
</tr>
<tr>
<td>Testing for reducing sugar

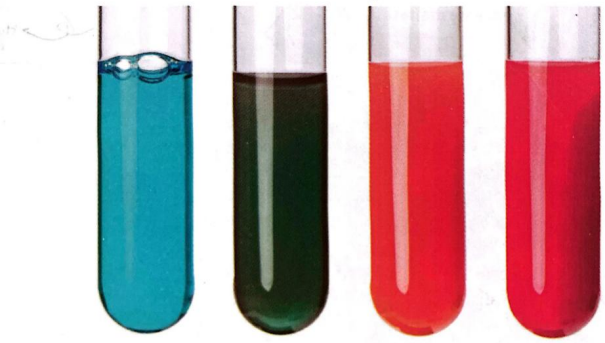
"O level syllabus"

(learn how to describe the test)</td>
<td>
Glucose, Fructose, Maltose, Lactose, and Galactose are known as reducing sugar. Reducing sugars will produce a brick red precipitate when boiled when Benedict's solution.

*Sucrose is a non-reducing sugar and will not give a red precipitate with this test

<u>Procedure</u>
1. Place 2cm^3 of each food sample into a test-tube
2. Add 2cm^3 of Benedict's solution to the food sample
3. Shake the mixture and place the test-tube in a boiling water-bath for 2-3 minutes
4. Record Colour of observation

<table>
<tr><th>Observation</th><th>Amount present</th></tr>
<tr><td>Solution remained blue</td><td>No reducing sugar</td></tr>
<tr><td>Benedict's solution turned from blue to green</td><td>Traces of reducing sugar</td></tr>
<tr><td>Benedict's solution turned from blue to yellow/orange</td><td>Moderate amount of reducing sugar</td></tr>
<tr><td>Benedict's solution turned from Blue to a brick-red precipitate</td><td>Large amount of reducing sugar</td></tr>
</table>
</td>
</tr>
</table>

	Figure 3.9 shows the colour change from blue to red indicating an increasing amount of reducing sugar present in the solutions.  Figure 3.9

Complex Carbohydrates

What are they?	A complex carbohydrate is made up of similar molecules of single sugar joined together to form a large molecule.
Types of Complex Carbohydrates "O level syllabus"	**Starch** A starch molecule is made up of several thousand glucose molecules joined together. It is the storage form of carbohydrates and is found in plants (e.g. potato tubers and tapioca). When needed, it can be digested to glucose to provide energy for cell activities.

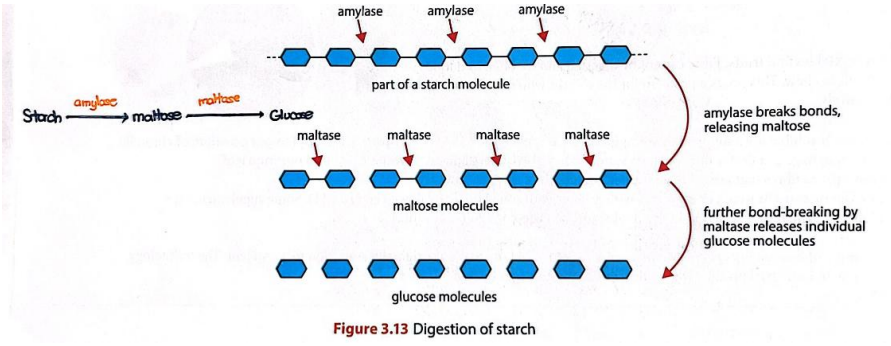
<table>
<tr><td></td><td> 

Figure 3.13 Digestion of starch</td></tr>
<tr><td></td><td><u>Glycogen</u>

Glycogen is a branched molecule made up of many glucose molecules joined together.

It is a storage form of carbohydrates stored in the liver and muscle of mammals. When needed, it is digested to glucose to provide energy for cell activities.</td></tr>
<tr><td></td><td><u>Similarities of Glycogen and Starch</u>

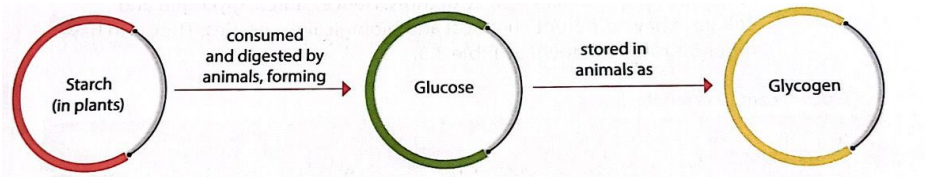
 

Figure 3.12 Glycogen and starch as stores of glucose

Both Glycogen and starch are suitable as storage materials in cells because…
- Insoluble in water → do not change the water potential in the cells
- Large molecules that cannot diffuse through cell membranes → cannot be lost from the cells
- Easily broken down to glucose when needed (e.g. tissue respiration)
- Molecules have compact shapes → occupy less space than all the individual glucose molecules that make up a glycogen or starch molecule</td></tr>
<tr><td></td><td><u>Cellulose</u>

A cellulose molecule is made up of many glucose molecules joined together. The bonds between glucose units are different from the one in starch.

Present in the cell walls of plants, cellulose cell walls protect plant cells from bursting or being damaged. Cellulose cannot be digested in our intestines and serve as dietary fibre that prevents constipation.</td></tr>
<tr><td>Functions of Carbohydrates</td><td>1. As a substrate for respiration, to provide energy for cell activities
2. To form supporting structures (e.g. cell walls in plants)</td></tr>
</table>

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<table>
<tr>
<td>"O level syllabus"

(just know, RARELY ask)</td>
<td>3. To be converted into other organic compounds like amino acids and fats
4. Formation of nucleic acids (e.g. DNA)
5. Synthesise lubricants (e.g. Mucus, which consist of a carbohydrate and a protein)
6. Synthesise the nectar in some flowers (Nectar = sweet liquid that plants produce to attract insects)</td>
</tr>
<tr>
<td>Test for starch

"O level syllabus"

(learn how to describe the test)</td>
<td><u>Procedure</u>
1. Add a few drops of iodine in potassium iodide solution to a food sample
2. Record your observations

<table>
<tr><th>Observation</th><th>Result</th></tr>
<tr><td>Iodine solution remains brown</td><td>No presence of starch</td></tr>
<tr><td>Iodine solution turns from brown to blue black</td><td>Prescence of starch</td></tr>
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<u>Fats</u>

What are fats? "O level syllabus"	Fats are organic molecules made up of the elements carbon, hydrogen and oxygen. But unlikely carbohydrates, fats contain much less oxygen in proportion to hydrogen. The proportions of the elements that make up fats are not fixed, so there is no general formula for fats.

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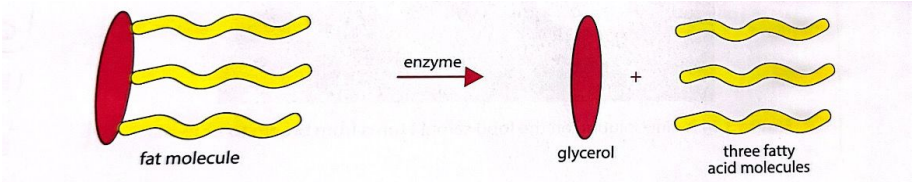
Breaking down of Fats "O level syllabus" (know how the structure look like, potential MCQ qn)	Fats can be broken down into simpler compounds such as fatty acids and glycerol. This reaction involves an enzyme (lipases).  **Figure 3.16** A fat molecule breaks down into glycerol and fatty acid.
What are the sources of fats?	- Food that are rich in fats include butter, cheese, fatty meat, olives, many nuts, peas, beans, seeds of castor oil and palm oil - The meat of most fishes and 'white meats' have relatively less fats. However, some fishes such as herring and salmon have lots of fats

What are the functions of fats?
 	
"O level syllabus"
 	
(out of function of all biological molecules, highest chance)
	- A source and a long-term storage of energy
	  - They are a suitable long-term storage material because fats have a higher energy value compared to carbohydrates.
	- An insulating material that prevents excessive heat loss. (For example, animals such as seals have a thick layer of fat beneath the skin to reduce heat loss)
	- A solvent for fat-soluble vitamins and many other vital substances such as hormones
	- An essential part of cells, especially in cell membranes
	- A way to reduce water loss from skin surface
	  - This oily substance forms a thin layer over the skin surface, reducing the rate of evaporation of water
	  - The oily substance also reduces the rate of heat loss from the skin

How can we test for fats? "O level syllabus" (learn how to describe the test)	We can test for fats through the ethanol emulsion test. A white emulsion is formed when ethanol and water are added to fats. <u>Procedure</u> For liquid samples: - Add 2cm^3 of ethanol to a drop of liquid sample in a test-tube and shake the mixture thoroughly - Add 2cm^3 of water to the mixture and shake the mixture. - Record your observations

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	For solid samples: - Crush the solid samples into small pieces with a mortar and pestle and place pieces into a test-tube - Add $2cm^3$ of ethanol into test-tube and shake thoroughly - Allow the solid particles to settle. Carefully pour off the top layer of ethanol into another test tube containing $2cm^3$ of water and shake the mixture - Record your observations

Observations	*Results*
A white emulsion is produces	Fat is present
A clear solution remains	Fat is absent

<u>Proteins</u>

What are proteins? "O level syllabus"	Proteins are organic molecules made up of the elements carbon, hydrogen, oxygen and nitrogen. Another element, Sulfur, may also be present. Proteins are present in all cells. Enzymes are proteins. Proteins are for growth and repair of cells. (All enzymes are proteins but not all proteins are enzymes)

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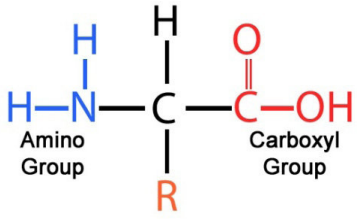
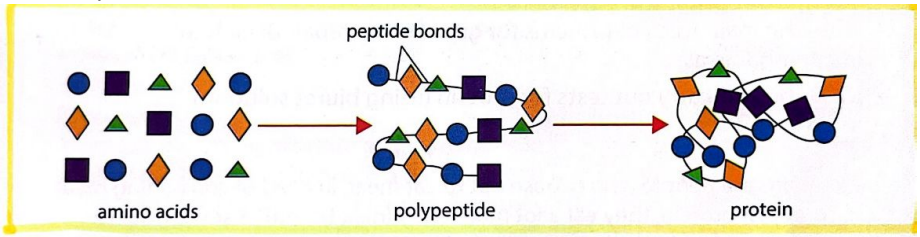
Amino Acids "O level syllabus"	A protein molecule is made up of simpler compounds known as amino acids. An amino acid is made up of an amino group ($-NH_2$) and an acidic group (-COOH) and a side chain (may contain sulfur)  Longer chains of amino acids are joined to form polypeptides, which link up to form proteins.  **Figure 3.22** Amino acids are joined to form polypeptides, which link up to form even longer chains of amino acids.
What are sources of proteins	Proteins can be found in animal and plant foods. Milk, eggs, seafood and meat, such as chicken and lean beef, are some animal foods rich in protein. Plant foods rick in protein include soya beans, nuts, grains and vegetables like French beans.
What are the functions of proteins?	- Synthesis of new cytoplasm, for growth and repair of worn-out body cells (body builders eat protein to build muscles) - Synthesis of enzymes and some hormones - Formation of antibodies to combat diseases
How can we test for proteins? "O level syllabus" (learn how to describe the test)	We can test for presence of proteins with biuret test. The biuret solution is a blue solution made up of sodium hydroxide and copper (II) sulfate. It turns violet (deep purple) when protein is present. <u>Procedure</u> - Add $2cm^3$ of liquid food sample and add an equal volume of biuret solution. - Shake well and allow the mixture to stand for 5 minutes - Record your observation

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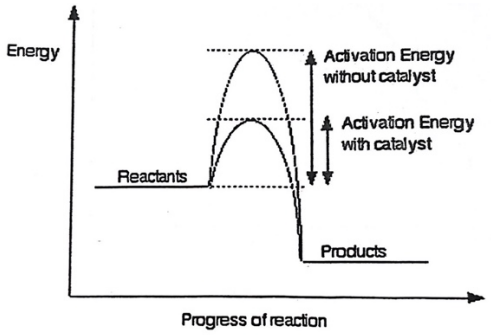
Observations	Results
Violet (deep purple)	Protein is present
Remains blue	Protein is not present

Chapter 4: Enzymes

O Level syllabus

- Explain the mode of action of enzymes in terms of an active site, enzyme-substrate complex, lowering of activation energy and enzyme specificity using the 'lock and key' hypothesis
- investigate and explain the effects of temperature and pH on the rate of enzyme catalysed reactions

Enzymes

What are catalysts?	A catalyst is a substance that can speed up a chemical reaction, without itself being chemically unchanged at the end of the reaction.
Enzymes = Biological Catalysts	Enzymes are proteins that are biological catalyst. They speed up the rate of chemical reactions by lowering the activation energy of the reaction. They remain chemically unchanged after the reaction.
Enzymes lower activation energy "O Level Syllabus"	Activation energy is the energy needed to start a chemical reaction. Enzymes provide an alternate pathway with lower activation energy (Initial pathway of higher activation energy still present, only got one "shortcut" so its "alternate") required to start a chemical reaction. They thus speed up the rate of chemical reaction by lowering the activation energy. 
Reactions that enzymes catalyse	Enzymes are required to break large molecules into simpler and smaller substances so that they are soluble in water and small enough to diffuse through cell membranes. *Examples of enzymes* 1) Amylase – digests starch to maltose (mouth, small intestine) 2) Maltase – digests maltose to glucose (small intestine) 3) Protease – digests proteins to polypeptides, then to amino acids

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	(stomach, small intestine) 4) Lipase – digests fats to fatty acids and glycerol (small intestine) *Enzymes either build up or break down complex substances* - Build up complex substances (anabolic reaction) → Building proteins from amino acids → Carbon dioxide and water is synthesised to form glucose during photosynthesis - Break down complex substances (catabolic reaction) → Breaking down of glucose to carbon dioxide and water during respiration → Larger molecules in food are broken down into smaller molecules by enzymes during digestion
Classification of enzymes	*Name of each enzyme:* - shows the substance on which the enzyme acts - ends in 'ase' *Examples* - Carbohydrases are enzymes that digest carbohydrates - Proteases are enzymes that digest proteins - Lipases are enzymes that digest fats (lipids)

<u>Characteristics of Enzymes</u>

"Lock-and-key" Hypothesis	Enzymes are highly specific in their action → The reaction can only be catalysed by a specific enzyme (one enzyme only one reaction)
"O Level Syllabus"	Enzyme reactions depends on the presence of active sites → only enzyme molecules and substrate molecule with complementary shape (≠ same shape) can fit (the enzyme is the lock, and the substrate is the key)

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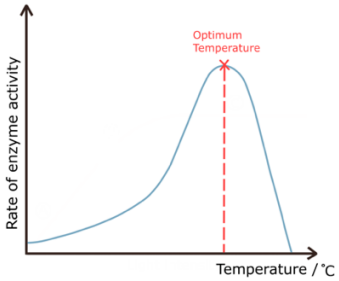
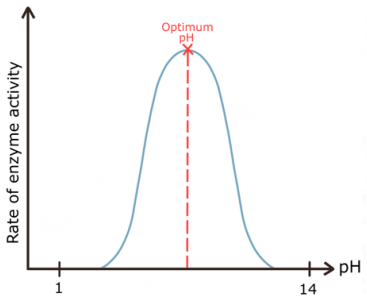
	1) The substrate fits onto the active site of the enzyme to form an enzyme-substrate complex just like a key (substrate) fit into a lock (enzyme). Only the substrate with a specific three-dimensional shape complementary to that of the active site can fit into the enzyme. 2) The enzyme then catalyses the reaction (by breaking / forming bonds). After the reaction, the products are no longer complementary to the active site, hence they leave the active site. The enzyme remains chemically unchanged and can accept a new substrate 
Characteristics of enzymes "O Level Syllabus" (MUST KNOW)	*1) Enzymes speed up chemical reactions (save time + save energy, since less energy = lower temperature)* Enzymes speed up a chemical reaction by lowering the activation energy needed to start the reaction
	2) Enzymes are specific in action (only intended reaction will occur) Only substrates with a specific 3D shape complementary to the active site can fit into the enzymes. (High temperatures, acids and alkalis may affect the shape of an enzyme and thus its function)
	3) Enzymes are required in minute amounts and remain chemically unchanged at the end of reactions (same money and resources) The same enzyme molecule can be used repeatedly. Thus, a small amount of enzyme can catalyse the reaction for a large amount of substrate.
	4) Enzymes are affected by TEMPERATURE (temperature is linked to kinetic energy possessed by molecules)



- At low temperatures, kinetic energy of molecules is low. Thus, rate of substrate molecules colliding with enzymes is very low.
- As the temperature increases from low until the optimum temperature, kinetic energy of molecules increases, increasing the frequency of effective collision and formation of an enzyme-substrate complex.
- At optimum temperature, enzyme is most action (about 40-45 Degree Celsius → different enzymes have different optimum temperature)
- As temperature increases beyond optimum temperature, (weak bonds within enzymes are broken), enzymes lose their original shape. This results in them not being complementary to the substrate molecules. Denature begins.

Denaturation: The change in the three-dimensional structure of an enzyme or any other soluble protein, cause by heat or chemicals such as acids / alkalis. (LOW TEMPERATURE, ENZYME IS NOT DENATURED)

5) Enzymes are affected by pH



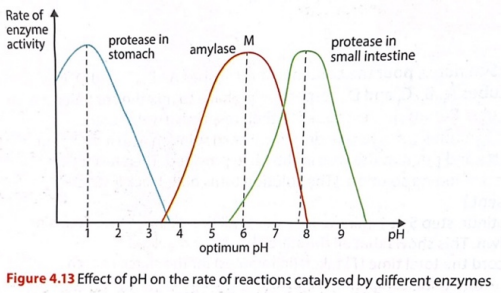


Figure 4.13 Effect of pH on the rate of reactions catalysed by different enzymes

- At pH 7, reaction rate is maximum as this is the enzyme's optimum pH.

- As pH moves further from pH 7, reaction rate decreases sharply. When pH moves too far from 7, (weak bonds within the enzyme are broken,) the enzyme loses the shape of its active site and becomes denatured.

- The substrate can no longer fit into the active site, hence rate decreases sharply until 0.

TO NOTE: Some enzymes work best in acidic solutions (e.g. protease in the stomach), others require alkaline solution (e.g. intestinal enzymes)

O Level syllabus

- describe the functions of the various parts of the digestive system: mouth, salivary glands, oesophagus, stomach, duodenum, pancreas, gall bladder, liver, ileum, colon, rectum, anus, in relation to ingestion, digestion, absorption, assimilation and egestion of food, as appropriate
- describe peristalsis in terms of rhythmic wave-like contractions of the muscles to mix and propel the contents of the alimentary canal
- describe the functions of enzymes (e.g. amylase, maltase, protease, lipase) in digestion, listing the substrates and end-products
- explain how the structure of a villus, including the capillaries and lacteal, is suited for its function of absorption
- state the function of the hepatic portal vein as the transport of blood rich in absorbed nutrients from the small intestine to the liver

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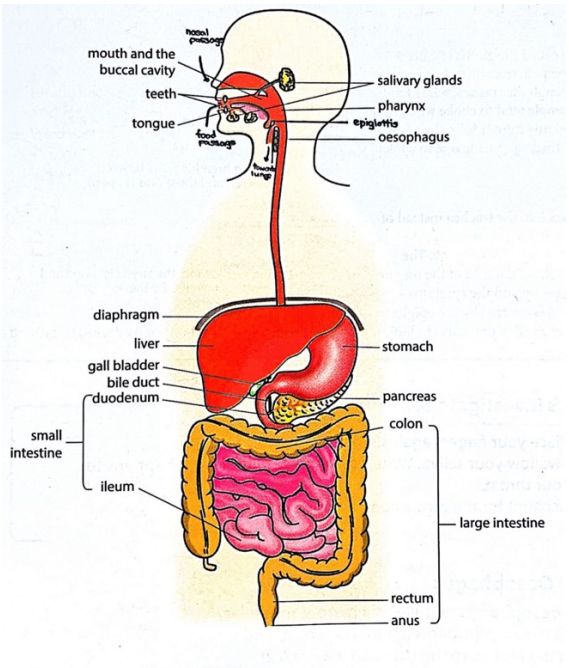
Nutrition

What is nutrition?	Nutrition is the process by which organisms obtain food and energy for growth, repair and maintenance of the body.
What processes are part of nutrition? 'O level syllabus'	- Feeding/ingestion → food is taken into the body - Digestion → large food molecules are broken down into smaller, soluble and simple molecules that can be absorbed into the body cells. - Absorption → nutrients move from the small intestine into the bloodstream - Assimilation → nutrients are used by cells to provide energy - Egestion → undigested matter is removed from the body

Parts of the Digestive System 'O level syllabus'

Done by MF (completed in 2024)

What are some parts of the Human Digestive system?	The human digestive system consists of the alimentary canal and the organs (liver, gall bladder and pancreas) associated with it. The alimentary canal is a nine-metre long tube that extends from the mouth to the anus.  **Figure 5.2** The human digestive system
The Mouth and the Buccal Cavity	The buccal cavity is the inside of the mouth and the biggening of the alimentary canal. (Teeth, Salivary gland, Tongue) - The teeth breaks large pieces of food into smaller pieces → this increases surface area to volume ratio of food so that enzymes can act more efficiently on it. - Salivary glands secrete saliva into the mouth. - The tongue mixes the food with saliva and moves the food to the back of the mouth during swallowing.
The Pharynx	The part of the alimentary canal that connects the buccal cavity to the oesophagus and the larynx. It also leads to the trachea (windpipe). (not v important, know can alr – more for respiration in humans)
The Oesophagus	The oesophagus is a narrow, muscular tube that passes through the thorax and joins the mouth to the stomach.

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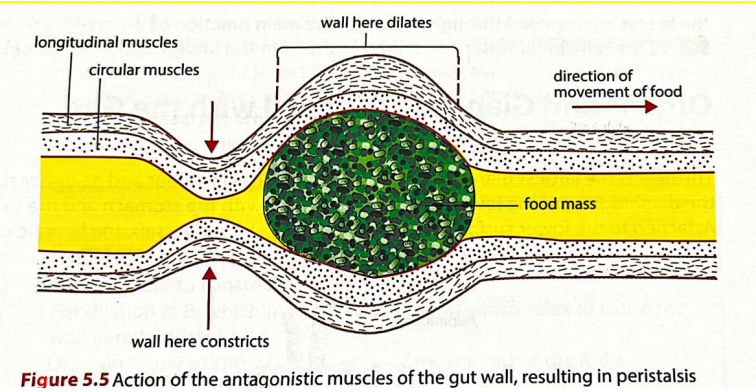
	(FAVOURITE QN – IDENTIFY WHICH MUSCLE IS WHICH) The walls of the oesophagus contains two layers of muscles → longitudinal muscles are on the outer side of the gut wall → circular muscles on the inner side of the gut wall Both sets of muscles produce long, slow contractions. These contractions move food along the gut via peristalsis.
	'O level syllabus' Peristalsis is the rhythmic, wave-like muscular contractions in the wall of the alimentary canal. Peristalsis enables food to be mixed with digestive juices and also pushes food down the alimentary canal. The longitudinal muscles and circular muscles are antagonistic muscles. (FAVOURITE QUESTION – TEST WHICH CONTRACT AND WHICH DILATE) → when the circular muscles contract the longitudinal muscles relax. The wall of the gut constricts, becoming narrower and longer. The food is then pushed forward. (CCLR) → when the longitudinal muscles contract, the circular muscles relax. The gut dilates, becoming wider and shorter. Food is then able to enter. (LCCR)  **Figure 5.5** Action of the antagonistic muscles of the gut wall, resulting in peristalsis
The stomach	The stomach is a distensible muscular bag, with thick and well-developed muscular walls. It lies to the left of the abdominal cavity and is partly covered by the liver. The inner surface of the stomach wall has numerous pits, the walls of which lined with gastric glands which secrete gastric juice (provides acidic environment so proteins can be digested) which plays an important part in digestion.
The small intestine	The small intestine consist of the U-shaped duodenum (first part of small intestine) and the ileum (coiled part).

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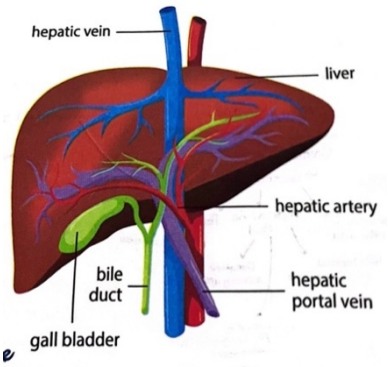
	The small intestine carries out most of the digestive process. The lining of the walls of the small intestine contains glands that secrete digestive enzymes. With these enzymes and the enzymes from the pancreas, food is digested. Water and nutrients from the food we eat are absorbed in the small intestine.
The large intestine	The large intestine consists of the colon, rectum and anus. Faeces are stored temporarily in the rectum. When the rectum contracts, faeces are expelled through the anus. The main function of the colon is to absorb about 90% of the remaining water and mineral salts from undigested food.
The liver and Gall Bladder (associated organs)	Liver cells produce and secretes bile (not an enzyme). Bile is stored temporarily in the gall bladder. When the gall bladder contracts, the bile flows into the duodenum via the bile duct.  **Figure 5.7** Liver and its blood vessels
The pancreas	The pancreas is connected to the duodenum by the pancreatic duct. The bile duct joins the pancreatic duct just before the pancreatic duct opens into the duodenum.

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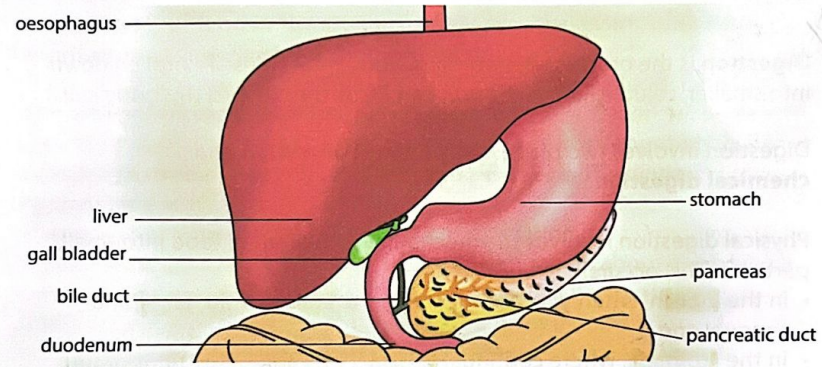
	The pancreas produced pancreatic juice which contains digestive enzymes, amylase, lipase and protease. The pancreas also secretes the hormones insulin and glucagon (important for the regulation of blood sugar level in body). Figure 5.8 shows some organs and glands related to digestion.  **Figure 5.8** Position of *liver* and pancreas in relation to stomach and duodenum

Digestion process in Humans 'O level syllabus'

Done by MF (completed in 2024)

What is digestion?	Digestion is the process whereby large food molecules are broken down into smaller, soluble and simpler molecules that can be absorbed into the body cells.
What types of digestions are there?	Physical digestion (just break down in size, still the same thing) → increases the surface area-to-volume ratio of the ingested food so that digestive enzymes can act on the food more efficiently → the mechanical break-up of food into small particles. This occurs in the mouth (chewing of food by action of teeth and tongue), stomach (continual contractions and relaxation of the muscles to cause churning action), and small intestine (fat are broken into smaller fat molecules – emulsification) Chemical digestion (substances is simplified, usually name of nutrients will change) → breaking down of large food molecules such as proteins, starch and fats, into small soluble molecules that can be absorbed
Processes that take place in the MOUTH	1. Food in the mouth stimulates the salivary glands to secrete saliva 2. Saliva is mixed with food to soften it 3. Saliva contains salivary amylase, digesting starch to maltose 4. Optimum pH for salivary amylase is 7, where enzymes are most active 5. Chewing breaks food into smaller pieces to increase surface area-to-volume ratio 6. Tongue rolls food into boli (small round masses) 7. Boli swallowed and passes down into oesophagus via pharynx 8. Peristalsis in walls of oesophagus pushes boli down into stomach. _____ Physical digestion: Teeth chewing and tongue Chemical digestion: Starch —(salivary amylase)→ Maltose

Processes that take place in the STOMACH	1. Prescence of food in stomach stimulates gastric glands to secrete gastric juice in stomach. 2. Peristalsis in the stomach walls churns and breaks up the food, it also mixes the food well with gastric juice. 3. Gastric juice contains hydrochloric acid, mucus and the enzyme pepsin (a protease). (The dilute hydrochloric acid denatures the salivary amylase, provides a low pH environment where proteases can digest proteins, and kills certain potentially harmful microorganisms in food) 4. The protease digests proteins into polypeptides. 5. Mucus layer protects the stomach wall from being digested. It also moistens the food to allow easy movement in the stomach. 6. Partly digested food is liquefied and forms chyme 7. Chyme passes in small amounts into the duodenum _____ Physical digestion: peristalsis in the stomach wall (churning) Chemical digestion: proteases (pepsin) proteins ⟶ polypeptides
Processes that take place in the SMALL INTESTINE	1. Chyme stimulates the pancreas to secrete pancreatic juice (contains enzyme pancreatic amylase, protease and pancreatic lipase). Chyme also stimulates the gall bladder to release Bile which contains bile salts to speed up digestion of fats. Chyme then stimulates the epithelial cells in the small intestine to produce the enzymes maltase, protease and lipase. 2. When the food comes into contact with pancreatic juice, bile and intestinal juice, it neutralise the acidic chyme and provides a suitable alkaline medium for the action of the oancreatic and intestinal enzymes _____ Physical digestion: emulsification (fat broken down) Chemical digestion: pancreatic amylase maltase starch ⟶ maltose ⟶ glucose proteases proteases proteins ⟶ polypeptides ⟶ amino acids lipases fats ⟶ fatty acids and glycerol

Digestion of different foods

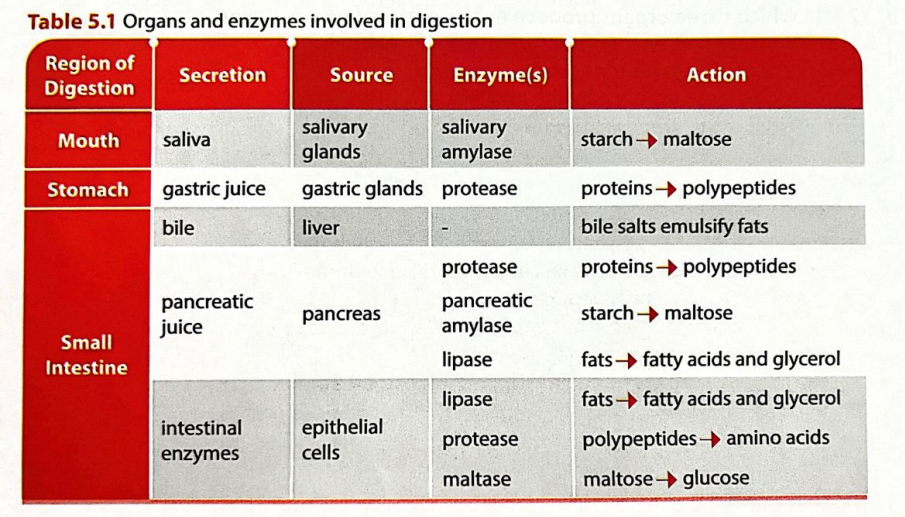
Carbohydrate digestion	1. Carbohydrate digestion begins in the mouth. Salivary amylase In the mouth digests starch into maltose. Only a little starch is digested in the mouth 2. No digestion of carbohydrates in the stomach 3. When carbohydrate enter the small intestine, they are fully digested into simple sugars (glucose)
Protein digestion	1. Protein digestion begins in the stomach, where stomach protease digests proteins into polypeptides 2. The undigested proteins that enter the small intestine are digested by intestinal proteases to polypeptides. 3. The polypeptides produced are further digested to amino acids by intestinal protease
Fat digestion	1. In the small intestine, bile salts emulsify fats by lowering the surface tension of fats to make fats break into tiny fat droplets suspended in water. 2. Emulsified fats are digested by lipases to fatty acids and glycerol. Emulsification: Emulsification is the breaking up of fats into tiny fat droplets
Summary 'O level syllabus'	

Table 5.1 Organs and enzymes involved in digestion

Region of Digestion	Secretion	Source	Enzyme(s)	Action
Mouth	saliva	salivary glands	salivary amylase	starch → maltose
Stomach	gastric juice	gastric glands	protease	proteins → polypeptides
Small Intestine	bile	liver	-	bile salts emulsify fats
	pancreatic juice	pancreas	protease	proteins → polypeptides
			pancreatic amylase	starch → maltose
			lipase	fats → fatty acids and glycerol
	intestinal enzymes	epithelial cells	lipase	fats → fatty acids and glycerol
			protease	polypeptides → amino acids
			maltase	maltose → glucose

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Absorption

What is absorption?	Absorption is the process whereby digested food substances are absorbed into body cells.
Where does absorption happen?	The products of digestion (simple sugars, amino acids, fatty acids, and glycerol) are absorbed throughout the small intestine, except the ileum. The absorbed nutrients diffuse from the cells of the small intestine into the bloodstream. Water and mineral salts are absorbed by the small intestine and the colon.
How is the small intestine adapted from absorption? 'O level syllabus'	- inner surface of the ileum is folded extensively and has numerous minute finger-like projections called villi → increases surface area for absorption - epithelium wall is one cell thick → provides a short diffusion distance for nutrients to pass through (WALL is ONE CELL THICK, not the same as only one cell) - cells of epithelium have many microvilli → increase surface area of the small intestine - each villus has many blood capillaries that allow blood to transport the absorbed glucose and amino acids in order to maintain the diffusion gradient - each villus contains a lacteal to transport absorbed fat away → maintain a steep diffusion gradient - epithelial cells contains many mitochondria to provide energy for active transport of nutrients into the villi

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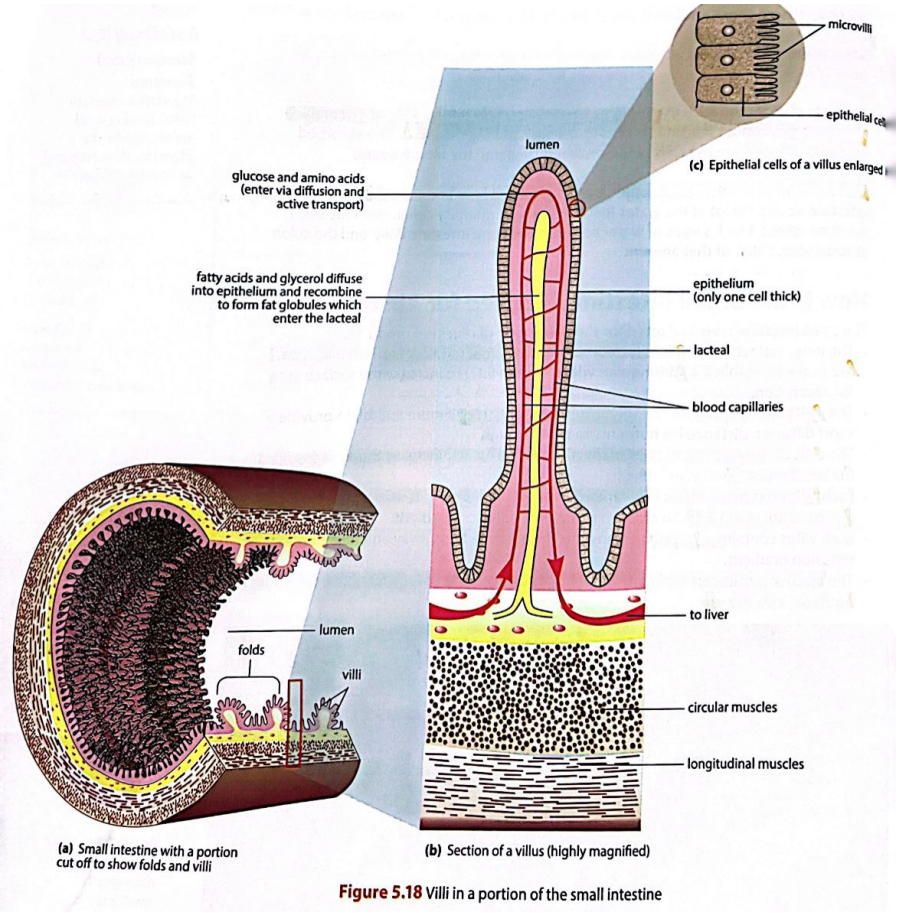
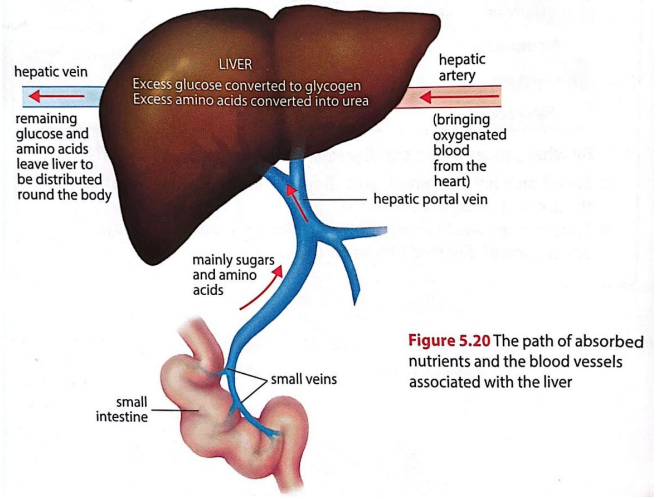
How does absorption take place in the bloodstream? 'O level syllabus'	- glucose and amino acids are absorbed by diffusion into the blood capillaries of the villi (also absorbed by active transport when lower concentration of these digested food substance in the lumen of the small intestine that in blood capillaries) - Glycerol and fatty acids diffuse into the epithelium and combine to form minute fat globules that enter the lacteals  **Figure 5.18** Villi in a portion of the small intestine
What happens to undigested and unabsorbed matter?	Stored temporarily in the rectum before they are discharged as faeces through the anus. The removal of undigested matter from the body is called egestion.

Absorbed nutrients

What is assimilation?	Assimilation is the process whereby some of the absorbed nutrients are converted into new cytoplasm or used to provide energy.
How are glucose and amino acids transported and utilised? 'O level syllabus'	After absorption, the blood in the villi is now rich in nutrients. The blood capillaries unite to form larger blood vessels, which in turn unite to form a large vein → hepatic portal vein. The hepatic portal vein transports mainly sugar and amino acids from the small intestine to the liver. (write "sugar and amino acid", "nutrients" too vague)  **Figure 5.20** The path of absorbed nutrients and the blood vessels associated with the liver - Excess glucose is returned to the liver and stored as glycogen. A hormone called insulin, which is produced by the islets of Langerhans in the pancreas, stimulated the liver cells to convert excess glucose into glycogen. (insulin stimulate conversion, it does not convert) - When the body needs energy, the liver converts the stored glycogen back into glucose. The glucose is then transported by the blood to the cells. (glucagon in place of insulin to convert back) - Amino acids that enter the cells are converted into new cytoplasm that is used for growth and repair of worn-out parts of the body, they are also used to form enzymes and hormones - Excess amino acids are deaminated in the liver.
How are fats transported and utilised?	- Under normal conditions when there is a sufficient supply of glucose, fats are not broken down. Instead fats are used to build protoplasm (e.g. cell membranes) - When glucose is in short supply, fats are broken down to provide energy needed for the vital activities of the body - Excess fats are stored in special tissues called adipose tissues (found under skin and around the heart and kidneys), which protect these organs by acting as shock absorbers

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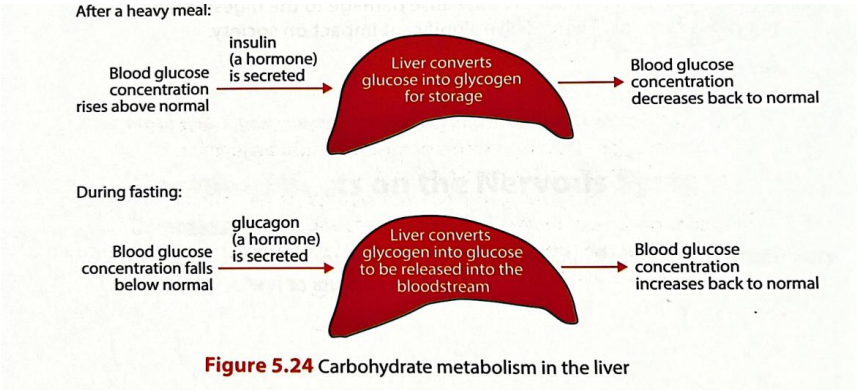
Liver

Production of Bile	Helps in digestion of fats by secreting bile. Bile is stored temporarily in the gall bladder before use.
Deamination of Amino Acids	Excess amino acids are transported to the liver. Their amino groups are removed and converted into urea. Deamination is the process by which the amino groups are removed from amino acids and converted to urea. Urea is removed from the body in the urine. The remains of the deaminated amino acids are converted into glucose in the liver and the excess glucose is converted to glycogen.
Regulation of blood glucose concentration	The pancreas contains special group of cells known as the islets of Langerhans which secretes the hormones insulin and glucagon into the bloodstream. (does not convert, hormones only stimulate a.k.a get other people to convert)  **Figure 5.24** Carbohydrate metabolism in the liver
Breakdown of Hormones	Hormones are broken down in the liver
Detoxification	Harmful substances may be absorbed into the blood from the gut. These substances are made harmless by the liver cells → detoxification. Alcohol is an example of a harmful substance that is broken down by the liver. Alcohol can cause damage to the digestive system and slow down brain functions. Liver cells contain an enzyme which breaks down alcohol to compounds that can be used in respiration, providing energy for cell activities.

Effects of alcohol consumption

Harmful effects on the digestive system	Alcohol stimulates acid secretion in the stomach. Excess stomach acid increases the risk of gastric ulcers. Prolonged alcohol abuse may lead to cirrhosis of the liver. Cirrhosis is a disease in which the liver cells are destroyed and replaced with fibrous tissue, making the liver less able to function. Patients with alcoholic cirrhosis may undergo heavy bleeding in the liver, leading to liver failure and death.
Harmful effects on the nervous system	Depressant → slows down brain functions Reduced self-control → a person becomes carefree as alcohol takes away his self-control and he may do things he regret after the effects of alcohol have worn off Effect on reaction time (increase reaction time = more time needed to react = bad) → Slurred speech, blurred vision and poor muscular coordination make him clumsy and unable to walk steadily → judgement deteriorates and tends to underestimate speed → cannot drive as he will be less caution and his reactions are slower Long term effects on alcohol consumption on brain → "wet brain" is a type of dementia caused by brain damage due to the interference of the absorption of vitamin B1 → shrinkage in brain volume, becoming smaller than normal especially in regions associated with memory and reasoning → heavy consumption during pregnancy may interfere with the development of the fetus' brain, which may lead to lifelong physical, mental and behavioural problems
Social implications	When there is frequent drinking of alcohol, this may lead to addiction to alcohol. The body becomes dependent on alcohol and he becomes an alcoholic. This leads to… → neglecting their work and family →exhibit violent behaviour, especially towards family members → commit crimes due to alcohol influence.

Done by MF (completed in 2024)

Chapter 6: Transport in Humans

O Level syllabus

- identify the main blood vessels to and from the heart, lungs, liver and kidney
- relate the structures of arteries, veins and capillaries to their functions (specific names of muscle layers in arteries and veins are not required)
- describe the transfer of materials between capillaries and tissue fluid
- state the components of blood and their roles in transport and defence:
    - red blood cells – haemoglobin for oxygen transport
    - plasma – transport of blood cells, ions, soluble food substances, hormones, carbon dioxide, urea, vitamins, plasma proteins
    - white blood cells – phagocytosis, antibody formation and tissue rejection
    - platelets – fibrinogen to fibrin, causing clotting
- list the different ABO blood groups and describe all possible combinations for the donor and recipient in blood transfusions
- describe the structure and function of the heart in terms of muscular contraction and the working of valves
- outline the cardiac cycle in terms of what happens during systole and diastole (histology of the heart muscle, names of nerves and transmitter substances are not required)
- describe coronary heart disease in terms of the occlusion of coronary arteries and list the possible causes, such as unhealthy diet, sedentary lifestyle, and smoking, stating the possible preventative measures

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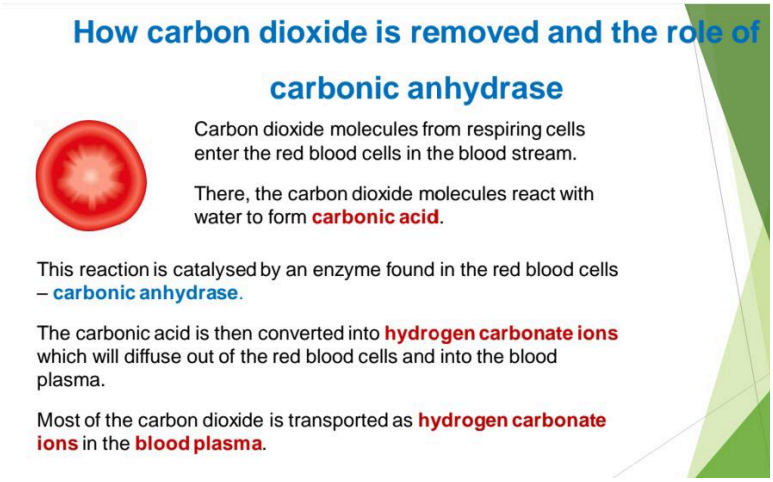
Main Components of Blood

Plasma	- Contains mainly water and substances such as glucose, salts, proteins, amino acids, fats, vitamins, hormones and excretory products like urea. It also contains red blood cells and white blood cells - Plasma transports - Blood cells around the body - Nutrients from the small intestine to other parts of the body E.g. Soluble Proteins – Prothrombin, Fibrinogen, Antibodies Dissolved mineral salts – Calcium Phosphate Digested Food Materials – Glucose, Amino Acids - Excretory products from organs where they are produced to excretory organs for removal (E.g. Urea) - Hormones from endocrine glands to target organs (E.g. Insulin)

Done by MF (completed in 2024)

Red Blood Cells	Red blood cells have a circular, biconcave shape. It has no nucleus. It contains a red pigment called haemoglobin and is flexible. Their main function is to transport oxygen from the lungs to other parts of the body. - To do this, haemoglobin can combine reversibly with oxygen. In the lungs where oxygen concentration is high, haemoglobin binds to oxygen to form oxyhaemoglobin. In tissues where oxygen concentration is low, oxyhaemoglobin releases its oxygen to the tissue cells. - They have a biconcave shape to increase the surface area to volume ratio which increases the rate of absorption and release of oxygen - They are flexible and can change into a bell-shaped structure so that they can flow easily through narrow blood capillaries - They have no nucleus, which means there's more space for haemoglobin to be stored If one lives in high altitudes, he/she will have more red blood cells with more haemoglobin to ensure that sufficient oxygen will be available for aerobic respiration to provide enough energy to meet the body's daily activities.  (Just need to know role of carbonic anhydrase in CO_2 removal. No details on transport of CO_2 process are needed.)

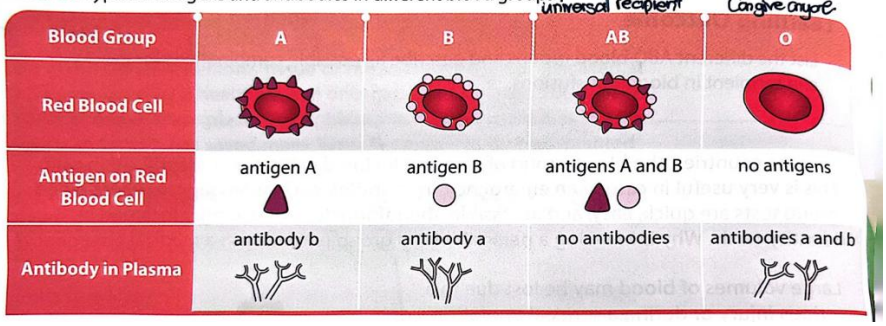
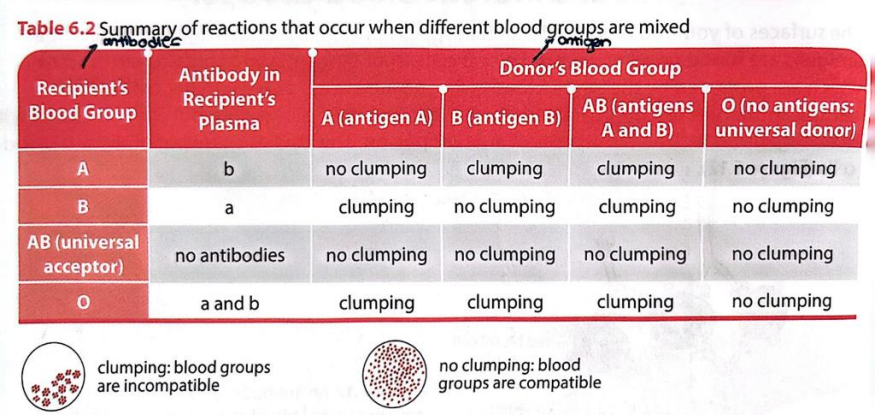
Done by MF (completed in 2024)

White Blood Cells	There are two main types of white blood cells. These are the phagocytes and the lymphocytes. The function of phagocytes is to perform phagocytosis → Phagocytosis is the process by which a white blood cell engulfs and destroys foreign particles such as bacteria Lymphocytes produced antibodies that… - recognise foreign particles - destroy disease-causing organisms - cause bacteria to clump together - neutralise toxins
Platelets	Contains an enzyme that catalyses the conversion of fibrinogen (soluble) to fibrin threads (insoluble) which forms a network that entangles red blood cells to form a clot → prevents excessive blood loss and the entry of harmful organisms

What processes can blood do?

Blood Clotting	1. Platelets are involved in converting the soluble protein fibrinogen to insoluble threads of fibrin. This process involves enzymes 2. Fibrin threads entangle blood cells and the whole mass forms a clot. The clot seals the wound, preventing entry of microorganisms and excessive loss of blood. Blood clotting helps… 1) to prevent excessive loss of blood 2) seals the wound to prevent entry of bacteria into the bloodstream EXAM Damaged tissues and platelets release thrombokinase. Prothrombin is activated by thrombokinase to form thrombin, in presence of calcium ions. Thrombin converts soluble fibrinogen into insoluble fibrin threads which entangle / trap blood cells to form a clot.
Organ transplant and tissue rejection	Any organ from another person may be treated as a foreign body by the recipient's immune system. The recipient's white blood cells may be respond by producing antibodies to destroy the transplanted organ Similarly, a foreign tissue may be recognised by the white blood cells. The white blood cells respond by producing antibodies to destroy the foreign tissue. This is known as tissue rejection.

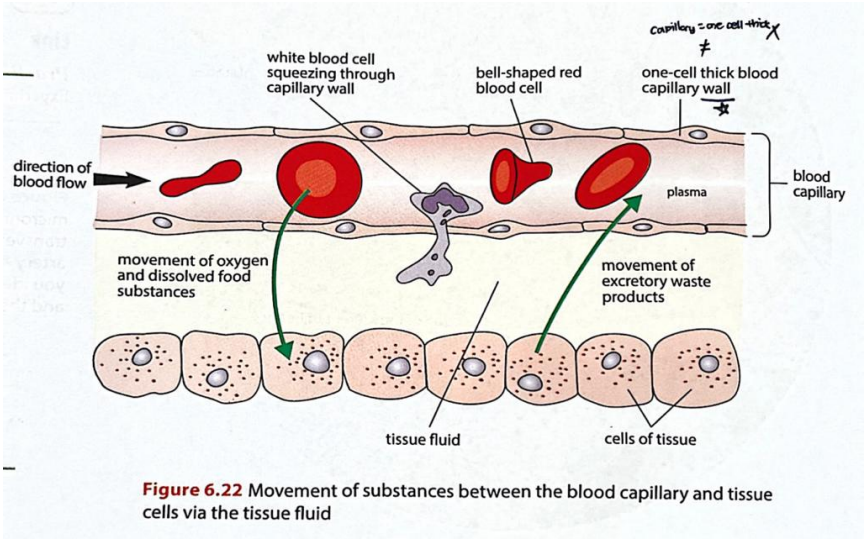
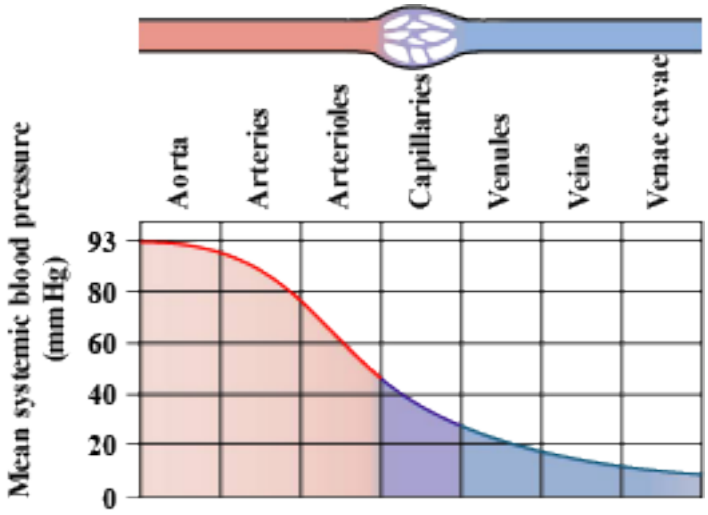
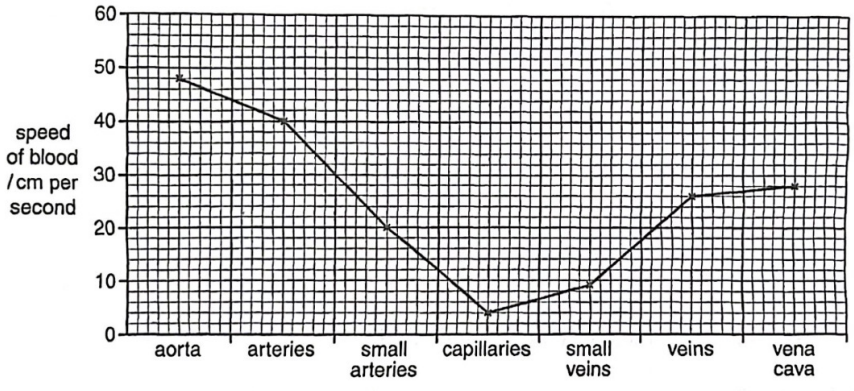
Blood groups

What is on the Red Blood Cells?	- The surfaces of red blood cells contains special proteins called antigens - Your blood plasma contains antibodies - These natural antibodies will not react with the antigens on your blood cells, but they may react with the antigens on the red blood cells of another person. This causes clumping.
Four different blood groups	**Table 6.1** Types of antigens and antibodies in different blood groups universal recipient Can give anyone 
What happens when blood groups are mixed?	**Table 6.2** Summary of reactions that occur when different blood groups are mixed antibodies antigen  Donor: Look at antigen Recipient: Look at the antibodies present

Done by MF (completed in 2024)

Blood vessels

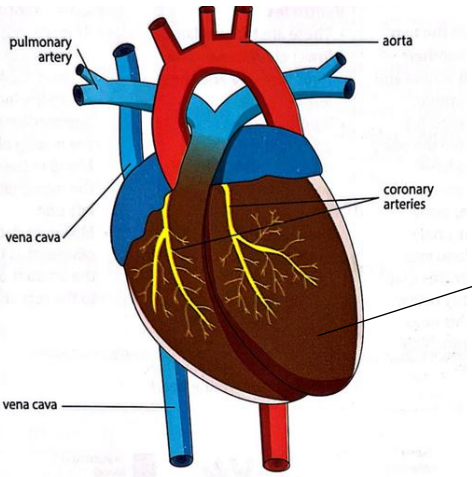
Heart	Blood is circulating throughout the body by the muscular pump (heart). When the heart relaxes, it fills up with blood. When it contracts, the blood is squeezed out with great force. The blood then circulates through the blood vessels, which direct the blood flow around the body.
Arteries	Arteries receive blood directly from the heart. They have a thick, muscular and elastic wall. The thick elastic walls help to withstand the high blood pressure in the artery. The elasticity enables the artery wall to stretch and recoil, which helps to push the blood in spurts and gives rise to pulse. Arteries carry oxygenated blood (except pulmonary arteries which carry deoxygenated blood from the heart to the lungs)
Arterioles	The arteries branch to form tiny vessels called arterioles. The arterioles divide and ultimately become tiny blood vessels called capillaries.
Blood capillaries	Capillaries are microscopic blood vessels that are found between the cells and almost all tissues. They have walls made of only a single layer of flattened cells. The capillary walls are partially permeable and allow for diffusion to occur quickly. The numerous branches of capillaries provides a large surface area for exchange of substance between blood and tissue cells The blood pressure is also lowered in capillaries as the total cross sectional area increases. This allows more time for exchange of substances.
Venules	Before the capillaries leave an organ or tissue, they unite to form small vessels called venules.
Veins	Veins transport blood towards the heart. They need not be as thick and muscular as arteries of the same size. Veins contains less elastic tissue. Instead, they have internal valves along their length to prevent backflow of blood.

How substances are transferred between capillaries and tissue fluid?	 **Figure 6.22** Movement of substances between the blood capillary and tissue cells via the tissue fluid
Blood Pressure graph as blood flows through different blood vessels	
Speed of Blood in different blood vessels	 Fig. 1.1

Done by MF (completed in 2024)

The human heart

Structure (chambers, valves)



Cardiac muscle
(O level asked in 2017)

Function:
Contracts to pump blood out of the heart to the rest of the body via the

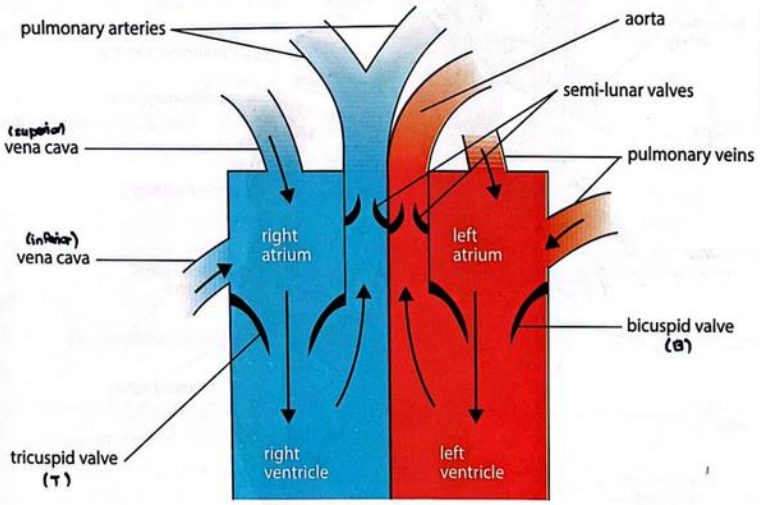


Figure 6.25 Structure of the human heart

My left My right

The flow of oxygenated and deoxygenated blood through the heart is controlled by the closing and opening of valves found in the heart (Figure 6.27).

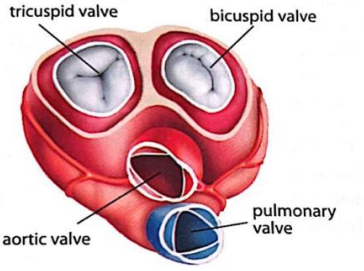


Figure 6.27 Superior (top) view of the heart

right atrium → right ventricle

Tricuspid valve: prevents backflow of blood from the right ventricle to the right atrium

left atrium → left ventricle

Bicuspid valve: prevents backflow of blood from left ventricle to the left atrium

Aortic valve (semi-lunar valve in the aorta): prevents backflow of blood from aorta to the left ventricle

Pulmonary valve (semi-lunar valve in the pulmonary artery): prevents backflow of blood from pulmonary artery to the right ventricle

Done by MF (completed in 2024)

The human heart has four chambers. Figure 6.26 shows a more detailed diagram of the human heart that has been cut open to show the four chambers and the blood vessels. The walls of the chambers are formed by the heart muscles. When the heart muscles contract and relax, they enable the heart to pump blood around the body.

The following parts form the heart chambers:

Atria

- These are the two upper chambers — the right atrium and the left atrium.
- The atria receive blood from the veins.
- The atria have comparatively thin muscular walls, since they only force blood into the ventricles that lie directly below them. This does not require high pressure.

Ventricles

- These are the two larger lower chambers — the right ventricle and the left ventricle.
- Ventricles have comparatively thick muscular walls. The left ventricle muscle is much thicker because it pumps blood around the whole body and this requires high pressure.
- The right ventricle has thinner walls than the left ventricle since it only pumps blood to the lungs, which is close to the heart.

Median septum

- This is a muscular wall that separates the right and left sides of the heart. It runs down the middle of the heart.
- The median septum prevents the mixing of deoxygenated blood in the right side with the oxygenated blood in the left side.
- Mixing of deoxygenated with oxygenated blood will reduce the amount of oxygen carried to the rest of the body.

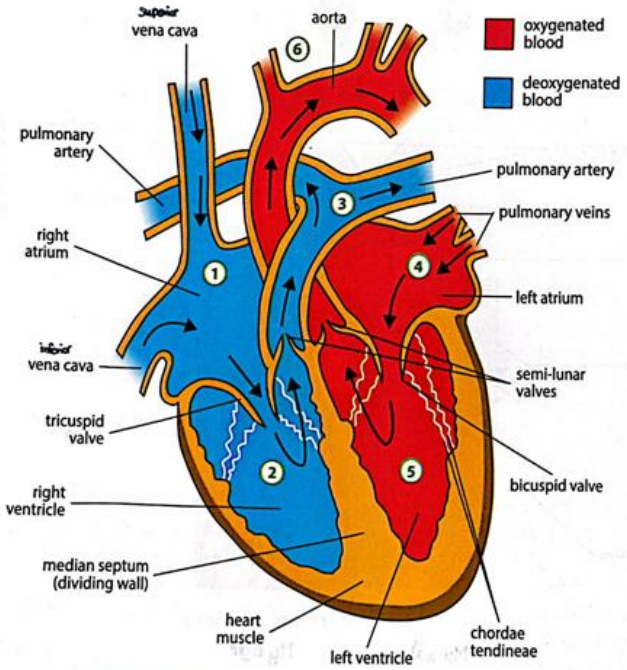
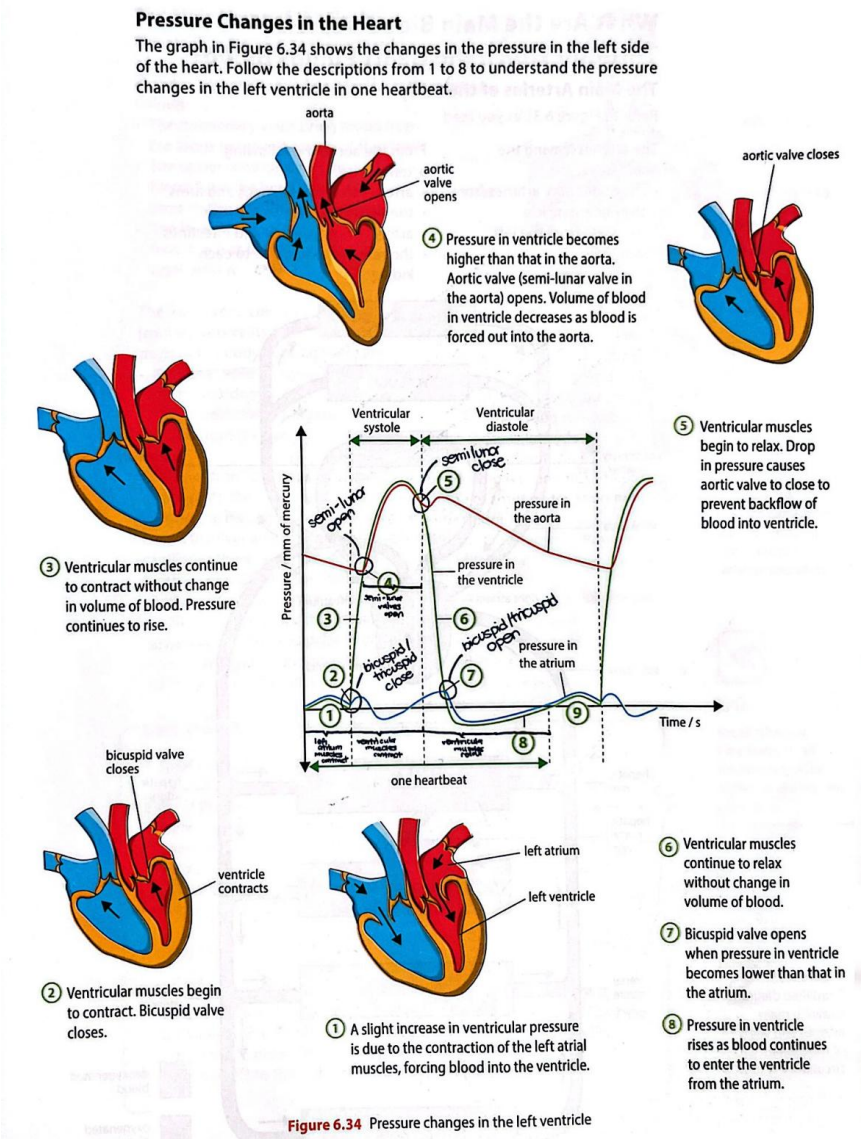


Figure 6.26 Longitudinal section of the human heart

Done by MF (completed in 2024)

What path does blood take through the heart?	1. Deoxygenated blood from the body returns to the right atrium of the heart through the vena cava. (Superior vena cava = head, necks, arms and Inferior vena cava = rest of body except lungs) 2. From the right atrium, the blood passes through the tricuspid valve into the right ventricle. The tricuspid valve consists of three flaps that point downwards into the ventricle. 3. From the right ventricle, the blood leaves the heart by the pulmonary arteries to the lungs. 4. Pulmonary veins transport oxygenated blood from the lungs to the left atrium 5. Blood passes from the left atrium, through the bicuspid valve into the left ventricle. The bicuspid valve has two flaps that point downwards into the left ventricle. 6. From the left ventricle, the blood leaves the heart and enters the aorta to be distributed around the body through different arteries.
Hole in the heart	- There will be mixing of oxygenated and deoxygenated blood, which causes less oxygen to be transported to the blood cells for respiration. - Patients with this conditions may suffer from shortness of breath and fatigue, and in serious cases, heart failure may occur.
Cardiac Cycle (MEMORISE)	1. Atrial muscles contract, forcing blood into ventricles 2. The ventricle muscles then contract which cause a rise in pressure in the ventricle. The rise in pressure in ventricles causes the bicuspid and tricuspid valves to close to prevent the backflow of blood into the atrium. This produced the louder “lub” sound. The semi-lunar valves open and the blood in ventricle flows into the pulmonary artery/aorta 3. As the ventricular muscles contract, the atrial muscles relax. The right atrium receives blood from vena cava while the left atrium receives blood from the pulmonary veins. 4. The ventricular muscles then relax. The fall in pressure causes the semi-lunar valves to close to prevent backflow of blood from the pulmonary artery and aorta into the ventricles. This produces a softer “dub” sound. The bicuspid and tricuspid valves also open and blood flows from the atria into the ventricles. 5. The atrial muscles contract again and the whole cycle repeats Systole = ventricle/atrium muscles contract Diastole = ventricle/atrium muscles relax
Role of Coronary Arteries	The coronary arteries transport oxygen and glucose to the cardiac muscles. Oxygen and glucose are needed for aerobic respiration to release energy for cell activities in the body.

Done by MF (completed in 2024)

Pressure changes in the heart (VERY IMPORTANT, NEED TO UNDERSTAND ENTIRE PROCESS)	 **Figure 6.34** Pressure changes in the left ventricle
Main Blood vessels	Arteries leaving the heart - Pulmonary arteries from the right ventricle - Aorta from the left ventricle From the aorta, the following arteries arise - Arteries to the head, arms and neck - Hepatic artery to the live - Arteries to the stomach and intestines - Renal arteries, one to each kidney

Done by MF (completed in 2024)

Main Veins	Blood returns to the heart as main veins - Pulmonary veins bring blood from the lungs to the left atrium of the heart - The upper vena cava returns blood from the head, neck and arms to the right atrium - The lower vena cave brings blood from the rest of the body to the right atrium Lower vena cava → renal vein bringing blood from the kidney → hepatic vein bringing blood from the liver → hepatic portal vein

Coronary Heart Disease

Heart Attack	During a heart attack, the blood flow to a particular part of the heart is completely blocked. The part of the heart does not receive sufficient oxygen and nutrients thus it dies. Heart is no longer able to pump blood to various parts of the body.
Cases of Coronary Heart Diseases	Fatty substances like cholesterol and saturated fats may be deposited on the inner surface of the coronary arteries. This narrows the lumen of the arteries and increases blood pressure. This increases the risk of blood clot formed in the artery. Supply of oxygen may then be cut off. Oxygen is needed aerobic respiration to release energy for the activities of the muscle cells. Without oxygen, the heart muscle cells may be damaged which leads to heart attack.
Risk Factors of Heart Diseases	Smoking → Nicotine in smoke increases blood pressure and the risk of blood clotting in the arteries. Unhealthy diet → A diet high in cholesterol, saturated fats and salt content increases the risk of high blood pressure and heart attack. Genetic factors → High blood pressure and high blood cholesterol can run in the family. Age → The risk of heart attack increases with age. Majority of people suffering from coronary heart disease are 65 or older. Sedentary lifestyle → Lack of exercise and being inactive leads to the build-up of fatty deposits that block the arteries.
Reducing the risks of coronary heart disease	- A healthy diet is important. Animal fats can be substituted with polyunsaturated plant fats. Such a diet will reduce cholesterol levels in the blood. - Smoking is harmful to the body and should be avoided - Regular exercise has a long-term beneficial effect on the circulatory system. It strengthens the heart and maintains the elasticity of the arterial walls.

Chapter 7: Respiration in Humans

O Level syllabus

- identify the larynx, trachea, bronchi, bronchioles, alveoli and associated capillaries and state their functions in human gaseous exchange
- describe the process of breathing and the role of cilia, diaphragm, ribs and internal and external intercostal muscles
- explain how the structure of an alveolus is suited for its function of gaseous exchange
- state the major toxic components of tobacco smoke – nicotine, tar and carbon monoxide, and describe their effects on health
- define aerobic respiration in human cells as the release of energy by the breakdown of glucose in the presence of oxygen and state the equation, in words and symbols
- define anaerobic respiration in human cells as the release of energy by the breakdown of glucose in the absence of oxygen and state the word equation
- explain why cells respire anaerobically during vigorous exercise resulting in an oxygen debt that is removed by rapid, deep breathing after exercise

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Types of Respiration

Why do living things respire?	Living organisms need energy to move, excrete, grow and reproduce. Since energy is stored in food molecules (e.g. glucose), living organisms release energy by consuming these molecules and breaking them down through a process known as respiration There are two forms of respiration: aerobic and anaerobic respiration
What is Aerobic Respiration? 'O level syllabus'	Aerobic respiration is the release of energy by the breakdown of glucose in the presence of oxygen. Carbon dioxide and water are released as waste products. Aerobic respiration releases a large amount of energy. The overall equation for aerobic respiration of glucose is: Chemical equation – $C_6H_{12}0_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ Word equation – Glucose + oxygen → carbon dioxide + water } large amount of energy (memorise chemical equation, useful for both chem and bio) In reality, respiration is carried out in a series of steps that are catalysed by enzymes. The mitochondria in cells are the 'factories' that contain these enzymes Complex organisms (trees and humans) respire aerobically as we need large amount of energy to survive. During respiration, some energy is also released as heat. The heat is circulated around our body to keep up warm

Done by MF (completed in 2024)

What is Anaerobic Respiration? 'O level syllabus' (know how to describe, especially why the need for anaerobic respiration)	Anaerobic respiration is the release of energy by the breakdown of glucose in the absence of oxygen. Anaerobic respiration releases a relatively small amount of energy e.g → during vigorous muscular contractions, your muscle cells respire aerobically at a high rate. However, there is a limit to the increase in the rate of breathing and heartbeat → When vigourous activity continues, muscular contractions are so vigourous that maximum aerobic respiration is unable to release energy fast enough to meet the demand. If vigourous musclar contractions continue, energy demand increases. The muscle cells carry out anaerobic respiration to meet the increased energy demand. Lactic acid is formed in the process. The overall equation for anaerobic respiration is: Word equation – Glucose → Lactic Acid } releases small amount of energy The small amount of energy released in anaerobic respiration, together with the energy released in aerobic respiration, helps muscles keep contracting. Since there is insufficient oxygen to meet the demands of the vigourous muscular contractions, the muscles are said to incur an oxygen debt
Aerobic respiration V.S. non-aerobic respiration (O level asked before)	Similarities: - Both release energy. - Both require glucose as a raw material / substrate. Differences: - Aerobic respiration occurs in the presence of oxygen while anaerobic respiration occurs in the absence of oxygen. - Aerobic respiration releases a large amount of energy but anaerobic respiration releases a small amount of energy. - Aerobic respiration produces water and carbon dioxide as waste products whereas anaerobic respiration produces lactic acid as a waste product.
What is oxygen debt?	Oxygen debt is the amount of oxygen required to remove lactic acid.
How can oxygen debt (lactic acid) be removed after a race? 'O level syllabus'	Continuous heart rate → continued and fast transport of lactic acid from muscles to the liver and oxygen from the lungs to the liver Continuation of deeper and faster breathing → continued and fast intake of oxygen by the lungs. Sufficient oxygen is required to remove the lactic acid from the blood. Once lactic acid is removed, oxygen debt is removed.

Done by MF (completed in 2024)

Experiments to test for aerobic and anaerobic respiration (not very important, just read can alr)	

Let's Investigate 7.1

Aim
To find out if carbon dioxide is given off during aerobic respiration

Procedure (a)
1 Set up the apparatus as shown in Figure 7.1. Potassium hydroxide solution is used to absorb carbon dioxide. Sodium hydroxide can also be used for this. Limewater is used to test the presence of carbon dioxide, which turns the limewater cloudy.
2 Use a suction pump to suck out the air through delivery tube E. This causes air to be drawn into flask A. The air flows through the apparatus as shown by the arrows.

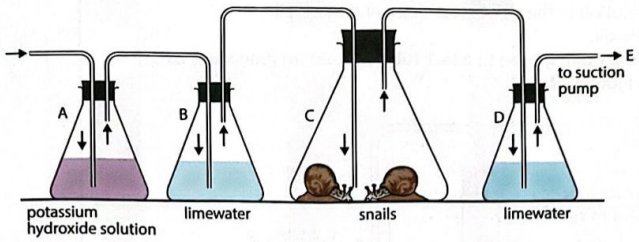


Figure 7.1

Questions
1 What purpose does the potassium hydroxide solution in flask A and limewater in flask B serve?
2 What happens to the limewater in flask D after some time? Explain your observation.
3 You need to set up a control. What changes would you make to flask C for the control?
4 If your investigation uses a potted green plant, what precautions must you take? Explain your answer.

Procedure (b)
Alternatively, we can use a hydrogencarbonate indicator, which can detect changes in carbon dioxide concentration. The colour changes in the indicator are shown in Figure 7.2.

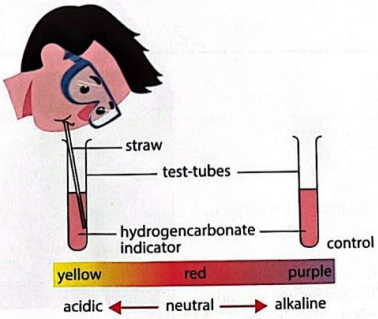


Figure 7.2

1 Set up the apparatus as shown in Figure 7.2.
2 Gently blow through the straw several times for 1 min.

Question
1 What changes do you see in the two tubes after 1 min? Why?

Done by MF (completed in 2024)

To study anaerobic respiration, yeast is used as a model organism.

Let's Investigate 7.2

Aim

To find out if carbon dioxide is given off during fermentation (anaerobic respiration)

Procedure

1 Add a few grains of dry yeast to some distilled water in a boiling tube. Stir well.
2 After 20 minutes, add an equal volume of boiled and cooled dilute glucose solution to the yeast suspension and mix well.
3 Add a little oil.
4 Connect the boiling tube to a test-tube containing limewater as shown in Figure 7.3.

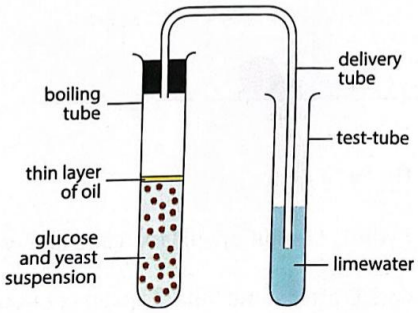
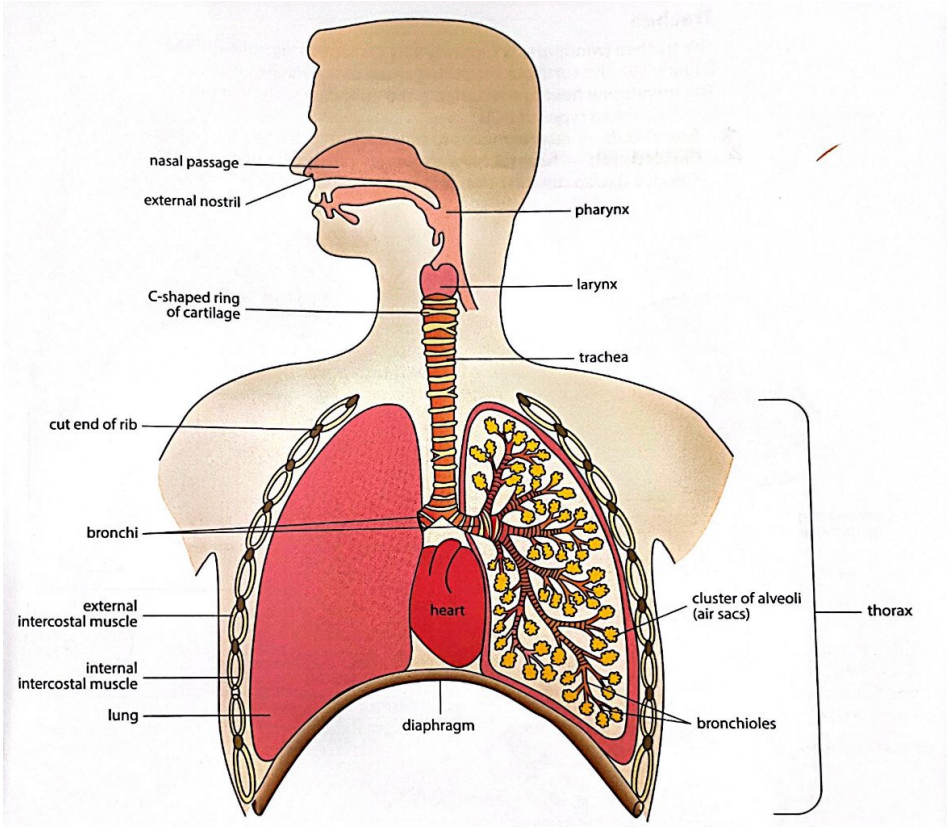


Figure 7.3

Questions

1 Why do you need to boil the glucose solution before carrying out the experiment?
2 What does the layer of oil serve as?
3 What do you observe after some time? Explain your answer.
4 What would you add to the boiling tube in a control experiment?

The Respiratory System

How do organisms take in oxygen for aerobic respiration?	Organisms take in oxygen for aerobic respiration through the process of gas exchange. Gas exchange is the exchange of gases between an organism and the environment. In humans, the absorption of atmospheric oxygen and the removal of carbon dioxide from the body occurs in the alveoli (air sacs) in the lungs.
The Human Gas Exchange System 'O level syllabus'	It consists of two lungs in in the thorax and the air passages leading to them. The air passages consist of the nasal passages, pharynx, larynx, trachea, bronchi and bronchioles. The thoracic cavity, ribs and diaphragm and related muscles are also vital parts of the gas exchange system.  **Figure 7.8** The human gas exchange system

Done by MF (completed in 2024)

The nose (most important is the hair and mucus)
→ Air usually enters your body through the two external nostrils. The walls of the nostrils bear a fringe of hairs. The nostrils lead into two nasal passages, which lined with a moist mucous membrane.
→ Advantages of breathing through the nose include
- Dust and foreign particles are trapped by the hairs in the nostrils as well as by the mucus on the mucous membrane.
- As air passes through the nasal passages, it is warmed and moistened.
- Harmful chemicals may be detected by small sensory cells in the mucous membrane.

From the nose to the trachea (pharynx abit like oesophagus, only connects)
→ The air in the nasal passages enters the pharynx. From the pharynx, air passes into your larynx and then into your trachea through an opening

Trachea
→ it is supported by C-shaped rings of cartilage. The cartilage keeps the lumen of the trachea open. The membrane next to the lumen is the epithelium.
→ The epithelium consists of two types of cells: (favourite to test)
- Gland cells – secretes mucus to trap dust particles and bacteria
- Ciliated cells – have hair-like structures called cilia on their surfaces. The cilia sweep the dust trapped mucus up the trachea.

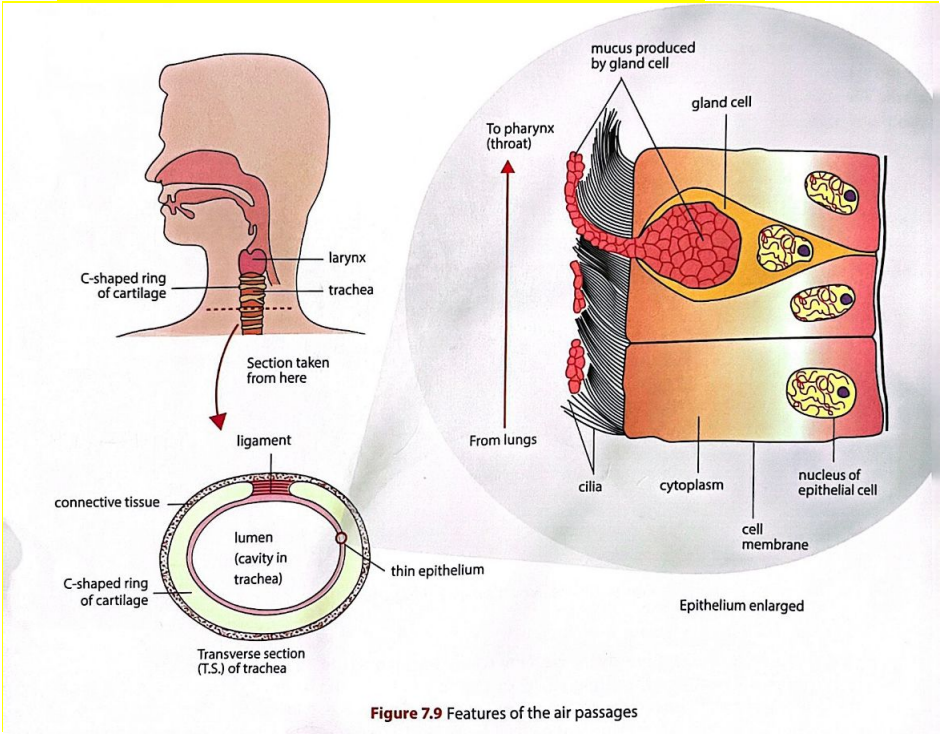
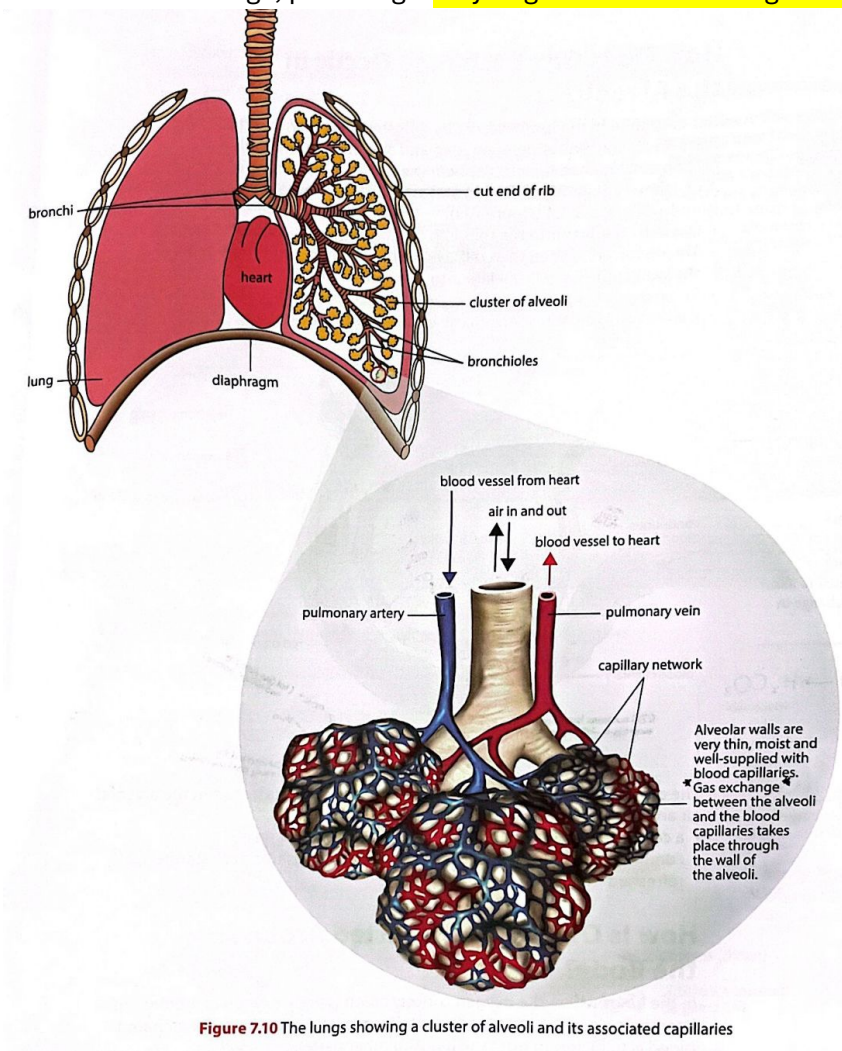


Figure 7.9 Features of the air passages

Done by MF (completed in 2024)

	Bronchi and Bronchioles → The trachea divides into two tubes called bronchi. Each bronchus carries air into the lung. The bronchi are similar in structure to the trachea. Each bronchus branches repeatedly, giving rise to numerous bronchioles. → Bronchioles are very fine tubes. Each bronchiole ends in a cluster of air sacs or alveoli Alveoli (Air sacs) (site of aerobic respiration as gas exchange occurs here) → Gas exchange takes place at the walls of the alveoli. Numerous alveoli are found in the lungs, providing a very large surface area for gas exchange  **Figure 7.10** The lungs showing a cluster of alveoli and its associated capillaries
How are the lungs adapted for efficient gas exchange? (very important pls know, know all 4)	- numerous alveoli in the lungs provide a large surface area - the wall of the alveolus is only one cell thick, this provides a short diffusion distance for gases, ensuring high rate of diffusion (wall is one cell thick, not cell) - a thin film of moisture covers the inner wall of the alveolus, allowing oxygen to dissolve (oxygen soluble in water, so need moisture) - the walls of the alveoli are richly supplied with blood capillaries. The flow of blood maintains the concentration gradient of gases.

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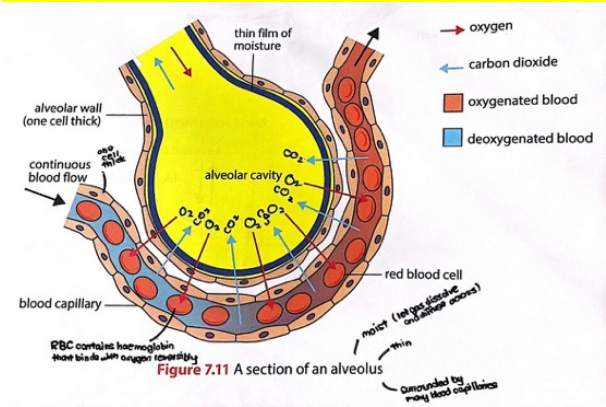
Gas exchange and Oxygen transport

How does gas exchange occur in the alveoli? 'O level syllabus'	Gas exchange in the lungs occurs by diffusion. Blood entering the lungs has a lower concentration of oxygen and a higher concentration of carbon dioxide than atmospheric air entering the alveoli in the lungs. A concentration gradient for oxygen and carbon dioxide is set up between the blood and alveolar air → oxygen dissolves into the thin film of moisture on the wall of the alveolus → the dissolved oxygen then diffuses through the wall of the alveolus and the walls of the blood capillary into the red blood cells → the oxygen combines with haemoglobin to form oxyhaemoglobin → carbon dioxide diffuses from the blood into the alveolar air The oxygen and carbon dioxide concentration gradients between the alveolar air and the blood are maintained by: - a continuous flow of blood through the blood capillaries - continuous breathing, causes air in lungs to be constantly refreshed  Figure 7.11 A section of an alveolus
Carbonic Anhydrase – found in RBC (not really in syllabus, but easier if you know)	How carbon dioxide is removed and the role of carbonic anhydrase  Carbon dioxide molecules from respiring cells enter the red blood cells in the blood stream. There, the carbon dioxide molecules react with water to form **carbonic acid**. This reaction is catalysed by an enzyme found in the red blood cells – **carbonic anhydrase**. The carbonic acid is then converted into **hydrogen carbonate ions** which will diffuse out of the red blood cells and into the blood plasma. Most of the carbon dioxide is transported as **hydrogen carbonate ions** in the **blood plasma**.
How is oxygen transported around the body?	oxygen + haemoglobin ⇌ oxyhaemoglobin (high oxygen concentration / low oxygen concentration)

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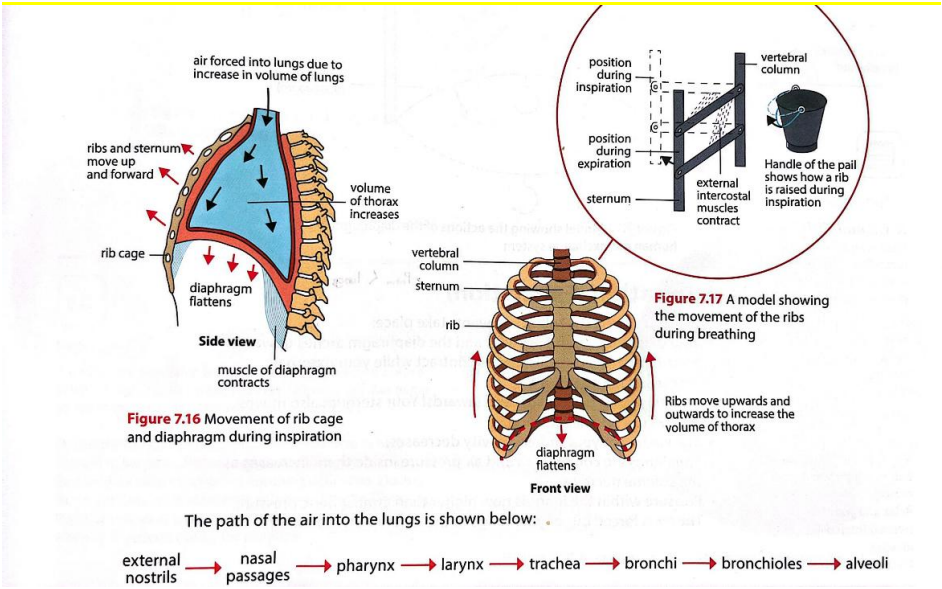
Breathing

The thoracic (chest) cavity	The chest wall is supported by the ribs. Between the ribs, two sets of muscles can be found. The external and internal intercoastal muscles. They are antagonistic muscles (one contract, other relaxes and vice versa). The thorax is separated from the abdomen by a dome-shaped sheet called the diaphragm. The diaphragm is made of muscle and elastic tissue. When the diaphragm muscles contract, the diaphragm flattens downwards and when the relax, the diaphragm arches downwards again.
Inhalation (Inspiration) 'O level syllabus' (they like to test inhale or exhale in section B P2, worth lots of marks so know the process) (if forget, do breathing during exam and observe if ribs move up/down, and if volume expands)	When we inspire, - Diaphragm muscle contracts and the diaphragm flattens - External intercoastal muscles contract while internal intercoastal muscle relax (RICE – relax internal contract external) - Ribs move upwards and outwards. Sternum also moves up and forward - Volume of thoracic cavity increases. (breathe in so more air so volume more) - Lungs expand and air pressure inside them decreases as volume increases (pressure is $\frac{mass}{volume}$, so when volume increase mass same pressure decrease) - Atmospheric pressure is now higher than the pressure within lungs. (pressure difference creates a force) - Air is forced into the lungs (need to use "forced", no other word)  Figure 7.16 Movement of rib cage and diaphragm during inspiration Figure 7.17 A model showing the movement of the ribs during breathing

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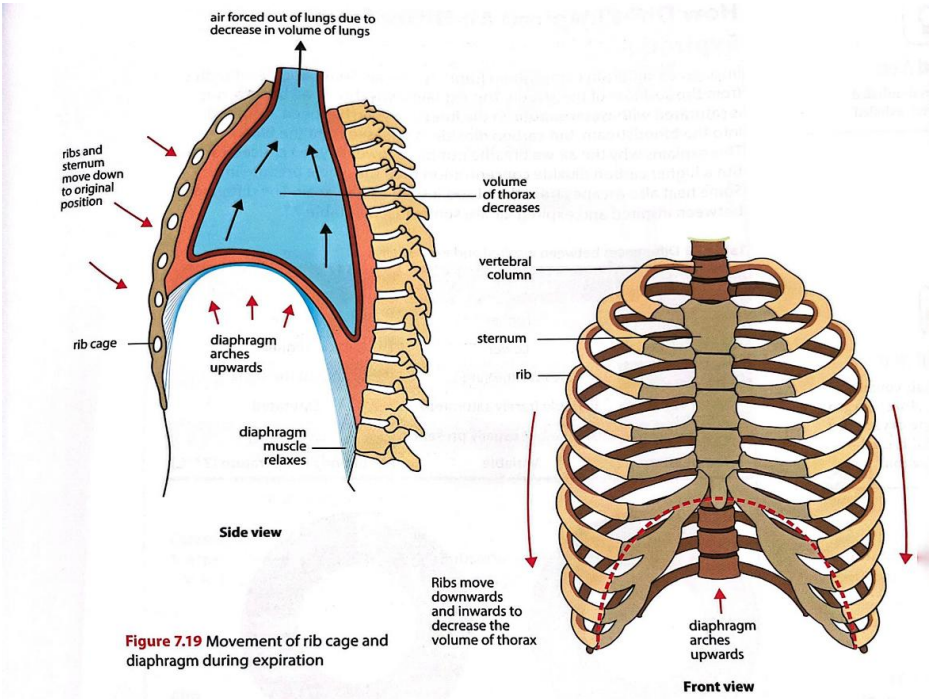
Exhalation (Expiration) 'O level syllabus'	When we expire, - Diaphragm muscles relax and arches upwards - Internal intercoastal muscles contract while external intercoastal muscles relax (ERIC – external, relax, internal contract) - Ribs move downwards and inwards, sternum moves down to its original position - Volume of thoracic cavity decreases - Lungs are compressed and air pressure inside them increases as the volume decreases - Pressure within the lungs is now higher than atmospheric pressure, air is forced out of lungs to exterior environment  **Figure 7.19** Movement of rib cage and diaphragm during expiration

Model of breathing

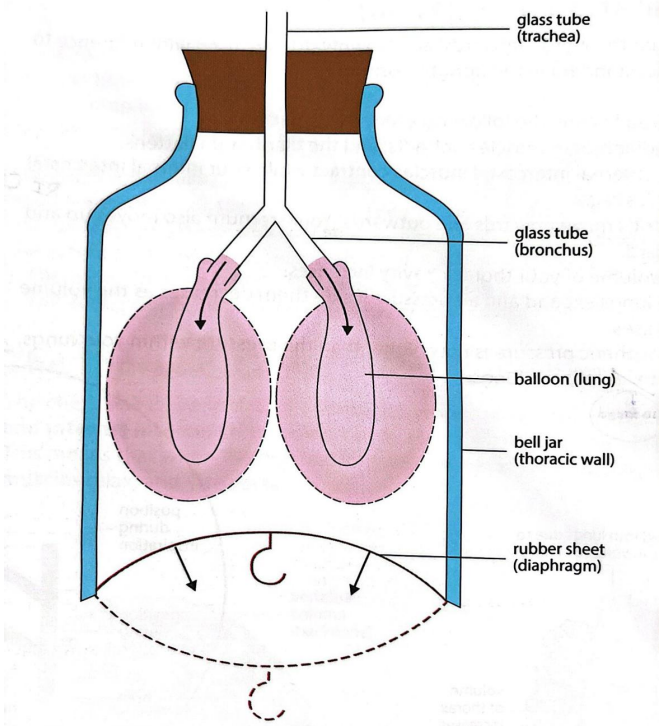


Figure 7.18 Model showing the actions of the diaphragm in the human gas exchange system

How does inspired air differ from expired air?

Component	Inspired Air	Expired Air
Oxygen	Higher	Lower
Carbon Dioxide	Lower	higher
Nitrogen	About the same	About the same
Water vapour	Variable (rarely saturated)	Saturated
Dust particles	Variable but usually present	Little, if any
Temperature	Variable	About body temperature (37°C)

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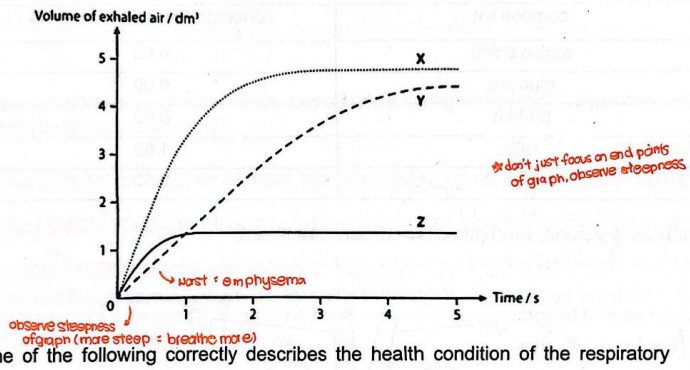
Tobacco Smoke

Chemicals in Tobacco smoke 'O level syllabus'	Nicotine (about arteries) (NA = nicotine arteries) - increases heartbeat rate and blood pressure (heart rate and blood pressure increase as smaller artery so need more strength to pump blood, and pressure increase because smaller space to push same amount of blood) - increases risk of blood clots in the arteries, lead to increased risk of coronary heart disease - increases risk of arteries to narrow - in a pregnant mother, narrow arteries decrease the amount of food substances reaching the fetus, affecting fetal development and may cause miscarriage Carbon Monoxide (about oxygen, because carbon monoxide many Os) - reduces the ability of blood to transport oxygen as carbon monoxide binds permanently with haemoglobin. Thus less haemoglobin available to transport oxygen (oxygen and carbon monoxide need to fight for transport) - in a pregnant mother, less oxygen reaches the fetus through the placenta which may affect fetal development - increases the risk of coronary heart disease Tar (disease/health problem related, DesignThinking = DiseaseTar) - increases risk of cancer in lungs (tar causes uncontrolled cell division) - increases risk of chronic bronchitis and emphysema (tar paralyses cilia lining the air passages, hence dust particles trapped in mucus lining cannot be removed)

Done by MF (completed in 2024)

What diseases are caused by Tobacco smoke?	Chronic Bronchitis - Epithelium lining of the air passages (airways), for example, the bronchi, becomes inflamed - Excessive mucus is secreted by the epithelium - The cilia on the epithelium are paralysed. Mucus and dust particles cannot be removed - Air passages become blocked, making breathing difficult - Persistent coughing occurs to clear the air passages. Increases the risk of lung infections Emphysema (build up from chronic bronchitis) - Persistent and violent coughing due to bronchitis may lead to emphysema - The partition walls between the alveoli break down due to persistent and violent coughing - The lungs lose their elasticity and become inflated with air - Breathing becomes difficult. Wheezing and severe breathlessness result Lung Cancer - The risk of lung cancer increases when a person smokes tobacco. - Cancer is the uncontrolled division of cells producing outgrowths or lumps of tissues. Apart from lung cancer, smoking also increases the risk of cancers of the mouth, throat, pancreas, kidneys and urinary bladder. TAKE NOTE – KILLER QUESTION (many think option C) The graph shows the volume of air exhaled by three individuals, **X**, **Y** and **Z**.  Which one of the following correctly describes the health condition of the respiratory system of individuals **X**, **Y** and **Z**? |	chronic bronchitis	emphysema	healthy lungs
---	---	---	---
A	X	Y	Z
B	X	Z	Y
C	Y	Z	X
D	Z ✓	Y ✓	X ✓	 (D)

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Chapter 8: Excretion in Humans

O Level syllabus

- define excretion and explain the importance of removing nitrogenous and other compounds from the body
- identify the kidneys, ureter, bladder and urethra and state their functions in excretion
- outline the function of the nephron with reference to ultra-filtration and selective reabsorption in the production of urine
- outline the mechanism of dialysis in the case of kidney failure

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Metabolic Waste Products

What are some metabolic waste products?	Carbon Dioxide → This is a product of aerobic respiration. The carbon dioxide level in our blood is usually not harmful. However, in certain cases when it is abnormally high, a condition called hypercarbia occurs. The person may suffer from headache, confusion, rapid breathing, and premature heartbeats. Urea → Urea is a waste product formed from the breakdown of proteins (deamination process). The concentration of urea in our blood is not harmful. However, abnormally high urea concentration in blood may cause abdominal pain, nausea or vomiting. It can even result in an irregular heartbeats and muscle cramps. Mineral Salts or Ions → Our body needs mineral salts. Deficiency of certain ions may result in deficiency diseases (e.g. a lack of calcium can result in weakening of bones) → Excess salts or ions in the blood can be harmful. They may lower the water potential in the blood plasma. And water may then be passed out of the tissue cells into the blood by osmosis. The cells will then become dehydrated. Water → Product of aerobic respiration, hence it is a metabolic product → Excess water will increase water potential in the blood plasma and by osmosis, water will enter the tissue cell causing it to swell and burst.

Excretion

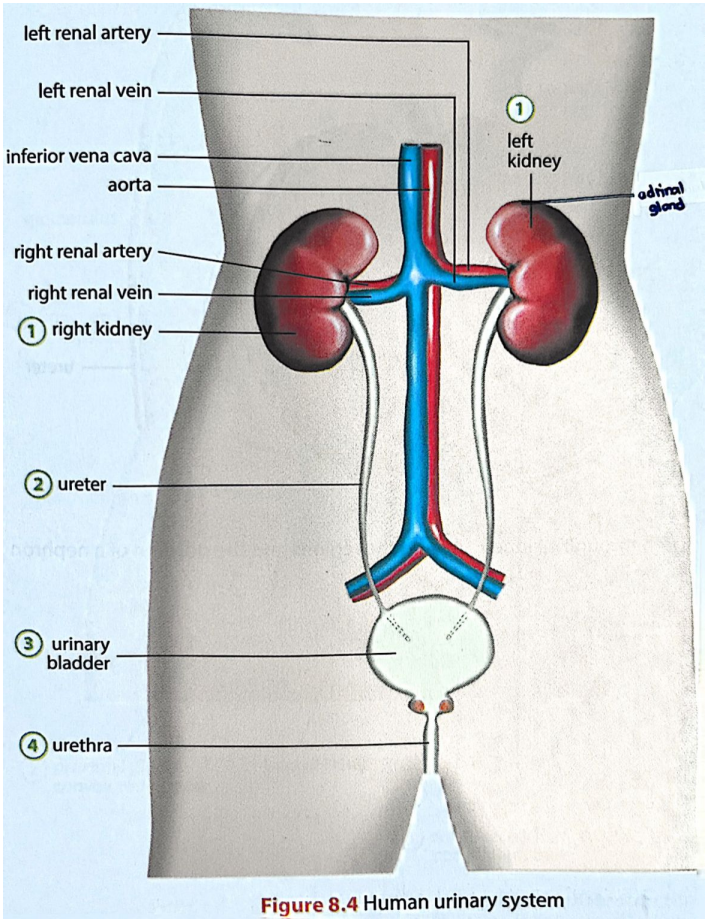
<table>
<tr>
<td>What is excretion?

'O level syllabus'</td>
<td>Excretion is the removal of metabolic waste products, toxic substances, and substances more than the body's requirements from the body of an organism. (must memorise, very important, need to have all highlighted parts)

<table>
<tr><th>Excretory Products</th><th>Excretory Organs</th><th>Excreted as…</th></tr>
<tr><td>Carbon Dioxide</td><td>Lungs</td><td>Gas in expired air</td></tr>
<tr><td>Excess mineral salts</td><td>Kidney
Skin</td><td>Constituent of urine
Constituent of sweat</td></tr>
<tr><td>Excess water</td><td>Kidney
Skin</td><td>Constituent of urine
Constituent of sweat</td></tr>
<tr><td>Urea</td><td>Kidney
Skin</td><td>Constituent of urine
Constituent (traces) in sweat</td></tr>
</table>
</td>
</tr>
<tr>
<td>Why is excretion important?

'O level syllabus'</td>
<td>The body excretes metabolic waste products (e.g. urea) and toxic substances so that they do not accumulate to a level that becomes harmful to the body</td>
</tr>
</table>

Human Urinary System

What makes up the Human Urinary System? 'O level syllabus'	The Human urinary system consists of a pair of kidneys, a pair of ureters, a urinary bladder, and the urethra.  Figure 8.4 Human urinary system 1. The kidneys are beaned-shaped organs. The kidney lies just above the waistline and the left kidney is slightly higher than the right kidney. The main function of the kidneys is to excrete urea and excess salt and water as urine. 2. The ureter is a narrow tube that connects the kidney to the urinary bladder. Urine from each kidney passes through the ureter to the urinary bladder. 3. The urinary bladder is an elastic muscular bag located in front of the rectum. It stores urine. 4. The urethra is the duct through which urine passes from the bladder to outside the body. Kidney (converts urine) → ureter → urinary bladder (store urine) → urethra (goes out of body)

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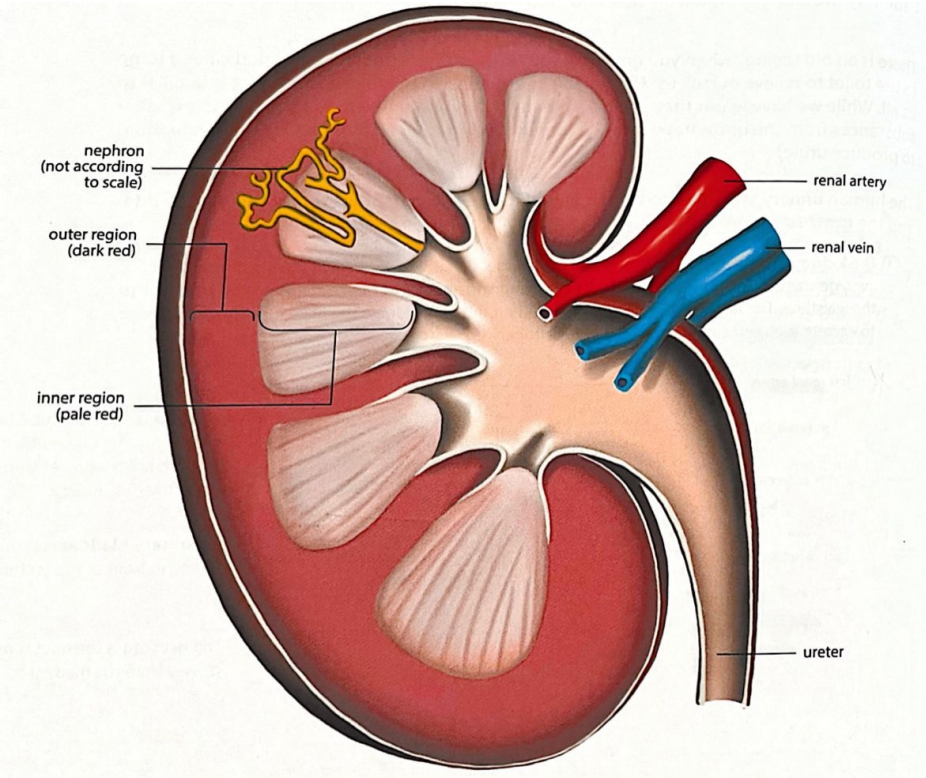
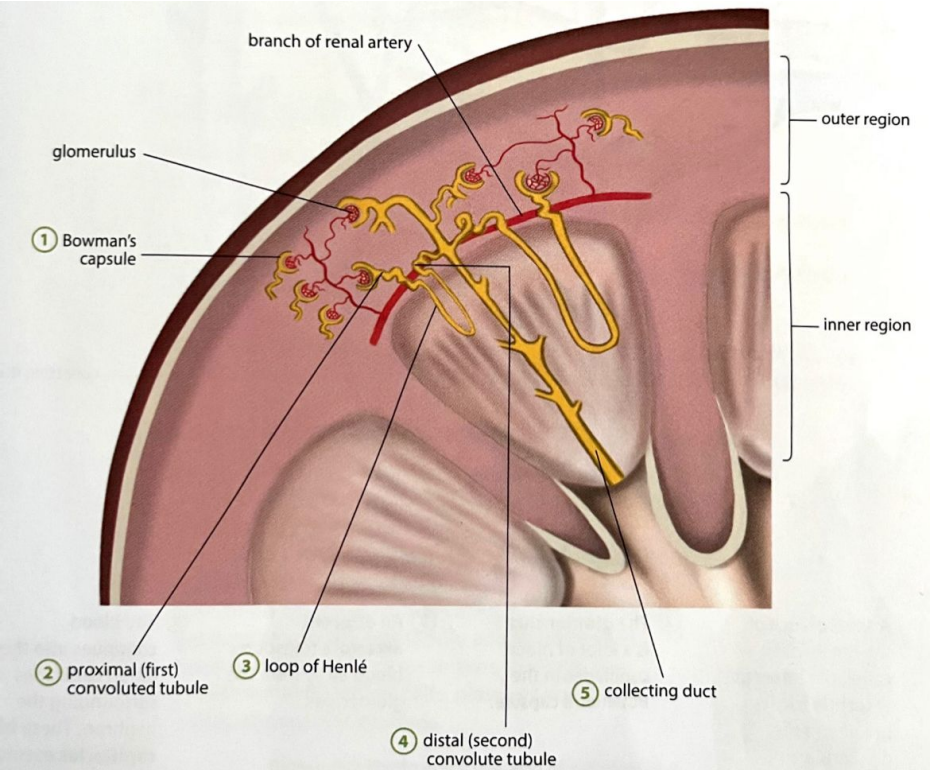
Structure of Kidney	Inside the kidney, there are numerous nephrons. Nephrons are the basic functional units of the kidney. They are tiny kidney tubules where urine is formed. The kidney is connected to the ureter, which drains the urine into the urinary bladder for removal. Function of Nephron (exam answer): The function of the nephron is to remove urea and excess water in the form of urine. Urine is produced via two processes – ultrafiltration and selective reabsorption. Ultrafiltration happens in the glomerulus. The high pressure at the glomerulus forces water, glucose, amino acids and urea out of the glomerulus into the renal capsule. At the proximal convoluted tubule, all glucose and amino acids are selectively reabsorbed into the bloodstream by diffusion and active transport. Some water is reabsorbed into the bloodstream by osmosis.  **Figure 8.5** Diagram of a section through a kidney showing the regions and the position of a nephron

Structure of a Nephron (main thing of excretion chapter)	 **Figure 8.6** Section of kidney showing the complete structure of two nephrons and the arterial supply (L.S.) 1. Bowman's Capsule → each nephron begins in the outer region of the kidney as a cup-like structure called the Bowman's capsule 2. Proximal (first) convoluted tubule → the capsule leads to a short, convoluted tubule which straightens out as it passes into the inner region of the kidney. 3. Loop of Henlé → in the inner region of the kidney, the tubule extends further in and makes a U-turn back into the outer region (The U-shaped portion of the tubule is known as the loop of Henlé) 4. Distal (second) convoluted tubule → When the tubule enters the inner region of the kidney again, it becomes convoluted again. 5. Collecting duct → the tubule then opens into a collecting duct that runs straight through the inner region. It eventually opens into a funnel-like space that leads to the ureter. (Proximal then Distal, P then D)

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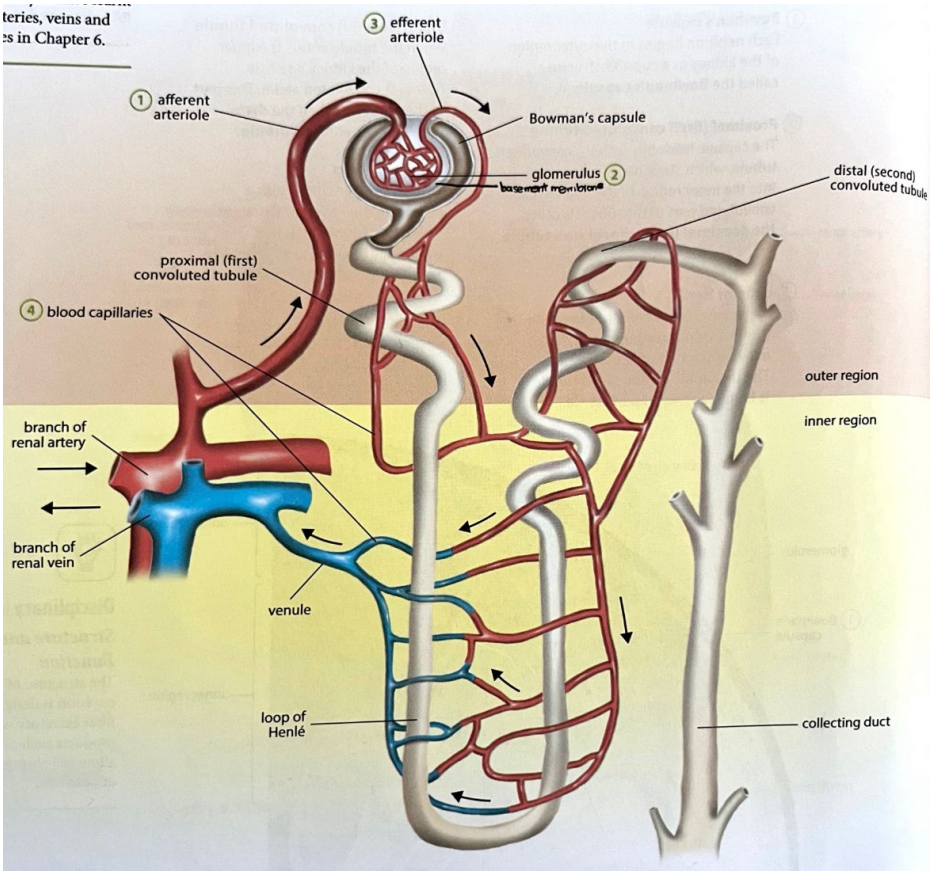
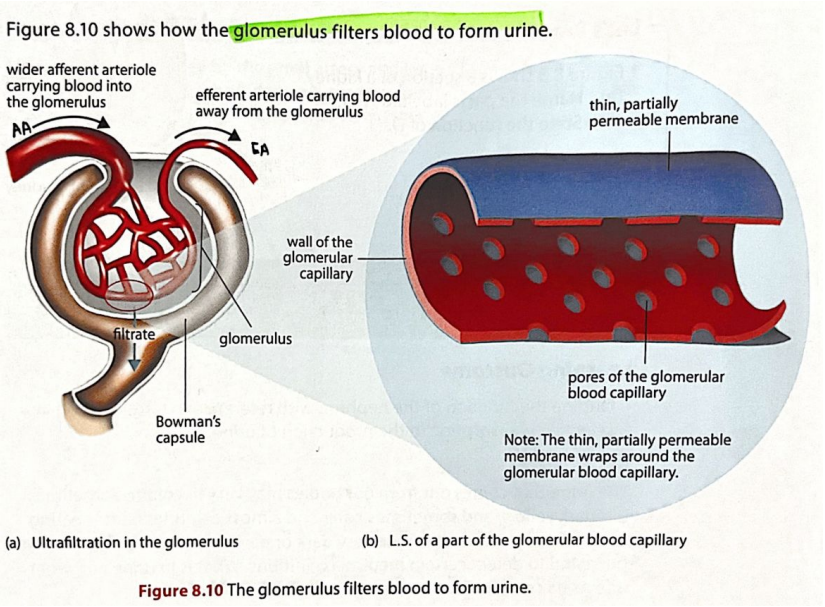
Blood capillaries around nephron	Blood enters the kidney by the renal artery and leave the kidney by the renal vein. Nephrons in the kidney are surrounded by blood vessel that are connected to the renal artery and the renal vein.  1. A small branch of the renal artery called the afferent arterioles carries blood into the glomerulus. 2. The glomerulus is a knot of blood capillaries in the Bowman's capsule. 3. An efferent arteriole transports blood away from the glomerulus 4. The blood continues into the blood capillaries surrounding the nephron. These blood capillaries eventually lead into a branch of a renal vein. (Afferent then Efferent, Accident and Emergency [A&E])

Process of excretion

How is urine formed?	Urine formation involves two main processes: ultrafiltration and selective reabsorption. (main thing of this chapter → ultrafiltration and selective reabsorption)
Ultrafiltration 'O level syllabus' (ultrafiltration filters everything, no matter good or bad) (ultrafiltration is caused by the contraction of the left ventricle)	The afferent arteriole being wider than the efferent arteriole creates a high **hydrostatic** pressure in the glomerulus. (blood need to squeeze, use "hydrostatic pressure") Blood plasma is forced out of the glomerular blood capillaries into the Bowman's capsule. (write "forced" because pressure difference) The filtered blood plasma is known as the glomerular filtrate. It contains small, soluble molecules (salts, water, glucose, amino acids, and waste products like urea) that are forced into the Bowman's capsule. *How is the Glomerulus suited to Urine Formation?* - The Glomerulus is a knot or network of blood capillaries. These provides a larger surface area for the filtration process. - The afferent arteriole is wider than the efferent arteriole. This results in high blood pressure at the glomerulus. - The blood capillaries have walls one-cell thick. There are tiny pores in the capillary wall. - The blood capillaries are covered by a thin partially permeable membrane. It only allows very small soluble molecules or ions to pass through. It is impermeable to blood cells, platelets and large molecules like proteins. (membrane like sieve, help filter out the small particles) Figure 8.10 shows how the glomerulus filters blood to form urine.  **Figure 8.10** The glomerulus filters blood to form urine.

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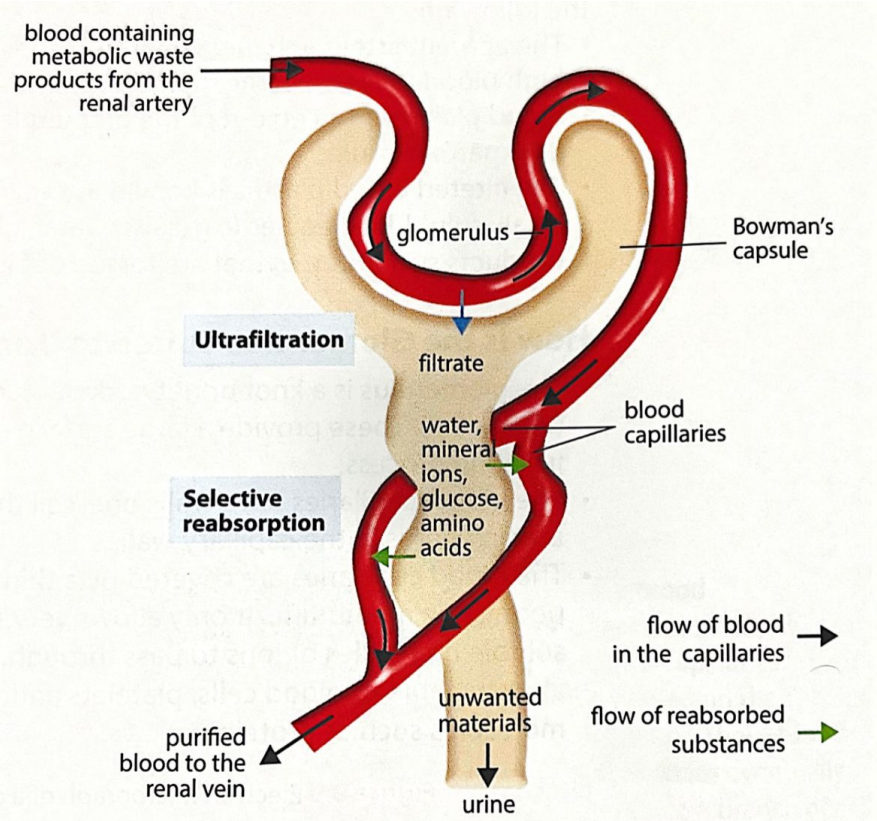
Selective Reabsorption 'O level syllabus' (separates and takes the good stuff from the bad)	As the glomerular filtrate passes along the nephron, useful substances are reabsorbed into surrounding blood capillaries. Only the substances that the body requires are reabsorbed. In this process: → most water is reabsorbed by osmosis (some for urine) → some mineral salts are reabsorbed by active transport → all the glucose and amino acids are reabsorbed by active transport → waste products like urea and excess water and mineral salts are passed out of the nephron as urine  **Figure 8.11** Overview of urine formation

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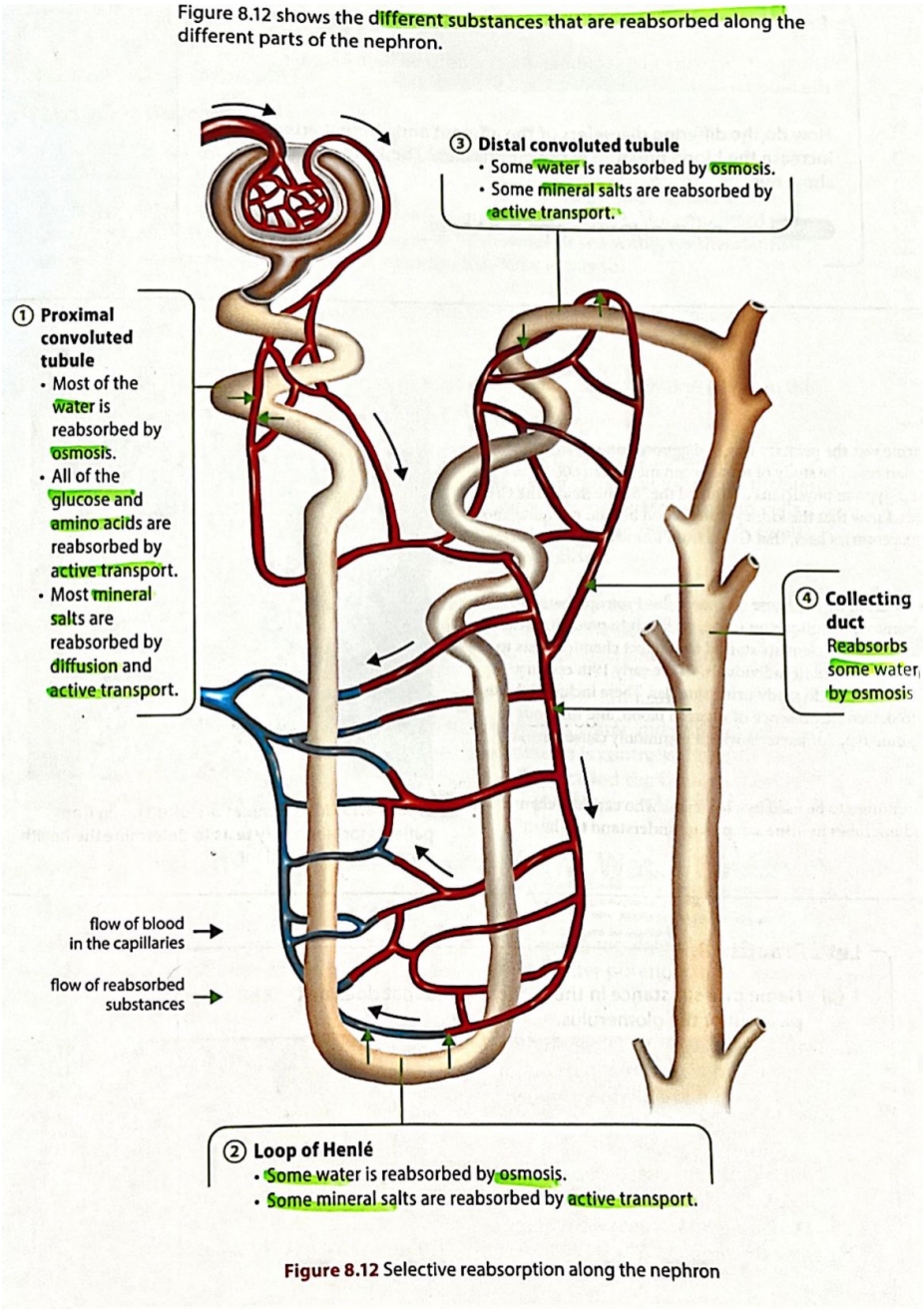
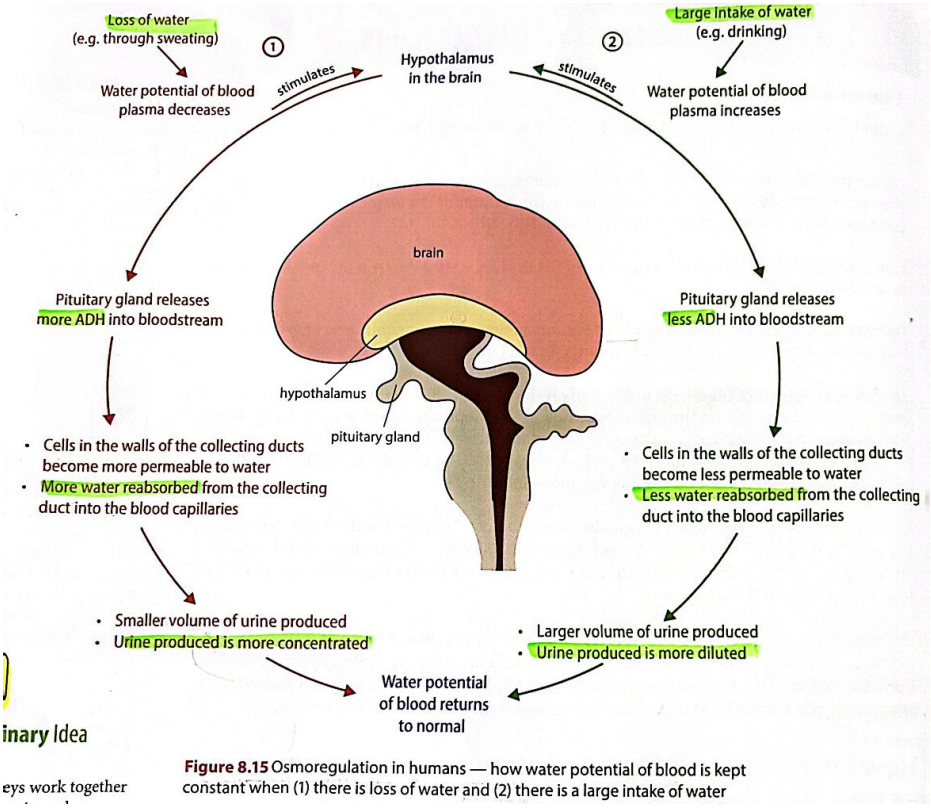
	Different substances are reabsorbed along different parts of the nephron:  **Figure 8.12** Selective reabsorption along the nephron - Glucose & Amino Acids: Proximal Convoluted Tubule (active transport) - Mineral Salts: Proximal Convoluted Tubule, Loop of Henle, Distal Convoluted Tubule (active transport) - Water: Proximal Convoluted Tubule, Loop of Henle, Distal Convoluted Tubule, Collecting duct (osmosis)

Done by MF (completed in 2024)

Osmoregulation

What is osmoregulation ?	Osmoregulation is the control of water potential and solute concentration in the blood to maintain a constant water potential in the body. → control water potential to maintain The water potential of the blood in the body must be kept relatively constant. Thus, how much water needs to be excreted from the body is controlled by this process. If blood plasma is too diluted (too much water inside), water will enter the blood cells by osmosis. The blood cells will swell and possibly burst. The tissue cells will also swell because water from the blood plasma will move into the cells. (Blood plasma have higher water potential than blood cells, thus water goes from blood plasma to blood cells through osmosis) If blood plasma is too concentrated, water will move out of the cell by osmosis. The blood cells and tissue cells will become dehydrated and shrink. They will not be able to carry out their metabolic functions properly. (recall osmosis → net movement of particles from a region of higher potential to a region of lower potential, across a partially permeable membrane) The water potential of the blood depends on the amount of water and mineral salts in the blood plasma. The amount of water in the blood plasma is controlled by the antidiuretic hormone (ADH). ADH produced by a region of the brain called the hypothalamus. It is released by the pituitary gland and increases water reabsorption at the nephrons.

How do kidneys help to regulate the water potential of blood?	The kidneys are called osmoregulators because they help to regulate the water potential and solute concentration in the blood.  **Figure 8.15** Osmoregulation in humans — how water potential of blood is kept constant when (1) there is loss of water and (2) there is a large intake of water (memorise, potential section B, can link with homeostasis)

Done by MF (completed in 2024)

Kidney failure

Why are the kidneys important?	The kidneys are excretory organs → they play an important role in excreting metabolic waste products (e.g. urea and excess water and mineral salts) in the form of urine The kidneys are osmoregulators → they regulate the solute concentration and water potential in blood thus maintaining a constant water potential.
What causes kidney to fail? (just know can alr)	Common causes of kidney failure include: → high blood pressure → diabetes → alcohol abuse (constant heavy drinking) → severe accidents that physically damage the kidney → complications from undergoing major surgery If one kidney fails to function, a person can still lead a normal life with the other kidney. However, if both kidneys fail to function, a person will die unless prompt medical treatment is given. Patients with kidney failure may get a kidney transplant. The patient can also be treated with dialysis using a dialysis machine (a dialysis machine mimics the functions of a kidney by cleaning the patient's blood from metabolic waste products and toxin).

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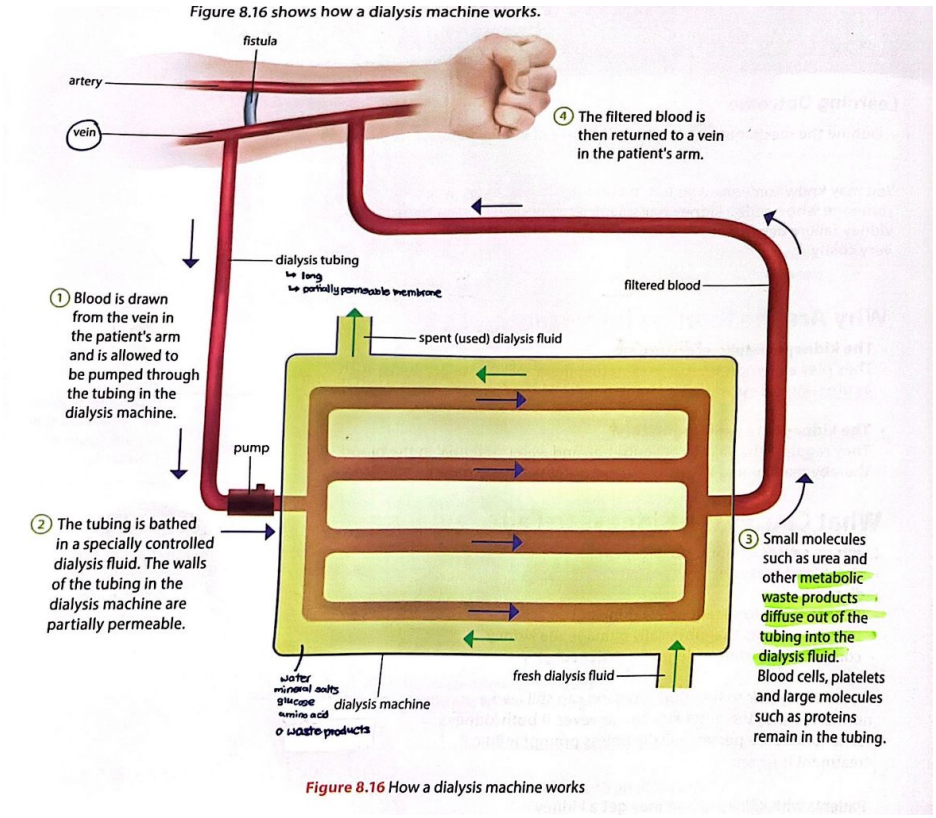
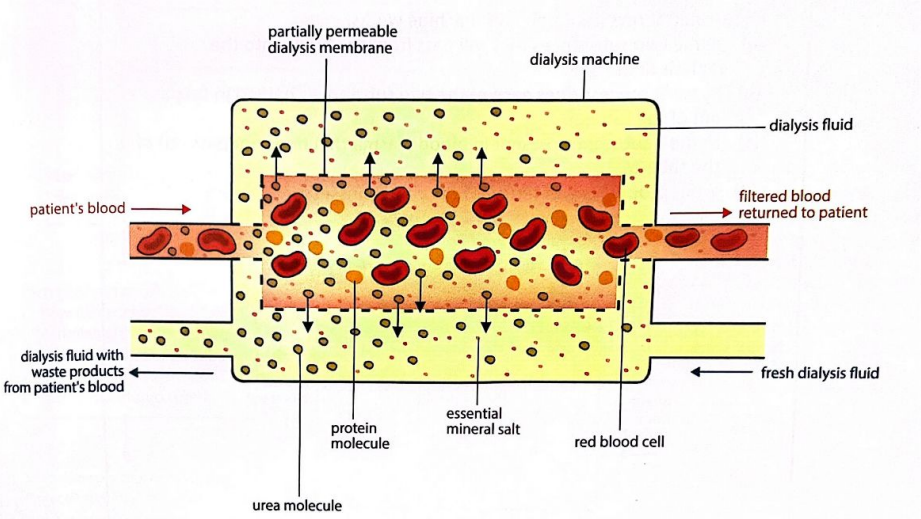
Dialysis

How does a dialysis machine work? 'O level syllabus' (know how it works)	 Figure 8.16 How a dialysis machine works
Function of dialysis fluid (tested in O levels 2021)	The dialysis fluid allows for removal of urea and metabolic waste products from the blood plasma through diffusion from higher concentration (in blood plasma) to lower concentration (in dialysis fluid). If the patient's blood plasma lacks essential nutrients, glucose and amino acids can also diffuse from the dialysis fluid into the blood plasma from higher to lower concentrations to restore normal levels in blood plasma.

Done by MF (completed in 2024)

What are the features of a Dialysis Machine? 'O level syllabus' (pls know, like to test)	The dialysis fluid contains the same concentration of essential substance as healthy blood → this is to ensure that essential substances (glucose, amino acids and mineral salts) do not diffuse out of the blood into dialysis fluid. (same concentration = no net movement) (specify essential substances, pls state "glucose, amino acids, mineral salts") The dialysis fluid does not contain metabolic waste products → this sets up a concentration gradient that allows waste products (urea, excess water and mineral salts) to diffuse out of the tubing into the dialysis fluid. The waste products are removed from the blood. This maintains the correct solute composition and water potential of the blood. (bigger difference, diffusion more) The tubing in the machine is narrow, long and coiled → increases the surface area-to-volume ratio which helps to speed up rate of exchange of substance between patient's blood and the dialysis fluid. The direction of the blood flow is opposite to the flow of dialysis fluid → maintain a concentration grandient for the removal of waste products  **Figure 8.18** How substances are exchanged between the blood and the dialysis fluid in a dialysis machine

Chapter 9: Homeostasis and Hormonal Control

O Level syllabus

- define homeostasis as the maintenance of a constant internal environment
- explain the basic principles of homeostasis in terms of stimulus resulting from a change in the internal environment, a corrective mechanism and negative feedback
- describe the maintenance of a constant body temperature in humans in terms of the role of:
  1. Temperature receptors in the skin detecting changes in temperature
  2. Sweating
  3. Shivering
  4. Altering blood flow through blood vessels near the skin surface
  5. The coordinating role of the hypothalamus
- define a hormone as a chemical substance, produced by a gland, carried by the blood, which alters the activity of one or more specific target organs
- explain what is meant by an endocrine gland, with reference to the islets of Langerhans in the pancreas
- explain how blood glucose concentration is regulated by insulin and glucagon as a homeostatic mechanism
- describe type 2 diabetes mellitus in terms of a persistently higher than normal blood glucose concentration due to the body's resistance to insulin or insufficient production of insulin
- identify the risk factors of (e.g. unhealthy diet and sedentary lifestyle) and ways to manage type 2 diabetes mellitus
- outline the role of anti-diuretic hormone (ADH) in osmoregulation

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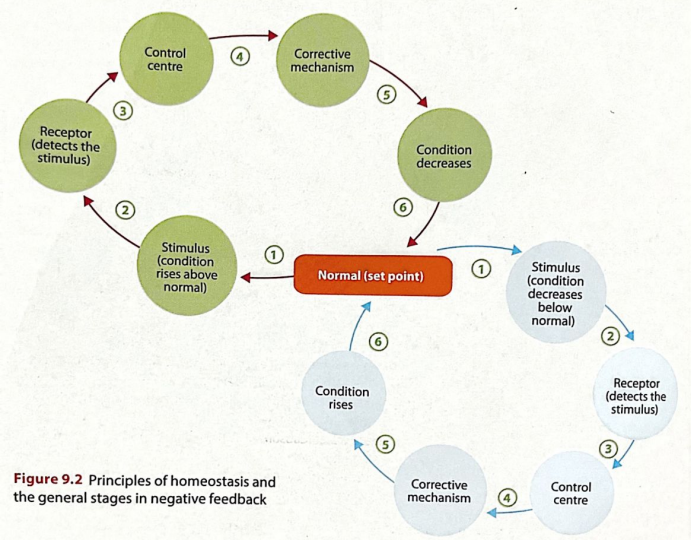
Homeostasis (know how to answer with all the answering structures, all potential section B questions)

What is Homeostasis? 'O Level Syllabus'	Homeostasis is the maintenance of a constant internal environment. The internal environment of the human body includes the blood and tissue fluids that surrounds the cells in the body. Homeostasis ensures that the conditions of the blood and tissue fluids in terms of temperature and water potential are kept within narrow limits. Principle of homeostasis Homeostasis is the maintenance of a constant internal environment. When there is a change in the internal environment of the body (above or below norm), receptors detect the change and sends signals to the effectors. The effectors activate a corrective mechanism in order to restore the change back to the set-point or normal condition. Once normal conditions are achieved, instructions are transmitted to the receptor to prevents further corrective action (negative feedback).

Done by MF (completed in 2024)

What are some examples of homeostasis?	Regulating body temperature → Our body cells must be kept at a constant temperature, because enzymes in our body can only work within a certain range of temperatures. Regulating water potential of blood and tissue fluid → The composition of blood plasma and tissue fluid must be kept within very narrow limits to ensure that they are kept at constant water potential. Drastic changes in water potential will affect cells. Regulating blood glucose concentration → These hormones (insulin and glucagon secreted in the islet of Langerhans) are important in the regulation of blood glucose concentration in the body. Body cells need glucose for cellular respiration, they provide cells with energy to perform vital activities.
How does Homeostasis work? 'O Level Syllabus'	In homeostatic control, your body reacts to bring the opposite effect to the changes detected. If the system (body) is disturbed, the disturbance sets in motion a sequence of events that tends to restore the system to the original state. → Negative feedback process There are organs or structures in our body that can detect changes in the body condition. These organs or structures are called receptors or sense organs. Any change from the normal condition is called the stimulus. For negative feedback process, there must be... - Normal level to be maintained - Stimulus, change in internal environment - Receptor, detect the stimulus and send signals to control centre - Corrective mechanism, brings reverse effect of the stimulus  **Figure 9.2** Principles of homeostasis and the general stages in negative feedback

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Regulating Blood water potential

How is blood water potential regulated? 'O Level Syllabus'	Chapter 8 (excretion) – Antidiuretic Hormone (ADH) acts on the kidneys to help regulate water potential in blood through osmoregulation. ADH affects the reabsorption of water in the kidneys. Less ADH will lead to more urine production, while more ADH will lead to less urine production.

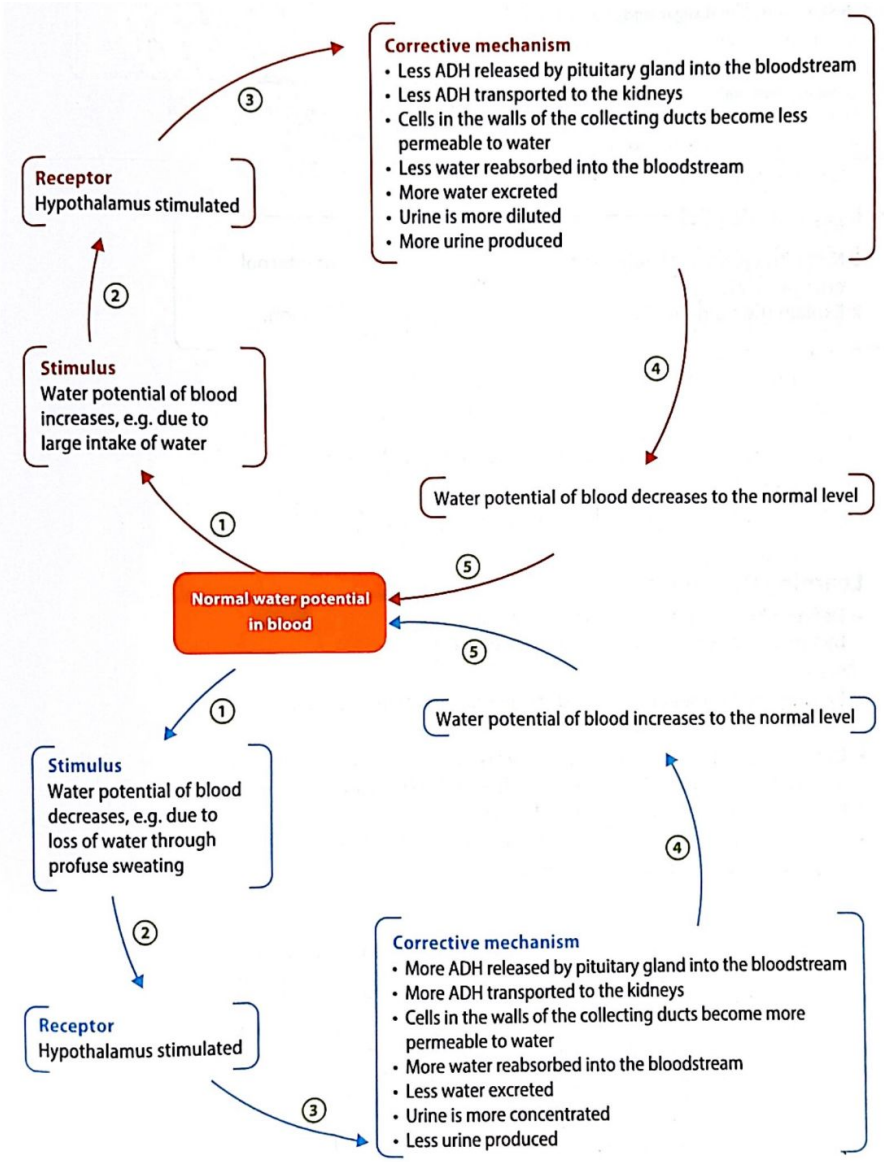

Figure 9.3 Homeostatic control of water potential in humans

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Hormones

What is a hormone? 'O Level Syllabus' (like to ask what are hormones, esp school papers)	A hormone is a chemical substance produced in minute quantities by an endocrine gland. It is transported in the bloodstream to target organs which it exerts its effects. After the hormone has performed their function, they are destroyed by the liver. Hormones can influence growth, development and activity of an organism. They are chemical messengers that help the various parts of the body to respond, develop and work together smoothly.
Where are hormones produced? 'O Level Syllabus'	Hormones are produced by glands. Glands with ducts (e.g. salivary gland, sweat gland) are called exocrine gland. Hormones are produced by ductless glands. The hormone produced by a ductless gland is secreted directly into the bloodstream. The bloodstream then distributes the hormone around the body. These ductless glands are known as endocrine glands. Some glands are purely endocrine glands (pituitary gland that secretes ADH), other glands such as the pancreas produce both hormones and other secretion (produces pancreatic juice, which is carried by the pancreatic duct to the duodenum, also contains a special group of cells known as the islets of Langerhans which secrete the hormones insulin and glucagon into bloodstream), hence pancreas can be classified as both endocrine and exocrine gland

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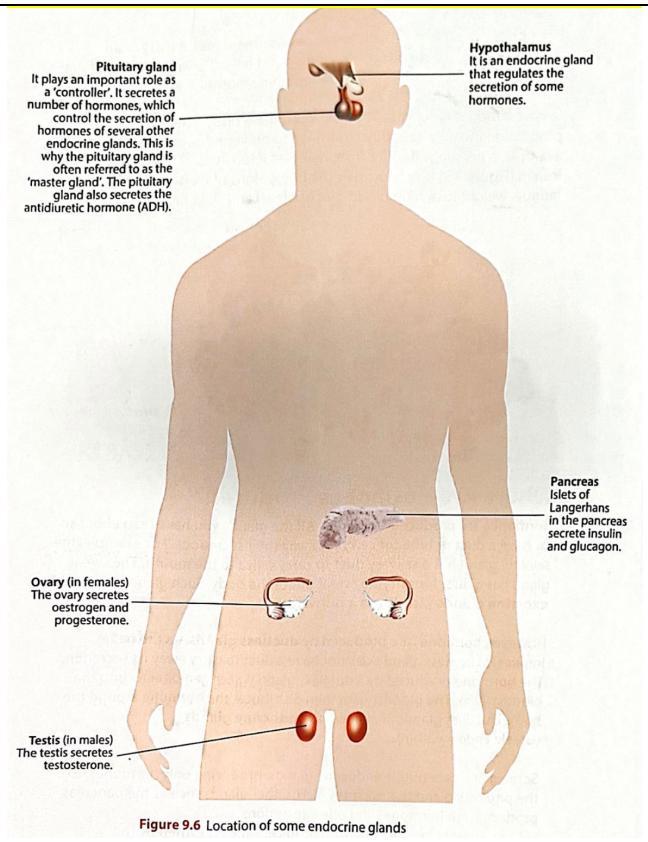
Where and what are some examples of endocrine glands?	 Figure 9.6 Location of some endocrine glands

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Insulin and glucagon

<table>
<tr>
<td>What are the effects of Insulin?</td>
<td>When concentration of blood glucose increases above normal levels, the islet of Langerhans in the pancreas increases the secretion of the hormone insulin.
<table>
<tr><th>Amount of Insulin secreted</th><th>Effect</th></tr>
<tr><td>Normal</td><td>Decreases blood glucose concentration by...
- making cell membranes more permeable to glucose, allow more glucose to diffuse into liver and muscle cells
- stimulating the liver and muscle cells to convert excess glucose into glycogen for storage
- increases the use of glucose for respiration.</td></tr>
<tr><td>Lack of secretion</td><td>Increases blood glucose concentration as...
- glucose cannot be stored by tissue cells (hence, blood glucose concentration rises. Some glucose is subsequently lost in urine →diabetes mellitus.

Muscle cells have no reserves of glycogen; the body feels weak and continuously lose weight.</td></tr>
<tr><td>Oversecretion</td><td>Abnormal decrease in blood glucose concentration such that...
- low blood glucose concentration results in a condition called shock
- seizures or fits, collapsing or passing out may follow.</td></tr>
</table>
</td>
</tr>
<tr>
<td>What are effects of Glucagon?</td>
<td>When concentration of blood glucose decreases above normal levels, the islet of Langerhans in the pancreas increases the secretion of the hormone glucagon.

The main target of glucagon is the liver. Glucagon increases blood glucose concentration by stimulating...
- the conversion of glycogen into glucose
- the conversion of fats and amino acids into glucose</td>
</tr>
</table>

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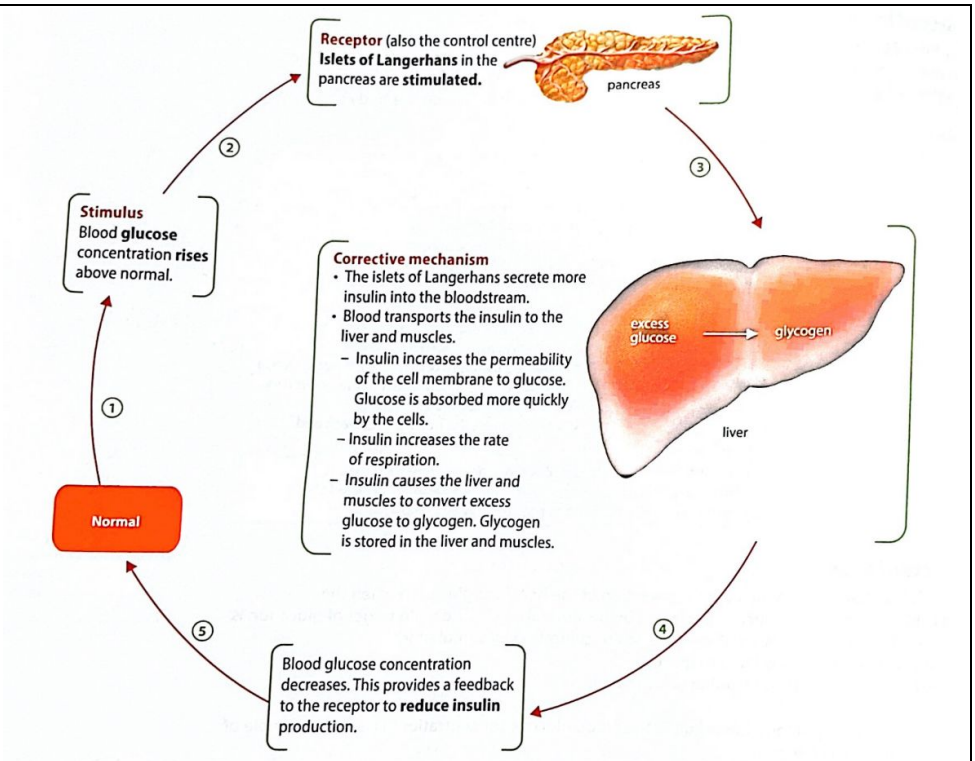
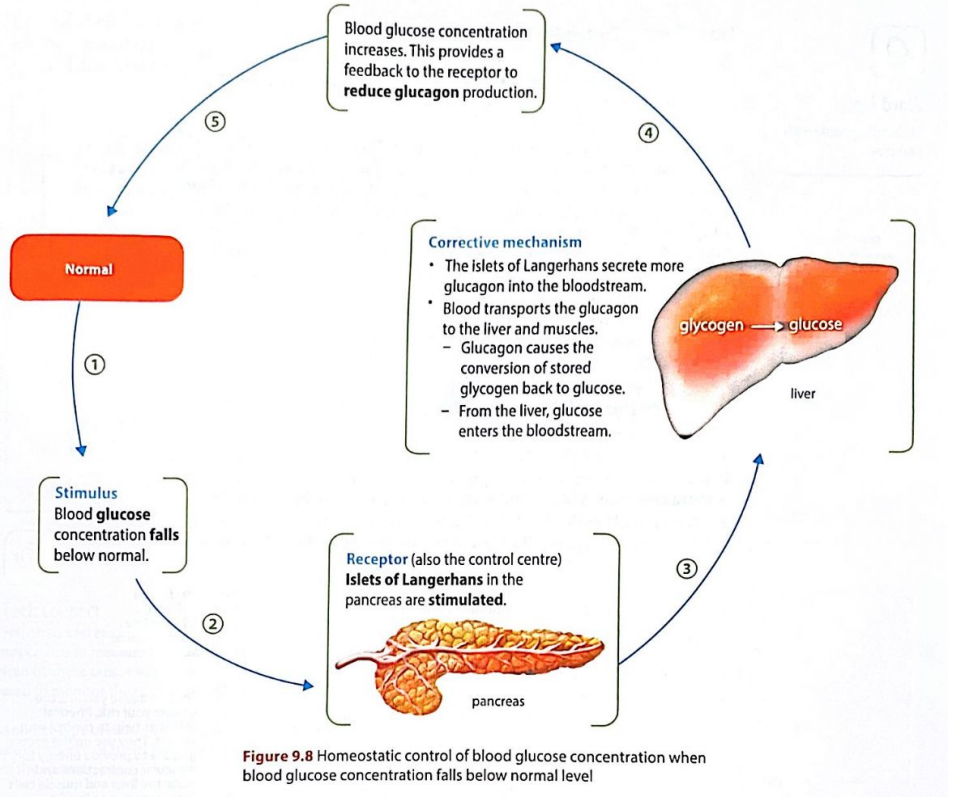
Regulating blood glucose concentration levels

Rises above normal 'O Level Syllabus'	 **Figure 9.7** Homeostatic control of blood glucose concentration when blood glucose concentration rises above normal level
Drops below normal 'O Level Syllabus'	 **Figure 9.8** Homeostatic control of blood glucose concentration when blood glucose concentration falls below normal level

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Diabetes Mellitus

What is Diabetes Mellitus?	Diabetes Mellitus/Diabetes is a disease in which the body is unable to control its blood glucose concentration for it to remain within normal limits. As a result of blood glucose concentration can rise to a level that exceeds the kidney's ability to completely reabsorb all the glucose. The glucose not absorbed is excreted in the urine. (normally urine should have no glucose)
What are the types of diabetes? 'O Level Syllabus'	Type 1 diabetes → develops early in a person's life, known as juvenile/early -onset diabetes. The islets of Langerhans are unable to produce or secrete sufficient insulin. It is inherited. Type 2 diabetes → occurs late in a person's life, known as late-onset diabetes. Overweight people are more likely to develop this. Type 2 diabetes develops when the target cells, such as the muscle cells, do not respond well to insulin.
Signs and symptoms	- Persistent high blood glucose level - Prescence of glucose in urine - Healing of wounds is slow/difficult - Frequent urination - Weight loss - Thirst
How can diabetes be treated?	Diabetics must measure their blood glucose concentrations and test their urine regularly. They also must watch their diets carefully, making sure that they do not take in too much carbohydrates. People with type 1 diabetes must inject insulin regularly into the fat tissue under the skin (e.g. into the abdomen). If they use too much insulin, their glucose levels will drop too low. Low blood glucose concentrations may cause them to go into a coma. Diabetics should also take medication that increases the uptake of glucose from the bloodstream into cells.

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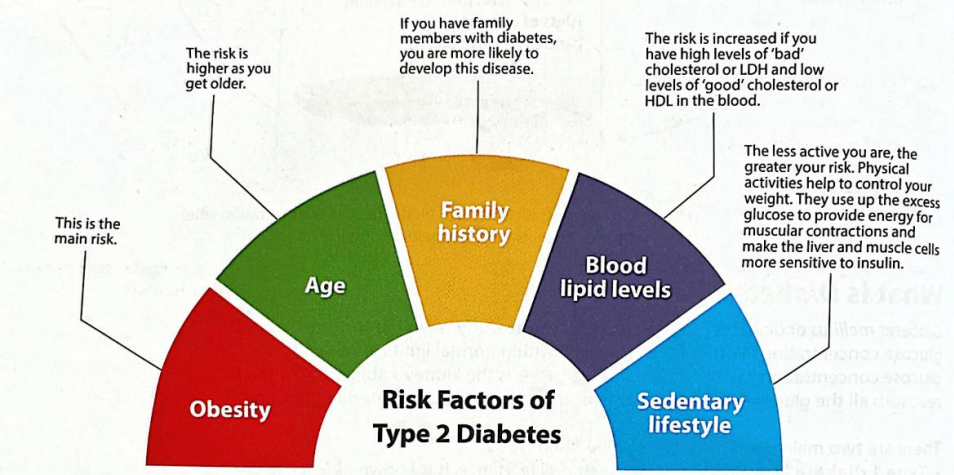
Risk factors of type 2 diabetes 'O Level Syllabus'	In type 2 diabetes, the liver and muscle cells do not respond well to insulin → insulin resistance. They are unable to take in excess glucose in the blood. Hence glucose levels remain high.  **Figure 9.9** Factors that may increase the risk of type 2 diabetes
Healthy lifestyle to reduce risk of type 2 diabetes	- eat healthily; consume foods that are low in calories and high in fibre (e.g. eat more fruits and vegetables) - engage in more active physical activities - avoid being inactive for long period of time - maintain a healthy body weight, based on age and height

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Structures involved in temperature regulation in the skin

What are the structures involved in temperature regulation in the skin?

'O Level Syllabus'

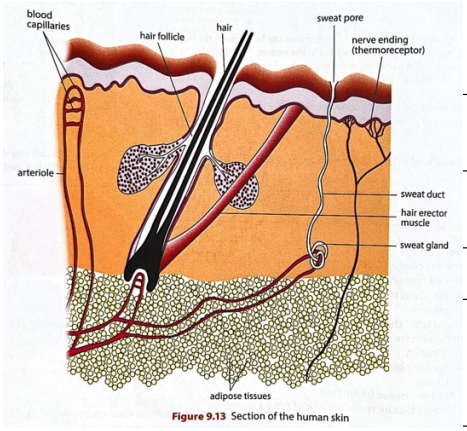

Figure 9.13 Section of the human skin

name	explanation
hair	hair erector muscles in skin contract, resulting in hair standing to trap air which is an insulator of heat
temperature receptor	temperature receptors in skin detects change in temperature below norm
sensory neurone	transmits nerve impulses to the relay neurone in central nervous system
adipose tissue	serve as insulating layer to reduce heat loss
blood capillary	constriction of arterioles allows less blood to flow to the blood capillary, resulting in less heat loss via convection, conduction and radiation

Blood vessels (capillaries and arterioles) under the skin surface
→ The constriction and dilation of arterioles are caused by the contraction and relaxation of muscles in the arteriole walls. The contraction and dilation of the arterioles help to regulate body temperature.
→ Dilation of arterioles (vasodilation). When the skin arterioles dilate, more blood is sent to blood capillaries in the skin, thus our skin turns red when numerous blood vessels dilate
→ constriction of arterioles (vasoconstriction). Reduces the amount of blood flowing through the capillaries in the skin and causes us to become pale

Sweat glands
→ secreted sweat flows through a sweat duct to a sweat pore that opens to skin surface. Secreted sweat is mainly made up of water and it contains dissolved salts and small amount of urea – skin is considered an excretory
→ sweat is secreted continuously, amount of sweat produced varies on the external and internal environmental conditions. Sweat produced in very small quantities evaporate almost immediately whereas sweat produced in large quantities appears as droplets on your skin – skin regulates body temperature.

Sensory receptors
→ The structures in the body that detect changes in the environment
→ enable you to sense pain, pressure, and temperature changes in the external environment. Receptors that detect temperature changes are called thermoreceptors.

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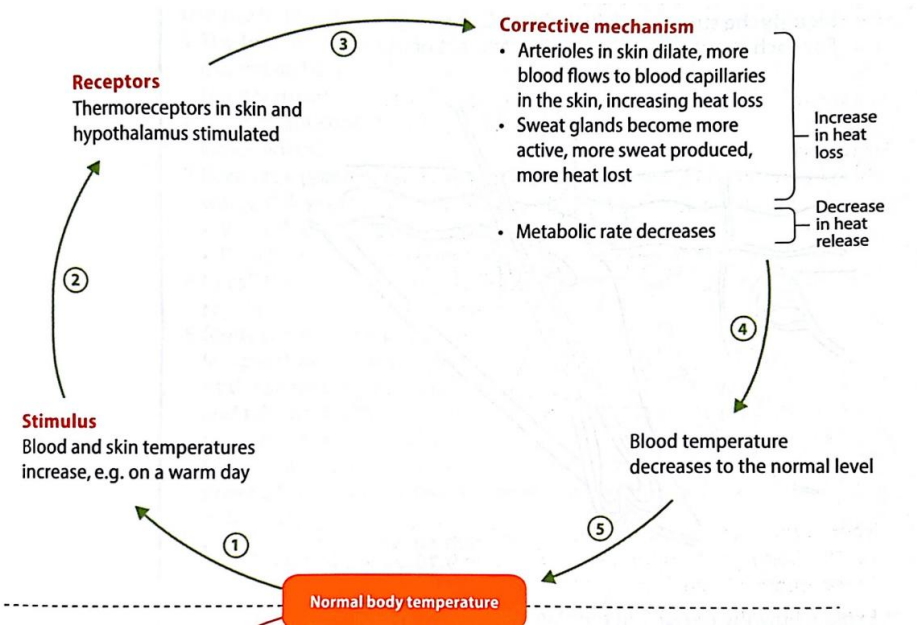
Heat gain and Heat loss by the body

Heat gained by body	Heat is released within the body because of metabolic activities such as cellular respiration. High levels of cellular respiration take place in the muscles and liver. Thus, a large amount of heat is released in these organs. Heat is distributed to the rest of the body through the bloodstream. The body gains extra heat through vigorous muscular exercise, consumption of hot food and being in a warm environment. Excess heat needs to be removed from the body
Heat lost by the body	Heat is lost through the skin, by evaporation of water in sweat from the surface of the skin, in the faeces and urine and in the air that is exhaled. The amount of blood flowing through the skin capillaries affects the heat loss through the skin surface.

Regulation of body temperature

How is the body temperature regulated? 'O Level Syllabus'	The hypothalamus in the brain monitors and regulates the body temperature. It receives information about temperature changes from 2 sources (thermoreceptors in the skin – temperature from environment and thermoreceptors in the hypothalamus – temperature from blood)
What happens when body temperature begins to rise? 'O Level Syllabus'	

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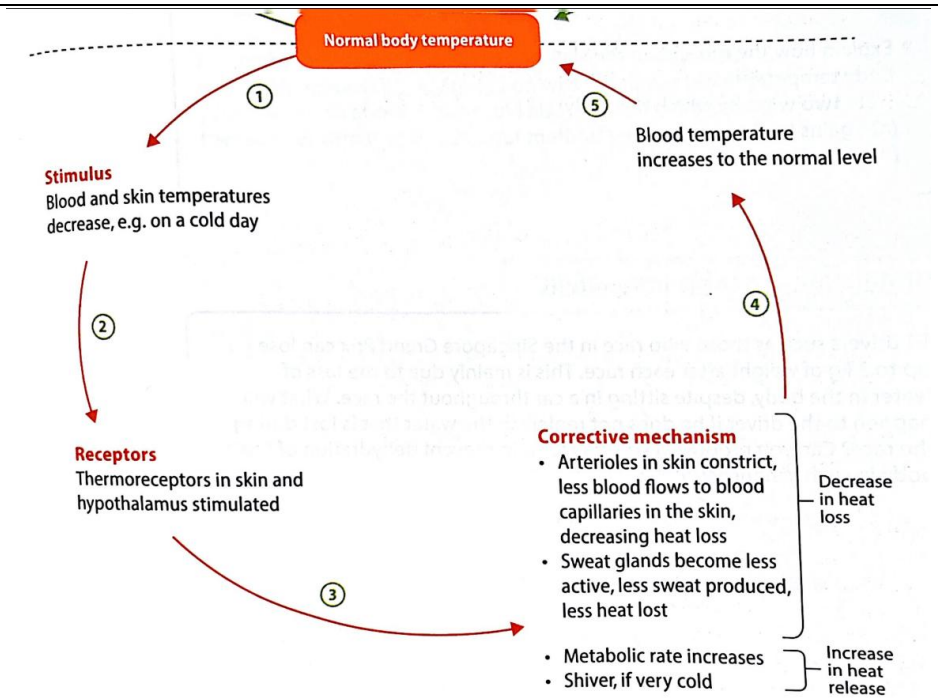
What happens when body temperature begins to fall? 'O Level Syllabus'	 **Figure 9.19** Summary of the homeostatic control of body temperature

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RESPONSE TO CHANGE IN ENVIRONMENT

	Change in body temperature	Change in blood glucose concentration	Change in blood water potential
Stimulus	**Rise in body temperature above normal levels**	**Increase in blood glucose concentration above normal levels**	**Increase in blood water potential above normal levels**
Receptor	• Temperature receptors in skin detect increase in skin temperature. • Hypothalamus in brain detect increase in blood temperature	Islets of Langerhans in pancreas detects increase in blood glucose concentration.	Hypothalamus detect increase in blood water potential.
Corrective mechanism	• Arterioles in skin dilate, more blood flows to blood capillaries in the skin. More heat loss by radiation, conduction and convection. • Sweat glands more active, more sweat produced, more water in sweat evaporates. More latent heat of vaporisation lost by radiation, conduction and convection. • Metabolic rate decreases.	• Islets of Langerhans in pancreas stimulated and secrete more insulin into bloodstream. • Insulin increases permeability of cell surface membrane to glucose. Glucose absorbed more quickly by the liver and muscle cells. • Insulin causes liver and muscles to convert excess glucose to glycogen which is stored in cells.	• Hypothalamus stimulated, less ADH released by pituitary gland. • Less ADH decreases permeability of collecting duct to water. • Less water reabsorbed by kidney tubules. • More water excreted. • Urine is more diluted/ More urine produced.
Stimulus	**Decrease in body temperature below normal levels**	**Decrease in blood glucose concentration below normal levels**	**Decrease in blood water potential below normal levels**
Receptor	• Temperature receptors in skin detect decrease in skin temperature. • Hypothalamus in brain detect decrease in blood temperature	Islets of Langerhans in pancreas detects decrease in blood glucose concentration.	Hypothalamus detect decrease in blood water potential.
Corrective mechanism	• Arterioles in skin constrict, less blood flows to blood capillaries in the skin. Less heat loss by radiation, conduction and convection. • Sweat glands less active, less sweat produced, less water in sweat evaporates. Less latent heat of vaporisation lost • Metabolic rate increases.	• Islets of Langerhans in pancreas stimulated and secrete glucagon into bloodstream. • Glucagon causes liver and muscles to convert stored glycogen to glucose.	• Hypothalamus stimulated, more ADH released by pituitary gland. • More ADH increases permeability of collecting duct to water. • More water reabsorbed by kidney tubules. • Less water excreted. • Urine is more concentrated/ Less urine produced.

Chapter 10(a): The Nervous System and the Eye

O Level syllabus

- state that the nervous system – brain, spinal cord and nerves, serves to co-ordinate and regulate bodily functions
- outline how receptors, sensory neurones, relay neurones (located in the spinal cord or brain), motor neurones and effectors work together to produce a coordinated response in a reflex action as a result of a specific stimulus
- describe the structure of the eye as seen in front view and in horizontal section?
- state the principal functions of component parts of the eye in producing a focused image of near and distant objects on the retina
- describe the pupil reflex in response to bright and dim light

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Part (a): Human Nervous System

Sensitivity & Stimulus

What is sensitivity? (unlikely will test, stimulus more important)	The ability to respond to a stimulus. Sensitivity is the ability to respond to a stimulus
	Any change in the environment that causes an organism to react is called a stimulus. An organism's reaction to a stimulus is called a response.

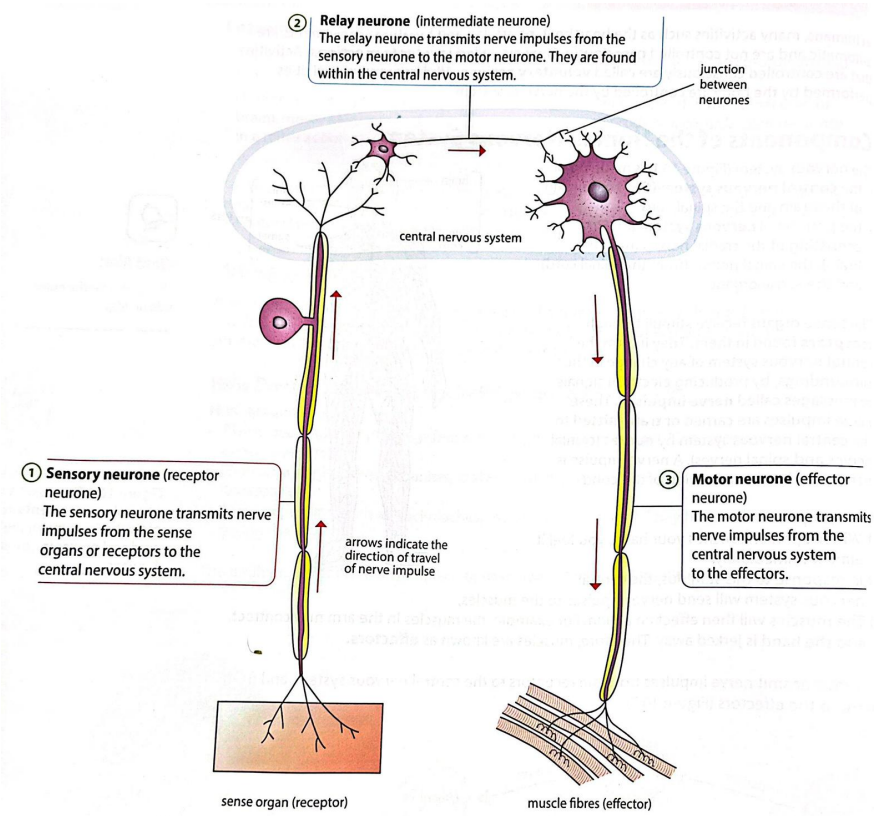
Role of Nervous system

What is the Role of Nervous System in Humans?	The nervous system in humans regulates bodily functions and activities and how we react to the surroundings (response). It consists of a well-developed brain, spinal cord, spinal nerves and highly specialize sense organs (sense organs detect changes in the environment)
What are activities performed by the Nervous System?	Involuntary Actions → Automatic and not controlled consciously (e.g. heartbeat, peristalsis and breathing movements) Voluntary Actions → controlled consciously

Components of Nervous System

What components are present in the Human Nervous System?	The Central Nervous System (CNS) consists of the brain and spinal cord. The Peripheral Nervous System (PNS) consists of the cranial nerves (from the brain) and the spinal nerves (from the spinal cord) and the sense organs. Both the CNS and the PNS serve to coordinate voluntary and involuntary actions.
What is the relationship between receptors, the central nervous system, and the effectors	The sense organs contain receptors. The receptors will receive the stimulus then produce nerve impulses which are transmitted to the central nervous system by nerves. The central nervous system then receives nerve impulses from the receptors. The nerve impulses are transmitted to the central nervous system by nerves (PNS). The nerves then transmit nerve impulses from the central nervous system to the effector and carry out the necessary action in response to the stimulus.

Neurones

What are Neurones?	The nervous system is made up of nervous tissues that consists of nerve cells called neurones.
What are some types of neurones?	The sensory neurone (receptor neurone) transmits nerve impulses from the receptors in the sense organs to the central nervous system The relay neurone (intermediate neurone) transmits nerve impulses from the sensory neurone to the motor neurone. They are found in the central nervous system (only in spinal cord or brain) The motor neurone (effector neurone) transmits nerve impulse from the central nervous system to the effectors  **Figure 10.3** Relation between a sensory neurone, a relay neurone and a motor neurone

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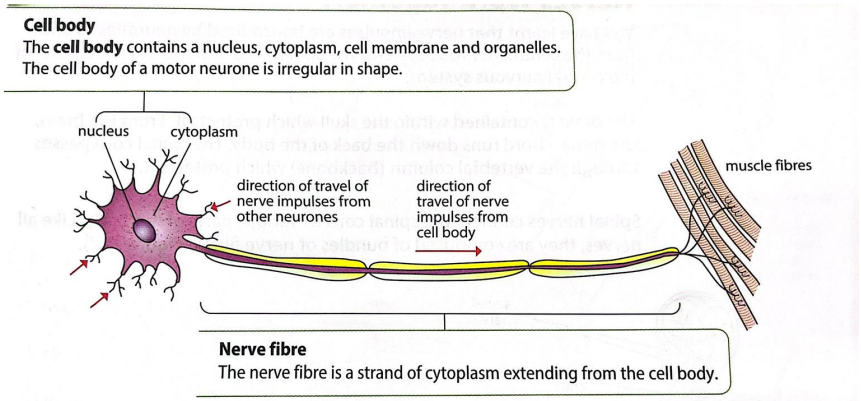
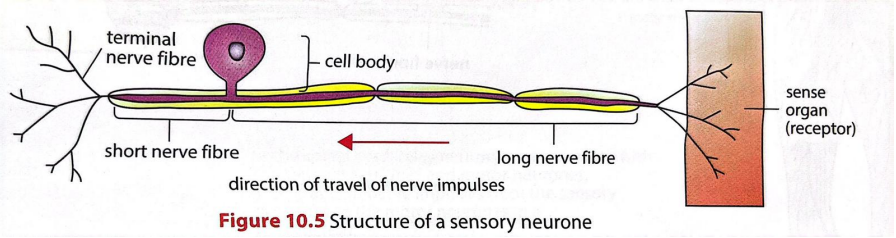
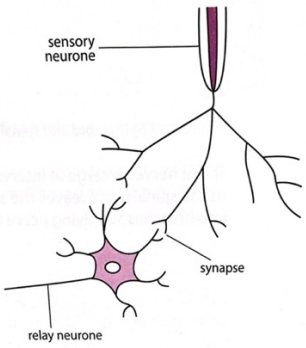
What is the structure of a motor neurone? (know how the structure looks like, potential MCQ question)	 **Figure 10.4** Structure of a motor neurone
What is the structure of the sensory neurone? (know how the structure looks like, potential MCQ question)	 **Figure 10.5** Structure of a sensory neurone
What is a Synapse? (“connections”, nerve impulse travel from the synapse of _____ to the synapse of _____)	The junction between two neurones is called a synapse. Nerve impulses cannot directly cross from one neurone to the next due to the tiny spaces between them. Nerve impulses are transmitted across a synapse by chemicals released by neurones.  **Figure 10.6** Synapse between a sensory neurone and a relay neurone

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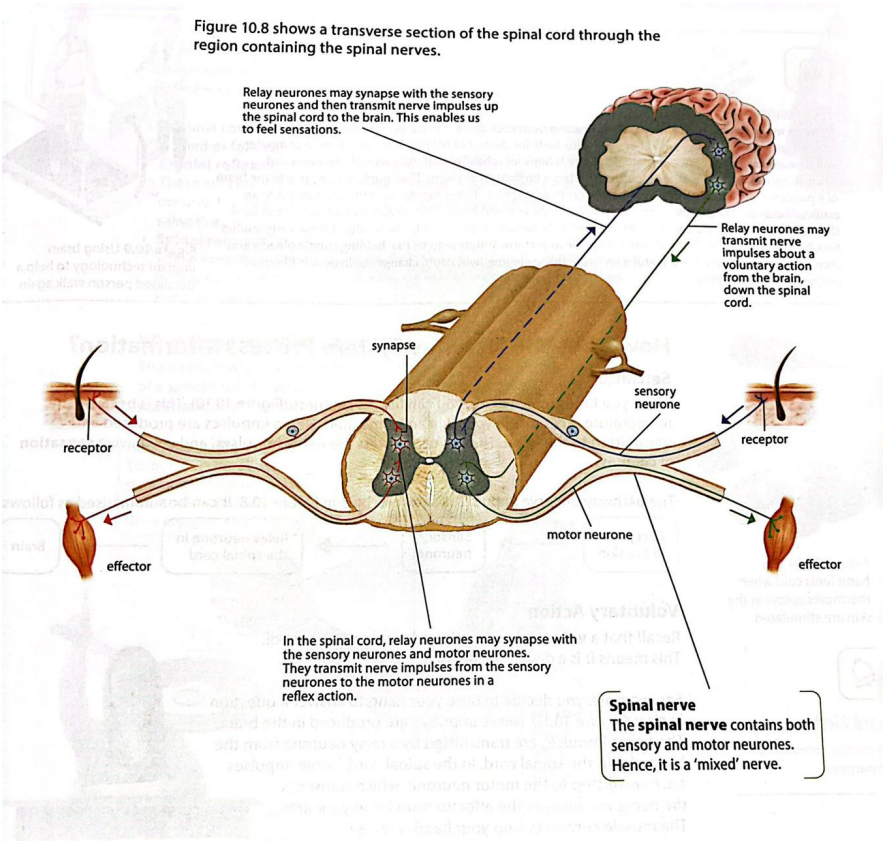
Brain, Spinal Cord and Spinal Nerves

How do the Brain, Spinal Cord and Spinal Nerves work together?	The brain is protected by the skull. From the brain, the spinal cord runs down the back of the body. The spinal cord passes through the backbone which protects it. Spinal nerves connect the spinal cord to various parts of the body. The spinal nerves are composed of bundles of nerve fibres (like all nerves) Spinal nerves emerge at intervals along the length of the spinal cord (like stem and branches). As the spinal nerve leaves the spinal cord, it progressively subdivides into branches supplying nerve fibres to various parts of the body. Figure 10.8 shows a transverse section of the spinal cord through the region containing the spinal nerves.  **Figure 10.8** Portion of spinal cord showing the pathway of nerve impulses As you may notice in Figure 10.8, synapses occur in the central inner part of the spinal cord, which transmits nerve impulses to and from the brain.

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How does the Nervous System process information?

Sensation	Temperature receptors in the skin are stimulated. Nerve impulses are produced and transmitted to the brain. The brain interprets the nerve impulses and we have a sensation e.g.: When you hold a piece of ice cube, we can feel it's coldness Receptor in skin → Sensory neurone → relay neurone in the spinal cord → brain
Voluntary Action (MOST IMPORTANT – learn to write the process)	Voluntary actions are under conscious control, it is a deliberate action. For example, you want to raise your hand. (Format is standard) Nerve impulses are produced in the brain. The nerve impulses are transmitted by the relay neurone from the brain, down the spinal cord. In the spinal cord, nerve impulses are transmitted to the motor neurone, which transmits the nerve impulses to the effector muscles in your arm. Muscle contracts and your hand is raised. Brain → Relay Neurone in spinal cord → motor neurone → effector

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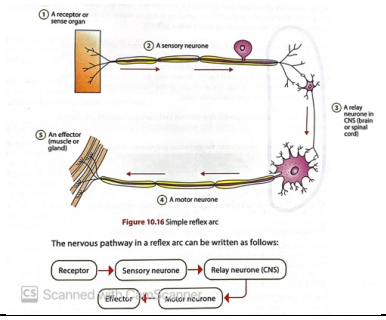
Reflex Action (MOST IMPORTANT – learn to write the process)	A reflex action is an immediate response to a specific stimulus without conscious control. Reflex actions are rapid and automatic. They are the simplest form of response in humans and can occur without any conscious effort. They are not able to be prevented consciously. The spinal cord and the brain are reflex centers. Reflex actions can be classified as: - Cranial reflexes → controlled by the brain (not of conscious will) and usually occur in the head region (e.g. pupil reflex, blinking, salivation) - Spinal reflexes → controlled by the spinal cord (e.g. the sudden withdrawal of the hand on touching a hot object and knee-jerk reflex) For example, the sudden withdrawal of the hand on touching a hot object. (Format is Standard) The heat from the object stimulates the nerve endings (receptors) in our skin. Nerve impulses are produced. The sensory neurone transmits the nerve impulses to the spinal cord. In the spinal cord, the nerve impulses are transmitted first across a synapse to the relay neurone, and then across another synapse to the motor neurone. The motor neurone transmits the nerve impulses to the effector after receiving it from the brain. The effector muscles contracts, resulting in the withdrawal of the hand from the hot object.
What is a reflex arc?	A reflex arc is the shortest pathway by which nerve impulses travel from the receptor to the effector in a reflex action. (the pathway by which the nerve impulses can travel from receptor to the effector)  Figure 10.16 Simple reflex arc The nervous pathway in a reflex arc can be written as follows: Receptor → Sensory neurone → Relay neurone (CNS) → Motor neurone → Effector

Endocrine (Hormonal) Control and Nervous Control

How are Endocrine (Hormonal) Control and Nervous Control different?

(know the differences)

In both cases, a stimulus causes the transmission of a message to a target organ (effector) which carries out the response.

However, the nervous control differs from the endocrine control in several ways. For example, nervous control may affect only a particular part of the body. Since hormones are usually transported around the body by the blood, several target organs may be affected by the same hormone.

Endocrine Control	**Nervous Control**
Involves hormones (chemical substances) as signals	Involves nerves impulses as signals
Hormones are transported by the blood	Nerve impulses are transmitted by neurones
Usually slow responses	Usually quick responses
Responses may be short lived (adrenaline) or long lived (growth hormone)	Responses are short-lived
Always involuntary	May be voluntary or involuntary
May affect more than one target organ	Usually localised

The Nervous System and the Eye

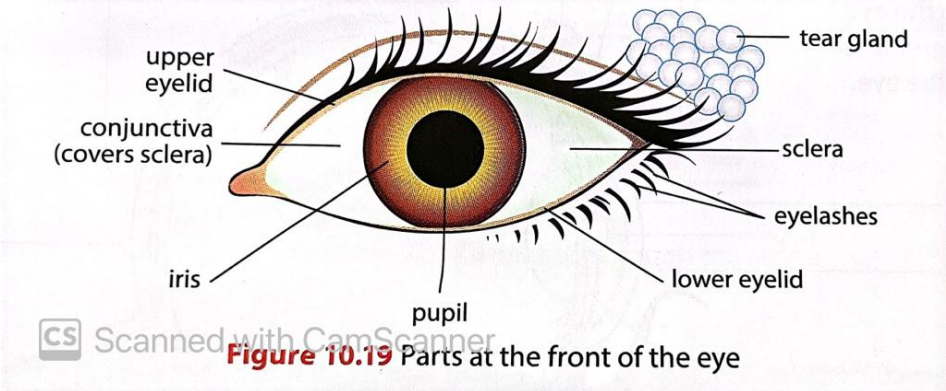
Part (b): The Human Eye

O Level syllabus

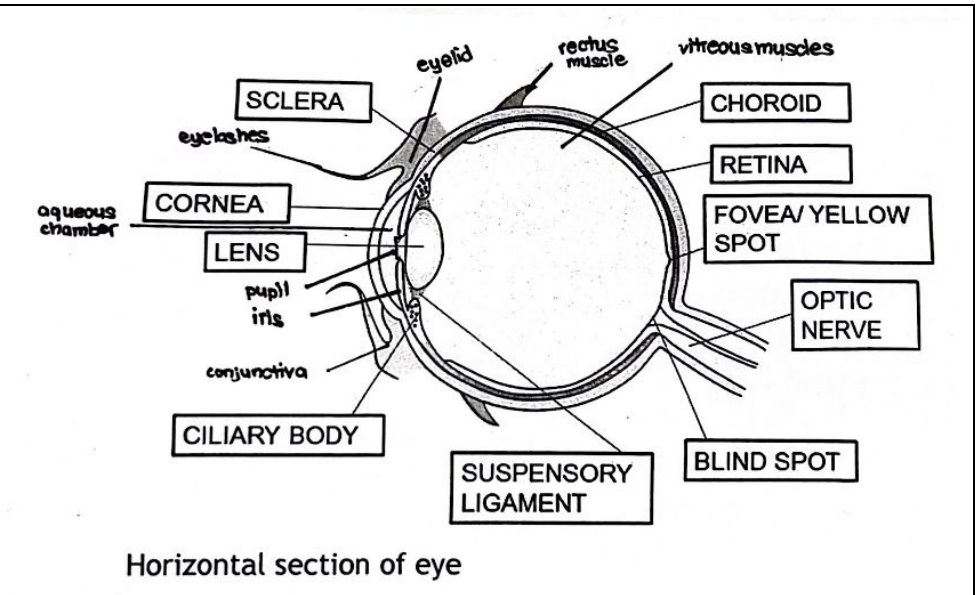
- describe the structure of the eye as seen in front view and in horizontal section
- state the principal functions of component parts of the eye in producing a focused image of near and distant objects on the retina
- describe the pupil reflex in response to bright and dim light

Done by MF (completed in 2024)

External Structure of the Eye

What forms the External Structure of the Eye? 'O level syllabus' (questions usually only ask you maximum to name the parts, very seldom ask the function of the parts)	The front part of the eyeball is covered by eyelids. Only a part of the eyeball can be seen.  **Figure 10.19** Parts at the front of the eye Sclera → tough, white outer covering of the eyeball. It is continuous wait the cornea, which is a dome-shaped transparent layer at the front of the eye. It protects the eye from mechanical damage. Conjunctiva → thin transparent membrane covering the sclera in front. It is a mucous membrane. It secretes mucus to keep the front of the eyeball moist Eyelashes → help to shield the eye from dust particles Tear Gland → Lies at the corner of the upper lid, secretes tears that wash away dust particles, keep the cornea moist for atmospheric oxygen to dissolve so that the dissolved oxygen can diffuse into the cornea, lubricates the conjunctiva reduces friction when the eyelids move Eyelids → The eyelids protect the cornea from mechanical damage. They can be partly closed (squinting prevents too much light from entering the eyelid and damaging the retina). Blinking spreads tears over the cornea and conjunctiva, and wipes dust particles off cornea Iris → circular sheet of muscles and radial muscles which controls the size of the pupil and therefore the amount of light entering the eye. It contains a pigment that gives the eye it's colour Pupil → a hole in the center of the iris that allows light to enter the eye

Internal structure of the eye

What forms the Internal structure of the eye? 'O level syllabus'	 Horizontal section of eye Retina → it is the innermost layer of the eyeball. It is the light-sensitive layer on which images are formed. It contains light-sensitive cells called photoreceptors. The photoreceptors are connected to the nerve endings from the optic nerve. Choroid → It is the middle layer of the eyeball. It is pigmented black to prevent internal reflection of light, and it contains blood vessels that bring oxygen and nutrients to the eyeball to remove metabolic waste products. Vitreous muscles → It is the space behind the lens and is filled with vitreous humour, a transparent, jelly-like substance. The vitreous humour keeps the eyeball firm and helps to refract light onto the retina. Rectus muscles → It attaches the eyeball to the skull and control eyeball rotation. Eyelid → The eyelids protect the cornea from mechanical damage. They can be partly closed (squinting prevents too much light from entering the eyelid and damaging the retina). Blinking spreads tears over the cornea and conjunctiva, and wipes dust particles off cornea Sclera → tough, white outer covering of the eyeball. It is continuous wait the cornea, which is a dome-shaped transparent layer at the front of the eye. It protects the eye from mechanical damage. Eyelashes → help to shield the eye from dust particles

Done by MF (completed in 2024)

	Cornea → It is a dome-shaped transparent layer continuous with the sclera. It refracts light rays into the eye. The cornea causes the greatest refraction of light into the eye. Aqueous Chamber →it is the space between the lens and the cornea that is filled with aqueous humour. It supplies cornea and lens with nutrients and maintains the convex shape of the cornea to help refract light into the pupil. Lens → It is a transparent, circular and biconvex structure. It is elastic as it is attached by the suspensory ligaments to the ciliary muscles. When light rays pass through the lens, refraction occurs. The shape and thickness of lens can change to focus light rays onto retina. Pupil → a hole in the center of the iris that allows light to enter the eye Iris → circular sheet of muscles and radial muscles which controls the size of the pupil and therefore the amount of light entering the eye. It contains a pigment that gives the eye it's colour Conjunctiva → thin transparent membrane covering the sclera in front. It is a mucous membrane. It secretes mucus to keep the front of the eyeball moist Ciliary body → It is a thickened region at the front end of the choroid. It contains ciliary muscles, which control curvature or thickness of the lens. Suspensory ligament → It is a connective tissue that attaches the edge of the lens to the ciliary body. Blind spot → It is the region where the optic nerve leaves the eye. It does not contain any rods or cones; thus it is not sensitive to light. You will not be able to see an object an object if its image falls on the blind spot. Optic nerve → It is the nerve that transmits nerve impulses to the brain when the photoreceptors in the retina are stimulated. Fovea → It is a small yellow depression in the retina. It is situated directly behind the lens, where images are normally focused. The fovea contains the greatest number of cones, but no rods, enabling the person to have detailed colour vision in bright light.

Receptors, rods and cones

What are photoreceptors, rods, and cones?

(not v important)

Rods and Cones are types of photoreceptors

Rods	Cones
Both convert light into nerve impulses to be transmitted to the brain along sensory neurones in the optic nerve	
Detect light of low intensity	Detect light of high intensity
Provides night vision/in dim light	Detect colours
Gives black and white visions/shades of grey	Three types of cones that respond to different wavelengths (red, green, blue)
Spreads over entire retina except fovea	Found mainly in the fovea

Helpful Note

Receptors that detect light changes are called **photoreceptors**. Photoreceptors in the retina consist of rods and cones. The photoreceptors are connected to the nerve endings from the optic nerve (Figure 10.21).

Cones enable us to see colours in bright light. They do not work well in dim light. The fovea contains only cones. It is where cones are the most densely packed in the retina. The fovea enables a person to have detailed colour vision in bright light. Rods are found throughout the retina except in the fovea. Rods are more sensitive to light than cones. They enable us to see in dim light, but only in black and white.

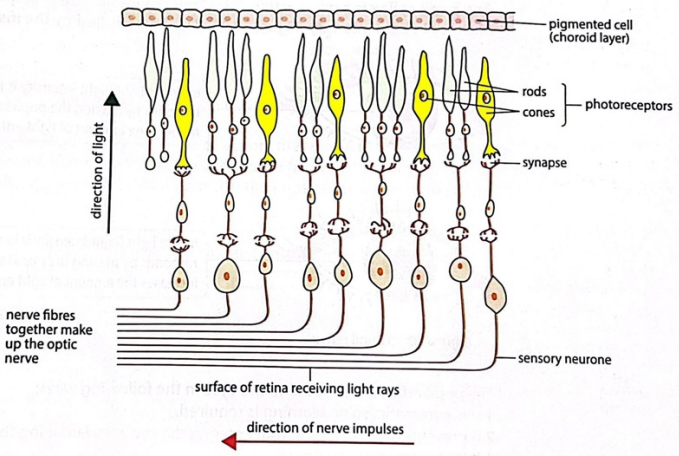


Figure 10.21 A section through the retina

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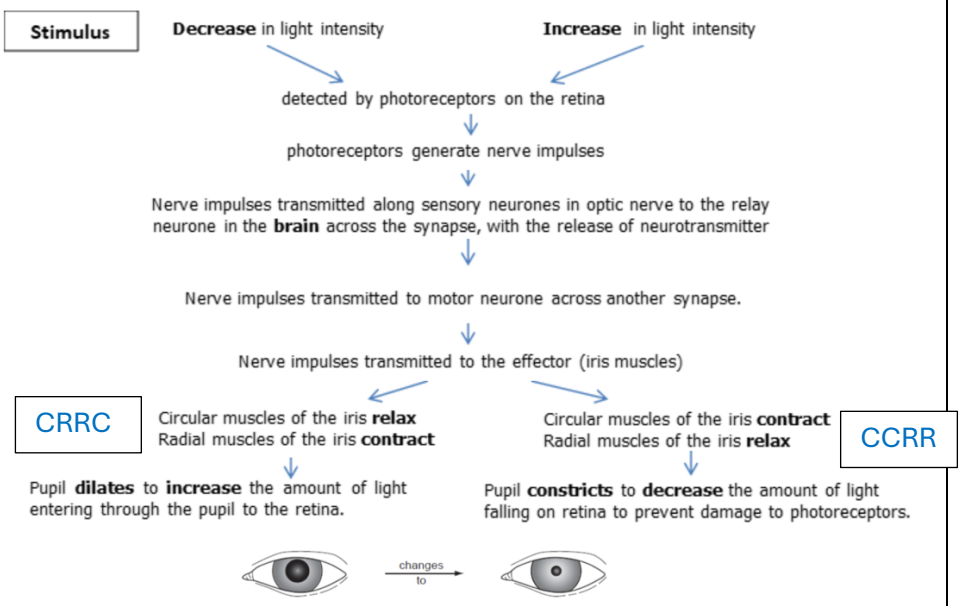
Pupil reflex & the iris

What is the pupil reflex?	The pupil reflex is a cranial reflex action. The pupil changes in size in response to changes in light intensity. It is an involuntary response of iris muscles to light intensity. It regulates the amount of light reaching the retina by controlling the diameter of the pupil
What happens during pupil reflex? 'O level syllabus' (MUST KNOW)	In bright light (light intensity is high), the iris responds by making the pupil smaller. This reduces the amount of light entering the eye. In dim light (light intensity is low), the iris responds by making the pupil larger. This increases the amount of light entering the eye. 
How is this beneficial?	The pupil reflex is beneficial because… - It is automatic, so no learning is required - It prevents excessive light from entering the eye and damaging the retina - It is an immediate response - It allows enough light to enter the eye to allow us to see

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How does the iris control the amount of light entering the eye? 'O level syllabus'	The size of the pupil is controlled by two sets on involuntary muscles in the iris. These are the circular muscles and the radial muscles. They are antagonistic muscles because when one set contracts, the other set relaxes and vice versa.

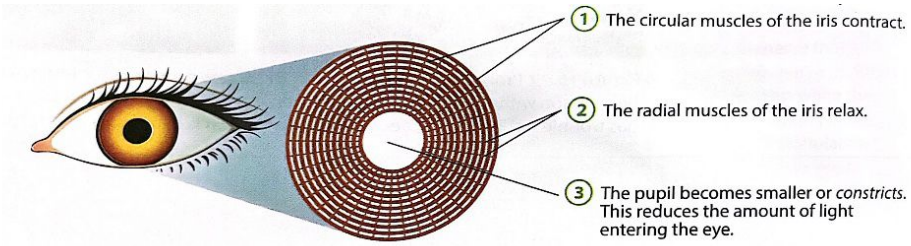


Figure 10.24 Action of the iris in bright light

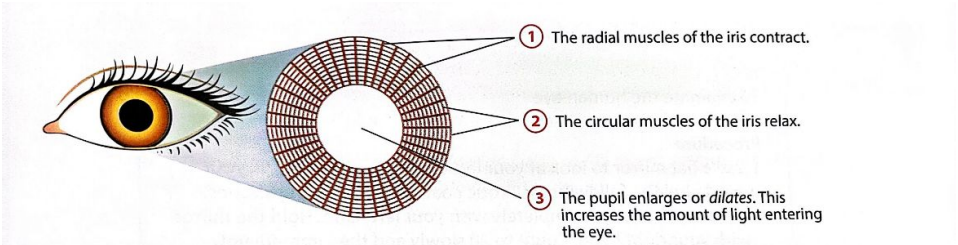


Figure 10.25 Action of the iris in dim light

In a reflex action, there must be a receptor and an effector. In the pupil reflex, the receptors are found in the retina and the effector in the iris.

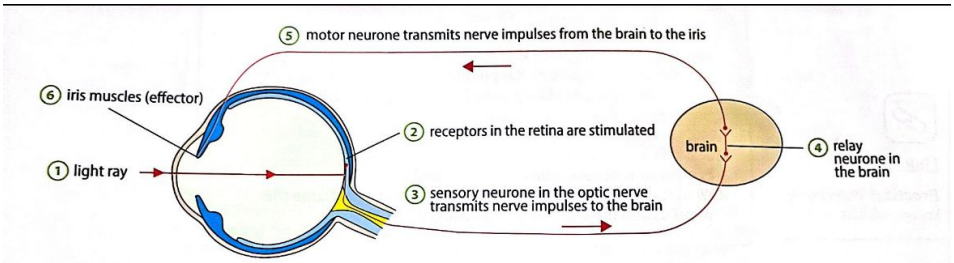
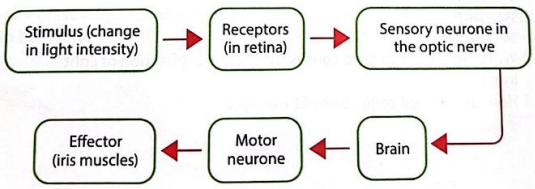


Figure 10.26 Nervous pathway in pupil reflex

The pathway of nerve impulses in the pupil reflex can be summarised as follows:



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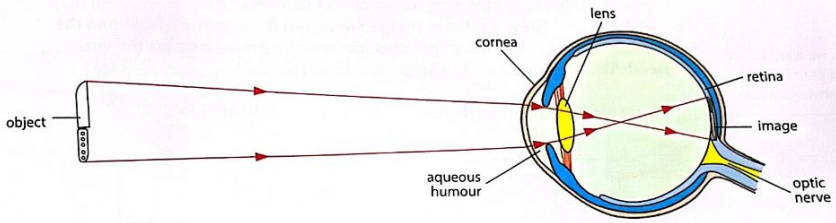
Seeing objects

How do we see?	When light falls on an object, rays of light are reflected from the object. Some of these reflected rays fall on the eye (Figure 10.28).  ① The light rays are refracted through the cornea and the aqueous humour onto the lens. ② The lens causes further refraction and the rays are brought to a focus on the retina. ③ The image on the retina stimulates either the rods or the cones, depending on the intensity of the light. The image formed on the retina is: • upside down (inverted) • laterally inverted • diminished (smaller in size than the actual object) **Figure 10.28** Formation of an image on the retina Nerve impulses are produced when light falls on the rods and cones. These nerve impulses are transmitted via the optic nerve to the brain. The brain interprets these nerve impulses so that we see the object the right way up, front to back, and the right size.

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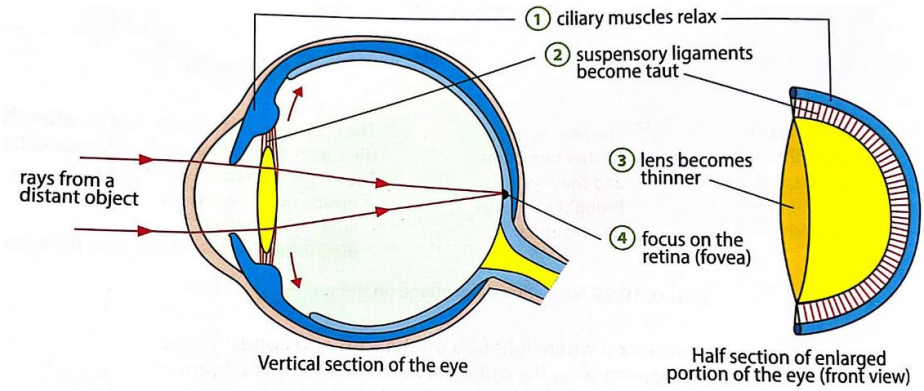
Focusing

What is focusing?	Focusing, also called accommodation, is the adjustment of the lens of the eye so that clear images of objects at different distances are formed on the retina. During focus, the thickness or curvature of the lens is adjusted and allows light rays to be focus on the retina
Focusing on distant objects (MUST KNOW)	When a person is looking at a distant object (7m or more), light rays reflecting off the object are almost parallel to each other when they reach the eye. These light rays are then refracted through the cornea and the aqueous humour into the pupil. Since the rays are almost parallel, the lens needs to be thinner as only a little refraction is needed.  **Figure 10.29** Focusing on a distant object The following changes occur in the eye when focusing on a distant object: **1** Ciliary muscles relax, pulling on the suspensory ligaments. **2** Suspensory ligaments become taut, pulling on the edge of the lens. **3** Lens becomes thinner and less convex. **4** Light rays from the distant object are sharply focused on the retina. **5** Photoreceptors are stimulated. **6** Nerve impulses produced are transmitted by the optic nerve to the brain. The brain interprets the nerve impulses, and the person sees the distant object.

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Focusing on near objects

(MUST KNOW)

When a person is looking at a near object, diverging light rays reflecting off the near object are refracted through the cornea and the aqueous humour into the pupil. Since the rays reaching the eyes are diverging, the lens needs to be thicker for the light ray to bend more.

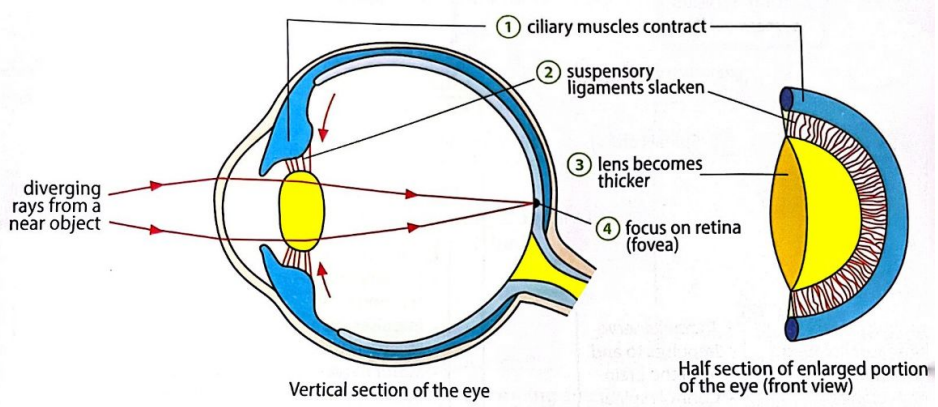
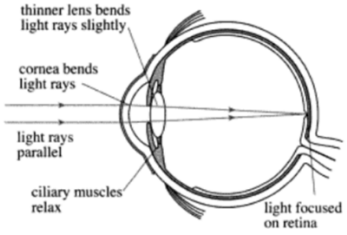
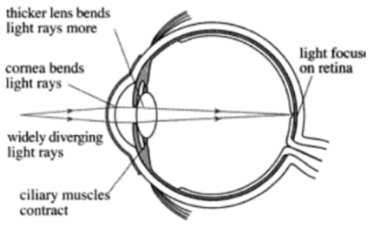


Figure 10.30 Focusing on a near object

The following changes occur in the eye when focusing on a near object:

1 Ciliary muscles contract, relaxing their pull on the suspensory ligaments.
2 Suspensory ligaments slacken, relaxing their pull on the lens.
3 The lens, being elastic, becomes thicker and more convex.
4 Light rays from the near object are sharply focused on the retina.
5 Photoreceptors are stimulated.
6 Nerve impulses produced are transmitted by the optic nerve to the brain. The brain interprets the nerve impulses, and the person sees the near object.

Difference between distant and near object

	Distant object	**Near object**
		
Ciliary muscles	Relax	contract
Suspensory ligaments	**Taut** and pulled on lens	**Slacken** and decrease tension on lens
Curvature of lens	Lens longer and less convex; longer focal length	Lens shorter and more convex; shorter focal length
Outcome	Less refraction of light by the lens towards the fovea	More refraction of light by the lens towards the fovea
	Light rays converge on the fovea to produce a focused image.	

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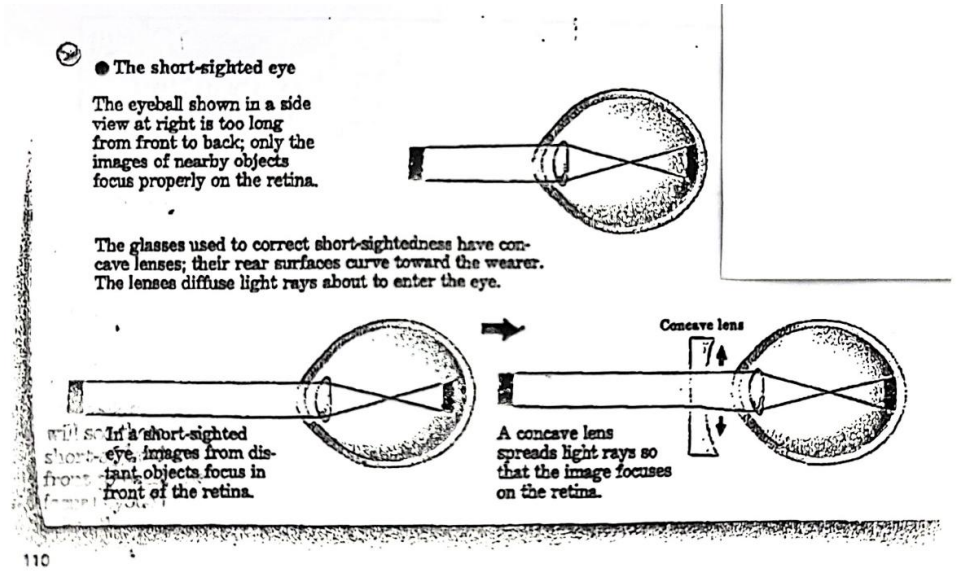
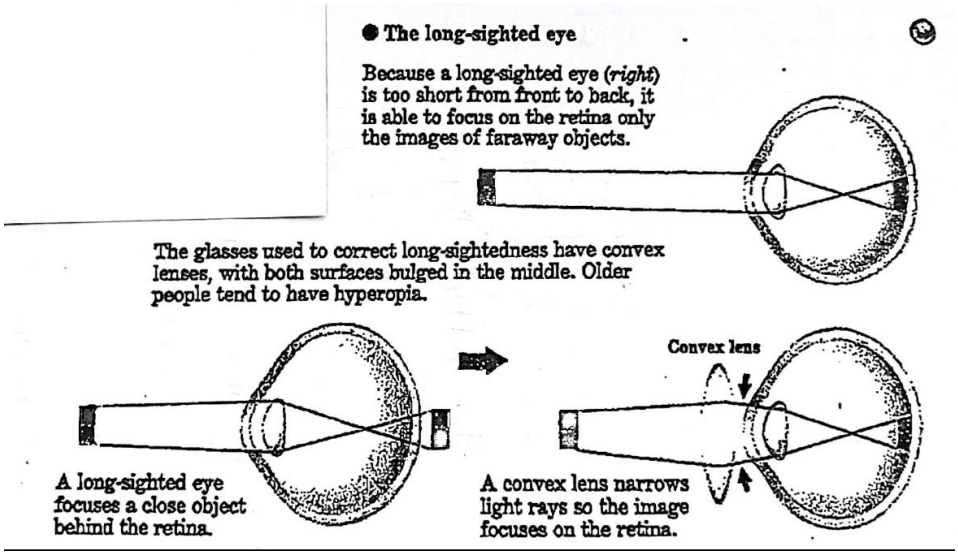
Myopia (short-sightedness) and Hyperopia (long-sightedness)

Myopia (short-sightedness)	
Hyperopia (long-sightedness)	

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Chapter 11: Infectious Diseases in Humans

O Level syllabus

- state that infectious diseases can be spread from person to person whereas non-infectious diseases cannot and identify examples of each
- explain that infectious diseases are caused by pathogens such as bacteria and viruses and can be spread from person to person through body fluids, food and water
- state that a typical virus has a protein coat enclosing its genetic material and reproduces only in living host cells
- state that a typical bacteria cell has a cell wall and DNA without a nucleus; some are pathogenic and some non-pathogenic
- describe the transmission and methods to reduce the transmission of: influenza virus and pneumococcus
- state that vaccines contain an agent that resembles a pathogen and prevent infectious diseases by stimulating white blood cells to quickly produce antibodies when the pathogen invades
- explain that antibiotics target bacteria by preventing synthesis of cellular structures but are ineffective against viruses due to structural and reproductive differences
- discuss how the misuse and overuse of antibiotics may accelerate the emergence of antibiotic-resistant bacteria

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Diseases

What is a disease?	A disease is a condition that causes the body to function less effectively. Diseases produce specific signs and symptoms. A sign of a disease can be observed or measured. (e.g. Rashes, fever, coughing and vomiting). A symptom can be described/felt by a patient (e.g. headaches, fatigue, nausea)
Infectious vs Non-infectious diseases "O level syllabus"	Infectious disease can be spread from one person to another. They are caused by disease causing organisms called pathogens. Examples of pathogens include bacteria and viruses. (E.g. influenza, HIV, and pneumococcal disease) Non-infectious diseases are not caused by pathogens and cannot be spread from one person to another. They may be inherited or caused by factors like malnutrition, environmental factors (pollution) and lifestyle choices. (E.g. excessive alcohol consumption of polyunsaturated fats and trans fats may cause coronary heart diseases. Cigarette smoking may cause atherosclerosis and coronary heart diseases. Others include type 2 diabetes and sickle cell anaemia)

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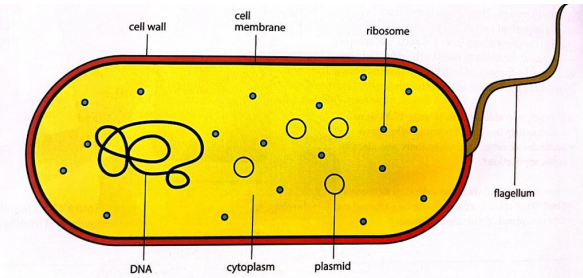
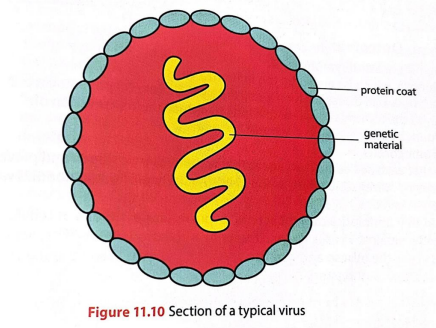
How are infectious disease spread? "O level syllabus"	***Through droplets in the air*** When a person coughs/sneezes, many tiny respiratory droplets are expelled. These droplets may contain pathogens. Anyone nearby (within 1m) may breathe in these droplets and become infected.
	By direct contact Some diseases like STIs, hepatitis B, syphilis and HIV are transmitted in this way. Infectious diseases can also be spread when blood from an infected person comes into contact with: - mucous membrane of an uninfected person (membranes lining the eye, nose, and mouth) - bloodstream of an uninfected person, such as through a break in the skin
	By contaminated food and water Food and water can be contaminated with pathogens such as bacteria that cause a disease known as cholera. This occurs when food and water are not properly handled. Way to prevent and control the spread of water-borne/food-borne diseases are - practicing hygiene food preparation and storage - having good personal hygiene - maintaining a clean water supply - ensuring proper sewage treatment

Bacteria and Viruses (know the structures well)

Structure of Bacterial cell "O level syllabus"	Bacteria are single-celled organisms. A bacterial cell does not have a membrane-bound nucleus (just DNA = nucleus) . It has a single circular DNA as its genetic material. Bacterial cells may have one or more flagella. Some bacteria are pathogenic (disease-causing) while some are non-pathogenic (non-disease causing)  **Figure 11.9** Section of a bacterial cell
Structure of a virus "O level syllabus"	A typical virus has a protein coat to enclose its genetic material (DNA or RNA)  **Figure 11.10** Section of a typical virus A virus has both living and non-living characteristics. A virus does have cellular structure, like a cell membrane, cytoplasm, or organelles. But unlike living things, it does not grow, move, feed, respire or excrete. However, it can reproduce, but only when it enters a living cell and acts as the host. This is because the living cell had necessary material for reproduction like enzymes and organelles like ribosomes.
Bacterial cell and a virus	**Table 11.1** Comparison of features of a bacterial cell and a virus

Feature	Bacterial Cell	Virus
Outer covering	Cell wall	Protein coat
Genetic material	DNA	DNA or RNA
Cell membrane	Present	Absent
Cytoplasm	Present	Absent
Ribosome	Present	Absent

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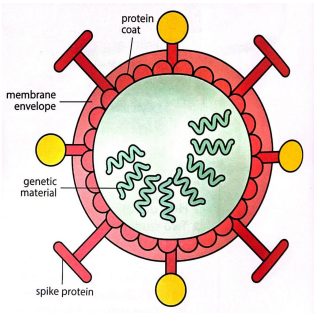
Prevention and management of infectious disease

Influenza "O level syllabus"	Influenza (flu) is a disease that attacks the respiratory system. Most people recover from this disease within two weeks.  Figure 11.11 Section of an influenza virus Influenza is caused by the influenza virus. Influenza is transmitted through droplets in the air and when a person touches an object, or a surface contaminated with the virus and then touches his/her mouth, nose, or eyes. Influenza produces signs and symptoms such as high fever, headache, stuffy nose, cough, sore throat and muscle aches. Methods to reduce transmission of the influenza virus - Get the influenza vaccine (annually). - Avoid close contact with people who have the flu - If you are sick, cover your mouth and nose with a tissue when your cough or sneeze and dispose use tissue properly - Wash your hands with soap and water or rub with disinfectant if you have touched objects that are likely to be contaminated with the virus - Avoid touching eyes, nose and mouth - Take antiviral drugs as prescribed by the doctor to treat illness
Pneumococcal Disease "O level syllabus"	Pneumococcal disease (learn the spelling) is one of the major causes of death worldwide. The bacteria may attack different parts of the body (e.g. middle ear infection, lung infection, inflammation of membranes of brain and spinal cord, infection of blood) It is caused by pneumococcus bacteria, also known as Streptococcus pneumoniae. It is mainly transmitted through respiratory droplets. Some signs and symptoms include fever, headache, vomiting, cough, chest pain, and rapid breathing. Methods to reduce transmission of the Pneumococcus Bacteria - Get pneumococcal vaccination - Take daily preventive actions (2^{nd} to 5^{th} points for influenza) - take antibiotics as prescribed by the doctor

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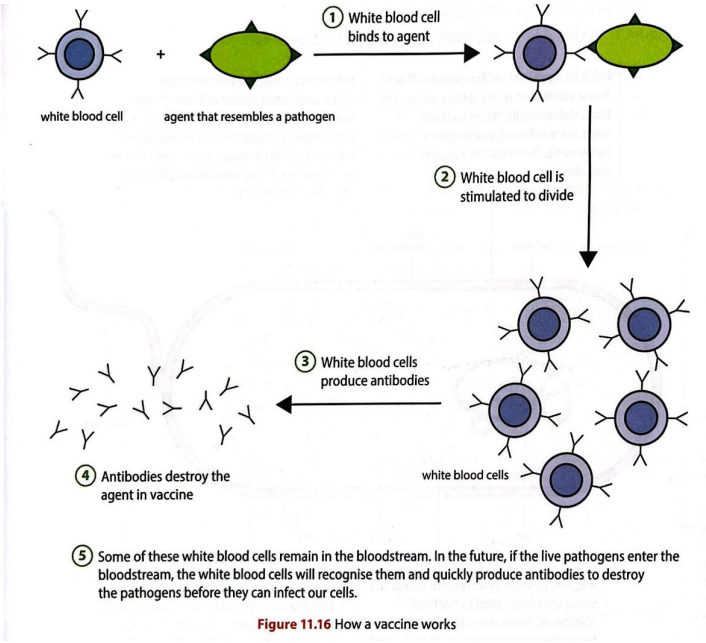
Vaccines "O level syllabus" (MUST KNOW)	A vaccine contains an agent that resembles a pathogen and prevents infectious diseases by stimulating white blood cells to quickly produce antibodies when the pathogen invades. How vaccine works (textbook explanation) Antigens trigger the production of antibodies. When foreign particles (pathogens) enter our bloodstream, they stimulate our white blood cells to produce antibodies against them. Proteins on the surfaces of the pathogens, like bacteria and viruses are examples of antigens. When a vaccine containing an agent that resembles a pathogen (antigen), enters the body, it stimulates the white blood cells to produce antibodies. Antibodies are proteins that destroy pathogens. They are specific in action and only destroy one type of pathogen.  Figure 11.16 How a vaccine works How does a vaccine work (Exam style answering techniques) • Pathogens have antigens (substances that trigger the production of antibodies), such as the proteins on the pathogens' surface • The agent in the vaccine have an antigen that the real pathogen has, thus resembling the pathogen • After vaccination, white blood cells recognise the specific antigen and produce antibodies against it • How vaccines protect you from the real pathogen: - Some of these white blood cells remain in the body for a long time - When the real pathogen enters the person, these white blood cells recognise it and quickly produce large amounts of antibodies to destroy the pathogen.

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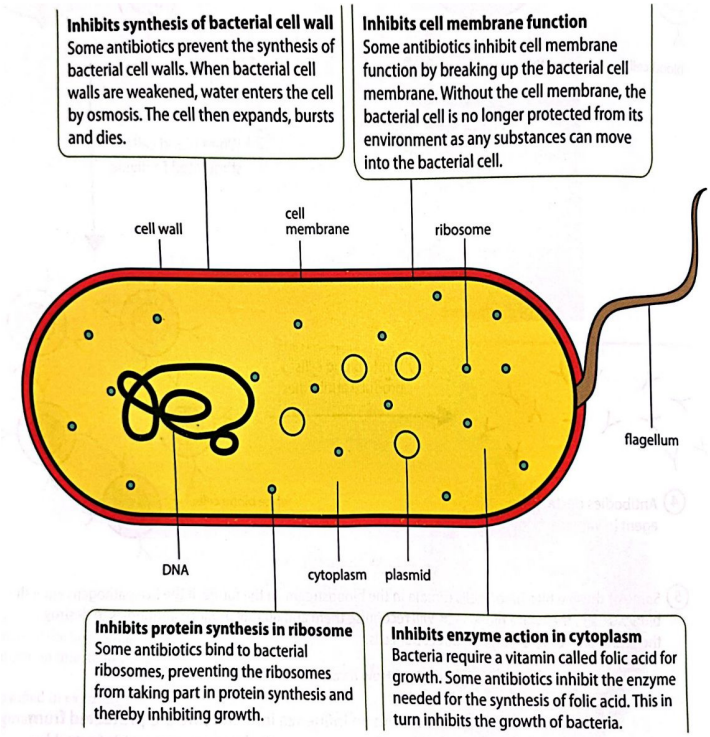
Antibiotics "O level syllabus" (MUST KNOW)	Antibiotics are drugs used to treat bacterial infections. They are made of microorganisms that are used to kill or stop the growth of bacteria. They work by interfering with the growth and metabolic activities of the bacteria. Antibiotics are ineffective against viruses. How it works? (potential question, 1 function 1 mark)  **Figure 11.18** How antibiotics work to destroy a bacterial cell Antibiotics can kill bacteria but not viruses because… - They act on bacterial cell walls. Viruses do not have cell walls - They break up cell membranes. Viruses do not have cell membranes - They act on ribosomes, stopping protein synthesis and growth. Viruses do not have ribosomes and do not grow. (CWCMR = CommonWealth Contains Many Robots)

Antibiotic resistance

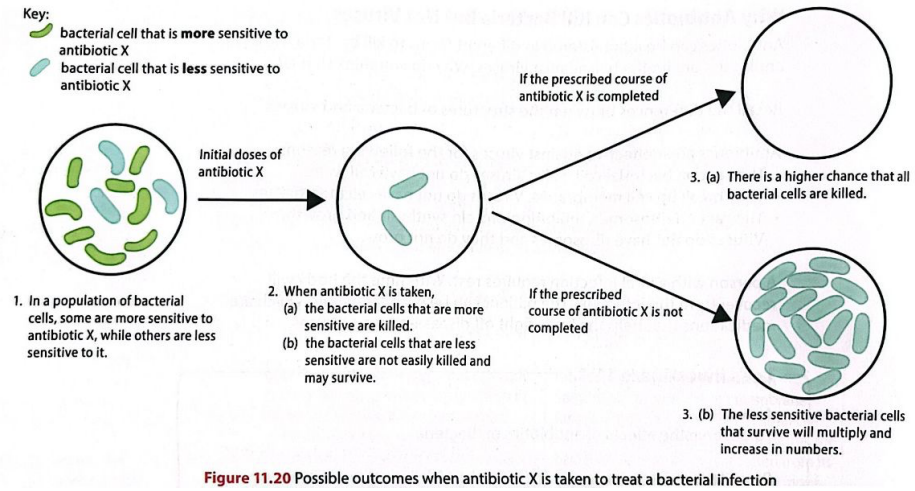


Figure 11.20 Possible outcomes when antibiotic X is taken to treat a bacterial infection

Over time, the subsequent generations of bacterial cells will become less sensitive to antibiotic X. This will make the population become resistant. Other types of antibiotics will be needed to treat the bacterial infection. Hence, to prevent antibiotics resistance in bacteria, a prescribed course of antibiotics should be completed.

How antibiotic resistances can be reduced
- not misusing or overusing antibiotics
- completing the full course of antibiotics prescribed by doctors so that all bacterias are killed
- using antibiotics only when necessary

Chapter 12: Nutrition and Transport in Flowering Plants

O Level Syllabus

- identify the cellular and tissue structure of a dicotyledonous leaf, as seen in transverse section using the light microscope and describe the significance of these features in terms of their functions, such as the
    - distribution of chloroplasts for photosynthesis
    - stomata and mesophyll cells for gaseous exchange
    - vascular bundles for transport
- identify the positions of and explain the functions of xylem vessels and phloem (sieve tube elements and companion cells) in sections of a herbaceous dicotyledonous leaf and stem, under the light microscope
- explain how the structure of a root hair cell is suited for its function of water and ion uptake
- state that chlorophyll absorbs light energy and converts it into chemical energy for the formation of carbohydrates and their subsequent uses
- briefly explain why most forms of life are completely dependent on photosynthesis
- state the equation, in words and symbols, for photosynthesis (details of light-dependent and light independent stages are not required)
- describe how carbon dioxide reaches mesophyll cells in a leaf
- investigate and discuss the effects of varying light intensity, carbon dioxide concentration and temperature on the rate of photosynthesis (e.g. in submerged aquatic plant)
- discuss light intensity, carbon dioxide concentration and temperature as limiting factors on the rate of photosynthesis
- define the term transpiration and explain that transpiration is a consequence of gaseous exchange in plants
- explain the movement of water between plant cells, and between them and the environment in terms of water potential (calculations on water potential are not required)
- outline the pathway by which water is transported into the roots and through the xylem vessels to the leaves by transpiration pull
- investigate and explain:
    - the effects of variation of air movement, temperature, humidity and light intensity on transpiration rate
    - how wilting occurs
- define the term translocation as the transport of food (mainly sucrose) in the phloem tissue and illustrate the process through translocation studies

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Key points for this chapter (~THE MUST KNOWS~)

- Internal structure of leaf + adaptations
- How CO_2 and H_2O enters the leaf
- Xylem and Phloem structure + Functions
- Limiting factor (how it works, how to tell from the graph, the various factors)
- How roots take in water, mineral ions etc
- Transpiration, Translocation
- Wilting and its adaptation

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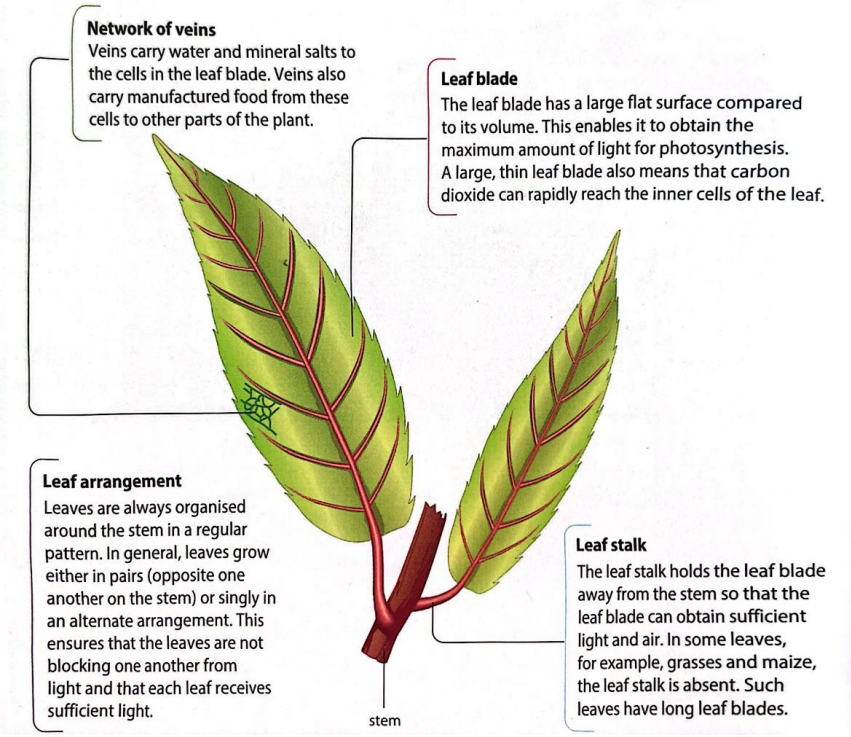
Leaf structure

External Feature of the leaf (Not important)	Main features of leaf include leaf blade and leaf stalk 

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Internal Structure of the leaf

"O-level syllabus"

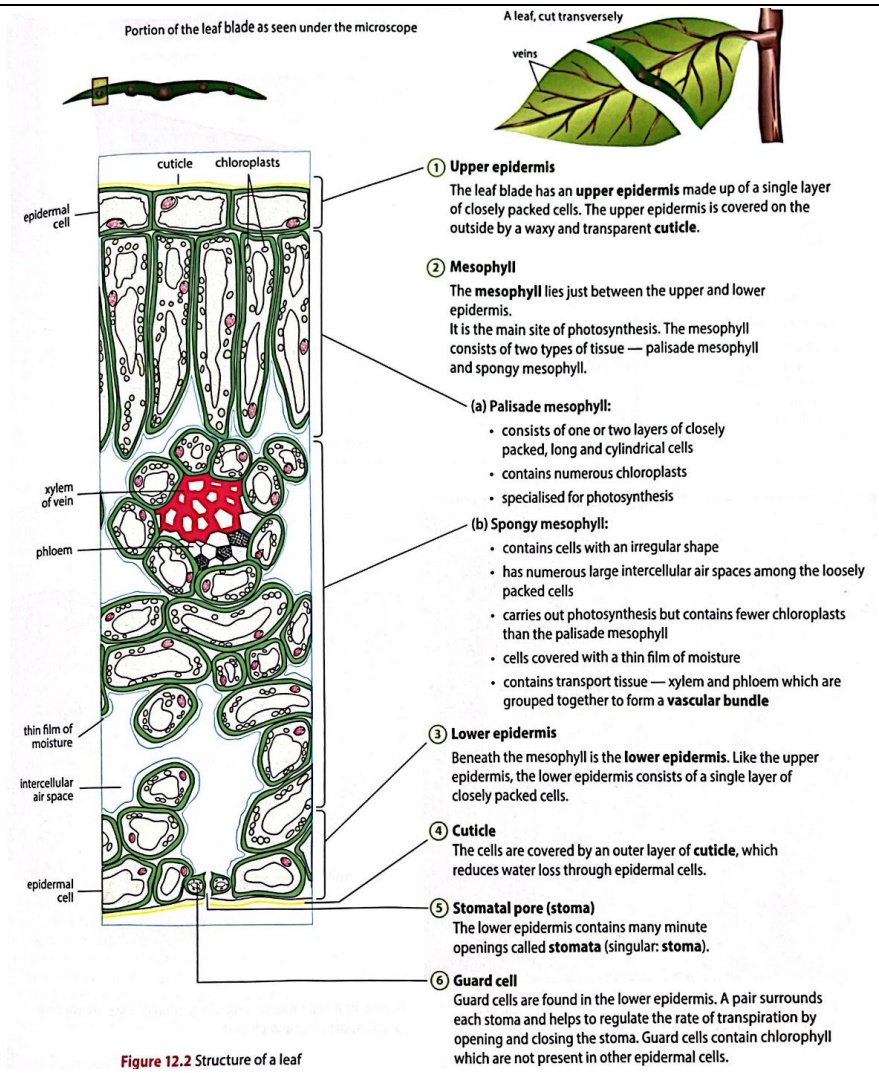

Figure 12.2 Structure of a leaf

Structure	Function
• Chloroplasts in all mesophyll cells • More chloroplasts in palisade mesophyll cells than in spongy mesophyll cells • No chloroplasts in upper and lower epidermal cells	• Mesophyll tissue is the main site for photosynthesis • More light energy can be absorbed by palisade mesophyll cells near the leaf surface than by spongy mesophyll cells • No photosynthesis takes place in upper and lower epidermis
• Stomata present in lower epidermis • No stomata present in upper epidermis	• Allow carbon dioxide to diffuse into leaf and oxygen to diffuse out of leaf • Reduce water loss by transpiration through the stomata
• Large intercellular air spaces in spongy mesophyll tissue	• Allow rapid diffusion of carbon dioxide and oxygen into and out of mesophyll cells
• Veins containing xylem and phloem close to mesophyll cells	• Xylem transports water and dissolved mineral salts from the roots to mesophyll cells • Phloem transports sucrose and amino acids from the leaf to other parts of the plant
• Waxy cuticle on upper and lower epidermis	• Reduce water loss by evaporation from the leaf • Transparent for light to enter the leaf

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Adaptation

<table>
<tr>
<td>How is the leaf adapted for photosynthesis?

"O-level syllabus"</td>
<td>
Table 12.1 Adaptation of the leaf for photosynthesis
<table>
<tr><th>Adaptation</th><th>Function</th></tr>
<tr><td>Waxy cuticle on upper and lower epidermis</td><td>It reduces water loss through evaporation from the leaf. It is transparent for light to enter the leaf.</td></tr>
<tr><td>Stomata present in the epidermal layers</td><td>Stomata open in the presence of light, allowing carbon dioxide to diffuse in and oxygen to diffuse out of the leaf.</td></tr>
<tr><td>Chloroplasts containing chlorophyll in all mesophyll cells</td><td>Chlorophyll absorbs energy from light and transfers it to chemical stores of energy in glucose molecules.</td></tr>
<tr><td>More chloroplasts in upper palisade tissue</td><td>More light can be absorbed near the upper leaf surface.</td></tr>
<tr><td>Interconnecting system of air spaces in the spongy mesophyll (Figure 12.3)</td><td>The air spaces allow rapid diffusion of carbon dioxide and oxygen into and out of mesophyll cells.</td></tr>
<tr><td>Veins containing xylem and phloem situated close to mesophyll cells (Figure 12.4)</td><td>Xylem transports water and mineral salts to mesophyll cells. Phloem transports sucrose away from the leaf.</td></tr>
</table>
</td>
</tr>
<tr>
<td>How do guard cells control the size of the stomata?</td>
<td>Guard cells help to regulate the passage of gases between the leaf and the environment.

Stomatal pore opens when guard cells are turgid and closes when they are flaccid. (OTCF = Overthink Takes Constant Focus)

- Guard cells become turgid when water enters via osmosis, due to a lower water potential of the cell sap when glucose concentration increases due to photosynthesis.
- Guard cells become flaccid when water evaporate excessively.</td>
</tr>
</table>

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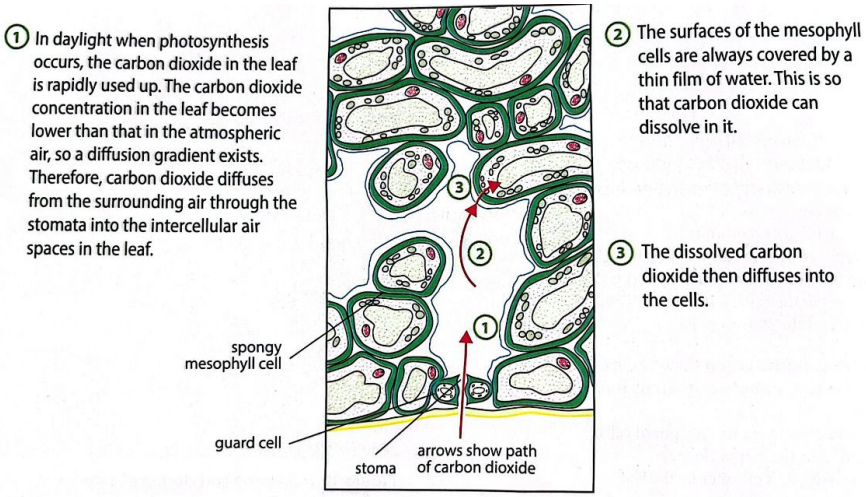
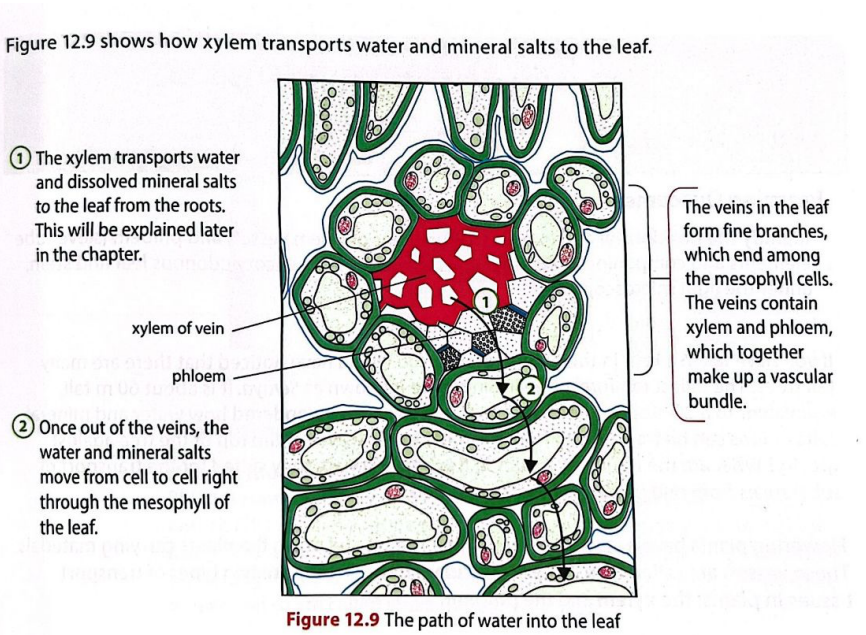
How does Carbon Dioxide enter the leaf? "O-level syllabus"	 **Figure 12.8** The path of carbon dioxide into the leaf
How does water enter the leaf? "O-level syllabus"	Figure 12.9 shows how xylem transports water and mineral salts to the leaf.  **Figure 12.9** The path of water into the leaf

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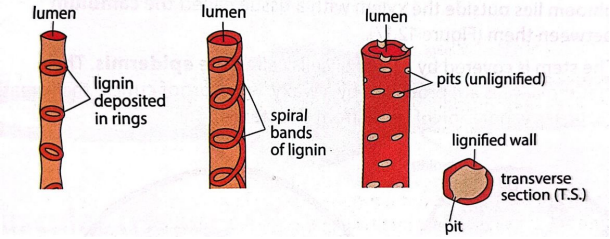
Functions of Xylem and Phloem

Xylem tissue "O-level syllabus"	Xylem tissue has two functions: 1) Conducting water and dissolved mineral slats from the roots to the stem and leaves 2) Providing mechanical support for the plant
	Adaptation to function - A xylem vessel is a long hollow tube stretching from the root to the leaf. The xylem vessel is a structure made up if many dead cells without cytoplasm or cross-walls → this reduces resistance to water flowing through the xylem - The inner walls of the xylem are strengthened by deposits of lignin. Together, all the xylem vessels provide mechanical support to the plant 
Phloem tissue "O-level syllabus"	Phloem tissue's function: It is to conduct manufactured food substances (sucrose and amino acids) from the green parts of the plant (especially the leaves) to other parts of the plant
	Adaptation to function - The companion cells in the phloem contain many mitochondria, which release energy during respiration needed by the cells to transport sucrose and amino acids from the mesophyll cells into the sieve tubes by active transport. - The holes in the sieve plates allow for faster transport of sucrose and amino acids from the leaves to the other parts of the plant.

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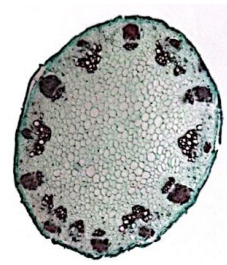
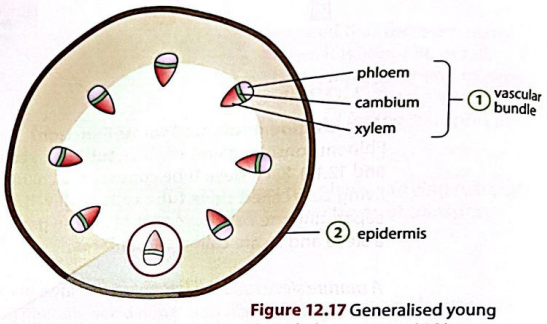
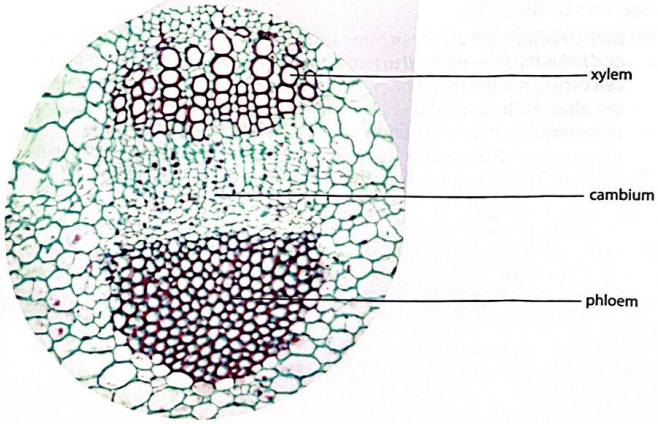
Vascular Tissue	<u>In stem</u> - Within a vascular bundle, the xylem is located closer inside. The phloem lies outside the xylem with a tissue called the cambium between them. - The stem is covered by a layer of cells called the epidermis. The epidermal cells are protected by a waxy, waterproof cuticle that greatly reduces evaporation of water from the stem.  **Figure 12.16** Photomicrograph showing the transverse section of a young stem  **Figure 12.17** Generalised young dicotyledonous stem (T.S.)  **Figure 12.18** Photomicrograph showing a vascular bundle (35x)

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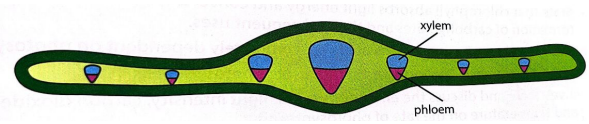
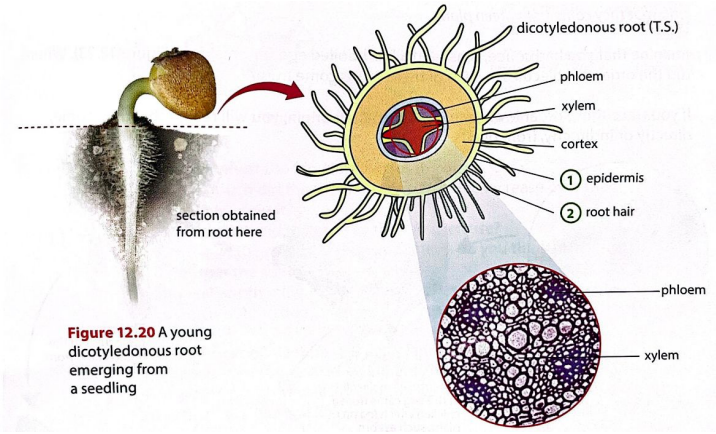
	<u>In leaves</u> Vascular bundles are found along the spongy mesophyll. Within a vascular bundle, the xylem is closer to the upper surface of the leaf and phloem closer to the lower surface of the leaf (take note xylem on top) 
	<u>In roots</u> - The epidermis of the root is the outermost layer of cells. It has root hairs. - Each root hair is a long and narrow extension growing out of an epidermal cell. → increases the surface area-to-volume ratio of the root hair cell. The rate of absorption of water and mineral salts increases.  **Figure 12.20** A young dicotyledonous root emerging from a seedling

Photosynthesis

Where could plants obtain carbon and energy from? "O-level syllabus"	In photosynthesis, chlorophyll (green pigment in plants) absorbs the energy from light to make glucose from carbon dioxide and water. The process releases oxygen. Carbon Dioxide + Water $\xrightarrow[\text{chlorophyll}]{\text{light}}$ glucose + oxygen
How can we study photosynthesis? (Not Important)	**Table 12.2** Basic knowledge required to carry out experiments on photosynthesis **Basic Knowledge** / **Explanation** / **Action to Take** Glucose is first formed from carbon dioxide during photosynthesis. — • The simplest energy-rich organic molecules are carbohydrates. • The simplest stable form of carbohydrates is glucose. — Not applicable. Presence of starch in the leaves suggests that photosynthesis has taken place. — • When glucose is formed more quickly than it is used up, the excess glucose is converted to starch for storage. • Note, however, that starch formation does not indicate that photosynthesis has taken place. Starch can be formed even in the roots or underground storage organs of plants. — Test for starch using iodine solution (see Let's Investigate 12.2). Destarching (removal of starch) must be carried out on the plants before the experiments. — • This ensures that starch is absent in the leaves prior to the experiments. • Thus, all starch present in the leaves after the experiments must have been formed during the experiments. — • Put the plants in the dark for two days. • In darkness, photosynthesis stops and enzymes in the leaves convert starch to sucrose, which is transported to other parts of the plant (see page 262).
What conditions are essential for photosynthesis?	Light, carbon dioxide and chlorophyll are essential for photosynthesis. For photosynthesis to take place, a suitable temperature (Photosynthesis depends on enzyme reaction in the chloroplasts, thus a suitable temperature is needed) and sufficient water are also needed.

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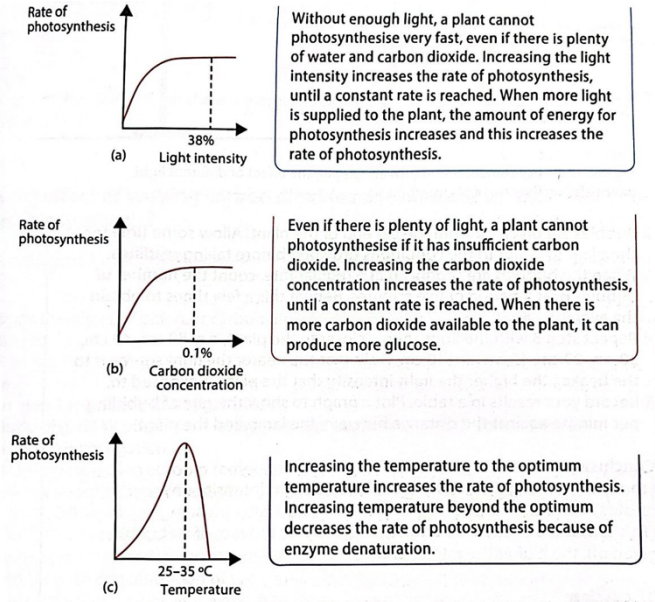
What happens during photosynthesis?	Photosynthesis is the process by which plants synthesise carbohydrates (e.g. glucose) from water and carbon dioxide. Water and carbon dioxide are the raw materials for photosynthesis. Oxygen is released during the process. During photosynthesis, chlorophyll absorbs energy from light and transfer it to chemical stores of energy in carbohydrates (e.g. sucrose), which are synthesised from water and carbon dioxide. Oxygen is released as a by-product. The rate of photosynthesis is affected by external factors such as light intensity, concentration of carbon dioxide and temperature.  **Figure 12.32** How the three factors affect the rate of photosynthesis

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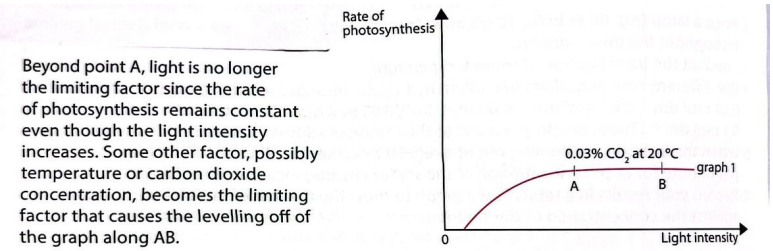
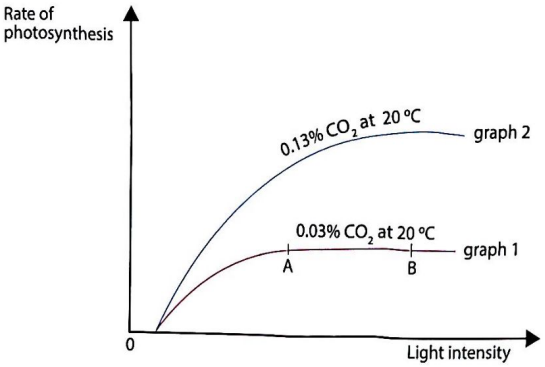
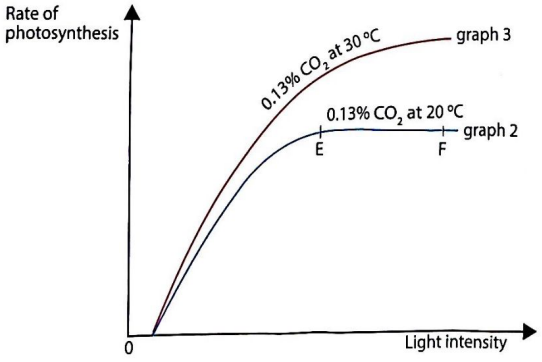
Limiting factor of photosynthesis? "O-level syllabus"	A limiting factor is any factor that directly affects the rate of a chemical reaction. The rate of the reaction can be increased only if the value of the limiting factor is increased.  **Figure 12.36** Effect of increasing light intensity on the rate of photosynthesis at 0.03% CO_2 at 20 °C Under natural conditions, carbon dioxide is an important limiting factor since atmospheric carbon dioxide remains constant at about 0.03%. Its concentration can be raised well above 0.03% only under experimental conditions.  **Figure 12.37** Effect of increasing carbon dioxide concentration on the rate of photosynthesis at 20 °C Study Figure 12.38, increasing the temperature from 20 °C to 30 °C, while keeping the carbon dioxide concentration constant at 0.13%, causes a large increase in the rate of photosynthesis as shown in graph 3. Therefore, *the temperature of the surroundings is the limiting factor* in EF in graph 2.  **Figure 12.38** Effect of increasing temperature on the rate of photosynthesis at 0.13% CO_2

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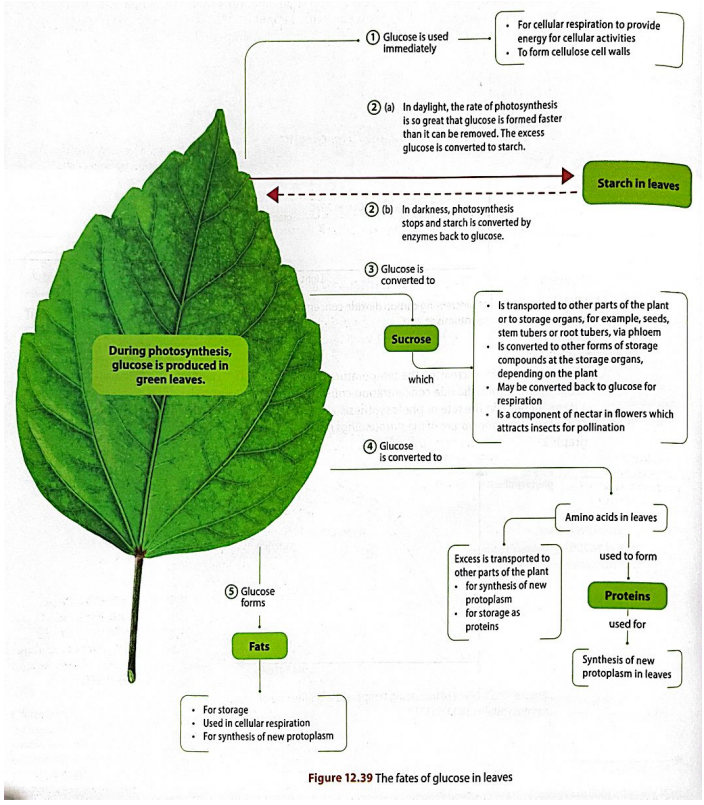
<table>
<tr>
<td>What happens to the glucose that is formed during photosynthesis?</td>
<td>The glucose formed during photosynthesis is either used immediately or stored in the plant.
 

Figure 12.39 The fates of glucose in leaves</td>
</tr>
<tr>
<td rowspan="3">Why is photosynthesis important?</td>
<td>Photosynthesis makes chemical energy available to animals and other organisms.

- During photosynthesis, chlorophyll absorbs energy from light and transfers it to chemical stores of energy in carbohydrate molecules.
- Fats, proteins, and other organic compounds can be formed from carbohydrates. All these substances eventually become the food of other organisms.
- All organisms thus obtain chemical energy directly or indirectly from plants, because plants are the producers in food chain.</td>
</tr>
<tr>
<td>Photosynthesis removes carbon dioxide and provides oxygen.

- The oxygen released is used by living organisms in respiration to release energy for cell activities. The process of photosynthesis maintains a constant level of oxygen and carbon dioxide in the atmosphere.</td>
</tr>
<tr>
<td>Energy stored in fossil fuels comes from photosynthesis.

- All the energy in fossil fuels comes from the sun, captured by photosynthesis. Burning of fossil fuels releases energy.</td>
</tr>
</table>

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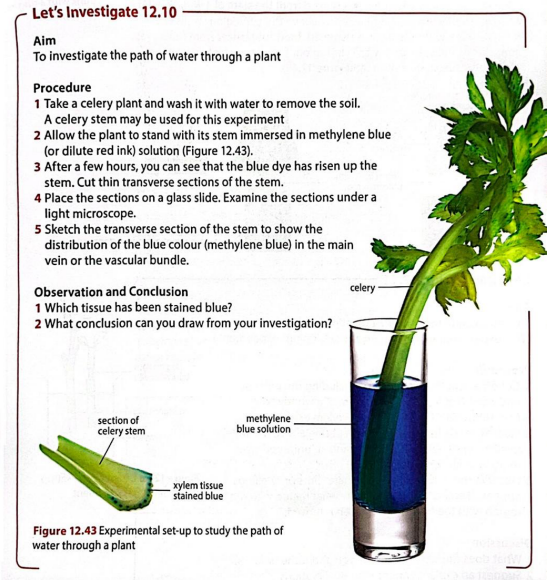
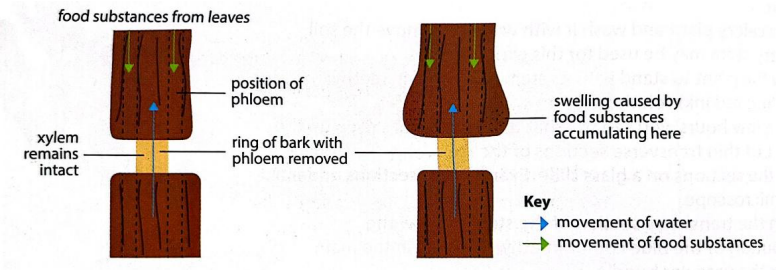
Movement of substances in plants

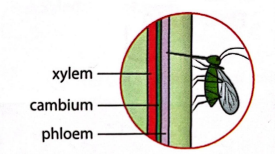
Studying the path water takes through a plant	
Studying the path food takes through a plant "O-level syllabus"	Translocation is the transport of manufactured food substances, such as sugars and amino acids, in plants. Using the "ringing" experiment A ring of bark with the phloem is removed from the stem. After some time, the stem immediately above the cut region swells up, this is because with the phloem removed, food substances from the leaves cannot reach the stem below the cut region. They accumulate above the cut region, causing it to swell up. 

Done by MF (completed in 2024)

<u>Using Aphids in translocation studies</u>

The long mouthpart of each aphid penetrates the leaf or stem. The body of the aphid can be cut off if it is anaesthetised with carbon dioxide when its feeding.

A liquid will flow out from the cut end of the mouthpiece. Analysing the fluid should contain sucrose and amino acids.



An aphid with its feeding stylet inserted through a stem

<u>Using isotopes in Translocation studies</u>

A leaf is provided with carbon dioxide containing the radioactive carbon, ^{14}C. When photosynthesis occurs, the sugars formed will contain radioactive carbon. The stem is then cut and a section of it is exposed onto an X-ray photographic film. It is found that radioactive substances are present in the phloem since radioactive substances cause the X-ray film to darken.

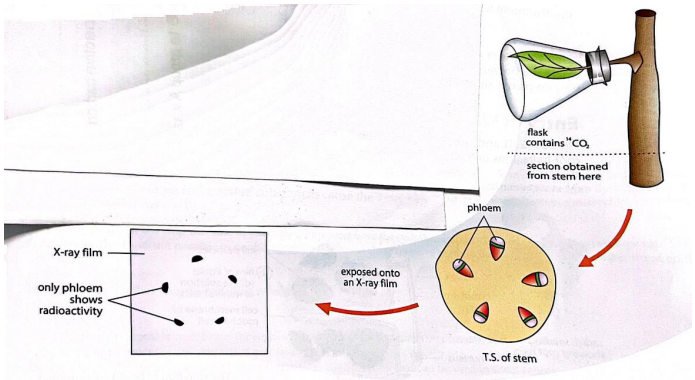
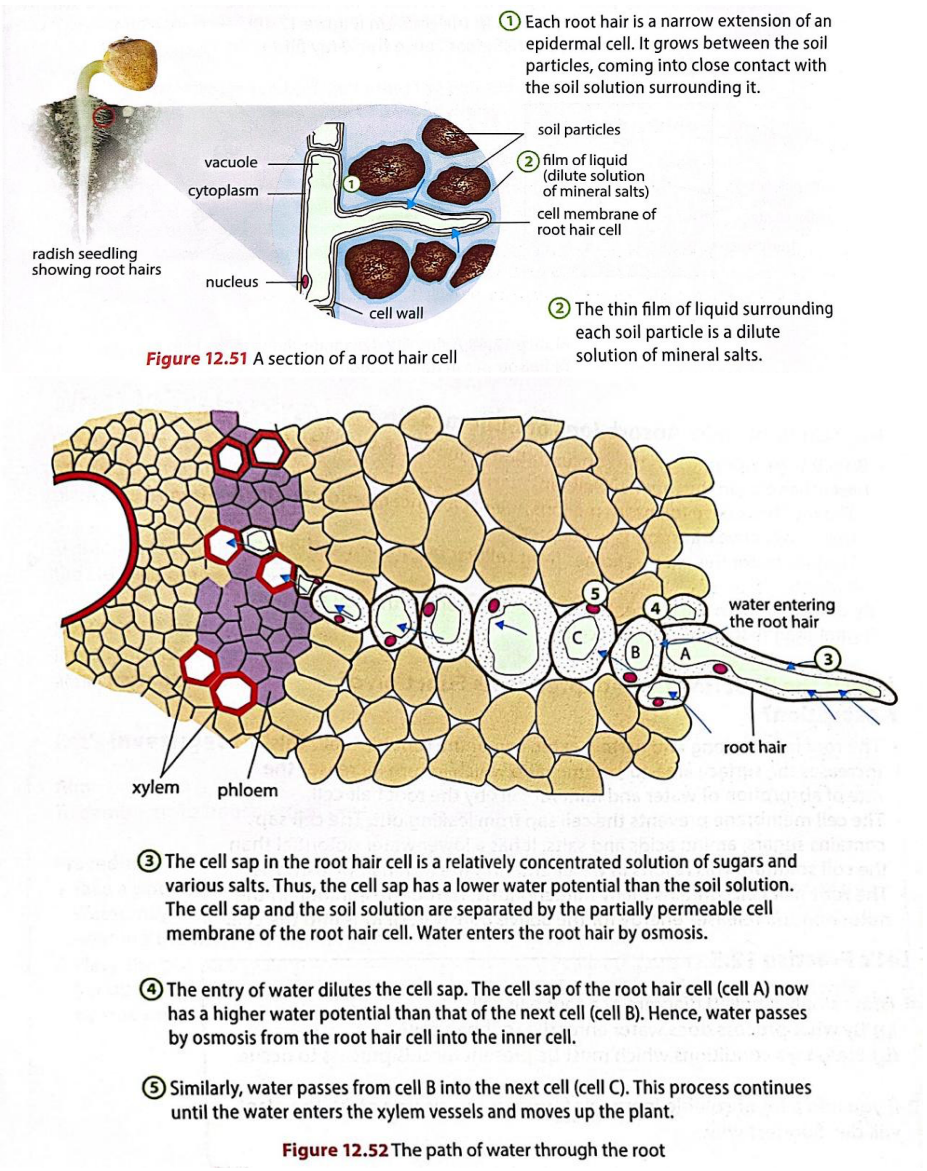


Figure 12.48 A simplified diagram showing the use of radioisotopes in translocation studies

Water entering the plant

Entry of water into a plant "O-level syllabus"	 **Figure 12.51** A section of a root hair cell **Figure 12.52** The path of water through the root
How do root hairs absorb ions or mineral salts? "O-level syllabus"	<u>Active transport</u> - This occurs when the concentration of ions in the soil solution is lower than that in the root hair cell sap (against a concentration gradient) - The energy for this process comes from cellular respiration in the root hair cell <u>Diffusion</u> - This occurs when the concentration of certain ions in the soil solution is higher than that in the root hair cell

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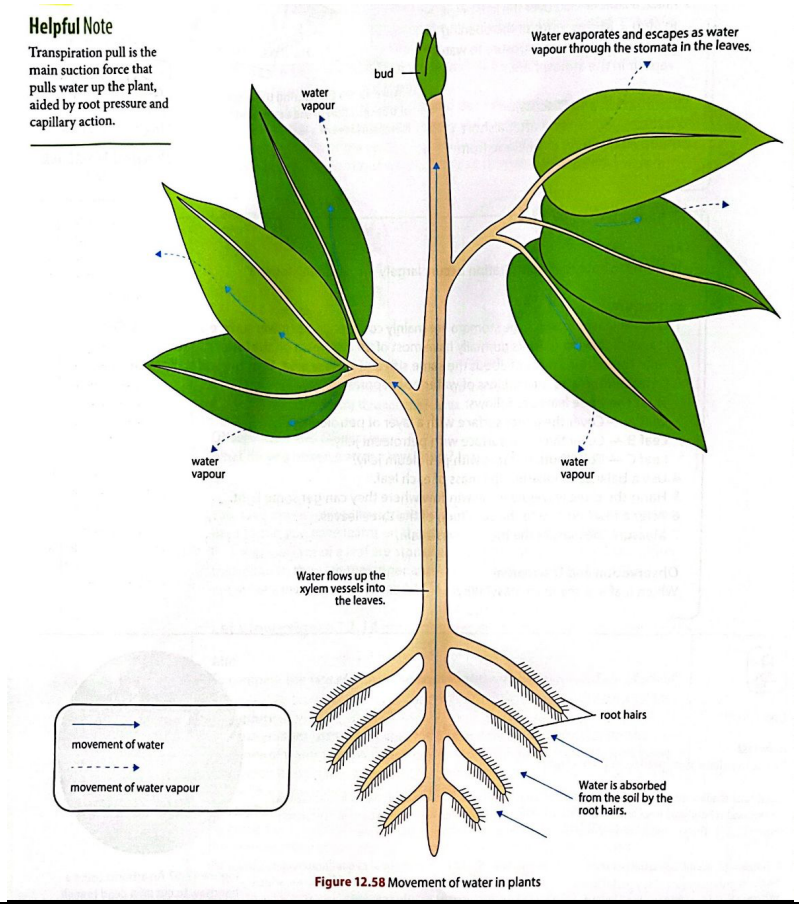
How is the root hair cell adapted to its function of absorption?	- Root hair has a long and narrow extension of the root hair cell. This increases surface area-to-volume ratio which in turn increases the rate of absorption of water and mineral salts by the root hair cell - The cell membrane prevents the cell sap from leaking out. The cell sap contains sugars, amino acids, and salts. It has a lower water potential than the soil solution allowing water to enter the root hair through osmosis - The root hair cell contains many mitochondria, aerobic respiration in the mitochondria releases energy for the active transport of ions into the cell

How water moves up in the plant?

What is transpiration? "O-level syllabus"	Transpiration is the loss of water vapour from the aerial parts of a plant, mainly through the stomata of the leaves.
Moving water against gravity "O-level syllabus"	The evaporation of water from the leaves removes water from the xylem vessels. This results in a suction force which pulls water up the xylem vessels. This suction force due to transpiration is known as transpiration pull. It is the main force in drawing water and mineral salts up the plant.  Figure 12.58 Movement of water in plants

Done by MF (completed in 2024)

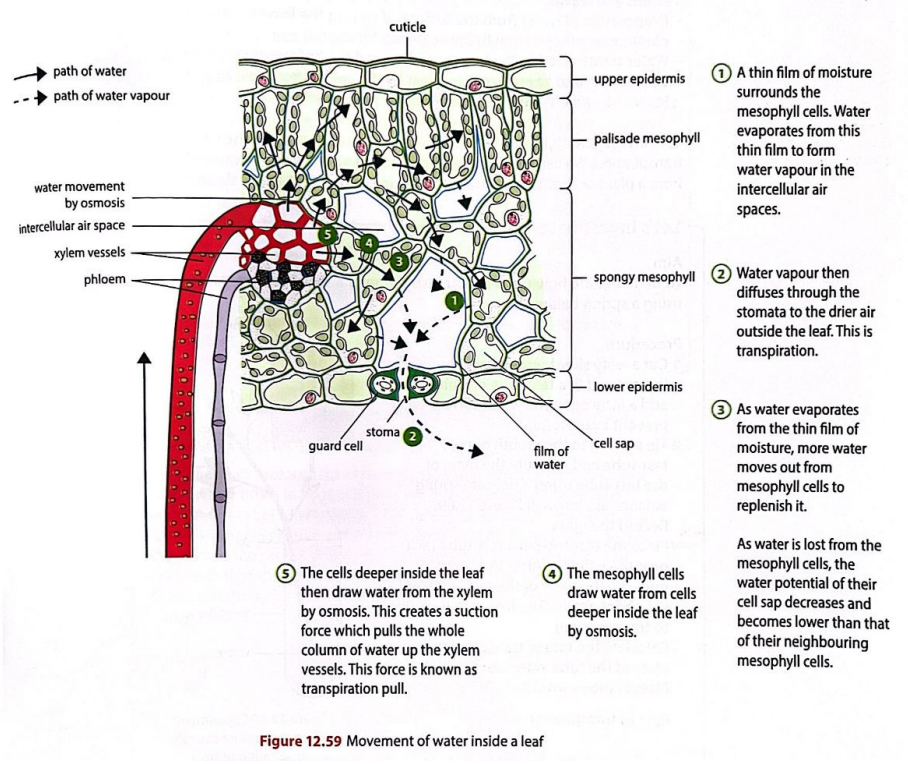
<table>
<tr>
<td></td>
<td>


Figure 12.59 Movement of water inside a leaf

As transpiration occurs mainly through the stomata, it is linked to gas exchange between the plant and the environment, in daylight, stomata open to allow carbon dioxide to diffuse into the leaf for photosynthesis. Oxygen and water vapour are more concentrated in the intercellular air spaces, so they diffuse out of the leaf through the stomata.
</td>
</tr>
<tr>
<td>Exam writing: Transpiration process

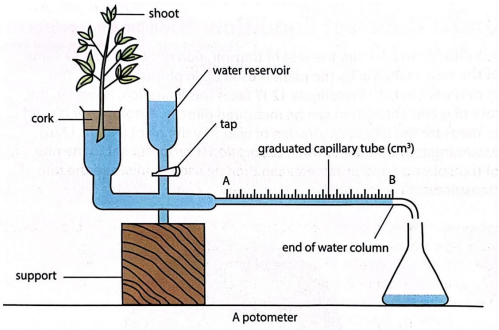
(IMPORTANT)</td>
<td>
Water constantly moves out of the xylem vessels, into the spongy mesophyll cells by osmosis.

Water then moves out of the mesophyll cells to form a thin film of moisture over their surfaces by osmosis from a region of higher water potential to region of lower water potential.

Water then evaporates from the thin film of moisture into the intercellular air spaces, to form water vapour.

The water vapour then diffuses through the stomata, 4 from region of high concentration to region of lower concentration in the atmosphere.

This process is called transpiration.
</td>
</tr>
</table>

Importance of transpiration	- Transpiration pull draws water and mineral salts from the roots to the stem and leaves. - Evaporation of water from the surface of cells in the leaves cools the plant, preventing it from being scorched by the hot sun. - Water transported to the leaves can be used in photosynthesis, to keep cells turgid, and to replace water lost by the cells. Turgid cells keep the leaves spread out widely to trap light for photosynthesis.
Measuring rate of transpiration under different conditions	We can measure rate of transpiration by measuring the rate of absorption. A potometer (see below) is used to measure the rate of absorption of water by the plant. Assumption made: Rate of water absorption is proportional to the rate of transpiration. A shoot that is to be used in a potometer must be cut under water. The cut end is kept immersed in water for a few hours before use. This is to allow the shoot to adjust to the conditions of the potometer. A potometer can also be used to determine the effect of different environmental conditions on the rate of transpiration. For example: • to investigate the effect of temperature, we can compare the rate of transpiration in a room with an air conditioner, where the temperature can be controlled. • to investigate the effect of wind speed, we can compare the rate of transpiration in a room with the ceiling fan switched on and switched off (in still air). • to investigate the effect of light intensity, we can compare the rate of transpiration in a dark room with a table lamp at various distances from the plant.  **Figure 12.62** Experimental set-up to measure the rate of transpiration using a potometer

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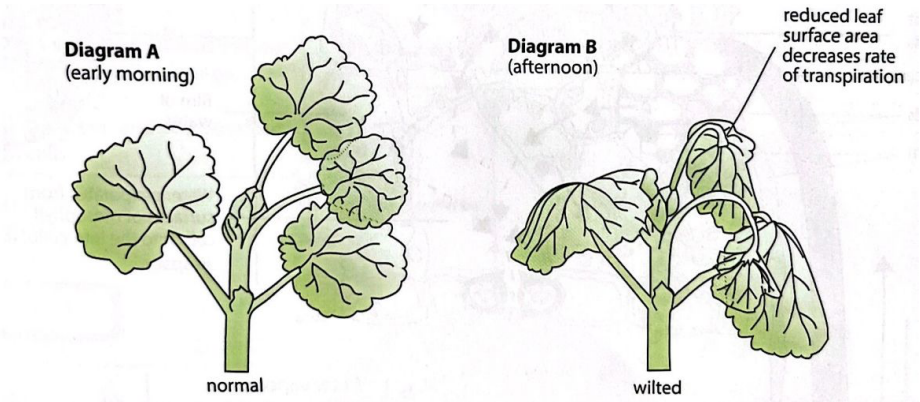
Factors that affect the rate of transpiration	Wind or air movement In still air, water vapour that diffuses out of the leaf accumulates outside the stomata. This makes the concentration gradient less steep. Rate of transpiration becomes lower. When wind is present, water vapour diffuses out of the leaf is blown away and does not accumulate. Thus, the concentration gradient of water vapour inside and outside the leaf is steeper. Rate of transpiration is higher when wind is stronger.
	Temperature of the air A rise in temperature increases the rate of evaporation of water from the cell surfaces. Thus, the rate of transpiration is higher at higher temperatures.
	Light Light affects the size of the stomata on the leaf. It will therefore affect the rate of transpiration. In the presence of light, the stomata open and become wider. This increases the rate of transpiration. In darkness, the stomata close, and less water is lost from the leaf.
	Humidity of the air The intercellular air spaces in the leaf are normally saturated with water vapour. There is a water vapour concentration gradient between the leak and the surrounding air. When the air outside the leaf is drier or less humid, the concentration gradient of water vapour is steeper. Rate of transpiration thus faster. Increasing the humidity in air will make the water vapour concentration gradient between the leaf and the surrounding air less step. Rate of transpiration will decrease.

Wilting "O-level syllabus"	The turgor pressure in the leaf mesophyll cells helps to support the leaf and keep it firm. This enables it to spread out widely to absorb light for photosynthesis. In strong light, rate of transpiration exceeds rate of absorption of water by the roots, cells lose its turgor. They become flaccid and the plant wilts.  **Figure 12.66** Parts of the same plant at different times of the day
	<u>Advantages of wilting</u> The surface area that is exposed to light is reduced (leaf folds up). Reduced exposed surface area of a leaf reduces exposure of stomata and reduces rate of water loss through the stomata. Excessive water loss caused guard cells to become flaccid and the stomata to close. Rate of transpiration decreases.
	<u>Disadvantage of wilting</u> The amount of carbon dioxide entering the leaf is also reduced. Carbon Dioxide becomes a limiting factor, and the rate of photosynthesis is reduced. Folding of leaves also reduced the surface are exposed to light, also reduced rate of photosynthesis.

Chapter 13: Organisms and Their Environment

O level syllabus

- describe the non-cyclical nature of energy flow
- describe the roles of producers, consumers and decomposers in food chains and food webs
- explain how energy losses occur along food chains, and discuss the efficiency of energy transfer between trophic levels
- describe and interpret pyramids of numbers and biomass
- describe how carbon is cycled within an ecosystem and outline the role of forests and oceans as carbon sinks
- describe how human activities, such as deforestation and use of fossil fuels, cause an increase in atmospheric carbon dioxide concentration, leading to global warming
- discuss how human actions can reduce the effects of global warming
- describe the effects of pollution caused by:
  - sewage in water
  - plastic wastes in the marine environment
  - insecticides and their biomagnification up food chains, impacting on top carnivores
- discuss how the conservation of species and sustainable use of natural resources contribute to the maintenance of biodiversity and a balanced ecosystem (e.g. coral reef, tropical rainforest, mangrove)

Nutrient and Energy Flow

What are producers? "O Level Syllabus"	A producer is an organism that makes its own food. It contains chlorophyll that absorbs light to covert carbon dioxide and water into glucose, through photosynthesis. They are at the base of all food chains. Examples of producers are plants and algae.
What are consumers? "O Level Syllabus"	Consumers are organisms that are not able to make their own food. They obtain energy and nutrients by feeding on other organisms. There are three kinds of consumers, depending on position in food chain. **Table 13.1** Types of consumers Primary Consumers — These are organisms that feed on plants only. Secondary Consumers — These are organisms that feed on primary consumers. Tertiary Consumers — These are organisms that feed on secondary consumers. Producer → Primary Consumer → Secondary Consumer → Tertiary Consumer

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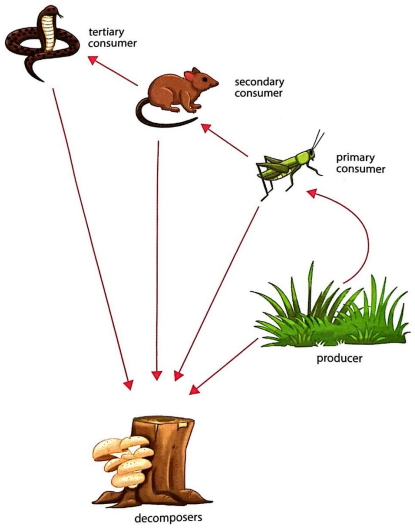
What are decomposers? "O Level Syllabus"	Decomposers are organisms that get their energy by breaking down dead organisms, faeces, and excretory products. Their activities return nutrients like mineral salts to the environment. Examples of decomposers are bacteria and fungi.
How are they related?	Energy and nutrients are transferred from producers to consumers to decomposers through feeding.  **Figure 13.1** Relationship between producers, consumers and decomposers

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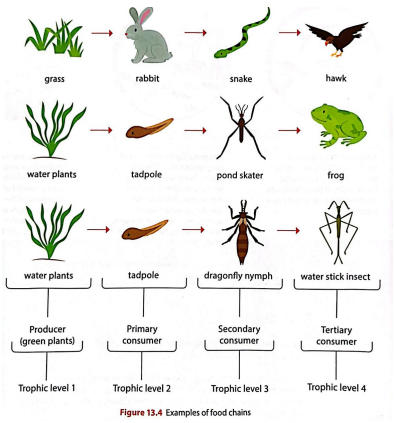
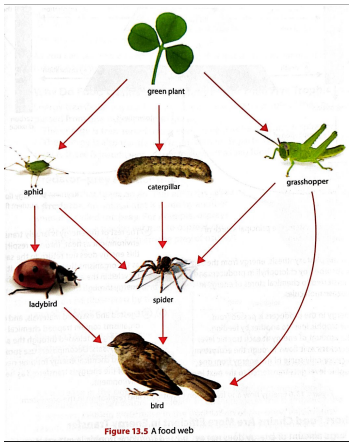
Food Chains V.S. Food Webs

Interaction of organisms at various levels of organisation	*Population* A group of organisms of the same species that live together in a habitat.
	Habitat The place where organisms' lives.
	Community Made up of different species living and interacting with one another. (includes plants and other animals)
	Ecosystem A community of organisms interacting with one another with its non-living environment. (includes physical and/or non-living components)
What are food chains?	A food chain is a series of organisms, beginning with the producer, through which energy and nutrients are transferred. (it always begins with the producer)  Figure 13.4 Examples of food chains Trophic level = stage in the food chain (usually no more than 4)
What is a food web?	A food web is made up of two or more food chains that are interlinked. It represents the inter-relationship between food chains.  Figure 13.5 A food web

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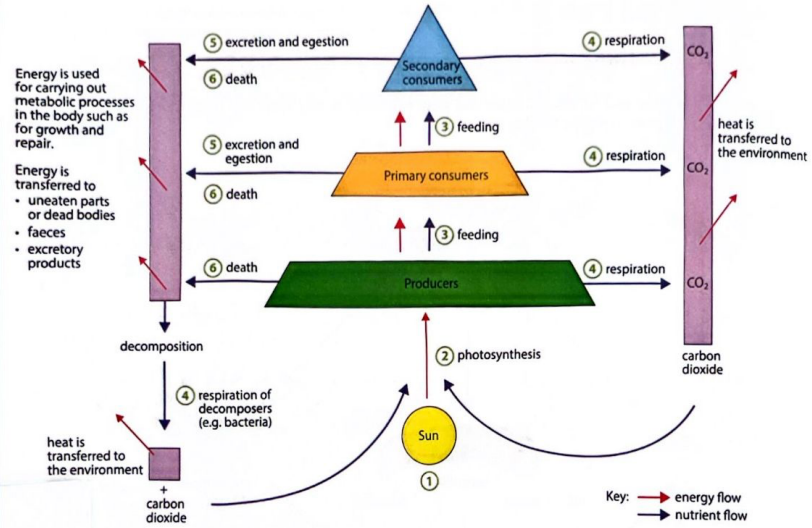
Non-cyclic energy flow in an ecosystem

How does the non-cyclical nature of energy flow work?

"O Level Syllabus"



1 In any ecosystem, the principal source of energy is the Sun.

2 During photosynthesis, energy from the Sun is absorbed by chlorophyll in producers and transferred to chemical stores of energy in glucose molecules.

3 Energy in the producers is passed from one trophic level to another by feeding. The amount of energy at each trophic level decreases as it flows through the ecosystem because only some of the energy from one trophic level gets transferred to the next level.

4 The rest of the energy is largely transferred to the environment as heat, through respiration. Since this energy does not return to the same system as the organisms that produced it, it cannot be recycled in the ecosystem. Hence, the flow of energy through the ecosystem is non-cyclical.

5, 6 Egested and excreted materials, and dead organisms contain trapped chemical energy. This energy is released through the activity of decomposers. Decomposers use some of this trapped chemical energy for their needs. The rest of the energy is transferred as heat to the environment.

Figure 13.6 Energy flow and its relation to nutrition and respiration in the ecosystem

EXAM

- Light energy is absorbed by chlorophyll in plants and converted to chemical energy during photosynthesis.
- Some energy is passed on from organism to organism during feeding.
- A lot of energy is lost as heat to the environment due to respiration. This energy cannot be recycled in the ecosystem.
- Hence energy in the form of light (from the sun) must be constantly supplied to the ecosystem.
- Energy flow is non-cyclical and linear.

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<table>
<tr><td rowspan="2">Shorter food chain = more efficient in energy transfer?

"O Level Syllabus"</td><td>A large amount of energy does not get passed from one trophic level to the next as it is lost to the environment as heat, or transferred to uneaten body parts, faeces, and excretory products,

There will then be lesser and lesser energy available for the organisms at the next tropic level as we move along the food chain. The shorter the food chain, the greater amount of energy available to the final consumer.</td></tr>
<tr><td>EXAM
Explain how energy losses occur along food chains, and discuss the efficiency of energy transfer between trophic levels.

• 90% of energy is lost when energy is transferred from one trophic level to the next.
• Heat is loss:
- As heat during respiration at each trophic level.
- In uneaten body parts.
- Through undigested food that is egested by consumers.
- Through metabolic waste products that are excreted by consumers.
• As less energy is available for the organism at the last trophic level, food chains are usually short.</td></tr>
<tr><td>Predator-prey relationship</td><td>An increase in the population size of the prey means that more food is available for the predators. This thus leads to an increase in the number if predator which will decrease the number of prey available.

The cycle of predator-prey relationship repeats over time. This increase and decrease in the population of the predators follow the corresponding increase and decrease in the population of the prey.</td></tr>
</table>

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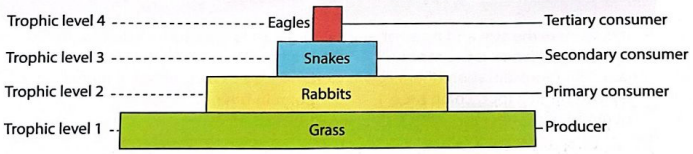
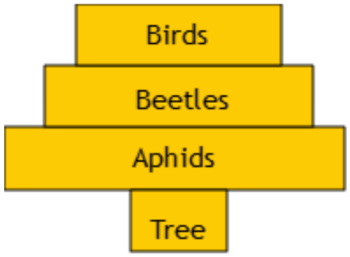
Ecological Pyramids

Pyramid of Numbers "O Level Syllabus"	Allows us to compare the number of organisms present in each trophic level in the area at a particular time. **How Is a Pyramid of Numbers Constructed?** Consider the food chain: grass → rabbit → snake → eagle, shown in Figure 13.10. Let us suppose that: • There are ten eagles in a given area, and each eagle needs to feed on one snake every day. In a month, the ten eagles will need 300 snakes to keep them alive. • If each snake eats two rabbits every day, 300 snakes will need 18 000 rabbits in a month. • If each rabbit eats about 15 grass plants every day, 18 000 rabbits will need about 8 100 000 grass plants in a month. The number of organisms in each trophic level can be used to construct a pyramid of numbers (Figure 13.11). The length of the bar in the pyramid represents the number of organisms present at that time. For this food chain, the pyramid will be broad at the base and narrow towards the top.  **Figure 13.11** A pyramid of numbers
	Inverted pyramid (not so common) **Inverted pyramid**  - Occurs if there are parasitic organisms. - Occurs if many small organisms feed on a large organism.
	Limitations of using this method - does not consider size and mass of organisms - does not consider if organisms are adult or juvenile

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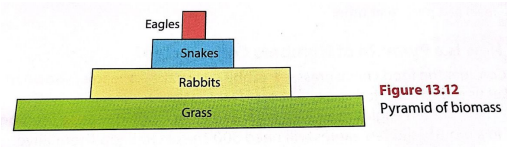
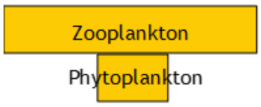
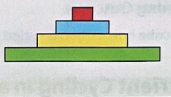
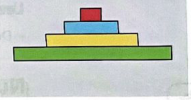
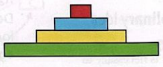
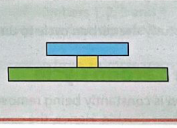
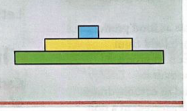
Pyramid of Biomass "O Level Syllabus"	Allows us to compare the mass of organisms present in each trophic level at a particular time. This is constructed based on standing mass = dry mass = mass of organism after removal of water  **Figure 13.12** Pyramid of biomass
	Inverted pyramid  - Inverted pyramids of biomass may be obtained if there are organisms that can reproduce rapidly.
	Benefits and Limitations **Table 13.2** Reasons for and limitations of using the pyramid of biomass

Reasons	Limitations
• It considers the size and mass of organisms. Hence, it is a more accurate representation of energy flow through a food chain than a pyramid of numbers.	• Organisms have to be killed to obtain biomass. • It has to be constructed at a particular point in time.

Sample exceptions	**Table 13.3** Some examples of food chains showing variations in ecological pyramids

Food Chain	Pyramid of Numbers	Pyramid of Biomass
grass → rabbit → snake → eagle		
tree → aphid → ladybird → small bird		
grass → zebra → tsetse fly		

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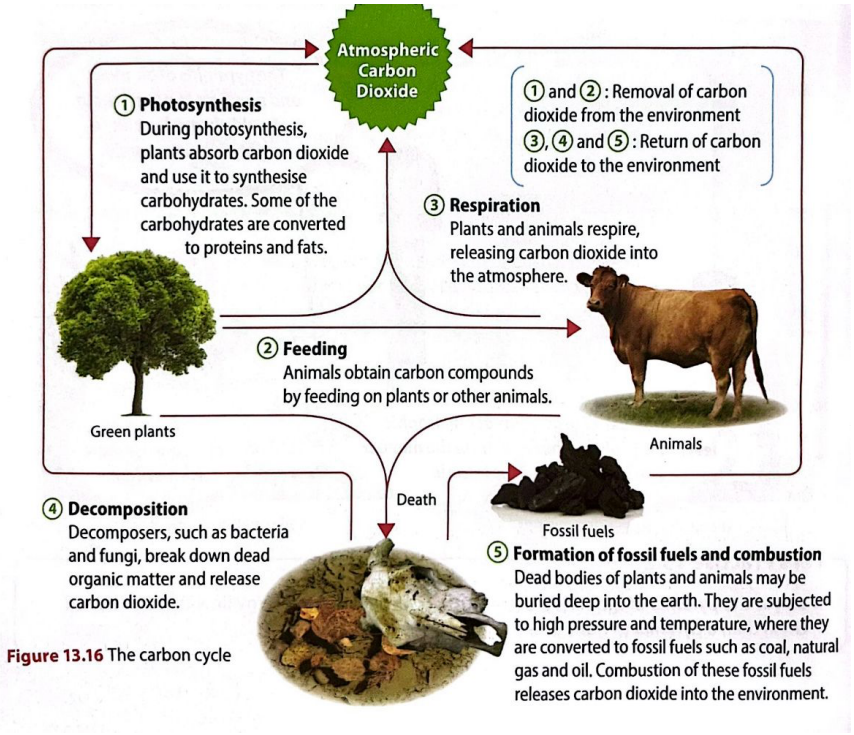
Nutrients cycling in an ecosystem

Nutrient cycling in an ecosystem	In a balanced ecosystem, nutrients are never lost but recycled. The cycling of nutrients is brought about by physical, chemical, and biological processes.
The carbon cycle "O Level Syllabus"	 **Figure 13.16** The carbon cycle
	Importance of the Carbon cycle - ensure the continuous supply of carbon dioxide for plants to carry out photosynthesis - enables energy to flow through the ecosystem (carbon compounds carry stored energy from organism to organism in food chain of ecosystem) - regulates the amount of carbon dioxide in the atmosphere

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Carbon Sinks

What are carbon sinks?	A carbon sink is an area that stores carbon from the atmosphere for a long period of time. It stores more carbon than it releases.
Oceans as carbon sinks "O Level Syllabus"	*Solubility* The Carbon Dioxide that dissolves in the ocean's water is absorbed.
	Photosynthesis During photosynthesis, aquatic plants take in carbon dioxide that is absorbed and photosynthesises.
	A portion of the carbon compounds are found buried beneath the seabed and is in the form of fossil fuels such as natural gas and oil.
Forests as carbon sinks "O Level Syllabus"	Atmospheric carbon dioxide is absorbed by the plants and used in photosynthesis. In forests, a large amount of carbon compounds is stored in trees. When trees die, their remains may be buried deep in the ground.
	Paris Agreements (not important) - Keep the rise in global average temperatures to below 2°C. It aims to limit the temperature increase to 1.5°C. This is expected to substantially reduce the effects of climate change. Carbon emissions should be reduced as soon as possible and reach a net-zero by middle of the 21st Century.
	Climate Action Plan in July 2016 (not important) - Plan provides details of the strategies for adapting to the impact of climate change, such as implementing coastal and infrastructure protection measures. It also mentions ways to reduce carbon emissions up to 2030, such as improving energy efficiency, reducing carbon emissions from power generation and developing cutting-edge low-carbon technologies.

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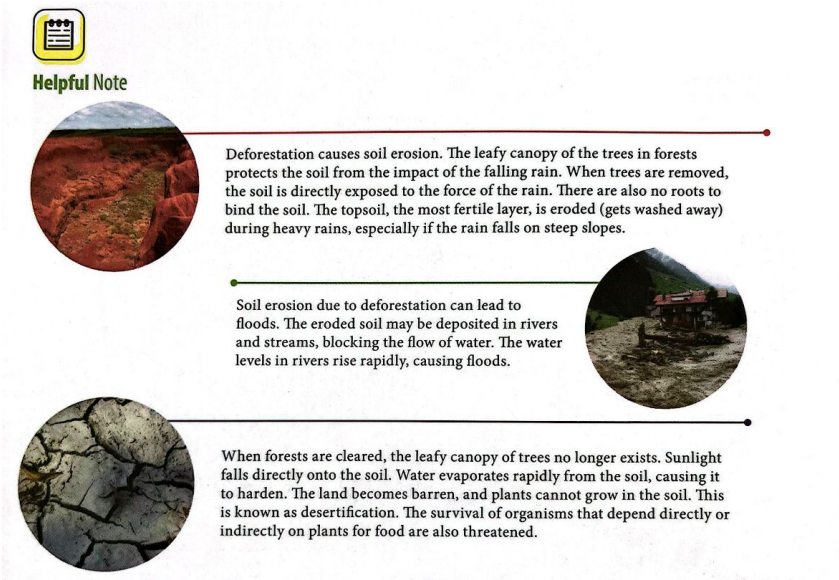
How do we affect the ecosystem?

Renewable natural resources V.S. Non-renewable natural resources	*Renewable Natural Resources* - They can be replaced in the ecosystem by natural cycles as long as humans do not overuse them - E.g. Air, water, soil, forests, and wildlife
	Non-renewable Natural Resources - They cannot be replaced in the ecosystem quick enough, as their formation takes millions of years - E.g. Fossil Fuels
Deforestation "O Level Syllabus"	*What is it?* - clearing of forests → cleared to meet the increasing demands for land and materials such as wood - With modern technology, forests can be clearer at a much faster rate than it can be replaced
	Undesirable Effects of Deforestation - Extinction and reduction in biodiversity → clearing forest = reduce land space for animals to live in, thus there may not be sufficient to support a breeding population of these animals. The animals may then become endangered or extinct. - Global Warming → When trees in the forests are cut down, they release into the atmosphere all the carbon dioxide they have been storing (excess carbon is stored in tree trunks, roots and in the soil). Further emission of carbon dioxide occurs when they are left to rot or burnt.  Helpful Note Deforestation causes soil erosion. The leafy canopy of the trees in forests protects the soil from the impact of the falling rain. When trees are removed, the soil is directly exposed to the force of the rain. There are also no roots to bind the soil. The topsoil, the most fertile layer, is eroded (gets washed away) during heavy rains, especially if the rain falls on steep slopes. Soil erosion due to deforestation can lead to floods. The eroded soil may be deposited in rivers and streams, blocking the flow of water. The water levels in rivers rise rapidly, causing floods. When forests are cleared, the leafy canopy of trees no longer exists. Sunlight falls directly onto the soil. Water evaporates rapidly from the soil, causing it to harden. The land becomes barren, and plants cannot grow in the soil. This is known as desertification. The survival of organisms that depend directly or indirectly on plants for food are also threatened.

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Effect of Human Activities on Global Warming	*Greenhouse effect* - Carbon Dioxide is a greenhouse gas and forms a layer around the Earth's surface. Heat is trapped and this is the greenhouse effect that cases global warming. (Enhanced greenhouse effect may result in climate change) - Rise in seawater temperature may result in a loss of biodiversity (e.g. causes coral bleaching and death of coral reefs → corals are stressed by changes in light, water or temperature and expel the algae that live in them and turn white)
	Effect on aquatic ecosystems - More atmospheric carbon dioxide dissolves in the seawater and make the seawater become more acidic. Acid dissolves calcium compounds in shells of shellfish which will weaken their shells and make them more vulnerable to predators.
	Difference between Global Warming and Climate Change - Global warming is the rise in global temperature. This process is accelerated by human activities that cause increasing concentrations of greenhouse gases, like carbon dioxide in the atmosphere. - Climate change refers to the changes in temperature and weather patterns over a long period of time. The effects of climate change include rising sea levels, melting of ice sheets in Greenland and Antarctica.
	How human actions can reduce the effects of enhanced global warming - Reduce use of fossil fuels (use renewable sources of energy like solar energy and wind) - Reduce energy consumption / using energy efficient devices (LED lamps) - Replace Petrol-powered vehicles with hybrid or electric vehicles - Reduce daily consumption of electricity, water, paper and plastic - Forest management (conserving forests, reforestation and education programmes should be conducted to make people aware of the importance of forests in our lives) - Singapore Green Plan 2030 → aims to ensure that Singapore will remain a green and liveable home for current and future generations. Key initiatives include reducing carbon emissions, save resources and energy, using cleaner energy and lower our carbon footprint.

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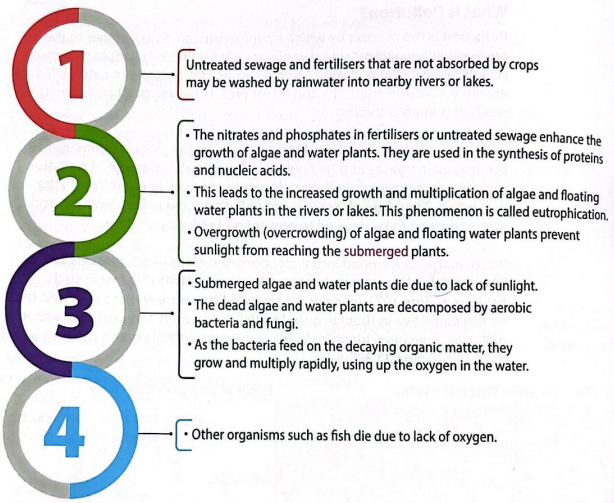
Pollution "O Level Syllabus"	*What is pollution?* - the process by which harmful substances are added to the environment, making it undesirable or unfit for life. - substances that causes pollution are called pollutants (natural pollutants include volcanic eruptions and forest fires, however most pollution are a result of human activities)
	Sewage - Water carried waste matter from homes or industries → should not be discharged into rivers or lakes as it may contain disease-causing organisms like bacteria (e.g. Cholera and Typhoid) - Untreated sewage contains phosphates and nitrates. This can result in excessive growth of algae and water plants in water bodies, promoting bacterial growth. - Eutrophication is the process by which water receives excess nutrients like phosphates and nitrates, causing excessive growth of algae and water plants The process and effects of eutrophication are described in Figure 13.32.  **Figure 13.32** Process and effects of eutrophication

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	Insecticides (used to kill insects) - Disadvantage: Insecticides become infection after some time. Some insects become resistant to the insecticides. They then pass the favourable genes to their offspring and over time the population of insects will rise again. - Disadvantage: Insecticides may end up affecting organisms other than insects. If insecticides are carried by rainwater into streams, rivers, and lakes, they can accumulate in high concentrations in the bodies of aquatic organisms such as fish. - E.g: DDT (dichlorodiphenyltrichloroethane) is an insecticide that is non-biodegradable. This means that it cannot be broken down by micro-organisms like bacteria. It remains in the soil or water for many years. If eaten, it accumulates in the bodies of consumers and will lead to bioaccumulation. - Biomagnification occurs when certain chemicals (e.g. insecticide) are passed along the food chain, increasing in concentration in the bodies of organisms along the trophic levels
	Effects of non-biodegradable plastic waste on the ecosystem - Harmful chemicals from plastic waste buried in landfills may be leached into the rivers and seas. They poison wildlife in the seas or rivers. - Plastic waste can created from disposables can be harmful to marine animals when washed into the sea - Plastic waste may be broken down into microplastic and could be ingested by marine organisms and accumulate in their bodies.

Conservation

Need for conservation	- Biodiversity refers to the range of species that are present in a particular ecosystem - Conservation is the protection and preservation of natural resources in the environment - We need conservation is because many species are becoming extinct before we even have the chance to discover or study about them
Reasons for conservation "O Level Syllabus"	*Maintaining biodiversity by preventing the extinction of species* - Maintenance of a large gene pool is important as many wild plants and animals possess favourable genes. By cross breeding the different varieties of wild plants and animals, we can improve agricultural produce. (E.g. plants with better resistance to diseases and drought can be produced by crossing domestic species with wild species) - Many tropical plants are of great importance as they are sources of medicinal drugs. (E.g. quinine, an anti-malarial drug from the bark of Cinchona, and vinblastine, a drug used to treat leukemia derived from the Madagascar rosy periwinkle. Many more medicinal drugs in plant species remain to be discovered. - To prevent extinction of a species, genetic diversity must be maintained. Any change in environmental conditions is less likely to wipe out the whole species.
	For Scientific Research - The student of wildlife provides useful information to humans. (E.g. we learn about evolution from studying wildlife)
	For economic purposes - Marine life needs to be conserved as they are a major source of human food. - Tropical rainforests also provide food. Rice, pineapple, and banana are examples of food plants that were developed from rainforest plants. - Tropical plants provide raw materials for industries. (E.g. rattan is used to make furniture, rubber from the latex of rubber trees is used to make tyres, and fibres from cotton plants are used to make cloth)
	To maintain a stable and balanced ecosystem - This prevents disruption of natural cycles such as the carbon cycle and prevents global warming.
	To preserve natural scenery and wildlife for people to appreciate - Natural resources enable outdoor recreational activities such as fishing, hiking and skiing.

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How can resources be conserved and managed sustainably?	*Conservation of forests*
	Conservation of Mangrove Swamps - Mangrove Restoration project → volunteers plant mangrove seedlings over a portion of the mangrove swamp. The trees that develop will protect low-lying areas against strong wind, waves, and tides. - Adopt a Mangrove Programme is a campaign initiated by Pulau Ubin to raise awareness about conservation and restoration of degraded areas to reduce the impact of global warming and climate change.
	Conservation of Coral Reefs - People visiting coral reefs should practise safe and responsible diving. Divers should not touch the reefs as they may damage the coral animals. Divers should not anchor their boats on the reefs as they may kill the corals. - Guidelines for visitors to the reefs should be followed → Avoid using sunscreen as some ingredients in sunscreen can be harmful to corals → Avoid purchasing living corals as this will encourage people to extract live corals for sale → Avoid polluting the coastline with trash, especially non-biodegradable plastic. Such marine debris may be blown or washed away into the ocean, which is harmful to coral reefs.

Chapter 14: Molecular Genetics

O level syllabus

- outline the relationships among DNA, genes and chromosomes
- state that DNA is a double helix comprising two strands of nucleotides, each nucleotide formed of a sugar, a phosphate group and one of four different bases
- state the rule of complementary base pairing
- state that each gene:
    - is a sequence of nucleotides, as part of a DNA molecule
    - codes for one polypeptide
    - is a unit of inheritance
- state that DNA is used to carry the genetic code, which is used to synthesise specific polypeptides (details of transcription and translation are not required)
- state that genes may be transferred from the cells of one organism to the cells of another to form transgenic organisms
- briefly explain how a gene that controls the production of human insulin can be inserted into bacterial DNA to produce human insulin in medical biotechnology
- discuss the possible benefits and ethical considerations of genetic engineering, in medicine and production of economically important plants and animals

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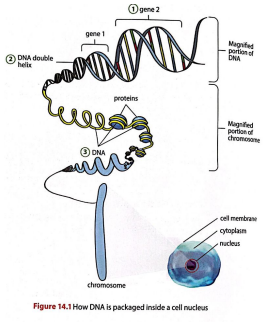
Deoxyribonucleic acid (DNA)

What is DNA? "O level syllabus"	- The chemical that makes up the genetic material in living organisms. - Organised into highly condensed structures called chromosomes in the nucleus of cells
What is a gene? "O level syllabus"	A gene is a unit of inheritance, and it is made up of a small segment of DNA (a sequence of nucleotides) in a chromosome.
How is DNA organised inside cells? "O level syllabus"	1) Gene → a unit of inheritance, and it is made up of a small segment of DNA (a sequence of nucleotides) in a chromosome. 2) DNA is made of two nucleotide strands wound together in a double helix shape. They form chromatin threads. 3) A molecule of DNA is wrapped around proteins to form a single chromosome.  Figure 14.1 How DNA is packaged inside a cell nucleus

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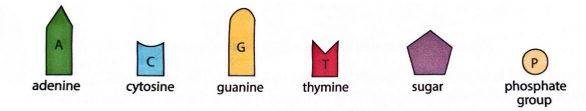
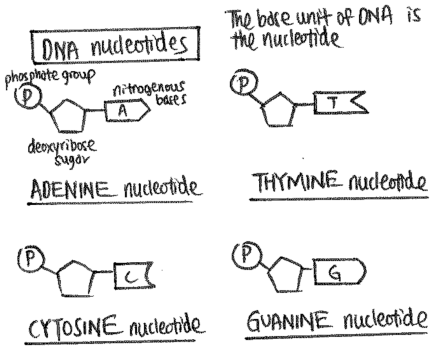
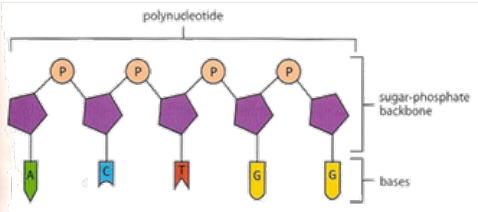
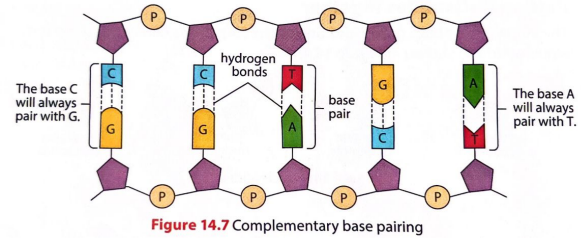
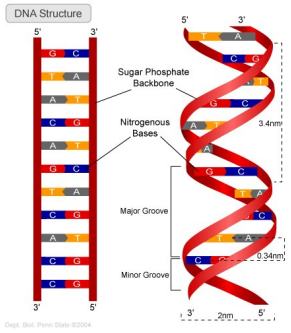
Basic Units of DNA "O level syllabus"	DNA is a double helix structure that is made up of nucleotides. Nucleotides are the basic unit of DNA. Each nucleotide is made up of... (1) A deoxyribose sugar (2) A phosphate group (3) A nitrogenous base (e.g. Adenine, thymine, cytosine, and guanine)  **Figure 14.3** Building blocks of nucleotides 
Complementary Base Pairing "O level syllabus"	Nucleotides can be joined together to form long chains called polynucleotides.  Adenine bonds with thymine and cytosine pairs with guanine in a ratio of 1:1. This is called complementary base pairing because A has a shape complementary to that of T and C has a shape complementary to that of G. The bases are held together by hydrogen bonds.  **Figure 14.7** Complementary base pairing 

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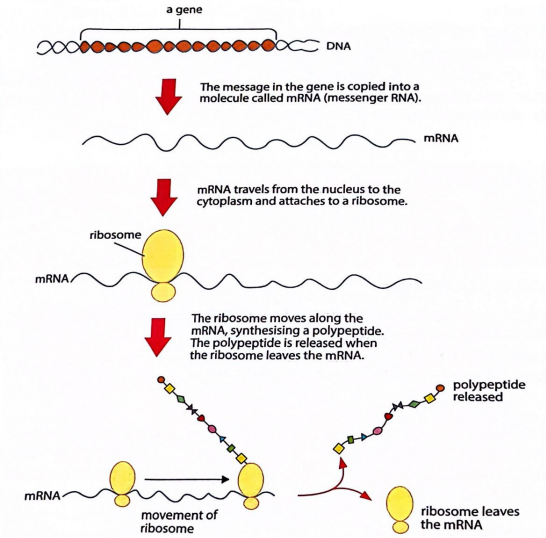
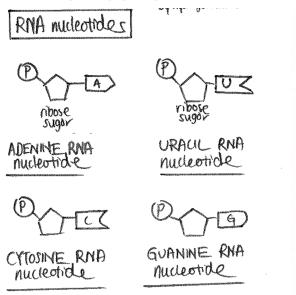
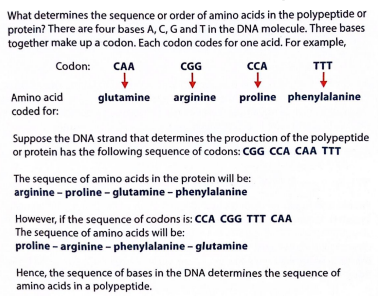
Genes

What is a gene? "O level syllabus"	A gene is a sequence of nucleotides that codes for a (particular) singular polypeptide. Each gene (genes are a segment of DNA) stores a genetic code that determines how a protein should be made in a cell.
How is a polypeptide or protein made? "O level syllabus"	Cells use the two-step process of transcription and translation to read each gene and produce the string of amino acids that makes up a polypeptide/protein.  **Figure 14.10** Production of a polypeptide
	Transcription - the copying of DNA template into a messenger RNA (mRNA) molecule - occurs in the nucleus - Every 3 nucleotides on the original DNA is a codon, and each codon determines an amino acid in the polypeptide
	Translation - the process where information in mRNA is used to synthesise a polypeptide - the mRNA molecule carries the message from the nucleus into the cytoplasm - mRNA attaches to a ribosome, the ribosome converts the message on the mRNA into a protein by attaching amino acids together according to the codons on the mRNA - The polypeptide is released, and folds into a protein   What determines the sequence or order of amino acids in the polypeptide or protein? There are four bases A, C, G and T in the DNA molecule. Three bases together make up a codon. Each codon codes for one acid. For example, Codon: CAA CGG CCA TTT Amino acid coded for: glutamine arginine proline phenylalanine Suppose the DNA strand that determines the production of the polypeptide or protein has the following sequence of codons: **CGG CCA CAA TTT** The sequence of amino acids in the protein will be: **arginine – proline – glutamine – phenylalanine** However, if the sequence of codons is: **CCA CGG TTT CAA** The sequence of amino acids will be: **proline – arginine – phenylalanine – glutamine** Hence, the sequence of bases in the DNA determines the sequence of amino acids in a polypeptide.

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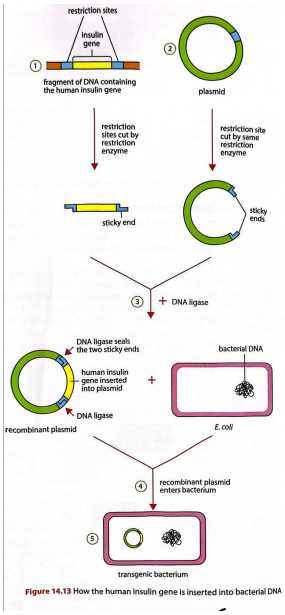
Genetic Engineering

What is genetic engineering? "O level syllabus"	Genetic engineering is a technique used to transfer genes from one organism to another. Individual genes may be cut off from the cells of one organism and inserted into the cells of another organism if the same or different species. The transferred gene can express itself in the recipient organism.
What is a transgenic organism?	An organism that contains genes from at least 2 different genes.
Transferring the Human Insulin Gene into Bacteria "O level syllabus"	1. The human insulin gene is identified and cut using a restriction enzyme, forming sticky ends. 2. A plasmid is cut using the same restriction enzyme to form complementary sticky ends. 3. The insulin gene is mixed with the plasmid and joined together with DNA ligase. 4. The recombinant plasmid is then mixed with bacteria and heat, or electric shock is applied to allow the bacteria to take up the plasmid. 5. The transgenic bacteria are placed in the fermenter with nutrients, optimum temperature, and pH for the bacteria to multiply. 6. The bacteria produce insulin which can be extracted and purified.  Figure 14.13 How the human insulin gene is inserted into bacterial DNA

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Advantages of producing insulin via genetic engineering	- It does not induce an allergic response in the patient as the insulin produced is identical to human insulin. - It is easier and cheaper to produce insulin in large quantities. - There is less risk of contamination by disease-causing microorganisms like bacteria as compared to insulin obtained from the pancreas of animals. - The ethical concerns of vegetarians or religious groups can be overcome. For example, vegetarians will object to the use of insulin obtained from animals.
Restriction enzyme and sticky ends	**Restriction Enzyme and Sticky Ends** To understand how a gene-of-interest can be transferred from one organism to another, we need to know what enzymes are involved and how these enzymes work (Figure 14.12). **1** A gene is a segment in the DNA molecule. On each side of the gene is a segment called the **restriction site**. **2** An enzyme called **restriction enzyme** can recognise and cut the restriction site to produce **sticky ends**. **3** DNA strands from two different organisms are cut by the same restriction enzyme to produce complementary sticky ends. **4** DNA fragments from two different sources are mixed together with an enzyme called **DNA ligase**. **5** The two different DNA fragments will bind together by complementary base pairing. They are then sealed together by the DNA ligase to form *recombinant DNA*.

Considerations surrounding genetic engineering

<table>
<tr>
<td>Applications of Genetic Engineering

“O level syllabus”</td>
<td>
Table 14.1 Benefits of genetic engineering
<table>
<tr><th>Applications of Genetic Engineering</th><th>Benefits to Society</th></tr>
<tr><td>Low-cost production of medicines</td><td>Genetic engineering of important drugs such as human insulin has drastically reduced the cost of these medicines. With these drugs becoming more affordable, more patients can get access to them and be treated.</td></tr>
<tr><td>Production of crops that grow in extreme conditions, for example:
• drought-resistant crops
• salt-tolerant crops
• crops that make more efficient use of nutrients</td><td>This allows farmers to grow crops even when the environmental conditions are not suitable for cultivating most crops.</td></tr>
<tr><td>Development of:
• crops that produce toxins that kill insect pests
• pesticide-resistant crops</td><td>The use of costly pesticides that may damage the environment is reduced. For example, the Bt gene from a certain bacterium can be inserted into plants to produce a toxin that kills certain insect pests.</td></tr>
<tr><td>Development of foods designed to meet specific nutritional goals</td><td>This has improved the nutritional quality of foods. For example, two genes from daffodil and one gene from the bacterium Erwinia uredovora inserted into rice plants produce ‘Golden Rice’. The rice grains have high vitamin A content.</td></tr>
</table>

Applications of genetic engineering
- Bt toxin gene from bacteria inserted into corn plant cells to produce pest-resistant crops
- Human insulin gene inserted into bacterium E. coli for large-scale low-cost production of insulin
- Two genes from daffodil and one gene from bacterium Erwinia uredarora inserted into rice plant cells to produce Golden Rice with high vitamin A content

</td>
</tr>
<tr>
<td>Implications of Genetic Engineering

“O level syllabus”</td>
<td>
- Genetic engineering may lead to class distinctions. Only individuals with sufficient financial means can afford to use gene technologies.
- Vegetarians are against genetic engineering. It exploits animals as animal genes are being inserted into plant cells.
- Some religions do not approve of genetic engineering as it is not appropriate to alter the genetic make-up of organisms and ‘play God’.
- New proteins in genetically modified food might cause allergies in humans that consume them.
- Modifying a single gene in plants may result in alteration of processes which lead to the production of toxins. Consumption of these plants or products made from these plants can pose serious health problems.
</td>
</tr>
</table>

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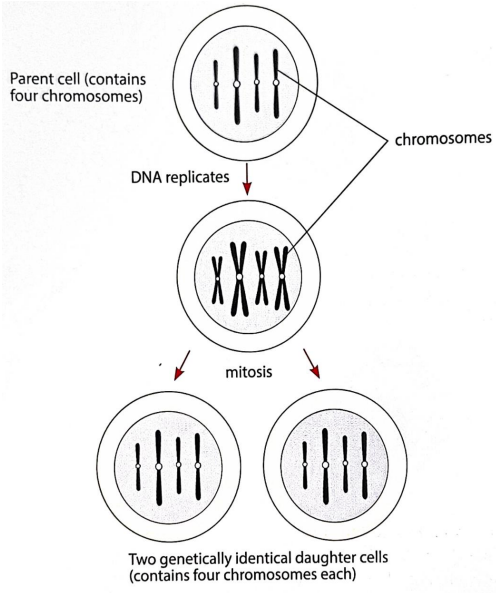
Chapter 15: Modes of Reproduction

O level syllabus

- define asexual reproduction as the process resulting in the production of genetically identical offspring from one parent
- state that mitosis is a type of cell division giving rise to genetically identical cells in which the chromosome number is maintained
- state the importance of mitosis in growth, repair and asexual reproduction
- define sexual reproduction as the process involving the fusion of nuclei of male and female gametes to form a zygote and the production of genetically dissimilar offspring
- define the terms haploid and diploid, and explain the need for a reduction division process prior to fertilisation in sexual reproduction
- state what is meant by homologous pairs of chromosomes
- state that meiosis is a type of cell division that gives rise to genetically dissimilar cells in which the chromosome number is halved due to the separation of homologous chromosomes
- state that meiosis is used in the formation of gametes

Asexual Reproduction + Mitosis

What is asexual reproduction? "O-level Syllabus"	*Definition* Asexual reproduction is the process that results in the production of genetically identical offspring from one parent, without the fusion of gametes
What is Mitosis? "O-level Syllabus"	Asexual reproduction involves mitosis, offspring produced asexually are genetically identical to the parent *Definition* Mitosis is a type of cell division giving rise to genetically identical cells in which the chromosome number is maintained. (start with 4 chromosomes in parent cell, end with 4 chromosomes in all cells)  **Figure 15.1** Mitosis results in two identical daughter cells.

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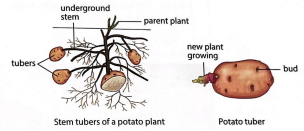
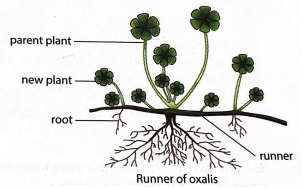
<table>
<tr><td>Importance of mitosis

“O-level Syllabus”</td><td colspan="2">1) Beneficial for <u>asexual reproduction</u>
- especially in plants as it causes shoots and roots to develop in storage organs, rhizomes, and bulbs.
2) Beneficial for the <u>growth of an organism</u>
- For multicellular organisms to grow, new cells are produced with mitosis.
3) Beneficial for <u>repair</u>
- Helps to heal wounds
- New cells are produced by miosis to replace cells/tissues that are dead or damaged</td></tr>
<tr><td rowspan="3">Examples of asexual reproduction</td><td>Stem Tuber

The swollen end of an underground stem. It has many buds. Buds will use up the food stored in the tuber to grow into new plants. There will be as many new plants as buds. Potato tubers are stem tubers.</td><td> 
</td></tr>
<tr><td>Rhizome

Underground storage stem, bears scale leaves and buds. Each bud can grow into a new plant</td><td> 
</td></tr>
<tr><td>Runner

Slender shoot that arises from a bud in the parent plant, it grows horizontally over the surface of the soil. Bud develops along its length. Each bud develops roots and leaves, and becomes a new plant</td><td> 
</td></tr>
<tr><td>Advantages and Disadvantages of Asexual Reproduction</td><td colspan="2">Table 15.1 Advantages and disadvantages of asexual reproduction

Advantages
• Only one parent is required.
• Fusion of gametes is not required.
• All the beneficial qualities are passed on to the offspring.
• This method of producing offspring is faster than sexual reproduction.

Disadvantages
• There is no genetic variation in offspring. Hence, species are not well-adapted to changes in the environment. For example, if the parent does not have resistance to a particular disease, the offspring too would not have resistance to the disease. This means that the whole population of plants could be wiped out by a particular disease.</td></tr>
</table>

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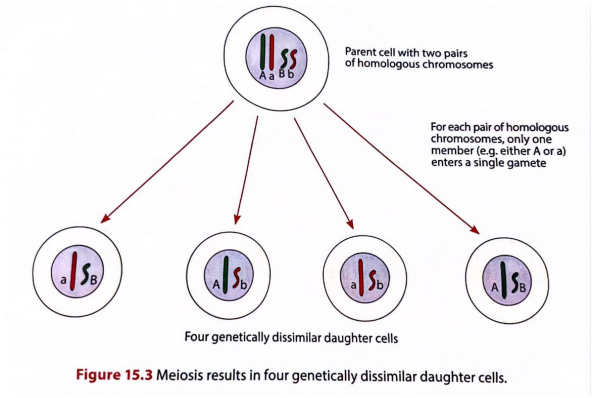
Sexual Reproduction + Meiosis

What is Sexual Reproduction? "O-level Syllabus"	*Definition* Sexual reproduction is a process involving the fusion of two gametes to form a zygote. It produces genetically dissimilar offspring.
	In humans… - Sperm is the male gamete - Egg is the female gamete - Gametes contain half the number of chromosomes as normal body cells
What is Meiosis? "O-level Syllabus"	During meiosis, the parent cell divides to produce four daughter cells that are genetically dissimilar. Meiosis is a reduction division; each gamete contains half the number of chromosomes as the parent cell. *Definition* Meiosis is a type of cell division that gives rise to genetically dissimilar cells in which the chromosome number is halved due to the separation of homologous chromosomes. It is used in the formation of gametes.  **Figure 15.3** Meiosis results in four genetically dissimilar daughter cells.
What are homologous pairs of chromosomes? "O-level Syllabus"	A pair of chromosomes of which one is paternal, and the other maternal in origin. (one chromosome from female, one from male) They are of same shape and length, same centromere position and contain similar genes at specific loci.

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<table>
<tr><td>Haploid V.S. Diploid

“O-level Syllabus”</td><td>- Haploid cell is a cell with one set of chromosomes (half the complete number of chromosomes) [e.g. sex cells]
- Diploid cell is a cell with two sets of chromosomes (complete number of chromosomes) → one from male parent and the other from female parent [e.g. all cells in our body except sex cells, zygote]

 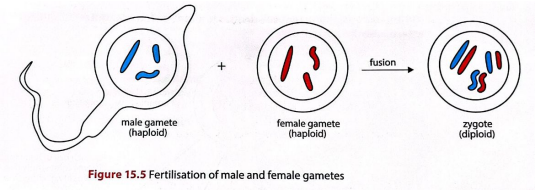

Figure 15.5 Fertilisation of male and female gametes</td></tr>
<tr><td rowspan="2">Why is Meiosis important?

“O-level Syllabus”</td><td>Meiosis produces <u>haploid gamete → reduction division</u>

(Background information)
Reduction division is the form of nuclear division such that the daughter cells produced contain half the number of chromosomes as the parent cells (haploid number). It takes place in the reproductive organs of an organism to form gametes (sex cells) which will fuse to form a zygote during fertilization in sexual reproduction.

During meiosis, each pair of homologous chromosomes in the parent nucleus separates to form daughter cells. Each daughter cell only receives one copy of the homologous chromosomes (haploid number). During fertilisation, the nucleus of the male and female gamete fuses and normal diploid number of chromosomes is restored in the zygote.</td></tr>
<tr><td>Meiosis produces gametes that are genetically dissimilar

The greater the genetic variation, the better the species is adapted to changes in the environment. (If organisms of the same species are varied, it is unlikely that a change in the environment will destroy the whole species. Those that survive will pass on their favourable genes to their offspring)</td></tr>
<tr><td>Advantages and Disadvantages of Sexual Reproduction</td><td>Table 15.2 Advantages and disadvantages of sexual reproduction
<table><tr><th>Advantages</th><th>Disadvantages</th></tr><tr><td>• Offspring may inherit beneficial qualities from both parents.
• There is genetic variation in the offspring that is better adapted to changes in the environment.</td><td>• Two parents are required (except in plants with bisexual flowers).
• Fusion of gametes is required.
• This method of producing offspring is slower than asexual reproduction.</td></tr></table></td></tr>
</table>

Asexual Reproduction V.S. Sexual Reproduction

Differences	**Table 15.3** Differences between asexual reproduction and sexual reproduction

Asexual Reproduction	Sexual Reproduction
Does not involve the fusion of gametes	Involves the fusion of a male gamete with a female gamete to form a zygote
Requires only one parent	Requires two parents (except for plants with bisexual flowers)
Offspring are genetically identical to the parent	Offspring are genetically dissimilar to the parent
Relatively quicker method of producing offspring	Slower method of producing offspring

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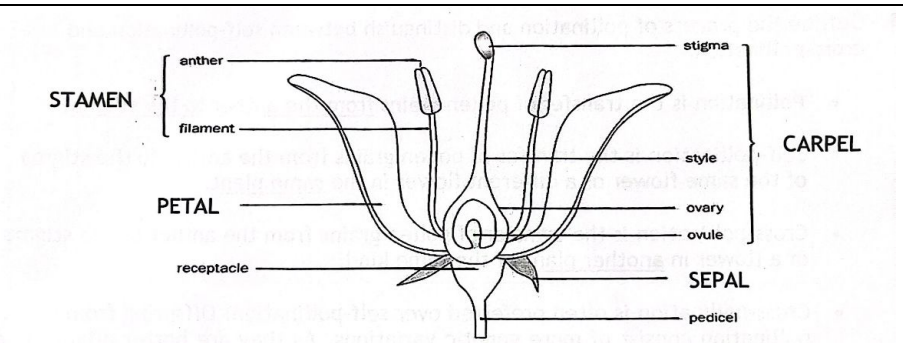
Chapter 16: Reproduction in Plants

O level syllabus

- identify, using a hand lens if necessary, the sepals, petals, stamens and carpels of insect-pollinated, dicotyledonous flowers, and examine the pollen grains under a light microscope
- state the functions of the sepals, petals, anthers and carpels
- identify, using a hand lens if necessary, the stamens and stigmas of wind-pollinated flowers, and examine the pollen grains under a light microscope
- outline the process of pollination and distinguish between self-pollination and cross-pollination
- compare, using fresh specimens, an insect-pollinated and a wind-pollinated flower and explain their differences
- outline the growth of the pollen tube and its entry into the ovule followed by fertilisation (production of endosperm and details of development are not required)

Parts of a Flower

Different parts in a flower 'O level syllabus'	
Function of general parts of the flower 'O level syllabus'	1) *Petal (for insect pollinated flowers)* - Brightly coloured to attract insects for pollination - Provide a platform for insects to land on - Lines that guide insects to the base of the petals to obtain nectar (nectar guide) 2) *Sepal* - Modified leaves - Enclose and protect other parts of the flower in the bud stage - Form the outermost layer of floral leaves 3) *Flower Stalk / Pedicel* - Attaches flower to the stem - Some flowers do not have stalks and are attached to the plant directly at the base 4) *Receptacle* - Swollen end of the flower stalk - base of the flower where the other parts of the flower are attached

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Function of Female Reproductive parts (Carpel) 'O level syllabus'	1) *Stigma* - Swollen structure at the end of the style - Receives pollen grains - Secretes sugary fluid that stimulates pollen grains to germinate 2) *Style* - Connects the stigma to the ovary - Holds the stigma in a suitable/good position to trap pollen grains 3) *Ovary* - Contains one or more ovules 4) *Ovules* - Becomes a seed after fertilisation - Contains ovum and definitive nucleus - An ovum = a female gamete or egg cell. The ovum is produced by meiosis, thus haploid
Functions of Male Reproductive parts (Stamen) 'O level syllabus'	1) *Filament* - Holds the anther in a suitable/good position to disperse pollen grains - Contains the vascular bundle (xylem + phloem) 2) *Anther* - Stores and produces pollen grains (each contain a male gamete) - When the anther matures, it splits open to release the pollen grains - (Pollen Grains) → contains male gamete which are produced by meiosis and are haploid (have half the number of chromosomes as a normal cell)

Pollination

What is pollination?	Pollination is the transfer of pollen grains from the anther to the stigma.
Self-pollination V.S. Cross-pollination 'O level syllabus'	*Self-pollination* - Self-pollination is the transfer of pollen grains from the anther to the sigma of the same flower or of a different flower on the same plant - Occurs when … 1) Bisexual flowers, both male and female parts (anther and stigma) mature at same time 2) Flower do not open, which only allows self-pollination to occur 3) The stigma is situated directly below the anther **Table 16.1** Advantages and disadvantages of self-pollination **Advantages** • Only one plant is required. • The offspring inherits its genes from the parent plant after fertilisation. Hence, beneficial qualities are more likely to be passed down to the offspring. • It does not need to depend on external factors such as insects or wind for pollination. • Since the anthers are close to the stigmas of the same flower, there is a higher probability that pollination will occur, as compared to cross-pollination. • Less pollen and energy are wasted in self-pollination as compared to cross-pollination. **Disadvantages** • Should fertilisation occur, there will be less genetic variation in the offspring as compared to cross-pollination. The species is less well-adapted to changes in the environment. • Continued self-pollination may lead to the offspring becoming weaker, smaller and less resistant to diseases. - TO NOTE: Self-pollination is NOT asexual reproduction. It involves fertilisation = it is sexual reproduction, hence there is still genetic variation, just lesser variation than cross-pollination

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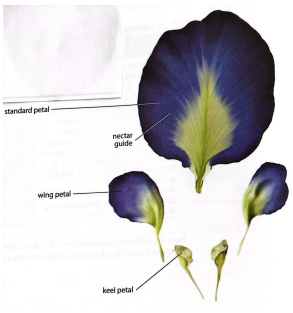
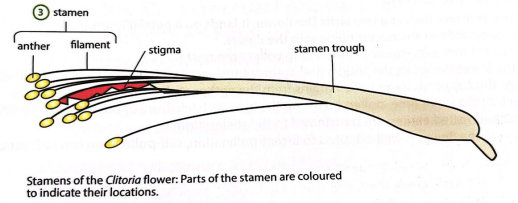
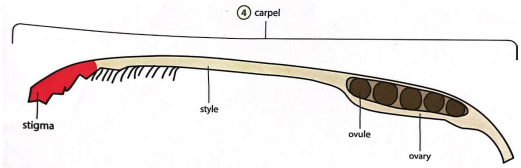
Cross-pollination

- Cross-pollination is the transfer of pollen grains from the anther of one plant to the stigma of a flower in another plant of the same species

- Occurs when…
  1) Male or female parts mature at different timings/flowers only either have male or female parts
  2) Flowers are open
  3) Anther is hanging lower than/situated further from the stigma
  4) A barrier is present between the anthers and stigmas in the same plant
  5) Pollen grains of a flower have no fertilising effect on the stigmas of the same plant

Table 16.2 Advantages and disadvantages of cross-pollination

Advantages	Disadvantages
• The offspring produced may have inherited beneficial qualities from both parents. • Should fertilisation occur, there will be greater genetic variation in the offspring produced as compared to self-pollination. This increases the chance of the species surviving changes in the environment because any change in the environment is less likely to destroy all the varieties *in* a species. • More viable seeds are produced. Such seeds are capable of surviving longer before germination.	• Two plants are required. • It depends on external factors such as insects or wind for pollination. • Since the pollen grains have to be transferred from the anther of one plant to the stigma of another plant, there is a lower probability that pollination will occur, as compared to self-pollination. • More energy and pollen are wasted as compared to self-pollination.

Insect-pollinated flower V.S. Wind-pollinated flower 'O level syllabus'	*Insect-pollinated flower* <u>Structure</u> 1) Flower has brightly coloured petals of different sizes and shapes → The large, coloured petals have lines in it that guide insects to where nectar is located (nectar guides).  2) The flower has stamen with long filaments. Nectar will be collected at the bottom of the stamen thus insects need a long tubular mouth or proboscis to reach the nectar  Stamens of the *Clitoria* flower: Parts of the stamen are coloured to indicate their locations. 3) The carpel consists of a stigma that is small and compact, a style that has a long, curved and hairy structure, and ovary that is long and narrow with a single row of ovules  Carpel of the *Clitoria* flower: Parts of the carpel are coloured to indicate their locations. <u>How is works</u> (1) When an insect (e.g. bee) visits the flower, it lands on the petal (2) The insect follows the nectar guide into the flower (3) The insect forces its way and moves in to collect the nectar (4) As the insect moves in, the stigma and anthers brush against the hair back of the insect. When this happens, some pollen grains from the anther stick to the hair back of the insect. As the same time, pollen grains on the insect's back (from another flower which the insect had visited before) are transferred to the sticky stigma (5) Although the flower is well-adapted to insect-pollination, self-pollination can still occur

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Wind-pollinated flower

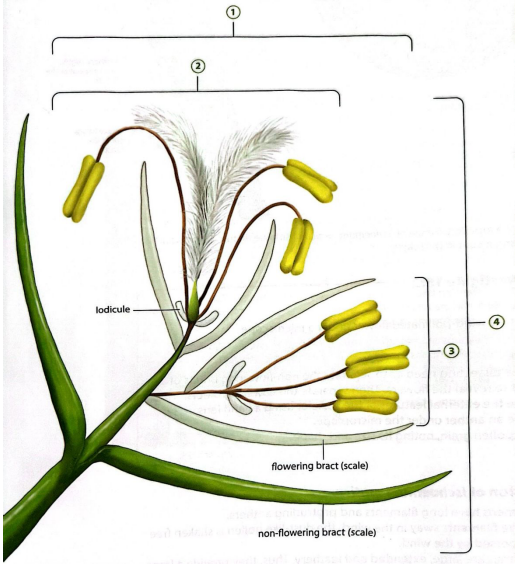
Structure

1) The flowers are in pairs. Each flower is enclosed by two transparent flowering bracts

2) Upper flower is bisexual. It consists of an ovary with two long feathery stigmas, the stamens and two tiny structures called lodicules at the base of the ovary. When flower is ready to reproduce, the lodicules swell and force the two flowering bracts slightly apart. This allows the stigma and anthers to emerge

3) Lower flower is unisexual. Consists of three stamens with long filaments and two lodicules

4) Each pair of flowers, together with a short stalk, forms a spikelet. At the base of each spikelet is a pair of empty or non-flowering bracts → they protect the two flowers in the spikelet



How it works

(1) The stamen have long filaments and protruding anthers

(2) When the filaments sway in the wind, the dust-like pollen is shaken free and dispersed by the wind

(3) The stigmas are large, extended and feathery. Thus, they provide a large surface area to receive any pollen that is floating around in the wind.

Feature	Insect-pollinated	Wind-pollinated
Petals	Large and brightly-coloured petals	Small, dull-coloured and without petals
Nectar	Present	Absent
Scent	Fragrant or sweet-smelling flowers	Odourless flowers
Stigmas	Small, compact and do not protrude from the flower	Large, feathery and protrude from the flower
Stamens	Non-pendulous and do not protrude from the flower	Long, pendulous filaments and protruding anthers
Pollen	Fairly abundant	More abundant
Pollen grains	Large with rough surfaces	Small, light with smooth surfaces
Nectar guide	Present	Absent

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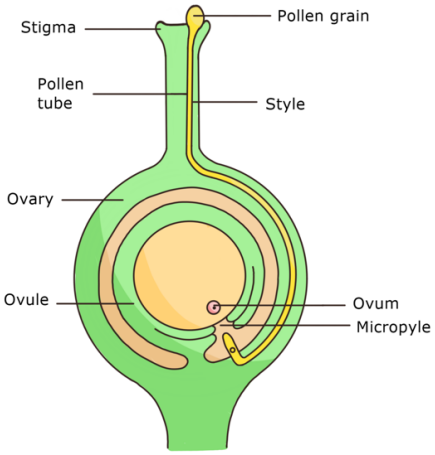
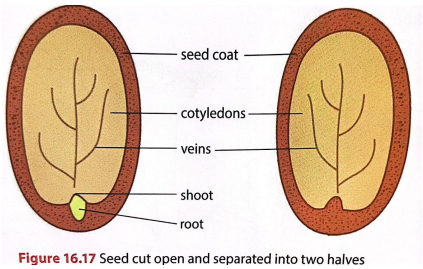
Fertilisation

What is fertilisation?	The fusion of male and female sex nuclei, resulting in a diploid zygote.
The fertilisation process 'O level syllabus'	1) After pollination, the mature stigma secretes a mature stigma. The pollen grain would then germinate 2) A pollen tube would grow from each pollen grain, secreting enzymes to digest a path through stigma, style and ovary wall. 3) The pollen tube grows and enters an ovule through an opening in the ovule wall called the micropyle 4) Within the ovule, the tip of the pollen tube absorbs sap and bursts, releasing the male sex nucleus / male gamete 5) The nucleus of the male gamete fuses with the ovum to form a diploid zygote. This is fertilisation 6) After fertilisation, the zygote divides and develops into an embryo in the seed. This leads to the ovary developing into a fruit and the ovule into the seed. 
Post-fertilisation process	(1) The ovary becomes the fruit (2) The ovule becomes the seed (3) The zygote becomes the embryo  **Figure 16.17** Seed cut open and separated into two halves (4) The petals, the style and stigma, and the anthers wither and drop off (5) If fertilisation does not occur in an ovule, it degenerates when the ovary turns into a fruit (6) At least 1 ovule must be fertilised for the ovary to turn into a fruit

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Chapter 17: Reproduction in Humans

O Level syllabus

- identify the male reproductive system and state the functions of: testes, scrotum, sperm ducts, prostate gland, urethra and penis
- identify the female reproductive system and state the functions of: ovaries, oviducts, uterus, cervix and vagina
- outline the menstrual cycle with reference to the alternation of menstruation and ovulation, the natural variation in its length, and the fertile and infertile phases of the cycle with reference to the effects of progesterone and oestrogen only
- describe fertilisation and early development of the zygote simply in terms of the formation of a ball of cells which becomes implanted in the wall of the uterus
- state the functions of the amniotic sac and the amniotic fluid
- describe the function of the placenta and umbilical cord in relation to exchange of dissolved nutrients, gases and excretory products (structural details are not required)
- discuss the transmission of human immunodeficiency virus (HIV) and methods to reduce transmission

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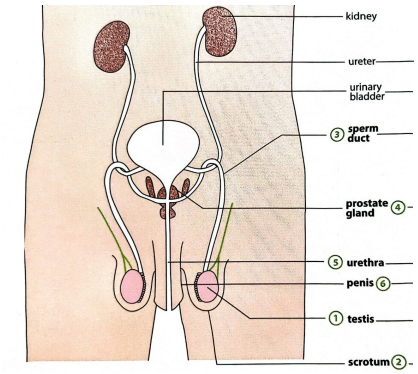
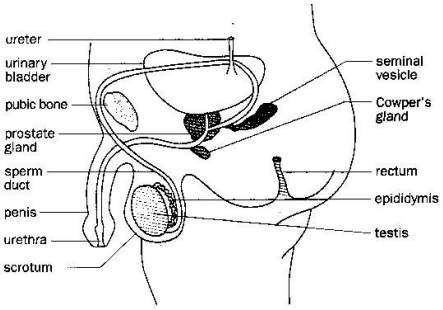
Reproductive Systems

Male reproductive system

'O Level Syllabus'





1) Testes (plural) / testis (singular)

→ Produces sperms and testosterone (male sex hormones, responsible for the development and maintenance of secondary sexual characteristics in males)

2) Scrotum

→ Testes lie in a pouch-like sac called the scrotum

→ Holds the testes outside the main body cavity to maintain the testes at a lower temperature than body temperature for proper sperm development (2°C for sperm production)

3) Sperm Duct

→ Transports sperms from the testes to the urethra

4) Prostate Gland

→ Base of the urinary bladder, where there two sperm ducts join the urethra

→ Produces a fluid (semen) that contains nutrients and enzymes to…

(a) nourish sperms (nutrients)

(b) activates sperm to swim actively (enzyme)

5) Urethra

→ A duct to transport semen from the sperm duct to outside of the body

→ A duct to transport urine from the bladder to outside of the body

6) Penis

→ Male erectile organ (becomes erect and hard when the blood spaces are filled with blood)

→ Inserted into the vagina of the women during sexual intercourse to deposit semen containing sperms

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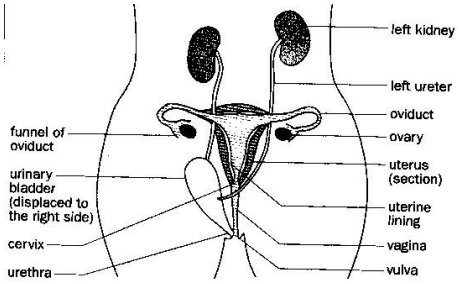
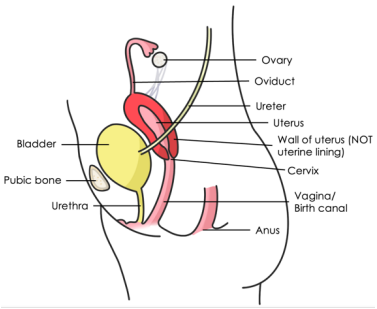
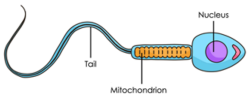
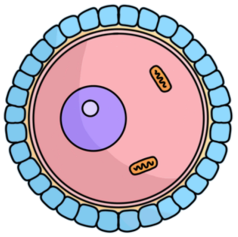
Female Reproductive System 'O Level Syllabus'	  *1) Ovary (singular) / Ovaries (plural)* → Produces ova (eggs) and is the site where they mature → Produces female sex hormones such as oestrogen and progesterone (responsible for the development and maintenance of the secondary sexual characteristics in females) *2) Oviduct* → Matured eggs are released into the oviduct → The site of fertilisation (Inner surface of the oviduct is lines with cilia. The movement of the cilia helps to move the egg along the oviduct) *3) Uterus* → The site of implantation of the embryo (uterine lining – the soft, smooth inner lining of the uterus) and the development of the fetus/foetus → Has elastic muscular walls with smooth muscle tissues that contract to push the fetus out during birth *4) Cervix* → ring of muscle that serves as an opening between the uterus and the vagina (allows menstrual blood to pass from the uterus to vagina, allows sperm from vagina to enter uterus, allows fetus to pass during birth from uterus to vagina) 5) Vagina → Site of deposit of semen containing sperms during sexual intercourse → Leads from the cervix to the outside

Male gamete V.S. Female gamete (Optional)	

Table 17.1 Male and female gametes

Feature	Male Gamete	Female Gamete
Structure	• Has a head, a middle piece and a tail • Nucleus contains either X or Y chromosome • About 60 µm long with a diameter of 2.5 µm for the head	• Spherical in shape • Nucleus has one X chromosome • Diameter of 120 µm to 150 µm
Motility	• Has a tail that enables it to swim towards the oviduct	• Passive movement of egg along the oviduct is due to the movement of cilia along the oviduct and peristalsis of the oviduct wall.
Numbers	• A large number of sperm is released per ejaculation.	• Only one egg is released per month. Both ovaries together produce about 500 mature eggs.





Done by MF (completed in 2024)

Menstrual Cycle

<table>
<tr><td>Puberty</td><td>The stage where a person becomes physically mature and capable of sexual reproduction.

Secondary sexual characteristics appear due to sex hormones (testosterone in males, oestrogen + progesterone in females):

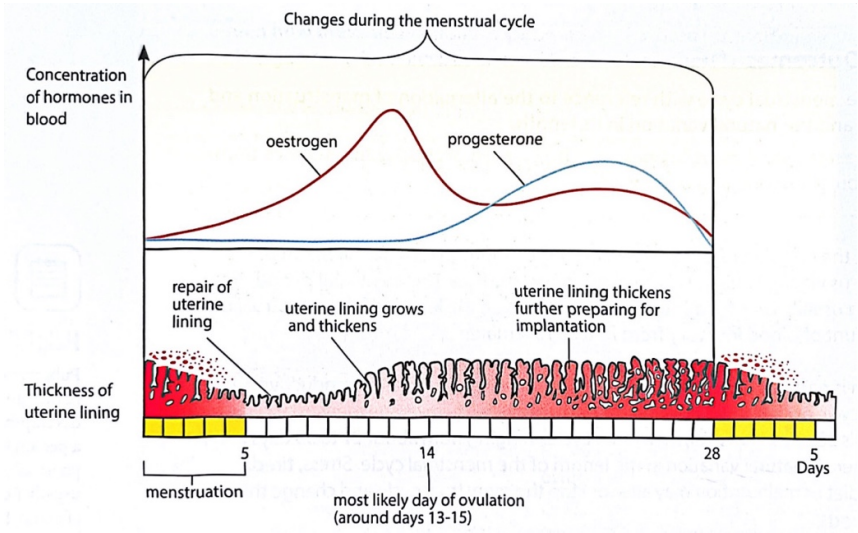
- Sexual organs enlarge, and the person begins to produce gametes
- In females, menstrual cycles begin
- Pubic and armpit hair appears
- Includes other physical changes, e.g. Voice deepening in men, hips broaden in women.</td></tr>
<tr><td>Menopause</td><td>As a female ages, the ovaries will eventually stop releasing eggs and the menstrual cycle will stop. This is menopause, it takes place between 45 and 55 years of age.</td></tr>
<tr><td>Menstrual Cycle

‘O Level Syllabus’</td><td>Typical menstrual cycle lasts for about 28 days, but it varies. It could vary more or stop completely if the person is experiencing high stress/poor diet/poor sleep, etc.

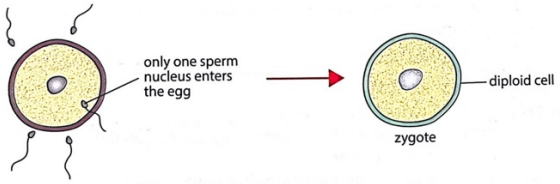
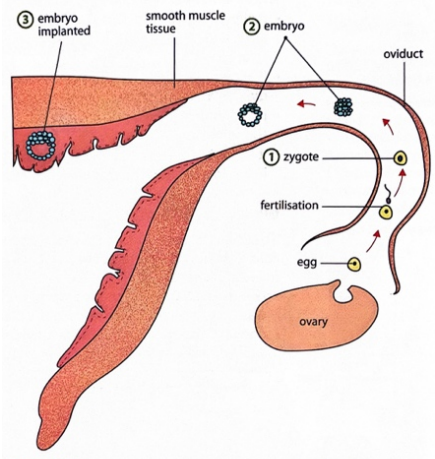
<table>
<tr><th>Day</th><th>Stage</th><th>What happens?</th></tr>
<tr><td>1-5</td><td>Menstruation (infertile)</td><td>The uterine lining and unfertilised egg break down and are shed with some blood (This is due to the decrease in progesterone levels)</td></tr>
<tr><td>6-13</td><td>Repair + Growth of endometrium (infertile)</td><td>The ovary produces oestrogen. This causes the repair and growth of the uterine lining. Uterine lining becomes thick and spongy with blood vessels (High oestrogen levels leads to ovulation)</td></tr>
<tr><td>10-15</td><td>Ovulation (fertile period)</td><td>Ovulation occurs at about the 14th day, where one ovary releases a mature ovum into the oviduct.
(Egg survives up to 1 day unless fertilised, whereas sperms survives up to 4 days. Therefore sexual intercourse during this period has highest chance of pregnancy.)</td></tr>
<tr><td>15-28</td><td>Growth + Maintenance (infertile)</td><td>Progesterone levels increases, thus uterine lining thickens further and more blood vessels grow within in to prepare for implantation

Nearing the end of the menstrual cycle, oestrogen and progesterone levels fall, causing the uterine lining to shed, starting the next menstrual cycle</td></tr>
</table>
</td></tr>
</table>

Done by MF (completed in 2024)

Hormone + Uterine lining graph	
Role of hormones	1) Oestrogen → Stimulates repair and thickening of uterine lining → Inhibits another ovulation during second half of the menstrual cycle (progesterone has a higher responsibility) 2) Progesterone → Maintains thickness and stimulates further thickening of uterine lining → Stimulates growth of more blood vessels in uterine lining → Inhibits another ovulation during second half of the menstrual cycle
What happens if fertilisation occurs?	- The fertilised egg becomes a zygote. The zygote develops into an embryo - The ovary secretes progesterone and oestrogen. This causes the maintenance and thickening of uterine lining for the implantation of the embryo. - The embryo embeds itself in the uterine lining until a structure called the placenta is formed. - The ovary continues to secrete progesterone and oestrogen until the placenta is able to take over the production of the two hormones.

Fertilisation

Build up to fertilisation	When a male is sexually aroused, blood is pumped into the penis faster than it can return to the bloodstream via the veins. Blood thus fills the spaces in the spongy tissues of the penis. The penis erects and becomes stiff to allow it to enter the vagina of a female. Semen containing sperm is then ejaculated into the vagina, along with a liquid made by the prostate gland. The sperm swims up the oviducts of the female in this liquid. The sperm tails helps to propel the sperm along the oviducts. Millions of sperm are released into the vagina during one ejaculation, but only one of these will fertilise the egg.
Fertilisation 'O Level Syllabus'	Fertilisation is the fusion of the nucleus of the sperm and the nucleus of the egg to produce a zygote. The process of fertilisation is shown in Figure 17.9. ① Only one sperm nucleus enters the egg. The sperm nucleus fuses with the egg nucleus, and a fertilised egg or zygote is formed. This process is known as *fertilisation*. ② As soon as the sperm has entered the egg, no other sperm can enter. The remaining sperm, which do not fertilise the egg, eventually die.  **Figure 17.9** Fertilisation
Early development of the zygote / implantation 'O Level Syllabus'	1. The zygote travels towards the uterus. This is with the help of the cilia lining the inner surface of the oviduct sweep the zygote along the oviduct. The peristaltic movements of the oviduct walls also helps to move the zygote to the uterus. 2. The zygote divides by mitosis to form a ball of cells which later becomes the embryo. 3. The embryo reaches the uterus 5 days after fertilisation, floating around for 2 days after. On Day 7, the embryo embeds itself into uterine lining during implantation. 4. The placenta, amniotic sac and foetus then develops 

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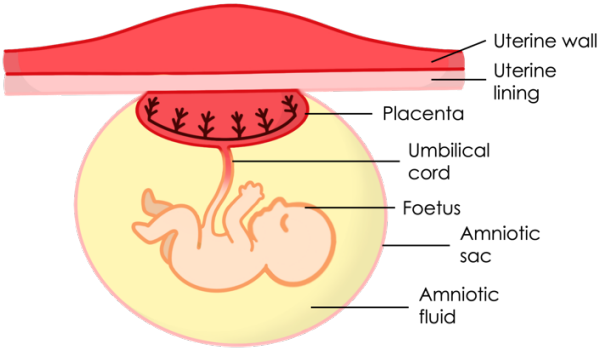
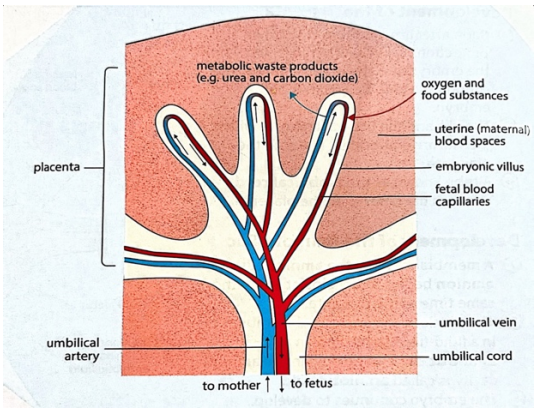
Foetal development 'O Level Syllabus'	 *Placenta* - After implantation, finger-like projections called the villi, containing blood vessels from the embryo, begins to grow from the embryo into the uterine lining. (The villi and the uterine lining make up the placenta) - The placenta has a few functions… → Placenta secretes progesterone to maintain thickness of the uterine lining, supporting pregnancy (secretes some oestrogen as well) → It allows oxygen and nutrients (dissolved food substances) like glucose, amino acids and mineral salts to diffuse from the maternal capillaries to the foetal capillaries → It allows metabolic waste produces such as urea and carbon dioxide to diffuse from the foetal capillaries to the maternal capillaries → It allows some antibodies to diffuse from the maternal to foetal capillaries, providing the foetus immunity against some diseases *Umbilical Cord* - Attaches the fetus to the placenta. It contains the blood vessels of the fetus - The umbilical cord has a few functions… → Contains two umbilical arteries that transports deoxygenated blood and metabolic waste products such as urea and carbon dioxide from the fetus to the placenta → Contains one umbilical vein that transports oxygenated blood and food substances like glucose and amino acids from the placenta to the fetus 

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	Amniotic Sac ("water bag") - This membrane begins to develop at about the same time as the placenta - The amniotic sav encloses the embryo in a fluid-filled space known as the amniotic cavity. The fluid in the amniotic cavity is called amniotic fluid *Amniotic Fluid* - The amniotic fluid has a few functions… → Supports and cushions the foetus before birth, serve as a shock absorber → Protects the fetus against mechanical injury as it is incompressible → Allows the fetus for some degree of movement, promoting muscular development → Lubricates and reduces friction during birth
Separation of Fetal blood system and Maternal blood system	The fetal blood capillaries are separated from the maternal blood system by only a thin layer of tissue. Diffusion of dissolved substances can occur across this layer of tissue. This may result in pathogens and toxins that are present in the maternal bloodstream to pass across the placenta and affect the fetus. The 2 blood systems are not continuous because… - The blood pressure of the mother would kill the fetus as it is much higher than that of the fetus - The blood group of the fetus may not be the same as the mother's. If the fetus and the mother have different blood groups and the two blood systems are allowed to mix, antibodies in the mother's blood may cause the fetal blood cells to agglutinate. This would be dangerous to both mother and fetus - This prevents potential harmful substances or pathogens from directly entering the fetal bloodstream.
Development of fetal	Sperm + Egg → Zygote → Embryo → Fetus

Human Immunodeficiency Virus (HIV)

Sexually transmitted infection (STI)	STIs are diseases that are spread or transmitted through sexual intercourse They can be transmitted by… 1. Through semen when it comes into contact with the mucous membrane in the vagina 2. Through fluid in the vagina when it comes into contact with the mucous membrane of the urethra 3. When blood of an infected person gets into the bloodstream of an uninfected person
Human Immunodeficiency Virus (HIV) 'O Level Syllabus'	- HIV is an STI - HIV may develop into AIDS in the later stages - Normally when foreign particles like bacteria or viruses enter our bloodstream, our white blood cells (lymphocytes) are able to identify them, The white blood cells are then stimulated to produce antibodies to destroy the bacteria and viruses. - But HIV destroys the white blood cells and causing the decrease in number. The body is thus unable to produce enough antibodies to protect the person against many other diseases. - How is HIV transmitted? → Unprotected sexual intercourse with an infected individual → Sharing of hypodermic needles with an infected person (needles that go through skin) → Through blood transfusion with blood from an infected person → Passed from mother to foetus during pregnancy - HIV can be prevented and controlled through… → Keeping to one sexual partner who is unaffected or abstain from having sexual intercourse → Males should wear a condom (physical barrier to prevent transmission) → Do not share instruments that are likely to break the skin and be contaminated with blood → Do not share needles or sterilise needles whenever used
Acquired Immune Deficiency Syndrome (AIDS)	Signs and symptoms of AIDS 1) Pneumonia (inflames the air sacs in one or both lungs) 2) Brain infection 3) Chronic or persistent fever 4) Widespread tuberculosis (a lung disease affecting many organs at the same time) 5) Severe diarrhoea lasting for months 6) Kaposi's sarcoma (cancer of blood vessels)

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Chapter 18: Inheritance

O level syllabus

- distinguish between the terms gene and allele
- explain the terms dominant, recessive, codominant, homozygous, heterozygous, phenotype and genotype
- predict the results of simple crosses with expected ratios of 3:1 and 1:1, using the terms homozygous, heterozygous, F1 generation and F2 generation
- explain why observed ratios often differ from expected ratios, especially when there are small numbers of progeny
- use genetic diagrams to solve problems involving monohybrid inheritance
- explain co-dominance and multiple alleles with reference to the inheritance of the ABO blood group phenotypes (A, B, AB, O) and the gene alleles (I^A, I^B and I^O)
- describe the determination of sex in humans – XX and XY chromosomes
- describe mutation as a change in the sequence of a gene such as in sickle cell anaemia, or in the chromosome number, such as the 47 chromosomes in the condition known as Down syndrome
- name ionising radiation (e.g. X-ray) and chemical mutagens as factors which may increase the rate of mutation
- distinguish between continuous and discontinuous variation and give examples of each
- state that variation and competition lead to differential survival of, and reproduction by, those organisms best fitted to the environment
- give examples of environmental factors that act as forces of natural selection
- explain the role of natural selection as a possible mechanism for evolution which is a gradual change in the inheritable characteristics of a population over time

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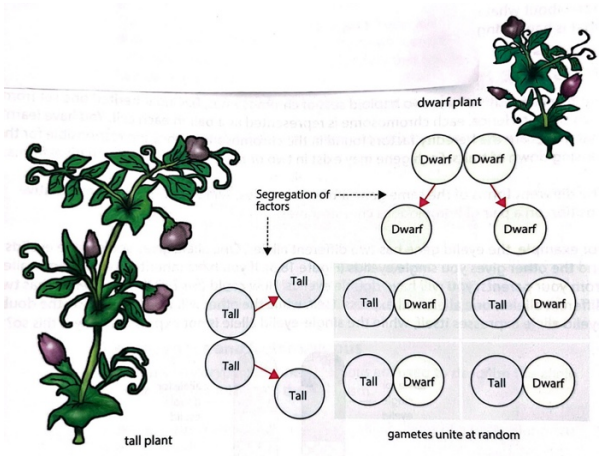
Mechanism of Inheritance

What is inheritance?	Inheritance refers to the transmission of traits form one generation to another.
Observed ratio V.S. Expected ratio "O level syllabus"	The observed ratio is based on chance and probabilities due to the random nature of fertilisation. Hence, the actual number of offspring would be unlikely to match the expected ratio precisely. (e.g. If the ratio of male : female is 1 : 1 $\neq$ second child will be female if first child is male)

Heredity Factors

Heredity Factors = Genes "O level syllabus"	Genes is a sequence of DNA nucleotides that controls the formation of a single polypeptide. (definition for molecular genetics) It is also a unit of inheritance (definition for inheritance)
Dominant V.S. Recessive	Each characteristic is controlled by a pair of factors in the cells of an organism. If factors differ only the dominant one will show its effect. The fusion of gametes at fertilisation restores the diploid condition in the zygote. Thus, the zygote contains two factors (one factor from each parent) for a particular characteristic. Gametes unite at random so that the ratio of characteristics among the offspring can be predicted 

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Alleles

<table>
<tr><td>What are alleles?

“O level syllabus”</td><td>Alleles are an alternative form of a gene.</td></tr>
<tr><td>Examples of alleles</td><td>The eyelid gene has two different alleles → double eyelids & single eyelids

If a person has two different alleles, the allele that expresses itself is called the dominant allele, while the other is called the recessive allele. The double-eyelid allele is dominant.</td></tr>
<tr><td>Recessive allele

“O level syllabus”</td><td>DEFINITION (weaker, usually gets masked)

A form of a gene that expresses itself only in the homozygous condition</td></tr>
<tr><td>Dominant allele

“O level syllabus”</td><td>DEFINITION (stronger)

A form of a gene that expresses itself and give the same phenotype in both homozygous and heterozygous conditions</td></tr>
<tr><td>Can a recessive gene express itself?</td><td>The person must have two alleles for single eyelid to have single eyelid.
<table><tr><td>Genotype</td><td>Phenotype</td></tr><tr><td>DD</td><td>Double Eyelids</td></tr><tr><td>Dd</td><td>Double Eyelids</td></tr><tr><td>dd</td><td>Single Eyelids</td></tr></table></td></tr>
<tr><td>Genotype

“O level syllabus”</td><td>DEFINITION (type of gene)

Genetic combination in an individual (combination of alleles)</td></tr>
<tr><td>Phenotype

“O level syllabus”</td><td>DEFINITION (type of physical trait)

Expressed outward appearance of a trait</td></tr>
<tr><td>Homozygous

“O level syllabus”</td><td>DEFINITION (Homo = one, so one type of allele)

An individual who has identical alleles for a particular trait</td></tr>
<tr><td>Heterozygous

“O level syllabus”</td><td>DEFINITION (Heter = contains different, so have different types of alleles)

An individual who has non-identical alleles for a particular trait</td></tr>
</table>

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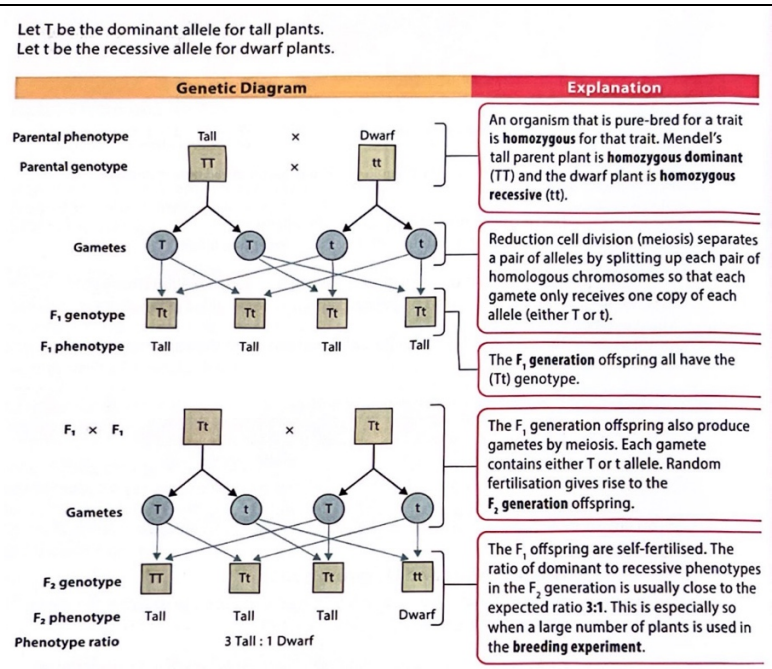
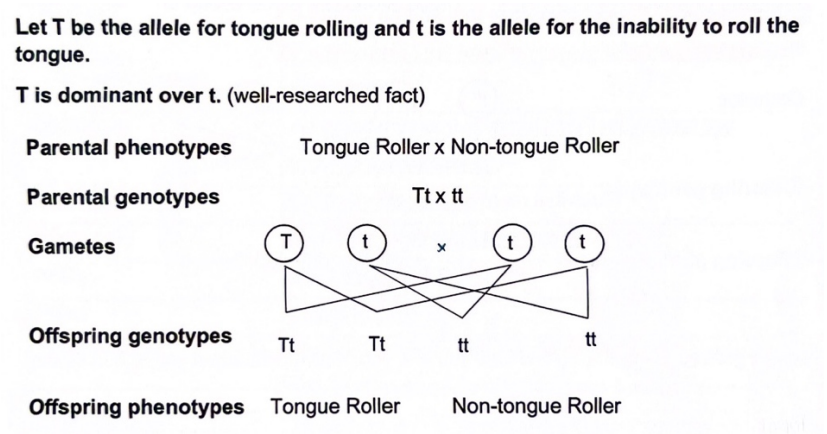
Genetic diagram

"O level syllabus"



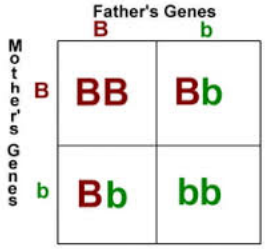
O level method (simplified)



Pointers

- Define terms if not known (don't need to define blood group only)
- Cross between 2 different parental phenotype, genotype and gametes (no need for offspring)
- Gametes need to circle
- Match the gametes
- "Offspring" can use "F1" and "F2" if drawing more than one generation
- Express the ratio only if question ask, if not don't need

Alternative (faster way, if just want the chances) – Punnett Square



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Incomplete dominance, Complete dominance, Codominance

Incomplete dominance	*DEFINITION* (removed from syllabus, potential only coming out in school exams) When both alleles in a heterozygous pairing exert their effects so that the offspring (hybrid) has a phenotype that is intermediate between that is found in the parents (e.g. Red flower + White flower → Pink flower)
Complete dominance	DEFINITION When one allele exerts its effects over the other allele and the offspring has a phenotype of the dominant alleles that is found between the parents.
Codominance "O level syllabus"	DEFINITION When both alleles in a heterozygous pairing are equally expressed. (e.g. Red petals + White petals → Red and white petals)

Blood Groups

What are multiple alleles	A gene that exists in more than two alleles
Alleles of blood groups "O level syllabus"	There are 4 alleles: I^A, I^B and I^O Blood Group / Genotype A / $I^A I^A$, $I^A I^O$ B / $I^B I^B$, $I^B I^O$ AB / $I^A I^B$ O / $I^O I^O$ I^A and I^B are codominant. I^O is recessive to both I^A and I^B.

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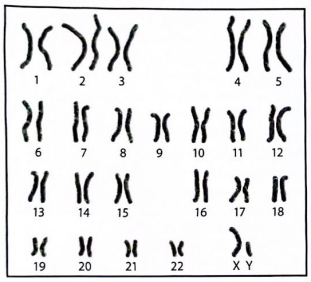
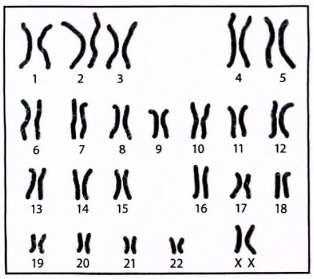
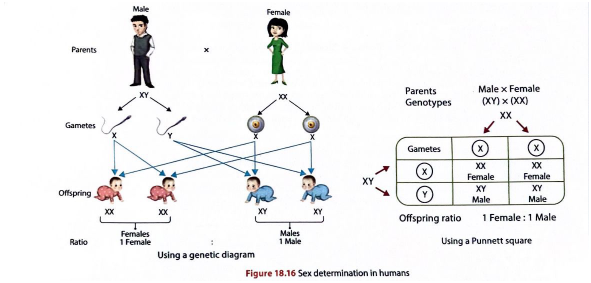
Sex

Chromosomes in male and Female "O level syllabus"	In a human body cell, there is one pair of sex chromosomes and 22 pairs of non-sex chromosomes. In male, the pair of sex chromosomes consists of one X chromosome and one shorter Y chromosome. Females have a pair of X chromosomes in each normal body cell.  **Figure 18.14** Chromosomes of a male  **Figure 18.15** Chromosomes of a female
Sex determination in humans	Random fertilisation will enable a couple to have equal chances of producing a boy or a girl.  **Figure 18.16** Sex determination in humans

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Variation

<table>
<tr><td>What is variation?</td><td>Variation refers to the differences in traits between individuals of the same species.</td></tr>
<tr><td>Discontinuous variation V.S. Continuous variation

“O level syllabus”</td><td>
<table>
<tr><th>Continuous variation</th><th>Discontinuous variation</th></tr>
<tr><td>A complete range of measurements from one extreme to another</td><td>Individuals fall into distinctive categories</td></tr>
<tr><td>Being affected by the environment</td><td>Largely unaffected by changes in the environment.</td></tr>
<tr><td>Many genes involved.</td><td>Being controlled by one or only a few genes.</td></tr>
<tr><td>Examples: height, weight and skin colour.</td><td>Examples: eye colour, blood groups and presence of sickle cell anaemia disease.</td></tr>
</table>
</td></tr>
<tr><td rowspan="3">Sources of Genetic Variation</td><td>Meiosis

Meiosis produces genetically dissimilar gametes with different combinations of the parental chromosomes, this results in offspring produced to be genetically different.</td></tr>
<tr><td>Random Fertilisation

During fertilisation, a random sperm fuses with a random egg and forms a unique zygote. As each gamete is unique, the offspring produced from the fusion of gametes during fertilisation is genetically dissimilar.</td></tr>
<tr><td>Mutation “O level syllabus”

Definition: Mutation is the random and spontaneous change in gene structure or chromosome number.

<table>
<tr><td>Gene Mutation</td><td>Chromosome mutation</td></tr>
<tr><td>Produces variation between individuals because of new alleles</td><td>Change in the number of chromosomes in an organism</td></tr>
</table>

Exposure to X-ray and chemical mutagens increase the rate of mutation.</td></tr>
</table>

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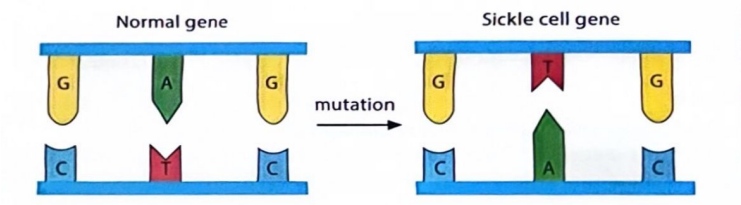
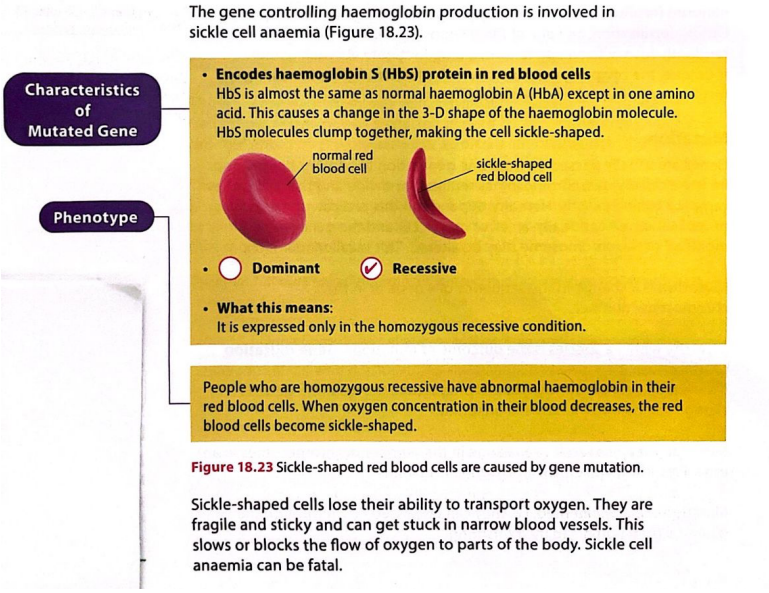
Mutation examples "O level syllabus"	Albinism - Example of a recessive gene mutation → Individuals who are homozygous for the albinism allele are albinos - Characterised by the absence of pigments in the skin, hair and eyes - Reddish-white skin, white hair, iris does not contain any pigment (appears red because of blood vessels) - sensitive to sunlight and skin get sunburnt easily
	Sickle Cell Anaemia - Example of gene mutation → changes structure of gene - Sickle cell anaemia is caused by the change in gene structure. The mutation causes the production of abnormal haemoglobin S (HbS), which is almost the same as normal haemoglobin A (HbA), except for one amino acid.  **Figure 18.22** The sickle cell gene is a result of gene mutation.  **Figure 18.23** Sickle-shaped red blood cells are caused by gene mutation. Sickle-shaped cells lose their ability to transport oxygen. They are fragile and sticky and can get stuck in narrow blood vessels. This slows or blocks the flow of oxygen to parts of the body. Sickle cell anaemia can be fatal.
	Down Syndrome - Mutation causes a change in chromosome number - Down syndrome is caused by the change in chromosome number. This mutation is a result of errors in Anaphase I and Anaphase II of meiosis, resulting in a gamete having two copies of chromosome 21. The defective gamete fertilises an egg or sperm to produce a zygote with three copies of chromosome 21.

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Natural Selection

What is natural selection?	Natural selection is the process by which those organisms which appear physically, physiologically and behaviourally better adapted to the environment, survive and reproduce to pass on favourable genes to the offspring.
Environmental factors "O level syllabus"	- amount of food or water - breeding space available for animals - availability of mineral salts, light and water for plants - numbers of predators or pathogens
Possible mechanism for evolution "O level syllabus"	- Mutation produces variation. - There is competition for the limited resources available. - Individuals who are better adapted to the environment survive and reproduce to pass on favourable genes to their offspring while the others die or decrease in numbers. - Evolution is a gradual change in the inheritable characteristics of a population over time.
Answering technique	Mutation produces variation in the (group of organisms). There is competition among the (group of organisms) strains for the limited resources available. The (group of organisms) which have genes that allow them (favourable trait) are better adapted to _____and are less likely to be die due to _____-. Those who survive better reproduce to pass on the allele that allows them to be better adapted to _____ to offspring.

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